1-15

SUSITNA
HYDROELECTRIC PROJECT

SUSPENDED SEDIMENT AND TURBIDITY

SETTLING COLUMN STUDY

1984

PREPARED BY

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

DRAFT REPORT
NOVEMBER 1984

UNDER CONTRACT TO

HARZA-EBASCO
SUSITNA JOINT VENTURE

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT
SUSPENDED SEDIMENT AND TURBIDITY
SETTLING COLUMN STUDY
1984

Report By:
R&M Consultants, Inc.

Under Contract to:
HARZA-EBASCO SUSITNA JOINT VENTURE

Prepared for:
ALASKA POWER AUTHORITY

DRAFT REPORT
November 1984

M14/15 2

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

ACKNOWLEDGMENTS

This report has been prepared for the Harza-Ebasco Susitna Joint Venture under contract to the Alaska Power Authority. I am grateful for the assistance provided by the Watana Camp staff and management. Assistance with coordination of this study was provided by Tom Stuart of Harza-Ebasco and Jeff Coffin of R&M Consultants. I also thank Jeff Koenings of ADF&G - FRED Division, Michael Bayard of Particle Data Laboratories, and Dan Bacon of Chemical and Geological Laboratories for their detailed explainations of procedures and clarification of data.

Carl Schoch

1.0 INTRODUCTION

1.1 Objectives

This report presents the sediment settling characteristics and particle size data resulting from settling column experiments on Susitna River water samples. This analysis is part of the glacial lake suspended sediment and turbidity study which will provide data and information necessary to calibrate the suspended sediment subroutine of the DYRESM reservoir/temperature model. In addition, the study will further define the relationship between total suspended solids and turbidity in a glacial river, and will quantify the physical and chemical characteristics of Susitna River suspended sediment. This information will be used to analyze with-project reservoir and outlet turbidities as well as supplementing previous studies of reservoir sedimentation and estimates of reservoir trap efficiencies.

1.2 Scope of Work

A settling column was constructed at Watana Camp and erected inside the warehouse. A 265 liter water sample was collected from the Susitna River and transferred to the column. The sample was monitored for 4 days. At time intervals of 0, 3, 6, 12, 24, 48, 72, and 96 hours, 1 liter samples were extracted from each of three ports. These subsamples were analyzed for turbidity, pH, conductivity, dissolved oxygen, and temperature. The samples were then preserved for subsequent laboratory determination of total suspended solids. Particle size and petrographic analyses were conducted on samples extracted from the top port at 0 hour and 96 hours. Air temperature outside the column was recorded at the time subsamples were extracted from the column. Upon completion of the first settling column run, the column was thoroughly cleaned. A second river sample was obtained, placed in the column and also monitored for 4 days. The same parameters were measured at the appropriate time intervals.

Discussion of the individual parameters analyzed from both the river samples and column samples are included in the following sections.

2.0 METHODS

2.1 Settling Column

The settling column used for this study was constructed from three sections of transparent acrylic tubes, each 4 feet long and 1 foot in diameter, with a wall thickness of 1/8 inch. One hole was drilled through the wall of each section. A through-hull marine fitting was used to provide the seal around a length of plastic tubing inserted in the drilled hole. The plastic tubing extended 3 inches from the wall towards the column center. This was to ensure that effects by the wall on settling velocities would not bias the sample during extraction. The interior orifice of the tubing was 1 inch below the port and oriented downward at a 45 degree angle. The tubing on the exterior side of the column extended within reach of the ground where it was sealed with a clamp.

A hole was drilled in the base plate and taped to allow for a valve fitting. This valve would facilitate draining of the column and aid in thorough flushing of residual sediments between sample runs. The acrylic tubes were cemented together and the base plate of 3/8-inch acrylic was fastened to one end. The total length of the column is 12-feet with sampling ports located at 2-feet, 6-feet and 10-feet from the top edge. The true depth of the sample would depend on the measured initial height of water within the column.

The extreme height to width ratio caused the column to be rather unstable when placed vertically on a timber platform. Therefore the design called for stabilizing guy wires. The acrylic tubes and the joints bonding them together were not designed to withstand the required stress for stability, so reinforcement consisted of three 1-inch x 2-inch boards, 8 feet long, strapped to the outside of the column wall. The boards were fitted with eyebolts, through which steel guys were threaded. The cables were anchored to floor timbers. Tension was applied to the cable and the downward force acted directly on the platform rather than on the column. Lateral tension was absorbed by the nylon bands holding the boards to the column wall. This nylon banding distributed the stress around the circumference of the column rather than concentrating it at any single point. Sufficient tension could be applied in this manner to prevent any lateral sway of the column.

2.2 Sampling Procedure

The Susitna River stage was monitored at the Watana streamgage so that samples could be obtained at flows exceeding 15,000 cfs. Figure 2.1 shows the locations of weather recorders at Watana, Denali and Kosina in the upper Susitna River Basin, and the streamgaging/sampling site at Watana. Figure 2.2 presents graphs showing mean daily air temperature and precipitation from the weather stations, and the streamflow hydrograph at Watana prior to and during the suspended sediment sampling. Two separate samples were collected. The first sample was taken on July 31, 1984 at a river flow of 23,500 cfs during a receding hydrograph and the second sample on August 6, 1984 at a flow of 23,000 cfs. The second sample had a particularly high concentration of sediment due to a warm period and substantial rainfall at Watana and Kosina. Warm air temperatures during the preceding week increased the glacial melt rate which subsequently increased the volume of fine sediments in the river. The heavy rainfall increased the tributary runoff, causing erosion and adding debris and sediment to the river.

River samples were collected near the proposed Watana damsite at the streamgaging and stage recorder site (Figure 2.3). Sampling was conducted near mid-channel. This section of channel represents relatively high velocities and sediments are probably well mixed vertically through the water column. Sampling was conducted from a boat held stationary at this point on the cross section. Ten samples were taken at equal - spaced intervals (0.1 x depth), using an electric pump to fill buckets at the surface. These samples were combined in the column and mixed comprising the depth-integrated sample.

A separate depth-integrated sample was extracted in order to measure the following parameters:

Water Temperature	pH
Conductivity	Dissolved Oxygen

This water quality data is presented in Tables 2.1 and 2.2 for each sample respectively.

From this river sample, a 1 liter subsample was retained for total suspended solid (TSS) and chemical oxygen demand (COD) analysis. A second 1 liter subsample was preserved by freezing for subsequent phosphorus analyses.

A third 1 liter subsample was drawn for determination of particle size distribution and a petrographic analysis.

The buckets of individual point samples were transferred by helicopter to Watana Camp (Figure 2.4). The column was filled and a circulating pump mixed the sample for at least 1 hour. Samples were extracted from each port at the following hour intervals:

0 Hour	24
3	48
6	72
12	96

The 0 hour corresponds to the time when the circulating pump was turned off.

2.3 Field Analysis

Prior to sampling from the column the height of the water within the column was noted. This would establish the depths of the sample ports. At the appropriate time intervals, 1 liter subsamples were extracted from each port and the following parameters were measured (Figure 2.5):

Water temperature	pH
Dissolved oxygen	Turbidity
Conductivity	

Water temperature was determined using a standard mercury thermometer. Dissolved oxygen and conductivity were measured with Yellow Springs Instruments electronic meters. A VWR electronic pH meter was used to measure the pH. A Hach, nephelometer (turbidimeter) was used for turbidity measurements. All electronic instruments were calibrated or standardized as per manufacturers instructions prior to measurements.

Water temperature, D.O, conductivity and pH are presented in Tables 2.1 and 2.2 for each run respectively.

The subsamples were transferred to bottles and stored on ice in a cooler for shipment to the lab for analysis of total suspended solids (TSS). In addition to the 3 subsamples at each time interval, separate subsamples were extracted from the top port at 0 hour and 96 hours for subsequent shipment to a laboratory for determination of particle size and mineralogy. Figures 2.6 to 2.9 are photographs showing the settling column at the beginning and end of each run.

2.4 Laboratory Analysis

Chemical and Geological Laboratories of Alaska, Inc. in Anchorage conducted the analyses of total suspended solids concentrations from the river water and settling column samples, and of chemical oxygen demand (COD) for the river samples. These data have been summarized in Tables 2.3 and 2.4.

Samples from the first run of the settling column, which began on August 1, 1984, were received by the lab on August 2 and August 7. Samples from the second run which began on August 6, 1984 were received on August 9 and August 13. Determination of total suspended solids (TSS) was conducted according to method #209 from Standard Methods for the Examination of Water and Wastewater (15th ed. 1980). Sediment particles are initially suspended in a known quantity of water which is filtered through a glass fiber filter of 0.45 micron mean pore diameter. The non-filterable sediment is then dried and weighed to get a mass concentration of solids per unit volume of fluid usually expressed in milligrams or grams per liter.

Phosphorus analyses were conducted by the Alaska Department of Fish and Game, FRED Division, in Soldotna. Values for the following were requested:

Organic particulate phosphorus
Inorganic particulate phosphorus
Ortho-phosphorus
Total phosphorus
Organic dissolved phosphorus

As of October 1984 the following data have been received:

	Run #1 July 31, 1984 (mg/l)	Run #2 August 6, 1984 (mg/l)
Total Phosphorus	118.7	497.6
Ortho-Phosphorus	15.9	77.1
Dissolved-Phosphorus	16.9	82.1
Total Particulate-P	101.8*	415.5*

*Difference between Total-P and Dissolved-P

The remaining data are pending further analysis of particulate phosphorus.

Particle size distribution, petrographic analyses and microphotography of the river and settling column samples was conducted by Particle Data Laboratories in Elmhurst, Illinois. Particle size analysis were performed using the well established electrozone method which has proven satisfactory in previous and on-going glacial lake sediment studies (R&M 1982). This method produces a good combination of high resolution, size range and sensitivity. Electrozone analysis is based on a uniform suspension of particles in an electrolyte. Single particles flow through a small orifice simultaneously with an electric current. The resulting sequence of particle pulses are electronically processed. The amplitude of each pulse is proportional to the particle volume. Particle diameter is the dimension specified for the electrozone size and refers to the equivalent spherical diameter, or the diameter of a sphere of equal volume as the measured particle.

Particle size distribution was provided both by volume and by count. The resulting data and significance of the distributions are discussed in the next section of this report.

The results of the petrographic analyses are presented as the mineralogic content of the sediment sample and the percentage of each mineral present in the respective samples. This will also be discussed in following sections.

Microphotographs of each sample were taken at 100x and 400x in order to show the relative size and shape of a representative collection of particles.

The complete data record from Particle Data Laboratories is included in the Appendix.

Table 2.1
Settling Column Run #1
Water Quality Parameters

	Water Tempera- ture (C°)	Dissolved Oxygen (mg/l)	Conduc- tivity (μmhos)	pH	COD (mg/l) Total/ Filtered
Susitna River (7/31/84)	11.5	-	90	-	20/16
0 Hours					
Top	15.2	9.0	103	-	-
Middle	15.0	9.0	104	-	-
Bottom	15.0	8.9	100	-	-
3 Hours					
Top	17.0	8.9	110	-	-
Middle	16.0	9.0	107	-	-
Bottom	15.5	9.0	105	-	-
6 Hours					
Top	17.5	9.0	110	-	-
Middle	16.5	8.9	106	-	-
Bottom	15.5	8.8	105	-	-
12 Hours					
Top	19.0	8.1	115	7.38	-
Middle	17.5	9.0	111	7.75	-
Bottom	16.0	8.8	106	7.74	-
24 Hours					
Top	20.0	8.3	117	7.26	-
Middle	19.5	8.4	116	7.46	-
Bottom	18.0	8.7	110	7.50	-
48 Hours					
Top	20.0	8.2	119	7.26	-
Middle	20.0	8.3	120	7.37	-
Bottom	18.5	8.4	111	7.45	-
72 Hours					
Top	20.0	7.9	120	7.24	-
Middle	20.0	7.8	117	7.41	-
Bottom	18.0	8.2	111	7.41	-
96 Hours					
Top	18.6	8.2	119	7.37	-
Middle	18.4	8.4	115	7.47	-
Bottom	18.0	7.8	111	7.39	-

Table 2.2
Settling Column Run #2
Water Quality Parameters

	Water Tempera-ture (C°)	Dissolved Oxygen (mg/l)	Conduc-tivity (μmhos)	pH	COD (mg/l) Total/ Filtered
Susitna River (8/6/84)	14.0	10.4	91	7.85	15/9
0 Hours					
Top	16.0	9.0	98	7.86	-
Middle	16.0	8.8	98	7.98	-
Bottom	16.0	9.0	97	7.69	-
3 Hours					
Top	17.0	8.6	103	7.94	-
Middle	17.0	8.7	100	7.95	-
Bottom	16.0	8.8	100	8.03	-
6 Hours					
Top	19.0	9.0	115	7.97	-
Middle	19.0	8.7	105	7.98	-
Bottom	18.0	8.7	104	7.97	-
12 Hours					
Top	22.0	8.7	115	7.83	-
Middle	21.0	8.7	110	7.64	-
Bottom	19.5	8.9	108	7.65	-
24 Hours					
Top	18.0	8.6	100	7.51	-
Middle	18.0	8.8	103	7.90	-
Bottom	16.0	8.8	100	7.59	-
48 Hours					
Top	16.0	8.4	102	7.49	-
Middle	16.0	8.8	100	7.54	-
Bottom	15.0	8.7	98	7.51	-
72 Hours					
Top	14.0	8.5	95	7.62	-
Middle	14.0	8.4	97	7.52	-
Bottom	12.0	8.5	91	7.50	-
96 Hours					
Top	14.0	8.2	100	7.43	-
Middle	14.0	8.3	95	7.46	-
Bottom	13.0	8.2	90	7.44	-

Table 2.3
Settling Column Run #1
Total Suspended Solids and Turbidity

	TSS (mg/l)	Avg TSS	Avg* Percent Remaining	Turbidity (NTU)	Avg Turbidity
Susitna River (7/31/84)	181	-	-	-	-
0 Hours					
Top	117			172	
Middle	146	124	100	174	165
Bottom	108			148	
3 Hours					
Top	120			134	
Middle	115	119	96	154	141
Bottom	122			136	
6 Hours					
Top	63			144	
Middle	105	93	75	125	138
Bottom	111			144	
12 Hours					
Top	49			100	
Middle	85	78	63	118	115
Bottom	100			126	
24 Hours					
Top	34			90	
Middle	64	57	46	108	101
Bottom	74			104	
48 Hours					
Top	32			90	
Middle	59	52	42	110	104
Bottom	66			112	
72 Hours					
Top	34			76	
Middle	48	50	41	112	103
Bottom	69			120	
96 Hours					
Top	38			90	
Middle	49	48	39	94	96
Bottom	56			104	

$$* \text{ Average Percent Remaining} = \frac{\text{Average TSS at Time (T)}}{\text{Average TSS at Time O}} \times 100$$

Table 2.4

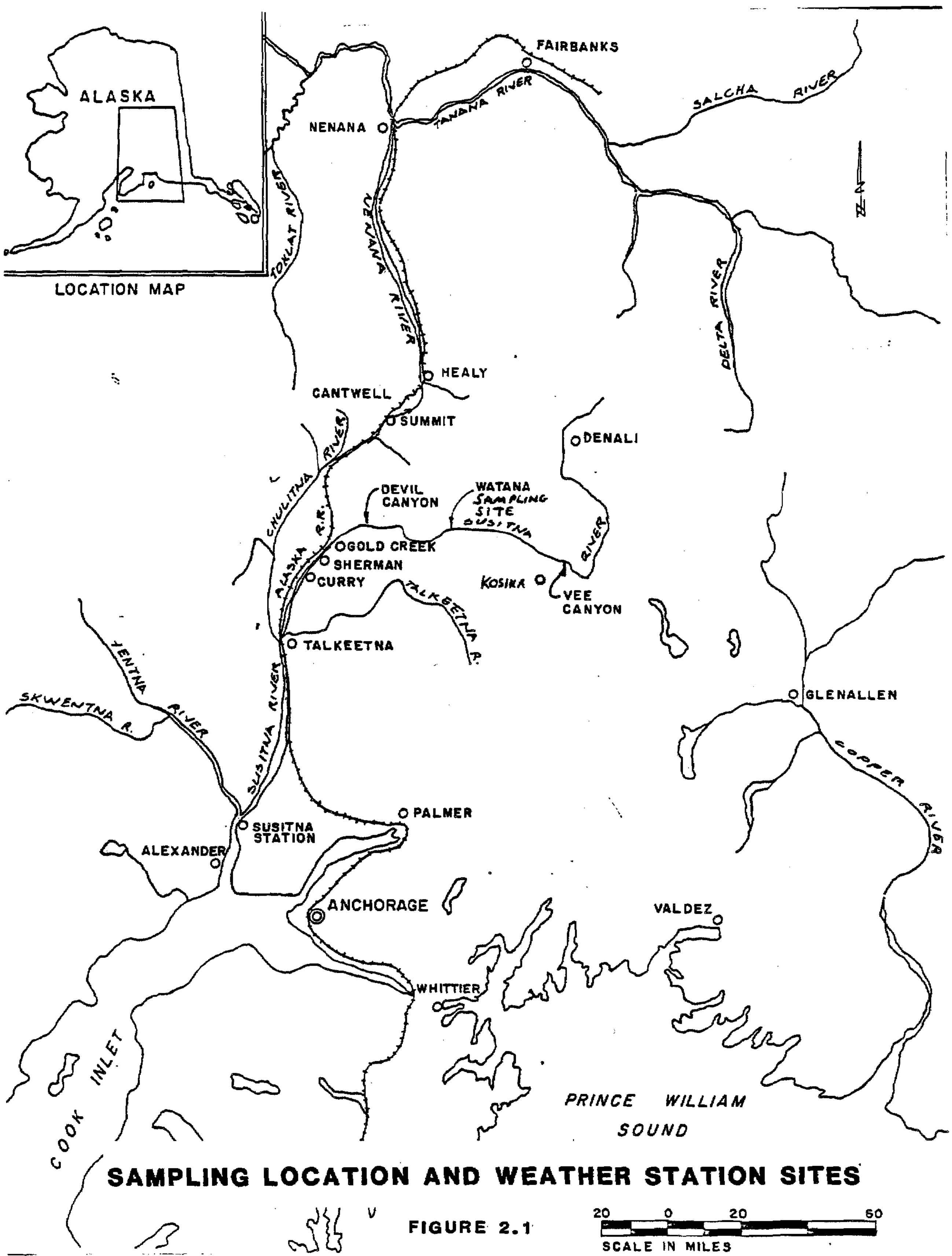
Settling Column Run #2

Total Suspended Solids and Turbidity

	TSS (mg/l)	Avg TSS	Avg* Percent Remaining	Turbidity (NTU)	Avg Turbidity
Susitna River (8/6/84)	410	-	-	-	-
0 Hours					
Top Part	320			308	
Middle Part	355	342	100	308	304
Bottom Part	350			296	
3 Hours					
Top	230			304	
Middle	300	283	83	280	300
Bottom	320			316	
6 Hours					
Top	190			280	
Middle	260	243	71	316	291
Bottom	280			276	
12 Hours					
Top	160			232	
Middle	245	215	63	240	228
Bottom	240			212	
24 Hours					
Top	145			244	
Middle	220	190	55	280	268
Bottom	205			280	
48 Hours					
Top	155			240	
Middle	175	167	49	244	241
Bottom	170			240	
72 Hours					
Top	93			220	
Middle	122	112	33	268	247
Bottom	120			252	
96 Hours					
Top	78			204	
Middle	106	101	30	208	210
Bottom	119			220	

$$* \text{ Average Percent Remaining} = \frac{\text{Average TSS at Time (T)}}{\text{Average TSS at Time O}} \times 100$$

M14/15 19

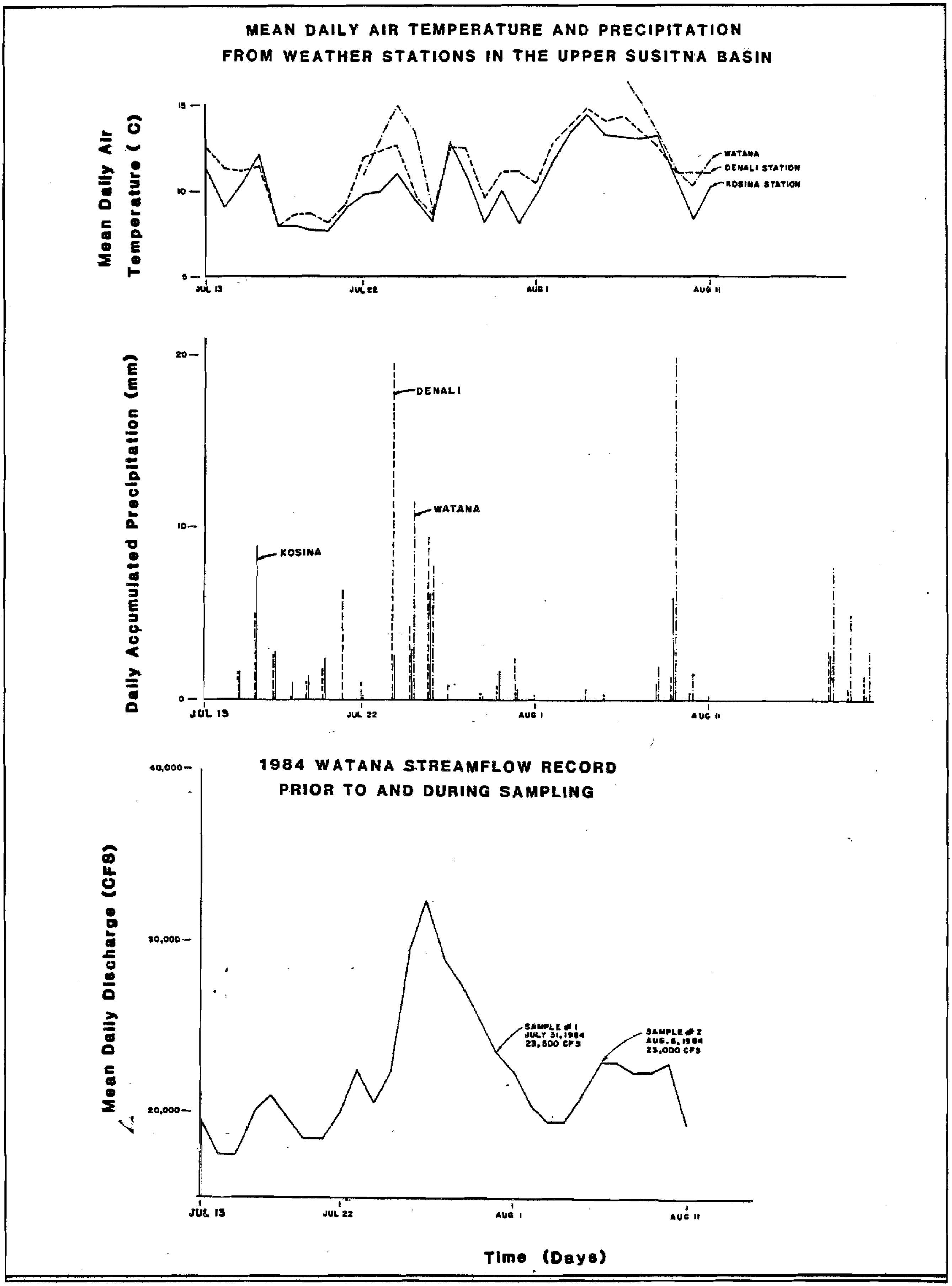


SAMPLING LOCATION AND WEATHER STATION SITES

FIGURE 2.1

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

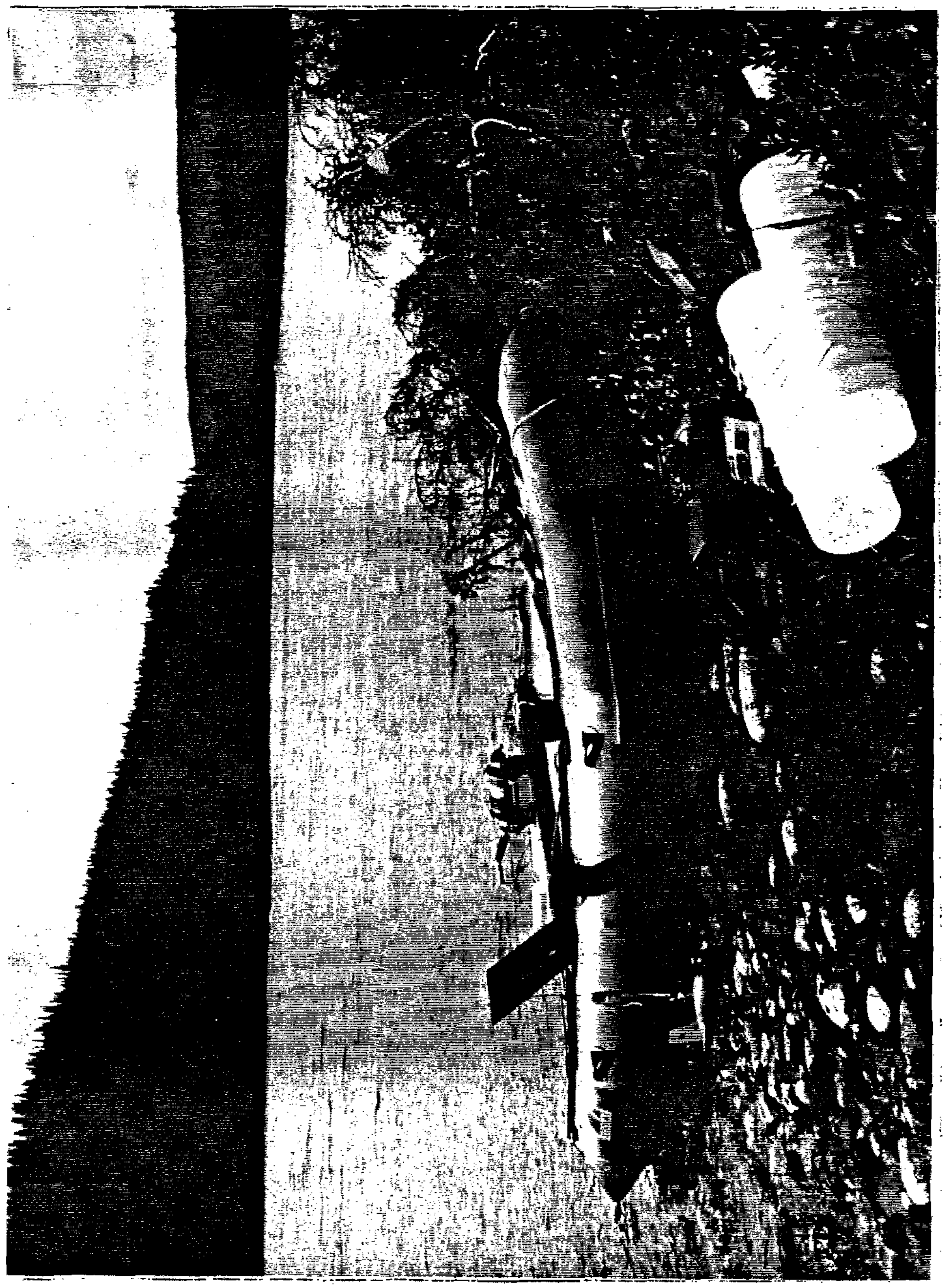
HARZA-EBASCO
SUSITNA JOINT VENTURE



R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

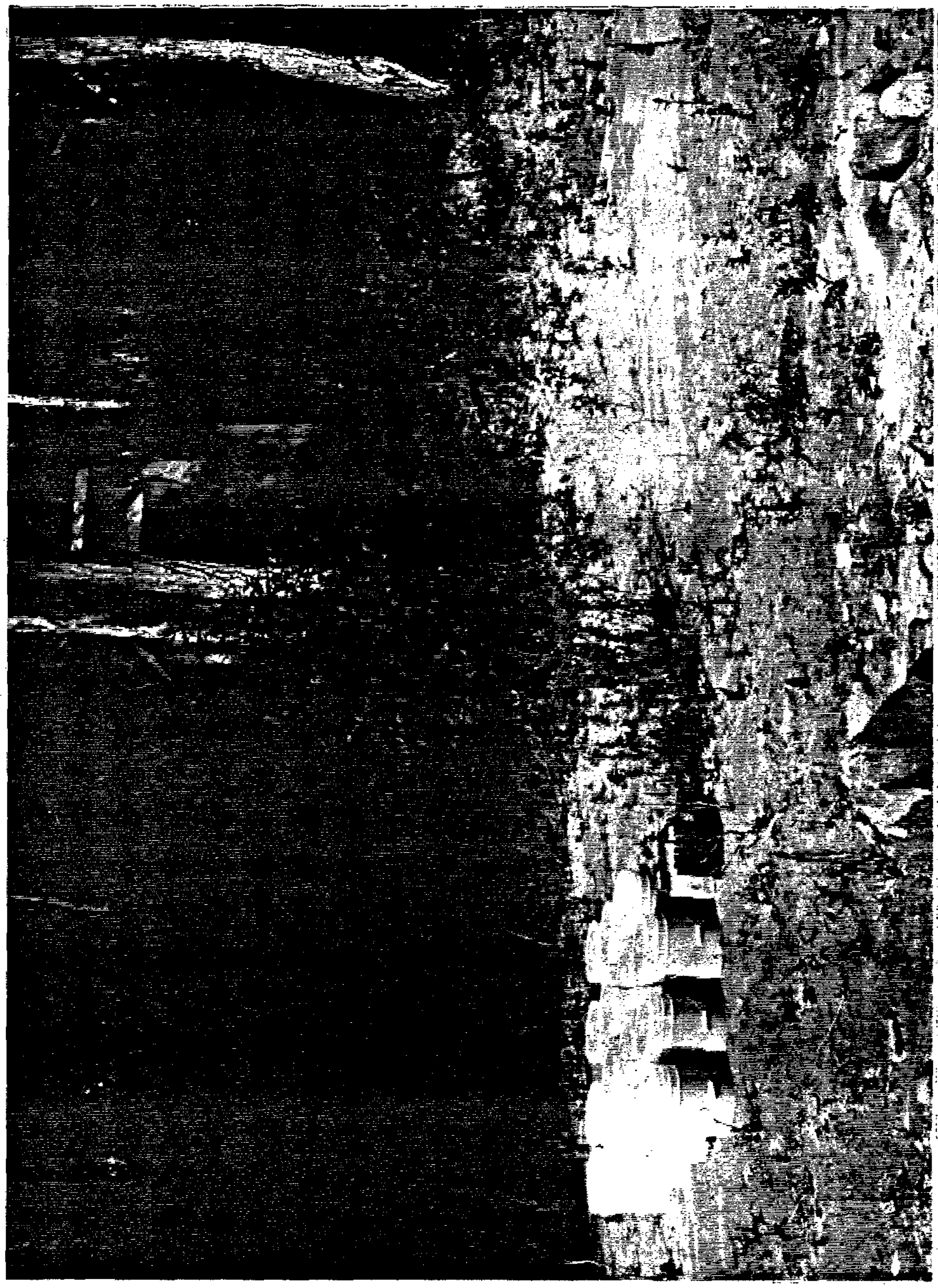
FIGURE 2.2

HARZA-EBASCO
SUSITNA JOINT VENTURE



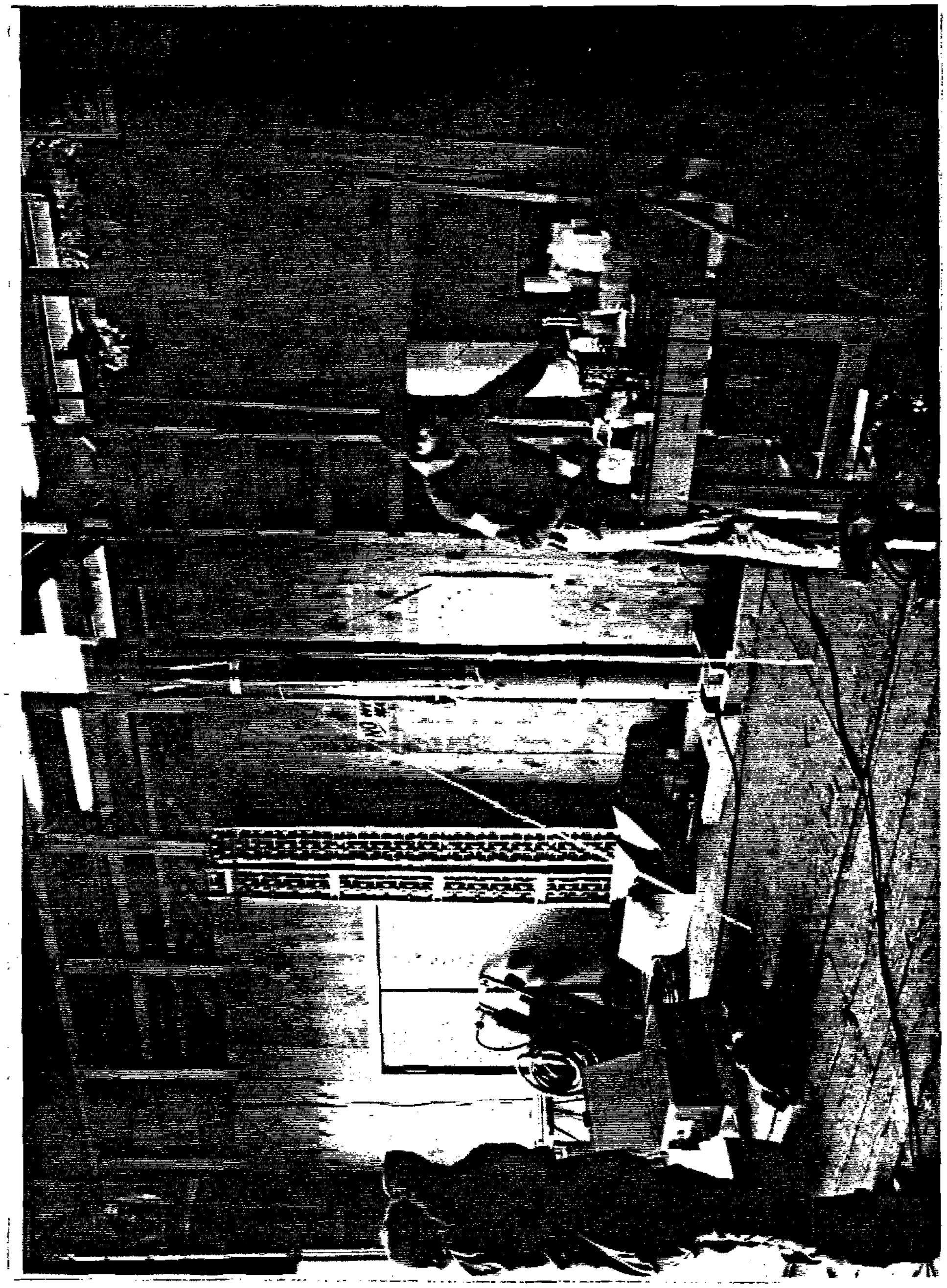
Water Sampling Apparatus
on August 6, 1984 at a flow of 23,000 cfs

FIGURE 2.3



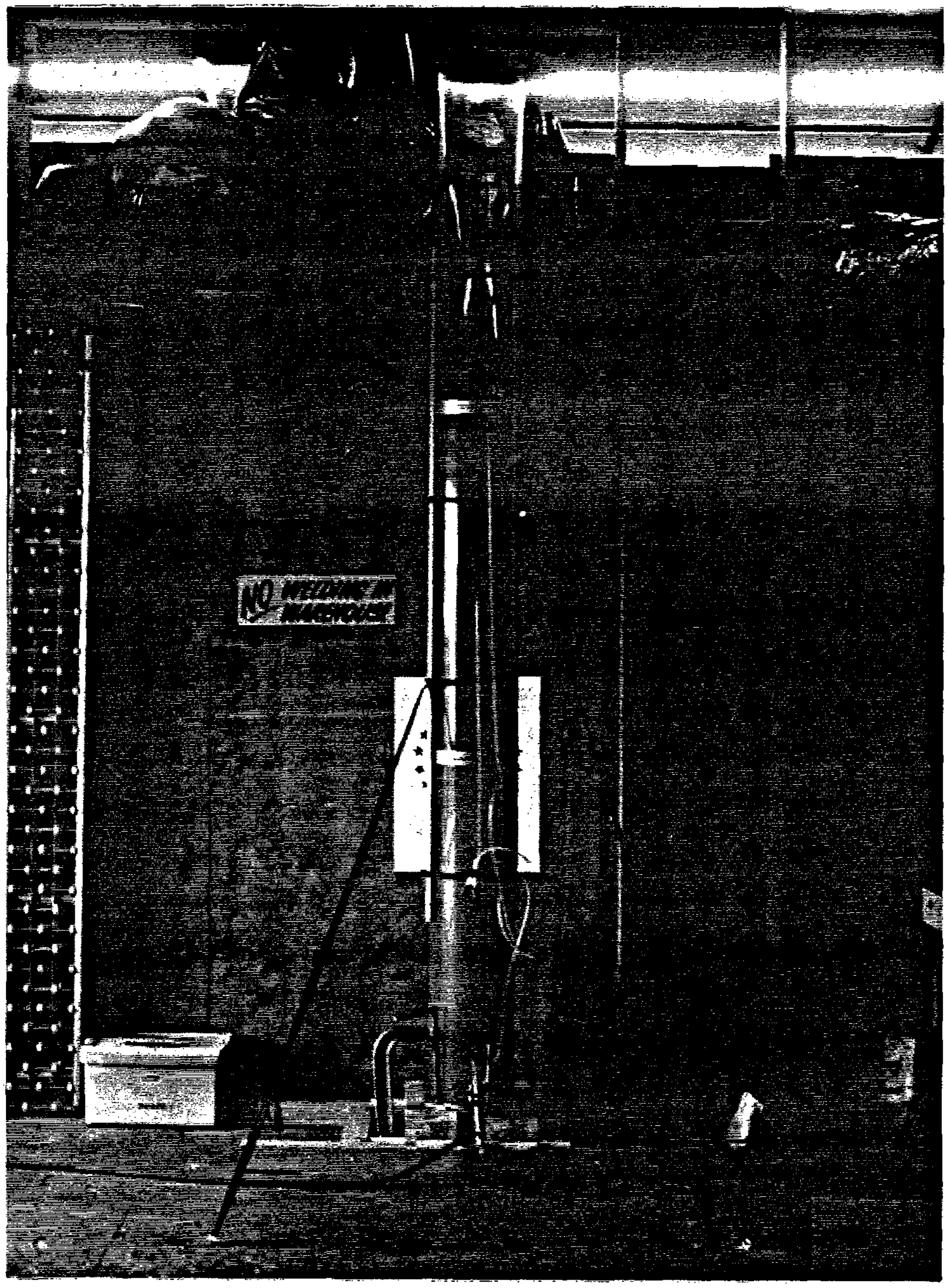
Water Samples in 5 Gallon Buckets
Awaiting Transfer to Watana Camp

FIGURE 2.4



Field Analysis of Subsamples From Column

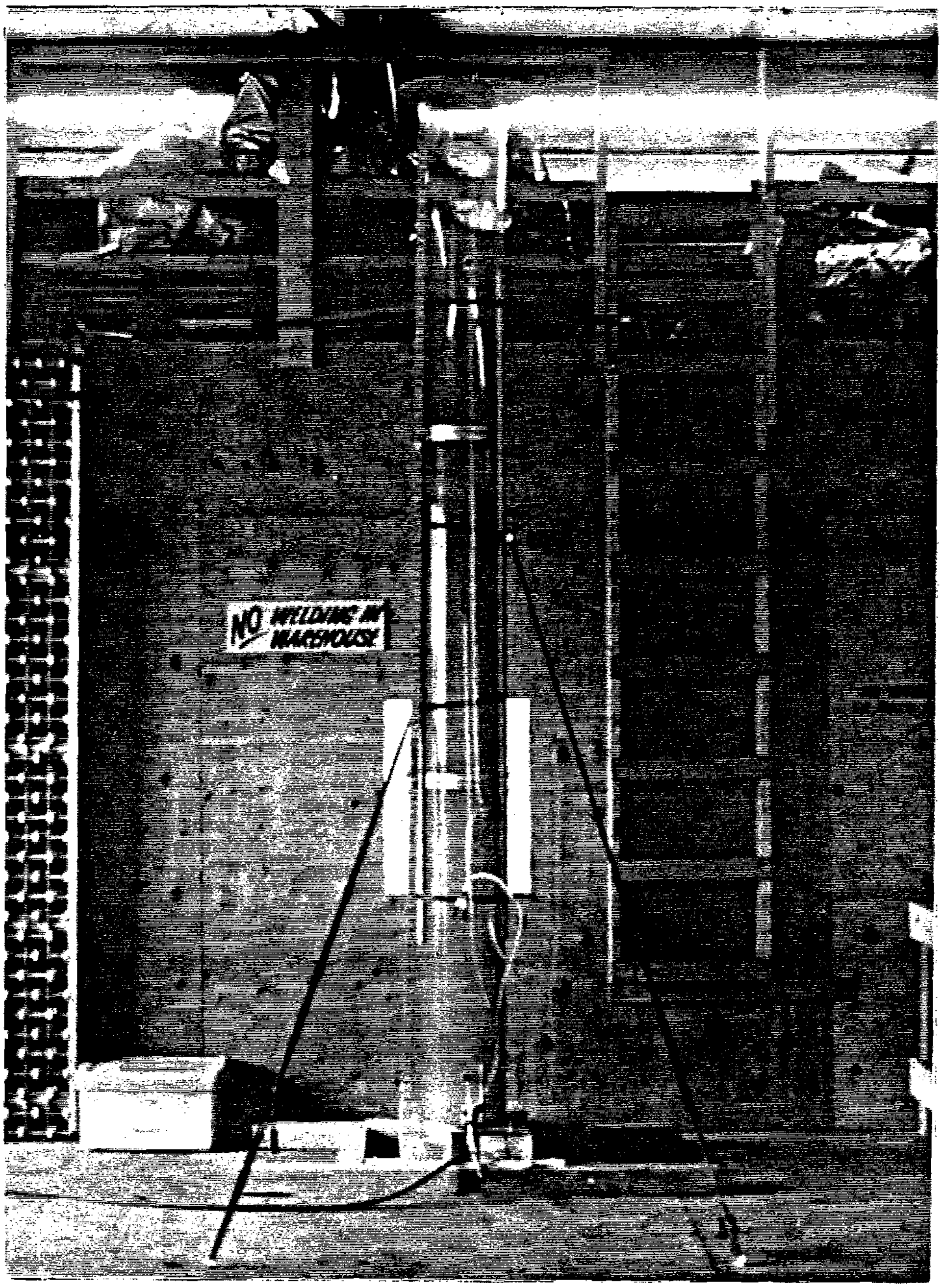
FIGURE 2.5



Settling Column Run #1
Sample from July 31, 1984 at 0 Hour

FIGURE 2.6

M14/15 23

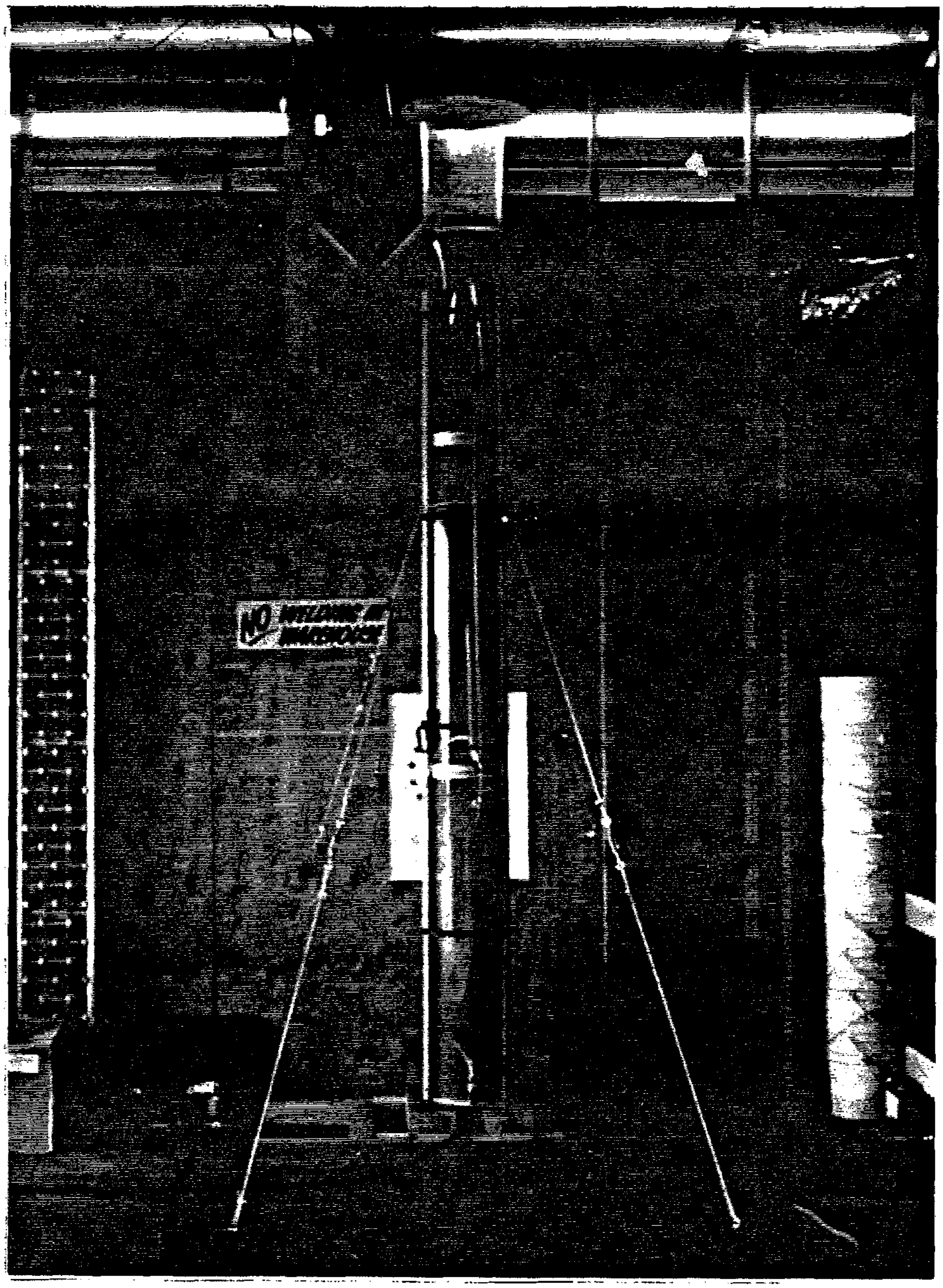


Settling Column Run #1
Sample from July 31, 1984 at 96 Hours

FIGURE 2.7

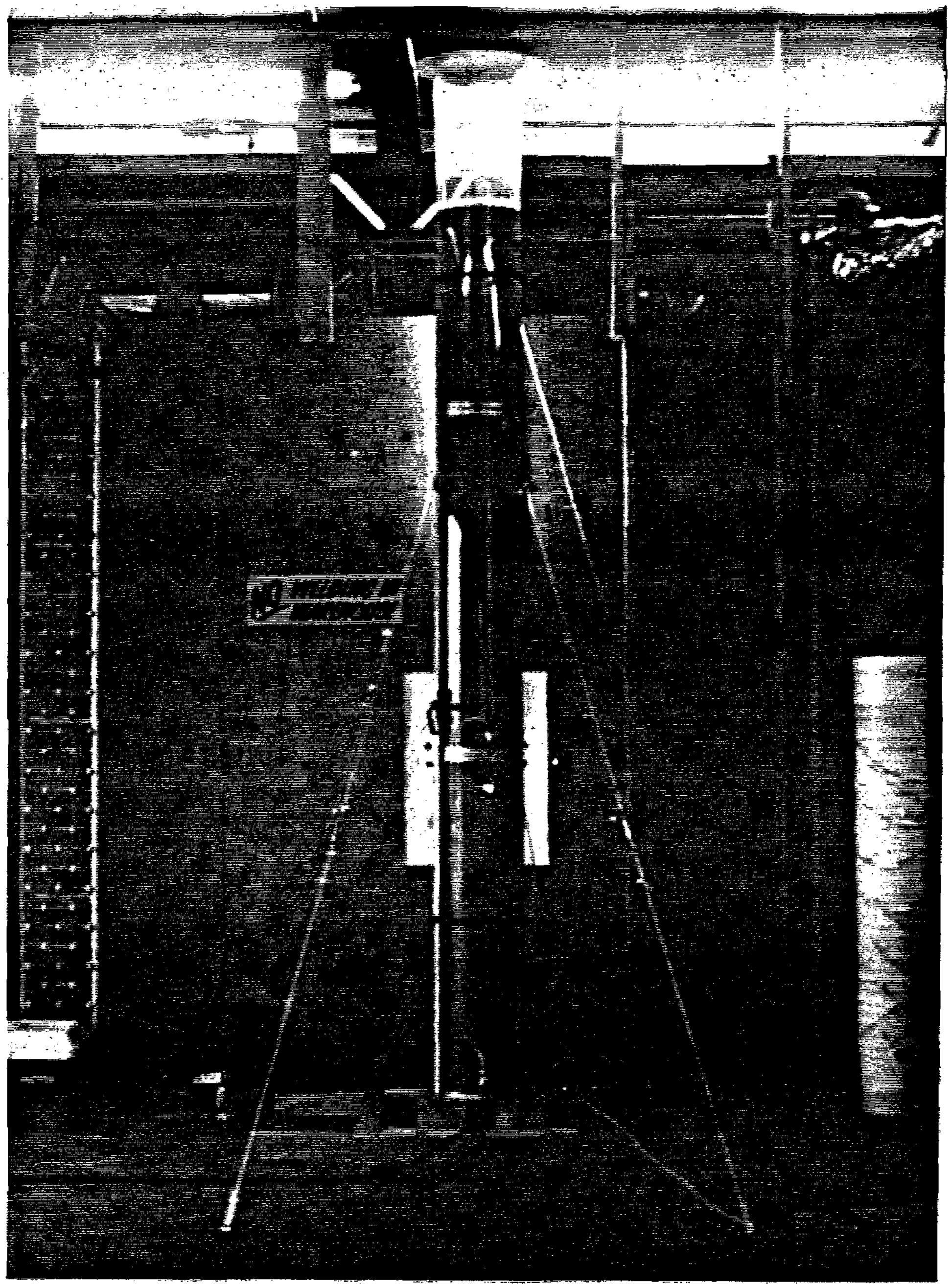
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

HARZA-EBASCO
SUSITNA JOINT VENTURE



Settling Column Run #2
Sample from August 6, 1984 at 0 Hour

FIGURE 2.8



Settling Column Run #2

Sample from August 6, 1984 at 96 Hours

FIGURE 2.9

3.0 RESULTS

3.1 Water Temperature

Ideally, the temperature of the water sample within the settling column should approximate the conditions of the river/reservoir system. This type of temperature control, however, proved to be impractical with a column 12 feet high and exposed to ambient air temperature. The column was placed indoors to avoid the direct influence of solar radiation but temperature variation could not be totally avoided. The effect of fluctuating air temperatures is shown in Figure 3.1.

Concerns about temperature control of the water sample stem from the potentially significant effects of the fluid temperature on fall velocity and physical/chemical characteristics of sediment particles. The settling column was kept as cool as possible. The large hangar-type door on the east side of the Watana Camp warehouse was kept open during the experiments so that air could circulate and moderate the column temperatures, especially near the warehouse ceiling. On sunny days the air temperature near the top of the column increased sharply. Water temperatures subsequently increased relative to the height above the ground. During the first run the temperature gradually increased about 5°C near the top port over the four day test period. Sunny weather during the second run caused the water temperature to increase about 6°C at the top port and 3.5°C at the bottom port. The graphs in Figure 3.1 show the stratification of temperature over time for both samples. Note that the temperature of the bottom samples never exceeded that of the middle and upper samples. If this had occurred, then thermal circulation could have been expected to alter the rate of settlement. The temperature pattern within the column remained relatively stable throughout each experiment, so no circulation should have occurred.

Water temperature will generally affect fall velocities according to Stokes' law:

$$w = \frac{gd^2}{18} \quad \frac{(\gamma_s - \gamma)}{v}$$

Where: w = Fall velocity (m/sec)

g = 9.8 m/sec^2

d = particle diameter (m)

γ_s = particle density

γ = density of water at temperature T°C

v = kinematic viscosity at temperature T°C

The variables affected by water temperature therefore are water viscosity and density. Fall velocities were computed for water temperatures at 5, 10, 15 and 20°C, corresponding to temperatures measured in the column and to temperatures which could be expected in the proposed river/reservoir system. Figure 3.2 shows the fall velocities for various temperatures and particle densities according to Stokes' Law.

The graph shows a greater variation in fall velocity with respect to temperature than to specific gravity of the particle. At a fixed temperature of 5°C the fall velocity ranges from about 1.42×10^{-7} m/sec for a 0.5 micron particle with a density of 2.6, to 1.95×10^{-7} m/sec for the same size particle with a higher density of 3.2. The same 0.5 micron particle of density 2.6 will fall at a rate of 2.2×10^{-7} m/sec at a temperature of 20°C.

The range in particle densities from 2.6 to 3.2 is relatively high compared to the widely accepted average of 2.65. This range represented the mineral densities of the suspended sediment samples found by petrographic analysis (Section 3.4).

The following concepts should be considered when reviewing water temperature data and settling velocities:

1. An increase in water temperature will increase the solubility of particles. Minerals will generally dissolve more readily in warming water, decreasing the particle size, and precipitate in cooling water, increasing the particle concentration.

2. An increase in water temperature decreases the water viscosity. Particles will generally fall faster in warmer water.

3. An increase in water temperature decreases the specific gravity of water. Warm water is less dense than cool water down to 4°C. Below 4°C the water density decreases as it cools.

4. An increase in water temperature increases the rate of chemical reactions, generally on the order of 2-3 times for every 10°C increase in temperature.

5. An increase in water temperature will increase the Brownian Movement. This pertains specifically to colloidal suspensions, to which Stokes' Law does not apply, but this was essentially the condition in the column after about the 48 hour interval. When particles in a colloid are viewed under a microscope they are seen as tiny specks of light moving in random directions. It is believed that this motion is due to a bombardment of the suspended particles by molecules in the solution. The molecules in a liquid move at relatively high speeds. When they collide with a larger particle (of colloidal size), the particle is moved in one direction or another. The net result is a zigzag motion. This Brownian Movement is a stability factor of colloidal solutions. The particles are kept from settling out because of this ceaseless molecular bombardment. An increase in temperature also increases the rate at which molecules move, which

increases the number of collisions as well as the force of impact. If follows then, that in warm water the Brownian movement will increase and subsequently larger particles will remain in suspension for longer period of time.

6. An increase in temperature will most likely decrease particle size by breaking down agglomerates. The petrographic analysis shows a high concentration of colloidal silica. These gel-like particles act to bond or cement together relatively large particles. In doing so, the ratio of specific gravity to particle size decreases. In cold water, a heavy mineral such as magnetite with a high specific gravity of 5.2 may agglomerate to several larger particles of quartz (s.g. 2.6) so that the average density of the agglomerate is less than the original particle of magnetite. The relative diameter of the particle has now increased and the settling velocity will therefore decrease with respect to the original grain of magnetite. When the temperature of the fluid medium is increased, the silica gel cementing the particles together may break down and the agglomerate will separate into the constituent particles.

3.2 Total Suspended Solids and Turbidity

A water sample was extracted from each port of the settling column at the specified time intervals. Usually the turbidity was in excess of the range the turbidimeter was capable of measuring. In order to standardize the procedure and minimize errors in measurement, all samples were diluted by a factor of 4. All the samples required dilution to some extent and a great deal of uncertainty would have resulted if the turbidity of a 50% dilution was compared to a 25% dilution.

As indicated by Figure 3.3, turbidity values were fairly erratic initially when the sample was well mixed. After approximately 24 hours for the first run the values stabilized at about 100 NTU and decreased little for the remaining 72 hours. Average turbidity values were relatively ordered at the beginning of the second run and then became erratic at 12 hours and did not appear to stabilize for the duration of the run. However, the general trend is similar to run #1 as the averages indicate in Figure 3.4. Note on this graph the higher values of turbidity for the second run. Most values for run #2 are over twice those of run #1. These higher turbidities are due to a higher concentration of total suspended solids (TSS).

Figure 3.5 shows the plot of TSS versus time for the two runs. Run #1 again shows an initial erratic pattern which stabilizes after 12 hours. Run #2 appears to have stabilized immediately, perhaps due to the relatively high concentration of coarse sediment. Values which appear anomalous can be attributed to the initial instability of sediments in suspension and also to the variation in concentration of particles, not only with depth but also horizontally across a section of the column. Varying concentrations of sediment could be seen as intermixed swirls of dark and lighter colored bands when viewed through the graduated cylinder, indicating that turbidity and sediment concentration were probably not uniform in any area at any time in the column.

The graphs show the steep initial slope indicating a major reduction of sediments within the first 24 hours and a more gradual settling rate for the remaining 72 hours. This trend is similar to the plot of turbidities for the respective runs.

Turbidity was plotted versus total suspended solids for each run on Figure 3.6. A fairly good correlation exists for the first run with an initial turbidity to TSS ratio of about 1:1 and a final ratio of about 3:1. For the second run the relationship is similar but the correlation is poor as indicated by the coefficient r^2 of 0.60. The initial turbidity to TSS ratio is again about 1:1 and the final is about

3:1. Figure 3.7 shows the data from both runs plotted together. The correlation is now better than either of the separate runs with an r^2 of 0.83. The least squares fit for the curves shown on the figures follow the form:

$$NTU = a\ (TSS)^b$$

Values for the coefficients a and b are shown on the figures. Figure 3.8 shows the relationship between TSS and depth for all the sampling time intervals. Run #2, with the higher initial sediment concentration, had a very orderly reduction of concentration during the entire 96 hours. In contrast, run #1 initially showed a slower decrease in concentration followed by a rapid reduction between 3 hours and 24 hours. After the 24 hour interval very little change in concentration occurred at any port depth. This is in contrast to Figures A-1 and A-2 in the report "Reservoir Sedimentation", (R&M Consultants 1982b). These figures are reproduced in this report as Figures 3.9 and 3.10. There is a distinct difference in both rate of settling and TSS concentration at 72 hours.

3.3 Particle Size Distribution

Samples were collected from the top port at 0 hour and at 96 hours for each run and analyzed for particle count, volume, and size distributions. The data as received from the lab are included in the Appendix.

Size distributions are presented in two formats, one as a percent by count and the other as a percent by volume. Since mass or weight is generally the standard unit in sediment analysis, the percent by volume is more applicable. The percent by volume refers to the relative volume of all the particles of a specific size compared to the total volume of all the particles in the sample. The larger particles account for the majority of the volume even though the number of large particles in these samples was small.

For the 0 hour sample from run #1 the partial breakdown of particle size by volume is as follows:

Particle Size Distribution for Run #1 (0 Hour)

1.6%	< 0.24 microns	colloidal size	(83.0)
11.4%	0.24-1.0 microns	fine clay	(15.9)
15.0%	1.0-2.0 microns	medium clay	(1.0)
72.0%	> 2.0 microns	coarse clay	(0.1)

The numbers in parentheses are the percentage of the actual number of particles of the respective size counted in the sample. Therefore, while 83% of the particles counted were less than 0.24 microns in size and these accounted for only 1.6% of the total sediment volume. Of the particles counted, only 0.1% were greater than 2 microns but these represented 72% of the volume.

The partial breakdown for the 96 hour sample from run #1 is:

Particle Size Distribution for Run #1 (96 Hour)

4.5%	< 0.24 microns	colloidal size	(79.0)
31.0%	0.24-1.0 microns	fine clay	(20.3)
24.0%	1.0-2.0 microns	medium clay	(0.5)
40.0%	> 2.0 microns	coarse clay	(0.2)

Particle volume versus size was plotted on log/probability paper, Figure 3.11. This graph shows a 44% relative reduction in particles of 2 microns or greater in four days, a 181% relative increase in particles less than 0.24 microns and a 171% relative increase in particles between 0.24 and 1 micron. This shift in particle size distribution indicates that particles less than about 2 microns essentially did not settle out of the top 1 foot of the column in the 4 day period and even particles of 2-10 microns were settling out of this zone slowly.

For the second settling column run with a higher TSS concentration the partial breakdown is:

Particle Size Distribution for Run #2

0 Hour Sample

0.1%	<0.24 microns	colloidal size	(38.0)
3.9%	0.24 - 1.0 microns	fine clay	(49.0)
11.0%	1.0 - 2.0 microns	medium clay	(12.0)
85.0%	>2.0 microns	coarse clay	(1.0)

96 Hour Sample

3.0%	<0.24 microns	collodial size	(79.0)
50.0%	0.24 - 1.0 microns	fine clay	(20.0)
12.0%	1.0 - 2.0 microns	medium clay	(0.5)
35.0%	>2.0 microns	coarse clay	(0.5)

The suspended sediment size analysis, Figure 3.12, shows a 58% reduction of volume in particles of greater than 2 microns, a 2900% relative increase in particles less than 0.24 microns and a 1182% relative increase in particles between 0.24 and 1 micron in size. This rather dramatic example shows that a vast majority of the sediment greater than 2.0 microns settled out of the top 1 foot in the column during the 4 day period. Particles with sizes of less than 1.0 micron accounted for most of the volume in the 96 hour sample. This is also reflected by the high turbidity of the top port sample at 96 hours (204 NTU), and relatively low TSS (78 mg/l).

3.4 Mineralogy

Petrographic analyses were conducted on samples taken from the top port of the settling column at 0 hours and 96 hours for both runs, as well as on a sample taken from the tailrace of Eklutna Reservoir. Elkutna Reservoir is currently being studied in order to define a suspended sediment and turbidity relationship in a glacial lake. Scanning electron microscopy, electron microprobe and petrographic microscopy techniques were used in the petrographic analyses. Because of the small particle sizes encountered, some mineral species were blended together, making precise identification difficult. Thus mineral identification was taken through general groups such as pyroxenes and feldspars. Most of the particles were combined grains of several minerals, primarily quartz containing inclusions of magnetite. Table 3.1 summarizes the mineralogical composition of the various samples. The following notes should be considered when reviewing this information.

1. There is a distinct similarity between the Eklutna Tailrace sample and the 96 hour samples from the settling column. The mineral calcite stands out in the Eklutna data since this mineral was not significantly present in the Susitna River samples.

2. The relative difference in percentages of quartz, feldspar and pyroxene for the 0 hour sample and the 96 hour sample from both runs indicates that these minerals settled out from the upper zone of the settling column. Quartz content in particular is reduced by over 50% in the first run. These minerals then probably constitute the particles greater than 2 microns in size as discussed in Section 3.3. The percentage of magnetite increased between 0 hour and 96 hours in both runs, indicating that this mineral did not settle very much, which is unusual considering it has the highest specific gravity of all the minerals

present in the samples. A possible explanation for this was presented in Section 3.1.

3. The high concentration of colloidal silica in the 96 hour samples indicates that sediment consolidation may be on-going with the silicon acting to cement particles together.

3.5 Settling Velocities

Analysis of settling velocities in the column, and comparisons to theoretical settling velocities is beyond the scope of this preliminary report but could be included in the final version.

Some analysis was performed to determine the rate at which natural particles of various sizes would settle under quiescent conditions. In order to most accurately approximate the true settling velocity, a coefficient must be applied to the theoretical fall velocity (which usually assumes a spherical shape) in order to account for various particle configurations. Natural particles are rarely spherical and therefore the actual fall velocity would be less than the theoretical.

The simplest and most commonly used coefficient is the Corey shape factor (CSF), (Dietrich, 1982)

$$CSF = \frac{c}{(ab)^{\frac{1}{2}}}$$

where a, b, and c are the longest, intermediate, and shortest axis of the particle, respectively and are mutually perpendicular. Values for CSF range from greater than zero to 1.0 and correspond to the ratio of the cross sectional area of a sphere to the maximum cross sectional area of an ellipsoid.

The result of the computed velocity using the Corey shape factor can be compared to the actual settling rates observed in the column. Knowing the mineral species which settled out and the rate of settling measured in the column, the effective particle diameter can be computed using Stokes' Law. By comparing this value to the spherical equivalent particle diameter with the same settling velocity, a coefficient can be computed to relate the difference in fall velocity to particle shape and roundness.

Figure 3.13 shows a plot of column depth versus time with the percent of suspended solids removed for each run. Figure 3.14 shows percent TSS remaining versus the observed settling velocity of the entire sediment mass in the column. The settling velocity was computed by dividing the sample depth by the total elapsed time since 0 hour. For run #1 the line shows that none of the particles had an average velocity faster than 2.80 x 10^{-4} m/sec. The plot of Stokes' Law (Figure 3.2) shows that this rate corresponds to a particle size range of 16-22 microns depending on fluid temperature and particle density. The electrozone analysis by PDL counted exactly 4 particles of this size range and these accounted for only 0.7% of the total sediment volume. There were essentially no particles larger than this detected by PDL. Therefore, the first run conforms closely to the theoretical behavior of particles settling in a fluid medium. In run #2, again, none of the particles traveled faster than 2.80 x 10^{-4} m/sec. The PDL analysis, however, shows that 264 particles larger than this size range were counted and they represent 1.34% of the total volume. This indicates that particle shape and roundness probably kept these particles in suspension longer than what Stokes' Law allowed, and a coefficient should be computed to account for this difference. The second sample had a much higher particle concentration and this may have significantly effected the rate of settlement.

TABLE 3.1
PERCENT COMPOSITION

Settling Column #2 Mineral (Density)	Eklutna Tailrace 7/21/84	Settling Column #1 0 Hours	Settling Column #1 96 Hours	Settling Column 0 Hours	96 Hours
Quartz (2.65)	10	40	15	30	15
Feldspars (2.6 - 3.0)	10	20	10	15	10
Pyroxenes (2.5 - 3.3)	5	10	5	15	10
Magnetite (5.18)	20	15	25	15	25
Limonite (2.7 - 4.3)	3	5	5	10	5
Clays (2.65)	2	2	3	1	1
Colloidal Silica (2.17 - 2.20)	30	2	30	1	35
Calcite (2.70)	20	-	3	-	-
Mica Biotite & Muscovite (2.77 - 2.88)	-	5	-	15	-

STOKES LAW FOR FALL VELOCITIES VARIATIONS WITH RESPECT TO TEMPERATURE AND PARTICLE DENSITY

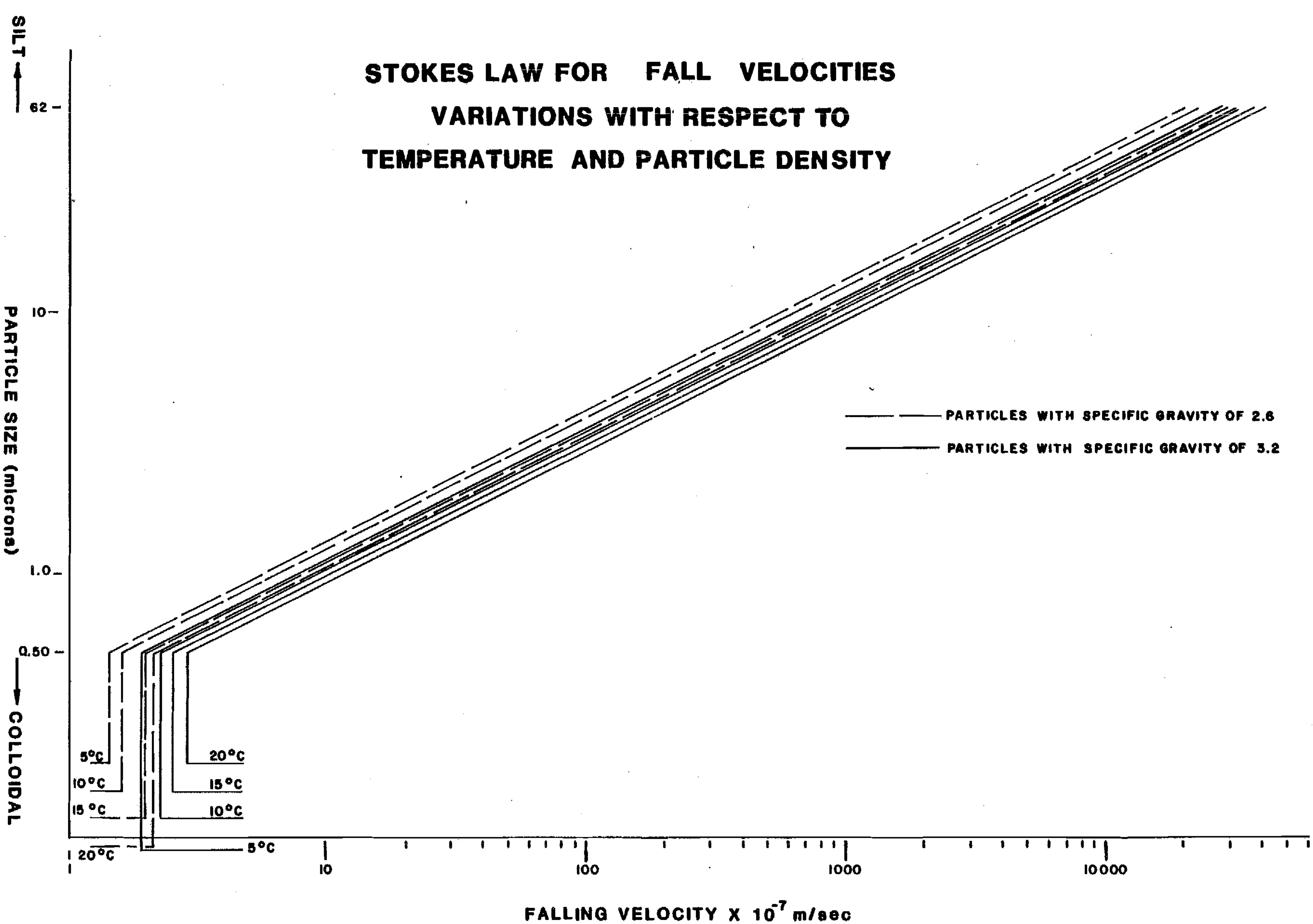


FIGURE 3.2

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

HARZA-EBASCO
SUSITNA JOINT VENTURE

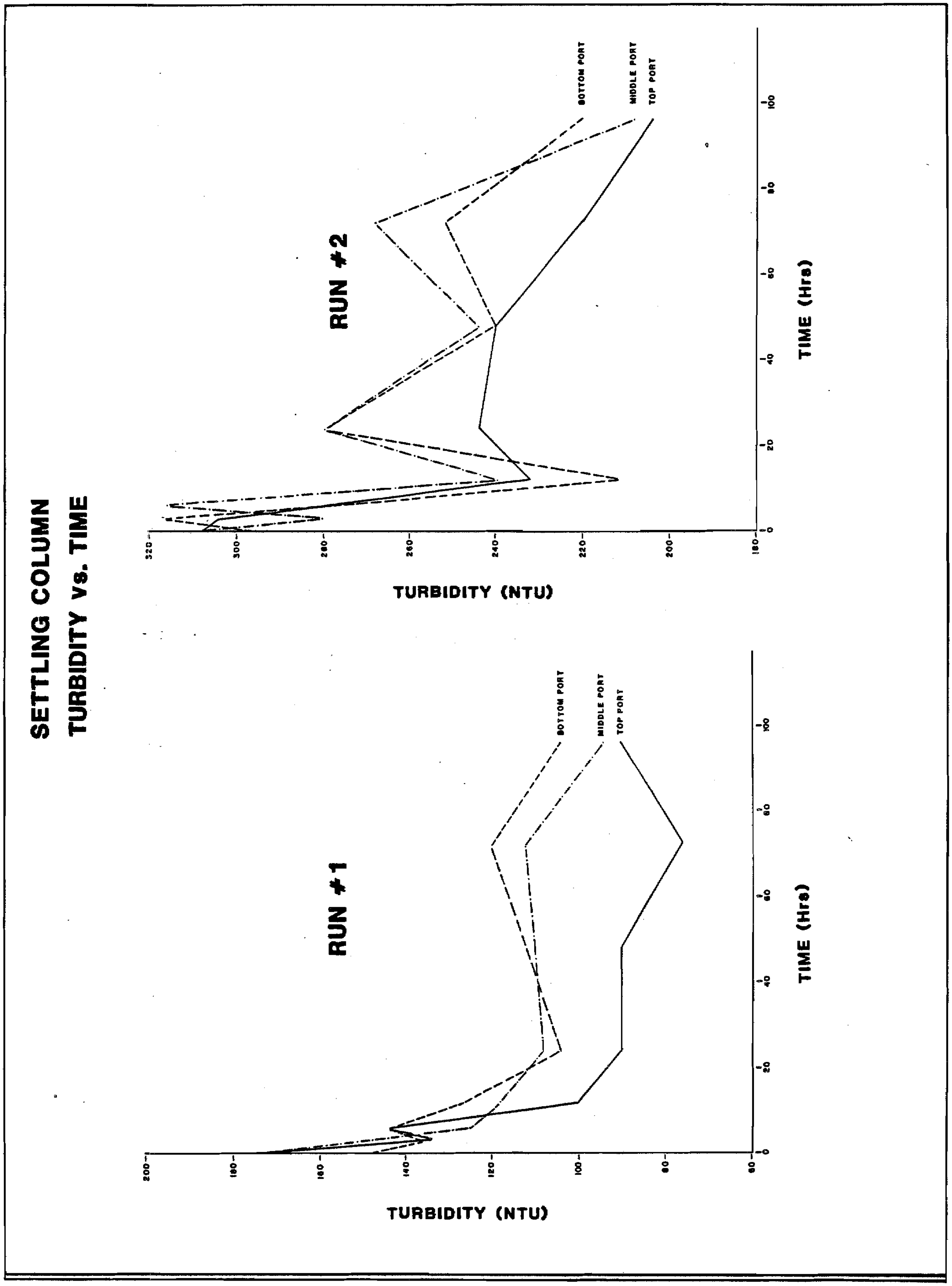
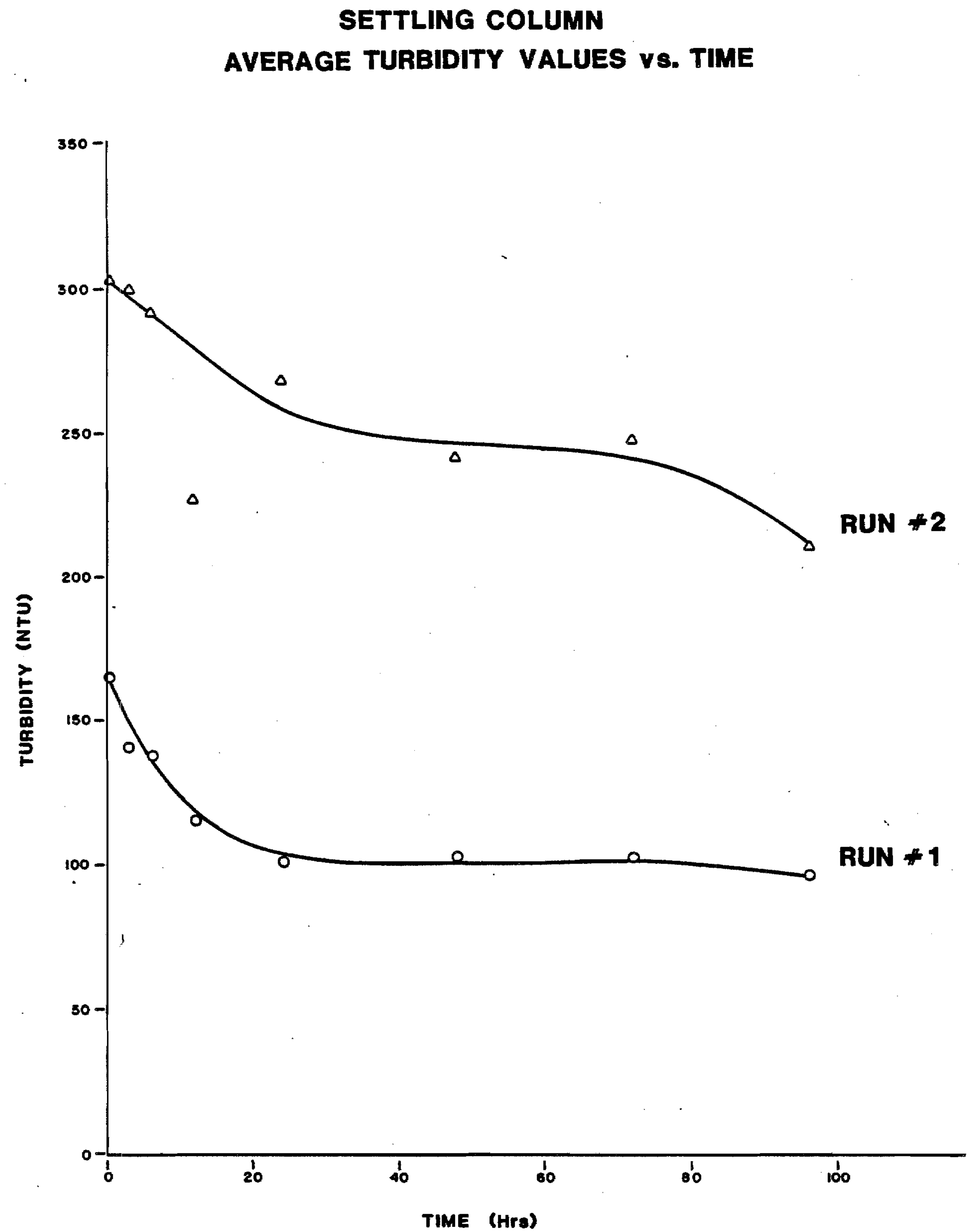


FIGURE 3.3

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

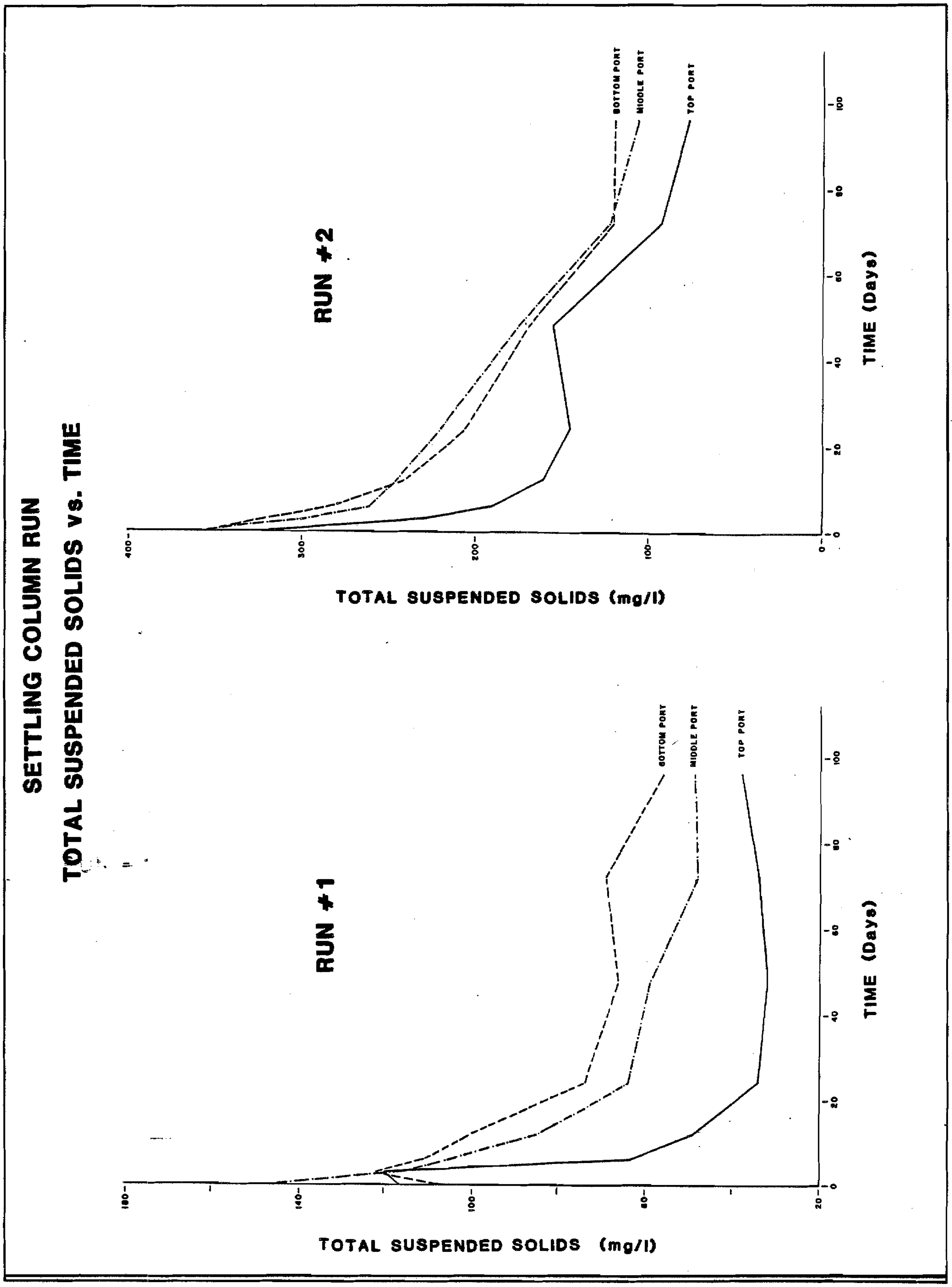
HARZA-EBASCO
SUSITNA JOINT VENTURE



R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 3.4

HARZA-EBASCO
SUSITNA JOINT VENTURE

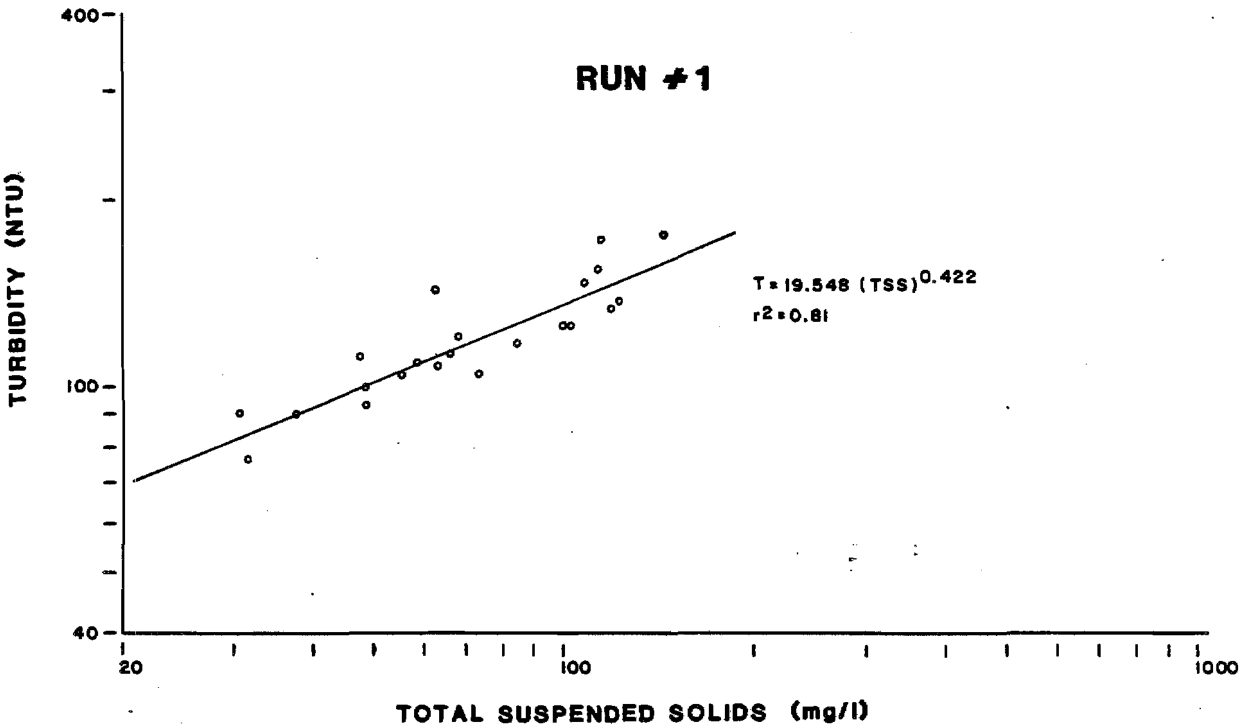


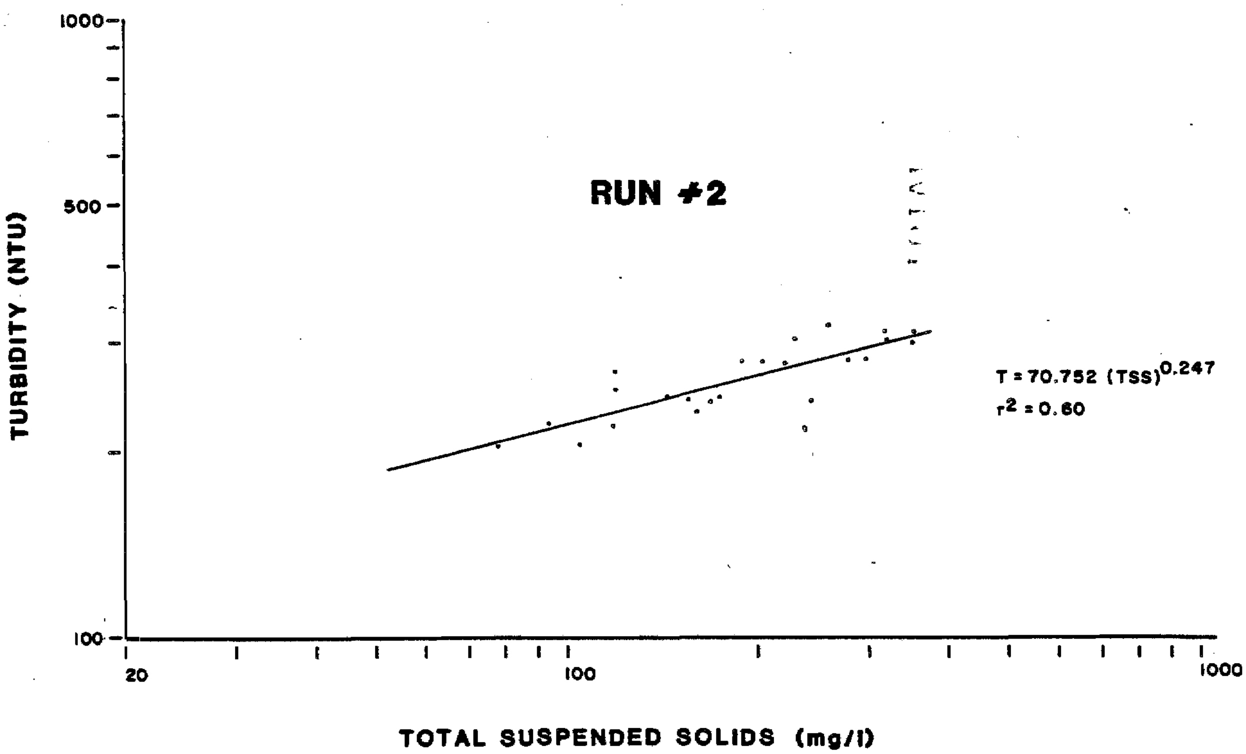
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 3.5

HARZA-EBASCO
SUSITNA JOINT VENTURE

TURBIDITY vs. SUSPENDED SOLIDS FROM SETTLING COLUMN

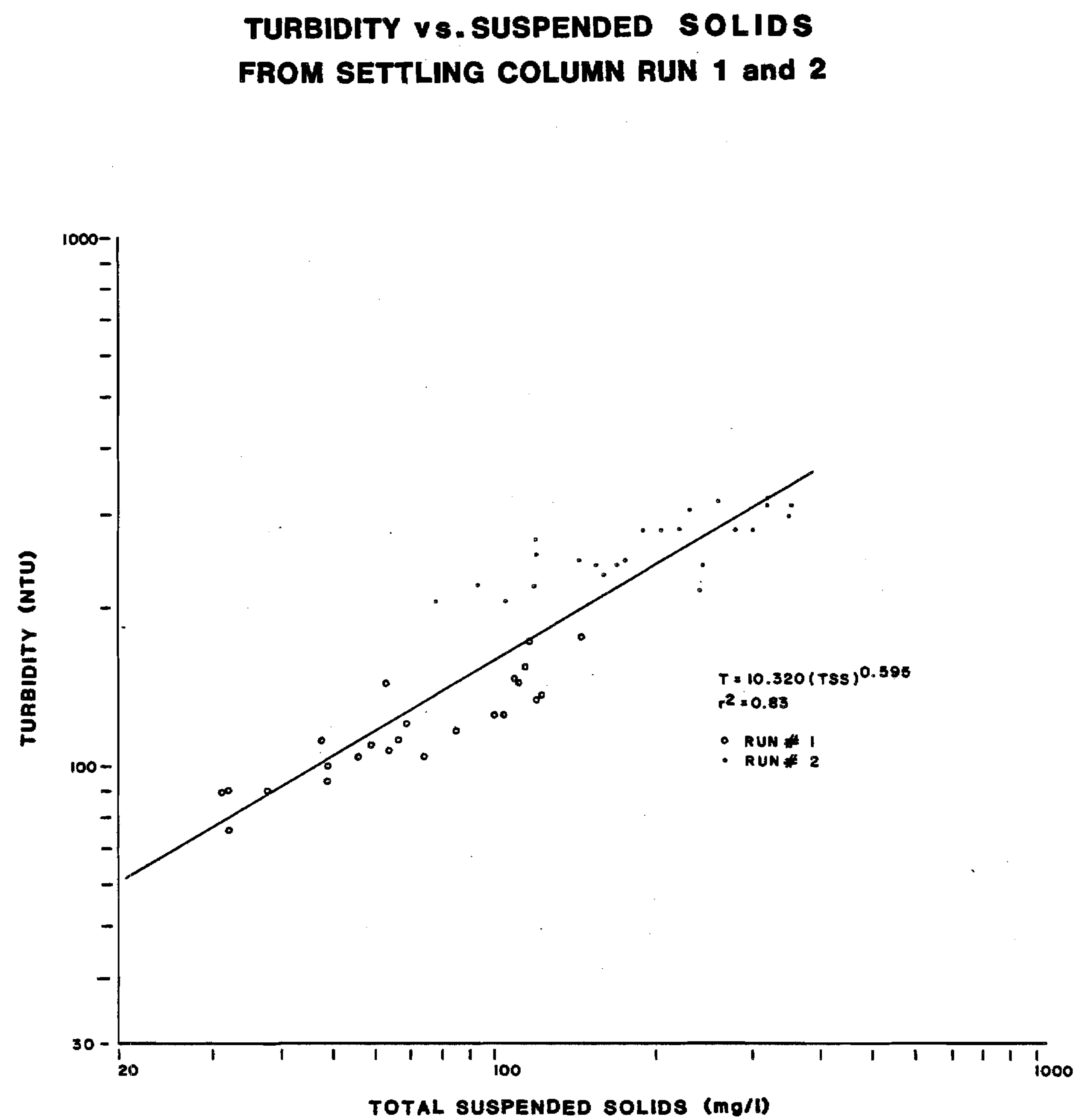




R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 3.6

HARZA-EBASCO
SUSITNA JOINT VENTURE

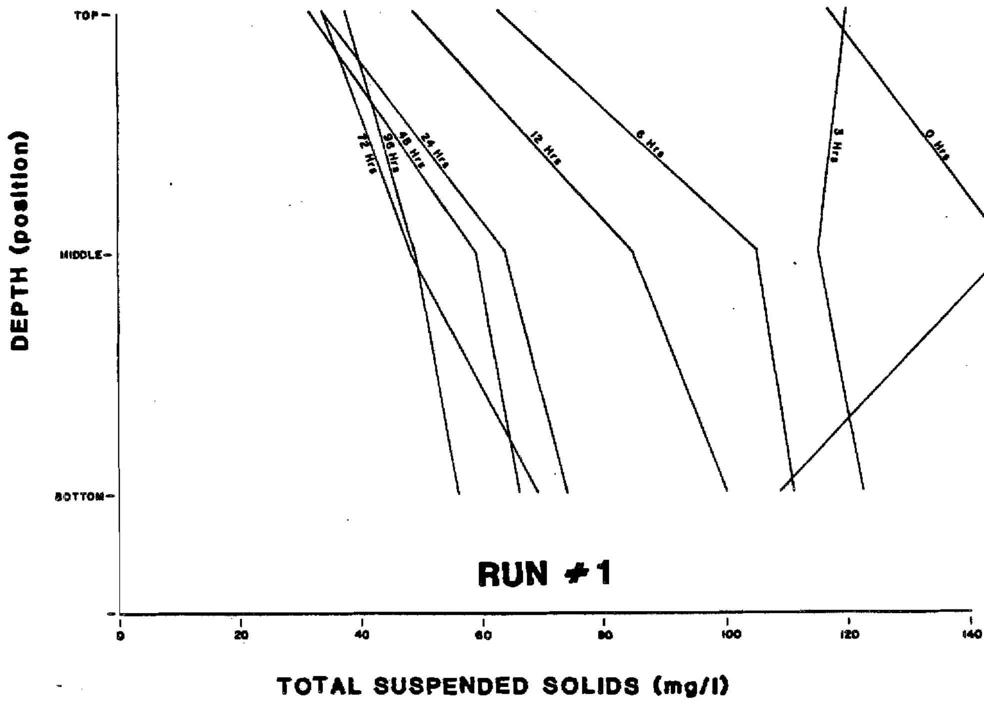


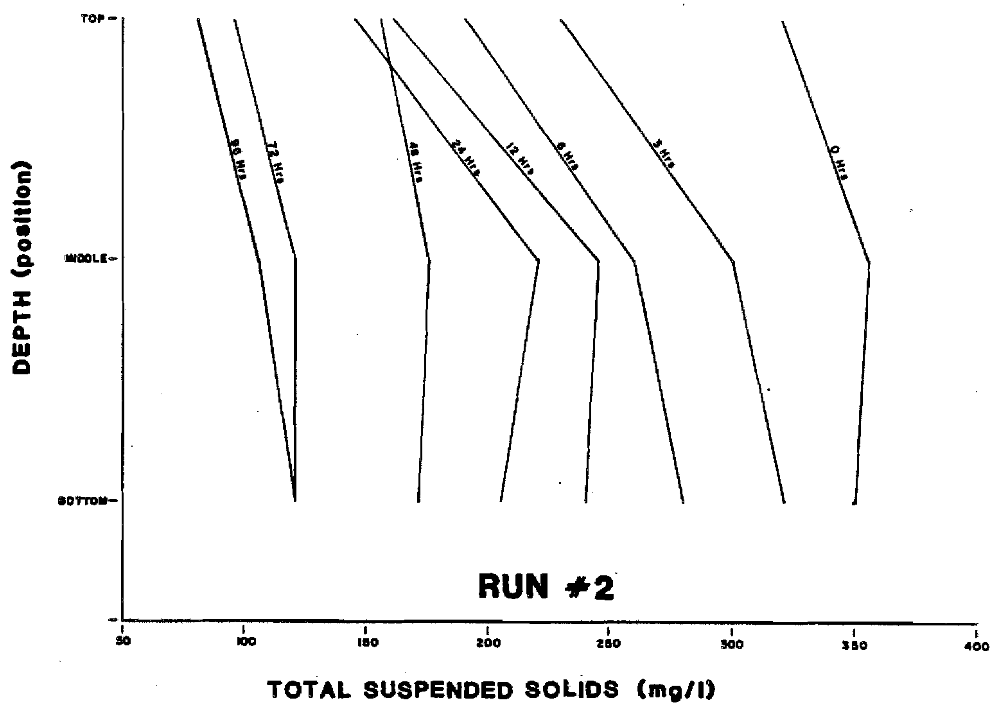
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 3.7

HARZA-EBASCO
SUSITNA JOINT VENTURE

SETTLING COLUMN
TOTAL SUSPENDED SOLIDS vs. SAMPLE DEPTH





R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

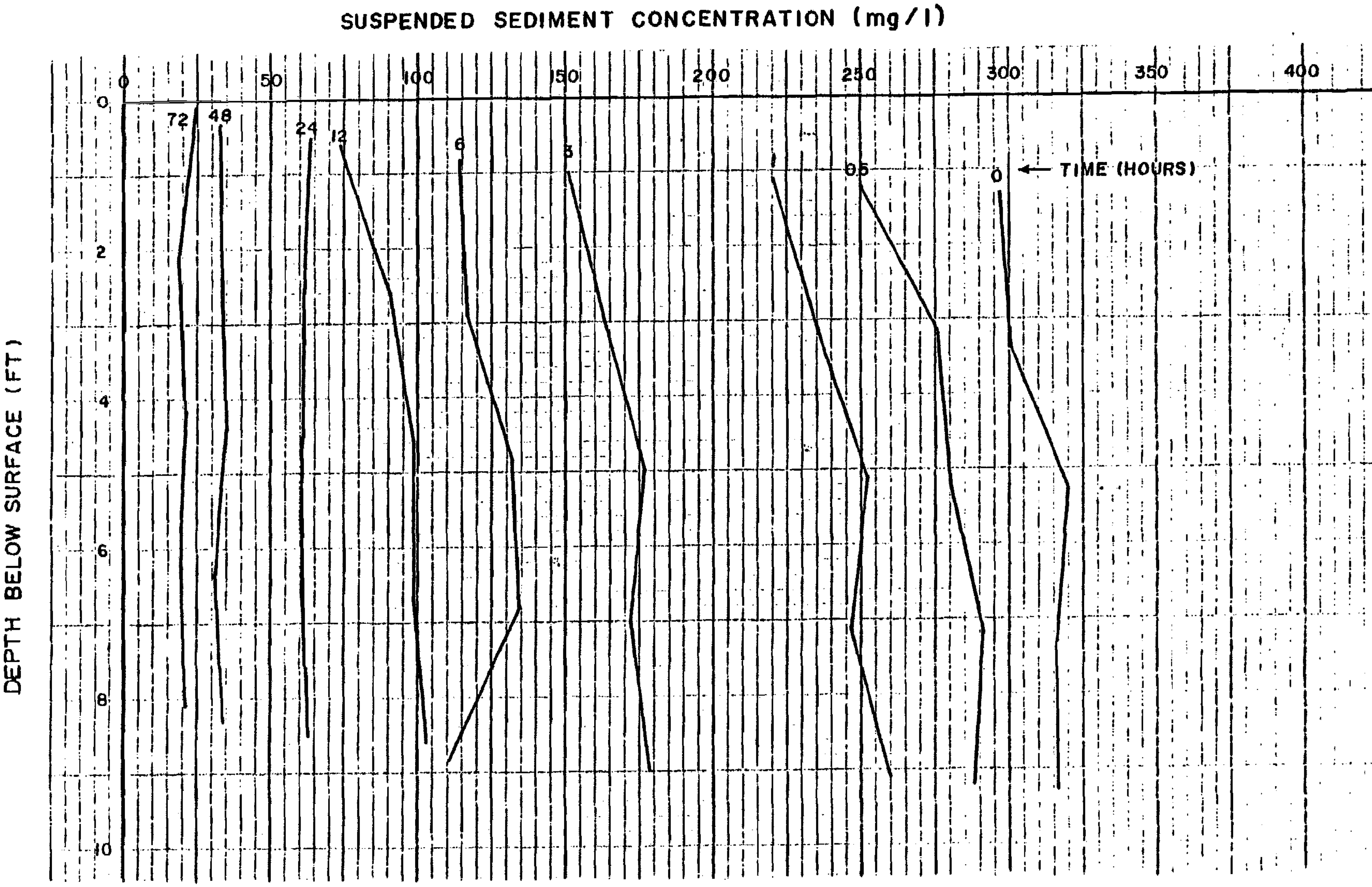
FIGURE 3.8

HARZA-EBASCO
SUSITNA JOINT VENTURE

FIGURE A-1 FROM RESERVOIR SEDIMENTATION

(R&M,1982b)

M14/15 19



SAMPLE COLLECTED ON 29 JULY 1981, 1 MILE ABOVE WATANA DAM SITE
WATER TEMPERATURE (7/29/81) = 50° F

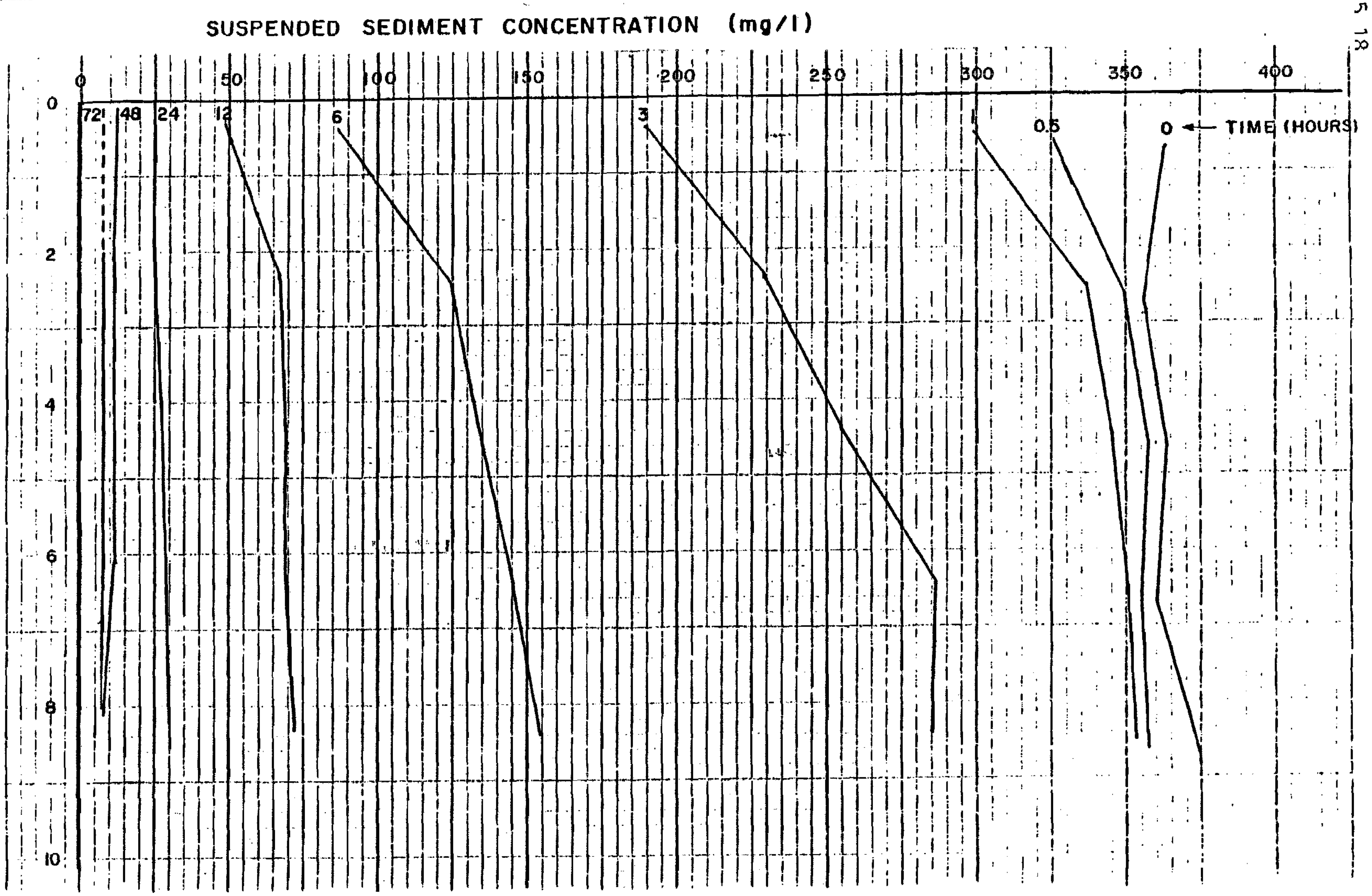
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 3.9

HARZA-EBASCO
SUSITNA JOINT VENTURE

FIGURE A-2 FROM RESERVOIR SEDIMENTATION

(R&M,1982b)



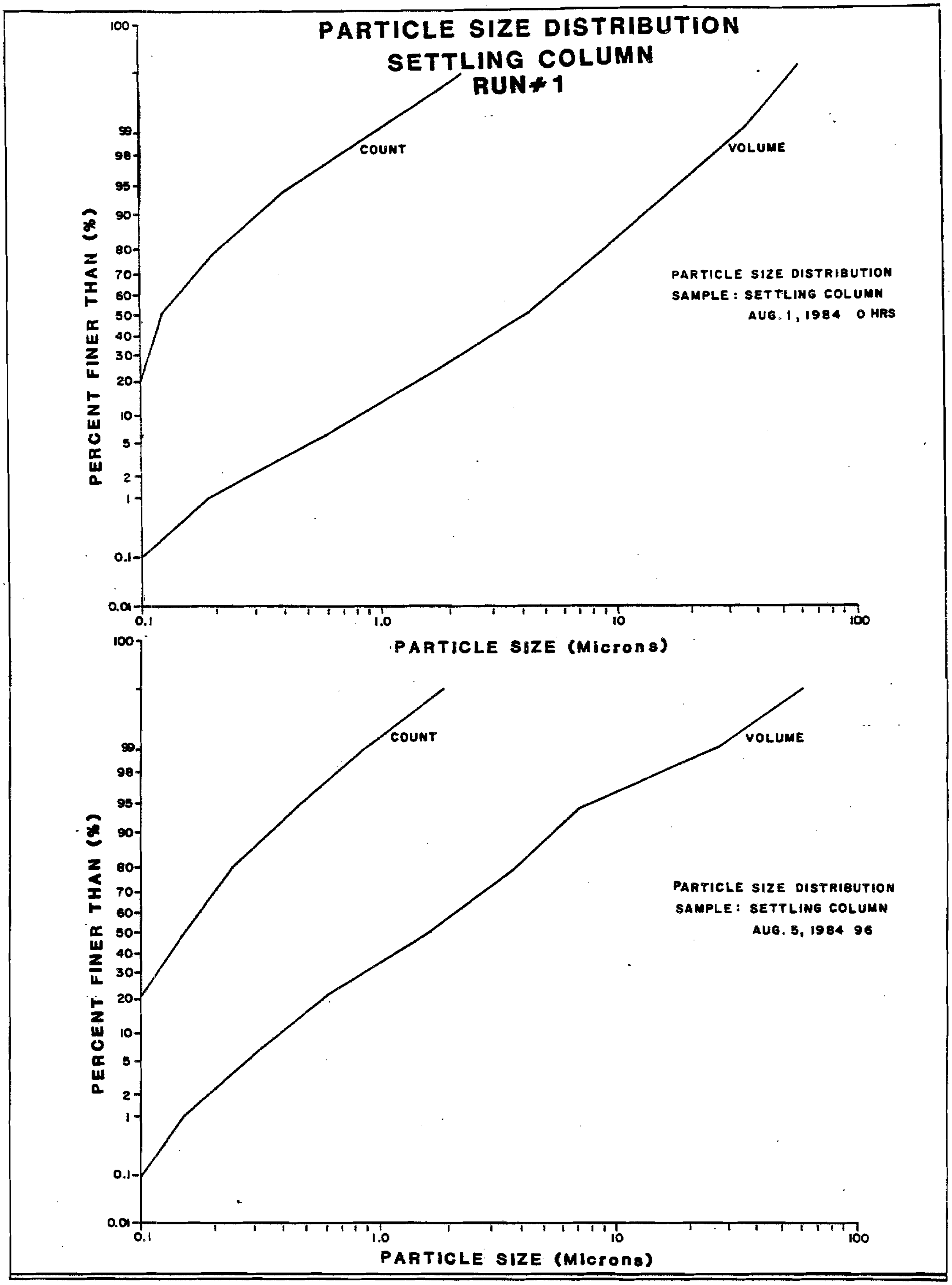
SAMPLE COLLECTED ON 3 SEPT. 1981, 1 MILE ABOVE WATANA DAM SITE
WATER TEMPERATURE (9/3/81) = 46°F

M14/15 18

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 3.10

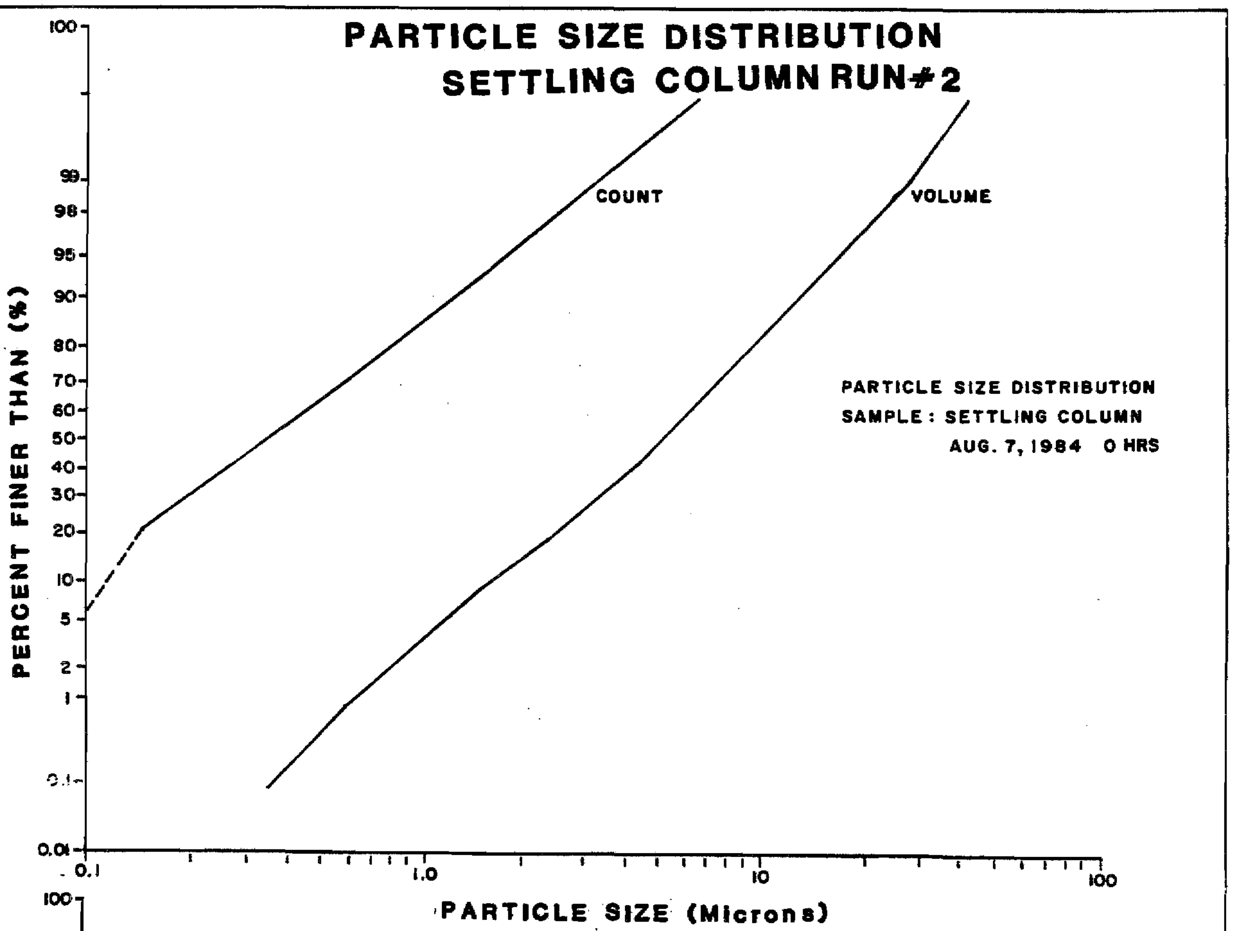
HARZA-EBASCO
SUSITNA JOINT VENTURE

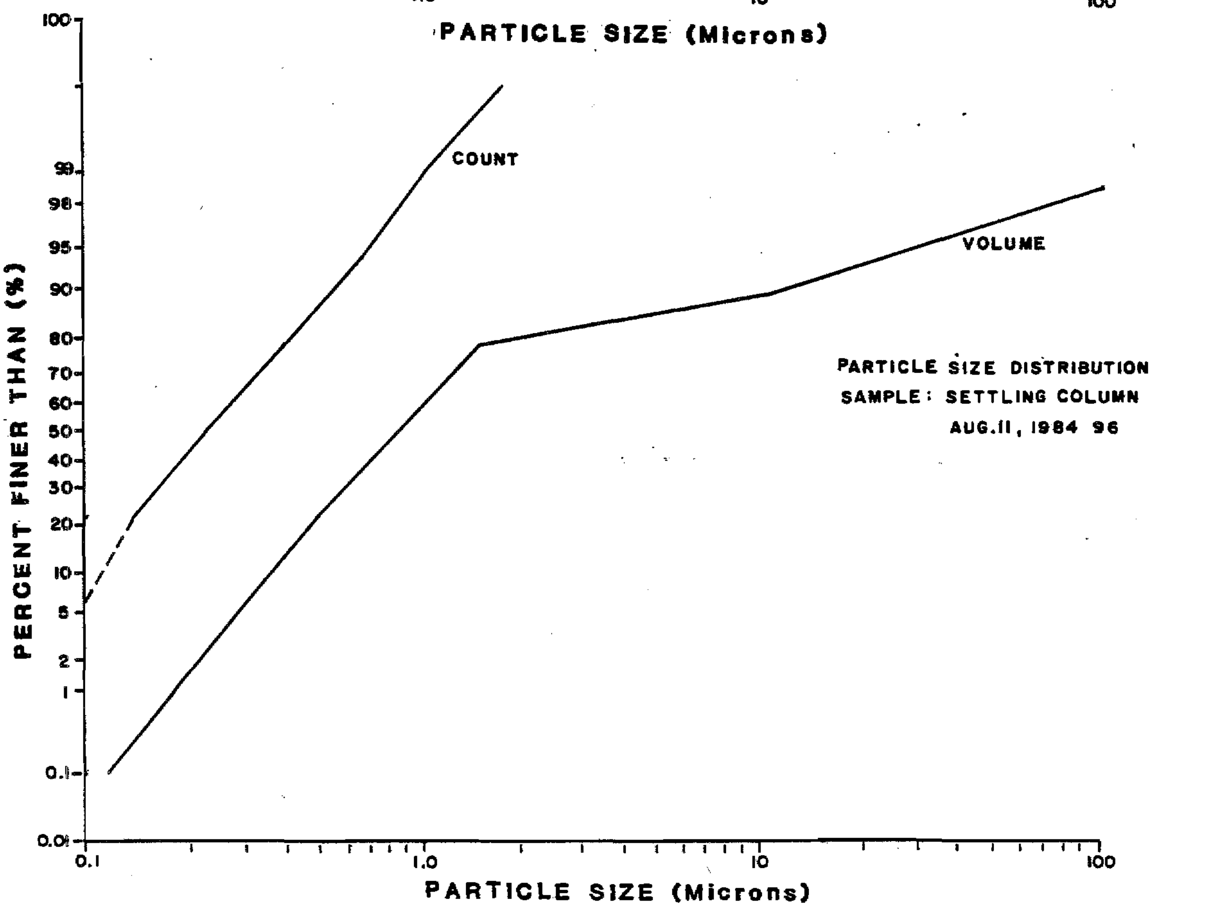


R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 3.11

HARZA-EBASCO
SUSITNA JOINT VENTURE





R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 3.12

HARZA-EBASCO
SUSITNA JOINT VENTURE

PERCENT REMOVAL OF SUSPENDED SOLIDS
SETTLING COLUMN

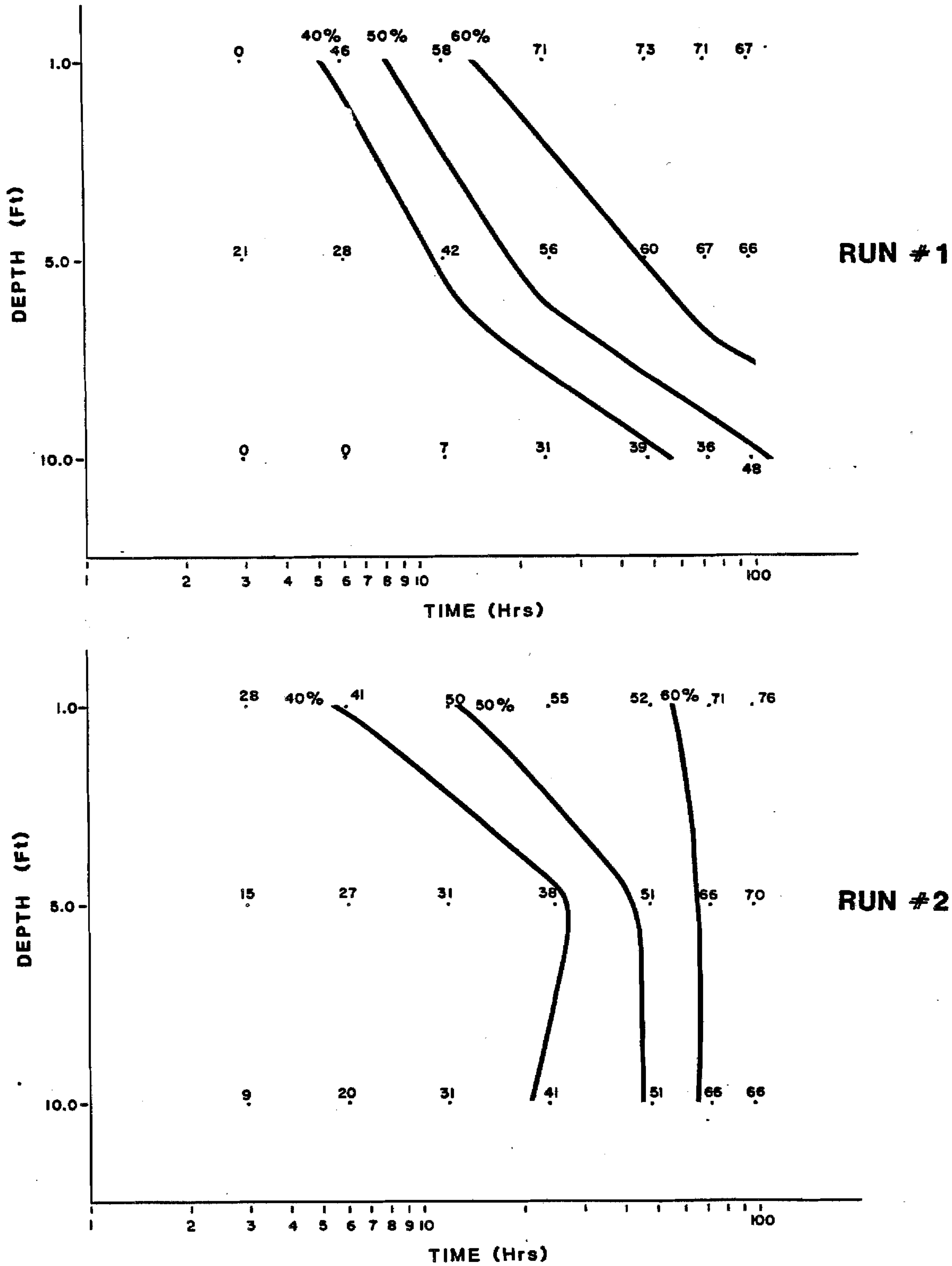
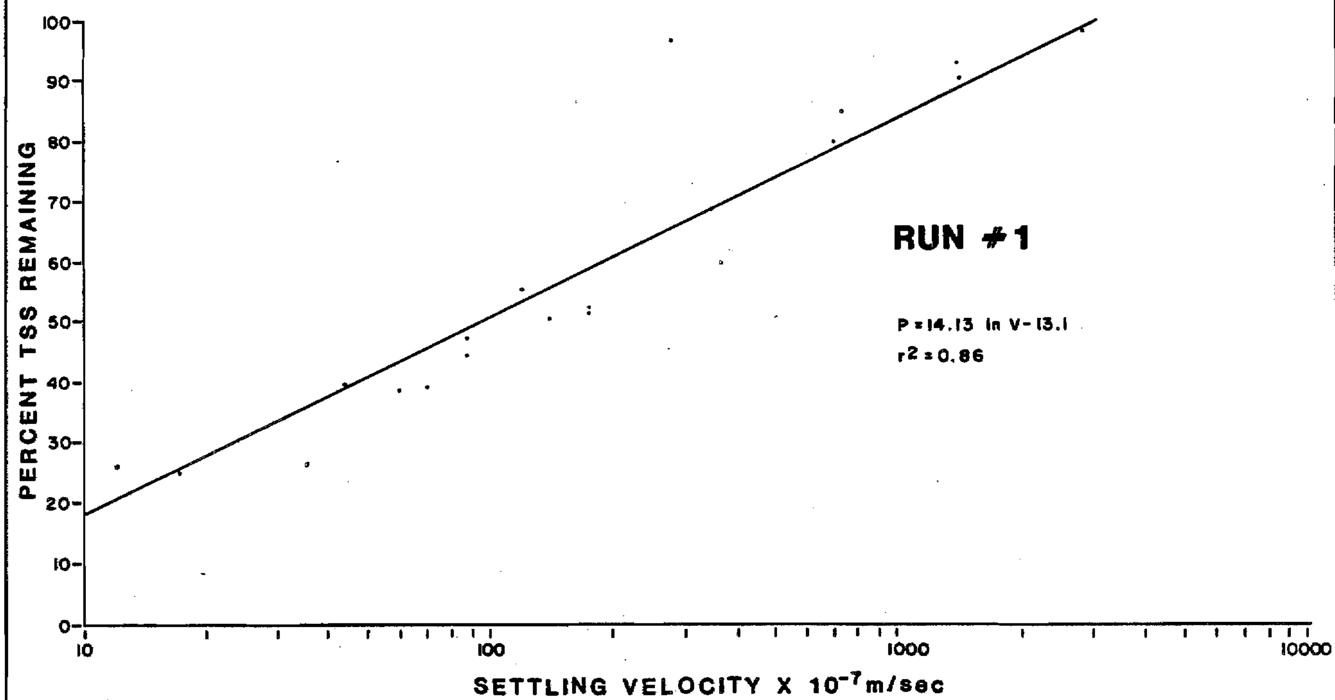


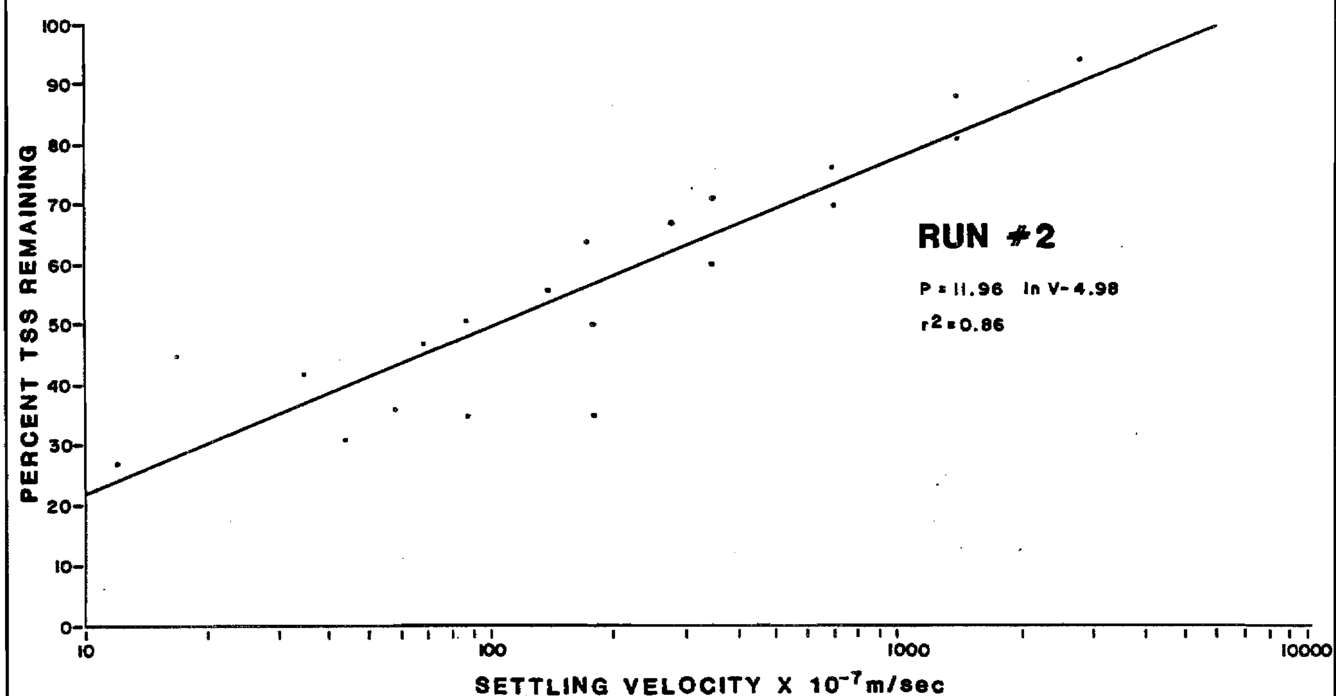
FIGURE 3.13

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

HARZA-EBASCO
SUSITNA JOINT VENTURE

SETTLING COLUMN
PERCENT TSS vs. ACTUAL SETTLING VELOCITIES





R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 3.14

HARZA-EBASCO
SUSITNA JOINT VENTURE

4.0 DISCUSSION

The results of the latest series of experiments on sediment settling rates in a quiescent column differ considerably from earlier studies. Figure 6.3 from "Reservoir Sedimentation", (R&M, 1982b), reproduced here as Figure 4.1 serves to illustrate the difference. Turbidity is plotted against time for 2 settling column runs conducted in 1981. The initial turbidities for each run in 1981 are almost twice the initial values in the 1984 settling column runs. The final 1981 values, however, are a fraction of the final turbidities in the 1984 experiments.

No particle size analysis was conducted on the 1981 samples so the information gained form those studies are limited to suspended sediment concentrations and turbidities. It appears from the data however that the 1981 samples contained a high concentration of coarse particles which rapidly settled out, and a low concentration of fines. This would explain the decrease in turbidity from about 500 NTU to less than 80 NTU in 72 hours.

The 1982 suspended sediment samples conversely contained a high concentration of fine particles and a low concentration of coarse particles. This explains the graph (Figure 3.4) of turbidity versus time, which indicates a rapid decrease in turbidity in the first 24 hours but subsequently a period of about 36 hours with little or no change in turbidity followed by a slight decrease of turbidity in the 96 hours sample. The most dramatic difference between the 1981 samples and the 1984 samples lies in the relative decrease in turbidity between 0 hour and 96 hours. The 1984 samples only decreased about 75 NTU over the 96 hour period whereas the 1981 samples decreased over 400 NTU in 72 hours.

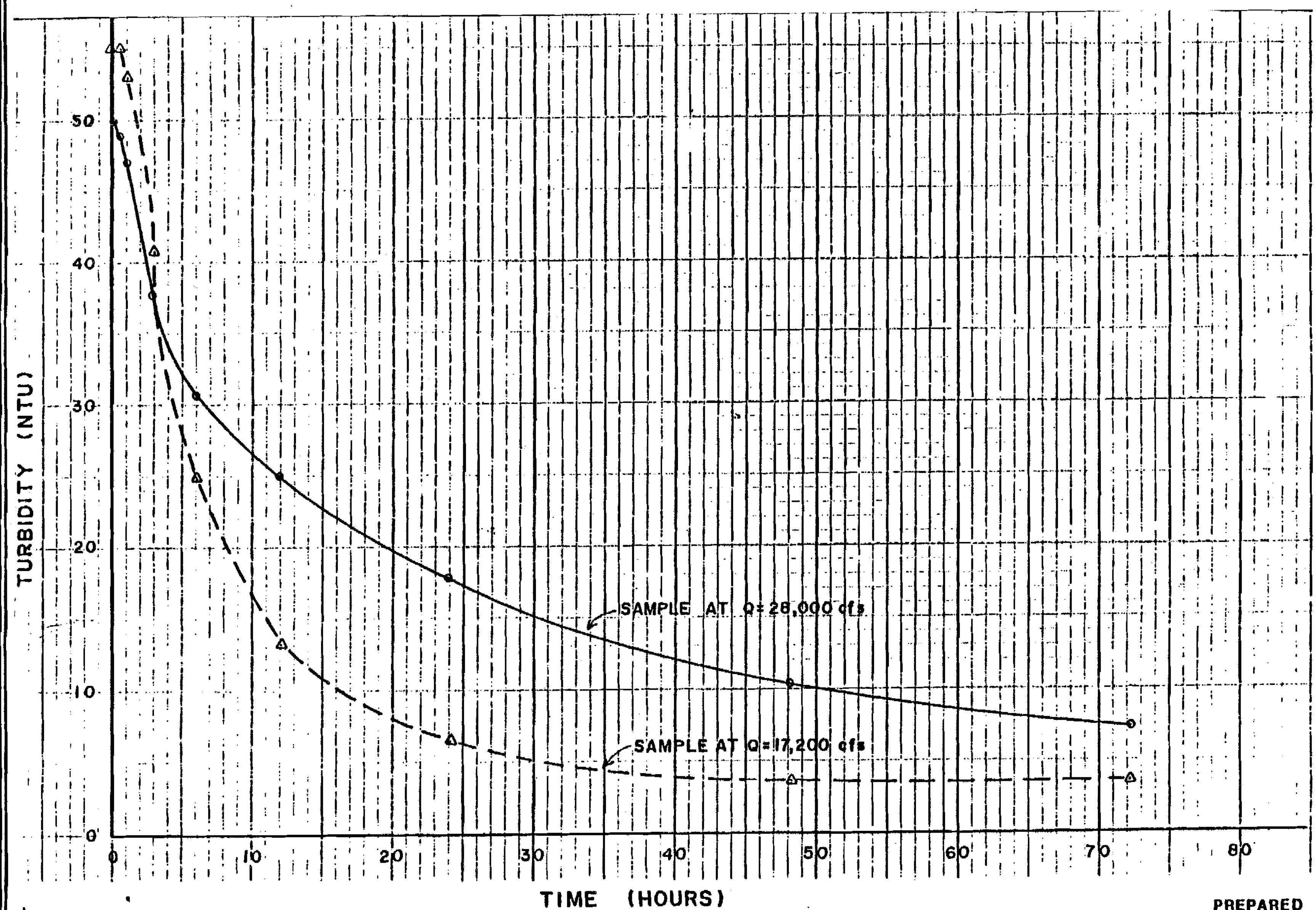
A possible explanation for the high fine particle concentration in the 1984 samples is illustrated in Figure 2.2. Warm air temperatures prevailed over the upper basin prior to sampling. This may have stimulated increased runoff from the glaciers which subsequently would contribute more fine sediment.

The 1981 sample was collected further upstream than the 1984 sample. That sampling site has generally more turbulence and higher water velocities. This may have caused a larger volume of coarse particles to enter the sample. This, however, does not explain the absence of fines from either of those particular samples.

The high concentration of fines in the 1984 sample may not be a natural condition. Figure 4.2 is a reproduction from "Susitna Reservoir Sedimentation and Water Quality Study", (Peratrovich, Nottingham & Drage, 1982), also included the FERC license application. This shows historical turbidity data for the river versus suspended sediment concentrations. This graph is not directly compatible with similar plots presented in this report (Figures 3.6 and 3.7) since it represents river turbidities and this report considers column (quiescent) turbidities, however, the lack of fine particles is evident. Fine particles are generally responsible for high turbidities at low suspended sediment concentrations. The plot on Figure 4.2 shows low turbidities even at high suspended sediment concentrations which would be expected if the majority of the sediments were coarse. Therefore, given the historical data base and the plot of that data, it appears that fine particles are generally in much lower concentrations than those measured in the 1984 settling column samples.

TURBIDITY VS TIME

1981 SETTLING COLUMN STUDY



PREPARED

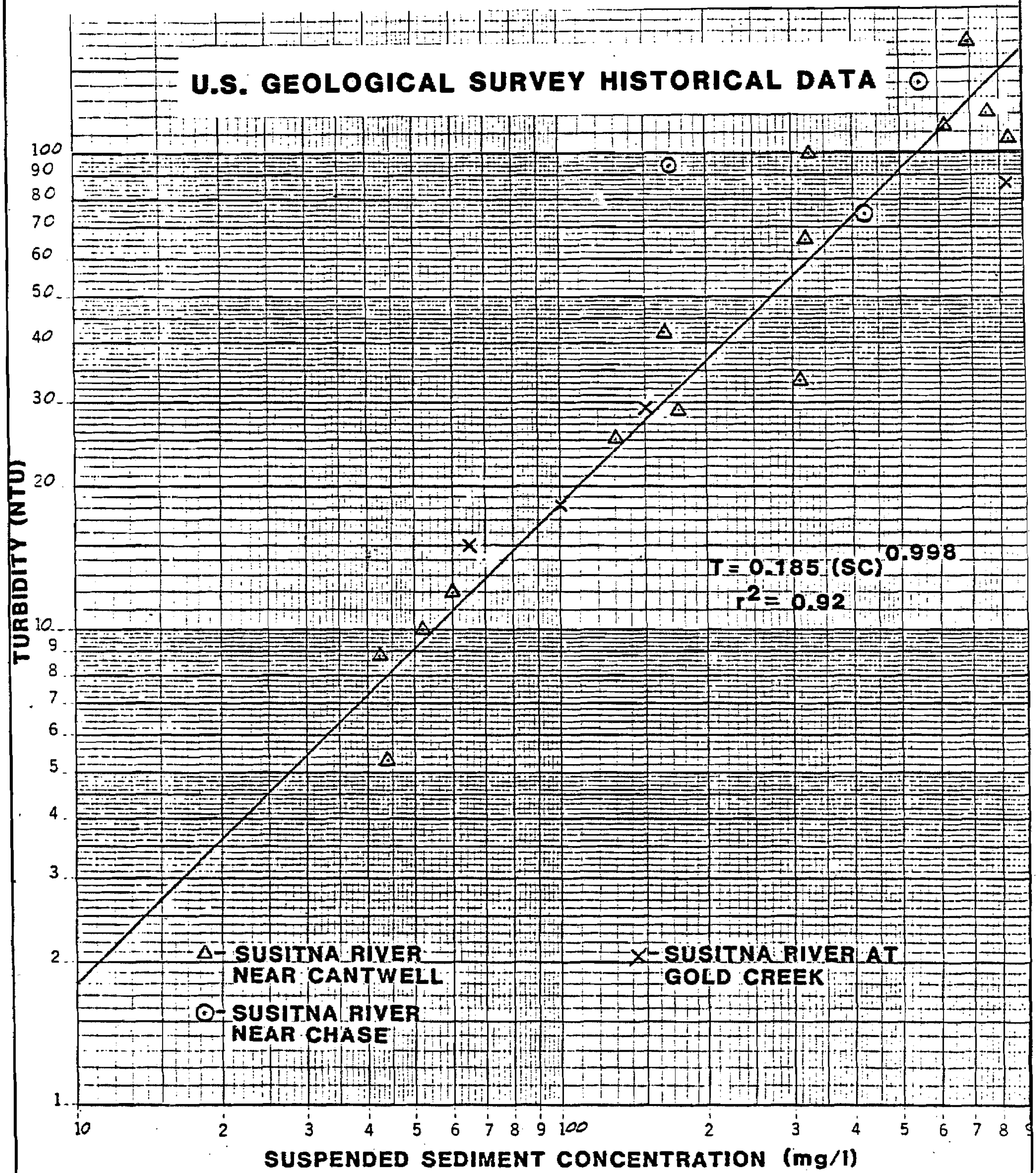
M14/15 19

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 4.1

HARZA-EBASCO
SUSITNA JOINT VENTURE

M14/15 20



TURBIDITY vs SUSPENDED SEDIMENT CONCENTRATION

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

FIGURE 4.2

HARZA-EBASCO
SUSITNA JOINT VENTURE

REFERENCES

Deer, W.A., R.A. Howie and J. Zussman. 1974. An Introduction to the Rock-Forming Minerals. Longman Group Limited, London.

Dietrich, William E. 1982. Settling Velocity of Natural Particles. Water Resources Research, Vol. 18, No. 16.

Karuhn, R.F. and R.H. Berg. 1982. Practical Aspects of Electrozone Size Analysis. Particle Data Laboratories, Elmhurst, Illinois.

Morris, Henry M. and James M. Wiggert. 1972. Applied Hydraulic in Engineering, 2nd Edition. Ronald Press company, New York.

Peratrovich, Nottingham and Drage, Inc. 1982. Susitna Reservoir Sedimentation and Water Clarity Study. Anchorage, Alaska. Alaska Power Authority. Susitna Hydroelectric Project. Report for Acres American, Inc. Vol. 1.

R&M Consultants, Inc. 1982. Placer Mining Wastewater, Settling Pond Demonstration Project. Report for State of Alaska, Department of Environmental Conservation.

R&M Consultants, Inc. 1982. Reservoir Sedimentation. Anchorage, Alaska. Alaska Power Authority. Susitna Hydroelectric Project. Report for Acres American, Inc. Vol. 1.

Wadell, Hakon. 1932. Volume, SHape and Roundness of Rock Particles. Journal of Geology, Volume 40.

APPENDIX

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/7/84 0 HRS 8213 : JOB NUMBER

VOLUME (MASS) DISTRIBUTION FROM DISPLAY AREA: 4
========================

INDICES

VOLUME MODE = 6.12 MEDIAN = 5.09 MICRONS AND LARGER

GEOMETRIC VOLUME MEAN = 4.70 +/- 5.95 (126.52%) SKEWNESS = -.24

ARITHMETIC VOLUME MEAN = 6.38 +/- 5.25 (82.28%) SKEWNESS = .05

FOR PLOTTING PROBABILITY ON LOG PAPER:

PERCENTILE: 00.1% OF VOLUME IS AT 40.73 MICRONS AND LARGER
PERCENTILE: 01.0% OF VOLUME IS AT 26.87 MICRONS AND LARGER
PERCENTILE: 06.0% OF VOLUME IS AT 14.74 MICRONS AND LARGER
PERCENTILE: 22.0% OF VOLUME IS AT 8.86 MICRONS AND LARGER
PERCENTILE: 50.0% OF VOLUME IS AT 5.09 MICRONS AND LARGER
PERCENTILE: 78.0% OF VOLUME IS AT 2.55 MICRONS AND LARGER
PERCENTILE: 94.0% OF VOLUME IS AT 1.22 MICRONS AND LARGER
PERCENTILE: 99.0% OF VOLUME IS AT .61 MICRONS AND LARGER
PERCENTILE: 99.9% OF VOLUME IS AT .35 MICRONS AND LARGER

COUNT (FREQUENCY) DISTRIBUTION FROM DISPLAY AREA: 5
============================

INDICES

COUNTS MODE = .33 MEDIAN = .33 MICRONS AND LARGER

GEOMETRIC COUNTS MEAN = .33 +/- .54 (163.02%) SKEWNESS = .00

ARITHMETIC COUNTS MEAN = .54 +/- .67 (124.78%) SKEWNESS = .31

FOR PLOTTING PROBABILITY ON LOG PAPER:

PERCENTILE: 00.1% OF COUNTS IS AT 6.87 MICRONS AND LARGER
PERCENTILE: 01.0% OF COUNTS IS AT 3.15 MICRONS AND LARGER
PERCENTILE: 06.0% OF COUNTS IS AT 1.58 MICRONS AND LARGER
PERCENTILE: 22.0% OF COUNTS IS AT .72 MICRONS AND LARGER
PERCENTILE: 50.0% OF COUNTS IS AT .33 MICRONS AND LARGER
PERCENTILE: 78.0% OF COUNTS IS AT .15 MICRONS AND LARGER
PERCENTILE: 94.0% OF COUNTS IS AT .08 MICRONS AND LARGER
PERCENTILE: 99.0% OF COUNTS IS AT .04 MICRONS AND LARGER
PERCENTILE: 99.9% OF COUNTS IS AT .02 MICRONS AND LARGER

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/7/84 0 HRS 8213 : JOB NUMBER

PARTICLE SIZE VS. COUNTS
ENCLOSING
LOW AT 1 .02 70185 HIGH AT 90 46.25 1

GRAPH OF DIAMETER SIZES VS. DIFFERENTIAL COUNTS FROM CHANNEL 1 TO 90, AND SKIP: 2

% MAX	SIZE
1.7	.02
3.4	.03
6.6	.03
11.8	.05
19.7	.06
30.5	.08
44.0	.10
59.1	.13
74.1	.17
86.4	.21
93.9	.28
95.0	.36
89.5	.47
78.5	.61
64.6	.79
49.2	1.02
34.8	1.33
22.9	1.72
14.3	2.23
7.9	2.89
4.2	3.75
2.2	4.86
1.1	6.30
.5	8.18
.2	10.60
.0	13.75
.0	17.83
.0	23.12
.0	29.99
.0	38.89

% MAX SIZE 0 10 20 30 40 50 60 70 80 90 100

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/7/84 0 HRS 8213 : JOB NUMBER

"TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS
TABULATION

DATA ID 8213 DATE 6 SEP
SIZE-NORMALIZED COUNTS DISTRIBUTION
TOTAL = 1.12727E 8

CHNL	SIZE	COUNTS	% >	CHNL	SIZE	COUNTS	% >	CHNL	SIZE	COUNTS	% >
1	.02	70185	100.00	31	.28	3937326	58.95	61	3.75	176766	.74
2	.02	90005	99.94	32	.30	3984239	55.45	62	4.09	143227	.59
3	.02	114515	99.86	33	.33	4000000	51.92	63	4.46	117978	.46
4	.03	144553	99.76	34	.36	3984239	48.37	64	4.86	93207	.35
5	.03	181035	99.63	35	.39	3937326	44.84	65	5.30	73207	.27
6	.03	224941	99.47	36	.43	3860361	41.34	66	5.78	58847	.21
7	.03	277298	99.27	37	.47	3755133	37.92	67	6.30	46330	.15
8	.04	339152	99.02	38	.51	3624043	34.59	68	6.87	35069	.11
9	.04	411541	98.72	39	.56	3470020	31.37	69	7.50	26359	.08
10	.05	495453	98.36	40	.61	3291358	28.30	70	8.18	20146	.06
11	.05	591783	97.92	41	.66	3089423	25.38	71	8.92	15379	.04
12	.05	701282	97.39	42	.72	2907472	22.64	72	9.72	10821	.03
13	.06	824506	96.77	43	.79	2710070	20.06	73	10.60	7163	.02
14	.06	961759	96.04	44	.86	2487019	17.65	74	11.56	4851	.01
15	.07	1113034	95.18	45	.94	2262861	15.45	75	12.61	3120	.01
16	.08	1277973	94.20	46	1.02	2062328	13.44	76	13.75	1915	.00
17	.08	1455813	93.06	47	1.11	1875017	11.61	77	14.99	1195	.00
18	.09	1645358	91.77	48	1.22	1662017	9.95	78	16.35	736	.00
19	.10	1844954	90.31	49	1.33	1459987	8.47	79	17.83	450	.00
20	.11	2052492	88.68	50	1.45	1299668	7.18	80	19.44	267	.00
21	.12	2265417	86.86	51	1.58	1139867	6.02	81	21.20	161	.00
22	.13	2480763	84.85	52	1.72	958727	5.01	82	23.12	106	.00
23	.14	2695215	82.64	53	1.87	813642	4.16	83	25.22	66	.00
24	.15	2905173	80.25	54	2.04	707747	3.44	84	27.50	40	.00
25	.17	3106857	77.68	55	2.23	599970	2.81	85	29.99	24	.00
26	.18	3296411	74.92	56	2.43	498933	2.28	86	32.70	14	.00
27	.20	3470020	72.00	57	2.65	407443	1.84	87	35.66	8	.00
28	.21	3624043	68.92	58	2.89	331991	1.48	88	38.89	3	.00
29	.23	3755133	65.70	59	3.15	273888	1.18	89	42.41	2	.00
30	.26	3860361	62.37	60	3.44	220161	.94	90	46.25	1	.00

DISPLAY AREA: 4

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS — 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/7/84 0 HRS — 8213 : JOB NUMBER

PARTICLE SIZE VS. VOLUME
ENCLOSING
LOW AT 1 .30 39353 HIGH AT 113 53.74 2974

GRAPH OF DIAMETER SIZES VS. DIFFERENTIAL VOLUME FROM CHANNEL 1 TO 113, AND SKIP: 2

% MAX	SIZE
.9	.30
1.4	.35
2.1	.40
3.1	.46
4.4	.53
6.2	.61
8.5	.70
11.5	.80
15.2	.92
19.7	1.06
25.0	1.22
31.1	1.40
38.0	1.60
43.7	1.84
52.6	2.12
60.0	2.43
65.8	2.79
72.6	3.21
78.9	3.68
84.4	4.23
89.0	4.86
94.0	5.58
95.0	6.41
93.7	7.37
90.2	8.46
82.6	9.72
65.3	11.17
48.0	12.83
36.0	14.74
23.5	16.93
16.1	19.44
11.6	22.34
8.0	25.66
5.5	29.47
3.4	33.85
2.2	38.89
.9	44.67
.6	51.31

% MAX SIZE 0 10 20 30 40 50 60 70 80 90 100

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/7/84 0 HRS 8213 : JOB NUMBER

"TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS
TABULATION

DATA ID 8213 DATE 6 SEP
SIZE-NORMALIZED VOLUME DISTRIBUTION
TOTAL =74151578

CHNL	SIZE	VOLUME	% >	CHNL	SIZE	VOLUME	% >	CHNL	SIZE	VOLUME	% >
1	.30	39353	100.00	39	1.76	1730196	87.94	77	10.18	3211820	17.71
2	.32	45316	99.98	40	1.84	1831440	86.95	78	10.66	3085651	15.87
3	.33	52070	99.95	41	1.93	2004484	85.90	79	11.17	2736946	14.09
4	.35	59700	99.92	42	2.02	2082473	84.75	80	11.70	2467802	12.52
5	.37	68298	99.89	43	2.12	2207398	83.55	81	12.25	2195155	11.11
6	.38	77962	99.85	44	2.22	2303797	82.28	82	12.83	2015185	9.84
7	.40	88801	99.80	45	2.32	2341329	80.96	83	13.44	1775377	8.69
8	.42	100924	99.75	46	2.43	2518098	79.62	84	14.07	1607986	7.67
9	.44	114453	99.69	47	2.55	2664804	78.17	85	14.74	1508167	6.74
10	.46	129512	99.63	48	2.67	2689056	76.64	86	15.43	1300600	5.88
11	.48	146230	99.55	49	2.79	2760247	75.10	87	16.16	1130109	5.13
12	.51	164748	99.47	50	2.92	2761569	73.51	88	16.93	985532	4.48
13	.53	185204	99.38	51	3.06	2890776	71.93	89	17.73	831255	3.92
14	.55	207744	99.27	52	3.21	3044353	70.27	90	18.57	727594	3.44
15	.58	232520	99.15	53	3.36	3038264	68.52	91	19.44	676463	3.02
16	.61	259680	99.02	54	3.52	3193066	66.77	92	20.36	589393	2.63
17	.64	289380	98.87	55	3.68	3308363	64.94	93	21.33	538004	2.30
18	.67	321771	98.70	56	3.86	3242379	63.04	94	22.34	487497	1.99
19	.70	357007	98.52	57	4.04	3426549	61.18	95	23.39	433426	1.71
20	.73	395236	98.31	58	4.23	3541622	59.21	96	24.50	381573	1.46
21	.77	436603	98.08	59	4.43	3525277	57.18	97	25.66	335156	1.24
22	.80	481244	97.83	60	4.64	3678918	55.15	98	26.87	288085	1.05
23	.84	529291	97.56	61	4.86	3731954	53.04	99	28.14	262298	.88
24	.88	580863	97.25	62	5.09	3840626	50.90	100	29.47	231788	.73
25	.92	636068	96.92	63	5.33	3871866	48.69	101	30.87	210363	.60
26	.96	694996	96.55	64	5.58	3942851	46.47	102	32.33	185100	.48
27	1.01	757724	96.16	65	5.85	3938553	44.20	103	33.85	140577	.37
28	1.06	824308	95.72	66	6.12	4000000	41.94	104	35.46	104377	.29
29	1.11	894784	95.25	67	6.41	3985599	39.65	105	37.13	88547	.23
30	1.16	969164	94.73	68	6.72	3974594	37.36	106	38.89	92108	.18
31	1.22	1047430	94.18	69	7.04	3960428	35.08	107	40.73	45009	.13
32	1.27	1129545	93.58	70	7.37	3929233	32.80	108	42.65	46970	.10
33	1.33	1215436	92.93	71	7.72	3929956	30.55	109	44.67	38170	.07
34	1.40	1304999	92.23	72	8.08	3823995	28.29	110	46.78	36791	.05
35	1.46	1398100	91.48	73	8.46	3782693	26.09	111	49.00	23790	.03
36	1.53	1494570	90.68	74	8.86	3735761	23.92	112	51.31	24246	.02
37	1.60	1594205	89.82	75	9.28	3615426	21.78	113	53.74	2974	.00
38	1.68	1671362	88.90	76	9.72	3465100	19.70				

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 7 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/11/84 96 HRS 8213 : JOB NUMBER

VOLUME (MASS) DISTRIBUTION FROM DISPLAY AREA: 4
========================

INDICES

VOLUME MODE = .80 MEDIAN = .86 MICRONS AND LARGER

GEOMETRIC VOLUME MEAN = 1.07 +/- 2.71 (252.70%) SKEWNESS = .10

ARITHMETIC VOLUME MEAN = 6.33 +/- 22.80 (360.27%) SKEWNESS = .24

FOR PLOTTING PROBABILITY ON LOG PAPER:

PERCENTILE: 00.1% OF VOLUME IS AT 145.14 MICRONS AND LARGER
PERCENTILE: 01.0% OF VOLUME IS AT 126.35 MICRONS AND LARGER
PERCENTILE: 06.0% OF VOLUME IS AT 10.42 MICRONS AND LARGER
PERCENTILE: 22.0% OF VOLUME IS AT 1.50 MICRONS AND LARGER
PERCENTILE: 50.0% OF VOLUME IS AT .86 MICRONS AND LARGER
PERCENTILE: 78.0% OF VOLUME IS AT .49 MICRONS AND LARGER
PERCENTILE: 94.0% OF VOLUME IS AT .30 MICRONS AND LARGER
PERCENTILE: 99.0% OF VOLUME IS AT .19 MICRONS AND LARGER
PERCENTILE: 99.9% OF VOLUME IS AT .12 MICRONS AND LARGER

COUNT (FREQUENCY) DISTRIBUTION FROM DISPLAY AREA: 5
=============================

INDICES

COUNTS MODE = .23 MEDIAN = .23 MICRONS AND LARGER

GEOMETRIC COUNTS MEAN = .23 +/- .22 (92.67%) SKEWNESS = -.01

ARITHMETIC COUNTS MEAN = .29 +/- .21 (72.39%) SKEWNESS = .26

FOR PLOTTING PROBABILITY ON LOG PAPER:

PERCENTILE: 00.1% OF COUNTS IS AT 1.72 MICRONS AND LARGER
PERCENTILE: 01.0% OF COUNTS IS AT 1.02 MICRONS AND LARGER
PERCENTILE: 06.0% OF COUNTS IS AT .66 MICRONS AND LARGER
PERCENTILE: 22.0% OF COUNTS IS AT .39 MICRONS AND LARGER
PERCENTILE: 50.0% OF COUNTS IS AT .23 MICRONS AND LARGER
PERCENTILE: 78.0% OF COUNTS IS AT .14 MICRONS AND LARGER
PERCENTILE: 94.0% OF COUNTS IS AT .08 MICRONS AND LARGER
PERCENTILE: 99.0% OF COUNTS IS AT .05 MICRONS AND LARGER
PERCENTILE: 99.9% OF COUNTS IS AT .03 MICRONS AND LARGER

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 7 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/11/84 96 HRS 8213 : JOB NUMBER

PARTICLE SIZE VS. COUNTS
ENCLOSING
LOW AT 1 .03 31573 HIGH AT 78 23.12 2

GRAPH OF DIAMETER SIZES VS. DIFFERENTIAL COUNTS FROM CHANNEL 1 TO 78, AND SKIP: 2

% MAX	SIZE
.8	.03
2.3	.04
6.3	.05
14.4	.06
28.4	.08
48.3	.11
70.5	.14
88.4	.18
95.4	.23
88.4	.30
71.7	.39
47.9	.51
26.9	.66
12.8	.86
5.4	1.11
1.8	1.45
.5	1.87
.2	2.43
.0	3.15
.0	4.09
.0	5.30
.0	6.87
.0	8.92
.0	11.56
.0	14.99
.0	19.44

% MAX SIZE 0 10 20 30 40 50 60 70 80 90 100

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 7 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/11/84 96 HRS 8213 : JOB NUMBER

"TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS
TABULATION

DATA ID 8213 DATE 2 FEB
SIZE-NORMALIZED COUNTS DISTRIBUTION
TOTAL = 7.67200E 7

CHNL	SIZE	COUNTS	% >	CHNL	SIZE	COUNTS	% >	CHNL	SIZE	COUNTS	% >
1	.03	31573	100.00	27	.28	3867743	41.90	53	2.65	3487	.01
2	.03	46869	99.96	28	.30	3708553	36.86	54	2.89	2075	.01
3	.03	68417	99.90	29	.33	3496635	32.03	55	3.15	1241	.00
4	.04	98207	99.81	30	.36	3241864	27.47	56	3.44	727	.00
5	.04	138617	99.68	31	.39	3006819	23.24	57	3.75	392	.00
6	.05	192393	99.50	32	.43	2671360	19.32	58	4.09	228	.00
7	.05	262581	99.25	33	.47	2325401	15.84	59	4.46	129	.00
8	.05	352398	98.91	34	.51	2009107	12.81	60	4.86	68	.00
9	.06	465055	98.45	35	.56	1705792	10.19	61	5.30	34	.00
10	.06	603494	97.84	36	.61	1401248	7.97	62	5.78	20	.00
11	.07	770089	97.05	37	.66	1127904	6.14	63	6.30	12	.00
12	.08	966289	96.05	38	.72	906942	4.67	64	6.87	7	.00
13	.08	1192263	94.79	39	.79	716043	3.49	65	7.50	6	.00
14	.09	1446560	93.24	40	.86	538106	2.56	66	8.18	4	.00
15	.10	1725834	91.35	41	.94	408182	1.85	67	8.92	3	.00
16	.11	2024698	89.10	42	1.02	307221	1.32	68	9.72	2	.00
17	.12	2335720	86.46	43	1.11	225243	.92	69	10.60	3	.00
18	.13	2649598	83.42	44	1.22	163035	.63	70	11.56	2	.00
19	.14	2955548	79.97	45	1.33	107086	.42	71	12.61	2	.00
20	.15	3241864	76.11	46	1.45	73476	.28	72	13.75	2	.00
21	.17	3496635	71.89	47	1.58	48777	.18	73	14.99	1	.00
22	.18	3708553	67.33	48	1.72	29321	.12	74	16.35	2	.00
23	.20	3867743	62.50	49	1.87	20316	.08	75	17.83	1	.00
24	.21	3966518	57.45	50	2.04	14919	.05	76	19.44	1	.00
25	.23	4000000	52.28	51	2.23	9977	.03	77	21.20	1	.00
26	.26	3966518	47.07	52	2.43	6407	.02	78	23.12	2	.00

DISPLAY AREA: 4

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 7 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/11/84 96 HRS 8213 : JOB NUMBER

PARTICLE SIZE VS. VOLUME
ENCLOSING
LOW AT 1 .09 11990 HIGH AT 108 155.55 32173

GRAPH OF DIAMETER SIZES VS. DIFFERENTIAL VOLUME FROM CHANNEL 1 TO 108, AND SKIP: 2

% MAX	SIZE
.3	.09
.8	.12
2.2	.14
5.1	.17
10.8	.21
20.3	.26
34.3	.33
52.1	.40
70.9	.49
86.6	.61
94.8	.75
93.5	.92
83.4	1.13
63.2	1.40
40.1	1.72
31.9	2.12
18.9	2.60
9.9	3.21
4.8	3.95
2.1	4.86
.9	5.98
.7	7.37
.5	9.07
.7	11.17
.9	13.75
1.3	16.93
1.3	20.84
1.0	25.66
1.1	31.59
1.3	38.89
.9	47.88
2.2	58.94
4.4	72.57
8.7	89.34
14.8	109.99
7.2	135.42

% MAX SIZE 0 10 20 30 40 50 60 70 80 90 100

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 7 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/11/84 96 HRS 8213 : JOB NUMBER

"TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS
TABULATION

DATA ID 8213 DATE 2 FEB
SIZE-NORMALIZED VOLUME DISTRIBUTION
TOTAL = 9.80708E 7

CHNL	SIZE	VOLUME	% >	CHNL	SIZE	VOLUME	% >	CHNL	SIZE	VOLUME	% >
1	.09	11990	100.00	37	1.13	3500139	35.83	73	13.75	39830	5.88
2	.10	17338	99.99	38	1.22	3388515	32.26	74	14.74	43976	5.84
3	.11	24769	99.97	39	1.30	2986344	28.81	75	15.79	55901	5.80
4	.12	34959	99.94	40	1.40	2652174	25.76	76	16.93	55769	5.74
5	.12	48750	99.91	41	1.50	2427106	23.06	77	18.14	51999	5.68
6	.13	67164	99.86	42	1.60	2042363	20.58	78	19.44	51772	5.63
7	.14	91419	99.79	43	1.72	1679877	18.50	79	20.84	55065	5.58
8	.15	122940	99.70	44	1.84	1551571	16.79	80	22.34	52290	5.52
9	.16	163342	99.57	45	1.97	1567995	15.21	81	23.94	44930	5.47
10	.17	214414	99.41	46	2.12	1337741	13.61	82	25.66	41731	5.42
11	.19	278070	99.19	47	2.27	1216495	12.24	83	27.50	41049	5.38
12	.20	356292	98.90	48	2.43	1061986	11.00	84	29.47	49985	5.34
13	.21	451031	98.54	49	2.60	793547	9.92	85	31.59	44764	5.29
14	.23	564097	98.08	50	2.79	645475	9.11	86	33.85	41467	5.24
15	.25	697030	97.51	51	2.99	490663	8.45	87	36.28	43812	5.20
16	.26	850937	96.79	52	3.21	416708	7.95	88	38.89	52924	5.16
17	.28	1026342	95.93	53	3.44	336824	7.53	89	41.68	30176	5.10
18	.30	1223026	94.88	54	3.68	254007	7.18	90	44.67	32668	5.07
19	.33	1439884	93.63	55	3.95	199762	6.92	91	47.88	37176	5.04
20	.35	1674822	92.17	56	4.23	152540	6.72	92	51.31	52785	5.00
21	.37	1924679	90.46	57	4.54	118975	6.56	93	55.00	63146	4.95
22	.40	2185226	88.49	58	4.86	87655	6.44	94	58.94	93001	4.88
23	.43	2451226	86.27	59	5.21	63058	6.35	95	63.17	88845	4.79
24	.46	2716560	83.77	60	5.58	47413	6.29	96	67.71	102199	4.70
25	.49	2974431	81.00	61	5.98	38391	6.24	97	72.57	186534	4.59
26	.53	3217637	77.96	62	6.41	30854	6.20	98	77.78	255492	4.40
27	.57	3438897	74.68	63	6.87	27286	6.17	99	83.36	401454	4.14
28	.61	3631197	71.18	64	7.37	28068	6.14	100	89.34	362880	3.73
29	.65	3788168	67.47	65	7.90	24216	6.11	101	95.75	436016	3.36
30	.70	3904428	63.61	66	8.46	22553	6.09	102	102.63	561766	2.92
31	.75	3975890	59.63	67	9.07	21922	6.07	103	109.99	620450	2.34
32	.80	4000000	55.58	68	9.72	24373	6.04	104	117.89	674084	1.71
33	.86	3922810	51.50	69	10.42	32318	6.02	105	126.35	563076	1.02
34	.92	3921127	47.50	70	11.17	30602	5.99	106	135.42	303970	.45
35	.99	3871263	43.50	71	11.97	34531	5.96	107	145.14	105114	.14
36	1.06	3648823	39.55	72	12.83	35506	5.92	108	155.55	32173	.03

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/5/84 96 HRS 8213 : JOB NUMBER

VOLUME (MASS) DISTRIBUTION FROM DISPLAY AREA: 4
========================

INDICES

VOLUME MODE = 3.13 MEDIAN = 1.56 MICRONS AND LARGER

GEOMETRIC VOLUME MEAN = 1.52 +/- 2.94 (193.50%) SKEWNESS = -.55

ARITHMETIC VOLUME MEAN = 2.79 +/- 4.72 (168.82%) SKEWNESS = -.07

FOR PLOTTING PROBABILITY ON LOG PAPER:

PERCENTILE: 00.1% OF VOLUME IS AT 56.76 MICRONS AND LARGER
PERCENTILE: 01.0% OF VOLUME IS AT 25.02 MICRONS AND LARGER
PERCENTILE: 06.0% OF VOLUME IS AT 6.66 MICRONS AND LARGER
PERCENTILE: 22.0% OF VOLUME IS AT 3.55 MICRONS AND LARGER
PERCENTILE: 50.0% OF VOLUME IS AT 1.56 MICRONS AND LARGER
PERCENTILE: 78.0% OF VOLUME IS AT .61 MICRONS AND LARGER
PERCENTILE: 94.0% OF VOLUME IS AT .29 MICRONS AND LARGER
PERCENTILE: 99.0% OF VOLUME IS AT .15 MICRONS AND LARGER
PERCENTILE: 99.9% OF VOLUME IS AT .10 MICRONS AND LARGER

COUNT (FREQUENCY) DISTRIBUTION FROM DISPLAY AREA: 5
===========================

INDICES

COUNTS MODE = .14 MEDIAN = .15 MICRONS AND LARGER

GEOMETRIC COUNTS MEAN = .15 +/- .13 (86.53%) SKEWNESS = .11

ARITHMETIC COUNTS MEAN = .19 +/- .17 (89.55%) SKEWNESS = .31

FOR PLOTTING PROBABILITY ON LOG PAPER:

PERCENTILE: 00.1% OF COUNTS IS AT 1.87 MICRONS AND LARGER
PERCENTILE: 01.0% OF COUNTS IS AT .86 MICRONS AND LARGER
PERCENTILE: 06.0% OF COUNTS IS AT .43 MICRONS AND LARGER
PERCENTILE: 22.0% OF COUNTS IS AT .23 MICRONS AND LARGER
PERCENTILE: 50.0% OF COUNTS IS AT .15 MICRONS AND LARGER
PERCENTILE: 78.0% OF COUNTS IS AT .10 MICRONS AND LARGER
PERCENTILE: 94.0% OF COUNTS IS AT .06 MICRONS AND LARGER
PERCENTILE: 99.0% OF COUNTS IS AT .04 MICRONS AND LARGER
PERCENTILE: 99.9% OF COUNTS IS AT .03 MICRONS AND LARGER

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/5/84 96 HRS 8213 : JOB NUMBER

PARTICLE SIZE VS. COUNTS
ENCLOSING
LOW AT 1 .02 4887 HIGH AT 81 21.20 1

GRAPH OF DIAMETER SIZES VS. DIFFERENTIAL COUNTS FROM CHANNEL 1 TO 81, AND SKIP: 2

% MAX	SIZE
.1	.02
.6	.03
2.7	.03
9.2	.05
23.9	.06
48.4	.08
76.4	.10
94.1	.13
90.2	.17
67.4	.21
44.1	.28
28.0	.36
17.1	.47
9.5	.61
4.9	.79
2.4	1.02
1.0	1.33
.5	1.72
.2	2.23
.1	2.89
.1	3.75
.0	4.86
.0	6.30
.0	8.18
.0	10.60
.0	13.75
.0	17.83

% MAX SIZE 0 10 20 30 40 50 60 70 80 90 100

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/5/84 96 HRS 8213 : JOB NUMBER

"TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS
TABULATION

DATA ID 8213 DATE 5 SEP
SIZE-NORMALIZED COUNTS DISTRIBUTION
TOTAL = 6.54574E 7

CHNL	SIZE	COUNTS	% >	CHNL	SIZE	COUNTS	% >	CHNL	SIZE	COUNTS	% >
1	.02	4887	100.00	28	.21	2828749	28.85	55	2.23	9208	.06
2	.02	8869	99.99	29	.23	2428788	24.53	56	2.43	7260	.05
3	.02	15654	99.98	30	.26	2098721	20.82	57	2.65	5774	.04
4	.03	26875	99.96	31	.28	1849334	17.61	58	2.89	4674	.03
5	.03	44878	99.91	32	.30	1595375	14.79	59	3.15	3725	.02
6	.03	72892	99.85	33	.33	1363933	12.35	60	3.44	2918	.02
7	.03	115158	99.73	34	.36	1174488	10.27	61	3.75	2245	.01
8	.04	176959	99.56	35	.39	1003649	8.47	62	4.09	1691	.01
9	.04	264491	99.29	36	.43	851020	6.94	63	4.46	1207	.01
10	.05	384515	98.88	37	.47	715821	5.64	64	4.86	799	.00
11	.05	543725	98.30	38	.51	597211	4.55	65	5.30	508	.00
12	.05	747837	97.47	39	.56	494236	3.63	66	5.78	325	.00
13	.06	1000456	96.32	40	.61	396767	2.88	67	6.30	203	.00
14	.06	1301823	94.79	41	.66	314004	2.27	68	6.87	121	.00
15	.07	1647663	92.81	42	.72	254698	1.79	69	7.50	71	.00
16	.08	2028372	90.29	43	.79	204537	1.40	70	8.18	42	.00
17	.08	2428788	87.19	44	.86	162327	1.09	71	8.92	24	.00
18	.09	2828749	83.48	45	.94	127969	.84	72	9.72	13	.00
19	.10	3204514	79.16	46	1.02	100332	.65	73	10.60	7	.00
20	.11	3530957	74.26	47	1.11	78108	.49	74	11.56	6	.00
21	.12	3784300	68.87	48	1.22	58069	.37	75	12.61	4	.00
22	.13	3944949	63.09	49	1.33	42766	.29	76	13.75	3	.00
23	.14	4000000	57.06	50	1.45	32669	.22	77	14.99	2	.00
24	.15	3944949	50.95	51	1.58	25037	.17	78	16.35	3	.00
25	.17	3784300	44.92	52	1.72	19309	.13	79	17.83	2	.00
26	.18	3530957	39.14	53	1.87	14955	.10	80	19.44	1	.00
27	.20	3204514	33.75	54	2.04	11649	.08	81	21.20	1	.00

DISPLAY AREA: 4

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.

115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE

SAMPLE: SETTLING COLUMN 8/5/84 96 HRS 8213 : JOB NUMBER

PARTICLE SIZE VS. VOLUME

ENCLOSING

LOW AT 1 .09 52875 HIGH AT 107 73.03 148

GRAPH OF DIAMETER SIZES VS. DIFFERENTIAL VOLUME FROM CHANNEL 1 TO 107, AND SKIP: 2

% MAX	SIZE
1.3	.09
4.0	.11
7.8	.13
12.5	.16
18.0	.20
24.9	.24
33.2	.29
42.8	.34
52.9	.42
62.8	.50
72.1	.61
79.2	.73
82.8	.89
85.0	1.07
82.6	1.29
79.5	1.56
78.2	1.89
81.3	2.28
90.7	2.76
94.2	3.33
91.9	4.02
73.7	4.86
48.6	5.87
26.8	7.09
14.4	8.57
8.4	10.35
8.0	12.51
6.2	15.11
6.1	18.26
5.6	22.06
4.3	26.65
3.8	32.19
1.9	38.89
2.6	46.98
1.9	56.76
.1	68.57

% MAX SIZE 0 10 20 30 40 50 60 70 80 90 100

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS — 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/5/84 96 HRS — 8213 : JOB NUMBER

'TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS
TABULATION

DATA ID 8213 DATE 5 SEP
SIZE-NORMALIZED VOLUME DISTRIBUTION
TOTAL =74788005

CHNL	SIZE	VOLUME	% >	CHNL	SIZE	VOLUME	% >	CHNL	SIZE	VOLUME	% >
1	.09	52875	100.00	37	.89	3474456	68.45	73	8.57	604227	4.13
2	.10	75506	99.97	38	.94	3524712	66.46	74	9.13	480480	3.78
3	.10	118165	99.93	39	1.01	3546310	64.45	75	9.72	388446	3.51
4	.11	165824	99.86	40	1.07	3563448	62.42	76	10.35	350573	3.29
5	.12	215050	99.76	41	1.14	3568376	60.38	77	11.03	340559	3.09
6	.13	256399	99.64	42	1.22	3524658	58.34	78	11.75	346869	2.89
7	.13	326770	99.49	43	1.29	3466136	56.32	79	12.51	334422	2.69
8	.14	399222	99.31	44	1.38	3417287	54.34	80	13.32	302447	2.50
9	.15	458624	99.08	45	1.47	3329219	52.38	81	14.19	261676	2.33
10	.16	524640	98.82	46	1.56	3333544	50.48	82	15.11	260650	2.18
11	.17	594697	98.52	47	1.67	3278697	48.57	83	16.09	258093	2.03
12	.18	671220	98.18	48	1.77	3264377	46.69	84	17.14	268360	1.88
13	.20	754355	97.79	49	1.89	3281955	44.83	85	18.26	256468	1.73
14	.21	844184	97.36	50	2.01	3284519	42.95	86	19.44	235402	1.58
15	.22	940711	96.88	51	2.14	3308251	41.07	87	20.71	243379	1.45
16	.24	1043858	96.34	52	2.28	3409022	39.18	88	22.06	235313	1.31
17	.25	1153446	95.74	53	2.43	3532149	37.23	89	23.49	220587	1.17
18	.27	1269201	95.08	54	2.59	3668379	35.21	90	25.02	204371	1.05
19	.29	1390739	94.36	55	2.76	3803594	33.11	91	26.65	178591	.93
20	.30	1522631	93.56	56	2.94	3873404	30.93	92	28.38	137866	.83
21	.32	1659622	92.69	57	3.13	4000000	28.72	93	30.22	141167	.75
22	.34	1795511	91.74	58	3.33	3950478	26.43	94	32.19	159761	.67
23	.37	1934335	90.71	59	3.55	3995776	24.17	95	34.28	146163	.58
24	.39	2075133	89.61	60	3.78	3927924	21.88	96	36.51	102249	.49
25	.42	2216847	88.42	61	4.02	3855716	19.63	97	38.89	78231	.44
26	.44	2358333	87.15	62	4.29	3691225	17.43	98	41.42	72449	.39
27	.47	2498379	85.80	63	4.56	3349253	15.32	99	44.11	95322	.35
28	.50	2635712	84.37	64	4.86	3090380	13.40	100	46.98	108421	.30
29	.54	2769025	82.86	65	5.18	2774699	11.63	101	50.04	106482	.23
30	.57	2896996	81.28	66	5.51	2401320	10.04	102	53.29	107666	.17
31	.61	3024757	79.62	67	5.87	2038807	8.67	103	56.76	78967	.11
32	.65	3118897	77.89	68	6.25	1709471	7.50	104	60.45	63724	.07
33	.69	3220189	76.11	69	6.66	1399331	6.53	105	64.38	44291	.03
34	.73	3322028	74.26	70	7.09	1125381	5.72	106	68.57	6030	.00
35	.78	3390248	72.36	71	7.56	910027	5.08	107	73.03	148	.00
36	.83	3450472	70.42	72	8.05	751273	4.56				

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/1/84 0HRS 8213 : JOB NUMBER

VOLUME (MASS) DISTRIBUTION FROM DISPLAY AREA: 4

INDICES

VOLUME MODE = 5.58 MEDIAN = 4.23 MICRONS AND LARGER

GEOMETRIC VOLUME MEAN = 3.64 +/- 7.20 (197.96%) SKEWNESS = -.27

ARITHMETIC VOLUME MEAN = 6.05 +/- 6.72 (111.01%) SKEWNESS = .07

FOR PLOTTING PROBABILITY ON LOG PAPER:

PERCENTILE: 00.1% OF VOLUME IS AT 55.00 MICRONS AND LARGER
PERCENTILE: 01.0% OF VOLUME IS AT 33.85 MICRONS AND LARGER
PERCENTILE: 06.0% OF VOLUME IS AT 16.93 MICRONS AND LARGER
PERCENTILE: 22.0% OF VOLUME IS AT 8.46 MICRONS AND LARGER
PERCENTILE: 50.0% OF VOLUME IS AT 4.23 MICRONS AND LARGER
PERCENTILE: 78.0% OF VOLUME IS AT 1.60 MICRONS AND LARGER
PERCENTILE: 94.0% OF VOLUME IS AT .57 MICRONS AND LARGER
PERCENTILE: 99.0% OF VOLUME IS AT .19 MICRONS AND LARGER
PERCENTILE: 99.9% OF VOLUME IS AT .09 MICRONS AND LARGER

COUNT (FREQUENCY) DISTRIBUTION FROM DISPLAY AREA: 5

INDICES

COUNTS MODE = .08 MEDIAN = .12 MICRONS AND LARGER

GEOMETRIC COUNTS MEAN = .15 +/- .11 (75.07%) SKEWNESS = .59

ARITHMETIC COUNTS MEAN = .18 +/- .21 (115.47%) SKEWNESS = .48

FOR PLOTTING PROBABILITY ON LOG PAPER:

PERCENTILE: 00.1% OF COUNTS IS AT 2.43 MICRONS AND LARGER
PERCENTILE: 01.0% OF COUNTS IS AT .99 MICRONS AND LARGER
PERCENTILE: 06.0% OF COUNTS IS AT .40 MICRONS AND LARGER
PERCENTILE: 22.0% OF COUNTS IS AT .20 MICRONS AND LARGER
PERCENTILE: 50.0% OF COUNTS IS AT .12 MICRONS AND LARGER
PERCENTILE: 78.0% OF COUNTS IS AT .09 MICRONS AND LARGER
PERCENTILE: 94.0% OF COUNTS IS AT .08 MICRONS AND LARGER
PERCENTILE: 99.0% OF COUNTS IS AT .08 MICRONS AND LARGER
PERCENTILE: 99.9% OF COUNTS IS AT .08 MICRONS AND LARGER

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/1/84 OHRS 8213 : JOB NUMBER

PARTICLE SIZE VS. COUNTS
ENCLOSING
LOW AT 1 .08 4000000 HIGH AT 85 27.50 1

GRAPH OF DIAMETER SIZES VS. DIFFERENTIAL COUNTS FROM CHANNEL 1 TO 85, AND SKIP: 2

% MAX	SIZE
95.4	.08
72.6	.10
54.5	.12
40.4	.15
29.5	.19
21.2	.23
15.1	.28
10.5	.35
7.3	.43
5.0	.53
3.3	.65
2.2	.80
1.4	.99
.9	1.22
.6	1.50
.4	1.84
.2	2.27
.1	2.79
.1	3.44
.0	4.23
.0	5.21
.0	6.41
.0	7.90
.0	9.72
.0	11.97
.0	14.74
.0	18.14
.0	22.34
.0	27.50

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/1/84 0HRS 8213 : JOB NUMBER

"TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS
TABULATION

DATA ID 8213 DATE 6 SEP
SIZE-NORMALIZED COUNTS DISTRIBUTION
TOTAL =41155654

CHNL	SIZE	COUNTS	% >	CHNL	SIZE	COUNTS	% >	CHNL	SIZE	COUNTS	% >
1	.08	4000000	100.00	30	.61	159688	2.89	59	4.54	1668	.02
2	.09	3658082	90.28	31	.65	139621	2.50	60	4.86	1405	.02
3	.09	3340176	81.39	32	.70	121884	2.16	61	5.21	1179	.01
4	.10	3045200	73.28	33	.75	106235	1.87	62	5.58	977	.01
5	.11	2771964	65.88	34	.80	92453	1.61	63	5.98	791	.01
6	.12	2519319	59.14	35	.86	80333	1.39	64	6.41	627	.01
7	.12	2286187	53.02	36	.92	69694	1.19	65	6.87	490	.00
8	.13	2070884	47.47	37	.99	60370	1.02	66	7.37	380	.00
9	.14	1873699	42.43	38	1.06	52213	.87	67	7.90	295	.00
10	.15	1692521	37.88	39	1.13	45088	.75	68	8.46	227	.00
11	.16	1526427	33.77	40	1.22	38875	.64	69	9.07	170	.00
12	.17	1374476	30.06	41	1.30	33466	.54	70	9.72	124	.00
13	.19	1235732	26.72	42	1.40	28765	.46	71	10.42	92	.00
14	.20	1109270	23.72	43	1.50	24687	.39	72	11.17	68	.00
15	.21	994206	21.02	44	1.60	21154	.33	73	11.97	50	.00
16	.23	889698	18.61	45	1.72	18099	.28	74	12.83	36	.00
17	.25	794942	16.44	46	1.84	15752	.24	75	13.75	25	.00
18	.26	709003	14.51	47	1.97	13256	.20	76	14.74	19	.00
19	.28	631628	12.79	48	2.12	10962	.17	77	15.79	14	.00
20	.30	561775	11.26	49	2.27	9278	.14	78	16.93	10	.00
21	.33	498854	9.89	50	2.43	7960	.12	79	18.14	7	.00
22	.35	442286	8.68	51	2.60	6672	.10	80	19.44	5	.00
23	.37	391523	7.60	52	2.79	5699	.08	81	20.84	3	.00
24	.40	346049	6.65	53	2.99	4815	.07	82	22.34	2	.00
25	.43	305383	5.81	54	3.21	4030	.06	83	23.94	2	.00
26	.46	269079	5.07	55	3.44	3389	.05	84	25.66	1	.00
27	.49	236723	4.42	56	3.68	2856	.04	85	27.50	1	.00
28	.53	207884	3.84	57	3.95	2383	.03				
29	.57	182349	3.34	58	4.23	1990	.03				

DISPLAY AREA: 4

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/1/84 0HRS 8213 : JOB NUMBER

PARTICLE SIZE VS. VOLUME
ENCLOSING
LOW AT 1 .08 50715 HIGH AT 99 72.57 347

GRAPH OF DIAMETER SIZES VS. DIFFERENTIAL VOLUME FROM CHANNEL 1 TO 99, AND SKIP: 2

% MAX	SIZE
1.2	.08
1.7	.10
2.4	.12
3.3	.15
4.5	.19
6.1	.23
8.1	.28
10.5	.35
13.6	.43
17.2	.53
21.6	.65
26.7	.80
32.5	.99
39.1	1.22
46.3	1.50
55.2	1.84
60.6	2.27
69.5	2.79
77.1	3.44
84.5	4.23
93.5	5.21
92.7	6.41
81.5	7.90
63.9	9.72
48.3	11.97
33.9	14.74
24.1	18.14
15.9	22.34
12.0	27.50
7.1	33.85
4.2	41.68
3.3	51.31
.9	63.17

% MAX SIZE 0 10 20 30 40 50 60 70 80 90 100

PARTICLE SIZE ANALYSIS BY ELZONE METHOD--PARTICLE DATA LABORATORIES, LTD.
115 HAHN STREET - ELMHURST, IL. 60126 - TELEPHONE: (312)832-5658

CLIENT: R & M CONSULTANTS 6 SEP 84 :DATE
SAMPLE: SETTLING COLUMN 8/1/84 OHRS 8213 : JOB NUMBER

"TOTAL IN TABULATION= TOTAL COUNT OR VOLUME IN ANALYSIS
TABULATION

DATA ID 8213 DATE 6 SEP
SIZE-NORMALIZED VOLUME DISTRIBUTION
TOTAL = 1.33654E 8

CHNL	SIZE	VOLUME	% >	CHNL	SIZE	VOLUME	% >	CHNL	SIZE	VOLUME	% >
1	.08	50715	100.00	34	.80	1119924	90.73	67	7.90	3420035	25.12
2	.09	57100	99.96	35	.86	1198045	89.90	68	8.46	3241642	22.56
3	.09	64189	99.92	36	.92	1279629	89.00	69	9.07	2991651	20.14
4	.10	72047	99.87	37	.99	1364652	88.04	70	9.72	2681446	17.90
5	.11	80741	99.82	38	1.06	1453071	87.02	71	10.42	2462352	15.89
6	.12	90345	99.76	39	1.13	1544822	85.93	72	11.17	2250145	14.05
7	.12	100934	99.69	40	1.22	1639823	84.78	73	11.97	2025156	12.37
8	.13	112590	99.61	41	1.30	1737970	83.55	74	12.83	1783136	10.85
9	.14	125396	99.53	42	1.40	1839138	82.25	75	13.75	1572611	9.52
10	.15	139445	99.44	43	1.50	1943180	80.87	76	14.74	1420928	8.34
11	.16	154825	99.33	44	1.60	2049928	79.42	77	15.79	1274026	7.28
12	.17	171636	99.22	45	1.72	2159190	77.89	78	16.93	1142854	6.33
13	.19	189979	99.09	46	1.84	2313398	76.27	79	18.14	1012720	5.47
14	.20	209956	98.95	47	1.97	2396056	74.54	80	19.44	879522	4.71
15	.21	231673	98.79	48	2.12	2440407	72.75	81	20.84	767042	4.06
16	.23	255241	98.61	49	2.27	2543040	70.92	82	22.34	666256	3.48
17	.25	280772	98.42	50	2.43	2686229	69.02	83	23.94	582667	2.98
18	.26	308377	98.21	51	2.60	2772025	67.01	84	25.66	519668	2.55
19	.28	338171	97.98	52	2.79	2914732	64.94	85	27.50	504330	2.16
20	.30	370271	97.73	53	2.99	3032021	62.75	86	29.47	417987	1.78
21	.33	404789	97.45	54	3.21	3124155	60.49	87	31.59	348679	1.47
22	.35	441840	97.15	55	3.44	3234236	58.15	88	33.85	299055	1.21
23	.37	481536	96.82	56	3.68	3355297	55.73	89	36.28	262075	.98
24	.40	523984	96.46	57	3.95	3445808	53.22	90	38.89	216682	.79
25	.43	569291	96.07	58	4.23	3545078	50.64	91	41.68	176611	.63
26	.46	617558	95.64	59	4.54	3657879	47.99	92	44.67	178205	.49
27	.49	668879	95.18	60	4.86	3793431	45.25	93	47.88	158646	.36
28	.53	723343	94.68	61	5.21	3919813	42.41	94	51.31	136993	.24
29	.57	781031	94.14	62	5.58	4000000	39.48	95	55.00	77782	.14
30	.61	842013	93.55	63	5.98	3984266	36.49	96	58.94	63922	.08
31	.65	906350	92.92	64	6.41	3887571	33.51	97	63.17	36970	.03
32	.70	974092	92.24	65	6.87	3746196	30.60	98	67.71	6824	.01
33	.75	1045276	91.52	66	7.37	3569392	27.79	99	72.57	347	.00