STABILITY ANALYSIS

KAISER STEEL DIKES
SUNNYSIDE, UTAH

March 1984

Rollins, Brown and Gunnell, Inc.
Professional Engineers
1435 West 820 North, P.O. Box 711
Provo, Utah 84603

ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

March 23, 1984

Kaiser Steel Corporation
P.O. Box D
Sunnyside, UT 84539

Attn: Roger Kohlman

Gentlemen:

A stability analysis has been completed for various refuse dikes in the refuse disposal area for the Kaiser Steel Mine near Sunnyside, Utah. The purpose of this investigation was to determine the slope stability for the east side dikes, the west side dikes, and the coal slurry water sediment ponds. The investigation has been completed in accordance with a written contract between Kaiser Steel and our organization, and the results of the investigation are outlined in the following sections of this report.

The information presented in the report is discussed under the following headings: (1) Existing Site Conditions, (2) Subsurface Soil and Water Conditions, (3) Stability Analysis of the Dikes, and (4) The Results of Field and Laboratory Tests.

1. EXISTING SITE CONDITIONS

The refuse disposal area for the Kaiser Mine is located south of Sunnyside, Utah. The main disposal area is presented in Figure No. 1, and the location of the east and west side dikes are presented in this figure. The contours of the dike area are also shown in Figure No. 1. The slope at both the east and west side dike is apparent from the topography shown in these figures. Refuse from the Kaiser Mine is currently being disposed of at the west side dike. At the time this investigation was performed, the dike was being extended to the west and had only reached a portion of its final height. It is our understanding that some effort is being made to densify the refuse currently being disposed of in this fill. The east side dike is inactive, and no refuse material is being disposed of in this area.

The coal slurry water sediment control system is located north of the refuse disposal area, and the general layout of the system is presented in Figure No. 13. It will be noted that three slurry ponds exist throughout this site and that the slurry ponds have been formed by excavating into the natural materials throughout the site. At the time of our investigation, these ponds were empty and were relatively inactive.

2. SUBSURFACE SOIL AND WATER CONDITIONS

In order to define the characteristics of the coal refuse at the east and west side fills, two test holes were drilled in these areas at locations as shown in Figure No. 1. The logs for the two test holes are presented in Figures 2 and 3, and it will be noted that Test Hole No. 1, which was drilled at the east side dike, extended to a depth of approximately 80 feet below the surface of the fill. Test Hole No. 2 was drilled at the west side fill and extended to a depth of 132 feet. The natural ground surface was encountered at a depth of about 64 feet below the fill elevation in Test Hole No. 1 and at a depth of about 120 feet below the existing ground surface in Test Hole No. 2.

During the subsurface investigation at each of these dikes, sampling was performed at 5-foot intervals throughout the depth investigated. Samples were obtained by driving a 2-inch split-spoon sampling tube through a distance of 18 inches using a 140-pound weight dropped from a distance of 30 inches. The number of blows to drive the sampling spoon through each 6 inches of penetration is defined as the standard penetration value. The standard penetration value provides a reasonable indication of the in-place density of sandy material, however considerable care must be exercised in evaluating the standard penetration value for gravelly-size material, particularly where the particle size exceeds the inside diameter of the sampling spoon. During the subsurface investigation for each of the test holes discussed above, recovery of the refuse material at each of the sampling locations was very good, indicating that the penetration value is a significant indicator of the density of the material in the profile at these two dikes. The results of the standard penetration tests performed at both dikes indicate that the coal refuse is in a medium-dense condition.

Each sample obtained in the field was classified in the laboratory according to the Unified Soil Classification System. The symbol designating the material type according to this system is presented in Figure No. 5, and the meaning of the various symbols shown on the boring logs can be obtained from this figure.

The subsurface materials generally classify as GM-type materials, however some materials were encountered throughout the profile which classified as an SM-type material. It should be recognized that the soil classification designation has significance only insofar as the textural characteristics of the material is concerned. The natural material below the refuse in Test Hole No. 1 consisted predominantly of a brown, silty sand with some sandstone fragments. The natural material underlying the coal refuse in Test Hole No. 2 consisted of brown, silty, sandy gravel.

No groundwater was encountered in either of the test borings drilled at this site, however we understand that some groundwater seeps out of the bottom of the slope at the west dike. In order to obtain a better indication of the in-place unit weight of the refuse material throughout the area, one test pit was excavated in the vicinity of Test Hole No. 1, while two test pits were excavated in the vicinity of Test Hole No. 2. Logs for these three test holes are presented in Figures 6 and 7.

In-place density tests were performed at 3-foot intervals in these test pits, and the results of the in-place density tests are presented on the boring logs. It will be observed that the in-place density of the refuse material generally varied from about 70 pounds per cubic foot to 91 pounds per cubic foot. This information has been used qualitatively to determine the density characteristics of the material as determined by the standard penetration tests.

3. STABILITY ANALYSIS OF THE DIKES

In performing the stability computations, a computer model of Spencer's Method has been used. Spencer's Method satisfies both force and moment equilibrium and is considered to be a satisfactory method of solving limiting equilibrium problems. The shear strength parameters used in the stability analysis are based on the results of laboratory tests performed to define the strength characteristics of the refuse material. The results of the laboratory tests defining the shear strength parameters are discussed in a subsequent section of this report. Stability computations include the slope at the east side dike, the overall stability of the west side dike when the extension is complete, the lower slope of the existing west side fill, and the upper slope of the west side dike above the fill extension.

The stability associated with each of these slopes is discussed below as follows:

A. East Side Slope

A profile through the refuse material at the east side dike is presented in Figure No. 8. Shear strength parameters used in the stability analysis along with the in-place unit weight of the refuse material and the natural material is also presented in this figure. The critical failure surface for this slope is presented in Figure No. 8, and it will be noted that the factor of safety for this slope is 1.42. It will be observed that a friction angle of 35 degrees was used for the refuse material.

The results of the laboratory tests performed on the refuse material indicated a friction angle of between 36 and 37.8 degrees. Using a friction angle of 37 degrees for the refuse material, the factor of safety for the east side slope is slightly greater than 1.5, which in our opinion is satisfactory for this facility

B. West Side Slope at the Ultimate Height

A cross-section through the west side dike when it reaches its ultimate height is presented in Figure No. 9, along with the shear strength parameters and the critical failure circle. It will be observed that a friction angle of 35 degrees and a cohesion of 200 pounds per cubic foot was used. It is recognized that the refuse material has no friction angle in a saturated condition, however in an unsaturated condition capillary pressures within the material can produce an apparent cohesion of at least this amount. Since there is essentially no opportunity for the refuse material to become completely saturated, it is our opinion that a cohesion of 200 pounds per square foot is a reasonable value. It will also be noted that a friction angle of 35 degrees was used, which is about 2 degrees less than the measured friction angle. It will be observed that using the shear strength parameters indicated above, a factor of safety of 2.31 was obtained, which is entirely satisfactory for the proposed slope.

C. Existing Slope at the West Side Dike Extension

The approximate elevation and profile of the existing west side dike extension is presented in Figure No. 10. The shear strength parameters of the refuse and the sandy gravel underlying the refuse is also presented in this figure. The stability analysis indicates a factor of safety of 2.39 for the critical failure surface for this slope. Since a factor of safety of 1.5 is generally considered satisfactory under limiting equilibrium conditions, the existing slope is satisfactory.

D. Existing Slope Above the West Side Dike Extension

As indicated earlier in this report, the west side dike extension is only partially complete. The profile of the refuse material above the west side extension is shown in Figure No. 11. A stability analysis has been performed for this slope using the shear strength parameters shown in Figure No. 11. The critical circle as shown in Figure No. 11 indicates a factor of safety of 1.03, which is unsatisfactory for this slope.

If the slope is cut back to the overall slope shown in Figure No. 12, a factor of safety of 1.46 is used using the shear strength parameters indicated. Since the slope will eventually be covered by the west side dike extension, it is our opinion that a factor of safety of 1.46 is satisfactory for this slope. If a friction angle of 37 degrees is used in the analysis, a factor of safety of 1.5 will be obtained.

E. Coal Slurry Water Sediment Control System

A plan view of the coal slurry water sediment control system is presented in Figure No. 13. As indicated earlier, the ponds at this location have been excavated into the existing ground. The contours showing the shape and topography are presented in Figure No. 1, along with sections through the slopes of each of the ponds. It will be observed that the side slopes vary from 2 horizontal to 1 vertical to 4.6 horizontal to 1 vertical. The depth of the ponds do not exceed 20 feet and an inspection of the area indicates that no slope stability problems exist for these facilities. Since the ponds are generally below ground, there is little or no possibility of a rupture which would release water from the ponds to adjacent areas. Any slope stability failure which would occur in the ponds would not result in any hazardous situation. It is our opinion that the slopes for these ponds are stable under the existing situation and that if any of the slopes failed, no serious problems could result.

4. THE RESULTS OF FIELD AND LABORATORY TESTS

Field and laboratory tests were limited to standard penetration tests, classification tests, and triaxial shear tests. The standard penetration tests have been previously discussed, and the results of these tests are presented on the boring logs.

In order to obtain and indication of the shearing strength of the subsurface material, three consolidated drained triaxial shear tests were performed on representative samples from Test Hole No. 1, and three consolidated drained triaxial shear tests were performed on representative samples from Test Hole No. 2. The results of these tests are presented in the form of a Mohr envelope in Figures 14 and 15. It will be noted that the in-place dry unit weight of the samples shown in Figure No. 14 varied from about 78 to 80 pounds per cubic foot, while the in-place unit weight of the materials in Test Hole No. 2 varied from about 74 to 75 pounds per cubic foot. All samples for triaxial shear tests were performed at their in-site moisture content. These tests covered the range in the in-place density as determined by the field tests, and it is our opinion that they provide a reasonable indication of the shearing strength of both the east and the west side dikes in their in-place condition. It will be noted that the friction angle varied from 36 degrees for the material obtained from Test Hole No. 2 to 37.8 degrees for the material obtained from Test Hole No. 1.

Conclusions and recommendations presented in this report are based upon the results of the field and laboratory tests which, in our opinion, define the characteristics of the material in the dikes in a reasonable manner. If there are any questions relative to the information contained herein, please advise us.

Yours truly,

ROLLINS, BROWN AND GUNNELL, INC.

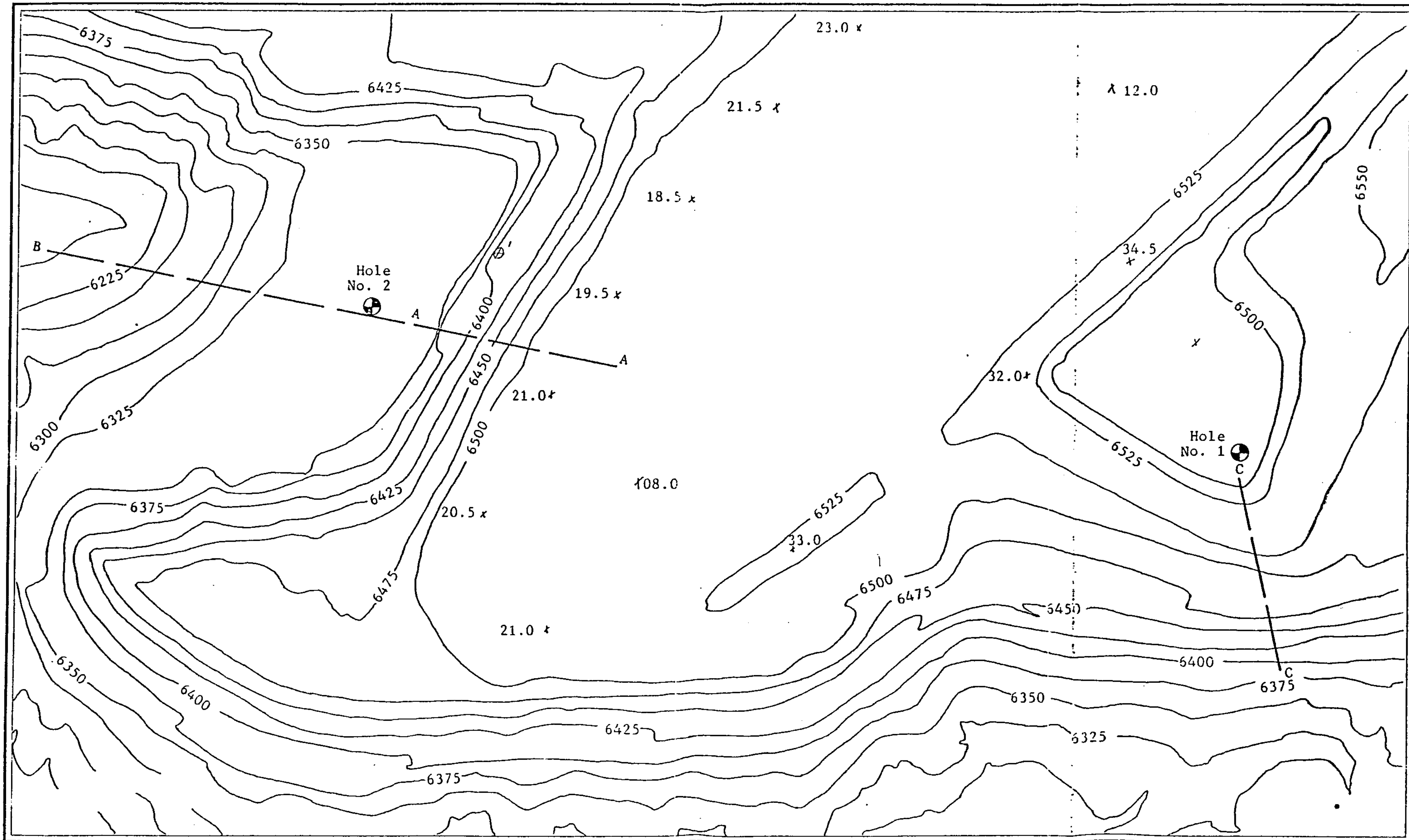
Ralph L Rollins

Ralph L. Rollins

REGISTERED PROFESSIONAL ENGINEER
RALPH L. ROLLINS
2306
State of Utah

RLR/lah

Enclosures



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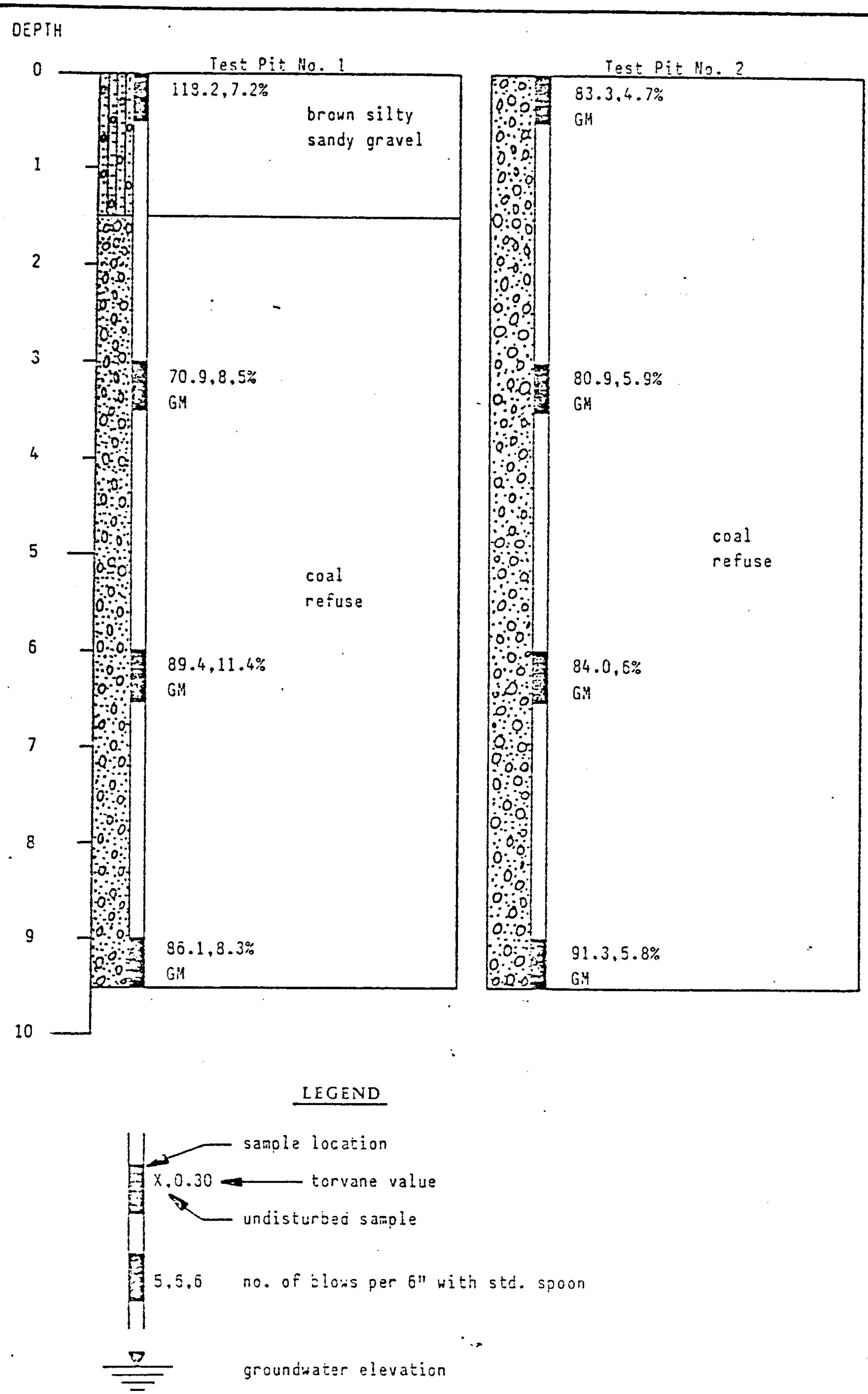
KAISER STEEL DIKE STABILITY
Stability Analysis--Slope Location
Sunnyside, Utah

FIGURE NO. 1



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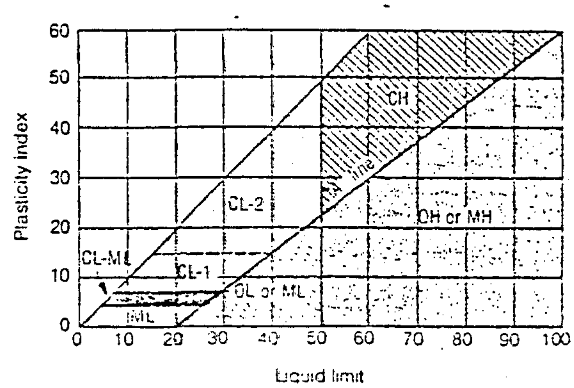
Log of Borings for:
Kaiser Steel Dike Stability
Sunnyside, Utah

Figure No. 5

Unified Soil Classification System

Major Divisions			Group Symbols		Typical Names	Laboratory Classification Criteria		
Coarse-grained Soils More than half of material is larger than No. 200 sieve	Gravels More than half of coarse fraction is larger than No. 4 sieve size	Clean Gravels (Little or no fines)	GW		Well graded gravels, gravel-sand mixtures, little or no fines.	Determine percentage of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows: Less than 5% ..... GW, GP, SW, SP More than 12% ..... GM, GC, SM, SC 5% to 12% ..... *Borderline* cases requiring use of dual symbols**	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP		Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM*	d	Silty gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits below "A" line, or *PI* less than 4	Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring uses of dual symbols
				u				
			GC		Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, or *PI* greater than 7	
	Sands More than half of coarse fraction is smaller than No. 4 sieve size	Clean Sands (Little or no fines)	SW		Well graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP		Poorly graded sands, gravelly sands, little or no fines.		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM*	d	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line, or *PI* less than 4	Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring uses of dual symbols
				u				
			SC		Clayey sands, poorly graded sand-clay mixtures		Atterberg limits above "A" line, or *PI* greater than 7	
Fine-grained Soils More than half of material is smaller than No. 200 sieve	Silt and Clays Liquid limit less than 50		ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity			
			CL	1	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
				2				
			OL		Organic silts and organic silt-clays of low plasticity			
	Silts and Clays Liquid limit greater than 50		MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH		Inorganic clays of high plasticity, fat clays			
			OH		Organic clays of medium to high plasticity, organic silts			
Highly Organic Soils			Pt		Peat and other highly organic soils			

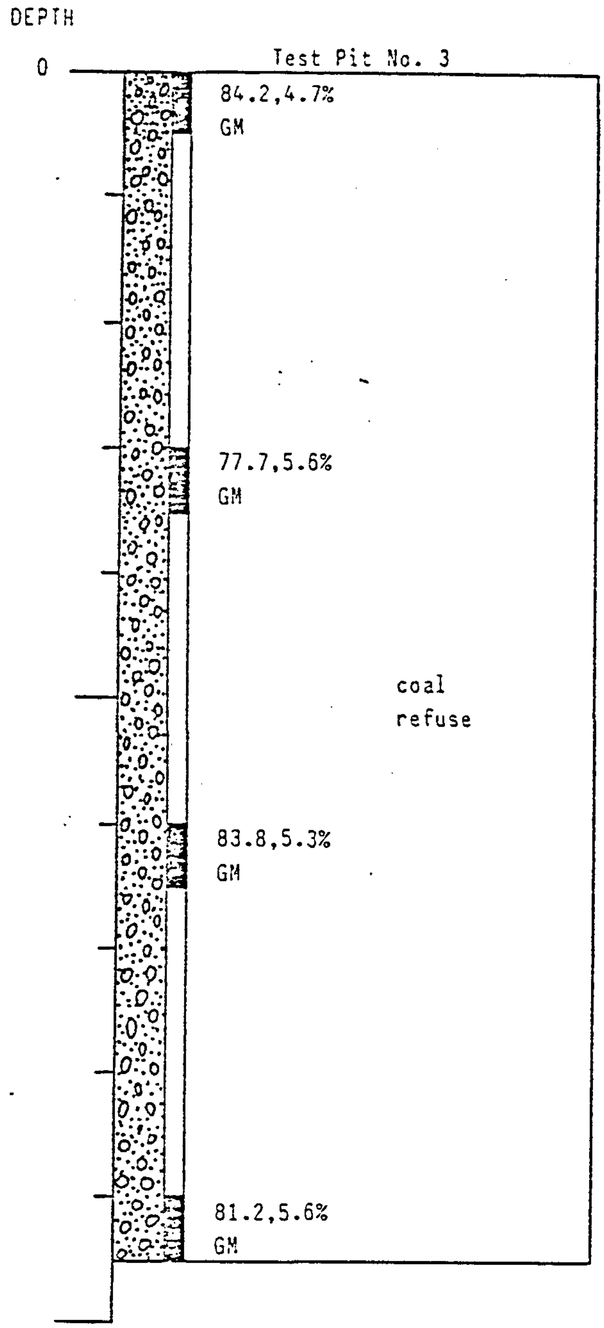


Plasticity Chart
For laboratory classification of fine-grained soils

*Division of GM and SM groups into subdivisions of d and u for roads and airfields only. Subdivision is based on Atterberg limits; suffix d used when liquid limit is 28 or less and the *PI* is 6 or less, the suffix u used when liquid limit is greater than 28.

***Borderline classification*: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder.

Figure No. 7



LEGEND

sample location

X.0.30 — torvane value

undisturbed sample

5,6,6 — no. of blows per 6" with std. spoon

groundwater elevation

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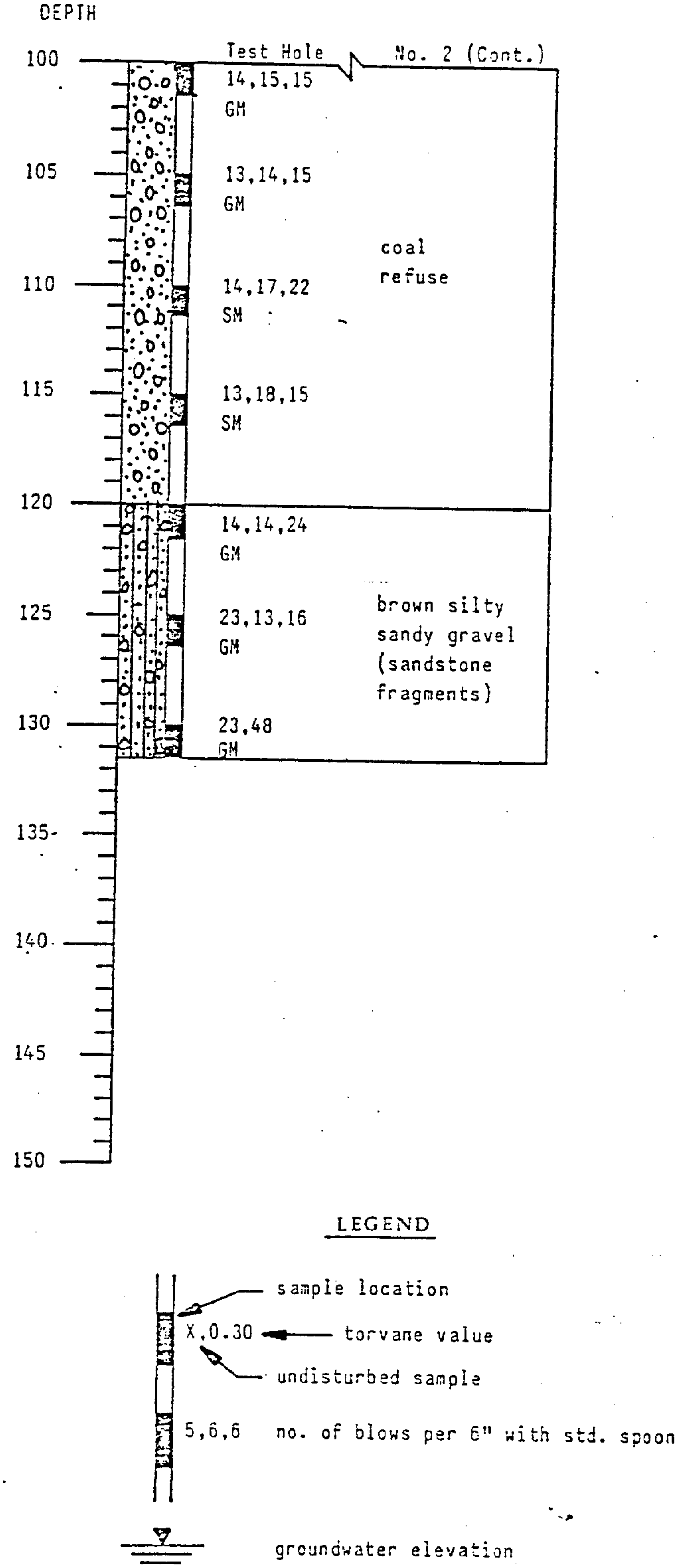
Log of Borings for:
Kaiser Steel Dike Stability
Sunnyside, Utah

Figure No. 6



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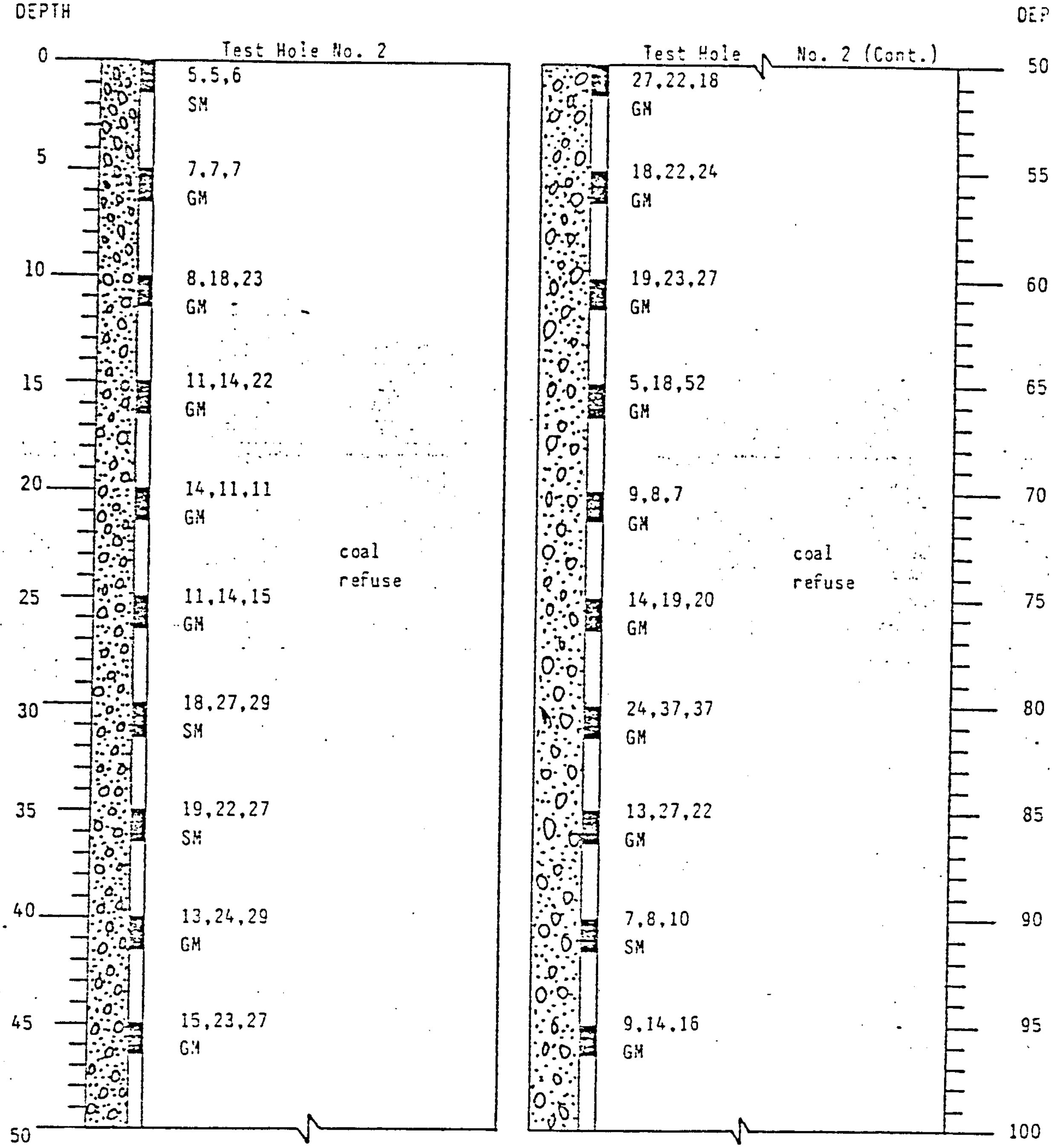
Log of Borings for:
Kaiser Steel Dike Stability
Sunnyside, Utah

Figure No. 4



LEGEND

sample location

X,0.30 ← torvane value

undisturbed sample

5,6,6 no. of blows per 6" with std. spoon

groundwater elevation

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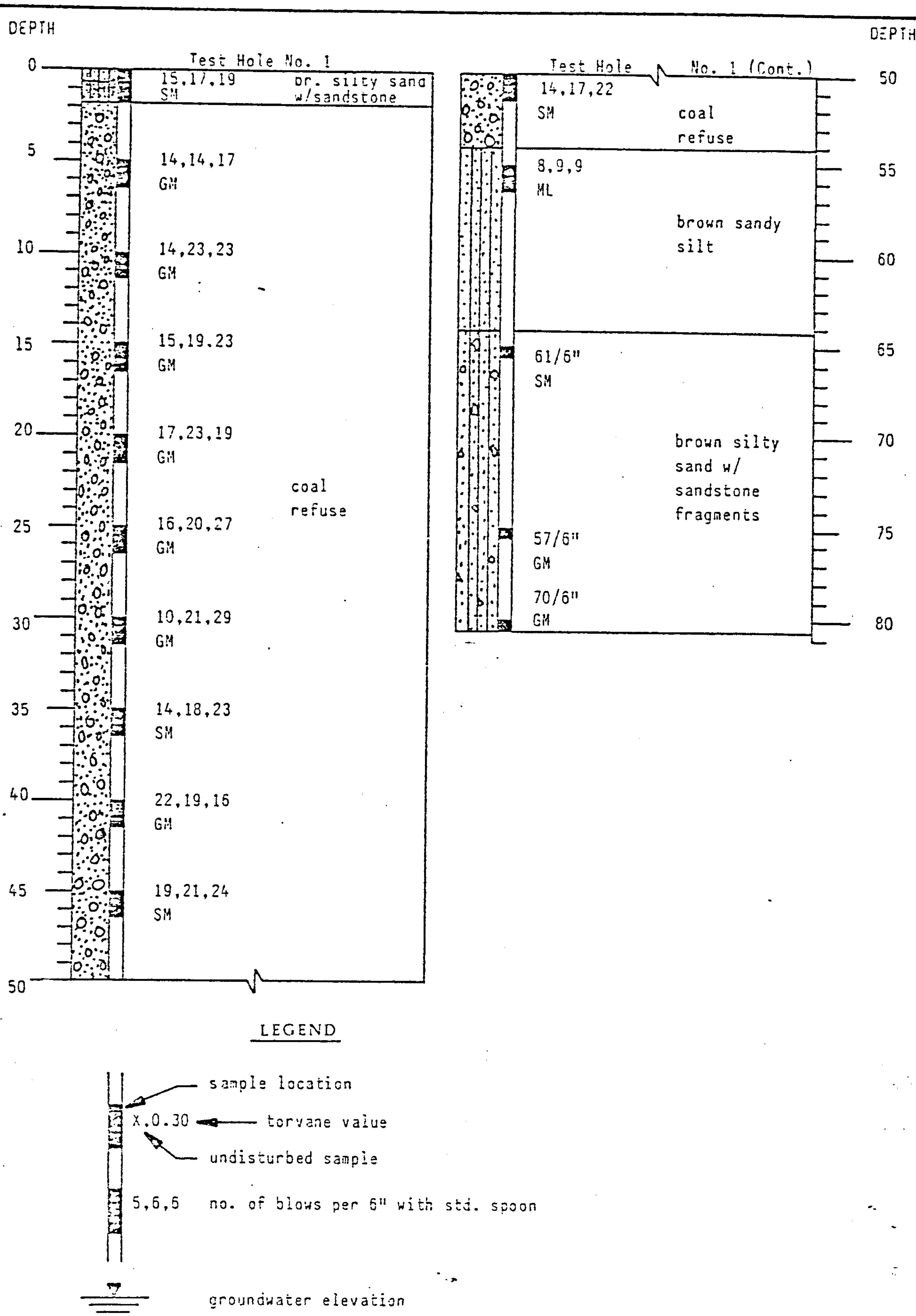
Log of Borings for:
Kaiser Steel Dike Stability
Sunnyside, Utah

Figure No. 3



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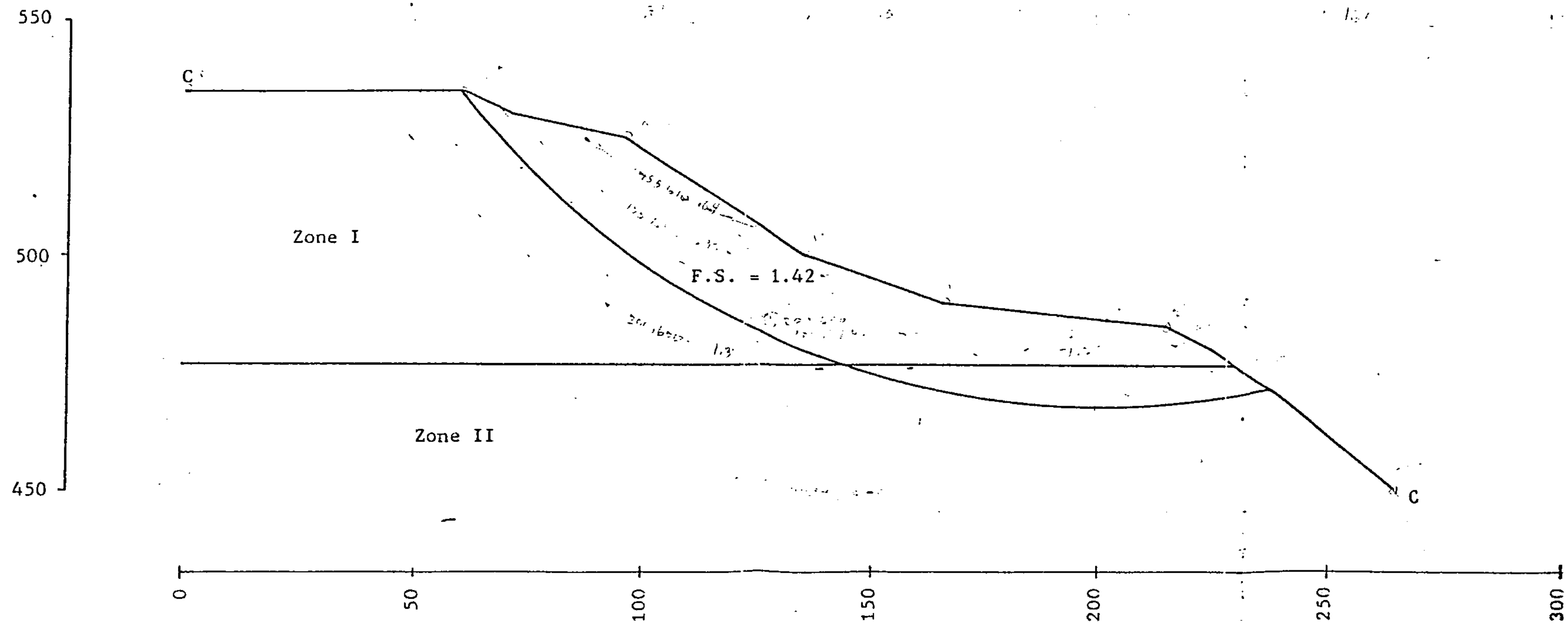
Log of Borings for:
Kaiser Steel Dike Stability
Sunnyside, Utah

Figure No. 2



Zone	Material	c, psf	Ø, deg	γ, pcf
I	Coal Refuse	0	35	80
II	Silty Sand, Sandy Silt	0	36	105

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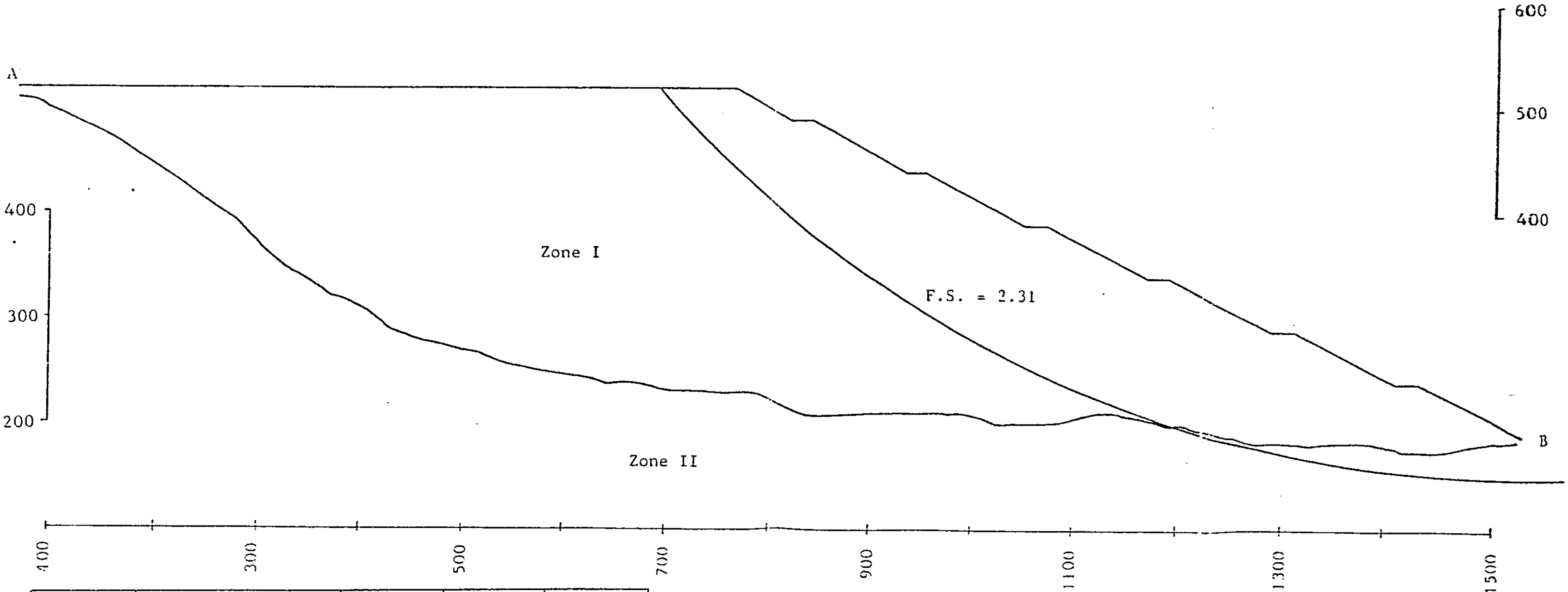
KAISER STEEL DIKE STABILITY
Stability Analysis--East Slope
Sunnyside, Utah

FIGURE NO. 8



Zone	Material	c	Ø	γ
I	Coal Refuse	200	35	80
II	Silty Sandy Gravel	0	36	130

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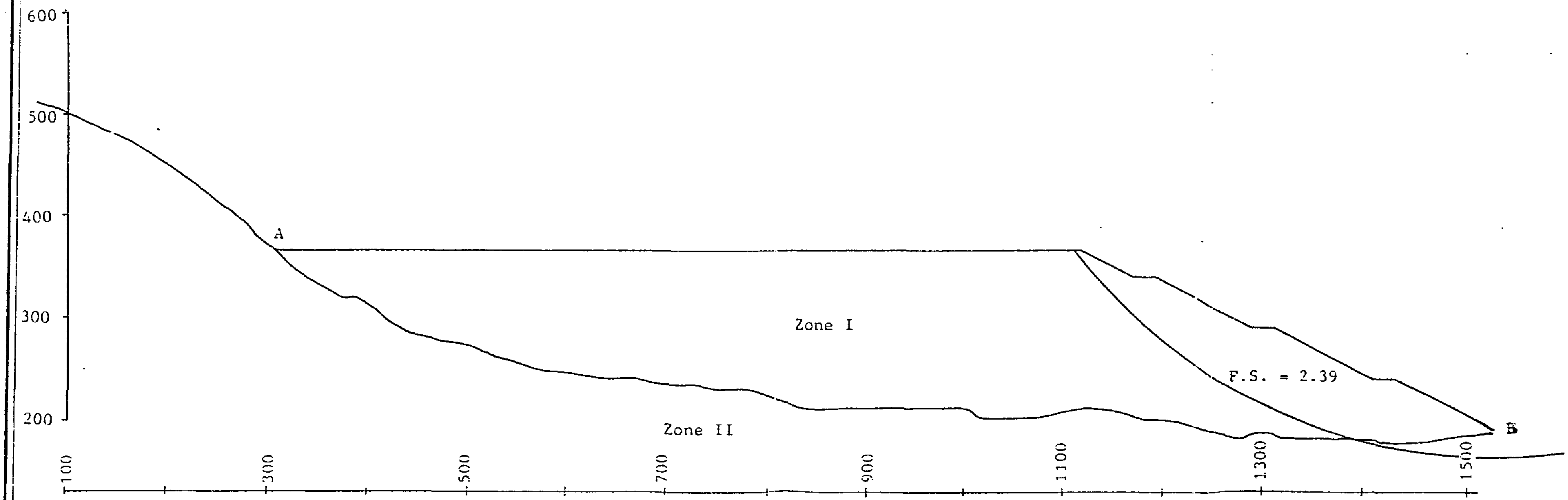
KAISER STEEL DIKE STABILITY
Stability Analysis--Total West Slope
Sunnyside, Utah

FIGURE NO. 9



Zone	Material	c	Ø	γ'
I	Coal Refuse	200	35	80
II	Silty Sandy Gravel	0	36	130

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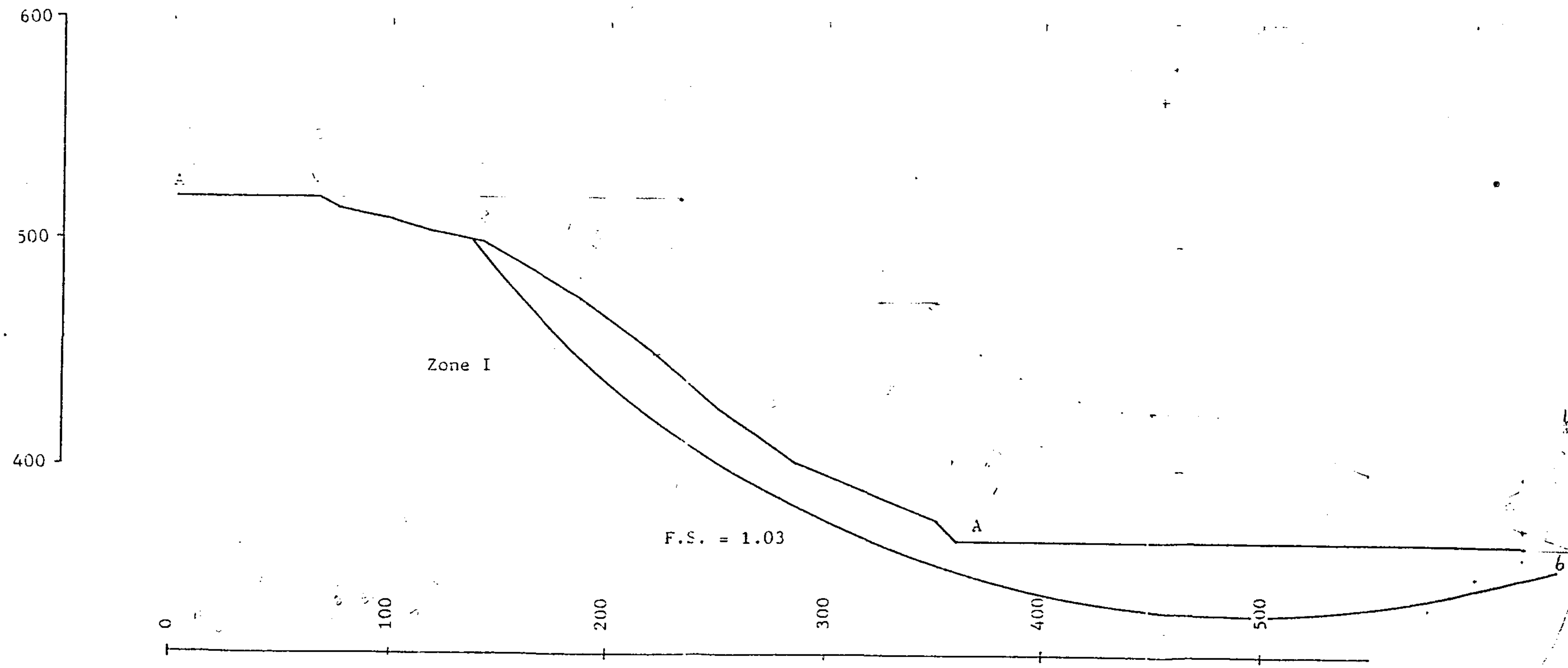
KAISER STEEL DIKE STABILITY
Stability Anaylsis--West Lower Slope
Sunnyside, Utah

FIGURE No 10



Zone	Material	c, psf	Ø, deg	γ, pcf
I	Coal Refuse	0	35	80

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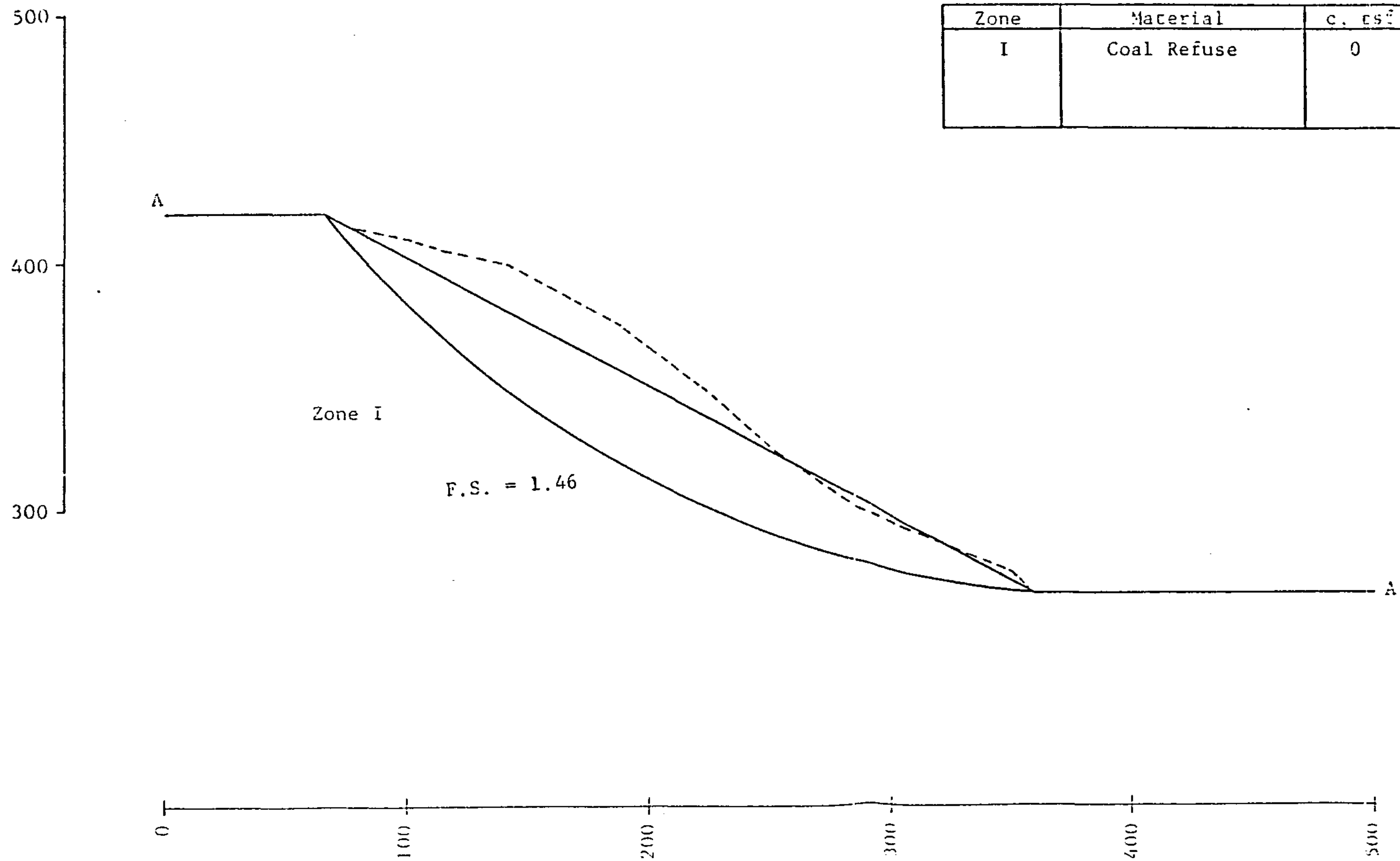
KAISER STEEL DIKE STABILITY
Stability Analysis--Existing West Upper Slope
Sunnyside, Utah

FIGURE
NO 11

Zone	Material	c, psf	φ, deg	γ, pcf
I	Coal Refuse	0	35	80



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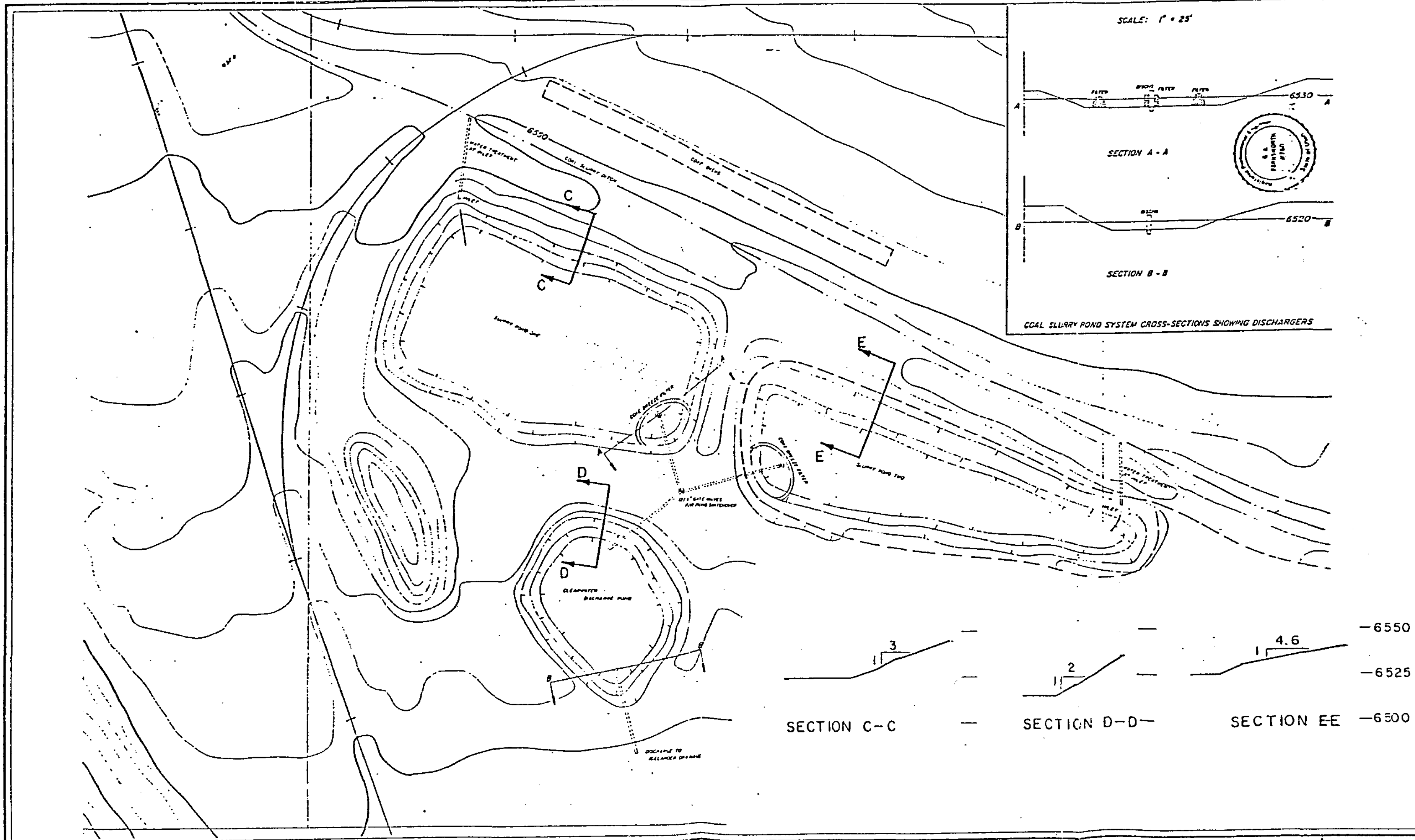
KAISER STEEL DIKE STABILITY
Stability Analysis--Proposed Upper West Slope
Sunnyside, Utah

FIGURE NO 12



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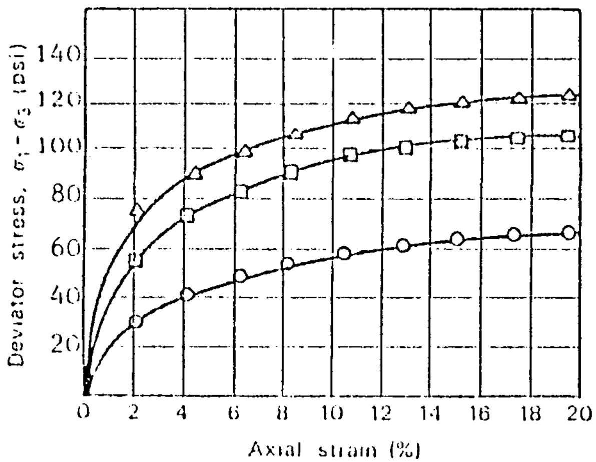
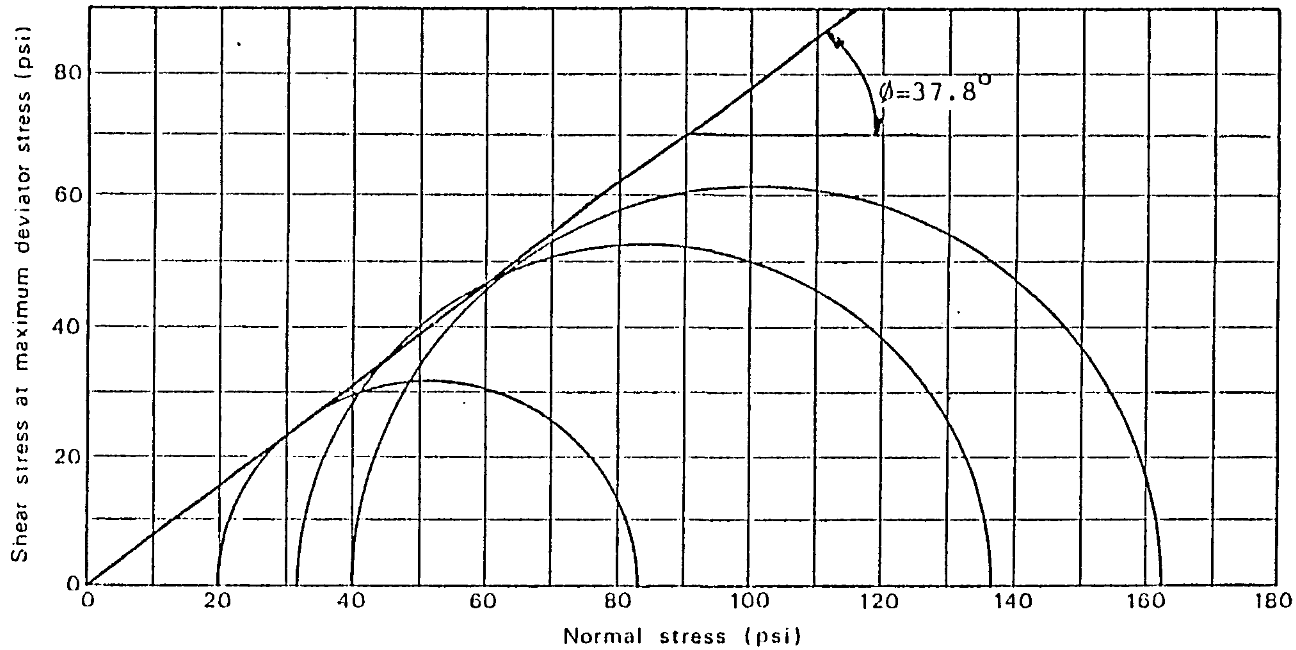
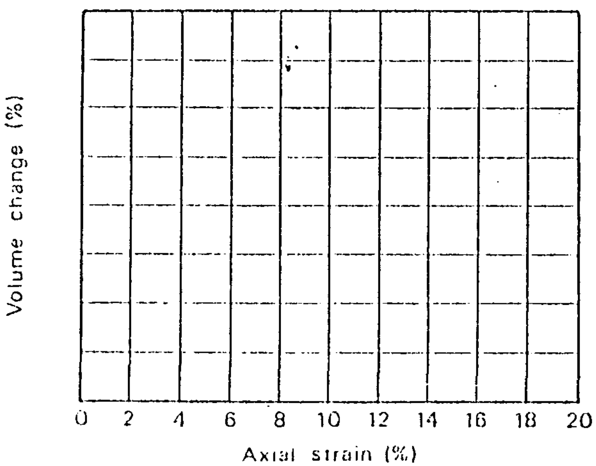
KAISER STEEL DIKE STABILITY
Coal Slurry Water Sediment Control System
Sunnyside, Utah

FIGURE NO. 13







Test no. or symbol	Boring no. or depth	Sample data: Dry density (pcf)	Sample data: Moisture content (%)	Degree of saturation (%)	Confining pressure (psi)	Maximum deviator stress (psi)	Strength values at failure: Friction angle φ (degrees)	Strength values at failure: Cohesion (c/psi)	Sample size, L/D (inches)	Strain rate (inches/minute)
○		77.9	8.3	0	20	64.8	37.8	0	2.87/1.32	.0093
□		80.2	8.3	0	32	105.2	37.8	0	2.87/1.32	.0093
△		78.9	8.3	0	40	123.3	37.8	0	2.87/1.32	.0093

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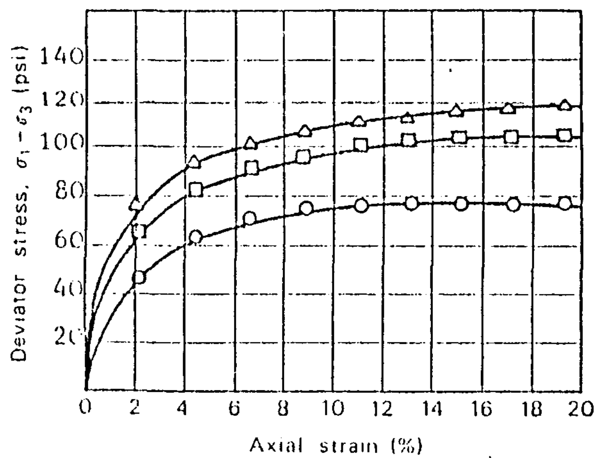
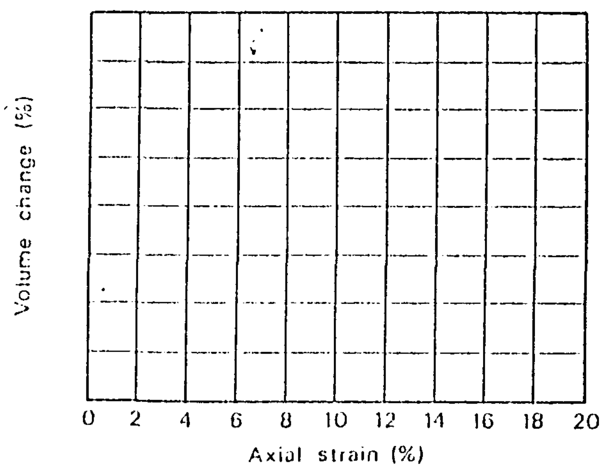
TRIAXIAL SHEAR TEST

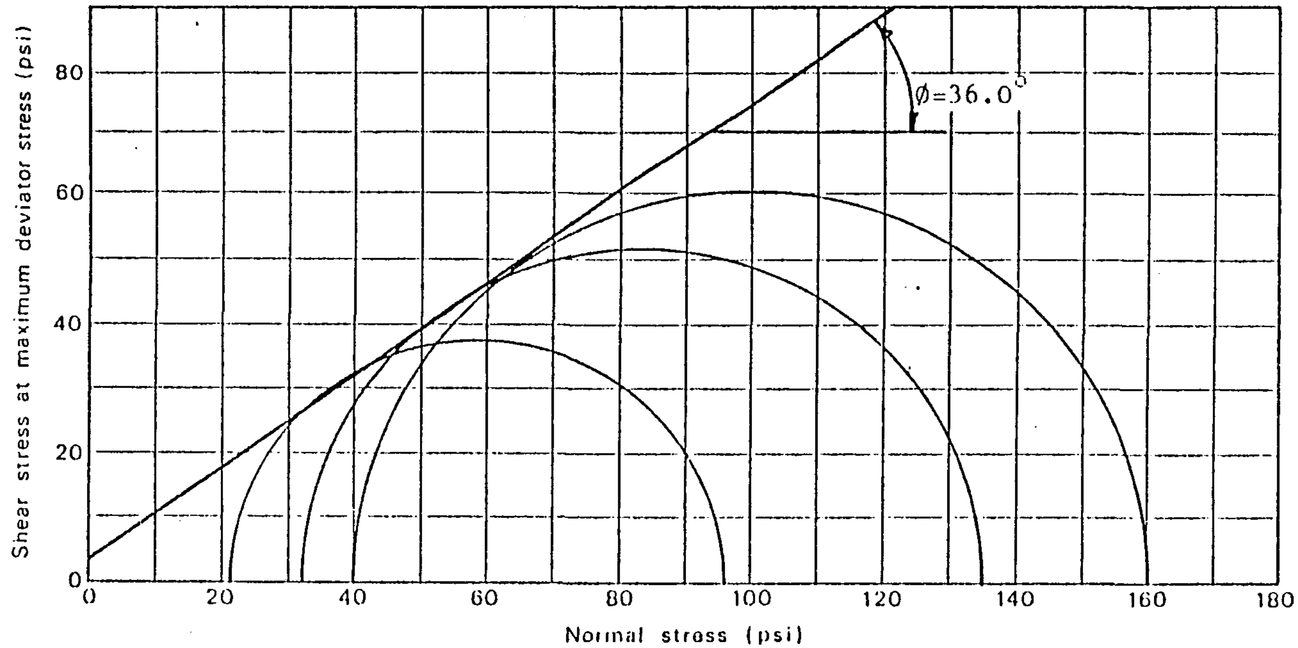
Project: Kaiser Steel Dike
Sunnyside, Utah

HOLE NO. 1
DEPTH: 6-10'

FIGURE NO. 14







Test no. or symbol	Boring no. or depth	Sample data: Dry density (pcf)	Sample data: Moisture content (%)	Degree of saturation (%)	Confining pressure (psi)	Maximum deviator stress (psi)	Strength values at failure: Friction angle ϕ (degrees)	Strength values at failure: Cohesion (c/psi)	Sample size, L/D (inches)	Strain rate (inches/minute)
○		74.0	6.0	0	21	75.5	36.0	3	2.8/1.32	.0093
□		74.9	6.0	0	32	105.3	36.0	3	2.8/1.32	.0093
△		73.6	6.0	0	40	119.4	36.0	3	2.8/1.32	.0093

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TRIAXIAL SHEAR TEST

Project: Kaiser Steel Dike
Sunnyside, Utah

HOLE NO. 2
DEPTH: 3-6'

FIGURE NO. 15

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March 30, 1984

Kaiser Steel Corporation
P.O. Box D
Sunnyside, UT 84539

Attn: Doug Pierce

Gentlemen:

This letter will supplement our report relative to the stability analysis of the Kaiser Steel dikes. In our report, submitted to you dated March 23, 1984, no consideration was given to the seismic stability of the existing dikes.

In the past, the earthquake stability of embankments have been assessed by applying a lateral force corresponding to some fraction of the gravitational acceleration. This procedure has been designated as a pseudo-static analysis, and the present state of the art in seismic stability analysis does not consider this procedure an acceptable method to determine the performance of an embankment under seismic conditions.

It is well known that loose, saturated sands and sensitive-type clays exhibit a substantial loss in strength when these materials are subjected to vibratory action; and massive failure usually accompanies seismic activity where such soils exist. The loss in strength in loose, saturated sands is due to the high pore pressures which develop in these materials under vibratory action and is termed liquefaction.

It should be noted that no groundwater was encountered in test holes drilled at either of the dikes during our investigations. Since the materials within the dikes are not saturated, the possibility of liquefaction of the subsurface materials is not possible. Furthermore, no sensitive-type clays were encountered in either of the test holes drilled in the dikes. As a consequence of this situation, the likelihood of a massive failure due to seismic activity is relatively remote for the existing dikes.

To further evaluate the seismic stability of the existing dikes, the comparison method developed by the Division of Water

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Resources of the State of California has also been applied to the existing dikes. Figure No. 1, attached hereto, defines the basic criteria relative to the behavior of embankments according to the California method. It will be noted that the basic criteria includes the state of compaction, the peak ground acceleration, and the type of soils.

Based upon the results of the standard penetration tests performed in the refuse material in the two test holes drilled at this site, the existing materials appear to be in at least a medium-dense condition. In the area where the dikes are located, the U.S. Geological Survey has established that the acceleration, having a 90 percent probability of not being exceeded in 250 years is 0.2g. The material existing within the dikes would generally fall into Soil Group I according to the California Method. It is apparent from the table shown in Figure No. 1, that a medium-dense material having a peak acceleration equal to or less than 0.2g falls into Zone 7, which indicates that no stability problems will exist for the existing facilities under seismic activity.

Based upon the above considerations, it is our opinion that the potential for seismic instability is very low for the refuse dikes in this area. If there are any questions relative to the information contained above, please advise us.

Yours truly,

ROLLINS, BROWN AND GUNNELL, INC.

Ralph L Rollins

Ralph L. Rollins

RLR/lah

Enclosure

FIGURE NO. 1

	Relative Compaction (ASTM 1557)	Relative Density
Very Dense	100-95.0	100-80
Dense	91.3-94.9	79-65
Medium Dense	88.7-91.2	64-55
Loose	88.6 or less	55 or less

In many cases the relative compaction testing was done using a standard other than ASTM 1557. However, Safety of Dams routinely faces this problem so conversion curves for various soils were included in the procedure.

Classify the level of acceleration.

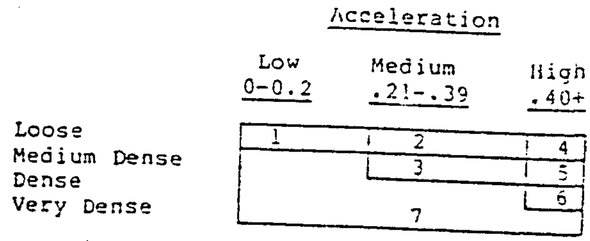
Peak Ground Acceleration	
Low	0.2g or less
Medium	0.21 to 0.39g
High	0.40g or greater

as noted that the duration of shaking was not uded but should be in deciding borderline es particularily for loose soils.

termine the soil group and possible behavior.

Soil Group	Classification	Behavior
I	GW, GP, GM, SW, SP	Liquefaction
II	SM, ML	Liquefaction and/or settlement-slip circle
III	GC, SC, CL, OL, MH, CH, OH	Settlement-slip circle

Predict behavior using the following chart.



Zones 1, 3, & 6 — Borderline Zones - Cases that fall in these zones may or may not present a problem. A small investigative program is desirable to determine if there is a problem. Group III soils (clayey) might experience 0-5 percent settlement. There is some possibility for liquefaction of Groups I and II soils.

Zones 2 & 5 — Problem Zones - Cases that fall in these zones will usually present some type of problem. An investigative program would be very desirable. Settlement for Group II soils might range from 5-10 percent. Liquefaction for Groups I and II is very possible.

Zone 4 — Real Problem Zone - An investigative program should be initiated immediately. Settlement for Group III soils might range from 10-20 percent. Probability of liquefaction for soil Groups I and II is very high.

Zone 7 — No Problem - Cases that fall in this zone will normally not present any problems.

ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

February 18, 1985

Kaiser Steel Corporation
P.O. Box D
Sunnyside, UT 84539

ATTN: Roger Kohlman

Gentlemen:

As you have requested, we have performed a stability analysis for the exterior slope of East Slurry Cell for the Kaiser Steel Mine Near Sunnyside, Utah.

In performing the stability computations, a computer model of Spencer's Method has been used. Spencer's Method satisfies both force and moment equilibrium and is considered to be a satisfactory method of solving limiting equilibrium problems. The shear strength parameters used in the stability analysis are based on the results of laboratory tests performed for the report submitted to your office on March 25, 1984.

As requested, we have performed this analysis with the slope under saturated conditions. The analysis indicates that the slope under saturated conditions has a factor of safety of only 0.49, which is obviously insufficient for a stable slope. The results of the analysis along with the failure surface are presented on Figure No. 1.

If we can be of any further assistance, please notify us.

Sincerely,

ROLLINS, BROWN AND GUNNELL, INC.

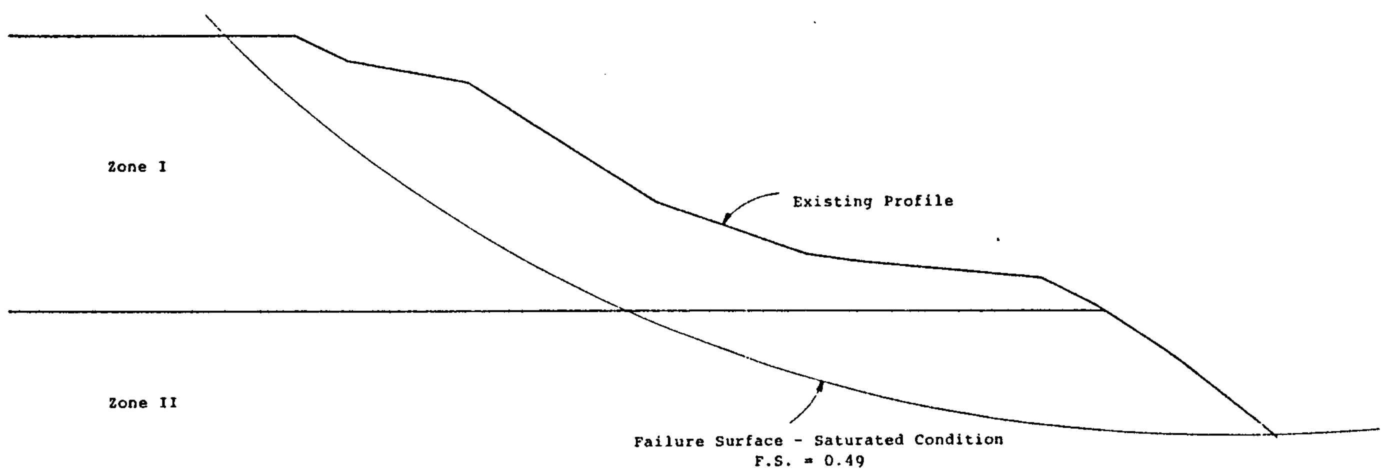
Ralph L. Rollins

Ralph L. Rollins

SLS:jbf
ENC

1435 West 820 North, P.O. Box 711 • Provo, Utah 84603 • (801) 374-5771

ZONE	MATERIAL	C, psf	ϕ,degrees	γ, pcf
I	Coal Refuse	0	35	80
II	Silty Sand, Sandy Silt	0	30	105



ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

SUNNYSIDE MINE - KAISER STEEL
Sunnyside, Utah

FIGURE NO. 1

SLOPE STABILITY ANALYSIS FOR RECLAIMED AREAS

KAISER STEEL CORPORATION
SUNNYSIDE, UTAH

October 1984

Rollins, Brown and Gunnell, Inc.
Professional Engineers
1435 West 820 North, P.O. Box 711
Provo, Utah 84603

ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

October 5, 1984

Kaiser Steel Corporation
P.O. Box D
Sunnyside, UT 84539

Gentlemen:

It is our understanding that the state and federal regulatory agencies require that each mine facility be restored as nearly as possible to its original configuration at the termination of the use of that facility. In accordance with these regulations, we understand that Kaiser Steel Corporation is preparing plans to submit to the regulatory agencies covering the restoration of nine sites at the Kaiser Steel Mining Facilities near Sunnyside, Utah.

These facilities include the No. 2 Mine Fan site, the Whitman Fan site, the Preparation Plant site, the Pole Canyon site, the Man Shaft site, the No. 2 Mine Portal site, the No. 2 Canyon Fan site, the Water Canyon Portal site, and the Loadout Facility site. Each of these sites are located on a hillside and the restoration involves restoring the slope to its original location. The regulatory agencies require that each restored slope have a factor of safety of at least 1.5. The purpose of this investigation was to determine the factor of safety of each of the restored slopes. Most of the slopes have a relatively low height and the general nature of the material can be observed at the cut face.

The drilling of test holes at each slope location would have been expensive, and would not have contributed greatly to a knowledge of the characteristics of the material at the site. Visual observation of each site indicates that the material within the slope is predominantly granular type soils. Representative samples of the material within each slope was obtained, and a particle size distribution analysis was performed on this material to provide a general characterization of the soils within the slope. Conservative shear strength parameters were used in estimating the factor of safety for each slope.

1435 West 820 North ■ P.O. Box 711 ■ Provo, Utah 84603 ■ (801) 374-5771

The stability analysis for each slope was performed using a computer program developed at the University of California at Berkeley. The program follows Spencer's Method which satisfies both force and moment equilibrium. The results of the stability analysis for each of the slopes indicated above is outlined below as follows:

1. **THE NO. 2 MINE FAN SITE**

A picture showing the characteristics of the cut slope in the vicinity of the No. 2 Mine Fan site is shown in Figure No. 1. The results of a particle size distribution analysis performed on a representative sample obtained from the cut slope are presented in Figure No. 2. It will be observed from Figure No. 2 that 62 percent of the sample consists of sand and gravel size particles, while the remainder of the sample are predominantly silty type soils. A profile showing the existing cut at the No. 2 Mine Fan site is presented in Figure No. 3 along with the proposed reclaimed contour.

A stability analysis was performed for this site using the shear strength parameters shown in Figure No. 3. It will be observed that a factor of safety of 1.57 was obtained for the restored slope. It is our opinion that shear strength parameters used for this analysis are reasonable and that the restored slope will have an adequate factor of safety.

2. **THE WHITMAN FAN SITE**

The cut slope at the Whitman Fan site is presented in Figure No. 1. It will be noted that the slope consists predominantly of granular type soils. The results of a particle size distribution analysis performed on a representative sample obtained from the slope is presented in Figure No. 4, and it will be noted that approximately 70 percent of the material in the sample is granular type material. The remainder of the sample consisted predominantly of low-plasticity cohesive soils.

A profile through the existing slope is presented in Figure No. 5 along with the proposed restored slope. The shear strength parameters used in the stability analysis for this slope are indicated in Figure No. 5, and the results of the stability computations indicate a factor of safety of 3.2. The height of this slope is small, and there is little doubt that the slope will be stable in its restored state.

3. THE PREPARATION PLANT SITE

A picture of the Preparation Plant site is presented in Figure No. 6, and a cross-section through the site is presented in Figure No. 7. The proposed finished contour is also presented in Figure No. 7. The results of a particle size distribution analysis for material within the Prep Plant slope is presented in Figure No. 8.

It will be observed that about 70 percent of the material in this sample are granular type soils, while the remainder of the sample are low-plasticity silts and clays. The shear strength parameters used in the stability analysis for the Prep Plant slope are shown in Figure No. 7, and it will be noted that a friction angle of 31 degrees and a cohesion of 150 psi were used in the analysis. It will be observed that the stability computations were performed for the overall slope, and for a small slope within the overall conditions. The factors of safety associated with these slopes were 2.3 and 2.4, respectively. The results of the stability analysis indicate that the finished slope will be stable with a relatively high factor of safety.

4. THE POLE CANYON SITE

A picture of the cut slope at the Pole Canyon site is presented in Figure No. 6. It will be observed that some rock ledges exist within this profile. A profile through the Pole Canyon site showing the existing slope along with the final contour is also presented in this figure.

Stability computations were performed for the overall slope along with a shallow slope in the center of the profile. The shear strength parameters used in performing the stability analysis at this location are presented in Figure No. 9, and it will be noted that a friction angle of 30 degrees and a cohesion of 125 pounds per square foot were used. The results of the stability computations indicate a factor of safety of 1.5 and 1.69, respectively for the finished slope.

The results of a particle size distribution analysis performed on a representative sample of the material obtained in the cut slope are presented in Figure No. 10. This figure indicates that the sample is approximately 76 percent granular type soils, while the remainder of the sample are low-plasticity silt and clays. The factors of safety for both of these slopes using relatively conservative shear strength parameters meet the requirements of the regulatory agencies.

5. THE MAN SHAFT SITE

A picture showing the cut slope at the man shaft site is presented in Figure No. 11, while the results of a particle size distribution analysis performed on a representative sample for this slope are presented in Figure No. 12. It will be noted from Figure No. 12 that approximately 84 percent of the sample is granular type material, while the remainder of the sample is low-plasticity silts and clays. The existing profile through the site is presented in Figure No. 13 along with the proposed finished grade line.

A stability analysis was performed for both the overall slope and for a shallow slope within the overall slope. The shear strength parameters used in performing the analysis are presented in Figure No. 13, and it will be observed that a friction angle of 32 degrees and a cohesion of 75 pounds per square foot were used. The factors of safety observed for the finished slope were 1.55 for the shallow slope, and 1.57 for the overall slope. It is our opinion, therefore, that the factor of safety of the finished slopes will be satisfactory.

6. THE NO. 2 MINE PORTAL

A picture of the existing slope for the No. 2 Mine Portal is presented in Figure No. 11. It will be observed that the slope appears to be relatively stable in its existing condition. It should also be noted that some sandstone rock ledges exist within this slope. The results of a particle size distribution analysis performed for a representative sample of the earth material within this slope are presented in Figure No. 14. It will be noted that approximately 61 percent of the material is in the granular size range, while the remainder of the sample is low-plasticity silt and clay.

A profile through the No. 2 Mine Portal site is presented in Figure No. 15, and it will be observed that some activity has occurred along both sides of the canyon at this location. The finished contour for the entire site is presented in Figure No. 15, along with the shear strength parameters used in performing the stabilty computations. It will be observed that the most critical area is on the left side of the canyon where a factor of safety of 1.4 was obtained for a friction angle of 32 degrees and a cohesion of 400 pounds per square foot. The factor of safety obtained for the other two sites investigated along the profile indicate factors of safety of 1.7 and 1.53, respectively. In performing the stability analysis no consideration has been given to rock ledges which may exist within the profile.

It should be noted that in the vicinity of the Station 1+00 to 2+00 a disturbance in the soil profile appears to be relatively small, and that the low factor of safety for the reclaimed profile exists because of the low factor of safety for the original slope. In view of this situation, it is our opinion that the factors of safety of the proposed reclaimed contour are as good as can be obtained for this site.

7. THE NO. 2 CANYON FAN SITE

A picture showing the cut at the No. 2 Fan Canyon site is presented in Figure No. 16. A particle size distribution analysis performed on a representative sample from this slope is presented in Figure No. 17. It will be observed that approximately 80 percent of this sample is in the granular size range with the remaining portion of the material being low-plasticity silts and clays.

A profile through the canyon at this site is presented in Figure No. 18 along with the proposed reclaimed contour. The shear strength parameters used in the stability analysis for this site are also shown in this figure, and it will be observed that a friction angle of 32 degrees and a cohesion of 150 pounds per square foot were used in the analysis. A factor of safety of 1.51 was obtained for the overall slope at this site. It is our opinion that the shear strength parameters used in the analysis for this site are conservative, and that the reclaimed slope will have a factor of safety meeting state and federal regulatory requirements.

8. WATER CANYON SITE

A picture showing the slope in the Water Canyon area is presented in Figure No. 16. It will be observed from the figure that the subsurface material is predominantly granular material, and the results of a particle size distribution analysis performed on a representative sample from this area, are presented in Figure No. 19.

The sample contained approximately 74 percent of granular type soils and 26 percent of low-plasticity silts and clays. A cross-section showing the existing contours along with the reclaimed contour for this site is presented in Figure No. 20. It will be observed that this slope has a low height and that a factor of safety of 2.31 was obtained for shear strength parameters of ϕ = 30 degrees and c = 100 pounds per square foot. It is apparent that the slope formed by the reclaimed contour will be entirely stable at this location.

9. **THE LOADOUT FACILITY**

Two pictures of the cut slopes in the area of the Loadout Facility are presented in Figure No. 21. It will be observed from these figures that the existing slopes are relatively steep, and that the material within the slope is predominantly granular type soils. The results of a particle size distribution analysis performed on a representative sample obtained from the cut slope is presented in Figure No. 22. This figure indicates that the sample contains approximately 84 percent material in the granular size range, and about 16 percent in the silt and clay size range. As indicated earlier in this report, the silt and clay size materials throughout the area generally has low-plasticity characteristics.

A profile through the Loadout area is presented in Figure No. 23, and a rock ledge exists at the top of the slope. The proposed finished contour is also presented in Figure No. 23. A stability analysis has been performed for the slope associated with the finished contour using the shear strength parameters as shown in Figure No. 23. The results of the stability computations indicate that the finished slope in the area shown will have a factor of safety of 1.90. This factor of safety is well above the requirements of the regulatory agencies and it is our opinion that the finished grade proposed in Figure No. 23 will stable under the proposed contour.

In performing the stability computations indicated above, it has been assumed that no pore pressures will develop in the slopes following the restoration activities. It is our opinion that this represents a reasonable assumption since essentially all of the subsurface materials within the slopes at this site are basically granular type soils which will drain quite easily. Insofar as we can determine, the cut slopes have been stable for a number of years.

If there are any questions relative to the information contained herein, please advise us.

Yours truly,

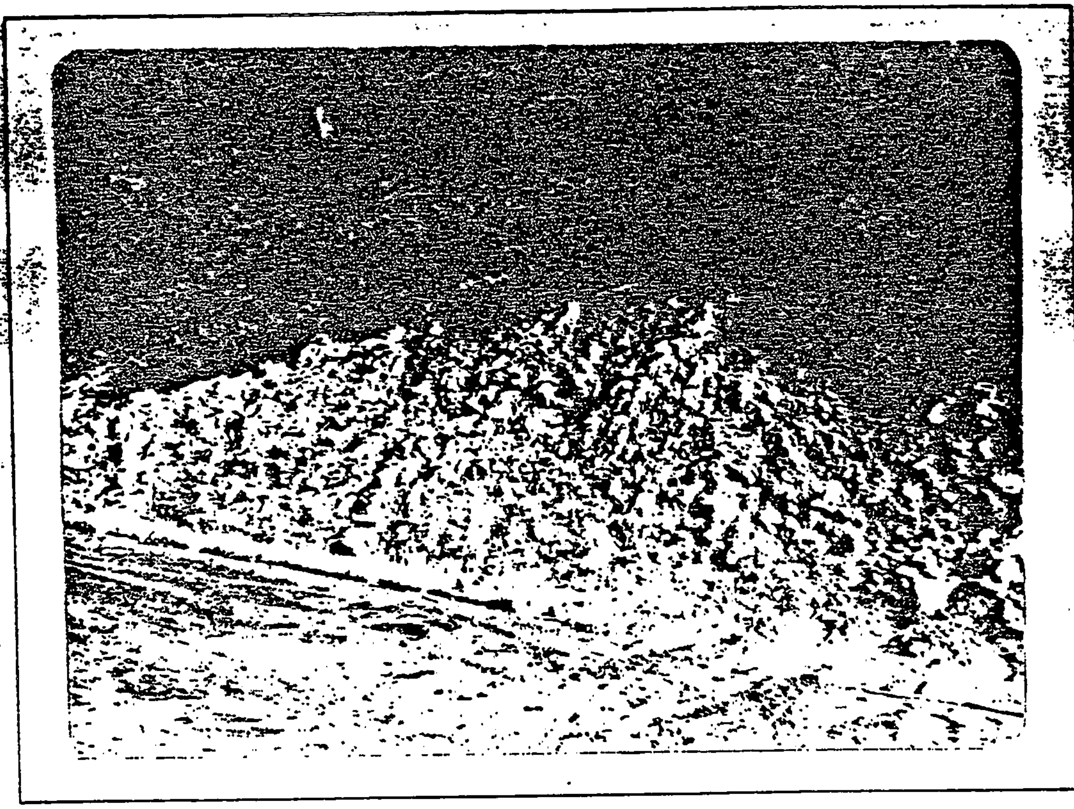
ROLLINS, BROWN AND GUNNELL, INC.

Ralph L Rollins

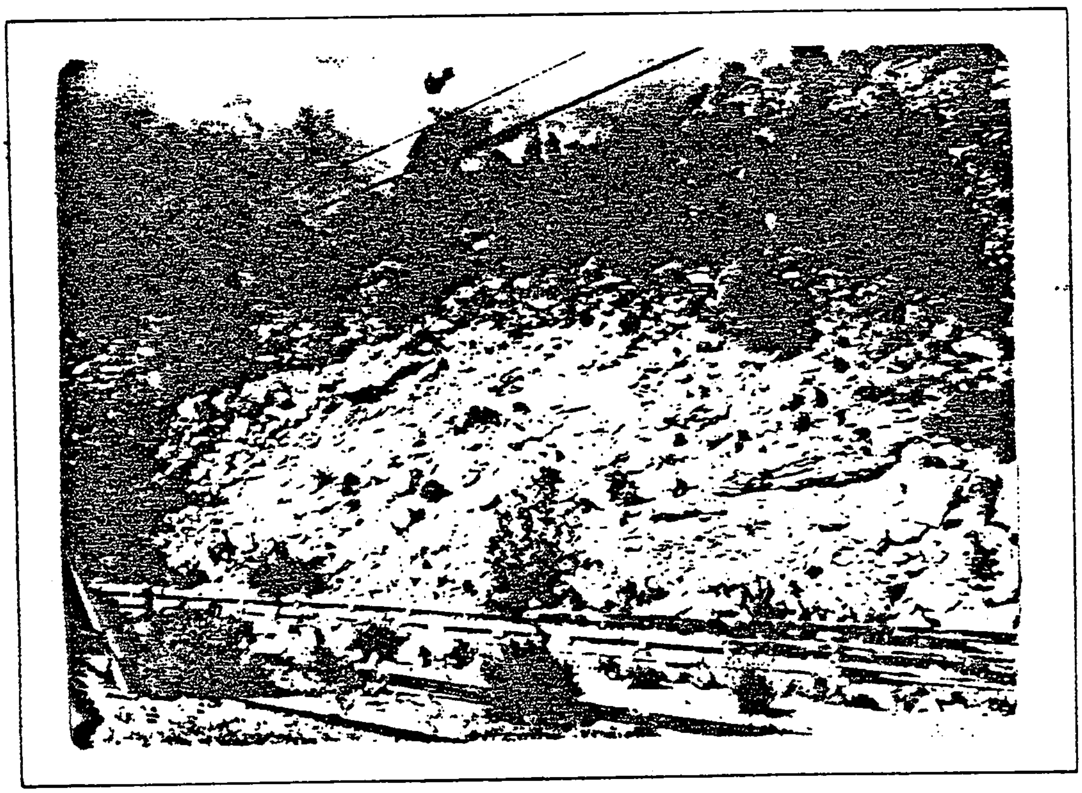
Ralph L. Rollins

REGISTERED PROFESSIONAL ENGINEER
RALPH L. ROLLINS
2306

RLR/jbt
Enclosures

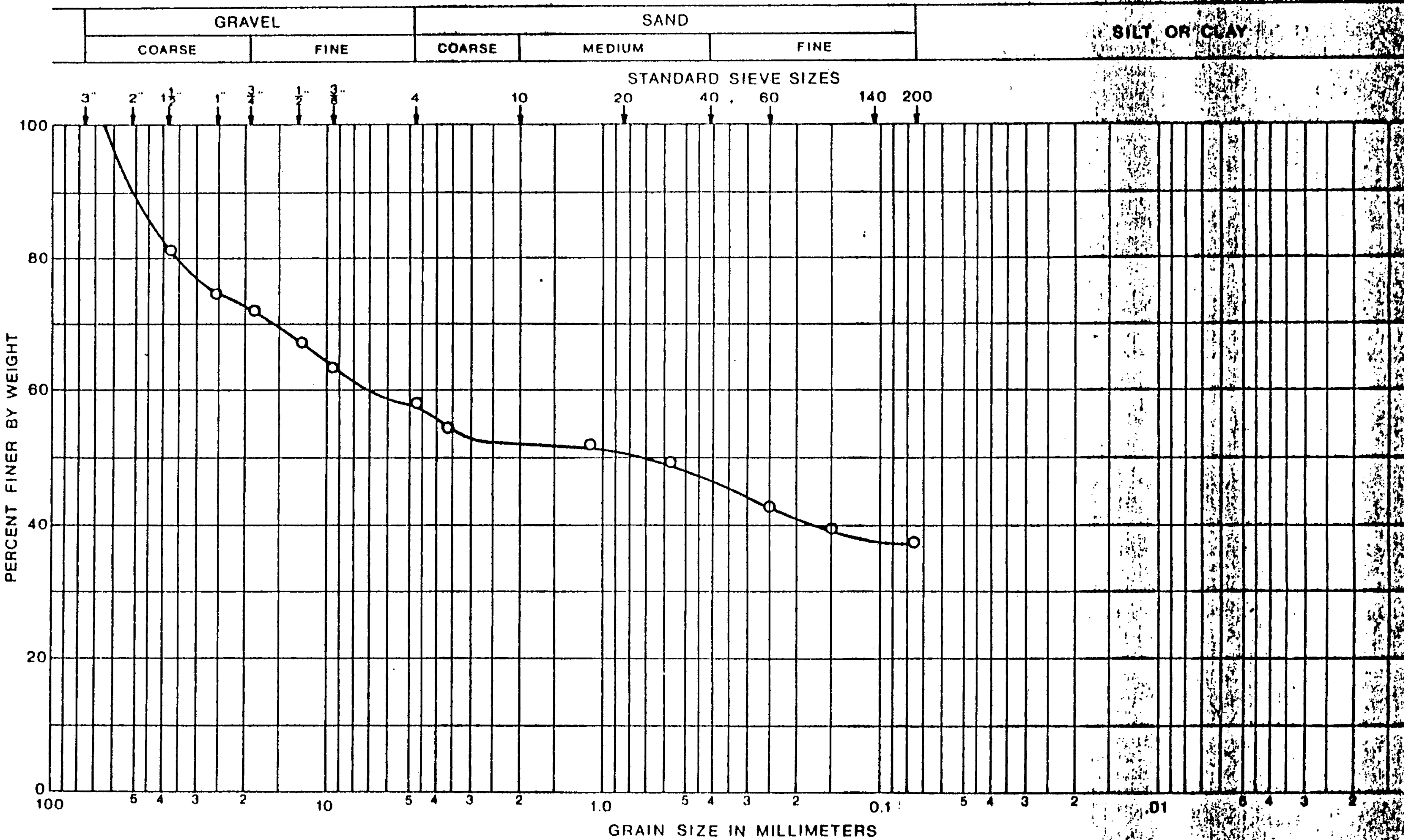


No. 2 Mine Fan Site



Whitman Fan Site

FIGURE NO. 1



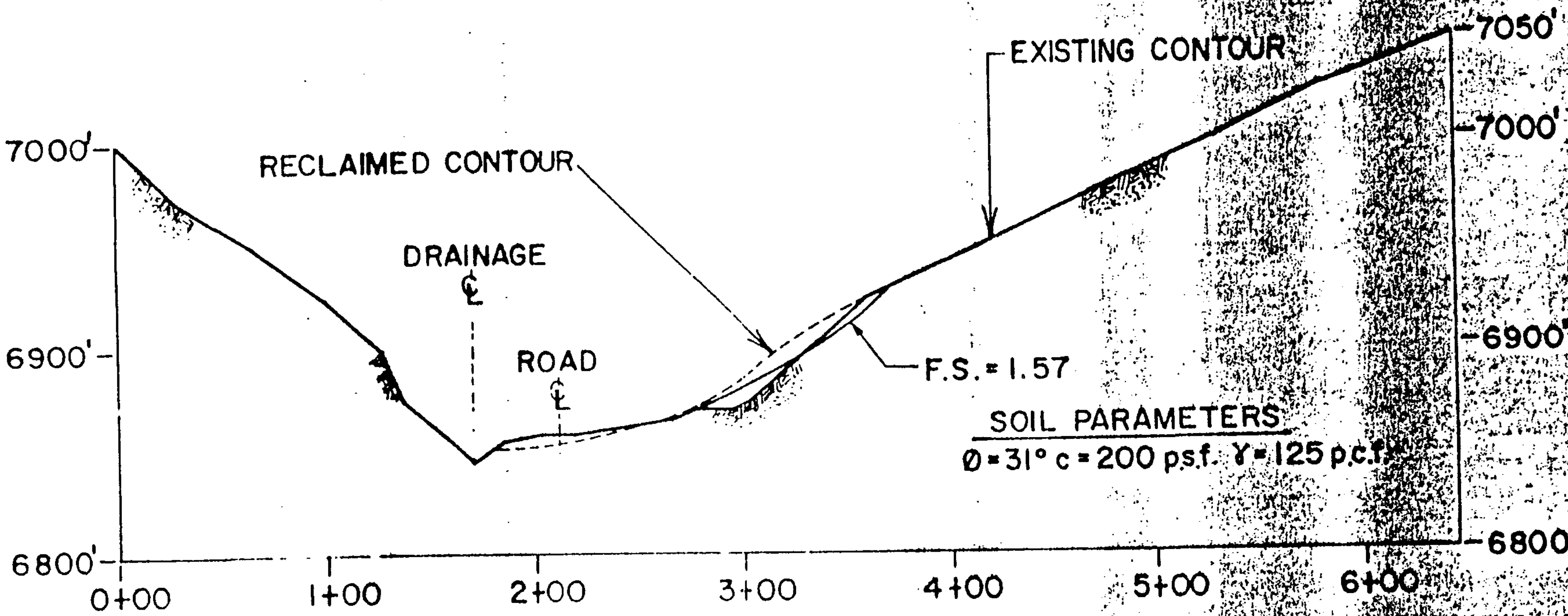
ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

GRAIN SIZE DISTRIBUTION CURVE

Project: Kaiser Steel
Location: No. 2 Mine Fan

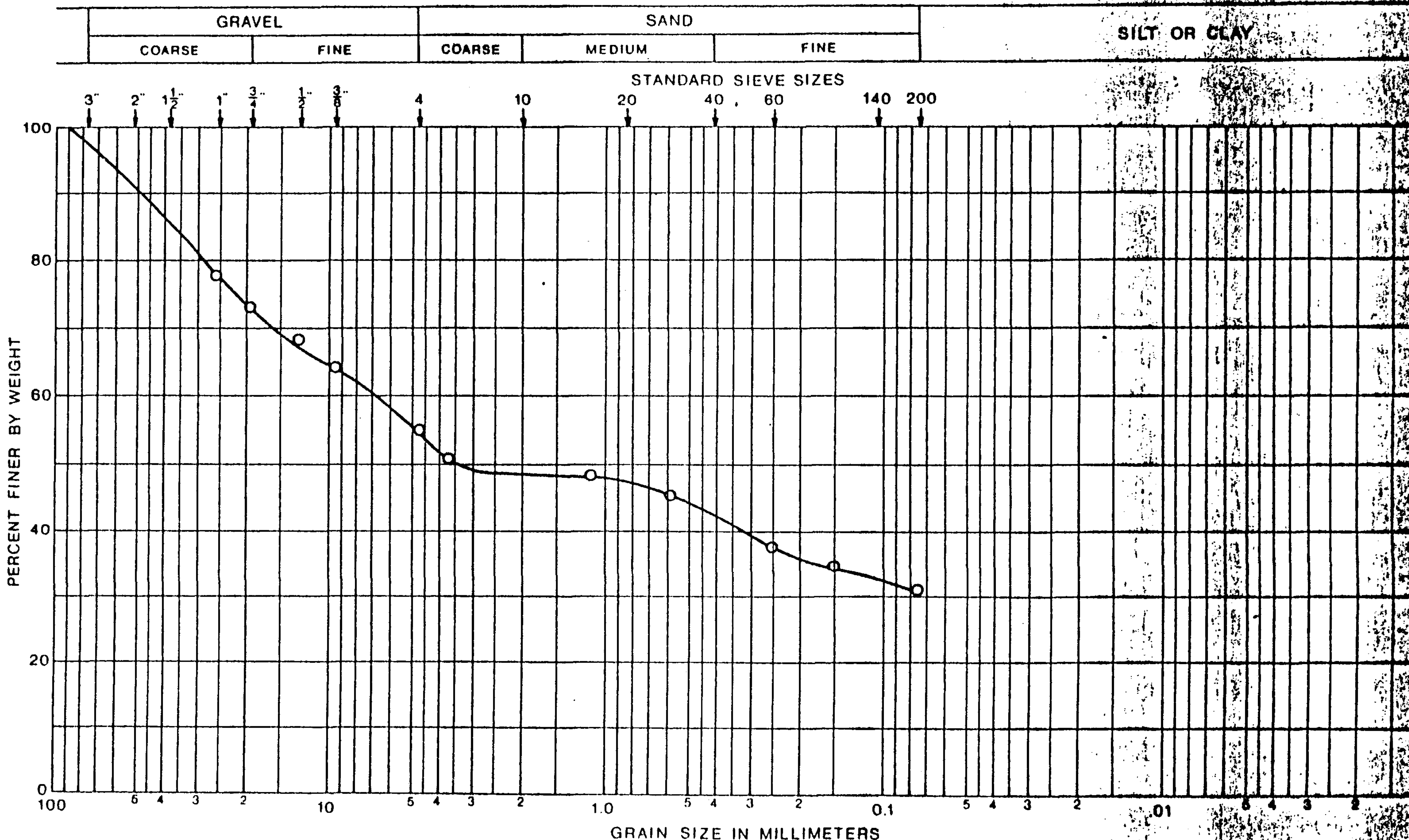
HOLE NO.
DEPTH:

FIGURE NO. 2



NO. 2 MINE FAN

ROLLINS, BROWN AND GUNNELL, INC. PROFESSIONAL ENGINEERS	SLOPE STABILITY RESULTS	KAISER STEEL	NO. 2 MINE FAN	FIGURE NO. 3



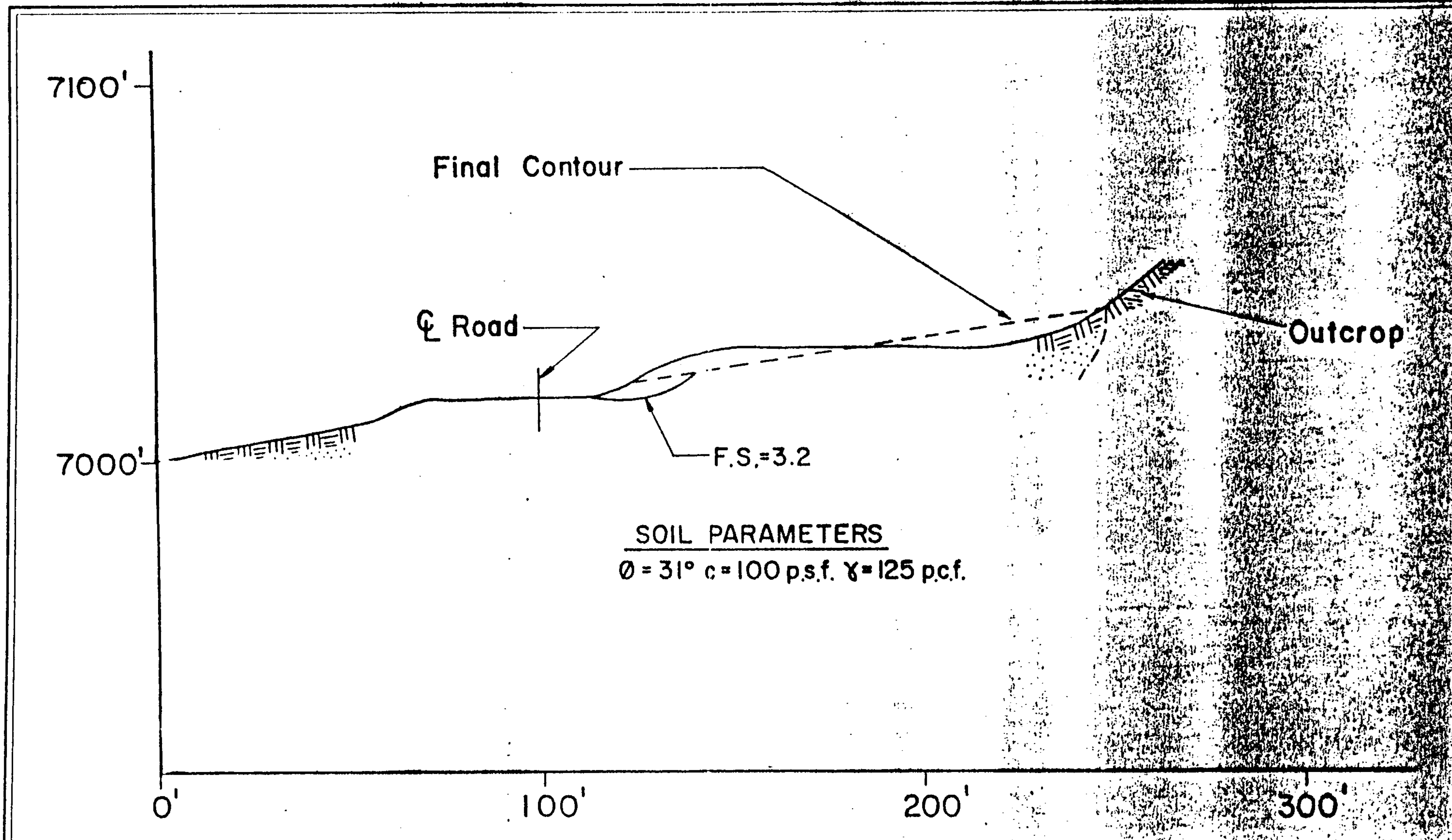
ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

GRAIN SIZE DISTRIBUTION CURVE

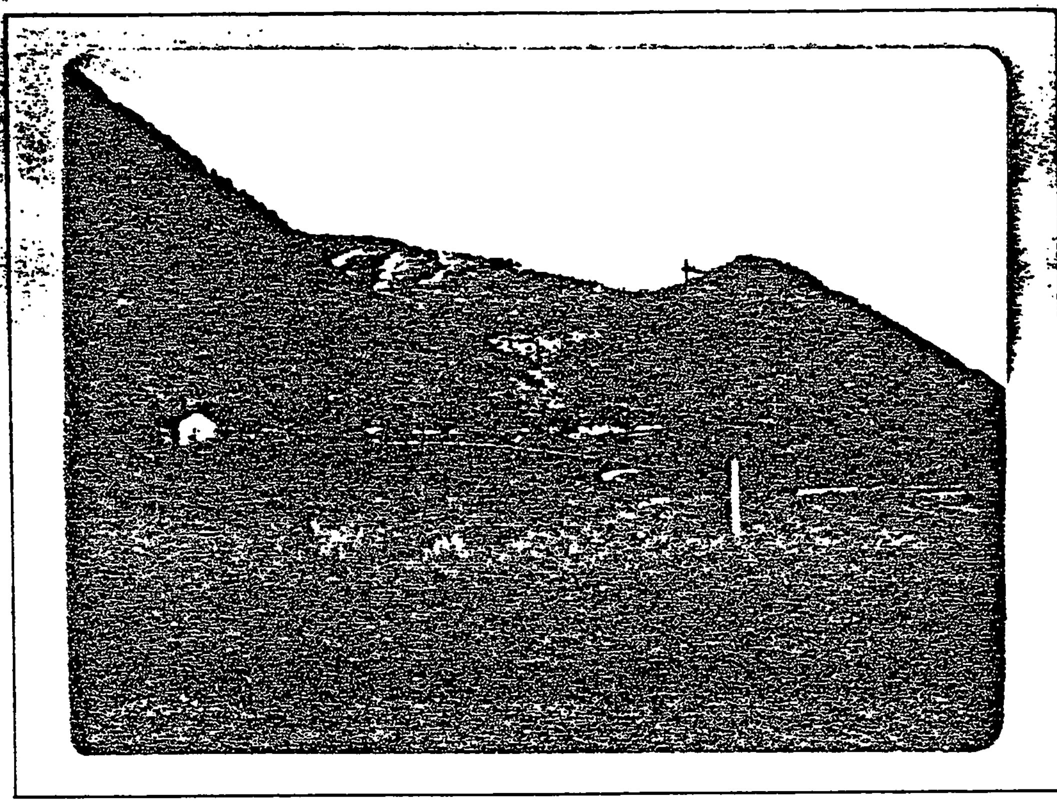
Project: Kaiser Steel
Location: Whitman Fan

HOLE NO.
DEPTH:

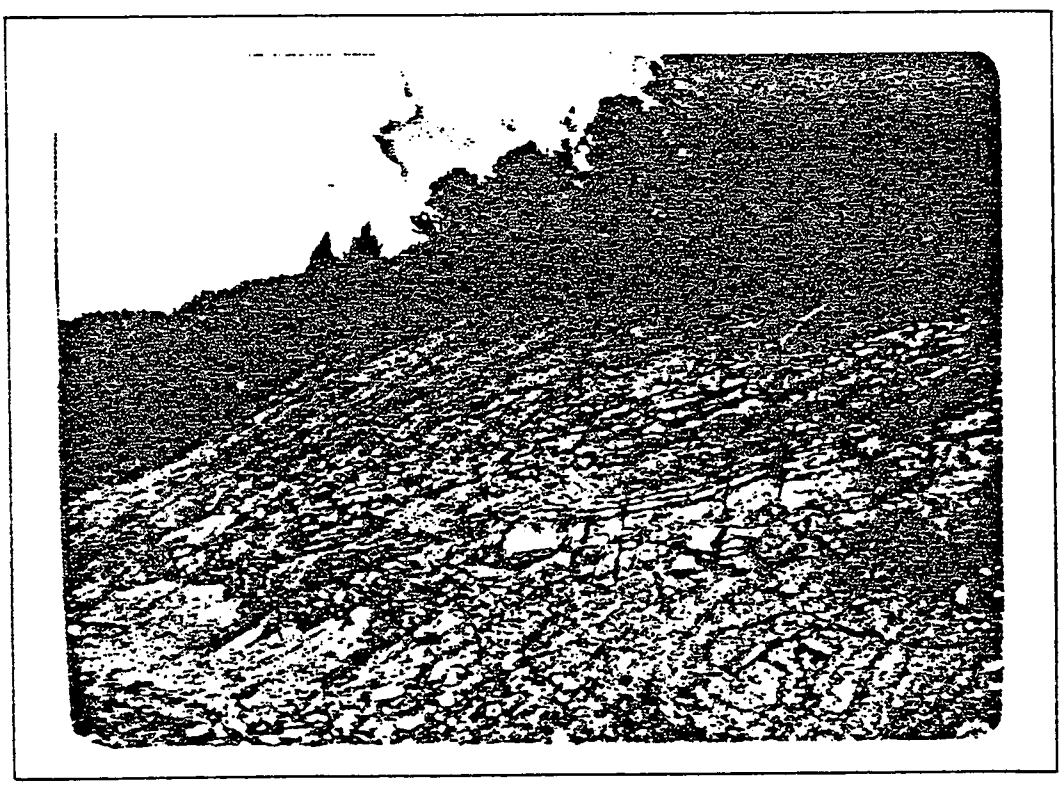
FIGURE NO. 4



ROLLINS, BROWN AND GUNNELL, INC. PROFESSIONAL ENGINEERS	SLOPE STABILITY RESULTS	KAISER STEEL	WHITMAN FAN	FIGURE NO.

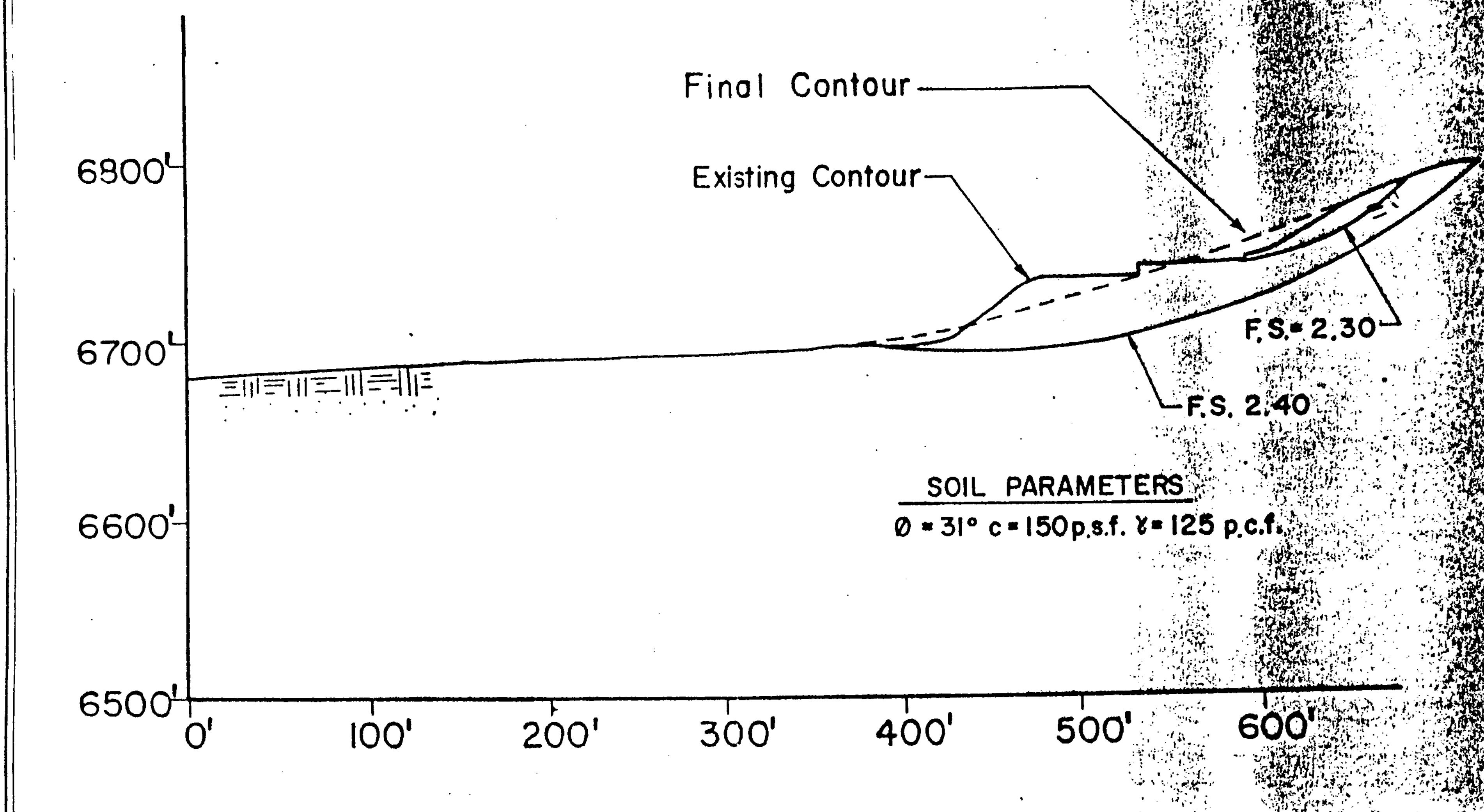


Preparation Plant Site



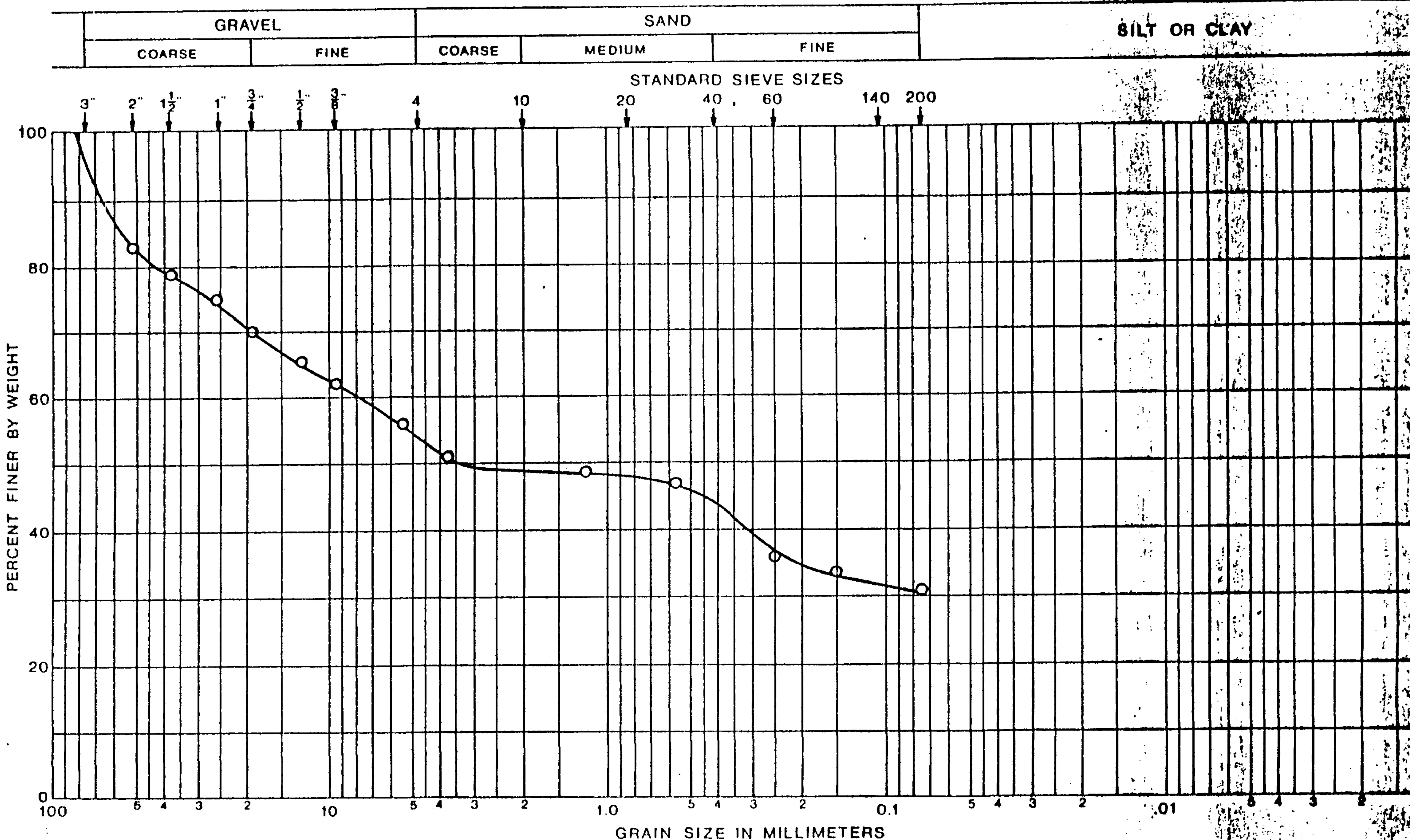
Pole Canyon Site

FIGURE NO. 6



ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

SLOPE STABILITY RESULTS	KAISER STEEL	PREPARATION PLANT	FIGURE NO. 7



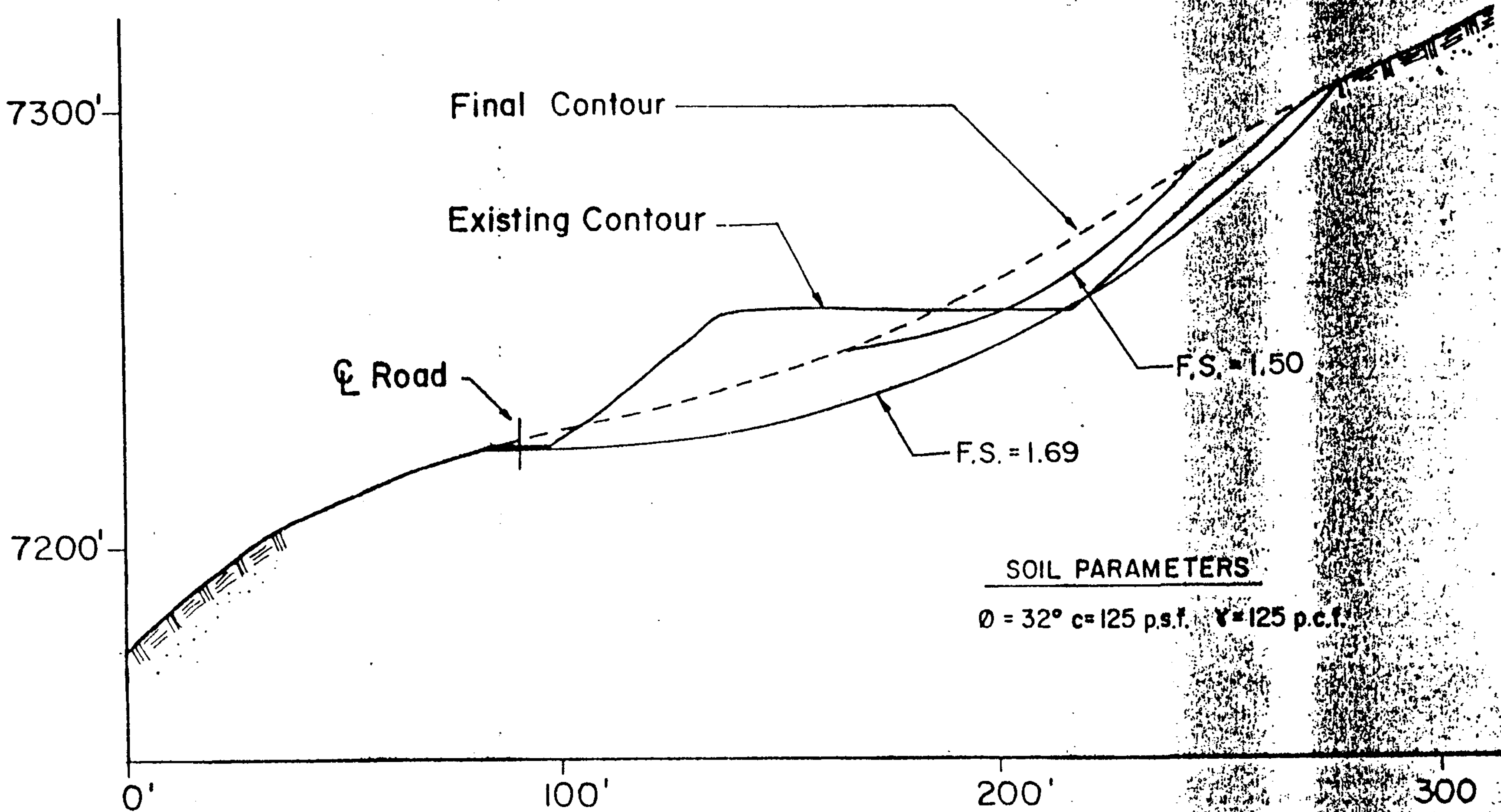
ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

GRAIN SIZE DISTRIBUTION CURVE

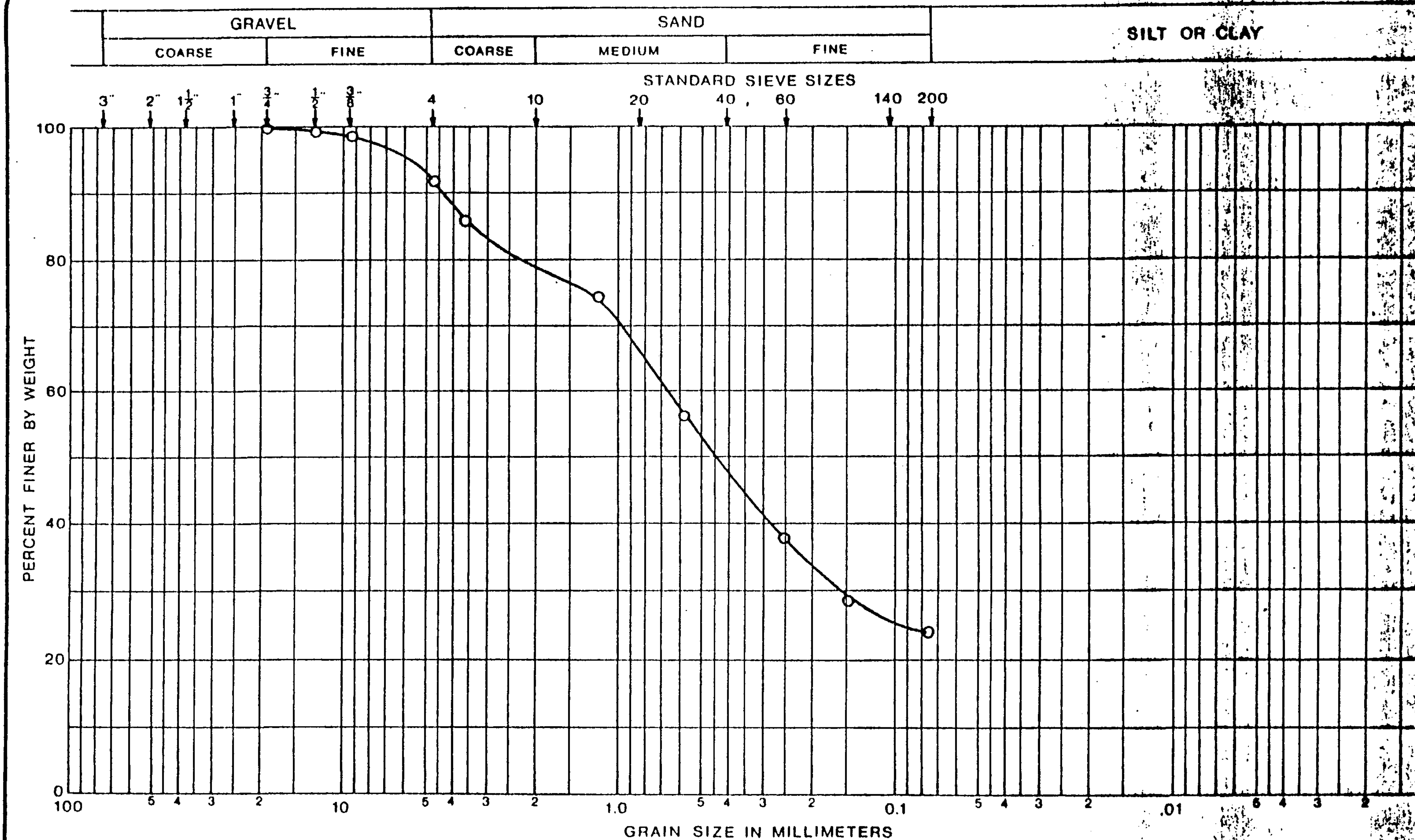
Project: Kaiser Steel
Location: Preparation Plant

HOLE NO.
DEPTH:

FIGURE NO. 8



ROLLINS, BROWN AND GUNNELL, INC. PROFESSIONAL ENGINEERS	SLOPE STABILITY RESULTS	KAISER STEEL	POLE CANYON	FIGURE NO. 9



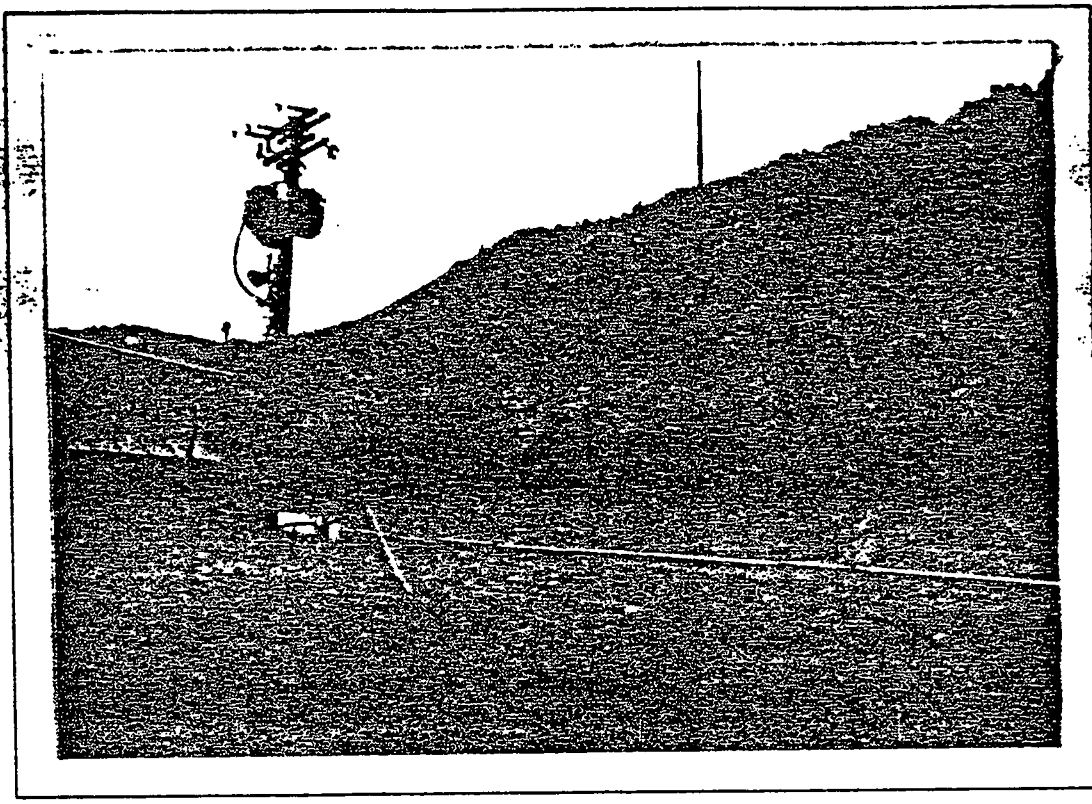
ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

GRAIN SIZE DISTRIBUTION CURVE

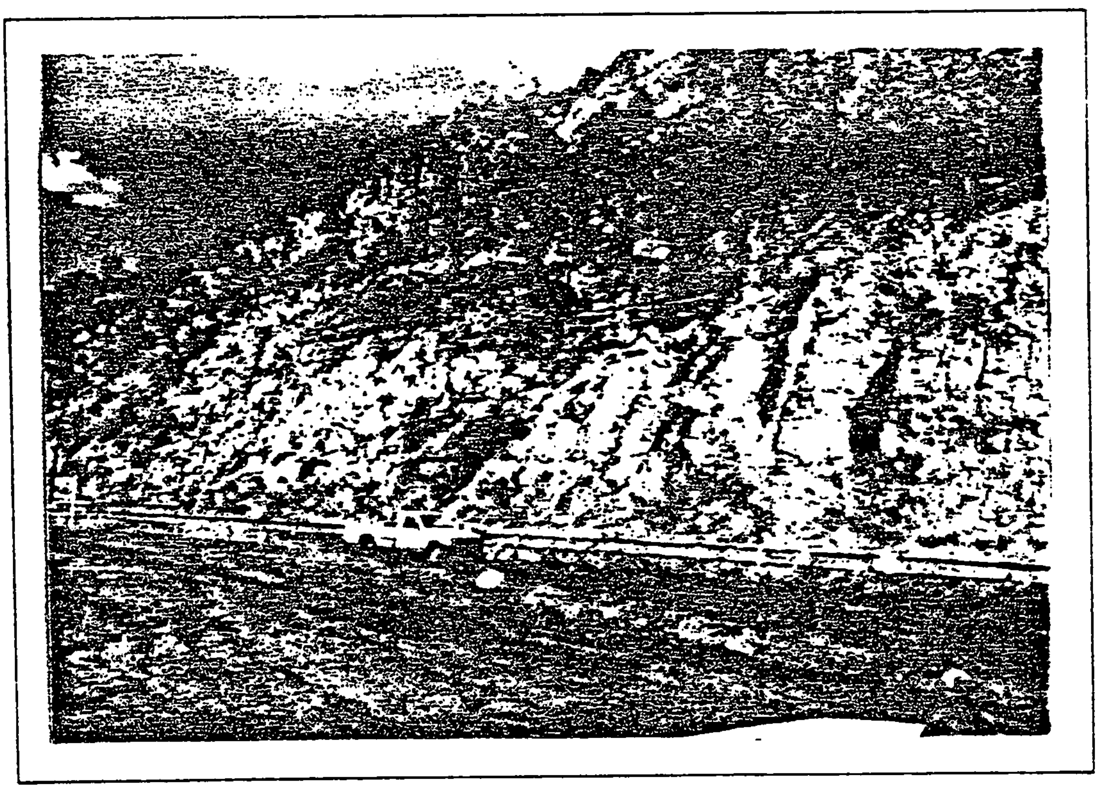
Project: Kaiser Steel
Location: Pole Canyon

DEPTH: Surface

FIGURE NO. 10

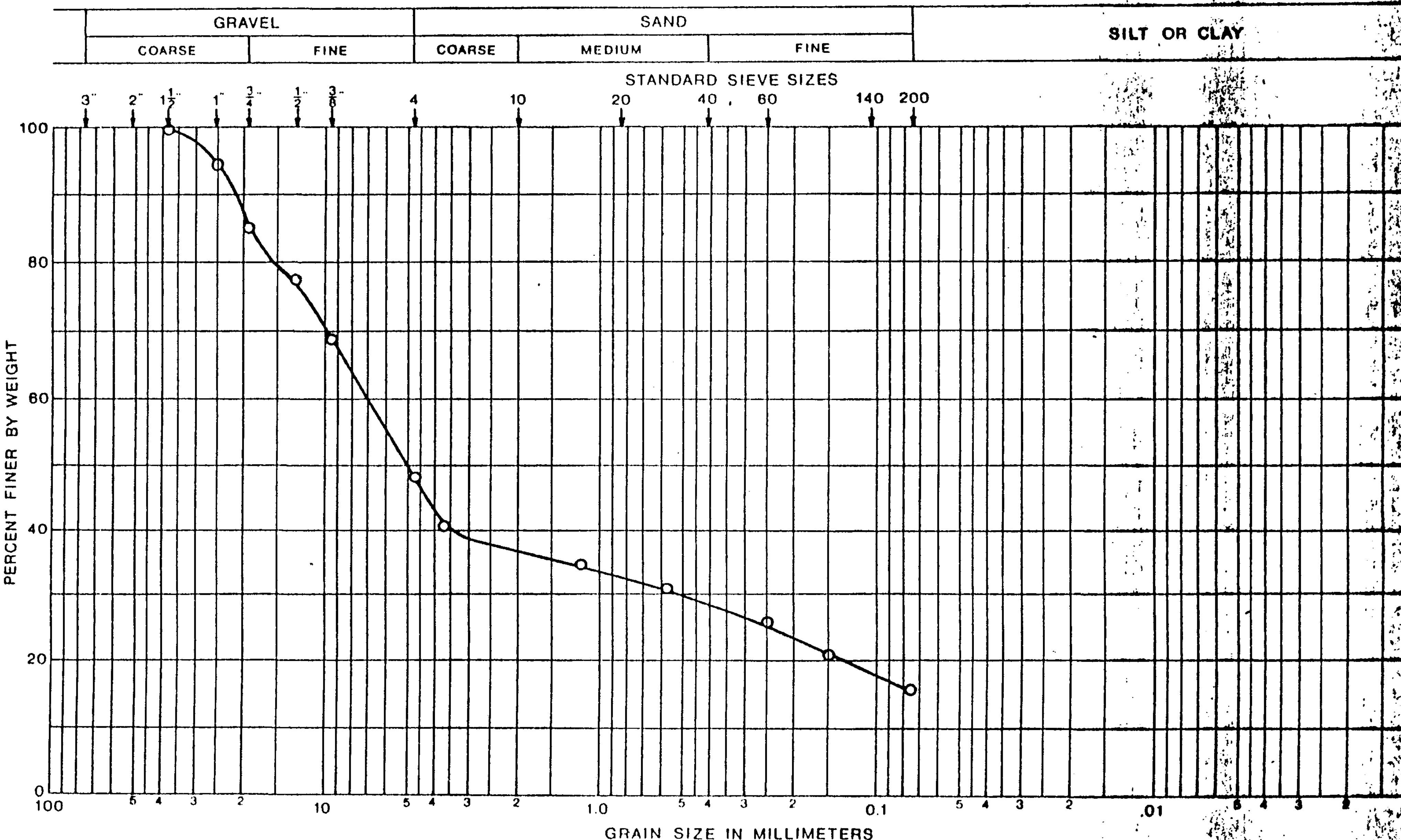


Mine Shaft Site



No. 2 Mine Portal Site

FIGURE NO. 11



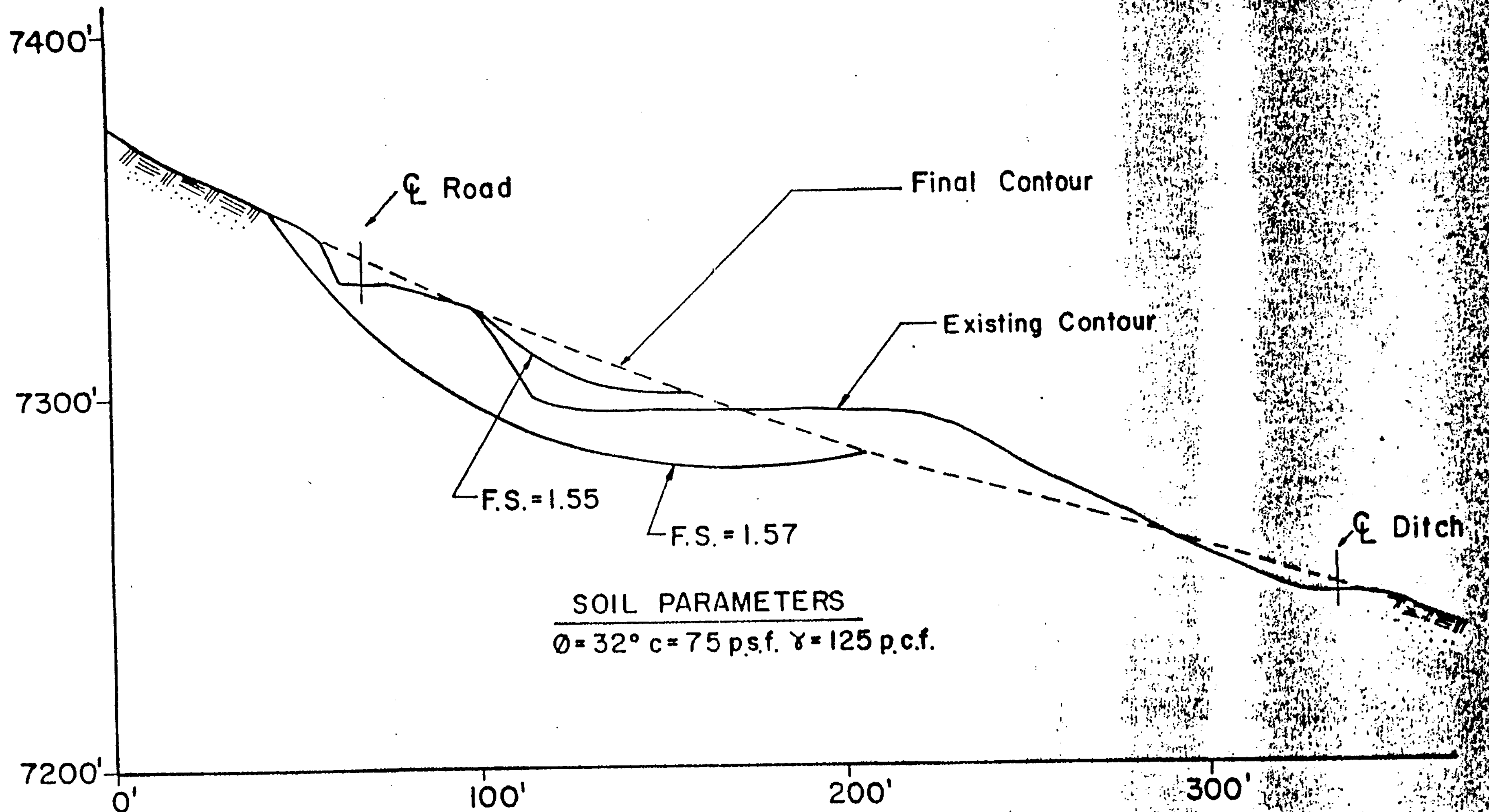
ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

GRAIN SIZE DISTRIBUTION CURVE

Project: Kaiser Steel
Location: Man Shaft

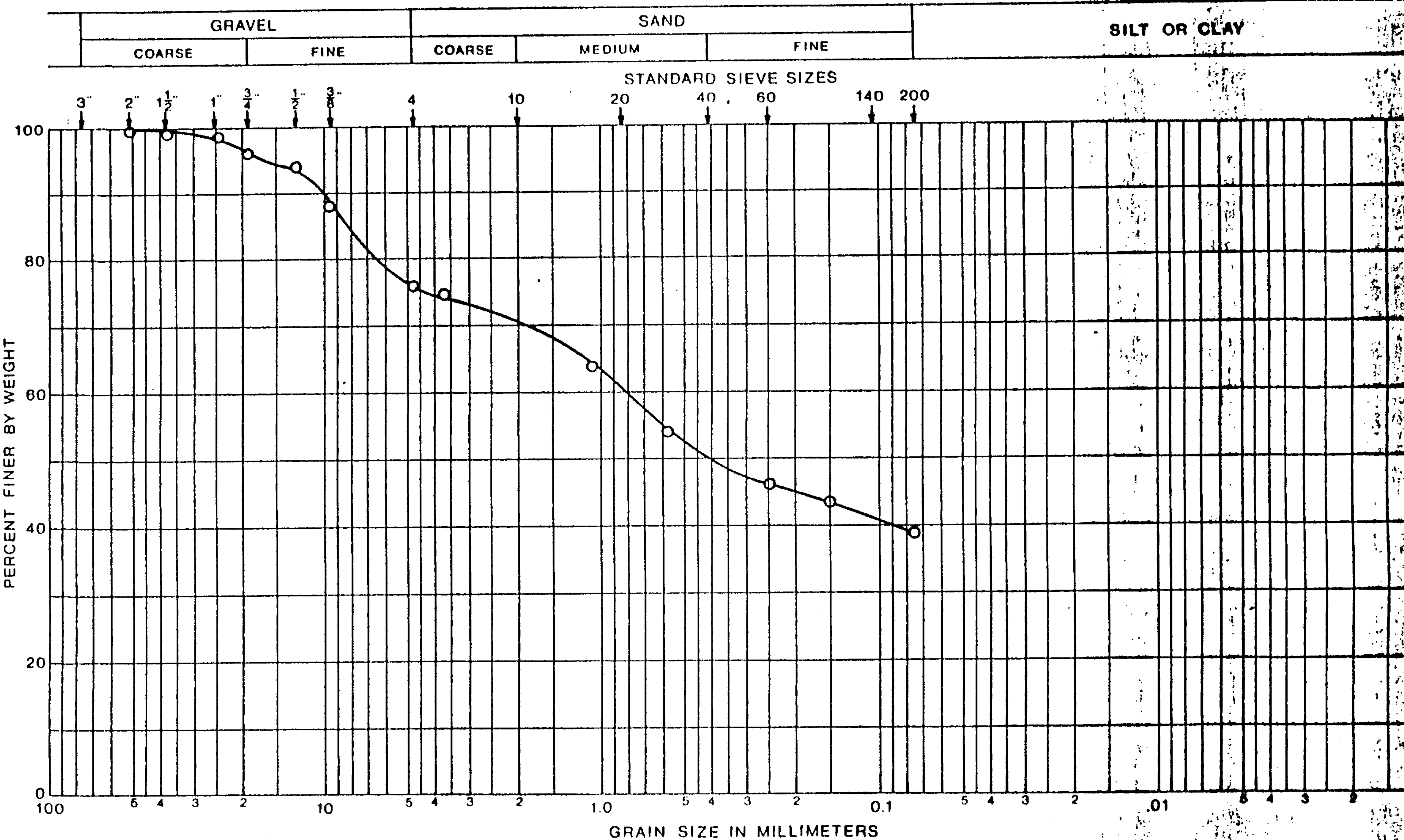
DEPTH: Surface

FIGURE NO. 12



ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

SLOPE STABILITY RESULTS	KAISER STEEL	MAN SHAFT	FIGURE NO. 13



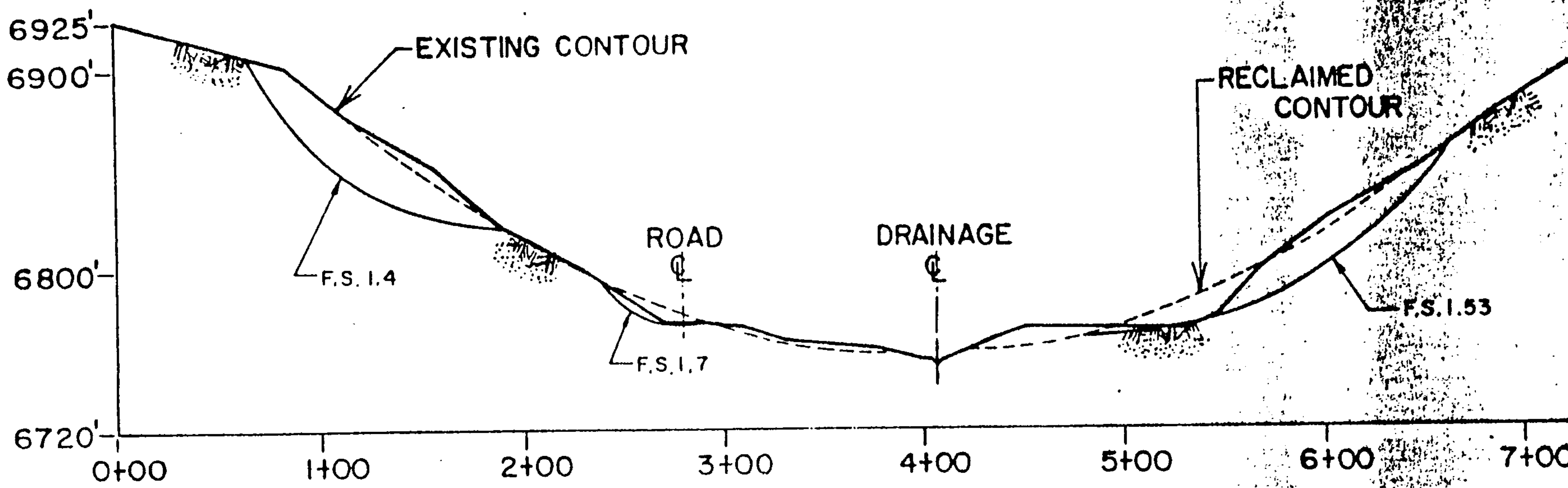
ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

GRAIN SIZE DISTRIBUTION CURVE

Project: Kaiser Steel
Location: No. 2 Mine Portal

DEPTH: Surface

FIGURE NO. 14



NO. 2 MINE PORTAL

STATION 0+00 TO STA. 2+00
SOIL PARAMETERS

Ø = 30° c = 150 p.s.f. 1.05 = F.S.
Ø = 30° c = 200 p.s.f. 1.11 = F.S.
Ø = 34° c = 200 p.s.f. 1.26 = F.S.
Ø = 32° c = 400 p.s.f. 1.41 = F.S.

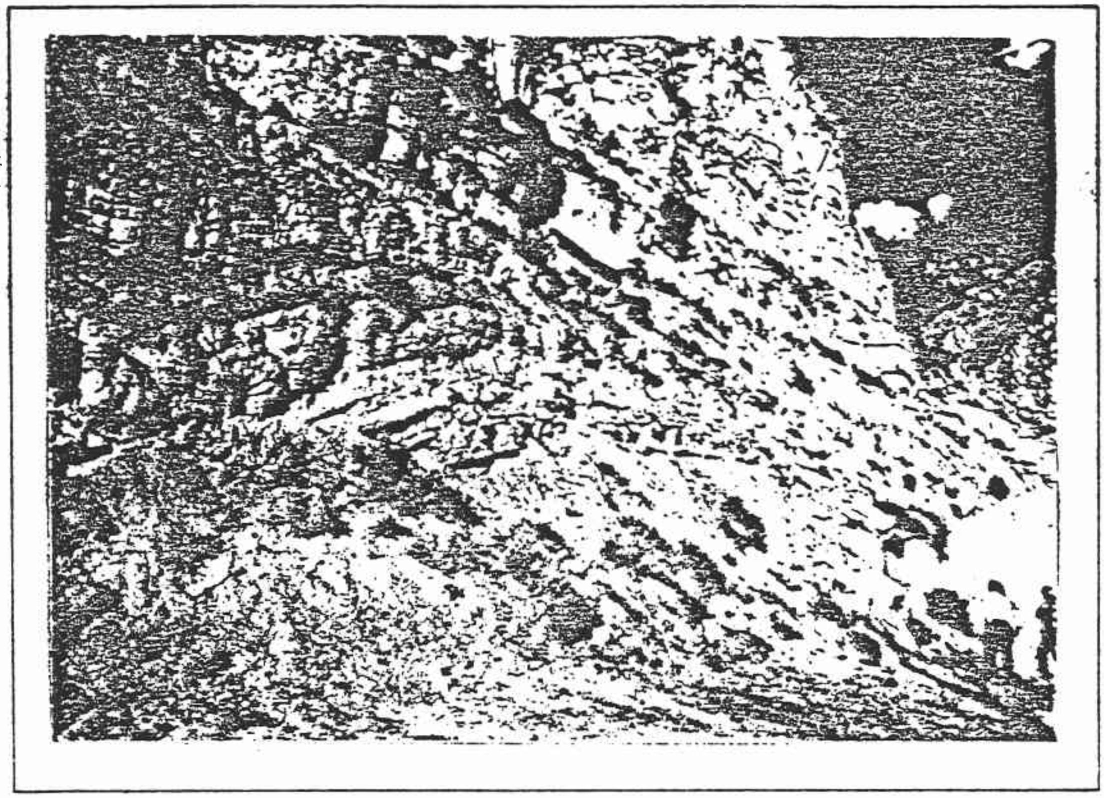
STA. 2+00 TO STA. 4+00
SOIL PARAMETERS

Ø = 30° c = 150 p.s.f. γ = 125 p.c.f.

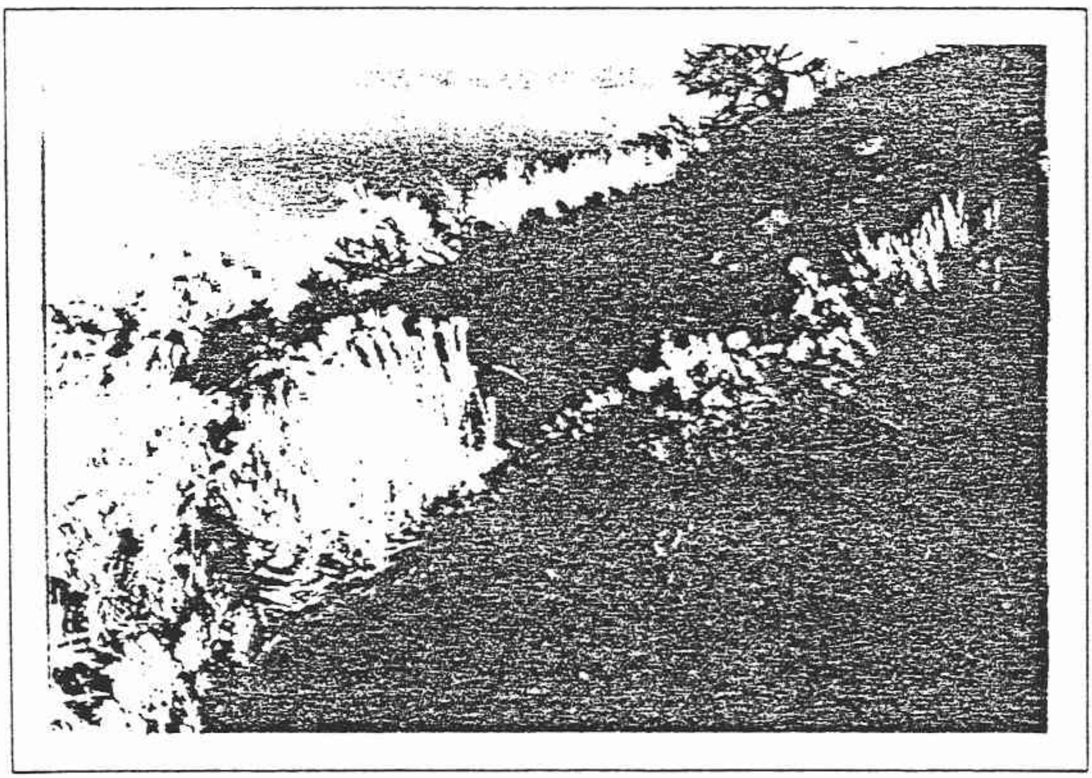
STA. 4+00 TO STA. 7+00
SOIL PARAMETERS

Ø = 30° c = 200 p.s.f. γ = 125 p.c.f.

ROLLINS, BROWN AND GUNNELL, INC. PROFESSIONAL ENGINEERS	SLOPE STABILITY RESULTS	KAISER STEEL	NO. 2 MINE PORTAL	FIGURE NO. 13

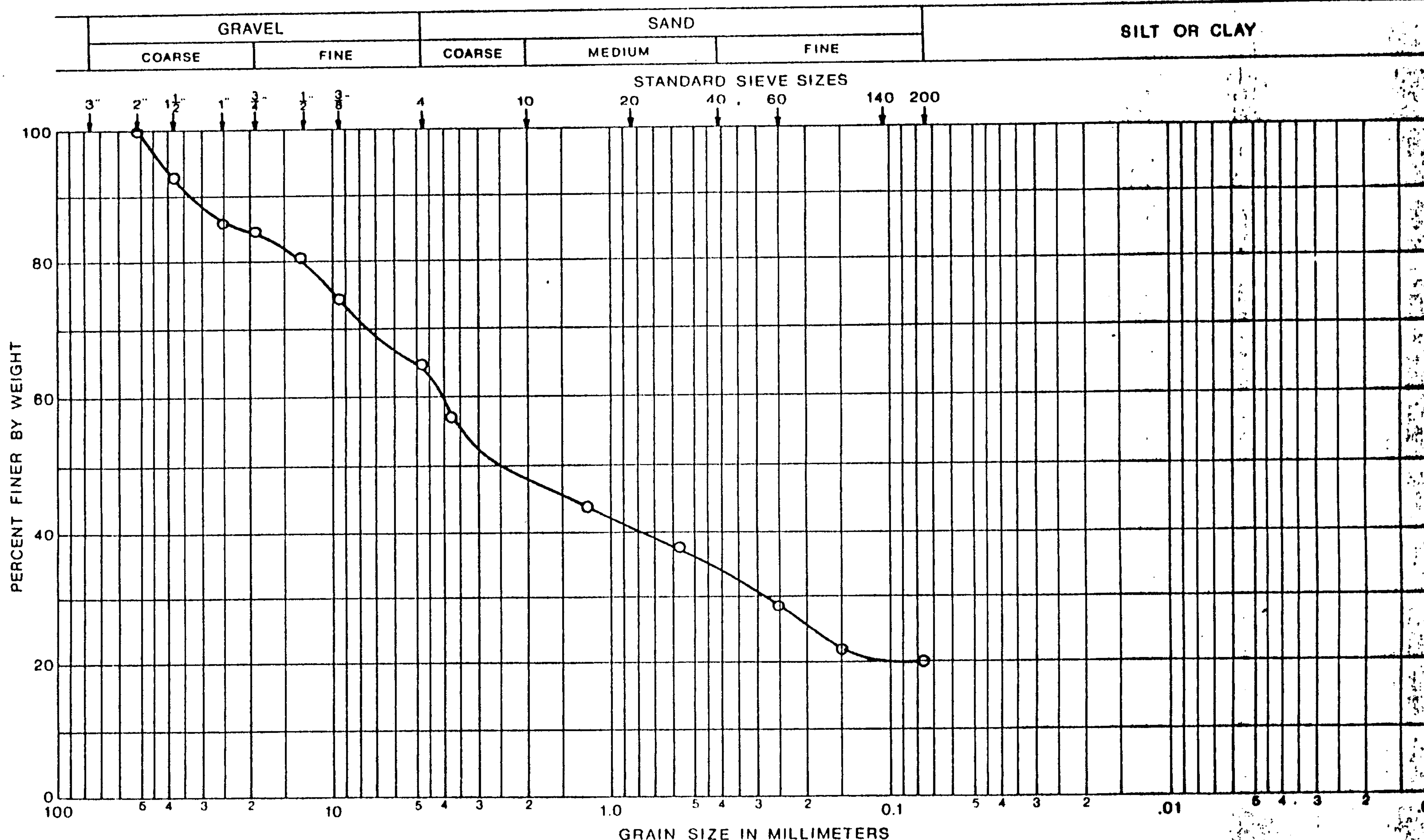


No. 2 Fan Canyon Site



Water Canyon Site

FIGURE NO. 16



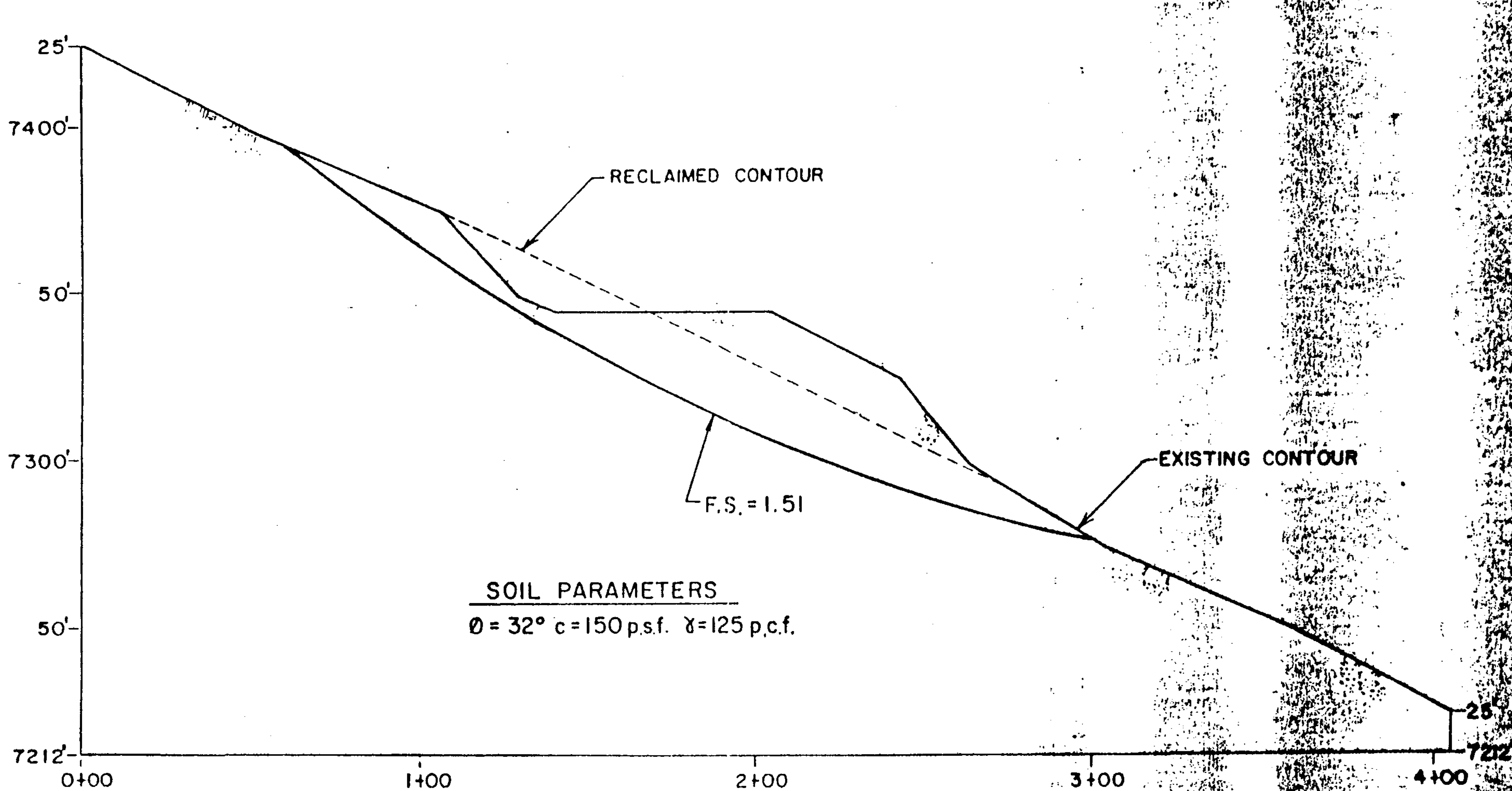
ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

GRAIN SIZE DISTRIBUTION CURVE

Project: Kaiser Steel
Location: Fan Canyon

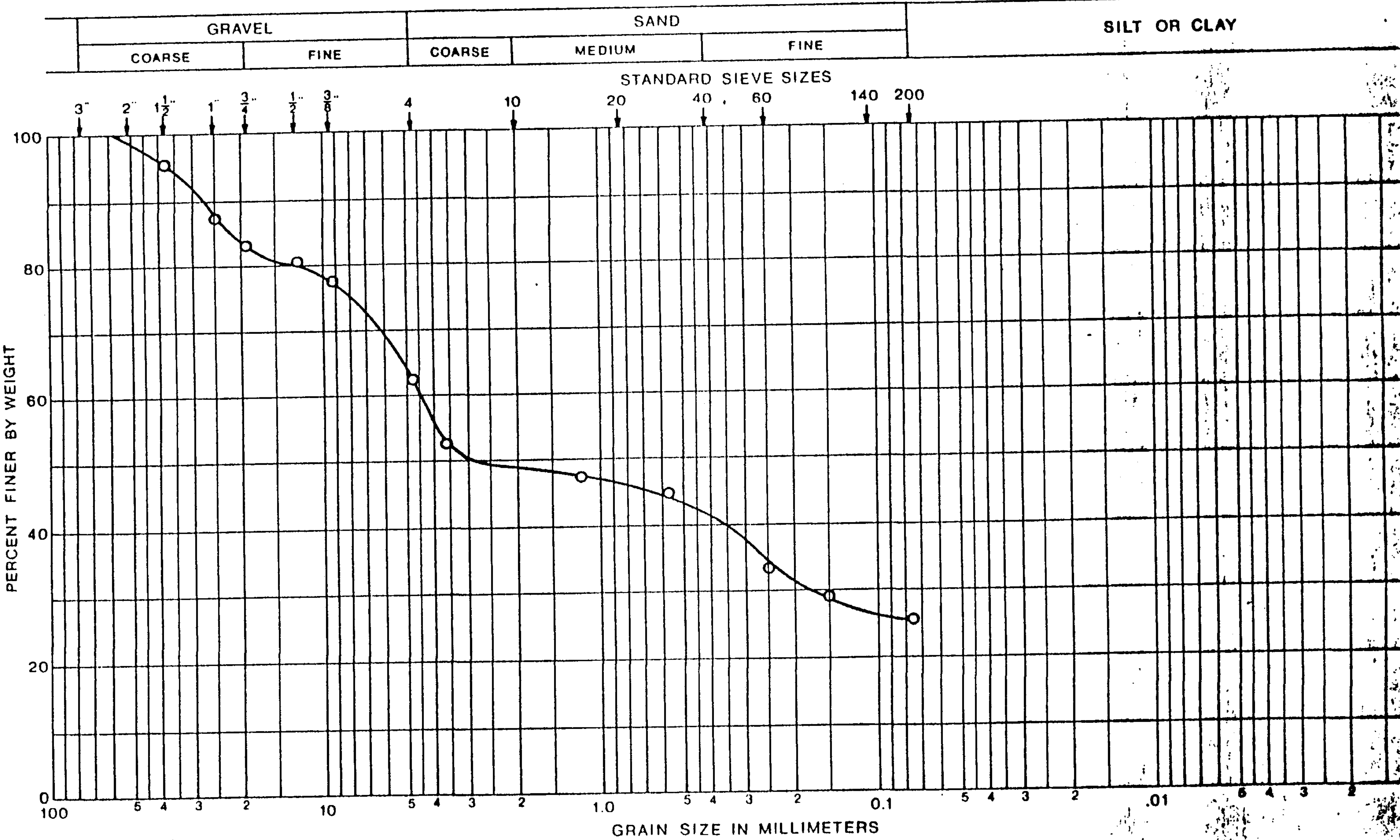
DEPTH: Surface

FIGURE NO. 17



NO. 2 CANYON FAN

ROLLINS, BROWN AND GUNNELL, INC. PROFESSIONAL ENGINEERS	SLOPE STABILITY RESULTS	KAISER STEEL	NO. 2 CANYON FAN	FIGURE NO. 18



ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

GRAIN SIZE DISTRIBUTION CURVE

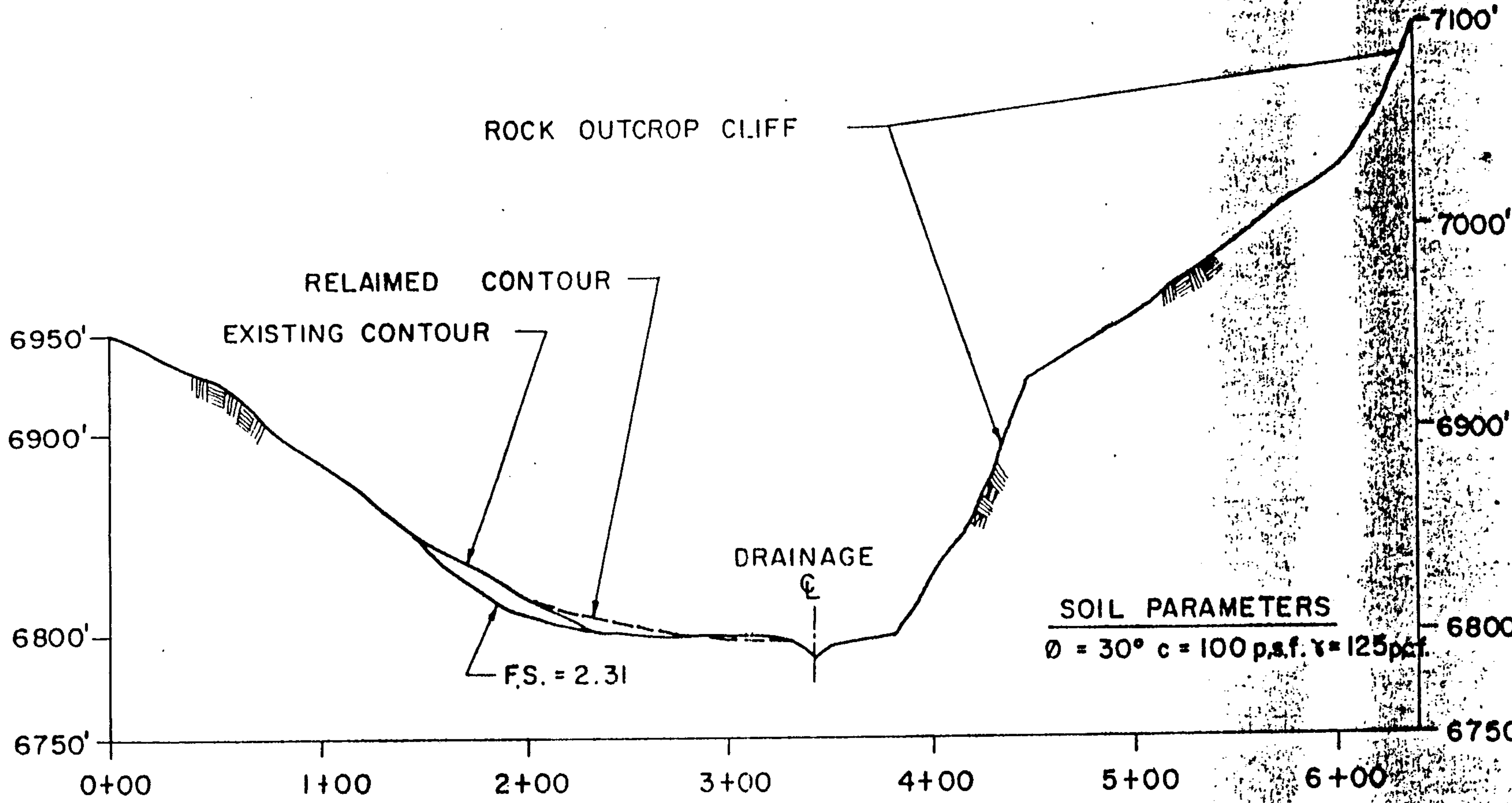
Project: Kaiser Steel

Location: Water Canyon

HOLE NO.

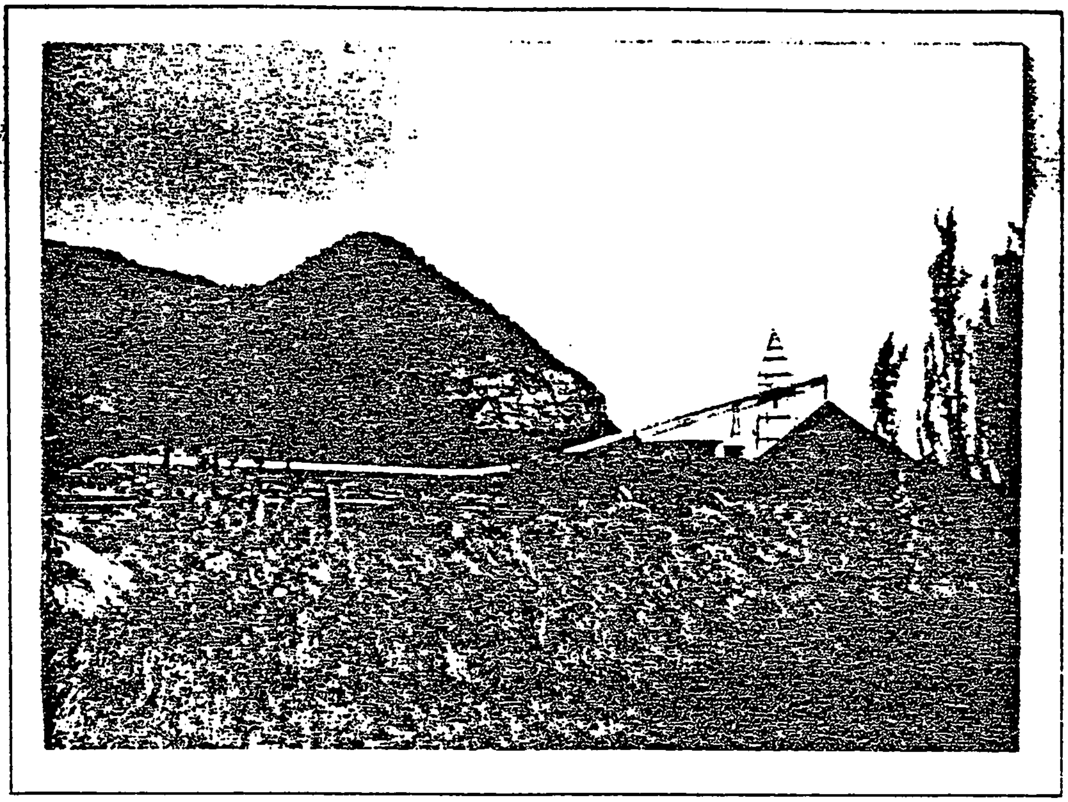
DEPTH:

FIGURE NO. 19



WATER CANYON PORTALS

ROLLINS, BROWN AND GUNNELL, INC. PROFESSIONAL ENGINEERS	SLOPE STABILITY RESULTS	KAISER STEEL	WATER CANYON PORTALS	FIGURE NO. 20



Loadout Area Site

(Stockpile)

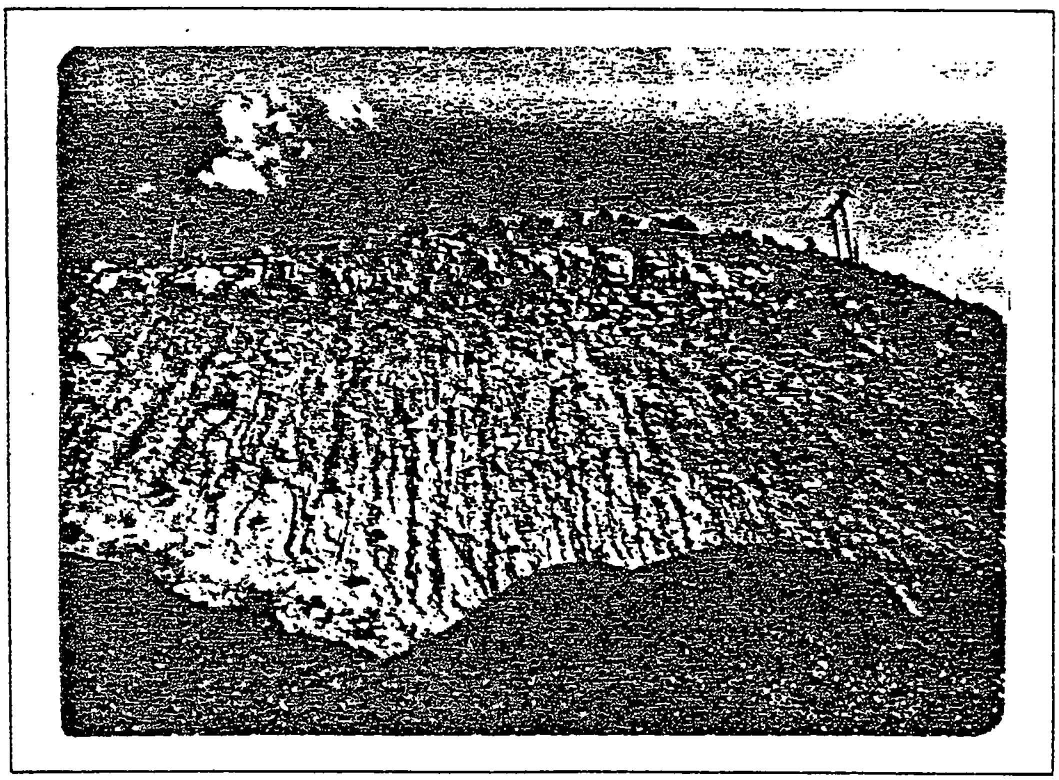
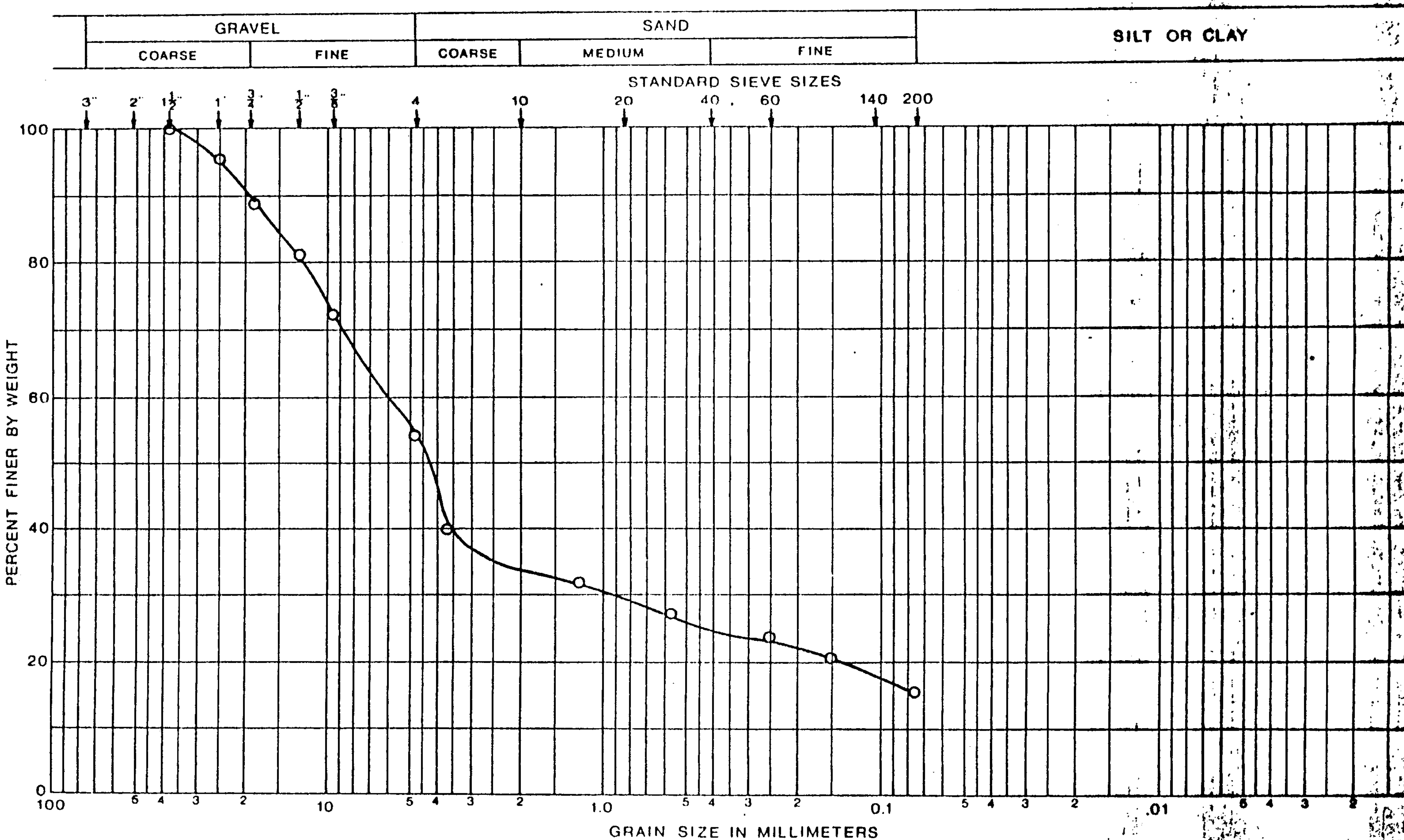


FIGURE NO. 21



ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

GRAIN SIZE DISTRIBUTION CURVE

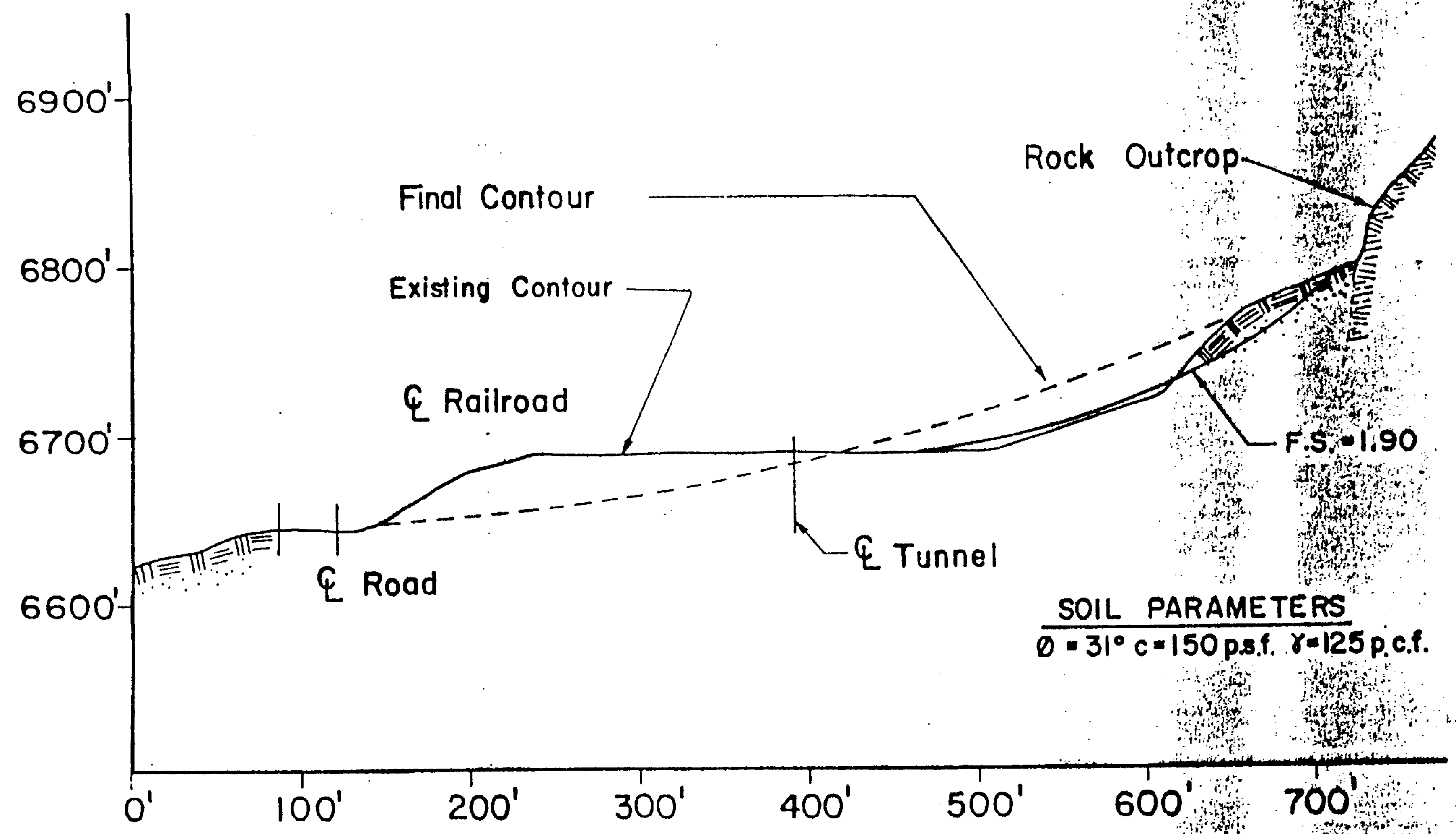
Project: Kaiser Steel

Location: Stockpile

HOLE NO.

DEPTH:

FIGURE NO. 22



ROLLINS, BROWN AND GUNNELL, INC. PROFESSIONAL ENGINEERS	SLOPE STABILITY RESULTS	KAISER STEEL	TRAIN LOADOUT	FIGURE NO. 23

Appendix 5-3

Appendix 5-3

Purpose and Design of Sunnyside Experimental Revegetation Plots on Coarse Refuse

When analyzing the results of the small experimental plots planted in 1980 it became apparent there may be problems establishing vegetation on coarse refuse (Vegetation Test Plot Study Report, 1982 Appendix 8.14.3 ACR). The coarse refuse pile and adjacent sites that have been disturbed by refuse at Sunnyside Mine occupy approximately 81 acres. Therefore the primary objective of the new experimental plots is to determine how the 81 acres of coarse refuse can be effectively revegetated. The plots will help determine if a covering of borrow material is necessary and at what depth. There is no stockpiled topsoil to cover the refuse area. The use of lime will also be tested to determine its effectiveness in countering the acidity problem found in old weathered refuse. Different plant species (Table 1) will be tested including: 10 grass species, four forb species, three shrubs and two trees.

To properly test and simulate the effects of refuse on plant growth a large pit (14' deep) was excavated and filled with refuse. This was done to simulate the coarse refuse pile where the refuse is deep and the plant roots will have to grow through several feet of refuse. The plot is about 1½ acres in size so that several treatments can be tested with sample sizes large enough to statistically analyze.

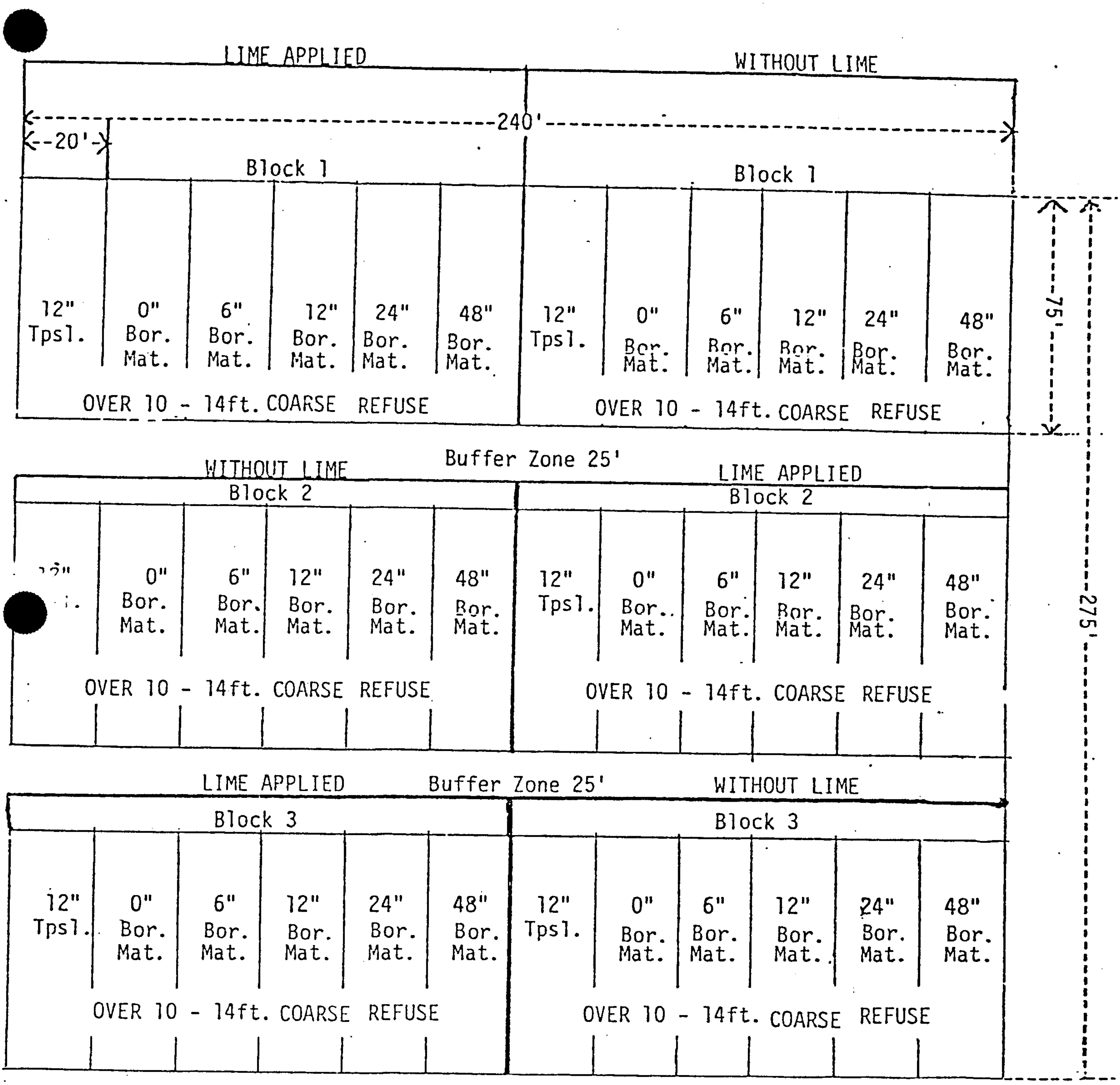
The experimental design (Figure 1) is a split plot design with three blocks serving as replications. Each block has two main plots and each main plot has six subplots. The main plots are limed vs nonlimed treatments and the subplots include topsoil covering refuse, pure refuse and four different depths of borrow material covering the refuse. The subplots were not randomly positioned between blocks because of equipment limitations. Within each block and across all subplots are three replications of the planting scheme as shown in Figure 2. In each planting replication there will be ten grass species and four forbs all seeded with one species per row and one foot row spacings. The three shrub species will be seeded with two foot row spacings. All species will be seeded at the rate that will provide fifty pure live seeds per square foot. The two tree species to be used will be planted as transplants in two rows using tubings (12"tall). There will be seven seedlings of each species per subplot and eighty-four seedlings in a block.

The list of species and varieties to be tested are listed in Table 1. These particuliar species were selected, with recommendations from Sam Stronathan of the SCS, on the basis of local adaptability and their potential to grow in acidic coarse refuse.

The sampling design currently planned will utilize the line intercept method, by placing a tape the length of the row and determining what percent of the tape in each subplot is intercepted by vegetation. Lone intercept will be used on every line, yielding three cover measurements for each species in each subplot. If this methodology becomes too time consuming, then maybe a series of short (3') randomly placed tapes will be utilized to estimate cover by species. A relative vigor estimate will also be recorded, giving the most vigorous subplots a value of five and the least a value of one. A value of zero will be used to indicate no plants present.

The density of living trees and shrubs will be determined by counting the number of plants along each line.

SUNNYSIDE EXPERIMENTAL REVEGETATION PLOTS



Exact amount of refuse under a plot can be determined by subtracting the depth of cover material from 14 ft.

Key

Bor. - Borrow material
Tpsl. - Topsoil

Figure 1.

Sunnyside Experimental Revegetation Test Plots; One of three blocks illustrating the replicated seeding layout that will be duplicated in the other two blocks.

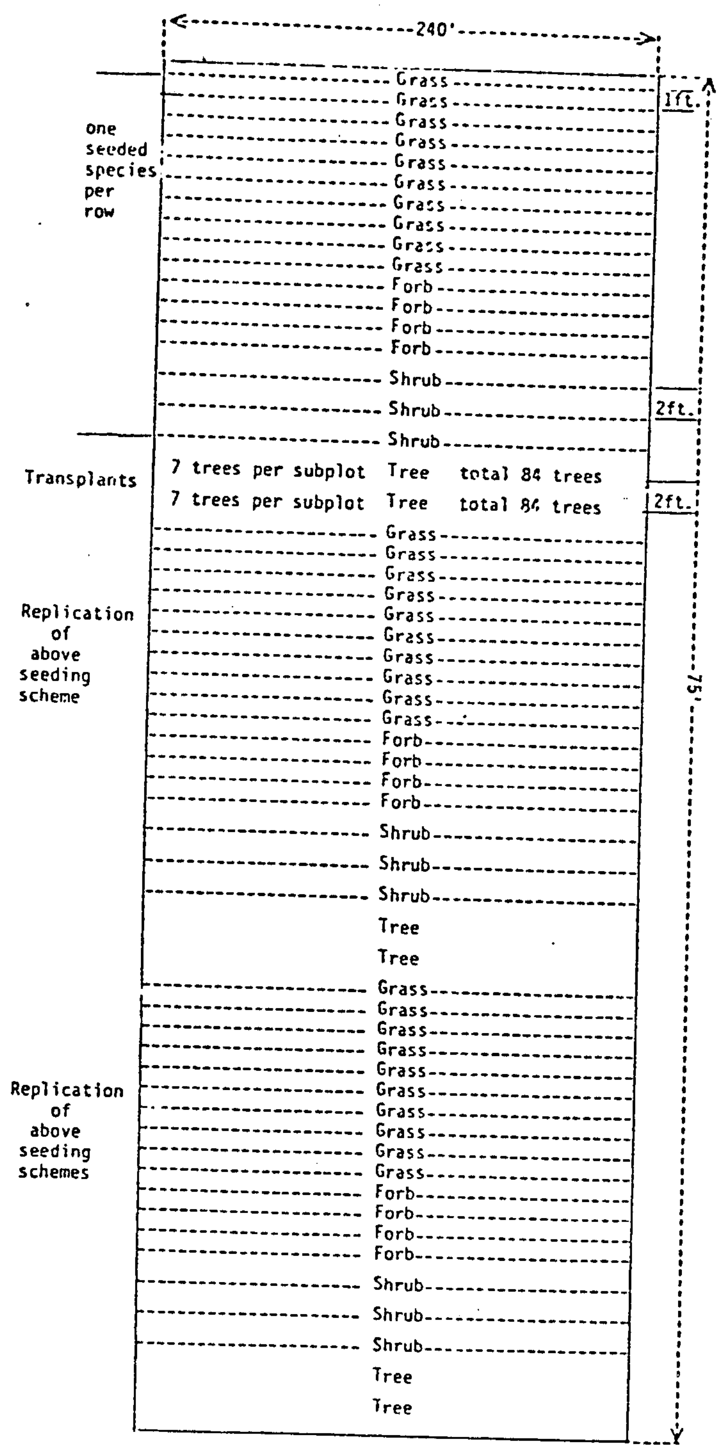


Figure 2.

Table 1. Sunnyside Experimental Revegetation Test Plots
The list of species to be tested in the plots.

Grasses	Variety	Common name
Agropyron smithii	'Arriba'	western wheatgrass
Agropyron spicatum		bluebunch wheatgrass
Bromus marginatus	'Bromar'	mountain brome
Elymus giganteus	'Volga'	mammoth wildrye
Elymus salina		salina wildrye
Festuca megalura		foxtail fescue
Oryzopsis hymenoides	'Nezpar'	Indian ricegrass
Poa pratensis		Kentucky bluegrass
Poa secunda		Sandberg bluegrass
Stipa comata		needleandthread grass
Forbs		
Balsamorhiza sagittata		arrowleaf sagittata
Artemisia ludoviciana		Louisiana sagewort
Hedysarum boreale		Utah sweetvetch
Oenothera hookeri		Hooker eveningprimrose
Shrubs		
Artemisia nova		black sagebrush
Atriplex canescens		fourwing saltbush
Purshia tridentata		Antelope bitterbrush
Trees		
Juniperus osteosperma		Utah juniper
Pinus edulis		pinyon pine

STATE OF UTAH
NATURAL RESOURCES
Oil, Gas & Mining

Scott M. Matheson, Governor
Temple A. Reynolds, Executive Director
Dr. G. A. (Jim) Shirazi, Division Director

State Office Building • Salt Lake City, UT 84114 • 801-533-5771

August 2, 1983

Ms. Marcia H. Wolfe
Reclamation Engineer/Ecologist
Kaiser Steel Corporation
Raton Coal Properties
Raton, New Mexico 87740

RE: Sunnyside Mine Revegetation
Test Plots
Sunnyside Mine
ACT/007/007, Folder #2
Carbon County, Utah

Dear Marcia:

The plans for revegetation test plots at the Sunnyside Mine, outlined in your letter of July 28, 1983, have been reviewed by the Division and found to be adequate.

The following comments are given as suggestions which may help insure the success and reliability of the plots.

1. All seed to be used should be obtained from a source as close to the Sunnyside Mine as possible or from an area which is environmentally similar.

2. A monitoring program which includes qualitative and quantitative assessment of the test plots should be implemented (see enclosed guidelines).

Ms. Marcia H. Wolfe
Reclamation Engineer/Ecologist
ACT/007/007, Folder #2
August 2, 1983
Page Two

3. Species should be planted in rows which run horizontally across treatments instead of vertically as proposed. This would help eliminate "edge of treatment" effects. If rows are to be seeded vertically, buffer zones should be maintained between treatments and species should be planted in rows which have been randomly selected within each treatment.

If we can be of further assistance to you, please feel free to call.

Sincerely,

Steve Cox

STEVE COX
RECLAMATION BIOLOGIST

SC:gl

cc: Lou Hamm, OSM
Ev Hooper, DOGM
Doug Pearce, Kaiser