SLOPE STABILITY ANALYSIS

MINE ACCESS ROAD IN CRANDALL CANYON
CASTLEGATE, UTAH

OCTOBER 1981

ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

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TELEPHONE 374-5771

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PROFESSIONAL ENGINEERS

October 8, 1981

Horrocks Engineers
1 West Main
American Fork, UT 84003

Gentlemen:

In accordance with your request, a slope stability analysis has been performed for a mine access road in Crandall Canyon located southwest of Castlegate, Utah. The purpose of the investigation was to obtain an indication of the stability of existing slopes and the slopes contemplated for modifications to the highway.

The work has been completed in accordance with a verbal proposal submitted to our organization, and the results of the investigation are outlined in the following sections of this report. The information contained in the report is discussed under the following headings. (1) General Site Conditions and Investigated Approach, (2) The Results of Field and Laboratory Tests, (3) A Slope Stability Analysis, and (4) Conclusions and Recommendations.

1. General Site Conditions and Investigated Approach

The proposed access road begins in the vicinity of the Price River Coal Company Mine and extends for a distance of 6700 feet down the canyon. An existing road is located in the canyon and it is anticipated that this road will be widened and modified during the new construction program. Typical roadway cross sections along the proposed alignment is presented in Figure No. 1. The subsurface materials along the proposed alignment generally consist of large rock fragments with a matrix of sandy silt.

The existing roadway was constructed by dumping the excavated material along the roadway over the slope and permitting it to reach equilibrium with the surrounding conditions. Insofar as we can determine no major slope stability problems have occurred along the existing alignment, and repairs to the road have consisted of removal of relatively small amounts of material which have sluffed downward from the adjacent slopes. Since constructing drilling locations uphill and downhill from the roadway would be

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relatively difficult and could only be performed at a substantial cost, and since the cut into the hillside where the roadway is located generally defines the character of the material throughout the soil profile in this area, field investigations have been limited to determining the in-place density of the subsurface materials along the natural slopes and along the cut and fill slopes performed during the construction of the original facility.

It is our opinion that the in-place density of the subsurface materials at a depth of approximately 1 to 2 feet below the existing ground surface will be the lowest in-place unit weight of any material within the soil profile along the slope. Since the natural material contains a considerable amount of rock fragments, it is not possible to obtain satisfactory undisturbed samples in the subsurface material. It is our opinion, however, that the shearing strength of the subsurface soils will likely be determined by the fine grain fraction which exists within the overburden materials throughout the profile.

It is believed that a reasonable estimate of the in-place shearing strength can be obtained by performing triaxial shear tests on samples of the fine grain material compacted to its in-place unit weight and natural moisture content. The shearing strengths obtained by this approach have been utilized in stability calculations to provide an indication of the factor of safety for the existing and contemplated slopes.

2. The Results of Field and Laboratory Tests

Field and laboratory tests performed during this investigation to determine the physical characteristics of the subsurface material in the area have included in-place unit weight, natural moisture content, Atterberg limits, mechanical analysis, and triaxial shear tests. The summary of all test data performed during the investigation with the exception of the triaxial shear tests are presented in Table No. 1, Summary of Test Data.

It will be noted from this table that the in-place unit weight varies from about 82.4 pounds per cubic foot to 105.0 pounds per cubic foot and that the natural moisture content varies from 8.4 to 16.6 percent. The results of mechanical analysis performed on relatively large samples obtained in the field indicate that the amount of material passing at 200 sieve will likely range from 35 to 37 percent. The results of the Atterburg limits performed on representative samples of the subsurface material indicate that the fine grain fraction of the overburden materials have low plasticity characteristics.

Three triaxial shear tests were performed on representative samples of the sand and silt fraction compacted at the natural moisture content to an in-place unit weight of about 100 pounds per cubic foot. The results of these tests are presented in the form of a Mohr Envelope in Figure No. 2 and it will be observed that a cohesion of 6 pounds per square inch and a friction angle of 31 degrees was obtained.

Three triaxial shear tests were also performed on representative samples of the silt and sand fraction compacted at the initial moisture content to a density of 82.5 pounds per cubic foot. The results of these three tests are also presented in the form of Mohr Envelope in Figure No. 3. It will be noted that a cohesion of 5 pounds per square inch and a friction angle of 30 degrees was obtained for this sample.

It should be noted that materials for the two triaxial tests were obtained at Station 59+30. The results of these tests were used in a stability analyisis to obtain an indication of the slope stability of the materials throughout this general area.

3. Slope Stability Analysis

A computer slope stability analysis has been performed for slopes along the proposed alignment using a computer program based upon Spencers method and developed by Steven Wright at the University of Texas. Spencers method satisfies both force and moment equilibrium and is considered to be an exact slope stability method. The method is based upon two dimensional considerations and is only as accurate as the shear strength parameters used in the analysis.

The stability analysis was performed for cross sections located at Station 10+50 and at Station 58+00. The cross sections at these two stations generally represent the steepest overall cross sections along the existing alignment. The cross sections for each of these stations are presented in Figures 4 and 5. The slopes along the various segments of the cross sections are presented in these figures. The shear strength parameters obtained from the triaxial tests were used in the stability analysis along with representative unit weights obtained from the in-place density tests. The factor of safety was determined for the overall slope conditions shown for the two cross sections shown in Figures 4 and 5. A localized slope stability analysis was performed for the slopes between points A and B in Figure No. 5. The results of the slope stability analysis are presented in Table No. 2 below. It will be observed that a factor of safety of 1.6 was obtained for the slope at Station 10+00 for a cohesion value of 200 psi and a friction angle of 30 degrees. A factor

of safety of 1.5 was obtained for the overall slope at Station 58+00 assuming a cohesion of 400 psi and a friction angle of 30 degrees. The analysis performed for the left hand side of the cross section at Station 58+00 indicated a factor of safety of 1.5 for a cohesion of 200 psi and a friction angle of 30 degrees.

TABLE 2
STABILITY ANALYSIS RESULTS

Friction Angle	Cohesion (psf)	Factor of Safety
Station 10+00		
30°	100	1.4
30°	200	1.6
Station 58+00 (Entire Slope)		
30°	100	1.0
30°	200	1.2
31°	200	1.2
30°	400	1.5
30°	500	1.7
Station 58+00 (Left Side of Slope)		
30°	100	1.0
30°	200	1.5
30°	400	2.0

It should be recognized that the slope stability analysis performed above were based upon shear strength parameters determined for materials at their natural moisture content. It has also been assumed that no pore pressures exist within the soil profile at this location.

Based upon the analysis performed above, it is our opinion that slopes characteristic of the profile defined by Figures 4 and 5 will be stable under ordinary conditions. If the environmental conditions throughout the area are such that the slopes become saturated, a decrease in the shearing strength will occur and some pore pressures may develop throughout the profile. Under these conditions, slumping of the steeper slopes will likely occur. It is not anticipated, however, that any massive land movement will occur in this area.

4. Conclusions and Recommendations

Based upon the investigation indicated above, it is our opinion that the following conclusions are warranted:

A. The subsurface materials along the proposed alignment consist of angular fragments with a matrix of silty sands and sandy silts. The entire soil mass constituting the overburden will most likely perform like a granular-type soil.

B. The in-place unit weight of the overburden materials throughout the site will likely vary from about 82.4 pounds per cubic foot to 105 pounds per cubic foot.

C. The shear strength characteristics of the - No. 10 material is a reasonable estimate of the entire soil mass along the alignment and that a cohesion of 5 pounds per square inch and a friction angle of 30 degrees is a reasonable estimate of the strength of these materials in their insitu condition.

D. Slopes characteristic of those shown in Figures 4 and 5 have factors of safety of 1.5 or greater for cohesive values varying from 200 to 400 psi and a friction angle of 30 degrees. The actual cohesion determined in the triaxial shear tests is generally greater than that required for stability.

E. If the subsurface material becomes saturated throughout the life of the facility, the cohesion of the subsurface materials are likely to decrease and slope failures on the steeper slopes will likely occur. Massive slope stability failures do not appear likely in this general area.

Based upon the results of this investigation, the following recommendations are made:

A. Since the strength characteristics of the subsurface materials are sensitive to moisture conditions, every effort should be made in the modification of the proposed facility to prevent surface waters from infiltrating into the subsurface material. A positive drainage system including subsurface pipe drains and cross drains where required should be incorporated into the design of the proposed facility. Cross drains should terminate well below a point where the discharge water could infiltrate into the subsurface materials.

B. Where possible, the roadway materials dumped over the edge of the slope should be densified to increase the shearing strength of these materials. The subgrade in cut areas should also be densified where possible to reduce the liklihood of penetration of moisture into the subsurface materials beneath the roadway.

If there are any questions concerning the information contained herein, please contact our office.

Yours truly,

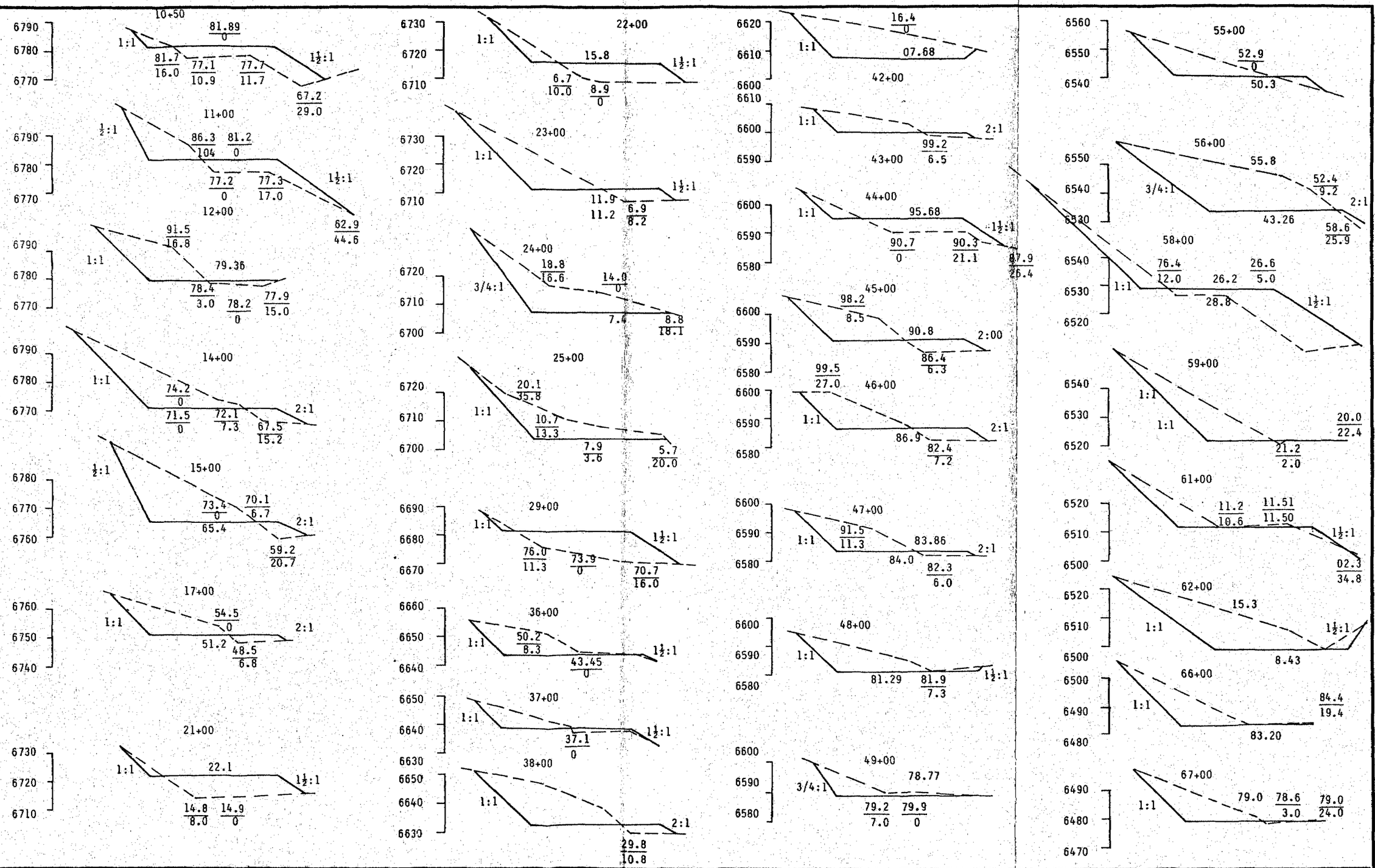
ROLLINS, BROWN AND GUNNELL, INC.

Ralph L. Rollins

Ralph L. Rollins

dlh

REGISTERED PROFESSIONAL ENGINEER
RLR
RALPH L. ROLLINS
2306
State of Utah



SCALE DESIGNED CHECKED DRAWN DATE APPROVED LICENSE NO.	**ROLLINS, BROWN & GUNNELL, Inc.** **CONSULTING ENGINEERS**	TYPICAL CROSS SECTIONS FOR ROADWAYS ALONG PROPOSED ALIGNMENT Price River Coal Company Slope Stability Analysis

Figure No. 1

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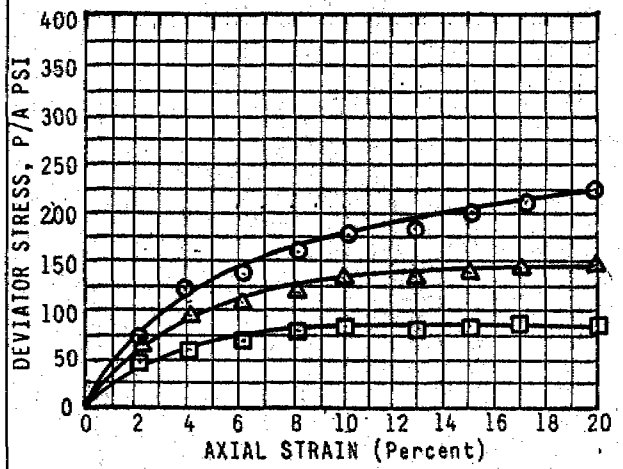
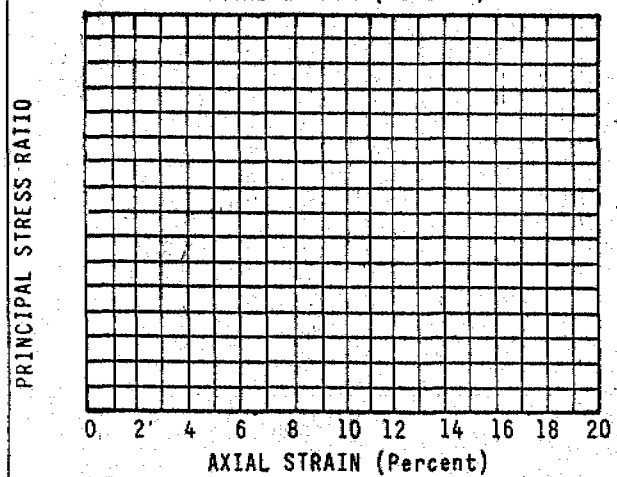
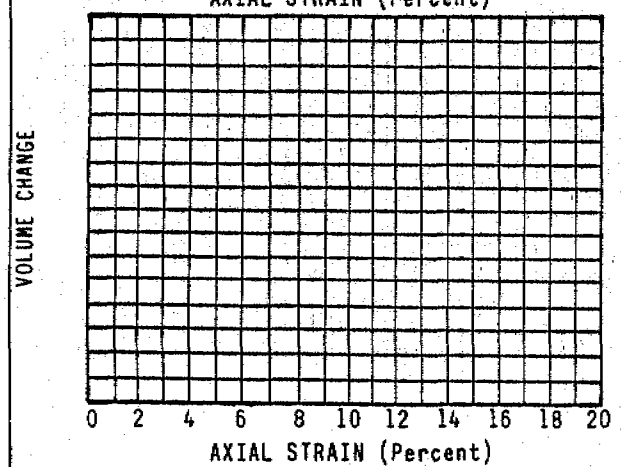
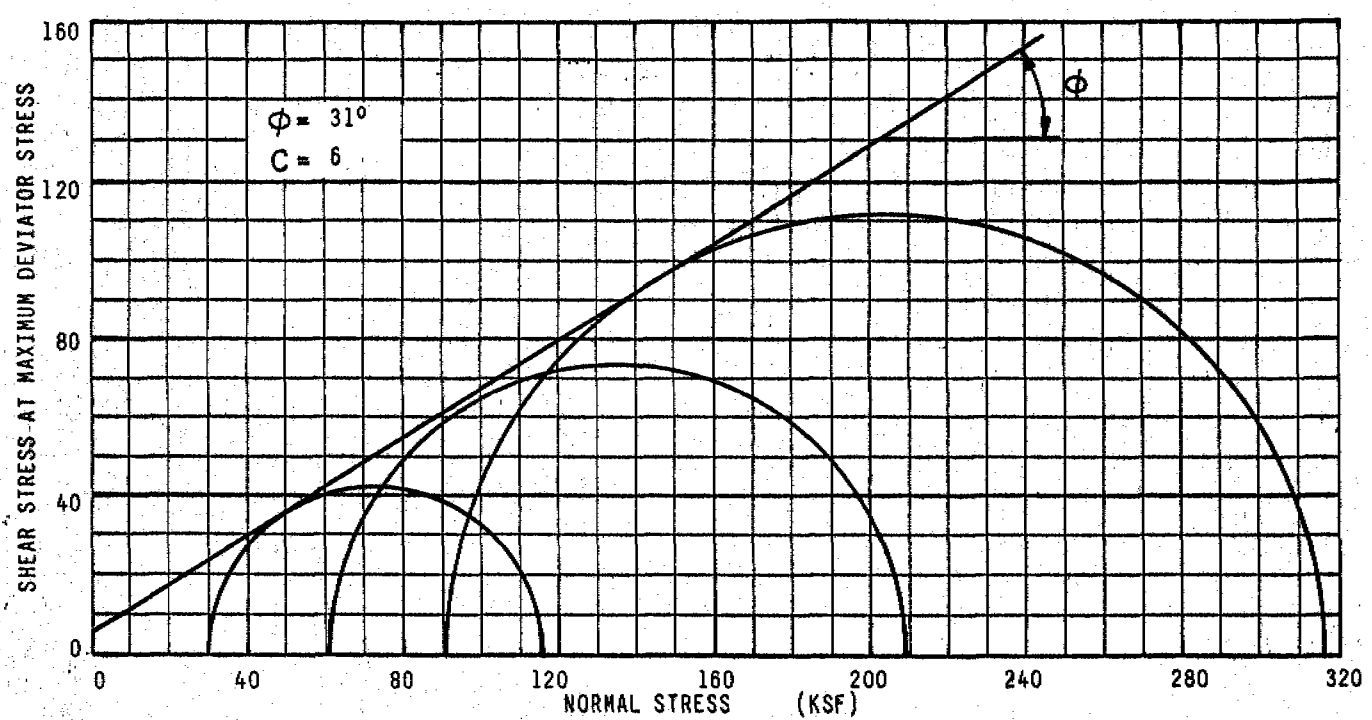






TRIAXIAL SHEAR TEST

SAMPLE NO.



TEST NO. OR SYMBOL	BORING NO. OR DEPTH	SAMPLE DATA			DEGREE OF SATURATION (%)	CONFINING PRESSURE IN PSI	MAXIMUM DEVIATOR STRESS	MAXIMUM PRINCIPAL STRESS RATIO	VALUES AT MOHR COULOMB FAIL.		SAMPLE SIZE LENGTH/DIA. INCHES	STRAIN RATE INCHES/MIN.
		DRY DENSITY (pcf)	MOISTURE % Ini.	MOISTURE % Final								
⊡	59+30	100.1	9.8		0	30						
△	3'up	100.2	9.8		0	60						
⊙	slope	100.2	9.8		0	90						

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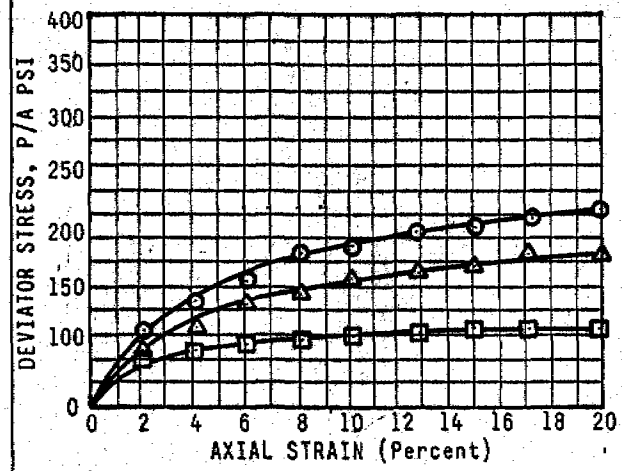
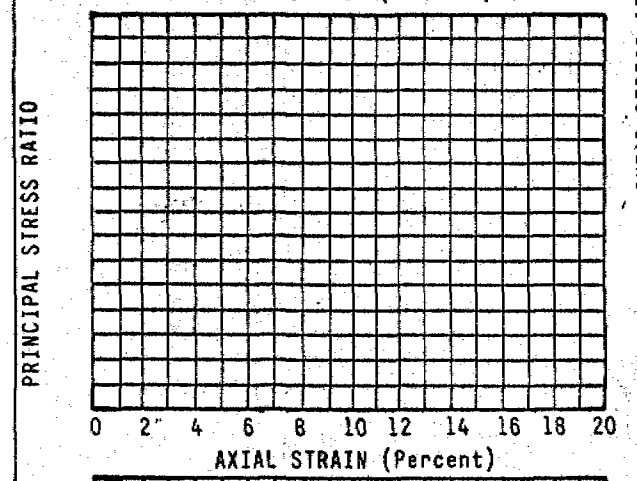
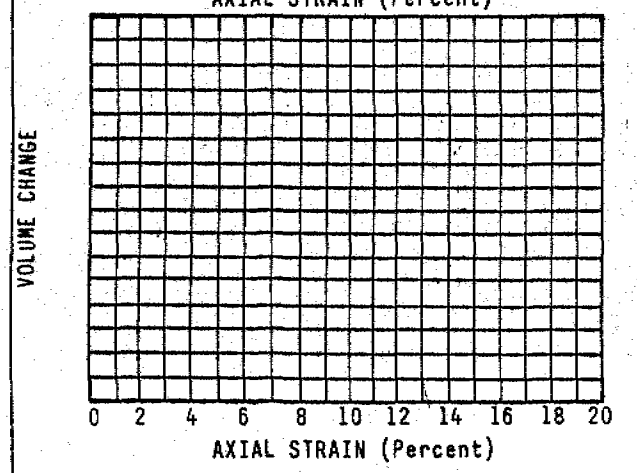
TRIAXIAL SHEAR TEST RESULTS

PRICE RIVER COAL

JOB NO.	DATE	FIGURE No. 2







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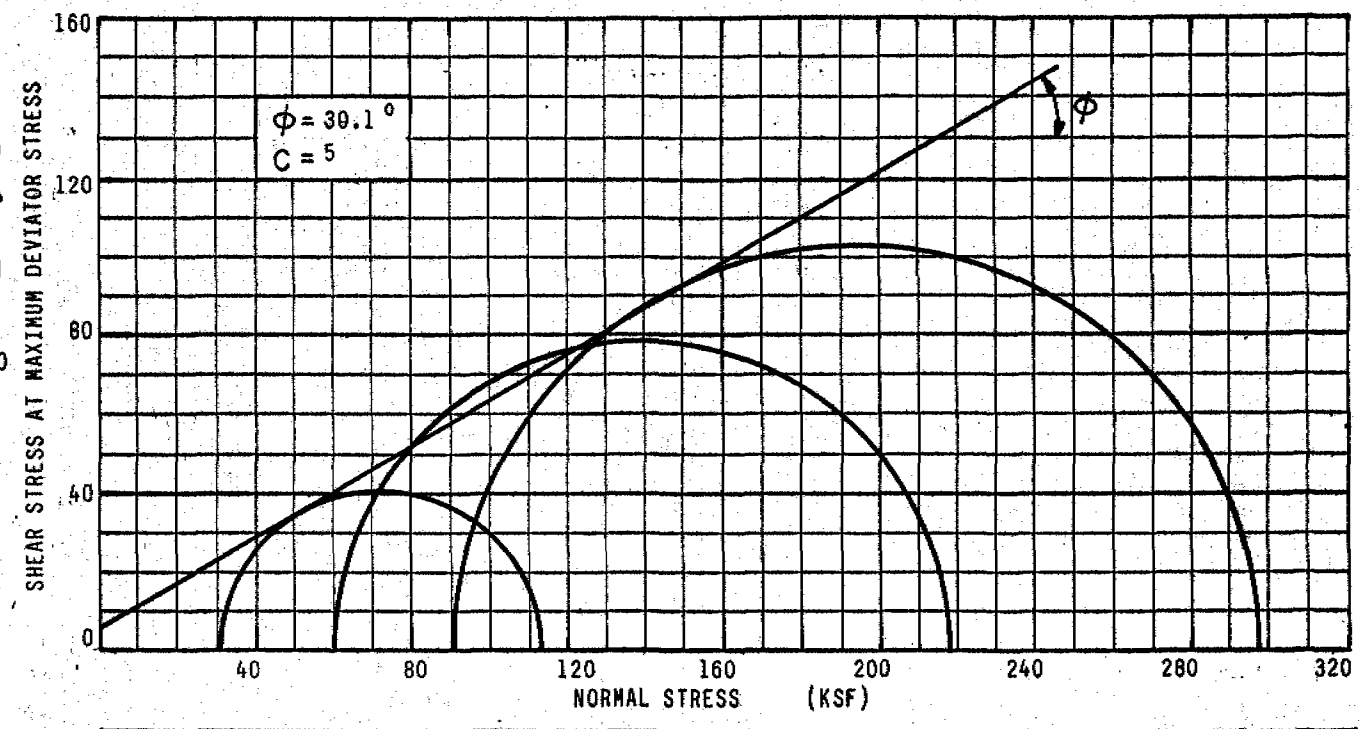

TEST NO. OR SYMBOL	BORING NO. OR DEPTH	SAMPLE DATA			DEGREE OF SATURATION (%)	CONFINING PRESSURE IN PSI	MAXIMUM DEVIATOR STRESS	MAXIMUM PRINCIPAL STRESS RATIO	VALUES AT MOHR COULOMB FAIL.		SAMPLE SIZE LENGTH/DIA. INCHES	STRAIN RATE INCHES/MIN.
		DRY DENSITY (pcf)	MOISTURE % Ini.	MOISTURE % Final								
▫	59+30	82.4	11.7			30						
△	12'up	82.5	11.7			60						
○	slope	82.5	11.7			90						

ROLLINS, BROWN AND GUNNELL, INC.
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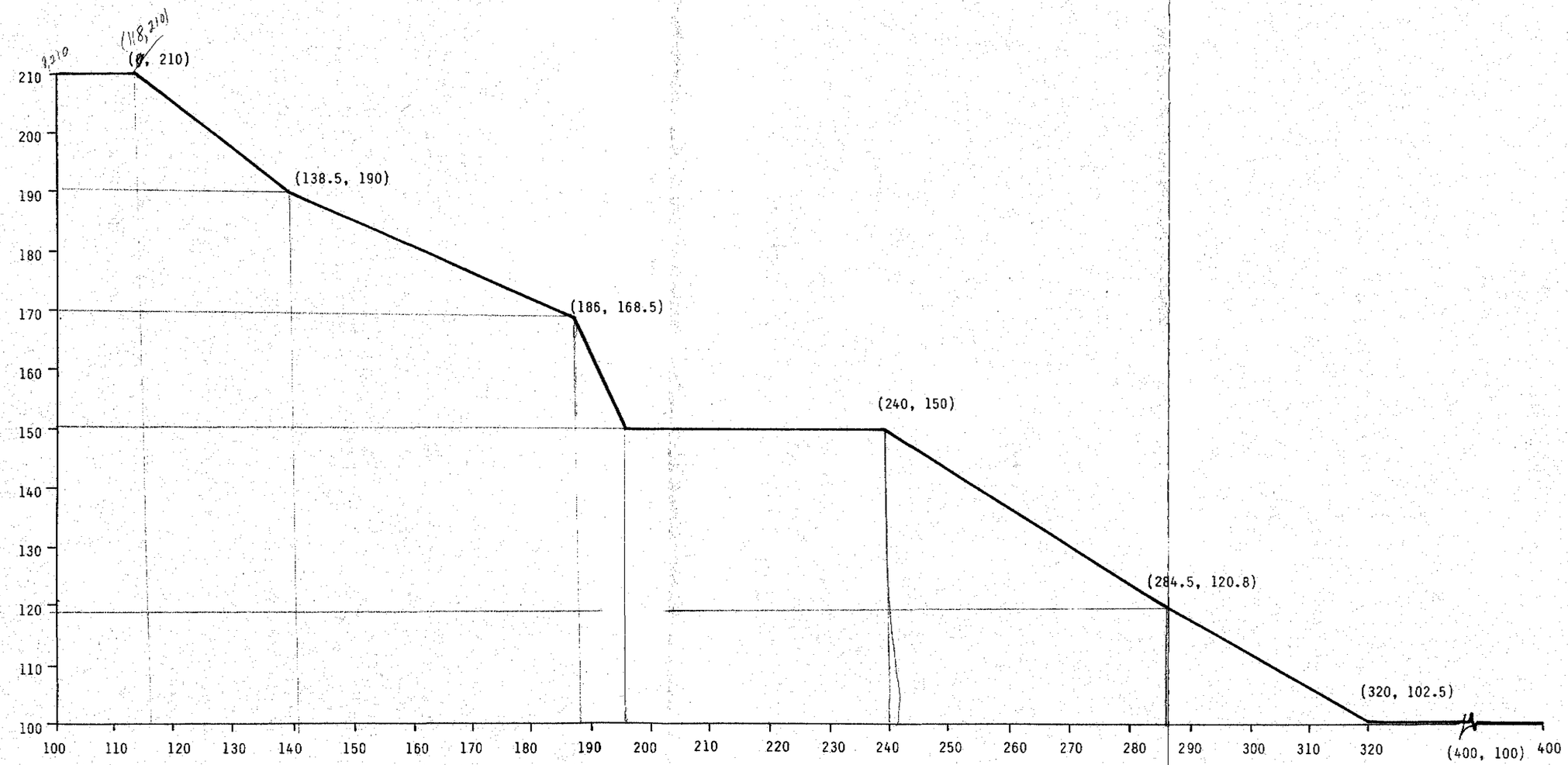
TRIAXIAL SHEAR TEST RESULTS

PRICE RIVER COAL

JOB NO.	DATE	FIGURE No. 3



STA. 10 + 00

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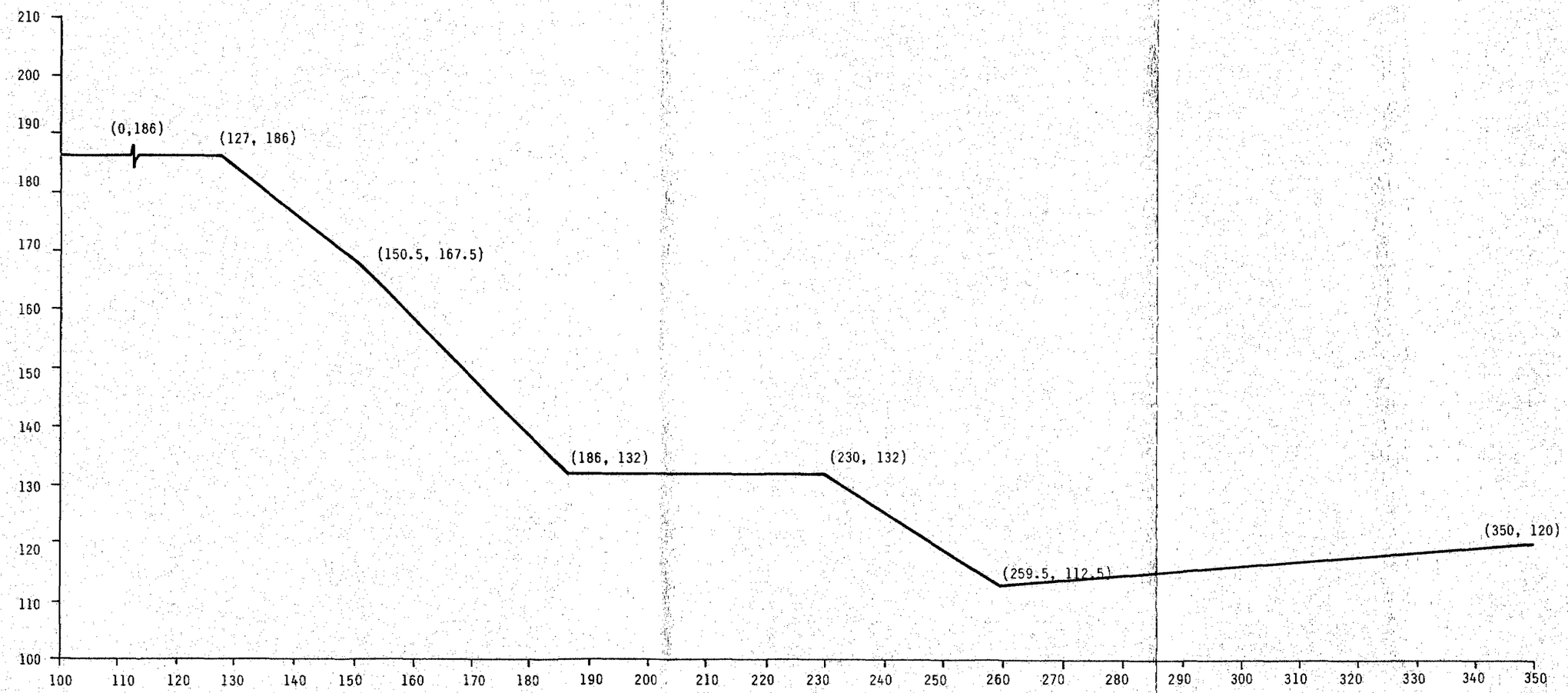

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SCALE DESIGNED CHECKED DRAWN DATE APPROVED LICENSE NO.	**ROLLINS, BROWN & GUNNELL, Inc.** **CONSULTING ENGINEERS**	Soil Profile Sta. 58+00 Price River Coal Company Slope Stability Analysis	Figure No. 5

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TABLE NO. 1 SUMMARY OF TEST DATA

PROJECT Price River Coal Company FEATURE Slopes LOCATION Castledale, Utah

HOLE NO.	STATIONS	LOCATIONS	IN-PLACE			UNCONFINED COMPRESSIVE STRENGTH LB/FT^2	FRICTION ANGLE ϕ	CONSISTENCY LIMITS			MECHANICAL ANALYSIS			UNIFIED SOIL CLASSIFICATION SYSTEM
			UNIT WEIGHT LB/FT^3	MOISTURE PERCENT	VOID RATIO			L.L. %	P.L. %	P.I. %	% GRAVEL	% SAND	% SILT & CLAY	
	10+50	3' upslope	100-1	9.1										
		6' upslope	104.2	8.4										
		9' upslope	106.0	8.5										
		12' upslope	102.8	8.9										
	44+45	3' upslope	93.8	9.1				24.9	19.1	5.8				CL-ML
		6' upslope	97.6	9.8				23.3	16.7	6.6				CL-ML
	58+00	3' upslope	86.4	16.6										
		6' upslope	105.0	8.6										
		9' upslope	101.9	8.9										
		12' upslope	99.5	10.0										
		15' upslope	97.5	10.8										
		3' down-slope	100.2	9.8										
		6' down-slope	102.0	8.9										
		9' down-slope	104.7	10.3										

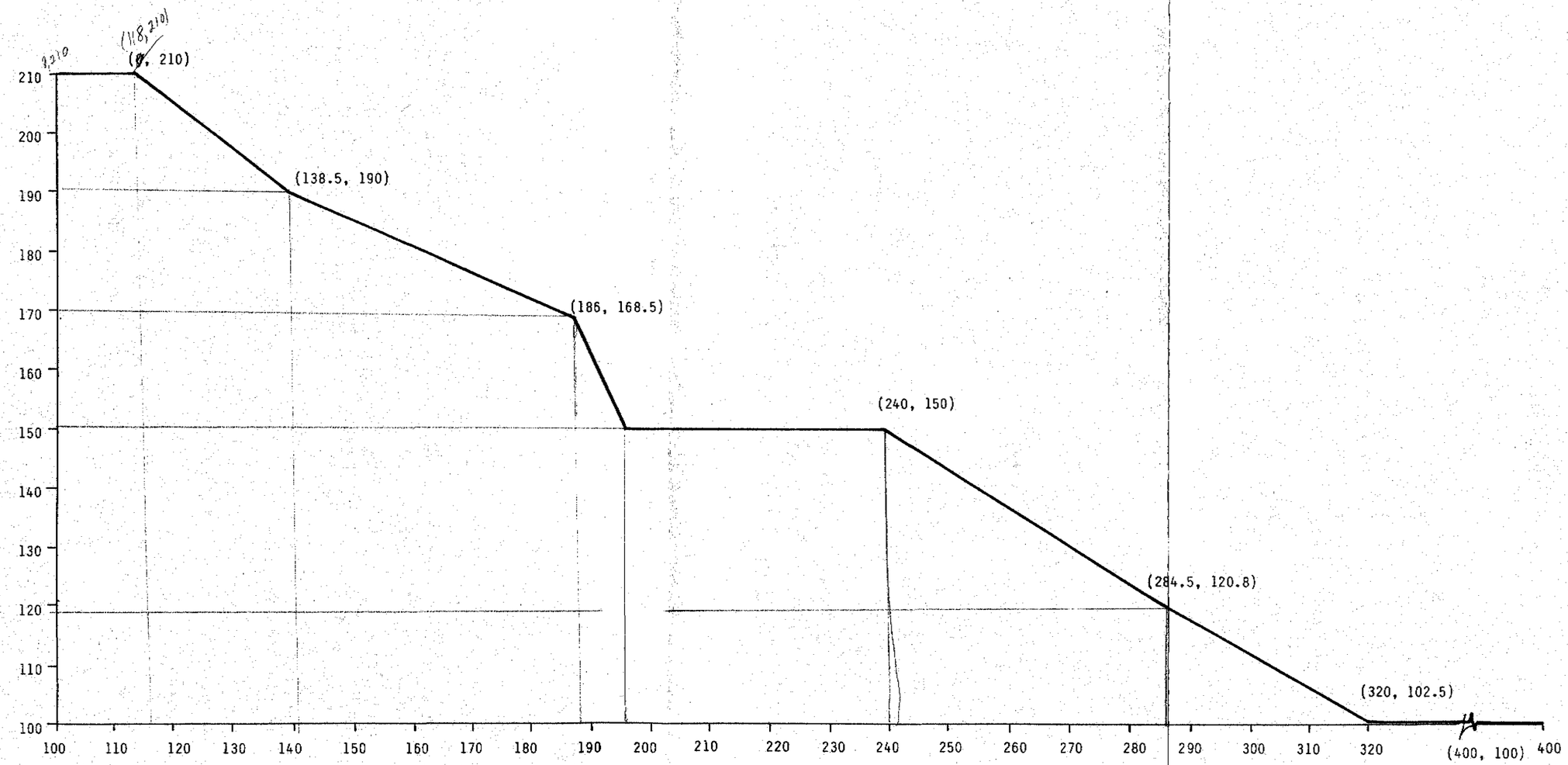
TABLE NO. 1 SUMMARY OF TEST DATA

PROJECT Price River Coal Company FEATURE Slopes LOCATION Castledale, Utah

HOLE NO.	STATIONS	LOCATIONS	IN-PLACE UNIT WEIGHT LB/FT³	IN-PLACE MOISTURE PERCENT	IN-PLACE VOID RATIO	UNCONFINED COMPRESSIVE STRENGTH LB/FT²	FRICTION ANGLE φ	CONSISTENCY LIMITS L.L. %	CONSISTENCY LIMITS P.L. %	CONSISTENCY LIMITS P.I. %	MECHANICAL ANALYSIS * % GRAVEL	MECHANICAL ANALYSIS % SAND	MECHANICAL ANALYSIS % SILT & CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	59+30	3' upslope	100.1	9.8				19.9	19.3	0.6	34.0	31.0	35.0	ML
		6' upslope	96.6	9.6				22.8	16.7	6.1	36.0	27.0	37.0	CL-ML
		9' upslope	92.4	9.7				26.5	19.6	6.9				CL-ML
		12' upslope	82.4	11.7				23.8	20.2	3.6				ML

NOTE: Visual observations indicate that approximately 30-40 percent of the overburden material consists of large size gravel and cobbles. This material was not included in the mechanical analysis shown in this table. The overall percent of the material in the silt and clay size range is somewhat less than the mechanical analysis shown herein.

*Less than 1 inch maximum.



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SCALE DESIGNED CHECKED DRAWN DATE APPROVED LICENSE NO.	**ROLLINS, BROWN & GUNNELL, Inc.** **CONSULTING ENGINEERS**	Soil Profile Sta. 10+00 Price River Coal Company Slope Stability Analysis	Figure No. 4

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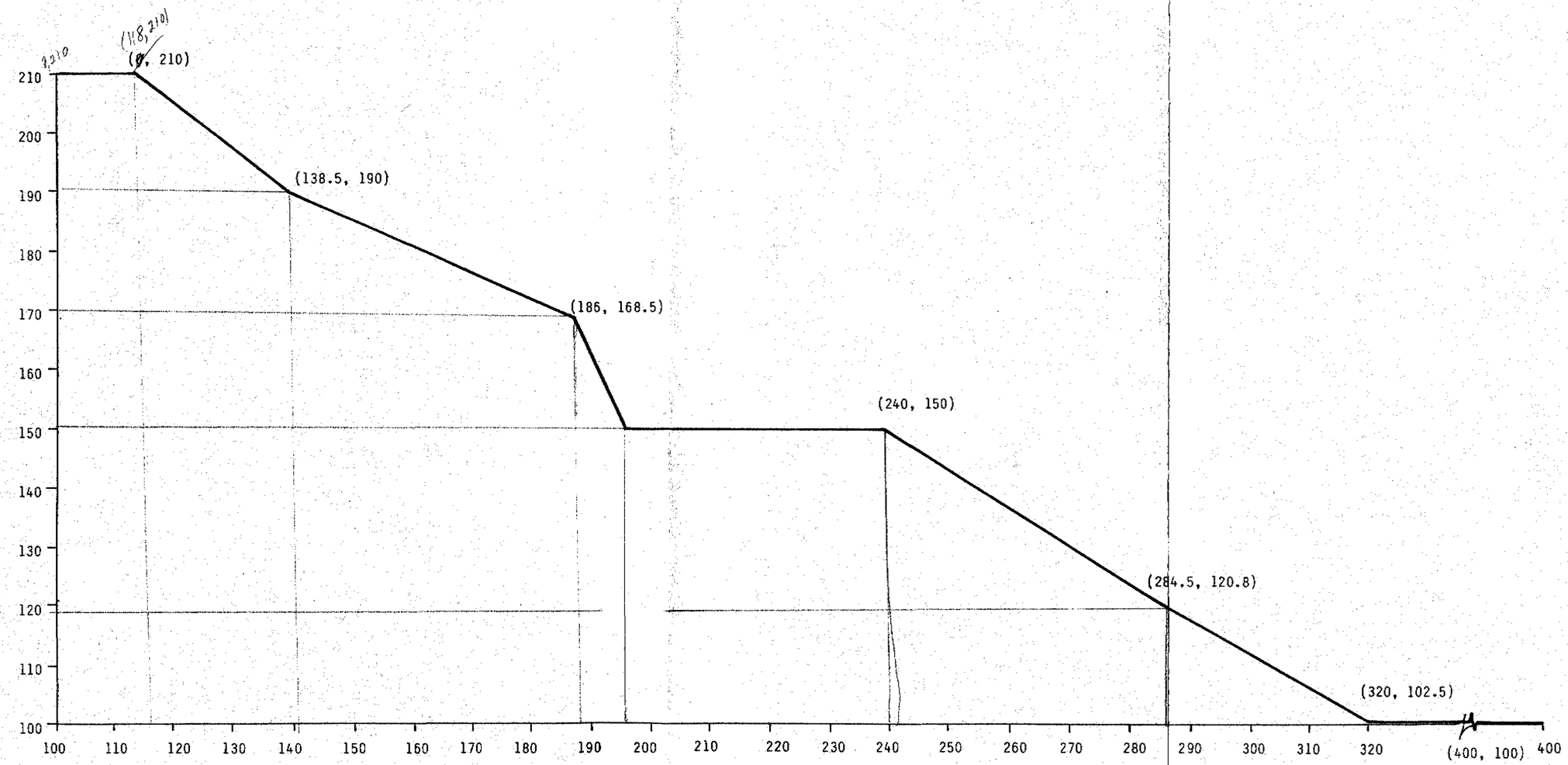

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