PART 3066

WM-68
10/24/90

DEPARTMENT OF ENERGY
ALBUQUERQUE OPERATIONS OFFICE
CONTRACT NO. DE-AC04-83AL18796

GREEN RIVER, UTAH

DRAFT

Completion Report

VOLUME 4A
APPENDIX B

Remedial Actions
Contractor
for the
Uranium Mill Tailings
Remedial Actions
Project

MAY 1990

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

9011080155

UMTRA PROJECT - GREEN RIVER, UTAH

CALCULATIONS

FINAL DESIGN

CONTENTS

MKE DOCUMENT NO. 5057-GRN-C-01-00275-01

Calculation Cover Sheet

Contract No. 5057-05 **Discipline** Earth Sciences **Calc. No.** 10-536-04-~~00~~ 01 **No. of Sheets** ~~64 appendix~~ 917 23

Project Green River, Utah

Feature Tailings Embankment

Item Stability of Excavation Cutslopes

Sources of Data

Sources of Formulae & References

1. "Remedial Action Plan and Site Conceptual Design of the Inactive Uranium Mill Tailings at Green River, Utah", Draft, January 1987.
2. (MKE) Calculation # 10-536-01-00
3. "STABL USER MANUAL", Ronald A. Siegel, Revised June 26, 1978.
4. (MKE) "UMTRA Design Procedures Manual", May 1987.

Preliminary Calc. ☐ **Final Calc.** ☒ **Supersedes Calc. No.** ____

Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
1	Change to Final Calc	Martin Goodman	[illegible]/87	D.K. [illegible]	[illegible]/87	D.K. [illegible]	[illegible]
0	—	Martin Goodman	9/11/87	D.K. [illegible]	9/21/87	D.K. [illegible]	9/21/87

Form 42-110

PURPOSE: Evaluate the stability of cutslopes that would be excavated during construction.

ASSUMPTIONS:

1. Based on references #1 and #2, the maximum of thickness of granular soil in the vicinity of the disposal embankment (see figure 1) is about 18 to 19 feet. The location of maximum granular soil thickness is near hole 567 (see figure 2).

2. The upper portion of the granular material is a loose to medium dense SAND with $\gamma = 95$ pcf and $\phi = 28°$. The lower portion of the granular material consists of dense SAND and GRAVEL with $\gamma = 130$ pcf and $\phi = 38°$ (see ref #2).

3. The maximum thickness of the loose to medium dense SAND layer, which is located near hole #567, is about 15 feet. The thickness of the underlying dense SAND and GRAVEL layer is about 3 to 4 feet (see ref #1).

4. The granular soil is underlain by rock. The excavation will extend about 10 feet beneath the soil-rock interface.

UMTRA/GRN
5057-05
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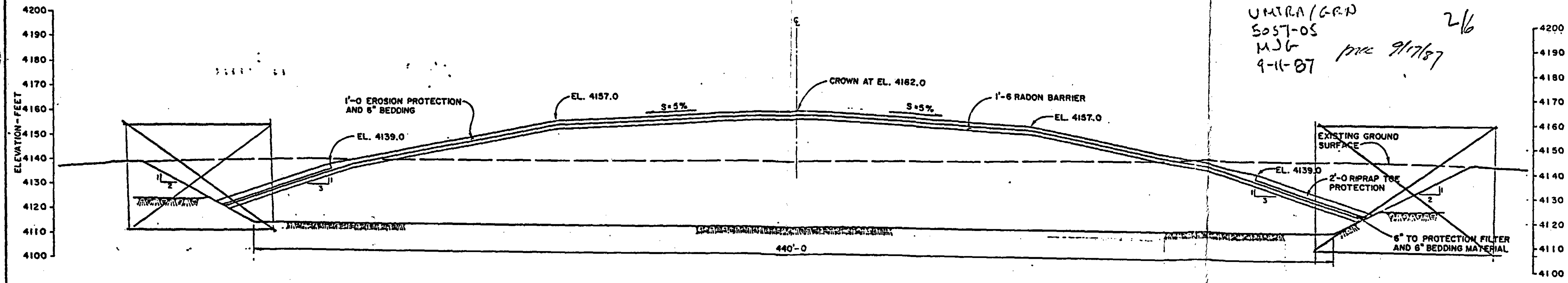
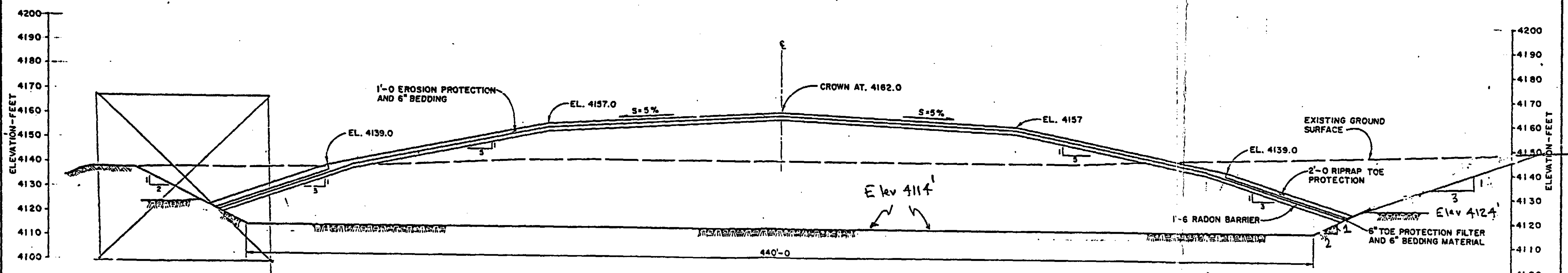
2/6



CROSS-SECTION (A) 0516

SCALE 20 0 20 40 FEET



CROSS-SECTION (B) 0516

SCALE 20 0 20 40 FEET

NOTES:

Figure 1

REFERENCE DRAWINGS:

GRN-PS-10-0516, TAILINGS EMBANKMENT-FINAL GRADING PLAN

QA MK-F	NO.	DATE	REVISIONS	BY	CK	ENG MGR.	CHIEF ENG.	TAC REV	DOE APP
	A		ISSUED FOR PRELIMINARY REVIEW	—	—	—	—	—	—

U. S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

DESIGNED | DRAWN | CHECKED | INSPECTED | RECOMMENDED | APPROVED | DATE | DOE PROJECT ENGINEER | DATE

GREEN RIVER SITE
GREEN RIVER, UTAH

TAILINGS EMBANKMENT
AND FINAL GRADING SECTIONS

MORRISON-KNUDSEN ENGINEERS, INC.
UMTRA PROJECT
180 HOWARD ST. SAN FRANCISCO, CA 94105

PROJECT NO. DE-AC04-83AL18796

DRAWING NO. GRN-PS-10-0517

REV. A

3-16

UMTRA/GRN
5057-05
MJG
9-11-87
pkc
9/17/87

NOTES:

REFERENCE DRAWINGS:

LEGEND:

⊙ Drill Hole 567

FIGURE 2

QA MK-F	NO.	DATE	REVISIONS	BY	CK	E&D MGR.	CHIEF ENG.	TAC REV	DOE APP.
	A		ISSUED FOR PRELIMINARY REVIEW						

U. S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

GREEN RIVER SITE
GREEN RIVER, UTAH

TAILINGS EMBANKMENT AND FINAL GRADING PLAN

DESIGNED | DRAWN | CHECKED | INSPECTED | RECOMMENDED | APPROVED | DATE | DOE PROJECT ENGINEER | DATE

MORRISON-KNUDSEN ENGINEERS, INC.
UMTRA PROJECT
180 HOWARD ST. SAN FRANCISCO, CA 94105

PROJECT NO. DE-AC04-83AL18796

DRAWING NO. GRN-PS-10-0516

REV. A

Assumptions: (continued)

5. Shear Strength of the rock is very high compared to the overlying soil. Therefore, slope stability is evaluated only in the soil deposits.

6 Saturation of the slope is not expected during construction of the embankment and as a consequence, the design earthquake should not liquefy the loose sands during construction of the embankment.

7. The design earthquake is simulated using a pseudo-static earthquake coefficient of 0.1 g (see reference # 1)

8. The cross-section on which stability is evaluated is shown below:

Soil	$\phi°$	γ (pcf)
Loose SAND	28	95
Dense SAND	38	130

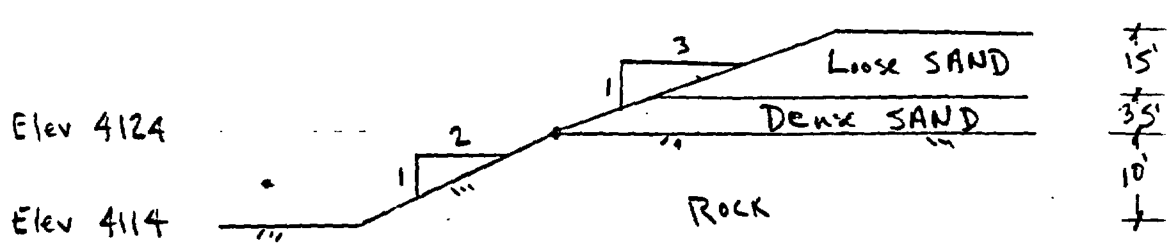


Figure 3

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA-GRN | Contract No. 5057-05 | Sheet 5/6 | File No.
Feature Disposal Embankment Excavation | Designed MJG | Date 9-11-87
Item Stability of Cut Slopes | Checked PKC | Date 9-17-87

Method of Analysis

The STABL program (reference 3) was used to perform slope stability calculations. The safety factor was calculated using the Modified Bishop Method.

RESULTS:

The computer runs used to calculate the factor of safety are appended. The safety factors calculated are as follows:

Run #	Earthquake Acceleration (% g)	Factor of Safety *	Minimum Allowable Factor of Safety **
1	0	1.60	1.3
2	10	1.19	1.10

* Factor of safety is calculated on shallow surfaces where confinement is low. Deeper surfaces have higher factors of safety.

** End of Construction / Short-term (see Ref # 4).

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN	Contract No. 5057-15	Sheet 6/6	File No.
Feature: Disposal Embankment Excavation	Designed MJG	Date 9-11-87	
Item: Stability of Cut Slopes	Checked PKC	Date 9/17/87	

CONCLUSIONS:

Based on the conservative design section analyzed, the sideslopes of the excavation may be cut at 3:1 (horz: vertical) or flatter. for cuts as great as 18 feet above the soil-rock interface. The rock may be cut to a slope of 2:1 (horz: vert) or flatter. The resulting sideslope excavation is shown in figure 3 (sheet 4).

Appendix

** PCSTABL5 **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

page A1/

MJG
9/11/87 PKC
5057-05 9/11/87

Time of Run: 4:00PM
Run By: MJG
Input Data Filename: IN
Output Filename: STAT1

PROBLEM DESCRIPTION CUTSLOPE STABILITY ABOVE BEDROCK W/OUT EARTHQUAKE LOADING

BOUNDARY COORDINATES

3 Top Boundaries
4 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	.00	10.50	3.50	2
2	10.50	3.50	55.50	18.50	1
3	55.50	18.50	70.00	18.50	1
4	10.50	3.50	70.00	3.50	2

ISOTROPIC SOIL PARAMETERS

2 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	95.0	.0	.0	27.0	.00	.0	1
2	130.0	.0	.0	38.0	.00	.0	1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

200 Trial Surfaces Have Been Generated.

200 Surfaces Initiate From Each Of 1 Points Equally Spaced
Along The Ground Surface Between X = .00 ft.
and X = .00 ft.

Each Surface Terminates Between X = 56.00 ft.
and X = 65.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of .0 And 20.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.76	1.54
3	9.52	3.08
4	14.27	4.62
5	19.02	6.17
6	23.77	7.73
7	28.52	9.30
8	33.27	10.87
9	38.02	12.44
10	42.76	14.02
11	47.50	15.61
12	52.24	17.20
13	56.09	18.50

Circle Center At X = ****** ; Y = 3915.9 and Radius, 4113.8

*** 1.604 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.77	1.51
3	9.53	3.04
4	14.29	4.57

5	19.05	6.10
6	23.80	7.65
7	28.55	9.20
8	33.30	10.77
9	38.05	12.34
10	42.79	13.91
11	47.54	15.50
12	52.28	17.10
13	56.43	18.50

A3/

MJG
9-11-87
5057-05

Circle Center At X = -887.5 ; Y = 2802.3 and Radius, 2939.4

PJC 9/11/87

*** 1.611 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.77	1.49
3	9.54	2.99
4	14.31	4.51
5	19.07	6.04
6	23.82	7.58
7	28.57	9.14
8	33.32	10.72
9	38.06	12.31
10	42.79	13.92
11	47.52	15.54
12	52.25	17.17
13	56.06	18.50

Circle Center At X = -477.0 ; Y = 1539.8 and Radius, 1612.0

*** 1.620 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.77	1.51
3	9.53	3.02
4	14.30	4.54
5	19.06	6.06
6	23.82	7.59
7	28.58	9.13
8	33.34	10.67
9	38.09	12.21

10	42.85	13.76
11	47.60	15.31
12	52.35	16.87
13	57.10	18.43
14	57.30	18.50

Circle Center At X = ****** ; Y = 4550.6 and Radius, 4772.3

*** 1.622 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.78	1.45
3	9.56	2.92
4	14.34	4.42
5	19.10	5.92
6	23.86	7.45
7	28.62	9.00
8	33.37	10.56
9	38.11	12.14
10	42.85	13.74
11	47.58	15.36
12	52.30	17.00
13	56.58	18.50

Circle Center At X = -373.5 ; Y = 1238.1 and Radius, 1293.2

*** 1.626 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.77	1.50
3	9.54	3.01
4	14.30	4.52
5	19.07	6.03
6	23.83	7.56
7	28.59	9.08
8	33.35	10.62
9	38.11	12.15
10	42.86	13.70
11	47.62	15.25
12	52.37	16.80
13	57.12	18.36

14	57.53	18.50

Circle Center At X = ****** ; Y = 4120.9 and Radius, 4319.1

*** 1.628 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.78	1.46
3	9.56	2.94
4	14.33	4.42
5	19.10	5.92
6	23.87	7.43
7	28.64	8.94
8	33.40	10.47
9	38.15	12.01
10	42.91	13.56
11	47.66	15.12
12	52.41	16.69
13	57.15	18.27
14	57.83	18.50

Circle Center At X = -655.2 ; Y = 2148.0 and Radius, 2245.7

*** 1.638 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.82	1.33
3	9.63	2.71
4	14.42	4.13
5	19.20	5.58
6	23.98	7.08
7	28.73	8.62
8	33.48	10.20
9	38.21	11.82
10	42.92	13.48
11	47.63	15.18
12	52.31	16.92
13	56.47	18.50

Circle Center At X = -153.8 ; Y = 565.2 and Radius, 585.7

*** 1.650 ***

A6/

MJG
9-11-87
5057-CS
P.W.
9-21-87

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.78	1.47
3	9.56	2.95
4	14.33	4.43
5	19.10	5.92
6	23.87	7.42
7	28.64	8.93
8	33.41	10.44
9	38.17	11.95
10	42.93	13.48
11	47.69	15.01
12	52.45	16.55
13	57.21	18.09
14	58.47	18.50

Circle Center At X = ****** ; Y = 3470.5 and Radius, 3630.5

*** 1.652 ***

Failure Surface Specified By 14 Coordinate Points

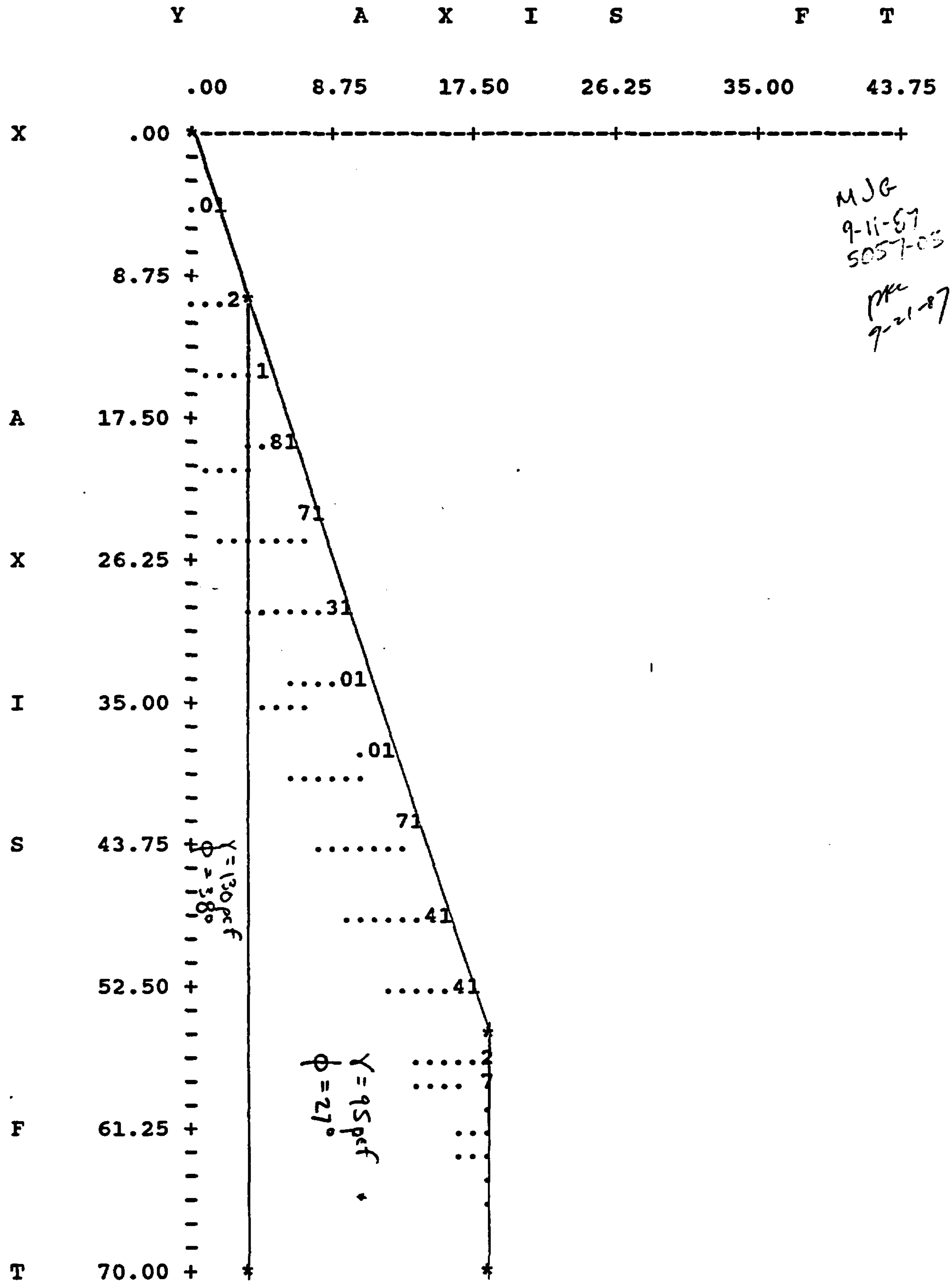
Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.83	1.31
3	9.64	2.65
4	14.45	4.04
5	19.24	5.46
6	24.02	6.93
7	28.79	8.43
8	33.54	9.98
9	38.29	11.56
10	43.01	13.19
11	47.73	14.85
12	52.43	16.55
13	57.12	18.29
14	57.66	18.50

Circle Center At X = -154.1 ; Y = 579.4 and Radius, 599.5

*** 1.659 ***

1

A7/



Y AXIS FT
.00
8.75
17.50
26.25
35.00
43.75
X AXIS FT
.00
8.75
17.50
26.25
35.00
43.75
52.50
61.25
70.00
.01
2
1
.81
71
31
.01
.01
71
41
41
2
7
γ = 130 pcf
φ = 38°
γ = 95 pcf
φ = 27°
MJG
9-11-87
5057-05
9-21-87

A8/

** PCSTABL5 **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date:	9-2-87
Time of Run:	4:00PM
Run By:	MJG
Input Data Filename:	IN
Output Filename:	DYN1

PROBLEM DESCRIPTION CUTSLOPE STABILITY ABOVE BEDROCK
WITH EARTHQUAKE LOADING

BOUNDARY COORDINATES

3 Top Boundaries
4 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	.00	10.50	3.50	2
2	10.50	3.50	55.50	18.50	1
3	55.50	18.50	70.00	18.50	1
4	10.50	3.50	70.00	3.50	2

1

ISOTROPIC SOIL PARAMETERS

2 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	95.0	.0	.0	27.0	.00	.0	1
2	130.0	.0	.0	38.0	.00	.0	1

A Horizontal Earthquake Loading Coefficient
Of .100 Has Been Assigned

A Vertical Earthquake Loading Coefficient
Of .000 Has Been Assigned

Cavitation Pressure =-2000.0 psf

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

200 Trial Surfaces Have Been Generated.

200 Surfaces Initiate From Each Of 1 Points Equally Spaced
Along The Ground Surface Between X = .00 ft.
and X = .00 ft.

Each Surface Terminates Between X = 56.00 ft.
and X = 65.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = .00 ft.

5.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of .0 And 20.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.76	1.54
3	9.52	3.08
4	14.27	4.62
5	19.02	6.17
6	23.77	7.73
7	28.52	9.30
8	33.27	10.87
9	38.02	12.44

10	42.76	14.02
11	47.50	15.61
12	52.24	17.20
13	56.09	18.50

Circle Center At X = ****** ; Y = 3915.9 and Radius, 4113.8

*** 1.192 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.77	1.51
3	9.53	3.04
4	14.29	4.57
5	19.05	6.10
6	23.80	7.65
7	28.55	9.20
8	33.30	10.77
9	38.05	12.34
10	42.79	13.91
11	47.54	15.50
12	52.28	17.10
13	56.43	18.50

Circle Center At X = -887.5 ; Y = 2802.3 and Radius, 2939.4

*** 1.195 ***

1

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.77	1.51
3	9.53	3.02
4	14.30	4.54
5	19.06	6.06
6	23.82	7.59
7	28.58	9.13
8	33.34	10.67
9	38.09	12.21
10	42.85	13.76
11	47.60	15.31
12	52.35	16.87
13	57.10	18.43
14	57.30	18.50

A11

MJC 9-11-07 5057-05

pkc 9-21-07

Circle Center At X = ****** ; Y = 4550.6 and Radius, 4772.3

*** 1.200 ***

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.77	1.50
3	9.54	3.01
4	14.30	4.52
5	19.07	6.03
6	23.83	7.56
7	28.59	9.08
8	33.35	10.62
9	38.11	12.15
10	42.86	13.70
11	47.62	15.25
12	52.37	16.80
13	57.12	18.36
14	57.53	18.50

Circle Center At X = ****** ; Y = 4120.9 and Radius, 4319.1

*** 1.203 ***

1

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.77	1.49
3	9.54	2.99
4	14.31	4.51
5	19.07	6.04
6	23.82	7.58
7	28.57	9.14
8	33.32	10.72
9	38.06	12.31
10	42.79	13.92
11	47.52	15.54
12	52.25	17.17
13	56.06	18.50

Circle Center At X = -477.0 ; Y = 1539.8 and Radius, 1612.0

*** 1.204 ***

A12

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.78	1.45
3	9.56	2.92
4	14.34	4.42
5	19.10	5.92
6	23.86	7.45
7	28.62	9.00
8	33.37	10.56
9	38.11	12.14
10	42.85	13.74
11	47.58	15.36
12	52.30	17.00
13	56.58	18.50

Circle Center At X = -373.5 ; Y = 1238.1 and Radius, 1293.2

*** 1.206 ***

1

Failure Surface Specified By 14 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.78	1.46
3	9.56	2.94
4	14.33	4.42
5	19.10	5.92
6	23.87	7.43
7	28.64	8.94
8	33.40	10.47
9	38.15	12.01
10	42.91	13.56
11	47.66	15.12
12	52.41	16.69
13	57.15	18.27
14	57.83	18.50

Circle Center At X = -655.2 ; Y = 2148.0 and Radius, 2245.7

*** 1.211 ***

Failure Surface Specified By 14 Coordinate Points

A13/

MJG 9-11-87 5057-05

PKC 9-11-87

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.78	1.47
3	9.56	2.95
4	14.33	4.43
5	19.10	5.92
6	23.87	7.42
7	28.64	8.93
8	33.41	10.44
9	38.17	11.95
10	42.93	13.48
11	47.69	15.01
12	52.45	16.55
13	57.21	18.09
14	58.47	18.50

Circle Center At X = ****** ; Y = 3470.5 and Radius, 3630.5

*** 1.217 ***

1

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	.00	.00
2	4.82	1.33
3	9.63	2.71
4	14.42	4.13
5	19.20	5.58
6	23.98	7.08
7	28.73	8.62
8	33.48	10.20
9	38.21	11.82
10	42.92	13.48
11	47.63	15.18
12	52.31	16.92
13	56.47	18.50

Circle Center At X = -153.8 ; Y = 565.2 and Radius, 585.7

*** 1.225 ***

Failure Surface Specified By 14 Coordinate Points

Point X-Surf Y-Surf

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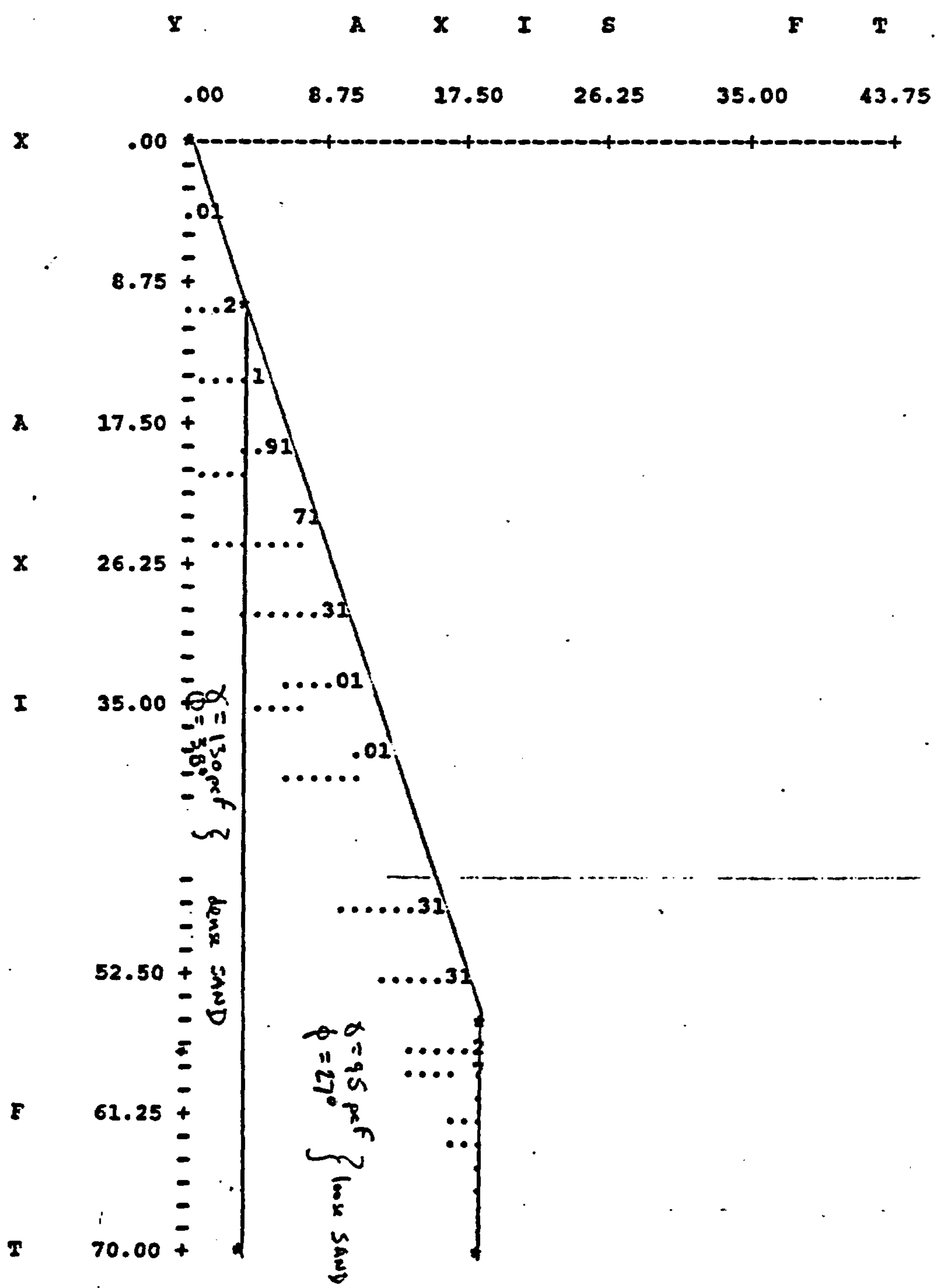
No.	(ft)	(ft)
1	.00	.00
2	4.83	1.31
3	9.64	2.65
4	14.45	4.04
5	19.24	5.46
6	24.02	6.93
7	28.79	8.43
8	33.54	9.98
9	38.29	11.56
10	43.01	13.19
11	47.73	14.85
12	52.43	16.55
13	57.12	18.29
14	57.66	18.50

Circle Center At X = -154.1 ; Y = 579.4 and Radius, 599.5

*** 1.229 ***

1



PURPOSE:

Check embankment excavation cut slope stability. This is an approximate hand-check of previous calculation.

METHOD

1. Use infinite slope analysis – soils are cohesionless (see strength values in previous calculation

2. Static Slope Stability: $SF = \tan\phi / \tan i$

   i = slope angle

3. Dynamic Slope Stability (Pseudo-static method)

$$SF = \frac{\tan\phi - k\tan\phi\tan i}{\tan i + k}$$

4. Assume dry slope. Existing ground water is greater than 60' below site, perched ground water is unlikely.

5. Dynamic slope stability

   A. Short term: Minimum SF = 1.1

   $k = \frac{1}{2}(a_{max})$

   B. Long Term: Not applicable, since excavation will not be open for long-term (1000 year) design life.

   C. $a_{max} = 0.21\,g$

6. Static Slope Stability SF = 1.5 Long-term
   SF = 1.3 Short-term

6. Soil Properties: Check weakest soil

$\phi = 27°$ $c = 0$ (short term and long term strength)

CALCULATIONS

[Assume 3:1 cut slope]:

1. Dynamic (Short Term)

$$SF = \frac{\tan 27° - 0.1 \tan 27° \tan 18.4°}{\tan 18.4° + 0.1} = \underline{\underline{1.14}}$$ ✓ ok

2. Static (Short Term and Long-Term) SF = $\underline{\underline{1.52}}$ ✓ ok

[Assume 2.75 : 1 cut slope]

1. Dynamic (Short term)   SF = 0.97   Not adequate

CONCLUSIONS

Use 3(H) : 1(V) cut slope or flatter

Do not allow vehicles (or other heavy equipment) closer than 10' (by judgement) to edge of excavation

MKE DOC. 5057-GRN-C-01-00853-01

Calculation Cover Sheet

Contract No. 5057-05 **Discipline** UMTRA **Calc. No.** 10-536-13-01
No. of Sheets 116 + cover

Project UMTRA-GRN

Feature Disposal Embankment

Item Slope Stability

~~Sources of Data~~

- This calculation supercedes calculation 10-536-13-00 in its entirety.

~~Sources of Formulas &~~ References

1. "Typical Center Line Cross-Sections Green River Remedial Action Project", Art Barker and Associates, 11-29-89, MKES Doc. # 5057-GRN-D-09-01835-00.
2. "Green River Utah Contaminated Material Moisture Content, Density and Compaction Data", November 1989, MKES Doc. # 5057-GRN-R-01-01764-00.
3. "Remedial Action Plan and Site Conceptual Design of the Inactive Uranium Mill Tailings at Green River, Utah", Final, Jan 1989 MKES Doc. # 5057-GRN-R-03-00874-01, Vol. I.

Preliminary Calc. ☐ Final Calc. ☒ Supersedes Calc. No. 10-536-13-00

Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
1	Check As-Built Conditions	Martin Gredman	4/5/90	[signature]	4/6/90	F.B. Gans	4-18-90

Form 42-110

4. "UMTRA Design Procedures Manual", Rev 7, 5-23-89, MKES Doc. # 4005-GEN-Q-01-00571-7.

5. "STABL User Manual", Ronald Siegel, revised 26 Jan 1978.
(Note that user manual is unchanged for PCSTABL5 for simplified Bishop w/out tieback loads).

6. MKES Calculation # 10-536-01-02, "Green River Embankment Design Geotechnical Design Parameters for Various Soils", MKES Doc # 5057-GRN-C-01-00252-02, 2/1/88.

INTRODUCTION

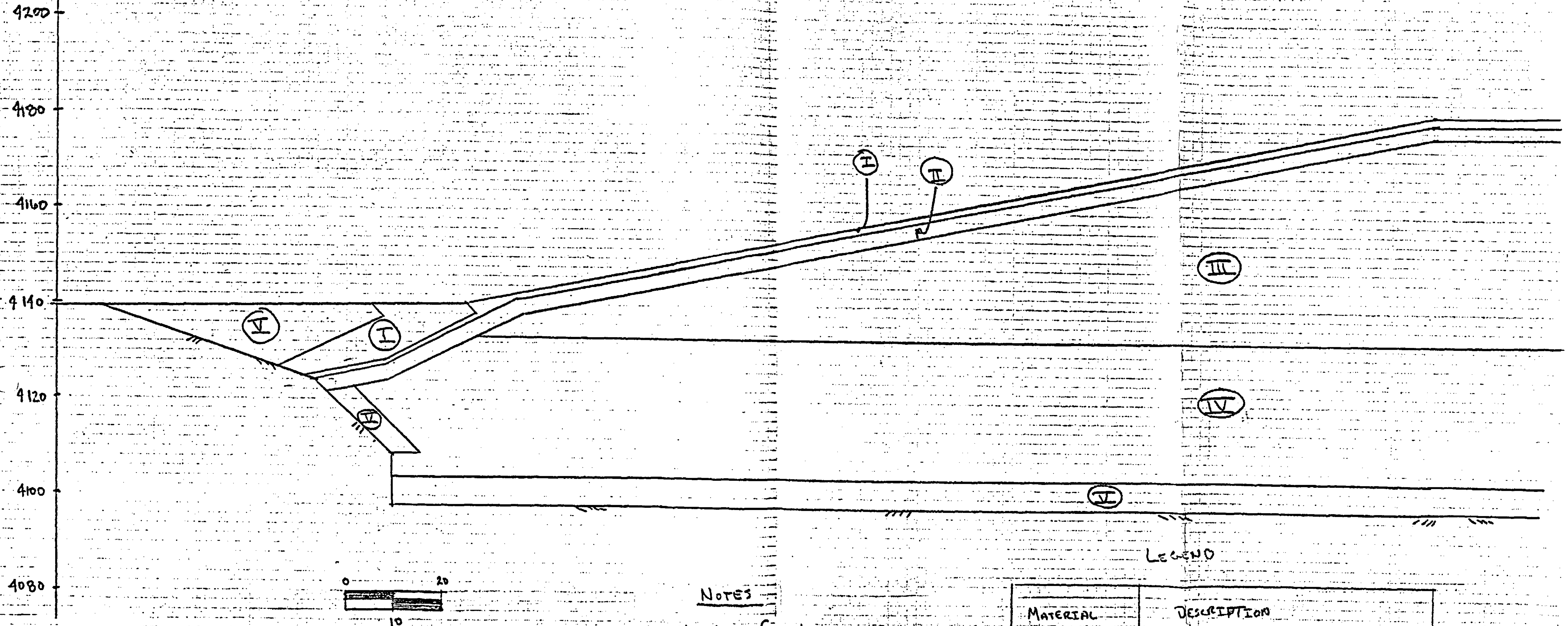
Subsequent to preparation of "Final Design For Construction" documents, the following changes occurred:

1. Additional contaminated materials were identified;
2. The radon barrier was constructed with 7% of bentonite (by dry weight).
3. The radon barrier thickness was increased to 36-inches.
4. The Frost protection and drain layers were deleted.

These changes together with the "as-built" embankment dimensions are used herein to evaluate slope stability of the completed disposal embankment.

ASSUMPTIONS

1. The critical embankment cross-section, adapted from the as-built center section as viewed from southwest side of cell (ref 1), is shown on figure 1. The simplified section analyzed is shown on fig 2.
2. For the range of vertical stress values in the disposal cell, strength of radon barrier material amended with 7% bentonite is not less than the strength of radon barrier material amended with only 3% bentonite (see Appendix C).
3. The contaminated materials will remain partially saturated.
4. Slope failure will not occur through materials beneath the disposal cell.



LEGEND

MATERIAL TYPE	DESCRIPTION
I	Riprap (Type A or B) or Bedding
II	Radon Barrier
III	Tailings
IV	Windblown / Vicinity Property
V	Select Fill (Type A or B)

NOTES

1. Elevation of Material type III / IV interface is estimated from ref. 2.

CRITICAL SECTION
VIEW FROM SW
SIDE OF CELL

FIGURE 1
(adapted from ref 1)

DISCRETIZATION OF FIG. 1
FOR ENTRY IN PROGRAM
PCSTABL5

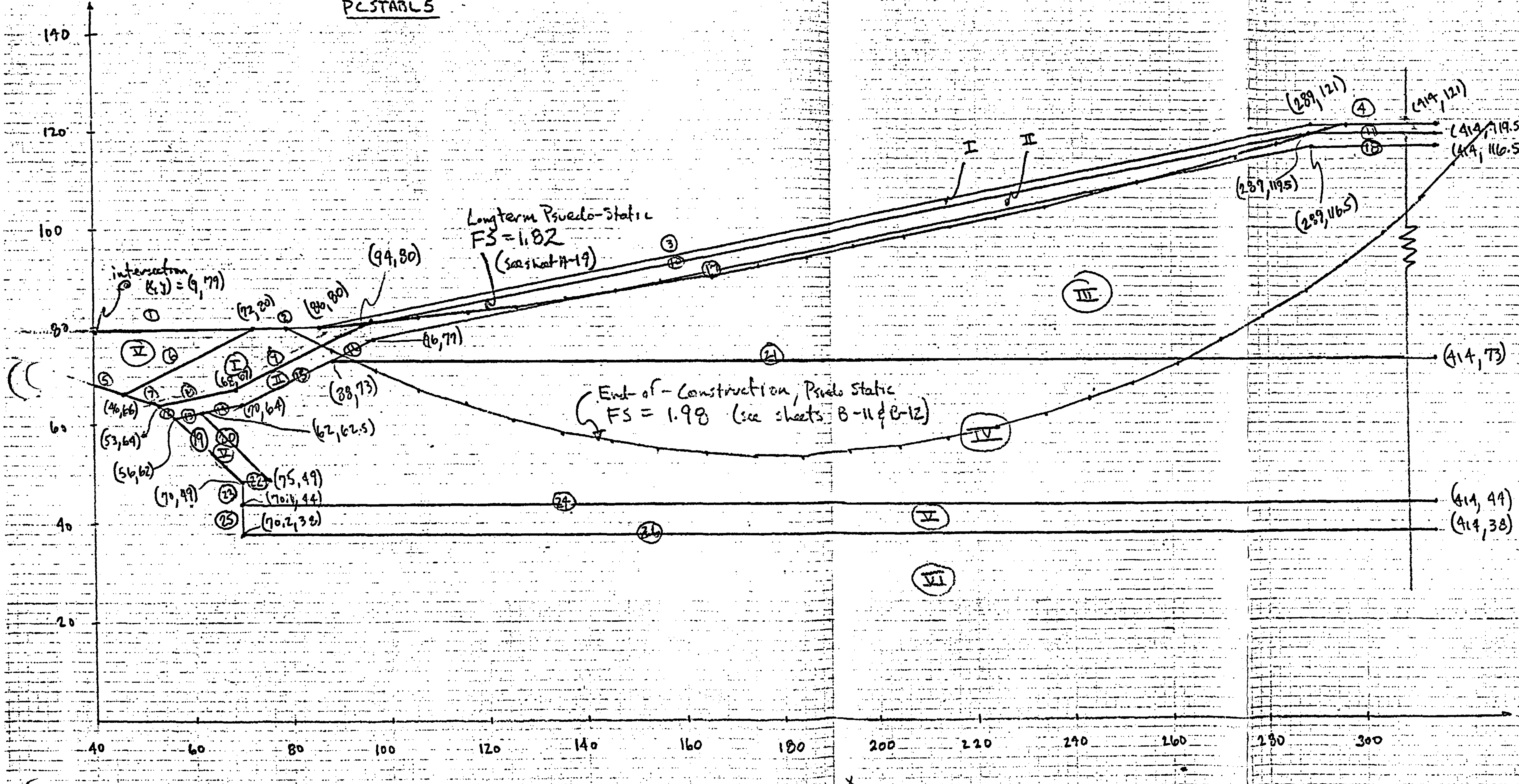


FIGURE 2

5. The following psuedo-static earthquake coefficients and minimum allowable safety factors should be used:

CONDITION	PSUEDO-STATIC EARTHQUAKE COEFFICIENT ①	MINIMUM ALLOWABLE SAFETY FACTOR ②
End of Construction		
- Static	0.0 g	1.3
- Psuedo-static	0.1 g	1.1
Long Term		
- Static	0.0 g	1.5
- Pseudo-static	0.14 g	1.1

① Ref. 3 and 4, based on PGA = 0.21 g
② Ref 4.

CALCULATIONS

The PCSTABL5 program (ref 5) is used herein to perform slope stability calculations. Safety factors values on circular-arc shaped surfaces are calculated using the Simplified Bishop procedure.

Design shear strength and density input are presented in Table I.

Longterm and End-of-Construction slope stability computer runs are appended in Appendices A and B respectively.

Table I - Material Parameters (1)

Material Description (3)	End-of-Construction Condition PGA = 0.10g			Long-Term Condition PGA = 0.14g		
	γ_t (pcf)	ϕ (°)	c (psf)	γ_t (pcf)	$\bar{\phi}$ (°)	$\bar{c}$ (psf)
Riprap (Types A & B)	130.	38.	—	130.	38.	—
Radon Barrier (2) (9% bentonite)	130.	25.	60.	130.	26.	—
Tailings	105.	35.	—	105.	35.	—
Windblown/ Vicinity Property	115.	16.	500.	115.	29.	—
Select Fill (Types A & B)	115.	16.	500.	115.	29.	—

Notes

1. Data based on ref. 6, (sheet 1b) except where noted.
2. See Appendix C for parameters of bentonite amended radon barrier material.
3. Material with high strength assumed for native soil and rock (see computer runs, Appendices A & B).

RESULTS

Minimum calculated safety factor are as follows (see Appendices A & B):

Load / Drainage Condition	Earthquake Condition	Safety Factor (Simplified Bishop)
End-of-Construction	Psuedo-Static	1.90
Long-Term	Psuedo-Static	1.82

Computer runs are not run for static conditions because calculated psuedo-static safety factor values exceed the minimum allowable static safety factor values (see sheet 4).

CONCLUSIONS

The disposal embankment is expected to be stable provided:

- Contaminated materials in the embankment do not become saturated;
- The embankment is not subject to earthquake accelleration greater than the design values (sheet 4).

Appendices

A. Long-Term stability
B. End-of-Construction Stability
C. Parameters for Bentonite Amended Radon Barrier Material.

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** PCSTABL5 **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

Run Date: 4/4/90
Time of Run: AFTERNOON
Run By: MJG
Input Data Filename: IN1
Output Filename: OUT1

PROBLEM DESCRIPTION LONGTERM STRENGTH W/EARTHQUAKE LOADING

BOUNDARY COORDINATES

4 Top Boundaries
26 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	9.00	79.00	72.00	80.00	5
2	72.00	80.00	86.00	80.00	1
3	86.00	80.00	289.00	121.00	1
4	289.00	121.00	414.00	121.00	1
5	9.00	79.00	46.00	66.00	6
6	46.00	66.00	72.00	80.00	1
7	46.00	66.00	53.00	64.00	6
8	53.00	64.00	68.00	67.00	2
9	68.00	67.00	94.00	80.00	2
10	94.00	80.00	289.00	119.50	2
11	289.00	119.50	414.00	119.50	2
12	53.00	64.00	56.00	62.00	6
13	56.00	62.00	62.00	62.50	5
14	62.00	62.50	70.00	64.00	4
15	70.00	64.00	88.00	73.00	4
16	88.00	73.00	96.00	77.00	3
17	96.00	77.00	289.00	116.50	3
18	289.00	116.50	414.00	116.50	3
19	62.00	62.50	75.00	49.00	5
20	56.00	62.00	70.00	49.00	6
21	70.00	49.00	75.00	49.00	4
22	88.00	73.00	414.00	73.00	4
23	70.00	49.00	70.10	44.00	6
24	70.10	44.00	414.00	44.00	5
25	70.10	44.00	70.20	38.00	6
26	70.20	38.00	414.00	38.00	6

ISOTROPIC SOIL PARAMETERS

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6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	130.0	.0	.0	38.0	.00	.0	1
2	130.0	.0	.0	26.0	.00	.0	1
3	105.0	.0	.0	35.0	.00	.0	1
4	115.0	.0	.0	29.0	.00	.0	1
5	115.0	.0	.0	29.0	.00	.0	1
6	100.0	.0	10000.0	.0	.00	.0	1

1

Searching Routine Will Be Limited To An Area Defined By 4 Boundaries Of Which The First 4 Boundaries Will Deflect Surfaces Upward

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)
1	9.00	79.00	53.00	64.00
2	53.00	64.00	70.00	49.00
3	70.00	49.00	70.20	38.00
4	70.20	38.00	414.00	38.00

A Horizontal Earthquake Loading Coefficient Of .140 Has Been Assigned

A Vertical Earthquake Loading Coefficient Of .000 Has Been Assigned

Cavitation Pressure = .0 psf

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

90 Trial Surfaces Have Been Generated.

30 Surfaces Initiate From Each Of 3 Points Equally Spaced Along The Ground Surface Between X = 10.00 ft. and X = 70.00 ft.

Each Surface Terminates Between X = 290.00 ft. and X = 410.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 38.00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -15.0

And -5.0 deg.

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Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	79.97
2	79.72	77.62
3	89.52	75.62
4	99.38	73.96
5	109.30	72.66
6	119.25	71.70
7	129.23	71.10
8	139.23	70.85
9	149.23	70.95
10	159.22	71.41
11	169.18	72.21
12	179.12	73.37
13	189.00	74.88
14	198.83	76.74
15	208.58	78.94
16	218.25	81.49
17	227.83	84.37
18	237.29	87.60
19	246.64	91.15
20	255.86	95.03
21	264.93	99.24
22	273.85	103.76
23	282.60	108.59
24	291.18	113.73
25	299.57	119.17
26	302.18	121.00

Circle Center At X = 141.3 ; Y = 354.1 and Radius, 283.2

*** 2.026 ***

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.70	77.06
3	59.47	74.94
4	69.31	73.13
5	79.20	71.65
6	89.13	70.49
7	99.09	69.65

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8	109.08	69.13
9	119.08	68.93
10	129.08	69.06
11	139.07	69.51
12	149.04	70.28
13	158.98	71.38
14	168.88	72.79
15	178.73	74.53
16	188.51	76.58
17	198.23	78.95
18	207.86	81.63
19	217.40	84.62
20	226.85	87.92
21	236.17	91.52
22	245.38	95.42
23	254.46	99.61
24	263.40	104.10
25	272.18	108.88
26	280.81	113.93
27	289.27	119.26
28	291.84	121.00

Circle Center At X = 120.1 ; Y = 378.2 and Radius, 309.3

*** 2.031 ***

1

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.71	77.10
3	59.49	75.00
4	69.32	73.19
5	79.20	71.66
6	89.13	70.44
7	99.09	69.51
8	109.07	68.87
9	119.06	68.53
10	129.06	68.48
11	139.06	68.73
12	149.04	69.28
13	159.01	70.12
14	168.94	71.26
15	178.84	72.69
16	188.69	74.42
17	198.48	76.43
18	208.21	78.74
19	217.87	81.33
20	227.45	84.21
21	236.94	87.37
22	246.33	90.81
23	255.61	94.52
24	264.78	98.51
25	273.83	102.77
26	282.75	107.29
27	291.53	112.08
28	300.16	117.13
29	306.36	121.00

Circle Center At X = 125.6 ; Y = 406.0 and Radius, 337.5

*** 2.036 ***

Failure Surface Specified By 30 Coordinate Points

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Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.67	76.94
3	59.41	74.69
4	69.22	72.72
5	79.08	71.06
6	88.98	69.69
7	98.93	68.62
8	108.90	67.85
9	118.89	67.39
10	128.89	67.22
11	138.88	67.36
12	148.87	67.80
13	158.85	68.53
14	168.79	69.57
15	178.70	70.91
16	188.57	72.55
17	198.38	74.48
18	208.13	76.71
19	217.81	79.23
20	227.40	82.04
21	236.91	85.14
22	246.32	88.52
23	255.62	92.19
24	264.81	96.13
25	273.88	100.36
26	282.81	104.85
27	291.61	109.61
28	300.25	114.63
29	308.75	119.91
30	310.39	121.00

Circle Center At X = 129.4 ; Y = 398.9 and Radius, 331.7

*** 2.037 ***

1

Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.68	76.98
3	59.43	74.76
4	69.24	72.83
5	79.11	71.19
6	89.02	69.84
7	98.96	68.79
8	108.93	68.03

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9	118.92	67.57
10	128.92	67.40
11	138.92	67.53
12	148.91	67.95
13	158.88	68.67
14	168.83	69.68
15	178.75	70.99
16	188.62	72.59
17	198.44	74.48
18	208.20	76.66
19	217.89	79.13
20	227.50	81.89
21	237.03	84.92
22	246.46	88.24
23	255.79	91.84
24	265.01	95.71
25	274.12	99.85
26	283.09	104.26
27	291.93	108.93
28	300.63	113.86
29	309.18	119.05
30	312.19	121.00

Circle Center At X = 129.6 ; Y = 405.4 and Radius, 338.0

*** 2.040 ***

Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.73	77.18
3	59.52	75.14
4	69.36	73.38
5	79.25	71.90
6	89.18	70.69
7	99.14	69.77
8	109.12	69.12
9	119.11	68.76
10	129.11	68.68
11	139.11	68.87
12	149.10	69.35
13	159.07	70.11
14	169.01	71.15
15	178.93	72.47
16	188.80	74.07
17	198.62	75.95
18	208.39	78.10
19	218.09	80.52
20	227.72	83.22
21	237.27	86.18
22	246.73	89.42
23	256.10	92.92
24	265.36	96.68
25	274.52	100.70
26	283.56	104.97
27	292.48	109.50
28	301.26	114.28
29	309.91	119.30
30	312.66	121.00

Circle Center At X = 127.1 ; Y = 424.2 and Radius, 355.5

*** 2.047 ***

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Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.66	76.91
3	59.40	74.62
4	69.19	72.61
5	79.04	70.89
6	88.94	69.46
7	98.88	68.32
8	108.84	67.47
9	118.82	66.92
10	128.82	66.65
11	138.82	66.68
12	148.81	67.00
13	158.80	67.62
14	168.75	68.52
15	178.68	69.72
16	188.57	71.21
17	198.41	72.99
18	208.20	75.05
19	217.92	77.40
20	227.56	80.03
21	237.13	82.95
22	246.61	86.14
23	255.98	89.61
24	265.26	93.36
25	274.42	97.37
26	283.45	101.65
27	292.36	106.19
28	301.13	110.99
29	309.76	116.05
30	317.67	121.00

Circle Center At X = 132.8 ; Y = 408.0 and Radius, 341.4

*** 2.047 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	79.97
2	79.96	79.03
3	89.93	78.33
4	99.92	77.90
5	109.92	77.71
6	119.92	77.78
7	129.92	78.10

8	139.90	78.68
9	149.86	79.50
10	159.81	80.58
11	169.72	81.91
12	179.59	83.49
13	189.42	85.33
14	199.20	87.40
15	208.93	89.73
16	218.59	92.30
17	228.19	95.12
18	237.71	98.17
19	247.15	101.47
20	256.50	105.01
21	265.77	108.78
22	274.93	112.78
23	283.99	117.02
24	291.97	121.00

Circle Center At X = 112.2 ; Y = 472.6 and Radius, 394.9

*** 2.053 ***

1

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.67	76.92
3	59.40	74.63
4	69.19	72.62
5	79.04	70.88
6	88.94	69.43
7	98.87	68.26
8	108.83	67.37
9	118.81	66.76
10	128.80	66.44
11	138.80	66.41
12	148.80	66.66
13	158.79	67.19
14	168.75	68.01
15	178.69	69.11
16	188.60	70.49
17	198.46	72.15
18	208.27	74.10
19	218.02	76.32
20	227.70	78.82
21	237.31	81.59
22	246.83	84.64
23	256.27	87.95
24	265.60	91.54
25	274.83	95.38
26	283.95	99.49
27	292.95	103.86
28	301.81	108.48
29	310.55	113.35
30	319.14	118.47
31	323.13	121.00

Circle Center At X = 135.1 ; Y = 417.7 and Radius, 351.3

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*** 2.058 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.66	76.91
3	59.39	74.60
4	69.18	72.57
5	79.03	70.81
6	88.92	69.33
7	98.84	68.13
8	108.80	67.20
9	118.78	66.56
10	128.77	66.19
11	138.77	66.11
12	148.77	66.30
13	158.76	66.78
14	168.73	67.54
15	178.68	68.57
16	188.59	69.89
17	198.46	71.48
18	208.29	73.35
19	218.06	75.49
20	227.76	77.90
21	237.39	80.59
22	246.94	83.55
23	256.41	86.77
24	265.78	90.26
25	275.05	94.01
26	284.22	98.01
27	293.26	102.28
28	302.18	106.79
29	310.98	111.55
30	319.63	116.56
31	326.83	121.00

Circle Center At X = 136.8 ; Y = 422.6 and Radius, 356.5

*** 2.065 ***

1

```
                  Y            A        X        I        S              F        T

                .00       51.75    103.50    155.25    207.00    258.75

 X        .00 +---------+---------+---------+---------+---------+
              -                  *
              -                  .
              -                 ..
              -
              -                *.2
        51.75 +               *  .2
              -               *.26
              -       * *     **2*
```

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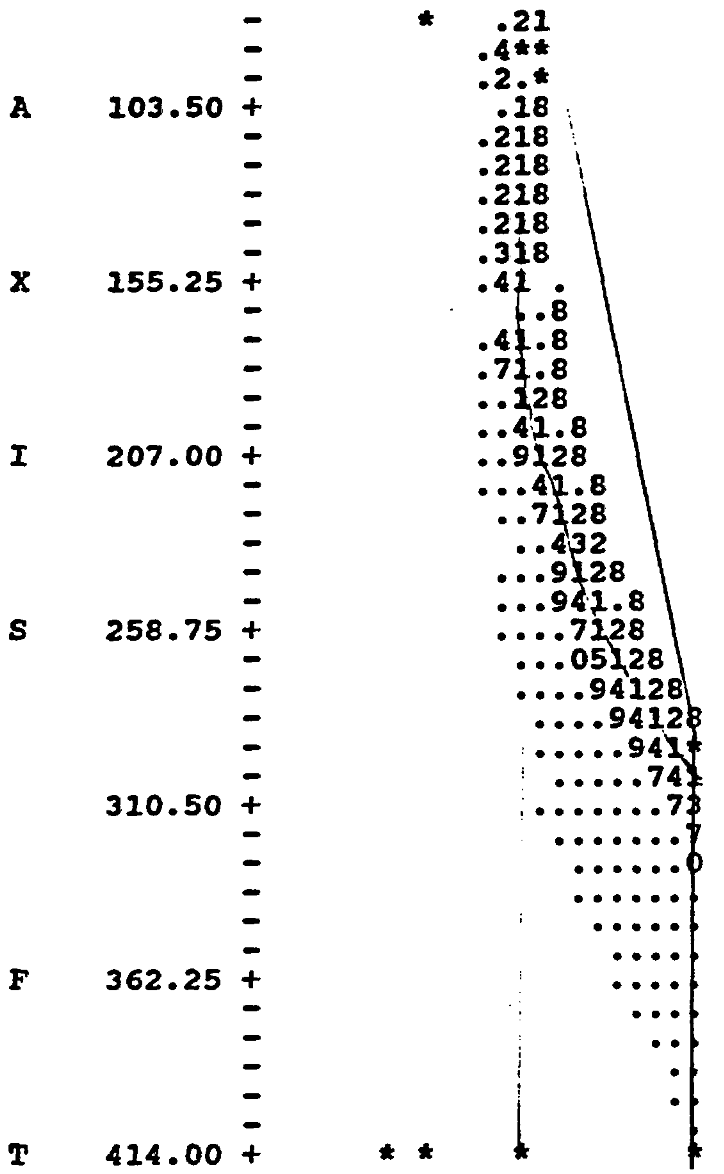

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

150 Trial Surfaces Have Been Generated.

50 Surfaces Initiate From Each Of 3 Points Equally Spaced Along The Ground Surface Between X = 73.00 ft. and X = 85.00 ft.

Each Surface Terminates Between X = 290.00 ft. and X = 410.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 38.00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation.
The Angle Has Been Restricted Between The Angles Of -45.0
And -5.0 deg.

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Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	82.33	76.40
3	91.82	73.26
4	101.46	70.57
5	111.21	68.35
6	121.05	66.60
7	130.97	65.32
8	140.94	64.53
9	150.93	64.21
10	160.93	64.38
11	170.91	65.02
12	180.85	66.14
13	190.72	67.74
14	200.50	69.81
15	210.17	72.35
16	219.71	75.35
17	229.10	78.81
18	238.30	82.71
19	247.31	87.05
20	256.10	91.82
21	264.65	97.01
22	272.95	102.60
23	280.96	108.58
24	288.68	114.94
25	295.35	121.00

Circle Center At X = 152.5 ; Y = 272.3 and Radius, 208.1

*** 2.011 ***

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	79.00	80.00
2	88.33	76.40
3	97.82	73.24
4	107.44	70.52
5	117.18	68.26
6	127.02	66.46

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7	136.93	65.12
8	146.89	64.25
9	156.88	63.84
10	166.88	63.90
11	176.87	64.42
12	186.82	65.42
13	196.71	66.87
14	206.53	68.79
15	216.24	71.17
16	225.83	73.99
17	235.28	77.27
18	244.57	80.98
19	253.67	85.12
20	262.57	89.68
21	271.24	94.65
22	279.68	100.03
23	287.85	105.79
24	295.75	111.93
25	303.34	118.43
26	306.08	121.00

Circle Center At X = 160.6 ; Y = 277.6 and Radius, 213.8

*** 2.030 ***

1

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	82.24	76.17
3	91.65	72.79
4	101.21	69.85
5	110.90	67.38
6	120.69	65.37
7	130.58	63.84
8	140.52	62.77
9	150.50	62.18
10	160.50	62.07
11	170.49	62.44
12	180.46	63.28
13	190.37	64.59
14	200.21	66.38
15	209.95	68.64
16	219.58	71.35
17	229.06	74.53
18	238.38	78.15
19	247.52	82.21
20	256.45	86.71
21	265.16	91.62
22	273.62	96.95
23	281.82	102.67
24	289.74	108.78
25	297.36	115.26
26	303.49	121.00

Circle Center At X = 157.8 ; Y = 271.6 and Radius, 209.5

*** 2.034 ***

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Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	82.34	76.43
3	91.83	73.27
4	101.44	70.52
5	111.17	68.19
6	120.99	66.29
7	130.88	64.81
8	140.82	63.76
9	150.80	63.14
10	160.80	62.96
11	170.80	63.21
12	180.77	63.89
13	190.71	65.00
14	200.59	66.54
15	210.40	68.51
16	220.11	70.90
17	229.70	73.71
18	239.17	76.93
19	248.49	80.56
20	257.64	84.59
21	266.61	89.01
22	275.38	93.82
23	283.93	99.00
24	292.26	104.55
25	300.33	110.45
26	308.14	116.69
27	313.07	121.00

Circle Center At X = 160.1 ; Y = 293.9 and Radius, 230.9

*** 2.035 ***

1

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	79.00	80.00
2	88.68	77.48
3	98.44	75.31
4	108.27	73.48
5	118.16	71.99
6	128.09	70.85
7	138.06	70.05
8	148.05	69.61
9	158.05	69.51
10	168.05	69.76
11	178.03	70.37
12	187.98	71.32
13	197.90	72.62
14	207.76	74.26
15	217.56	76.25

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16	227.29	78.58
17	236.93	81.24
18	246.47	84.25
19	255.89	87.58
20	265.20	91.24
21	274.37	95.23
22	283.40	99.53
23	292.27	104.14
24	300.97	109.07
25	309.50	114.29
26	317.84	119.81
27	319.51	121.00

Circle Center At X = 155.8 ; Y = 355.6 and Radius, 286.1

*** 2.053 ***

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	79.00	80.00
2	88.35	76.46
3	97.85	73.33
4	107.47	70.61
5	117.20	68.30
6	127.02	66.42
7	136.92	64.95
8	146.86	63.91
9	156.84	63.30
10	166.84	63.12
11	176.84	63.37
12	186.82	64.04
13	196.76	65.15
14	206.64	66.68
15	216.45	68.63
16	226.16	71.00
17	235.76	73.78
18	245.24	76.98
19	254.57	80.58
20	263.74	84.57
21	272.73	88.95
22	281.52	93.72
23	290.10	98.86
24	298.45	104.36
25	306.55	110.22
26	314.40	116.41
27	319.72	121.00

Circle Center At X = 166.1 ; Y = 296.2 and Radius, 233.0

*** 2.056 ***

Failure Surface Specified By 28 Coordinate Points

Point X-Surf Y-Surf

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No.	(ft)	(ft)
1	79.00	80.00
2	88.40	76.60
3	97.94	73.58
4	107.59	70.96
5	117.34	68.73
6	127.17	66.91
7	137.07	65.48
8	147.01	64.46
9	157.00	63.84
10	166.99	63.64
11	176.99	63.84
12	186.97	64.45
13	196.92	65.46
14	206.82	66.88
15	216.65	68.70
16	226.40	70.93
17	236.05	73.54
18	245.59	76.55
19	255.00	79.95
20	264.26	83.72
21	273.35	87.87
22	282.28	92.39
23	291.00	97.27
24	299.53	102.50
25	307.83	108.07
26	315.90	113.98
27	323.72	120.21
28	324.63	121.00

Circle Center At X = 167.1 ; Y = 308.8 and Radius, 245.2

*** 2.062 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	85.00	80.00
2	94.14	75.95
3	103.49	72.40
4	113.02	69.36
5	122.69	66.83
6	132.49	64.83
7	142.38	63.36
8	152.34	62.42
9	162.33	62.02
10	172.33	62.16
11	182.31	62.84
12	192.23	64.05
13	202.08	65.79
14	211.82	68.07
15	221.42	70.86
16	230.86	74.17
17	240.10	77.97
18	249.13	82.28
19	257.91	87.06
20	266.43	92.30
21	274.64	98.00
22	282.54	104.13

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23	290.10	110.68
24	297.30	117.63
25	300.43	121.00

Circle Center At X = 164.8 ; Y = 247.7 and Radius, 185.7

*** 2.065 ***

1

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	85.00	80.00
2	94.65	77.37
3	104.39	75.09
4	114.20	73.18
5	124.08	71.62
6	134.01	70.43
7	143.97	69.61
8	153.96	69.15
9	163.96	69.06
10	173.96	69.34
11	183.94	69.98
12	193.89	70.99
13	203.79	72.37
14	213.64	74.11
15	223.42	76.21
16	233.11	78.66
17	242.71	81.48
18	252.19	84.64
19	261.56	88.15
20	270.78	92.00
21	279.87	96.19
22	288.79	100.71
23	297.53	105.55
24	306.10	110.71
25	314.47	116.19
26	321.27	121.00

Circle Center At X = 161.4 ; Y = 341.1 and Radius, 272.0

*** 2.066 ***

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	82.18	76.04
3	91.53	72.49
4	101.03	69.36
5	110.66	66.65
6	120.39	64.38
7	130.22	62.54
8	140.12	61.14

9	150.08	60.17
10	160.06	59.66
11	170.06	59.58
12	180.06	59.95
13	190.02	60.76
14	199.95	62.02
15	209.80	63.71
16	219.57	65.84
17	229.24	68.40
18	238.78	71.39
19	248.18	74.79
20	257.42	78.62
21	266.49	82.85
22	275.35	87.47
23	284.00	92.49
24	292.42	97.88
25	300.59	103.65
26	308.50	109.77
27	316.13	116.23
28	321.27	121.00

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Circle Center At X = 166.8 ; Y = 284.7 and Radius, 225.2

*** 2.079 ***

```
                Y           A       X       I       S               F       T

                 .00     51.75    103.50    155.25    207.00    258.75
X          .00 +---------+---------+---------+---------+---------+
               -              *
               -
               -
               -
               -           *
        51.75  +          *
               -          *
               -     * *  ** *
               -       *    .2
               -           .**
               -          ..1*
A      103.50  +         ..319
               -        ...15.
               -       ...015.
               -      ....315.
               -      ....125.
               -      ....15..
X      155.25  +      ....25..
               -     .....15..
               -     .....31...
               -     .....215..
               -     .....315..
               -      ....015..
I      207.00  +     .....021..
               -     ......621..
               -     .......25..
               -     .......0315..
               -      .......031..
               -      .......0.21..
S      258.75  +      .......7421..
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               -          .........6421.
               -          ..........6421.
               -           ..........64211.
               -           ...........6432*
               -            ..........64.2
       310.50  +             ..........654
               -              ..........75
               -             ............7
               -              ...........
               -               ..........
               -               ..........
 F     362.25  +                .........
               -                 .......
               -                  ......
               -                    .....
               -                      ...
               -                       ..
 T     414.00  +       * *    *         *
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1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

150 Trial Surfaces Have Been Generated.

75 Surfaces Initiate From Each Of 2 Points Equally Spaced Along The Ground Surface Between X = 86.10 ft. and X = 86.20 ft.

Each Surface Terminates Between X = 290.00 ft. and X = 410.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 38.00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -5.0 And 6.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02

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2	96.05	80.97
3	106.00	82.02
4	115.93	83.17
5	125.86	84.41
6	135.77	85.75
7	145.66	87.18
8	155.55	88.71
9	165.41	90.33
10	175.26	92.05
11	185.10	93.86
12	194.92	95.77
13	204.71	97.77
14	214.49	99.87
15	224.25	102.06
16	233.98	104.35
17	243.70	106.73
18	253.38	109.20
19	263.05	111.77
20	272.69	114.42
21	282.30	117.18
22	291.89	120.02
23	295.08	121.00

Circle Center At X = -7.8 ; Y = 1112.5 and Radius, 1036.7

*** 1.822 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.06	80.95
3	106.01	81.97
4	115.94	83.07
5	125.87	84.27
6	135.79	85.56
7	145.69	86.93
8	155.59	88.39
9	165.47	89.95
10	175.33	91.59
11	185.18	93.32
12	195.01	95.13
13	204.83	97.04
14	214.63	99.03
15	224.41	101.11
16	234.17	103.28
17	243.91	105.54
18	253.63	107.89
19	263.33	110.32
20	273.01	112.84
21	282.67	115.44
22	292.30	118.13
23	301.90	120.91
24	302.20	121.00

Circle Center At X = -12.3 ; Y = 1189.2 and Radius, 1113.5

*** 1.911 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.08	80.61
3	106.06	81.33
4	116.02	82.18
5	125.97	83.15
6	135.91	84.26
7	145.84	85.50
8	155.74	86.86
9	165.63	88.35
10	175.50	89.97
11	185.34	91.72
12	195.17	93.60
13	204.96	95.60
14	214.73	97.74
15	224.47	99.99
16	234.19	102.38
17	243.87	104.89
18	253.51	107.52
19	263.12	110.28
20	272.70	113.17
21	282.24	116.18
22	291.73	119.31
23	296.64	121.00

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Circle Center At X = 45.7 ; Y = 849.2 and Radius, 770.2

*** 1.935 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.08	80.60
3	106.06	81.30
4	116.02	82.13
5	125.98	83.08
6	135.92	84.16
7	145.85	85.37
8	155.76	86.69
9	165.65	88.15
10	175.53	89.72
11	185.38	91.42
12	195.21	93.25
13	205.02	95.20
14	214.81	97.27
15	224.56	99.46
16	234.29	101.78
17	243.99	104.22
18	253.66	106.77
19	263.29	109.46
20	272.89	112.26

21	282.45	115.18
22	291.98	118.22
23	300.32	121.00

Circle Center At X = 45.1 ; Y = 874.8 and Radius, 795.9

*** 1.961 ***

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Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	96.20	80.22
3	106.19	80.57
4	116.18	81.10
5	126.15	81.80
6	136.12	82.67
7	146.06	83.72
8	155.99	84.94
9	165.89	86.34
10	175.76	87.90
11	185.61	89.64
12	195.43	91.55
13	205.21	93.63
14	214.95	95.88
15	224.66	98.30
16	234.31	100.89
17	243.93	103.65
18	253.49	106.57
19	263.00	109.66
20	272.46	112.92
21	281.85	116.34
22	291.19	119.92
23	293.86	121.00

Circle Center At X = 81.0 ; Y = 653.7 and Radius, 573.7

*** 1.973 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	96.19	80.46
3	106.18	81.02
4	116.15	81.72
5	126.12	82.56
6	136.07	83.55
7	146.00	84.67
8	155.92	85.94
9	165.82	87.35
10	175.70	88.90
11	185.56	90.59

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12	195.39	92.43
13	205.19	94.40
14	214.97	96.51
15	224.71	98.76
16	234.42	101.15
17	244.10	103.68
18	253.73	106.34
19	263.33	109.14
20	272.89	112.08
21	282.41	115.16
22	291.88	118.37
23	299.29	121.00

Circle Center At X = 62.0 ; Y = 781.1 and Radius, 701.5

*** 1.974 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.07	80.74
3	106.04	81.57
4	116.00	82.50
5	125.94	83.52
6	135.88	84.65
7	145.81	85.87
8	155.72	87.20
9	165.61	88.63
10	175.50	90.15
11	185.36	91.78
12	195.21	93.51
13	205.05	95.33
14	214.86	97.26
15	224.65	99.28
16	234.43	101.40
17	244.18	103.62
18	253.90	105.94
19	263.61	108.35
20	273.29	110.87
21	282.94	113.48
22	292.56	116.19
23	302.16	119.00
24	308.77	121.00

Circle Center At X = 19.3 ; Y = 1068.8 and Radius, 991.0

*** 1.995 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02

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2	96.06	80.97
3	106.00	82.00
4	115.94	83.10
5	125.87	84.27
6	135.79	85.52
7	145.71	86.85
8	155.61	88.24
9	165.50	89.71
10	175.38	91.26
11	185.25	92.88
12	195.10	94.57
13	204.95	96.33
14	214.78	98.17
15	224.59	100.09
16	234.39	102.07
17	244.18	104.13
18	253.95	106.26
19	263.70	108.47
20	273.44	110.75
21	283.16	113.10
22	292.86	115.52
23	302.54	118.01
24	312.21	120.58
25	313.74	121.00

Circle Center At X = -36.4 ; Y = 1413.4 and Radius, 1339.0

*** 1.996 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.10	79.77
3	106.10	79.72
4	116.10	79.88
5	126.09	80.25
6	136.07	80.83
7	146.04	81.62
8	155.99	82.62
9	165.92	83.83
10	175.82	85.24
11	185.69	86.86
12	195.52	88.68
13	205.31	90.71
14	215.06	92.95
15	224.75	95.39
16	234.40	98.03
17	243.99	100.87
18	253.51	103.91
19	262.97	107.15
20	272.37	110.59
21	281.68	114.22
22	290.92	118.04
23	297.66	121.00

Circle Center At X = 103.3 ; Y = 558.0 and Radius, 478.3

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*** 2.023 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	96.19	79.59
3	106.19	79.37
4	116.19	79.38
5	126.18	79.62
6	136.17	80.10
7	146.15	80.81
8	156.10	81.74
9	166.04	82.91
10	175.94	84.31
11	185.80	85.95
12	195.63	87.80
13	205.41	89.89
14	215.14	92.20
15	224.81	94.74
16	234.42	97.50
17	243.97	100.49
18	253.44	103.69
19	262.83	107.12
20	272.15	110.76
21	281.37	114.62
22	290.51	118.69
23	295.38	121.00

Circle Center At X = 110.7 ; Y = 509.9 and Radius, 430.5

*** 2.031 ***

1

```
                Y                A         X         I         S              F         T

                .00        51.75     103.50     155.25     207.00     258.75

X        .00 +---------+---------+---------+---------+---------+
             -              *
             -              |
             -              |
             -              |
             -         *    |
      51.75  +        *     |
             -        *     |
             -   *  *  **  *
             -      *       |
             -          **
             -              *1
A    103.50  +              91
             -              91
             -
             -              01
             -              031
             -              .41
```

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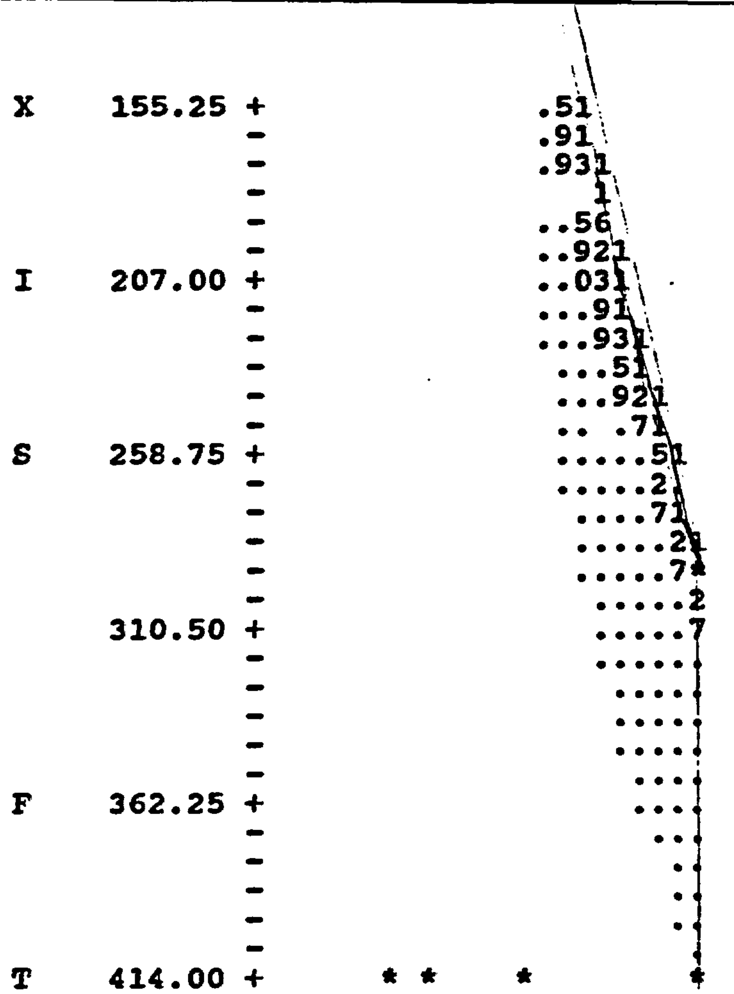

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

150 Trial Surfaces Have Been Generated.

75 Surfaces Initiate From Each Of 2 Points Equally Spaced Along The Ground Surface Between X = 86.10 ft. and X = 86.20 ft.

Each Surface Terminates Between X = 290.00 ft. and X = 410.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 38.00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -45.0 And -5.0 deg.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical

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First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	95.37	76.26
3	104.82	73.00
4	114.43	70.24
5	124.18	68.01
6	134.03	66.31
7	143.96	65.13
8	153.94	64.49
9	163.94	64.38
10	173.93	64.81
11	183.89	65.77
12	193.78	67.27
13	203.57	69.29
14	213.24	71.84
15	222.76	74.90
16	232.10	78.46
17	241.24	82.52
18	250.15	87.07
19	258.80	92.08
20	267.17	97.55
21	275.24	103.46
22	282.98	109.80
23	290.36	116.54
24	294.76	121.00

Circle Center At X = 160.9 ; Y = 251.0 and Radius, 186.6

*** 2.043 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.06	79.09
3	106.04	78.44
4	116.03	78.08
5	126.03	78.00
6	136.03	78.21
7	146.02	78.70
8	155.99	79.47
9	165.93	80.53
10	175.84	81.87
11	185.71	83.49
12	195.52	85.39
13	205.28	87.57
14	214.98	90.02
15	224.60	92.75
16	234.14	95.76

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17	243.59	99.03
18	252.94	102.57
19	262.19	106.37
20	271.32	110.44
21	280.34	114.76
22	289.23	119.34
23	292.24	121.00

Circle Center At X = 123.8 ; Y = 429.7 and Radius, 351.7

*** 2.060 ***

1

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	95.48	76.31
3	104.92	73.02
4	114.52	70.20
5	124.23	67.84
6	134.05	65.95
7	143.95	64.53
8	153.91	63.60
9	163.90	63.14
10	173.90	63.16
11	183.88	63.67
12	193.84	64.66
13	203.73	66.12
14	213.54	68.06
15	223.24	70.47
16	232.82	73.34
17	242.25	76.67
18	251.51	80.45
19	260.57	84.67
20	269.43	89.33
21	278.04	94.40
22	286.41	99.89
23	294.49	105.76
24	302.29	112.03
25	309.78	118.66
26	312.18	121.00

Circle Center At X = 168.4 ; Y = 270.8 and Radius, 207.7

*** 2.065 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	95.26	75.81
3	104.55	72.11
4	114.04	68.96

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5	123.70	66.37
6	133.49	64.34
7	143.39	62.88
8	153.35	62.00
9	163.34	61.69
10	173.34	61.97
11	183.30	62.83
12	193.20	64.26
13	203.00	66.27
14	212.66	68.84
15	222.16	71.97
16	231.46	75.64
17	240.53	79.85
18	249.34	84.57
19	257.87	89.80
20	266.07	95.52
21	273.93	101.70
22	281.42	108.33
23	288.51	115.38
24	293.55	121.00

Circle Center At X = 163.6 ; Y = 234.0 and Radius, 172.3

*** 2.079 ***

1

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	95.55	76.76
3	105.13	73.88
4	114.81	71.39
5	124.59	69.29
6	134.45	67.59
7	144.36	66.28
8	154.32	65.38
9	164.31	64.87
10	174.31	64.77
11	184.30	65.07
12	194.28	65.78
13	204.22	66.88
14	214.10	68.39
15	223.92	70.29
16	233.65	72.59
17	243.28	75.27
18	252.80	78.35
19	262.19	81.80
20	271.42	85.63
21	280.50	89.82
22	289.40	94.38
23	298.11	99.29
24	306.62	104.55
25	314.90	110.15
26	322.96	116.08
27	329.11	121.00

Circle Center At X = 171.8 ; Y = 313.0 and Radius, 248.3

*** 2.087 ***

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Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	95.46	76.27
3	104.88	72.91
4	114.44	69.98
5	124.12	67.48
6	133.91	65.40
7	143.77	63.77
8	153.70	62.57
9	163.67	61.82
10	173.67	61.51
11	183.67	61.64
12	193.65	62.22
13	203.60	63.24
14	213.49	64.71
15	223.31	66.61
16	233.03	68.95
17	242.64	71.71
18	252.12	74.90
19	261.44	78.51
20	270.60	82.53
21	279.57	86.95
22	288.33	91.77
23	296.88	96.97
24	305.18	102.54
25	313.22	108.48
26	321.00	114.77
27	328.03	121.00

Circle Center At X = 175.6 ; Y = 286.5 and Radius, 225.0

*** 2.107 ***

1

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	95.87	77.87
3	105.71	76.08
4	115.60	74.67
5	125.55	73.62
6	135.53	72.94
7	145.52	72.64
8	155.52	72.71
9	165.51	73.15
10	175.48	73.96
11	185.41	75.14
12	195.29	76.69
13	205.10	78.61
14	214.84	80.89

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15	224.48	83.53
16	234.02	86.53
17	243.44	89.89
18	252.73	93.59
19	261.88	97.64
20	270.87	102.02
21	279.68	106.73
22	288.32	111.77
23	296.76	117.13
24	302.38	121.00

Circle Center At X = 148.7 ; Y = 341.1 and Radius, 268.5

*** 2.110 ***

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	95.69	76.88
3	105.29	74.08
4	114.99	71.65
5	124.77	69.58
6	134.63	67.88
7	144.54	66.55
8	154.49	65.59
9	164.47	65.01
10	174.47	64.80
11	184.47	64.97
12	194.46	65.51
13	204.41	66.43
14	214.33	67.72
15	224.19	69.39
16	233.98	71.42
17	243.69	73.82
18	253.30	76.58
19	262.80	79.70
20	272.18	83.18
21	281.42	87.00
22	290.50	91.17
23	299.43	95.68
24	308.18	100.52
25	316.74	105.69
26	325.11	111.17
27	333.26	116.97
28	338.50	121.00

Circle Center At X = 175.0 ; Y = 331.0 and Radius, 266.2

*** 2.113 ***

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)

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1	86.20	80.04
2	95.86	77.44
3	105.59	75.17
4	115.40	73.21
5	125.27	71.59
6	135.18	70.29
7	145.14	69.32
8	155.12	68.68
9	165.11	68.38
10	175.11	68.40
11	185.11	68.76
12	195.08	69.45
13	205.03	70.47
14	214.94	71.82
15	224.80	73.49
16	234.60	75.49
17	244.32	77.82
18	253.96	80.47
19	263.51	83.43
20	272.96	86.71
21	282.29	90.31
22	291.50	94.21
23	300.58	98.41
24	309.50	102.91
25	318.28	107.71
26	326.89	112.79
27	335.33	118.16
28	339.49	121.00

Circle Center At X = 169.3 ; Y = 369.8 and Radius, 301.5

*** 2.121 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	96.06	78.35
3	105.97	77.00
4	115.91	75.98
5	125.89	75.31
6	135.88	74.97
7	145.88	74.97
8	155.88	75.31
9	165.86	75.99
10	175.80	77.00
11	185.71	78.36
12	195.57	80.05
13	205.36	82.07
14	215.08	84.42
15	224.71	87.10
16	234.25	90.11
17	243.68	93.44
18	252.99	97.09
19	262.17	101.05
20	271.22	105.32
21	280.11	109.90
22	288.84	114.77
23	297.40	119.94

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24 299.03 121.00

Circle Center At X = 140.9 ; Y = 369.6 and Radius, 294.7

*** 2.133 ***

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```
                   Y            A     X     I     S            F     T

                    .00     51.75    103.50    155.25    207.00    258.75
        X       .00 +---------+---------+---------+---------+---------+
                    -              *
                    -
                    -
                    -
                    -            *
              51.75 +           *
                    -           *
                    -      * *  ** *
                    -        *
                    -             **
                    -             .*
        A    103.50 +            .12
                    -           .412
                    -          ..1.
                    -         ..4 72
                    -        ....172
                    -       ....3172
        X    155.25 +       ....1572
                    -       ....15702
                    -      .....31702
                    -      .....31.7
                    -      .....31.02
                    -      ......5.7 2
        I    207.00 +      .....619702
                    -      ......31.72
                    -      .......61.702
                    -       .....631.7 2
                    -      .......631702
                    -       ......6531702
        S    258.75 +       .......6341702
                    -       ........634172
                    -        .......863.17
                    -        ........563.12
                    -         ........563..*
                    -         ........856.37
             310.50 +         .........856.3
                    -          .........855.
                    -           .........895
                    -           ...........8
                    -            ...........
                    -             ..........
        F    362.25 +              .........
                    -               ........
                    -                .......
                    -                  .....
                    -                    ...
                    -                      .
        T    414.00 +      * *    *        *
```

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** PCSTABL5 **

by
Purdue University

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer's Method of Slices

PRC from
B-1 thru B-33
4/6/9.

Run Date: 4 APRIL 90
Time of Run: AFTERNOON
Run By: MJG
Input Data Filename: IN2
Output Filename: OUT2

PROBLEM DESCRIPTION END OF CONSTRUCTION CASE W/EARTHQUAKE LO
ADING

BOUNDARY COORDINATES

4 Top Boundaries
26 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	9.00	79.00	72.00	80.00	5
2	72.00	80.00	86.00	80.00	1
3	86.00	80.00	289.00	121.00	1
4	289.00	121.00	414.00	121.00	1
5	9.00	79.00	46.00	66.00	6
6	46.00	66.00	72.00	80.00	1
7	46.00	66.00	53.00	64.00	6
8	53.00	64.00	68.00	67.00	2
9	68.00	67.00	94.00	80.00	2
10	94.00	80.00	289.00	119.50	2
11	289.00	119.50	414.00	119.50	2
12	53.00	64.00	56.00	62.00	6
13	56.00	62.00	62.00	62.50	5
14	62.00	62.50	70.00	64.00	4
15	70.00	64.00	88.00	73.00	4
16	88.00	73.00	96.00	77.00	3
17	96.00	77.00	289.00	116.50	3
18	289.00	116.50	414.00	116.50	3
19	62.00	62.50	75.00	49.00	5
20	56.00	62.00	70.00	49.00	6
21	70.00	49.00	75.00	49.00	4
22	88.00	73.00	414.00	73.00	4
23	70.00	49.00	70.10	44.00	6
24	70.10	44.00	414.00	44.00	5
25	70.10	44.00	70.20	38.00	6
26	70.20	38.00	414.00	38.00	6

ISOTROPIC SOIL PARAMETERS

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6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	130.0	.0	.0	38.0	.00	.0	1
2	130.0	.0	60.0	25.0	.00	.0	1
3	105.0	.0	.0	35.0	.00	.0	1
4	115.0	.0	500.0	16.0	.00	.0	1
5	115.0	.0	500.0	16.0	.00	.0	1
6	100.0	.0	10000.0	.0	.00	.0	1

1

Searching Routine Will Be Limited To An Area Defined By 4 Boundaries Of Which The First 4 Boundaries Will Deflect Surfaces Upward

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)
1	9.00	79.00	53.00	64.00
2	53.00	64.00	70.00	49.00
3	70.00	49.00	70.20	38.00
4	70.20	38.00	414.00	38.00

A Horizontal Earthquake Loading Coefficient Of .100 Has Been Assigned

A Vertical Earthquake Loading Coefficient Of .000 Has Been Assigned

Cavitation Pressure = .0 psf

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

90 Trial Surfaces Have Been Generated.

30 Surfaces Initiate From Each Of 3 Points Equally Spaced Along The Ground Surface Between X = 10.00 ft. and X = 70.00 ft.

Each Surface Terminates Between X = 290.00 ft. and X = 410.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 38.00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -15.0

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And -5.0 deg.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	79.97
2	79.67	77.43
3	89.42	75.19
4	99.22	73.23
5	109.09	71.56
6	118.99	70.19
7	128.93	69.11
8	138.90	68.33
9	148.89	67.85
10	158.89	67.66
11	168.89	67.76
12	178.88	68.17
13	188.85	68.87
14	198.81	69.86
15	208.72	71.15
16	218.60	72.74
17	228.42	74.61
18	238.18	76.78
19	247.87	79.23
20	257.49	81.98
21	267.02	85.00
22	276.46	88.31
23	285.79	91.89
24	295.02	95.75
25	304.13	99.89
26	313.10	104.29
27	321.95	108.95
28	330.65	113.88
29	339.21	119.06
30	342.20	121.00

Circle Center At X = 160.3 ; Y = 404.7 and Radius, 337.1

*** 2.249 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	79.97
2	79.66	77.38
3	89.39	75.07

4	99.18	73.04
5	109.03	71.30
6	118.92	69.83
7	128.85	68.65
8	138.81	67.75
9	148.79	67.14
10	158.79	66.81
11	168.79	66.77
12	178.78	67.02
13	188.77	67.55
14	198.73	68.37
15	208.67	69.47
16	218.58	70.86
17	228.44	72.53
18	238.24	74.48
19	247.99	76.71
20	257.67	79.22
21	267.28	82.01
22	276.80	85.07
23	286.23	88.40
24	295.56	91.99
25	304.78	95.86
26	313.89	99.98
27	322.88	104.37
28	331.73	109.01
29	340.46	113.90
30	349.03	119.04
31	352.09	121.00

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Circle Center At X = 165.2 ; Y = 416.1 and Radius, 349.4

*** 2.250 ***

1

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	79.97
2	79.66	77.38
3	89.39	75.07
4	99.18	73.03
5	109.02	71.26
6	118.91	69.77
7	128.84	68.56
8	138.79	67.63
9	148.77	66.97
10	158.76	66.59
11	168.76	66.49
12	178.76	66.68
13	188.75	67.14
14	198.72	67.88
15	208.67	68.90
16	218.59	70.19
17	228.46	71.77
18	238.29	73.62
19	248.06	75.74
20	257.77	78.13
21	267.41	80.80
22	276.97	83.73
23	286.44	86.93

24	295.82	90.40
25	305.11	94.12
26	314.28	98.10
27	323.34	102.34
28	332.27	106.83
29	341.08	111.57
30	349.75	116.55
31	357.02	121.00

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Circle Center At X = 167.3 ; Y = 424.2 and Radius, 357.7

*** 2.257 ***

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	79.97
2	79.72	77.62
3	89.52	75.62
4	99.38	73.96
5	109.30	72.66
6	119.25	71.70
7	129.23	71.10
8	139.23	70.85
9	149.23	70.95
10	159.22	71.41
11	169.18	72.21
12	179.12	73.37
13	189.00	74.88
14	198.83	76.74
15	208.58	78.94
16	218.25	81.49
17	227.83	84.37
18	237.29	87.60
19	246.64	91.15
20	255.86	95.03
21	264.93	99.24
22	273.85	103.76
23	282.60	108.59
24	291.18	113.73
25	299.57	119.17
26	302.18	121.00

Circle Center At X = 141.3 ; Y = 354.1 and Radius, 283.2

*** 2.278 ***

1

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.66	76.91
3	59.39	74.60

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4	69.18	72.57
5	79.03	70.81
6	88.92	69.33
7	98.84	68.13
8	108.80	67.20
9	118.78	66.56
10	128.77	66.19
11	138.77	66.11
12	148.77	66.30
13	158.76	66.78
14	168.73	67.54
15	178.68	68.57
16	188.59	69.89
17	198.46	71.48
18	208.29	73.35
19	218.06	75.49
20	227.76	77.90
21	237.39	80.59
22	246.94	83.55
23	256.41	86.77
24	265.78	90.26
25	275.05	94.01
26	284.22	98.01
27	293.26	102.28
28	302.18	106.79
29	310.98	111.55
30	319.63	116.56
31	326.83	121.00

Circle Center At X = 136.8 ; Y = 422.6 and Radius, 356.5

*** 2.282 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	79.97
2	79.69	77.49
3	89.44	75.27
4	99.25	73.31
5	109.10	71.63
6	119.00	70.21
7	128.94	69.06
8	138.90	68.18
9	148.88	67.58
10	158.87	67.24
11	168.87	67.18
12	178.87	67.38
13	188.86	67.86
14	198.83	68.61
15	208.78	69.63
16	218.70	70.92
17	228.57	72.48
18	238.40	74.30
19	248.18	76.40
20	257.90	78.75
21	267.55	81.37
22	277.13	84.26
23	286.62	87.40
24	296.03	90.79

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25	305.34	94.44
26	314.54	98.35
27	323.64	102.50
28	332.62	106.89
29	341.48	111.53
30	350.21	116.41
31	357.93	121.00

Circle Center At X = 166.3 ; Y = 435.4 and Radius, 368.2

*** 2.286 ***

1

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.67	76.92
3	59.40	74.63
4	69.19	72.62
5	79.04	70.88
6	88.94	69.43
7	98.87	68.26
8	108.83	67.37
9	118.81	66.76
10	128.80	66.44
11	138.80	66.41
12	148.80	66.66
13	158.79	67.19
14	168.75	68.01
15	178.69	69.11
16	188.60	70.49
17	198.46	72.15
18	208.27	74.10
19	218.02	76.32
20	227.70	78.82
21	237.31	81.59
22	246.83	84.64
23	256.27	87.95
24	265.60	91.54
25	274.83	95.38
26	283.95	99.49
27	292.95	103.86
28	301.81	108.48
29	310.55	113.35
30	319.14	118.47
31	323.13	121.00

Circle Center At X = 135.1 ; Y = 417.7 and Radius, 351.3

*** 2.287 ***

Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)

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1	40.00	79.49
2	49.66	76.91
3	59.40	74.62
4	69.19	72.61
5	79.04	70.89
6	88.94	69.46
7	98.88	68.32
8	108.84	67.47
9	118.82	66.92
10	128.82	66.65
11	138.82	66.68
12	148.81	67.00
13	158.80	67.62
14	168.75	68.52
15	178.68	69.72
16	188.57	71.21
17	198.41	72.99
18	208.20	75.05
19	217.92	77.40
20	227.56	80.03
21	237.13	82.95
22	246.61	86.14
23	255.98	89.61
24	265.26	93.36
25	274.42	97.37
26	283.45	101.65
27	292.36	106.19
28	301.13	110.99
29	309.76	116.05
30	317.67	121.00

Circle Center At X = 132.8 ; Y = 408.0 and Radius, 341.4

*** 2.287 ***

1

Failure Surface Specified By 32 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	79.97
2	79.69	77.48
3	89.44	75.26
4	99.24	73.29
5	109.09	71.59
6	118.99	70.14
7	128.92	68.97
8	138.88	68.05
9	148.86	67.41
10	158.85	67.03
11	168.85	66.91
12	178.85	67.06
13	188.84	67.48
14	198.82	68.16
15	208.77	69.11
16	218.70	70.33
17	228.59	71.80
18	238.43	73.54
19	248.23	75.55
20	257.97	77.81

21	267.65	80.33
22	277.26	83.11
23	286.79	86.14
24	296.23	89.42
25	305.59	92.96
26	314.84	96.74
27	324.00	100.77
28	333.04	105.04
29	341.96	109.55
30	350.76	114.29
31	359.44	119.27
32	362.27	121.00

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Circle Center At X = 168.2 ; Y = 442.4 and Radius, 375.5

*** 2.291 ***

Failure Surface Specified By 34 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	40.00	79.49
2	49.67	76.94
3	59.40	74.63
4	69.18	72.55
5	79.01	70.72
6	88.88	69.12
7	98.79	67.76
8	108.73	66.65
9	118.69	65.78
10	128.67	65.15
11	138.66	64.77
12	148.66	64.63
13	158.66	64.73
14	168.66	65.08
15	178.64	65.67
16	188.60	66.50
17	198.55	67.58
18	208.46	68.90
19	218.34	70.46
20	228.17	72.26
21	237.96	74.30
22	247.70	76.57
23	257.38	79.09
24	266.99	81.84
25	276.54	84.82
26	286.01	88.03
27	295.39	91.48
28	304.70	95.15
29	313.91	99.05
30	323.02	103.17
31	332.02	107.51
32	340.92	112.07
33	349.71	116.85
34	356.92	121.00

Circle Center At X = 149.4 ; Y = 474.8 and Radius, 410.2

*** 2.299 ***

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           Y            A     X     I     S            F     T

            .00     51.75   103.50    155.25    207.00    258.75

X       .00 +---------+---------+---------+---------+---------+
            -              *
            -              .
            -             ..
            -
            -            *.5
      51.75 +           * .5
            -           *.5.
            -      * *  **5*
            -        *   .51
            -           .5**
            -           .52*
A    103.50 +            .1.
            -           .51.
            -           .21.
            -           .14.
            -           .14.
            -           014.
X    155.25 +           .14 .
            -              ...
            -           .14..
            -           .14..
            -           .14..
            -           .154..
I    207.00 +           .214..
            -           ..154..
            -            .154..
            -             6.8..
            -            .2154..
            -            ..1584..
S    258.75 +            ..2154..
            -             ..1574..
            -             ..21584..
            -              ..21584..
            -              ..321584*
            -               ..31.5.4
     310.50 +              ....21.5.
            -               ...921.5
            -                ..96215
            -                ...9321
            -                 ...931
            -                  ...62
F    362.25 +                  ....9
            -                   ....
            -                    ...
            -                     ..
            -                     ..
            -                      .
T    414.00 +      * *    *        *
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1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

150 Trial Surfaces Have Been Generated.

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50 Surfaces Initiate From Each Of 3 Points Equally Spaced
Along The Ground Surface Between X = 73.00 ft.
and X = 85.00 ft.

Each Surface Terminates Between X = 290.00 ft.
and X = 410.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y = 38.00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation.
The Angle Has Been Restricted Between The Angles Of -45.0
And -5.0 deg.

1

Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Examined. They Are Ordered - Most Critical
First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	79.00	80.00
2	87.78	75.21
3	96.79	70.87
4	106.00	66.99
5	115.41	63.59
6	124.97	60.67
7	134.67	58.24
8	144.49	56.31
9	154.38	54.89
10	164.34	53.96
11	174.33	53.55
12	184.33	53.64
13	194.31	54.24
14	204.25	55.35
15	214.12	56.97
16	223.89	59.08
17	233.55	61.69
18	243.06	64.79
19	252.39	68.37
20	261.54	72.41
21	270.47	76.92
22	279.15	81.88
23	287.57	87.27
24	295.71	93.08
25	303.54	99.30
26	311.04	105.91
27	318.20	112.90

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28	324.99	120.24
29	325.63	121.00

Circle Center At X = 177.5 ; Y = 249.9 and Radius, 196.4

*** 1.980 ***

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	81.95	75.53
3	91.10	71.51
4	100.45	67.94
5	109.95	64.84
6	119.60	62.20
7	129.36	60.04
8	139.22	58.36
9	149.15	57.16
10	159.12	56.46
11	169.12	56.24
12	179.12	56.51
13	189.09	57.27
14	199.01	58.52
15	208.86	60.26
16	218.61	62.47
17	228.24	65.16
18	237.73	68.32
19	247.05	71.94
20	256.18	76.01
21	265.10	80.53
22	273.80	85.47
23	282.23	90.84
24	290.40	96.61
25	298.27	102.78
26	305.83	109.33
27	313.06	116.23
28	317.58	121.00

Circle Center At X = 168.6 ; Y = 260.3 and Radius, 204.0

*** 1.980 ***

1

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	81.37	74.53
3	90.05	69.56
4	99.01	65.12
5	108.21	61.21
6	117.63	57.86
7	127.24	55.06

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8	136.99	52.85
9	146.85	51.21
10	156.80	50.16
11	166.79	49.71
12	176.79	49.84
13	186.76	50.57
14	196.67	51.88
15	206.49	53.78
16	216.18	56.26
17	225.70	59.31
18	235.03	62.92
19	244.13	67.07
20	252.96	71.75
21	261.50	76.95
22	269.72	82.65
23	277.59	88.82
24	285.08	95.45
25	292.16	102.51
26	298.81	109.98
27	305.01	117.82
28	307.23	121.00

Circle Center At X = 169.5 ; Y = 218.5 and Radius, 168.8

*** 1.980 ***

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	81.85	75.34
3	90.94	71.17
4	100.24	67.50
5	109.73	64.34
6	119.37	61.70
7	129.15	59.58
8	139.02	58.00
9	148.97	56.96
10	158.95	56.45
11	168.95	56.49
12	178.94	57.07
13	188.87	58.19
14	198.74	59.85
15	208.49	62.04
16	218.12	64.75
17	227.58	67.98
18	236.85	71.72
19	245.91	75.96
20	254.73	80.69
21	263.27	85.88
22	271.52	91.53
23	279.46	97.62
24	287.05	104.13
25	294.27	111.04
26	301.12	118.33
27	303.36	121.00

Circle Center At X = 163.3 ; Y = 240.8 and Radius, 184.4

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*** 1.981 ***

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	81.61	74.91
3	90.50	70.34
4	99.65	66.29
5	109.01	62.79
6	118.57	59.84
7	128.28	57.46
8	138.12	55.65
9	148.04	54.42
10	158.02	53.78
11	168.02	53.72
12	178.00	54.24
13	187.94	55.36
14	197.80	57.05
15	207.54	59.32
16	217.13	62.15
17	226.54	65.54
18	235.73	69.48
19	244.67	73.95
20	253.34	78.94
21	261.70	84.42
22	269.73	90.39
23	277.39	96.82
24	284.66	103.68
25	291.51	110.96
26	297.93	118.63
27	299.69	121.00

Circle Center At X = 164.0 ; Y = 224.2 and Radius, 170.5

*** 1.981 ***

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	79.00	80.00
2	87.30	74.42
3	95.93	69.37
4	104.86	64.87
5	114.05	60.93
6	123.47	57.56
7	133.07	54.78
8	142.83	52.61
9	152.71	51.05
10	162.67	50.10
11	172.66	49.77
12	182.66	50.06
13	192.62	50.97
14	202.50	52.49

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15	212.27	54.63
16	221.89	57.37
17	231.32	60.69
18	240.52	64.60
19	249.47	69.07
20	258.12	74.09
21	266.44	79.63
22	274.40	85.68
23	281.98	92.21
24	289.13	99.20
25	295.83	106.62
26	302.07	114.44
27	306.66	121.00

Circle Center At X = 173.0 ; Y = 210.9 and Radius, 161.2

*** 1.992 ***

1

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	73.00	80.00
2	81.17	74.23
3	89.64	68.92
4	98.39	64.07
5	107.39	59.71
6	116.61	55.84
7	126.03	52.49
8	135.62	49.64
9	145.34	47.33
10	155.18	45.55
11	165.11	44.31
12	175.08	43.61
13	185.08	43.45
14	195.07	43.84
15	205.03	44.77
16	214.92	46.24
17	224.72	48.25
18	234.39	50.79
19	243.91	53.85
20	253.25	57.43
21	262.38	61.50
22	271.27	66.07
23	279.91	71.12
24	288.25	76.63
25	296.29	82.58
26	303.98	88.97
27	311.32	95.76
28	318.28	102.95
29	324.83	110.50
30	330.97	118.39
31	332.78	121.00

Circle Center At X = 183.0 ; Y = 227.1 and Radius, 183.6

*** 1.993 ***

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Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	79.00	80.00
2	87.41	74.59
3	96.09	69.62
4	105.01	65.10
5	114.16	61.06
6	123.50	57.49
7	133.01	54.42
8	142.67	51.84
9	152.46	49.76
10	162.33	48.20
11	172.28	47.15
12	182.26	46.61
13	192.26	46.60
14	202.25	47.10
15	212.20	48.12
16	222.08	49.65
17	231.87	51.69
18	241.54	54.24
19	251.07	57.29
20	260.42	60.82
21	269.58	64.84
22	278.52	69.32
23	287.21	74.26
24	295.64	79.65
25	303.77	85.47
26	311.59	91.69
27	319.08	98.32
28	326.22	105.33
29	332.98	112.69
30	339.36	120.40
31	339.80	121.00

Circle Center At X = 187.6 ; Y = 239.4 and Radius, 192.9

*** 1.993 ***

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	85.00	80.00
2	93.67	75.01
3	102.62	70.55
4	111.82	66.63
5	121.24	63.28
6	130.85	60.51
7	140.60	58.31
8	150.47	56.71
9	160.42	55.71
10	170.41	55.30
11	180.41	55.50
12	190.38	56.31
13	200.28	57.71

14	210.08	59.70
15	219.74	62.29
16	229.23	65.45
17	238.51	69.17
18	247.55	73.45
19	256.31	78.27
20	264.77	83.60
21	272.89	89.44
22	280.64	95.75
23	288.00	102.52
24	294.94	109.73
25	301.43	117.33
26	304.20	121.00

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Circle Center At X = 172.1 ; Y = 221.2 and Radius, 165.9

*** 1.997 ***

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	85.00	80.00
2	93.58	74.86
3	102.42	70.18
4	111.50	65.99
5	120.79	62.29
6	130.26	59.09
7	139.89	56.40
8	149.65	54.23
9	159.52	52.59
10	169.46	51.48
11	179.44	50.90
12	189.44	50.85
13	199.43	51.34
14	209.37	52.37
15	219.25	53.93
16	229.03	56.01
17	238.69	58.61
18	248.19	61.73
19	257.51	65.35
20	266.63	69.46
21	275.51	74.06
22	284.13	79.13
23	292.47	84.65
24	300.50	90.60
25	308.20	96.98
26	315.55	103.77
27	322.52	110.93
28	329.10	118.46
29	331.09	121.00

Circle Center At X = 185.3 ; Y = 237.6 and Radius, 186.7

*** 1.998 ***

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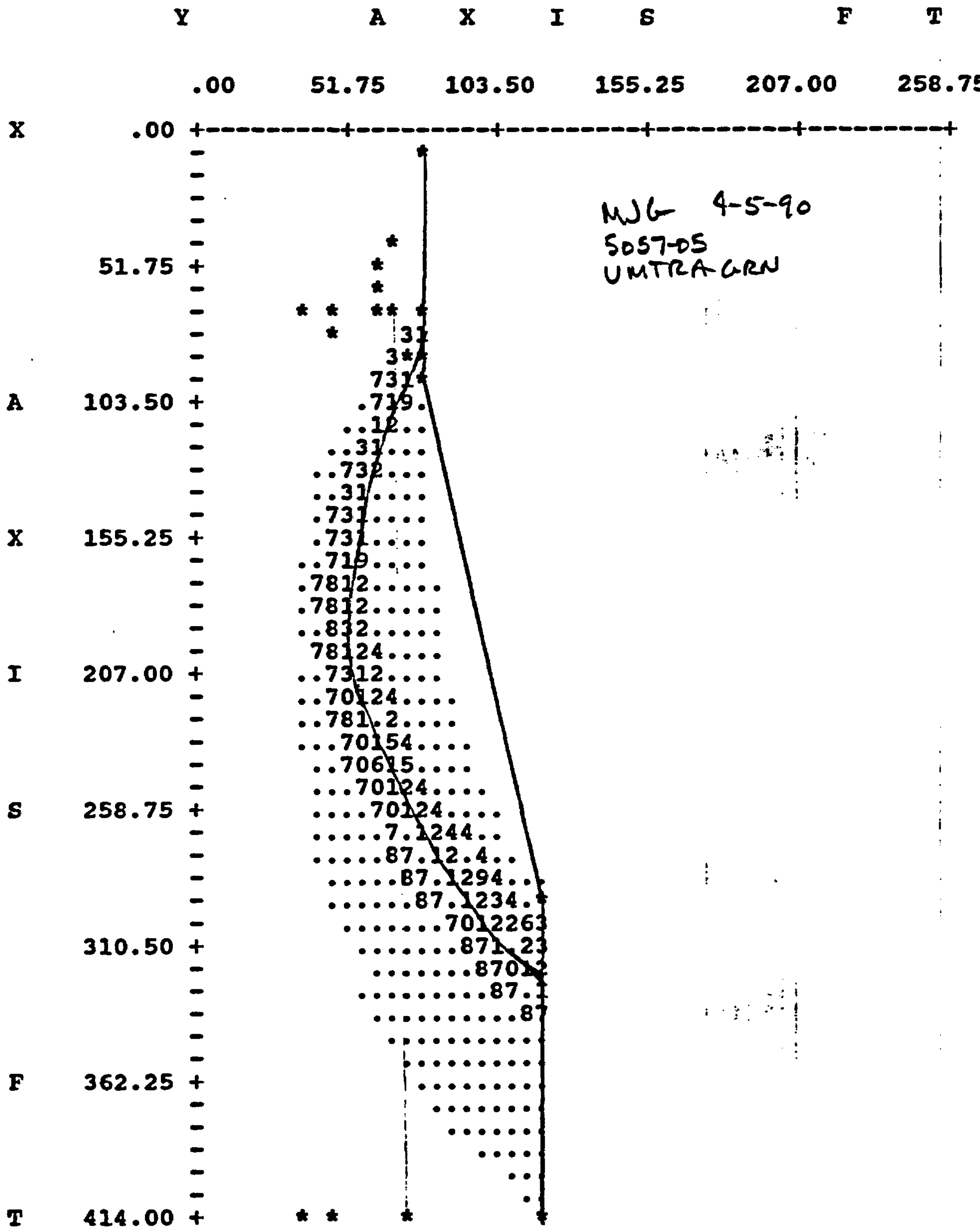

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

150 Trial Surfaces Have Been Generated.

75 Surfaces Initiate From Each Of 2 Points Equally Spaced Along The Ground Surface Between X = 86.10 ft.

and X = 86.20 ft.

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Each Surface Terminates Between X = 290.00 ft.
and X = 410.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 38.00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -5.0 And 6.0 deg.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.05	80.97
3	106.00	82.02
4	115.93	83.17
5	125.86	84.41
6	135.77	85.75
7	145.66	87.18
8	155.55	88.71
9	165.41	90.33
10	175.26	92.05
11	185.10	93.86
12	194.92	95.77
13	204.71	97.77
14	214.49	99.87
15	224.25	102.06
16	233.98	104.35
17	243.70	106.73
18	253.38	109.20
19	263.05	111.77
20	272.69	114.42
21	282.30	117.18
22	291.89	120.02
23	295.08	121.00

Circle Center At X = -7.8 ; Y = 1112.5 and Radius, 1036.7

*** 2.209 ***

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Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.06	80.95
3	106.01	81.97
4	115.94	83.07
5	125.87	84.27
6	135.79	85.56
7	145.69	86.93
8	155.59	88.39
9	165.47	89.95
10	175.33	91.59
11	185.18	93.32
12	195.01	95.13
13	204.83	97.04
14	214.63	99.03
15	224.41	101.11
16	234.17	103.28
17	243.91	105.54
18	253.63	107.89
19	263.33	110.32
20	273.01	112.84
21	282.67	115.44
22	292.30	118.13
23	301.90	120.91
24	302.20	121.00

Circle Center At X = -12.3 ; Y = 1189.2 and Radius, 1113.5

*** 2.266 ***

1

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.08	80.61
3	106.06	81.33
4	116.02	82.18
5	125.97	83.15
6	135.91	84.26
7	145.84	85.50
8	155.74	86.86
9	165.63	88.35
10	175.50	89.97
11	185.34	91.72
12	195.17	93.60
13	204.96	95.60
14	214.73	97.74
15	224.47	99.99
16	234.19	102.38
17	243.87	104.89
18	253.51	107.52
19	263.12	110.28
20	272.70	113.17
21	282.24	116.18

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22	291.73	119.31
23	296.64	121.00

Circle Center At X = 45.7 ; Y = 849.2 and Radius, 770.2

*** 2.269 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.08	80.60
3	106.06	81.30
4	116.02	82.13
5	125.98	83.08
6	135.92	84.16
7	145.85	85.37
8	155.76	86.69
9	165.65	88.15
10	175.53	89.72
11	185.38	91.42
12	195.21	93.25
13	205.02	95.20
14	214.81	97.27
15	224.56	99.46
16	234.29	101.78
17	243.99	104.22
18	253.66	106.77
19	263.29	109.46
20	272.89	112.26
21	282.45	115.18
22	291.98	118.22
23	300.32	121.00

Circle Center At X = 45.1 ; Y = 874.8 and Radius, 795.9

*** 2.290 ***

1

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	96.20	80.22
3	106.19	80.57
4	116.18	81.10
5	126.15	81.80
6	136.12	82.67
7	146.06	83.72
8	155.99	84.94
9	165.89	86.34
10	175.76	87.90
11	185.61	89.64
12	195.43	91.55

13	205.21	93.63
14	214.95	95.88
15	224.66	98.30
16	234.31	100.89
17	243.93	103.65
18	253.49	106.57
19	263.00	109.66
20	272.46	112.92
21	281.85	116.34
22	291.19	119.92
23	293.86	121.00

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Circle Center At X = 81.0 ; Y = 653.7 and Radius, 573.7

*** 2.292 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	96.19	80.46
3	106.18	81.02
4	116.15	81.72
5	126.12	82.56
6	136.07	83.55
7	146.00	84.67
8	155.92	85.94
9	165.82	87.35
10	175.70	88.90
11	185.56	90.59
12	195.39	92.43
13	205.19	94.40
14	214.97	96.51
15	224.71	98.76
16	234.42	101.15
17	244.10	103.68
18	253.73	106.34
19	263.33	109.14
20	272.89	112.08
21	282.41	115.16
22	291.88	118.37
23	299.29	121.00

Circle Center At X = 62.0 ; Y = 781.1 and Radius, 701.5

*** 2.296 ***

1

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.10	79.77
3	106.10	79.72

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4	116.10	79.88
5	126.09	80.25
6	136.07	80.83
7	146.04	81.62
8	155.99	82.62
9	165.92	83.83
10	175.82	85.24
11	185.69	86.86
12	195.52	88.68
13	205.31	90.71
14	215.06	92.95
15	224.75	95.39
16	234.40	98.03
17	243.99	100.87
18	253.51	103.91
19	262.97	107.15
20	272.37	110.59
21	281.68	114.22
22	290.92	118.04
23	297.66	121.00

Circle Center At X = 103.3 ; Y = 558.0 and Radius, 478.3

*** 2.332 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.07	80.74
3	106.04	81.57
4	116.00	82.50
5	125.94	83.52
6	135.88	84.65
7	145.81	85.87
8	155.72	87.20
9	165.61	88.63
10	175.50	90.15
11	185.36	91.78
12	195.21	93.51
13	205.05	95.33
14	214.86	97.26
15	224.65	99.28
16	234.43	101.40
17	244.18	103.62
18	253.90	105.94
19	263.61	108.35
20	273.29	110.87
21	282.94	113.48
22	292.56	116.19
23	302.16	119.00
24	308.77	121.00

Circle Center At X = 19.3 ; Y = 1068.8 and Radius, 991.0

*** 2.332 ***

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Failure Surface Specified By 23 Coordinate Points

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Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	96.19	79.59
3	106.19	79.37
4	116.19	79.38
5	126.18	79.62
6	136.17	80.10
7	146.15	80.81
8	156.10	81.74
9	166.04	82.91
10	175.94	84.31
11	185.80	85.95
12	195.63	87.80
13	205.41	89.89
14	215.14	92.20
15	224.81	94.74
16	234.42	97.50
17	243.97	100.49
18	253.44	103.69
19	262.83	107.12
20	272.15	110.76
21	281.37	114.62
22	290.51	118.69
23	295.38	121.00

Circle Center At X = 110.7 ; Y = 509.9 and Radius, 430.5

*** 2.337 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	96.08	79.43
3	106.08	79.09
4	116.08	79.00
5	126.08	79.16
6	136.07	79.57
7	146.05	80.22
8	156.01	81.12
9	165.94	82.28
10	175.84	83.67
11	185.70	85.32
12	195.52	87.21
13	205.29	89.34
14	215.01	91.72
15	224.66	94.33
16	234.24	97.19
17	243.75	100.28
18	253.18	103.61
19	262.52	107.18
20	271.78	110.97
21	280.93	115.00
22	289.98	119.25

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   23          293.49        121.00
Circle Center At X =  114.7 ; Y =  480.7  and Radius,  401.7

      ***      2.343     ***
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                Y            A     X     I     S             F     T

              .00      51.75    103.50    155.25    207.00    258.75
X      .00 +---------+---------+---------+---------+---------+
           -              *
           -
           -
           -
           -            *
     51.75 +           *
           -           *
           -      * *  ** *
           -        *
           -             **
           -              *1
A   103.50 +              71
           -              71
           -
           -              91
           -              931
           -              .41
X   155.25 +              .51
           -              .71
           -              .731
           -                 1
           -              .056
           -              ..721
I   207.00 +              ..931
           -              ...71
           -              ...731
           -               ...51
           -               ...721
           -               .. .71
S   258.75 +               .....51
           -               .....2.
           -                ....71
           -                .....21
           -                .....8*
           -                 .....2
    310.50 +                 .....8
           -                 ......
           -                  .....
           -                  .....
           -                  .....
           -                   ....
F   362.25 +                   ....
           -                    ...
           -                     ..
           -                     ..
           -                     ..
           -                      .
T   414.00 +      * *    *        *
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A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.

150 Trial Surfaces Have Been Generated.

75 Surfaces Initiate From Each Of 2 Points Equally Spaced Along The Ground Surface Between X = 86.10 ft.
and X = 86.20 ft.

Each Surface Terminates Between X = 290.00 ft.
and X = 410.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 38.00 ft.

10.00 ft. Line Segments Define Each Trial Failure Surface.

Restrictions Have Been Imposed Upon The Angle Of Initiation. The Angle Has Been Restricted Between The Angles Of -45.0 And -5.0 deg.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Bishop Method * *

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	94.77	74.88
3	103.62	70.23
4	112.74	66.12
5	122.08	62.56
6	131.62	59.55
7	141.32	57.12
8	151.14	55.27
9	161.06	54.00
10	171.04	53.32
11	181.04	53.24
12	191.03	53.75
13	200.97	54.84
14	210.82	56.53
15	220.56	58.80
16	230.15	61.64
17	239.55	65.04
18	248.74	69.00
19	257.67	73.49
20	266.32	78.51

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21	274.66	84.03
22	282.66	90.03
23	290.29	96.50
24	297.52	103.41
25	304.32	110.73
26	310.69	118.45
27	312.55	121.00

Circle Center At X = 177.5 ; Y = 221.8 and Radius, 168.6

*** 1.998 ***

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	94.95	75.36
3	104.04	71.20
4	113.35	67.54
5	122.84	64.39
6	132.49	61.77
7	142.27	59.69
8	152.15	58.14
9	162.10	57.14
10	172.09	56.69
11	182.09	56.78
12	192.07	57.43
13	202.00	58.62
14	211.85	60.35
15	221.58	62.62
16	231.18	65.43
17	240.61	68.75
18	249.85	72.59
19	258.86	76.93
20	267.62	81.75
21	276.10	87.05
22	284.27	92.81
23	292.12	99.01
24	299.62	105.62
25	306.74	112.64
26	313.47	120.04
27	314.24	121.00

Circle Center At X = 175.4 ; Y = 238.8 and Radius, 182.2

*** 1.999 ***

Failure Surface Specified By 27 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	94.68	74.74
3	103.46	69.95

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4	112.51	65.69
5	121.79	61.97
6	131.27	58.80
7	140.93	56.20
8	150.72	54.18
9	160.62	52.74
10	170.58	51.88
11	180.58	51.62
12	190.57	51.94
13	200.53	52.86
14	210.42	54.36
15	220.20	56.44
16	229.84	59.10
17	239.30	62.33
18	248.56	66.10
19	257.58	70.42
20	266.33	75.26
21	274.78	80.61
22	282.90	86.46
23	290.65	92.77
24	298.02	99.52
25	304.98	106.71
26	311.51	114.29
27	316.63	121.00

Circle Center At X = 180.1 ; Y = 220.8 and Radius, 169.2

*** 2.001 ***

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	94.72	74.81
3	103.52	70.06
4	112.57	65.81
5	121.85	62.07
6	131.32	58.86
7	140.95	56.18
8	150.72	54.04
9	160.59	52.45
10	170.54	51.41
11	180.53	50.94
12	190.53	51.02
13	200.51	51.66
14	210.44	52.85
15	220.28	54.60
16	230.02	56.90
17	239.61	59.73
18	249.02	63.10
19	258.24	66.99
20	267.22	71.38
21	275.94	76.27
22	284.38	81.64
23	292.50	87.48
24	300.28	93.75
25	307.70	100.46
26	314.74	107.56
27	321.37	115.05
28	326.07	121.00

Circle Center At X = 184.1 ; Y = 229.9 and Radius, 179.0

*** 2.001 ***

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1

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	94.44	74.50
3	103.08	69.48
4	112.00	64.95
5	121.17	60.95
6	130.55	57.48
7	140.11	54.56
8	149.83	52.19
9	159.66	50.39
10	169.59	49.15
11	179.56	48.49
12	189.56	48.40
13	199.55	48.89
14	209.50	49.95
15	219.36	51.59
16	229.12	53.78
17	238.73	56.54
18	248.17	59.84
19	257.40	63.68
20	266.40	68.05
21	275.13	72.93
22	283.56	78.30
23	291.68	84.14
24	299.44	90.45
25	306.83	97.19
26	313.81	104.34
27	320.38	111.89
28	326.50	119.79
29	327.32	121.00

Circle Center At X = 186.1 ; Y = 222.1 and Radius, 173.7

*** 2.009 ***

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	94.53	74.63
3	103.28	69.81
4	112.34	65.56
5	121.65	61.91
6	131.18	58.87
7	140.88	56.46
8	150.72	54.69

9	160.66	53.56
10	170.65	53.08
11	180.64	53.24
12	190.61	54.06
13	200.50	55.52
14	210.28	57.63
15	219.90	60.36
16	229.32	63.72
17	238.50	67.68
18	247.41	72.22
19	256.00	77.34
20	264.24	83.01
21	272.09	89.20
22	279.53	95.88
23	286.52	103.04
24	293.02	110.63
25	299.02	118.64
26	300.56	121.00

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Circle Center At X = 173.1 ; Y = 206.8 and Radius, 153.7

*** 2.012 ***

1

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	94.55	74.54
3	103.20	69.52
4	112.11	64.98
5	121.26	60.95
6	130.62	57.42
7	140.16	54.43
8	149.85	51.96
9	159.67	50.04
10	169.57	48.67
11	179.54	47.85
12	189.53	47.58
13	199.53	47.87
14	209.49	48.72
15	219.40	50.11
16	229.21	52.05
17	238.89	54.54
18	248.43	57.56
19	257.78	61.10
20	266.92	65.15
21	275.82	69.71
22	284.45	74.76
23	292.80	80.27
24	300.82	86.24
25	308.50	92.65
26	315.81	99.47
27	322.73	106.69
28	329.24	114.28
29	334.38	121.00

Circle Center At X = 189.3 ; Y = 227.7 and Radius, 180.1

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*** 2.014 ***

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	94.35	74.36
3	102.91	69.20
4	111.77	64.56
5	120.89	60.46
6	130.23	56.90
7	139.77	53.90
8	149.48	51.48
9	159.30	49.63
10	169.23	48.37
11	179.20	47.71
12	189.20	47.63
13	199.19	48.16
14	209.13	49.27
15	218.98	50.97
16	228.72	53.25
17	238.30	56.11
18	247.70	59.53
19	256.87	63.50
20	265.80	68.01
21	274.44	73.05
22	282.77	78.58
23	290.75	84.61
24	298.36	91.09
25	305.58	98.02
26	312.37	105.36
27	318.71	113.09
28	324.45	121.00

Circle Center At X = 185.4 ; Y = 215.9 and Radius, 168.3

*** 2.014 ***

1

Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.10	80.02
2	94.56	74.69
3	103.29	69.81
4	112.26	65.39
5	121.45	61.44
6	130.83	57.97
7	140.37	54.99
8	150.06	52.52
9	159.86	50.54
10	169.76	49.08
11	179.71	48.13
12	189.70	47.70
13	199.70	47.78

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14	209.68	48.39
15	219.62	49.51
16	229.49	51.14
17	239.25	53.29
18	248.90	55.94
19	258.39	59.08
20	267.71	62.71
21	276.82	66.82
22	285.72	71.40
23	294.36	76.43
24	302.73	81.90
25	310.80	87.80
26	318.56	94.11
27	325.98	100.81
28	333.05	107.89
29	339.73	115.32
30	344.33	121.00

Circle Center At X = 193.0 ; Y = 240.6 and Radius, 192.9

*** 2.017 ***

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	86.20	80.04
2	94.49	74.44
3	103.07	69.32
4	111.94	64.68
5	121.05	60.56
6	130.37	56.95
7	139.89	53.88
8	149.56	51.35
9	159.36	49.36
10	169.26	47.93
11	179.22	47.06
12	189.22	46.76
13	199.21	47.01
14	209.18	47.83
15	219.08	49.21
16	228.90	51.15
17	238.58	53.63
18	248.11	56.66
19	257.46	60.22
20	266.59	64.30
21	275.47	68.89
22	284.09	73.97
23	292.40	79.52
24	300.39	85.54
25	308.02	92.00
26	315.28	98.88
27	322.14	106.15
28	328.58	113.80
29	333.97	121.00

Circle Center At X = 189.7 ; Y = 224.2 and Radius, 177.4

*** 2.017 ***

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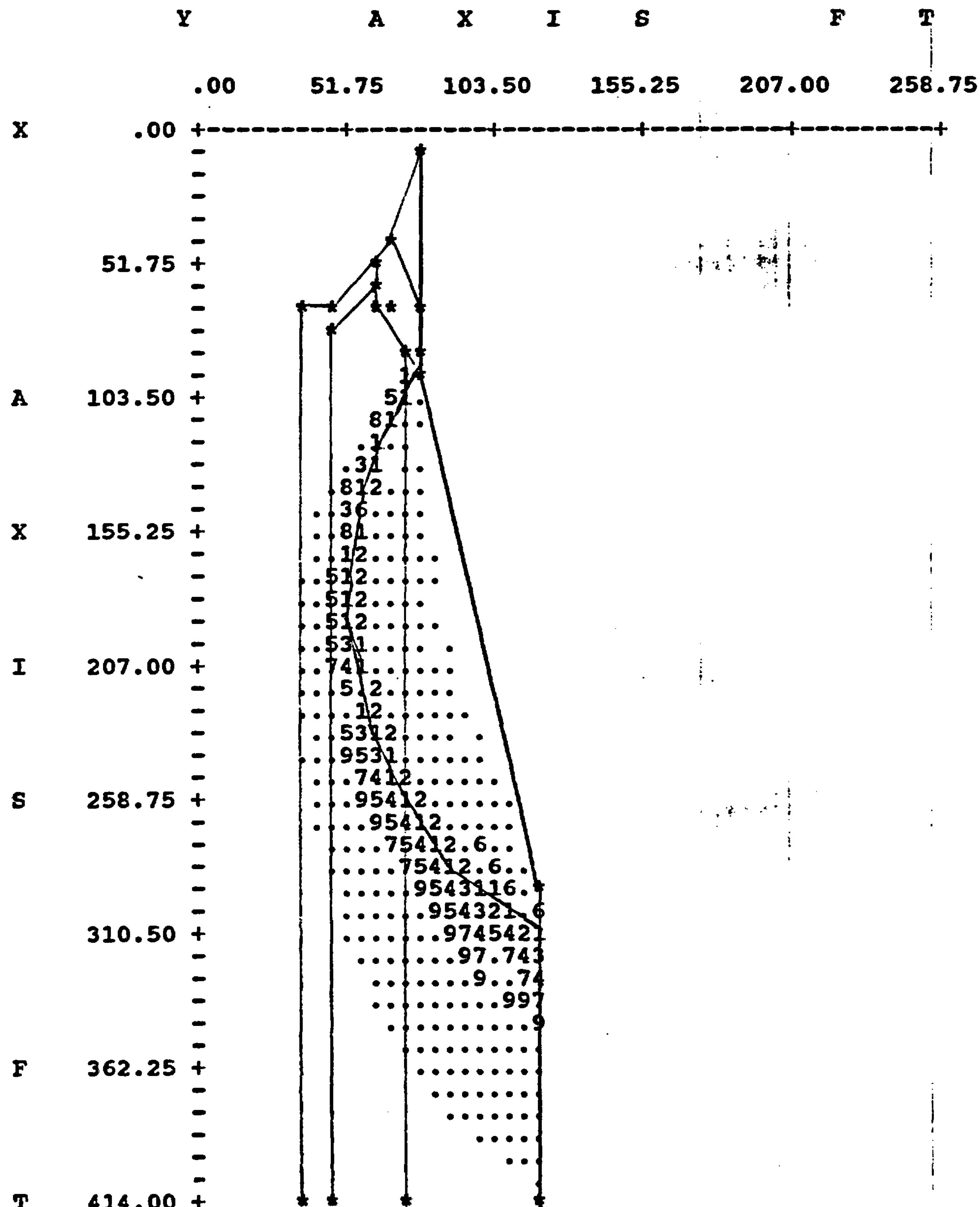

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Project UMTRA-GRN	Contract No. 5057	Sheet C-1	File No.
Feature SLOPE STABILITY	Designed FBG	Date 3-15-90	
Item	Checked [illegible]	Date 3-21-90	

APPENDIX C

PURPOSE: This evaluation determines adequate soil strength values, for slope stability analysis, of the in-place radon barrier at the Green River, Utah site.

GIVEN

A. Radon barrier is compacted to 100% or more of maximum dry density by ASTM D698 (Construction Specification Section 02200, Rev. 5)

B. Soils from the borrow source are amended with 6% by weight of bentonite (Specification Section 02200, Rev. 5)

C. References:

C-1: U.S. Department of Energy, February 1988, Remedial Action Plan and Final Design for Stabilization of the Inactive Uranium Mill Tailings at Green River, Utah, Final, UMTRA-DOE/AL 050510.GRNO, Albuquerque, NM.

C-2: Chen and Associates*, October 28, 1987, Laboratory Test Results, (Tables III, IV, & V, plus Figures 5-14 inclusive), Job No. 1 620 87, Green River, Utah (MKE Doc. No. 5057-GRN-C-09-00432-00) (Copy attached) (* Denver)

C-3: Chen and Associates, February 15, 1988, "Laboratory Testing, Radon Barrier Materials, UMTRA Project, Green River, Utah, PO # 3050-511-5902 C.O. 5, Job. No. 1 104 88," Denver, Colorado (MKE Doc. No. 5057-GRN-L-09-00709-00) (Copy attached)

C-4: Chen and Associates, January 27, 1988, "Laboratory Testing, Radon Barrier Materials, UMTRA Project, Green River, Utah" P.O. # 3050-511-9502 C.O. 5, Job No. 1 104 88, Denver, Colorado, (MKE Doc. No. 5057-GRN-L-09-01635-00) (Copy Attached)

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Project UMTRA - GRN | Contract No. 5057 | Sheet C-2 | File No.
Feature SLOPE STABILITY | Designed FBG | Date 3-17-90
Item | Checked PKC | Date 3-21-90

C. References (continued)

C-5 : Fox Consultants, August 31, 1989, "Field Sampling and Laboratory Testing, Radon Barrier, Green River, Utah" Job No. 1-4250-7993-10, (Letter to MK-Ferguson, Green River Utah) Denver Office, Wheat Ridge, Colorado
(MKE Doc. Nos. 5057-GRN-L-09-01693-00 and 5057-GRN-R-09-01694-00)

C-6 Mitchell, J.K., 1976, Fundamentals of Soil Behavior John Wiley and Sons, New York.

C-7 Huang, Y.H., 1983, Stability Analysis of Earth Slopes, Van Nostrand Rheinhold Co., New York

SHEAR STRENGTH EVALUATION

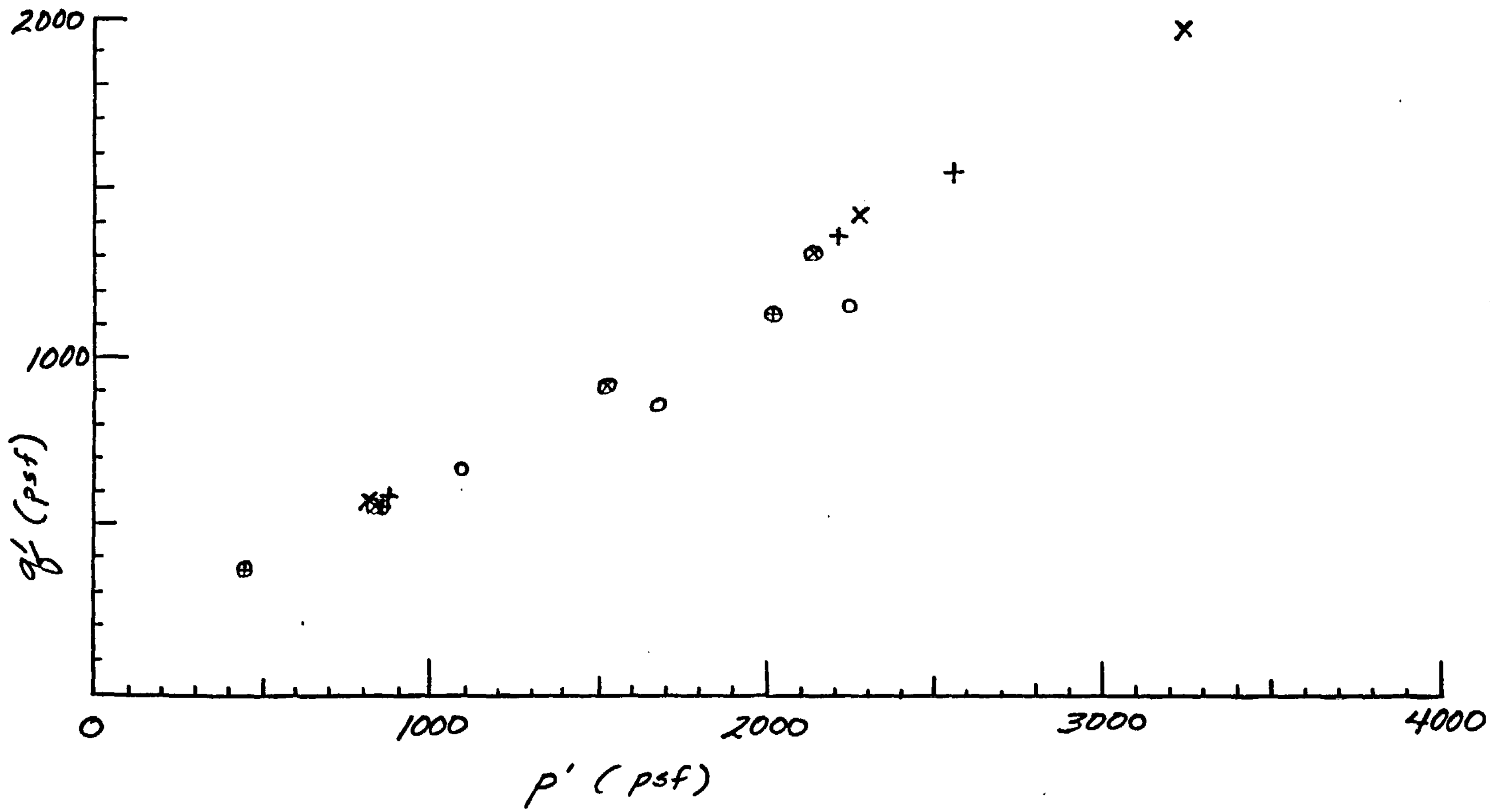
A. Available data include the following test types and sample characteristics

1. TX/CU/PP for 94-95% compaction, no bentonite
2. " for 99-100% compaction, 3% bentonite
3. TX/UU for 96% compaction, no bentonite, saturated
4. TX/UU for 94% compaction, no bentonite, unsaturated

(Triaxial test data are plotted on sheets C-4 – C-6.)

5. Atterberg limits for borrow area soils without bentonite and for in-place radon barrier materials (with 6% bentonite). Data are given on sheet C-11.

B. Data indicate that shear strength for soils with 3% bentonite at 100% compaction is generally greater than strength for soils with no bentonite and 95% compaction, for TX/CU tests (effective and total stress conditions)



EFFECTIVE STRESS DATA (TX/CU/PP)

LEGEND:

+	3 RADBOR	(3% bentonite, 99% $\gamma_{d\,MAX}$ ASTM D698)	Ref. C-3
×	7 RADBOR	(3% bentonite, 100% " " ")	Ref. C-3
⊗	6 RADBOR	(94% $\gamma_{d\,MAX}$ ASTM D698)	Ref. C-2
⊕	9 RADBOR	(94% " " ")	Ref. C-2
o	GRN06-02-01	(95% " " ")	Ref. 2

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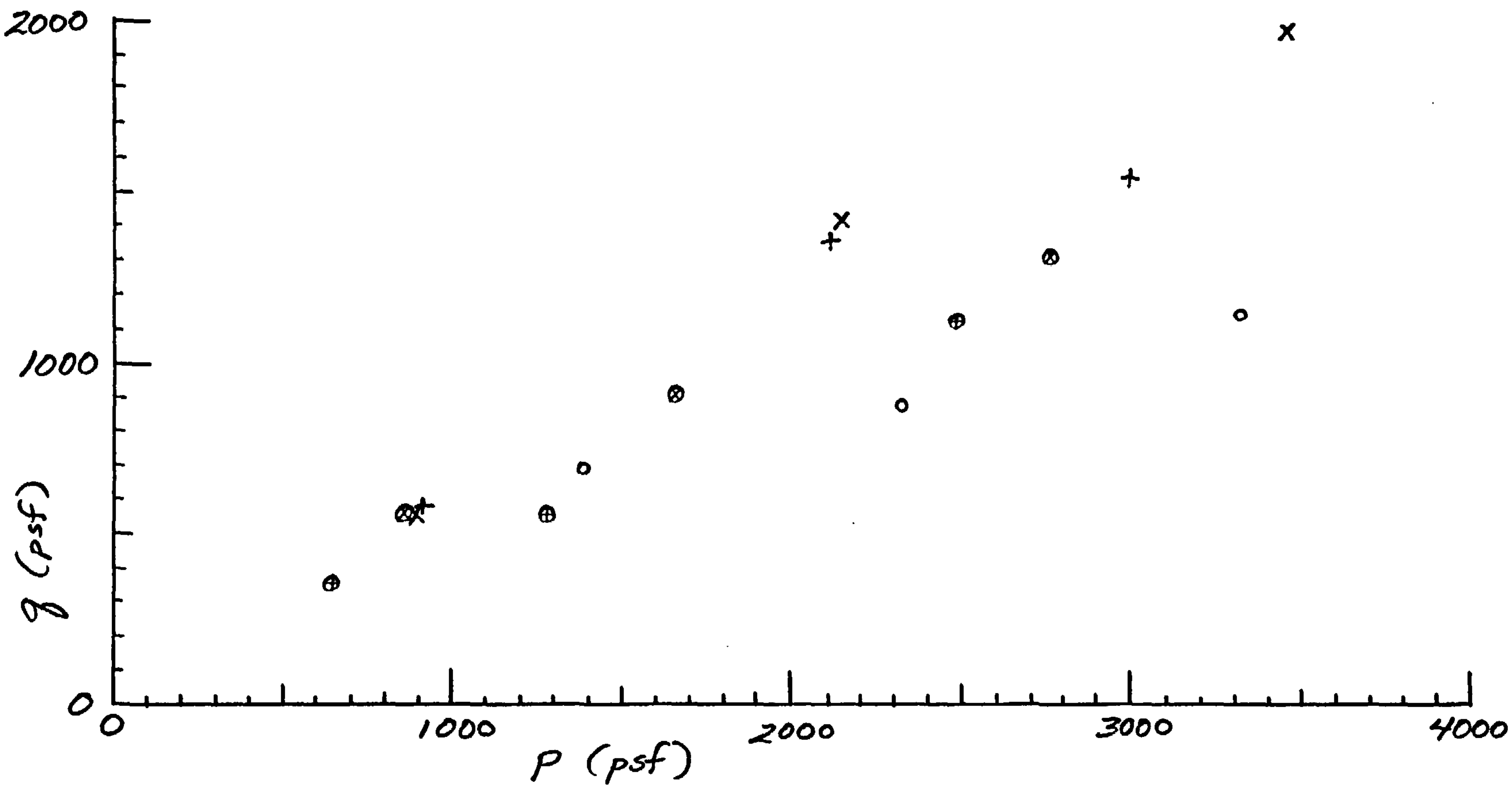
File No.
Date 3-17-90
Date 4-6-90



TOTAL STRESS DATA (TX/CU/PP)

LEGEND

+ 3RADBOR (3% bentonite, 99% $\gamma_{d\,MAX}$ ASTM D698) Ref. C-3
× 7RADBOR (3% " , 100% " " ") Ref. C-3

⊗ 6 RADBOR (94% $\gamma_{d\,MAX}$ ASTM D698) Ref. C-2
⊕ 9 RADBOR (94% " " ") Ref. C-2
o GRN06-02-01 (95% " " ") Ref. 2

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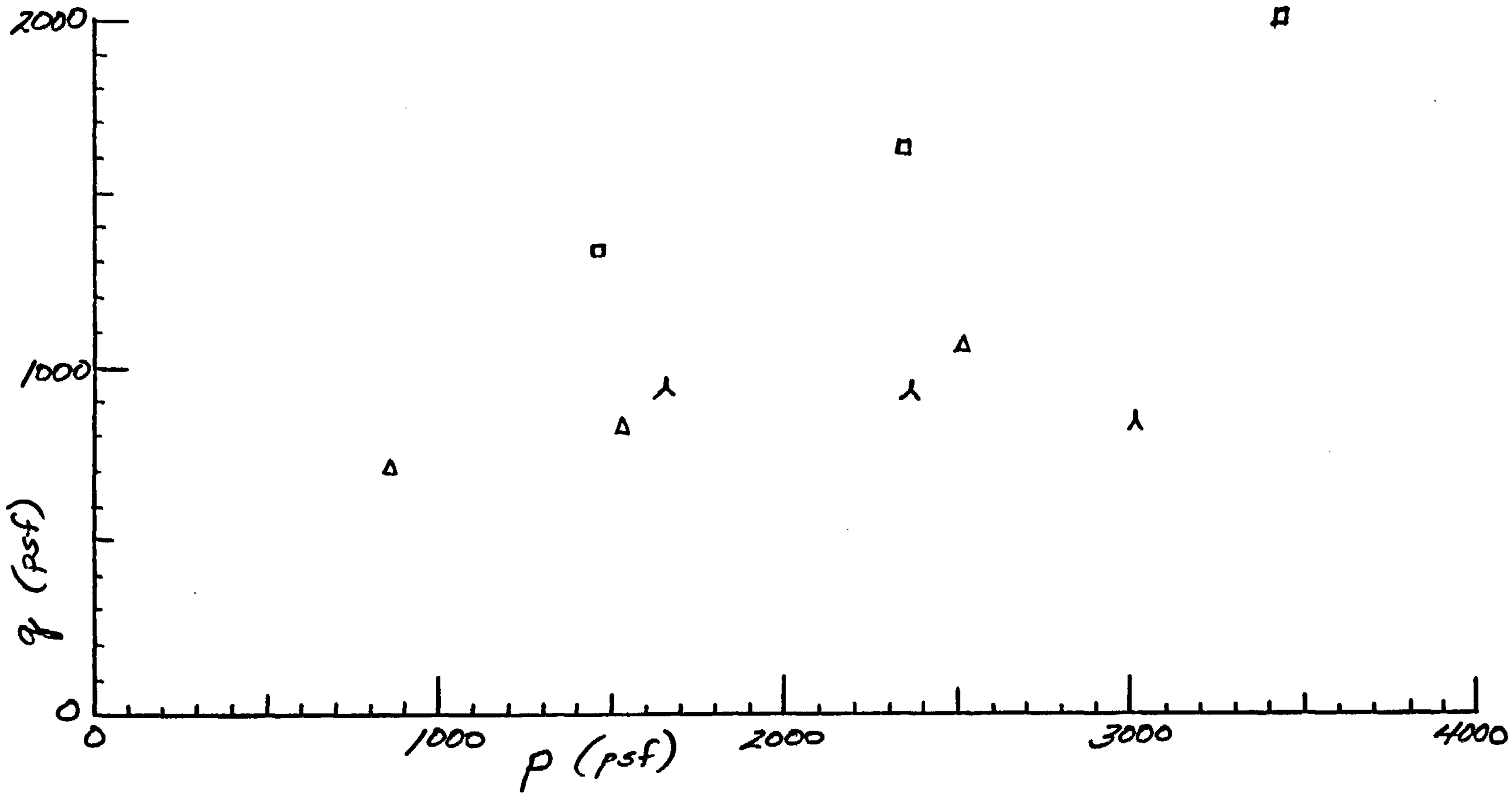

TOTAL STRESS DATA (TX/UU)

LEGEND:

⅄ GRN06-02-01 (96% $\gamma_{d\,max}$ ASTM D698, SATURATED)

Δ 6 RADBOR (94% $\gamma_{d\,max}$, ASTM D698, UNSATURATED)
□ 9 RADBOR (94% " " " ")

C. Stress range of interest: The maximum σ_V and σ_V' values of interest are approximately as follows, for 3' thick radon barrier covered by 1' of riprap and 0.5' of bedding: 4.5' x 130 pcf = <u>585 psf</u>

(By inspection of disposal cell perimeter construction details and available strength data, the minor amount of more deeply buried radon barrier will not control the critical case for slope stability)

D. TX/UU shear strength will not control the short-term slope stability, based on 1) available data showing TX/UU shear strength greater than TX/CU shear strength at low stress levels, and 2) the expected increase in TX/UU strength due to increased plasticity from 3% bentonite to 6% bentonite ($S_u/\bar{P}$ increases with increasing plasticity, see sheet C-8).

E. Adjust TX/CU results (effective and total stresses) for increased bentonite from 3% (TX/CU samples) to 6% (in-place radon barrier):

1. Atterberg limit data are not available for soil with 3% bentonite. For approximate purposes, →

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FBS 3-20-90
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Table 3.3 Undrained Shear Strength of Soils.

CONSISTENCY	UNDRAINED SHEAR STRENGTH, tsf	FIELD TEST
Very soft	0–1	Squeezed between fingers when fist is closed
Soft	1–2	Easily molded by fingers
Firm	2–4	Molded by strong pressure of fingers
Stiff	4–6	Dented by strong pressures of fingers
Very stiff	6–8	Dented only slightly by finger pressure
Hard	8⁺	Dented only slightly by pencil point

(After Sowers, 1979; 1 tsf = 95.8 kPa)

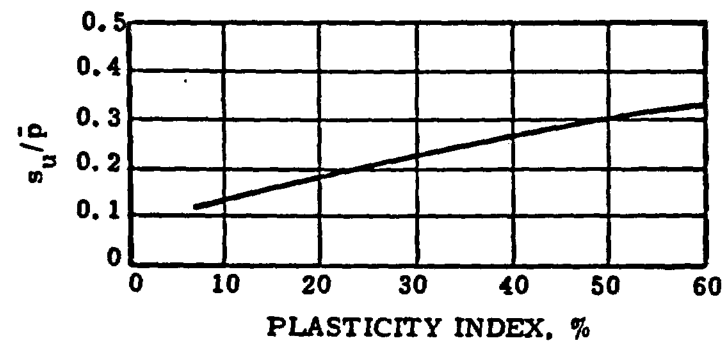

FIGURE 3.13. Plasticity index versus $s_u/\bar{p}$. (After Bjerrum and Simons, 1960)

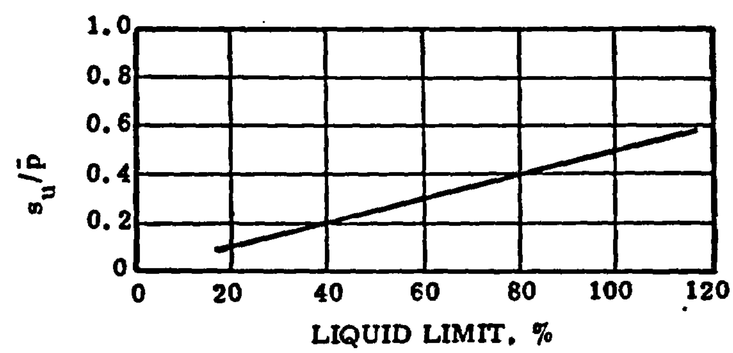

FIGURE 3.14. Liquid limit versus $s_u/\bar{p}$. (After Karlsson and Viberg, 1967)

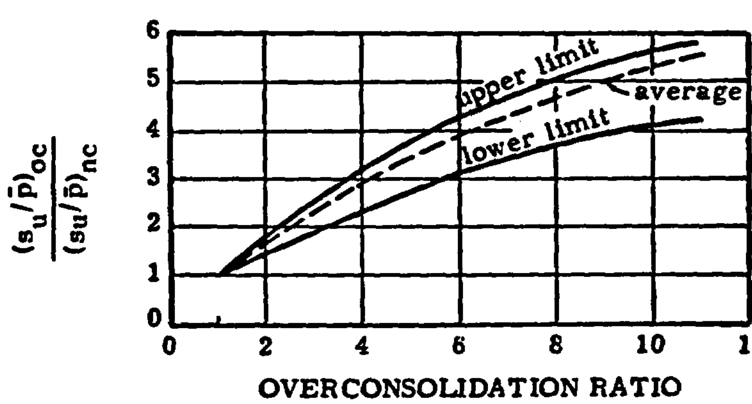

FIGURE 3.15. Relationship between overconsolidated and normally consolidated $s_u/\bar{p}$. (After Ladd and Foott, 1974)

Source: Ref. C-7

E. (continued)

1. (continued) → use the approximate increase in plasticity from 0% to 6% bentonite to estimate reduction in sin φ' (according to Ref. C-6, Fig. 14.1 - see sheet C-10)

From sheet C-11, :

Average PI (no bentonite, 11 samples) = 9

Average PI (6% bentonite, 3 samples) ≈ 30
(round up due to limited data)

2. For comparison, check sin φ' and PI for samples without bentonite with published data (see p. C-10). (assume $\bar{c} = 0$)

SAMPLE No.	PI (sheet)	φ' (sheet C-12)	
6 RADBOR	4	39°	→ Out of range of published data
9 RADBOR	13	36°	} compares well to published data
GRN06-02-01	19	33°	

3. From p. C-10, use relationship shown by dashed line to estimate reduced φ':

PI = 9   sin φ' = 0.59   φ' = 36°

PI = 30   sin φ' = 0.47   φ' = 28°

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SLOPE STABILITY

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example plane strain versus triaxial compression). The strength of saturated clay is influenced most by drainage conditions, disturbance (which is manifested by a change in effective stress and a loss of cementation), overconsolidation ratio, and creep effects. The peak strength of a clay may be considerably greater than the strength after very large strain or shear displacement.

2. In the absence of chemical cementation between grains, the strength of sand and normally consolidated clay depends directly on effective stress,

$$\tau_{ff} = \sigma_{ff}' \tan \phi' \qquad (14.3)$$

where the primes designate effective stresses.

3. The peak value of ϕ' for clays decreases with increasing plasticity index and activity, as may be seen in Fig. 14.1.
4. The residual friction angle decreases with increasing plasticity as shown in Fig. 14.2. The residual strength is the shear strength along a well-defined failure surface at large displacements. It is independent of stress history and original structure. For a given set of testing conditions it depends only on composition and effective stress.
5. The post-peak shearing displacement required to cause a reduction in friction angle to the residual value varies with soil type, normal stress on the shear plane, and test conditions. For example, for shale mylonite in contact with smooth steel or other polished, hard surfaces, a shearing displacement of only 1 or 2 mm is sufficient to give residual strength (Deere, 1974, personal communication). For soil against soil, however, a slip along the shear plane of many centimeters may be required; as shown by Fig. 14.3.
6. Failure envelopes for peak and residual values of friction angle are curved in the manner shown in Fig. 14.4. This behavior in sands can be caused by dilatancy effects and, at higher confining pressures, by grain crushing. Curved failure envelopes are also observed for some clays. Two examples of the stress-dependency of the residual friction angle are shown in Fig. 14.5. Possible causes of this behavior are discussed in Section 14.8. Not all clays exhibit this stress-dependency; Bishop et al. (1971) found the residual strength of blue London clay to be independent of normal stress.
7. Overconsolidated clays may have a higher strength at a given effective stress than nor-

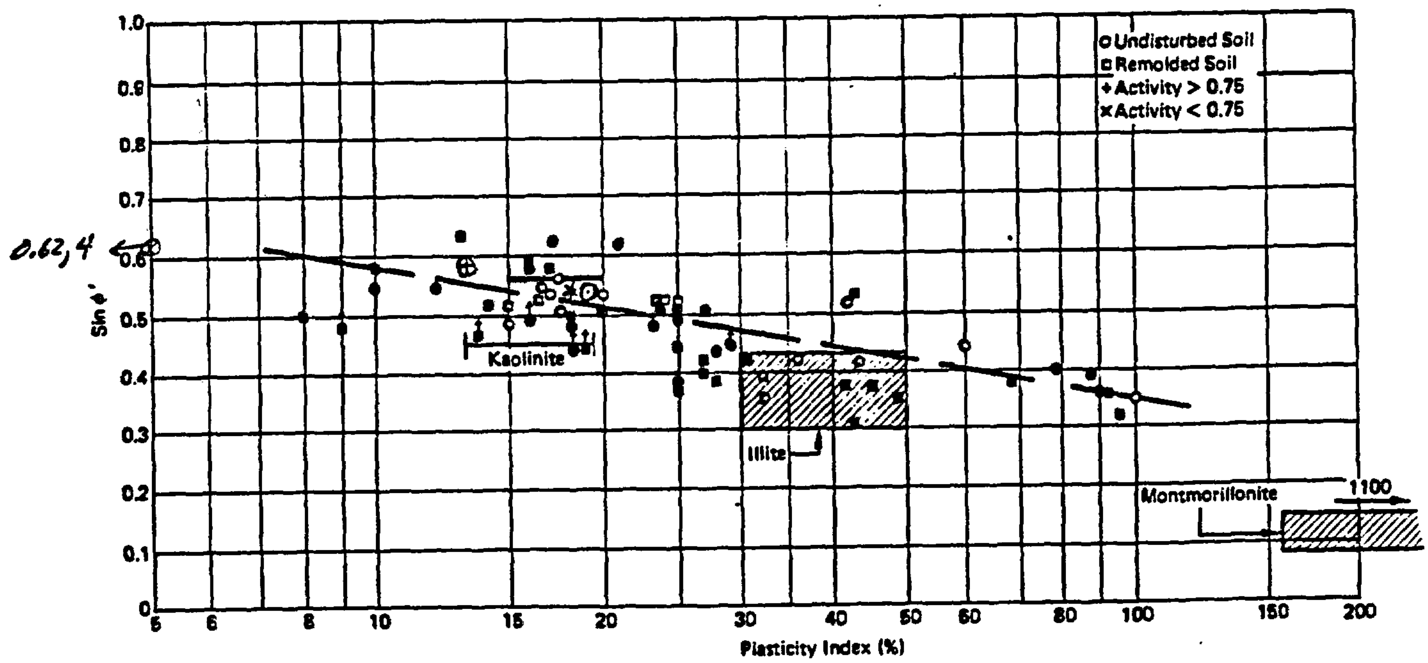

Fig. 14.1 Relationship between sin ϕ and plasticity index for normally consolidated soils (Kenney, 1959). (Data for pure clays from Olson, 1974.)

SOURCE: REF. C-6

⊗ 6 RADBOR
⊕ 9 RADBOR
*⊙ GRN06-02-01

from Sheet C-9

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SLOPE STABILITY

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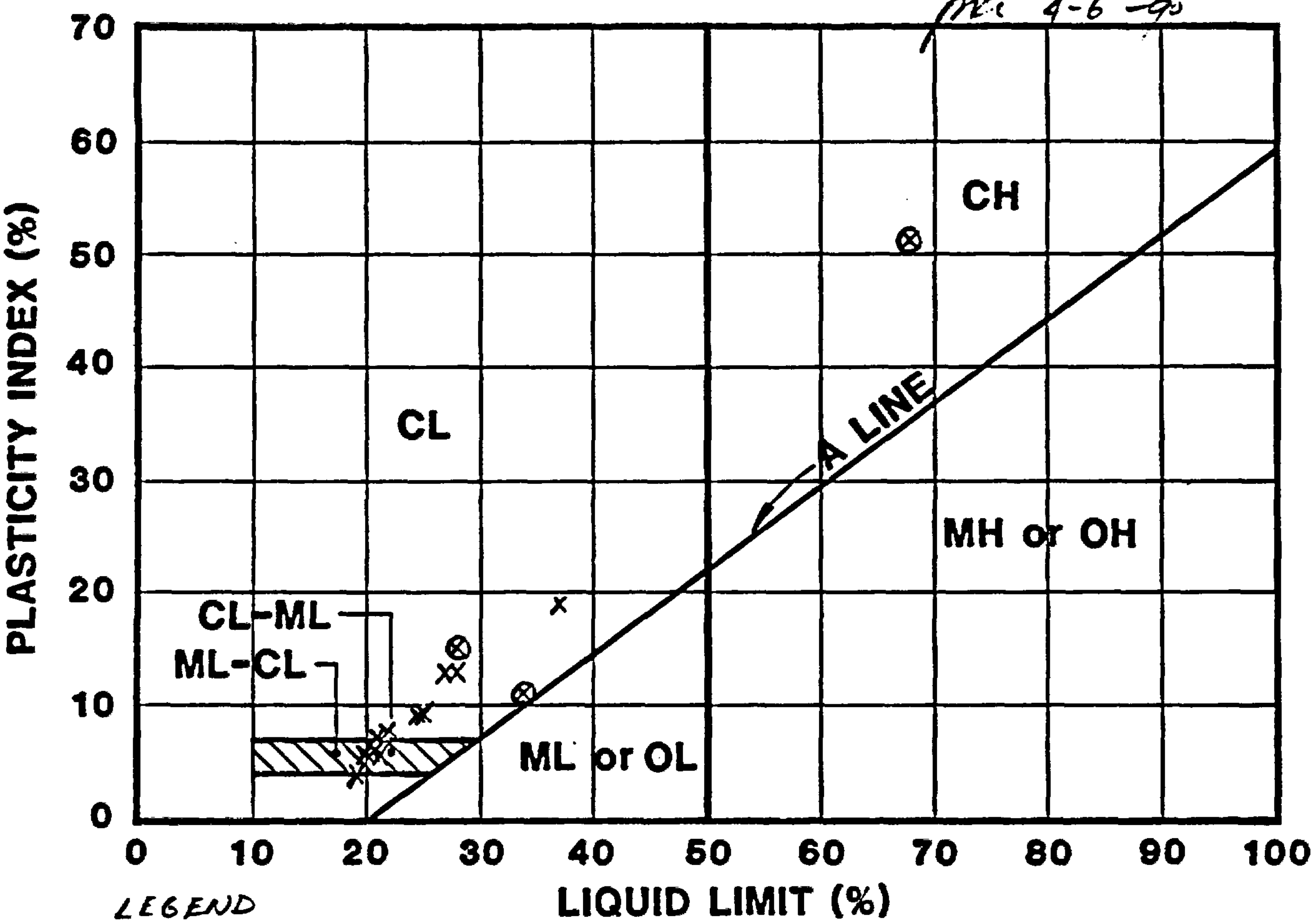

LEGEND
X = NATURAL SOILS
⊗ = IN-PLACE RADON BARRIER (6% BENTONITE)

REF. No. ~~SYMBOL~~	CLASSIFICATION AND SOURCE	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	~~% PASSING #200 SIEVE~~
C-3	GRN06-02-01/CL	37	18	19	NATURAL SOILS
C-3	GRN06-13-02/CL-ML	21	14	7	
C-2	1 RADBOR/CL	22	14	8	
C-2	2 RADBOR/CL-ML	21	15	6	
C-2	3 RADBOR/CL-ML	20	14	6	
C-2	4 RADBOR/CL	25	16	9	
C-2	5 RADBOR/CL	25	16	9	
C-2	6 RADBOR/CL-ML	19	15	4	
C-2	7 RADBOR/CL-ML	21	15	6	
C-3	8 RADBOR/CL	27	14	13	
C-2	9 RADBOR/CL	28	15	13	
C-5	PB-1 / CL	34	23	11	IN-PLACE RADON BARRIER (6% BENTONITE)
C-5	PB-2 / CL	28	13	15	
C-5	PB-3 / CH	68	17	51	

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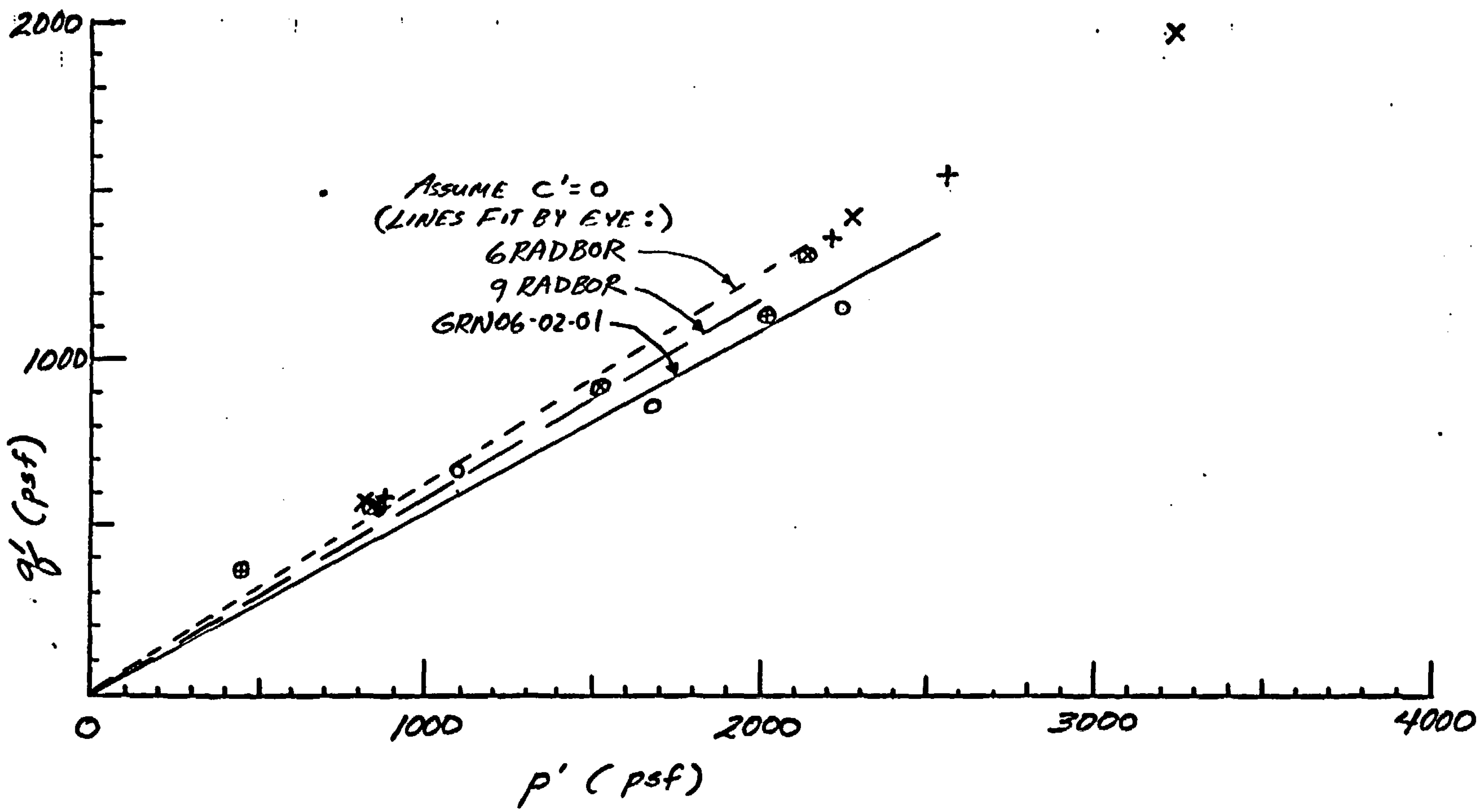


EFFECTIVE STRESS DATA (TX/KU/PP)

LEGEND:

+	3 RADBOR	(3% bentonite, 99% $\gamma_{d\,MAX}$ ASTM D698)	Ref. C-3		
×	7 RADBOR	(3% bentonite, 100% " " ")	Ref. C-3		
⊗	6 RADBOR	(94% $\gamma_{d\,MAX}$ ASTM D698)	Ref. C-2	$\alpha = 32.2°$	$\phi' = 39°$
⊕	9 RADBOR	(94% " " ")	Ref. C-2	$\alpha = 30.5°$	$\phi' = 36°$
o	GRN06-02-01	(95% " " ")	Ref. 2	$\alpha = 28.5°$	$\phi' = 33°$

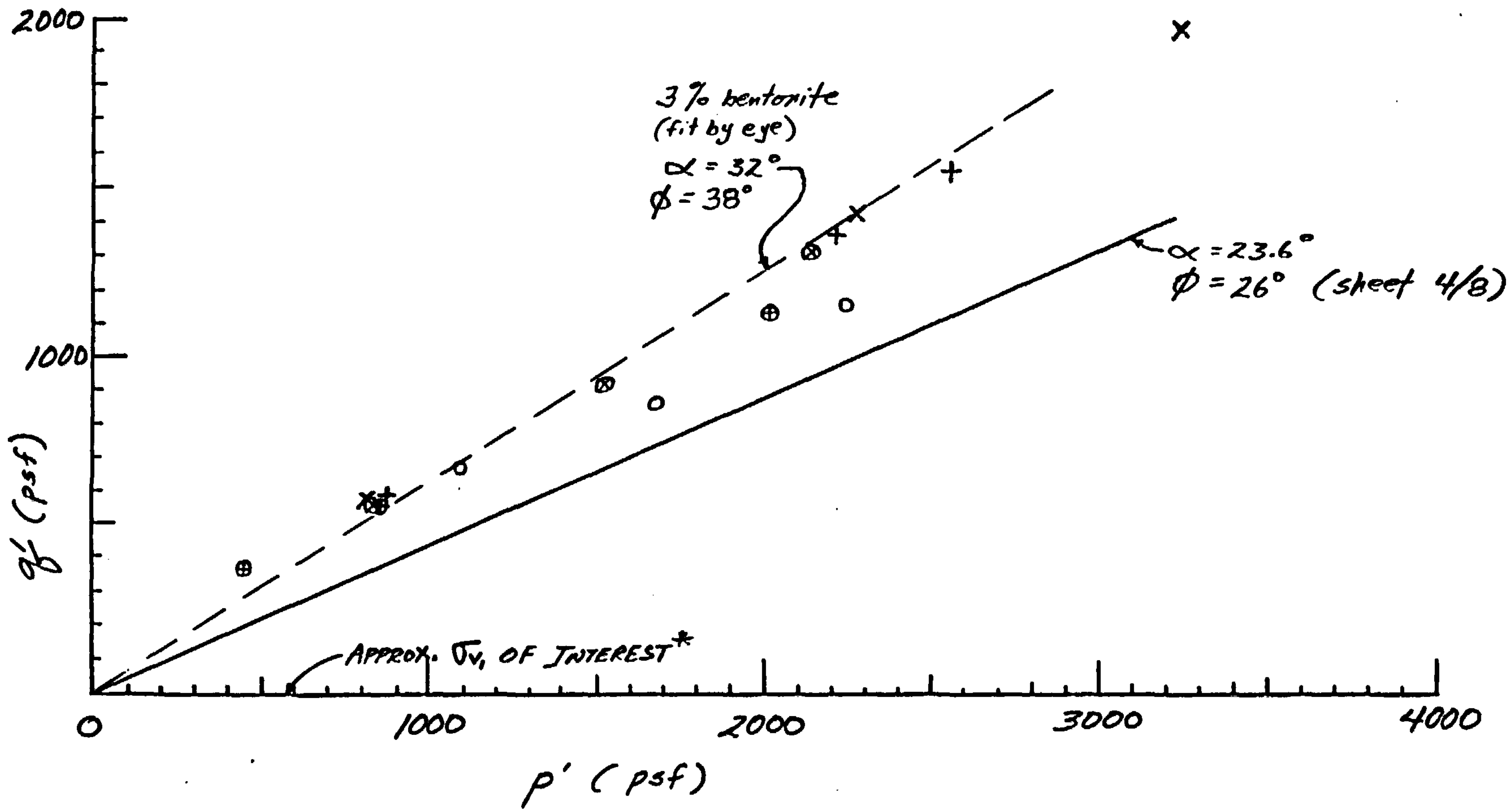
F. Compare reduced ϕ' with design values for 95% compaction, no bentonite, and samples with {100% compaction, 3% bentonite}.

CASE	DESIGN VALUES FOR 95% COMPACTION, NO BENTONITE (sheet 4/8)	VALUES FOR SAMPLES WITH 3% BENTONITE, 100% COMPACTION
End of Construction (sheet C-15)	$\phi = 25°$ $c = 60$ psf	$\phi = 33°$ $c = 64$ psf *
Long-Term (sheet C-14)	$\phi = 26°$ $c = 0$	$\phi' = 38°$ $c = 0$ } sheet C-14

*Assumes $a = 54$ psf is unchanged from design value from $\phi = 25°$, $c = 60$ psf (see sheet C-15)

Observe that $\sin 38° = 0.62$, which lies above the average relationship of $\sin \phi'$ vs. PI (sheet C-10), & at the upper end of data for normally consolidated soils. Use of the average relationship therefore seems to be relatively conservative for radon barrier borrow soils at 100% compaction (ASTM D698)

For TX/CU results, assuming a = constant (i.e., $c \sim$ constant) for increased bentonite content is considered conservative for interpretation/approximation of strength values. For 3% bentonite and →



EFFECTIVE STRESS DATA (TX/CU/PP)

LEGEND:

+	3 RADBOR	(3% bentonite, 99% $\gamma_{d MAX}$ ASTM D698)	Ref. C-3
×	7 RADBOR	(3% bentonite, 100% " " ")	Ref. C-3
⊗	6 RADBOR	(94% $\gamma_{d MAX}$ ASTM D698)	Ref. C-2
⊕	9 RADBOR	(94% " " ")	Ref. C-2
o	GRN06-02-01	(95% " " ")	Ref. 2

* 585 psf = 4.5' (γ_T)
= 4.5' (130 pcf)
↳ ASSUMED FOR APPROXIMATE PURPOSES

$\tan \alpha = \sin \phi$

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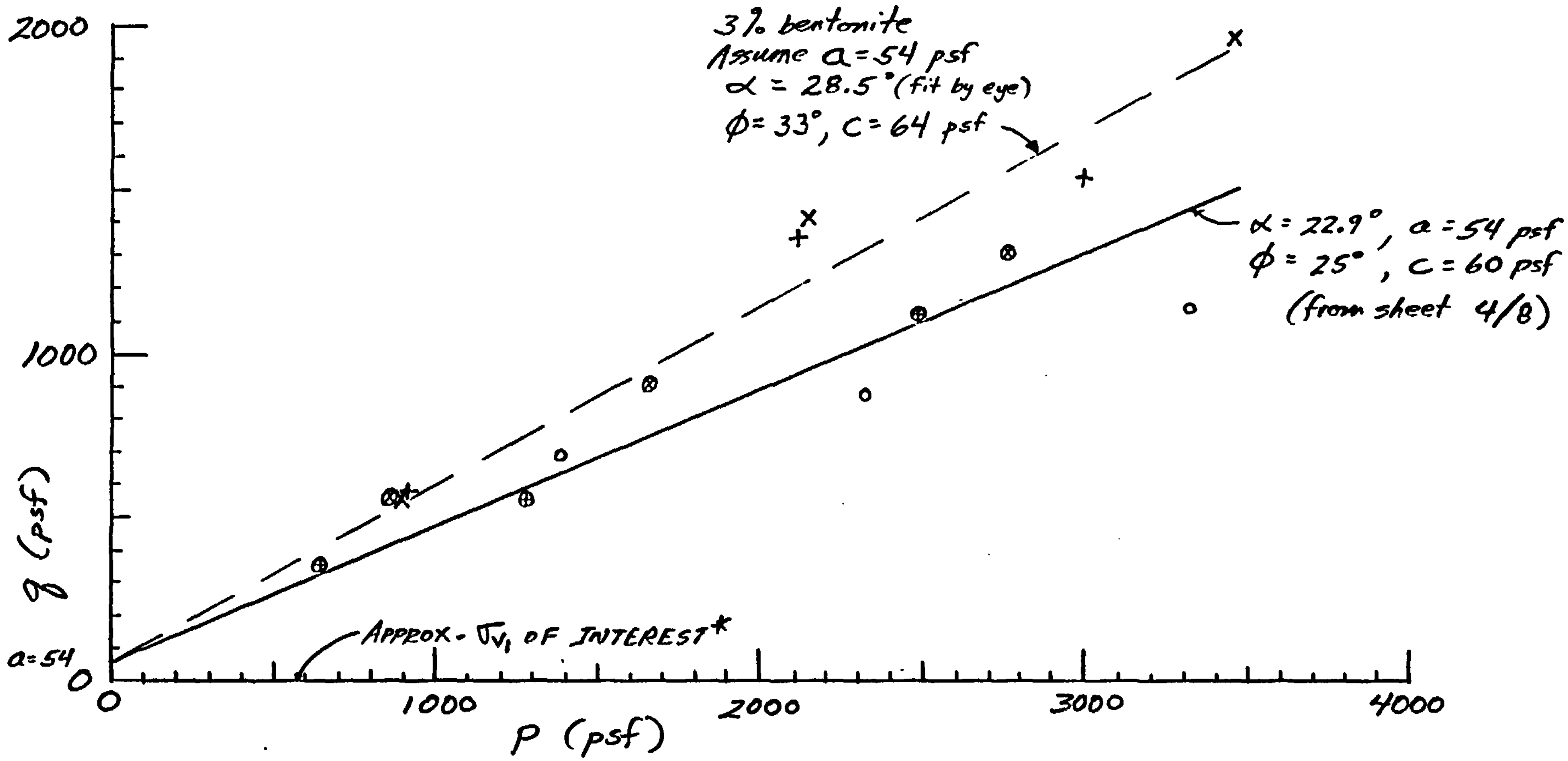

TOTAL STRESS DATA (TX/CU/PP)

* 585 psf = 4.5' (130 pcf)
↳ ASSUMED FOR APPROXIMATE PURPOSES

LEGEND

+	3 RADBOR	(3% bentonite, 99% $\gamma_{d\,MAX}$ ASTM D698)	Ref. C-3
×	7 RADBOR	(3% " , 100% " " ")	Ref. C-3
⊗	6 RADBOR	(94% $\gamma_{d\,MAX}$ ASTM D698)	Ref. C-2
⊕	9 RADBOR	(94% " " ")	Ref. C-2
o	GRN06-02-01	(95% " " ")	Ref. 2

$\tan\alpha = \sin\phi$

$a = c(\cos\phi)$

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F. (continued) → 100% compaction, $\phi \sim 33°$ and $c \sim 64$ psf using this assumption. Assume the same reduction in ϕ as for ϕ' due to increase in average PI from 9 to 30, ie. $\Delta\phi \sim (-8°)$. (This is not an unreasonable approximation, due to the relatively small c values used (60-64 psf) and the lesser effect of ϕ on strength at the lower confining stresses of interest relative to greater confining stresses and the effect of the assumed cohesion strength). Even if the full reduction in ϕ' from no bentonite to 6% bentonite is applied to results for ϕ for 3% bentonite ($\phi = 33°$), the result is the same ($\phi = 33° - 8° = 25°$) used previously for 95% compaction and no bentonite.

Therefore, design strength values used for final design* appear to be appropriate (if not conservative) for the radon barrier compacted to 100% $\gamma_{d MAX}$ (ASTM D698), even with 6% bentonite. The increased compaction (from 95% to 100%) appears to strengthen the soil in the stress range of interest a sufficient amount to equal (or overcome) the reduced strength due to addition of 6% bentonite. (*see note on sheet C-17)

6. CONCLUSIONS - SHEAR STRENGTH OF RADON BARRIER

Design values for 95% compaction, no bentonite, are considered suitable for slope stability evaluation of the in-place radon barrier (100% compaction, 6% bentonite). This conclusion is based on available data for PI and strength, and approximate adjustments using published relationships.

For design, use previous strength values* (Sheet 5) to estimate slope stability of as-built disposal cell.

* Same values as used for final design, MKE Calc. No. 10-536-13-00.

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Green River, Utah
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TABLE III

SUMMARY OF LABORATORY TEST RESULTS

Sample Location		Atterberg Limits*		Shrinkage Limits	
Test Pit	Depth, Feet	Liquid Limit	Plastic Index	Shrinkage Limit	Shrinkage Ratio
4	7.0	25	9	11	2
5	6.0	25	9	12	2
8	7.0	27	13	10	2
9	8.0	28	13	10	2

*Previously reported on Table I (Aug. 27, 1987)

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TABLE IV

SUMMARY OF PERMEABILITY TEST RESULTS

Test Pit	Initial Moisture Content, %	Initial Dry Density, pcf	Initial Compaction, %	Final Moisture Content, %	Final Dry Density, pcf	Coefficient of Permeability, cm/sec
1	12.8	113.0	95.8	18.5	112.4	$3.5x10^{-5}$
2	12.6	107.8	90.0	18.4	112.6	$2.1x10^{-5}$
2	12.5	114.2	95.3	16.9	115.7	$2.2x10^{-5}$
2	12.4	120.3	100.4	15.4	120.8	~~$3.0x10^{-7}$~~ *
3	12.3	108.3	90.7	18.0	109.3	$8.5x10^{-5}$
3	12.4	114.2	95.6	16.7	114.8	$3.1x10^{-5}$
3	11.7	120.6	100.0	14.3	121.2	$9.2x10^{-8}$
6	12.3	107.6	89.7	18.9	109.7	$1.6x10^{-4}$
6	12.0	114.5	95.5	17.1	116.3	$6.0x10^{-5}$
6	11.9	120.1	100.2	14.9	121.0	~~$9.0x10^{-6}$~~ *
7	12.2	113.7	95.6	18.2	113.1	$2.1x10^{-5}$

*Results revised in January 19, 1988 report from Chen and Associates (MKE Doc. No. 5057-GRN-C-09-00611-00)

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PFC 4-6-90

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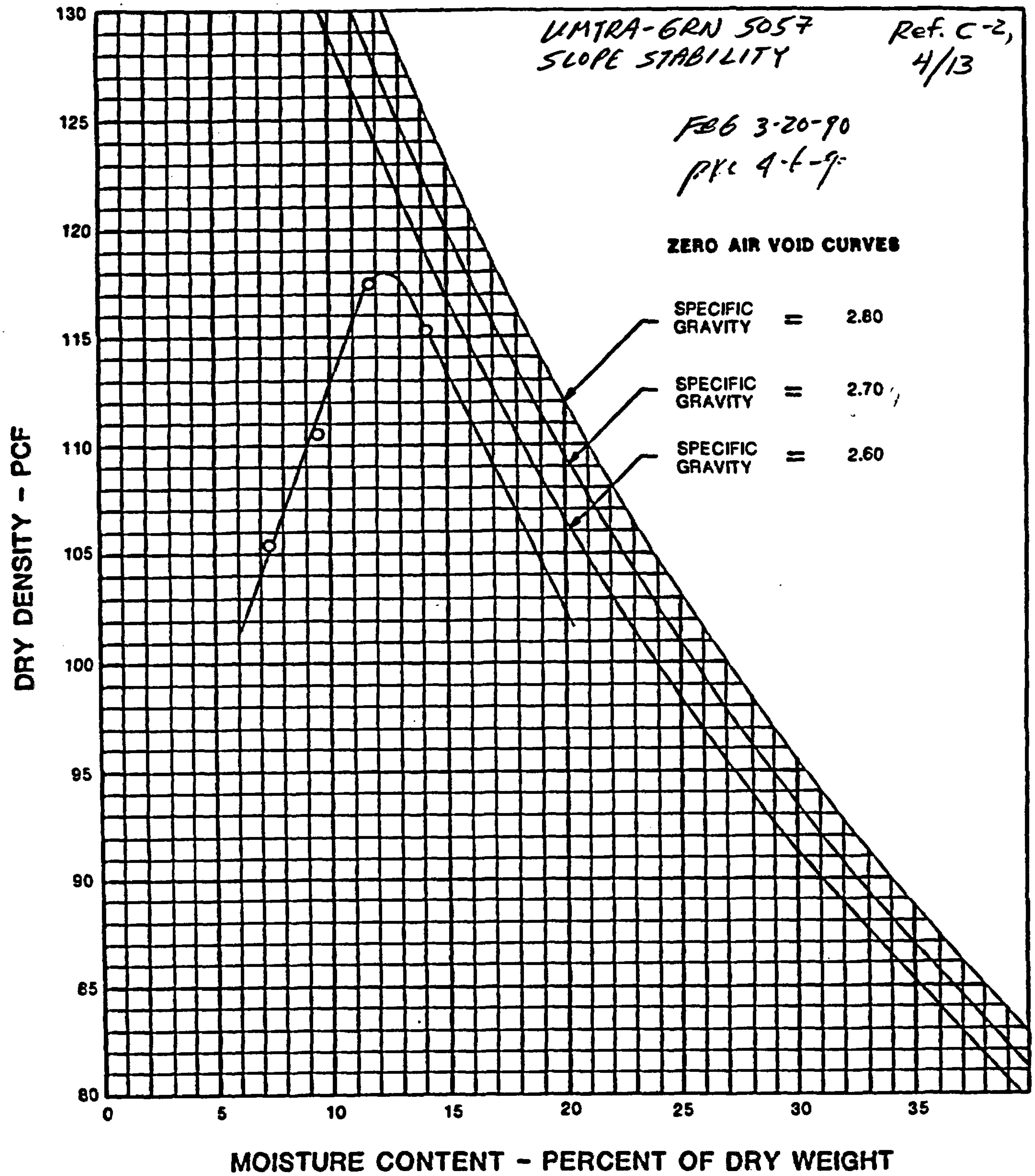
TABLE V

SUMMARY OF CAPILLARY-MOISTURE RELATIONSHIP TEST RESULTS

Sample Location	Test Pit 2	Test Pit 3	Test Pit 6
Initial Moisture Content, % (Avg.)	13.08	13.12	12.43
Initial Dry Density, pcf (Avg.)	112.8	112.6	113.0
Tension, bar			
0.1	13.32	13.37	12.37
0.3	12.96	12.87	12.08
0.5	12.84	12.72	11.71
1.0	12.49	12.32	11.25
2.0	12.03	11.84	10.43
7.0	11.22	11.28	9.73
15.0	10.55	10.71	9.68

C-21



LOCATION : Test Pit 1 DEPTH : 4.0 SAMPLE NO. :	MOISTURE-DENSITY RELATIONSHIPS
SOIL DESCRIPTION : Lean clay with sand - CL	**Chen & Associates**
MAX. DRY DENSITY : 117.9 PCF OPT. MOIST. CONTENT : 12.5 %	PROCEDURE : ASTM D698-78, Method A
LIQUID LIMIT : 22 PLASTICITY INDEX : 8	JOB NO. 1 620 87 FIG. NO. 5
GRAVEL : 0 % SAND : 25 % SILT AND CLAY (-200) : 75 %	DATE : 9-21-87

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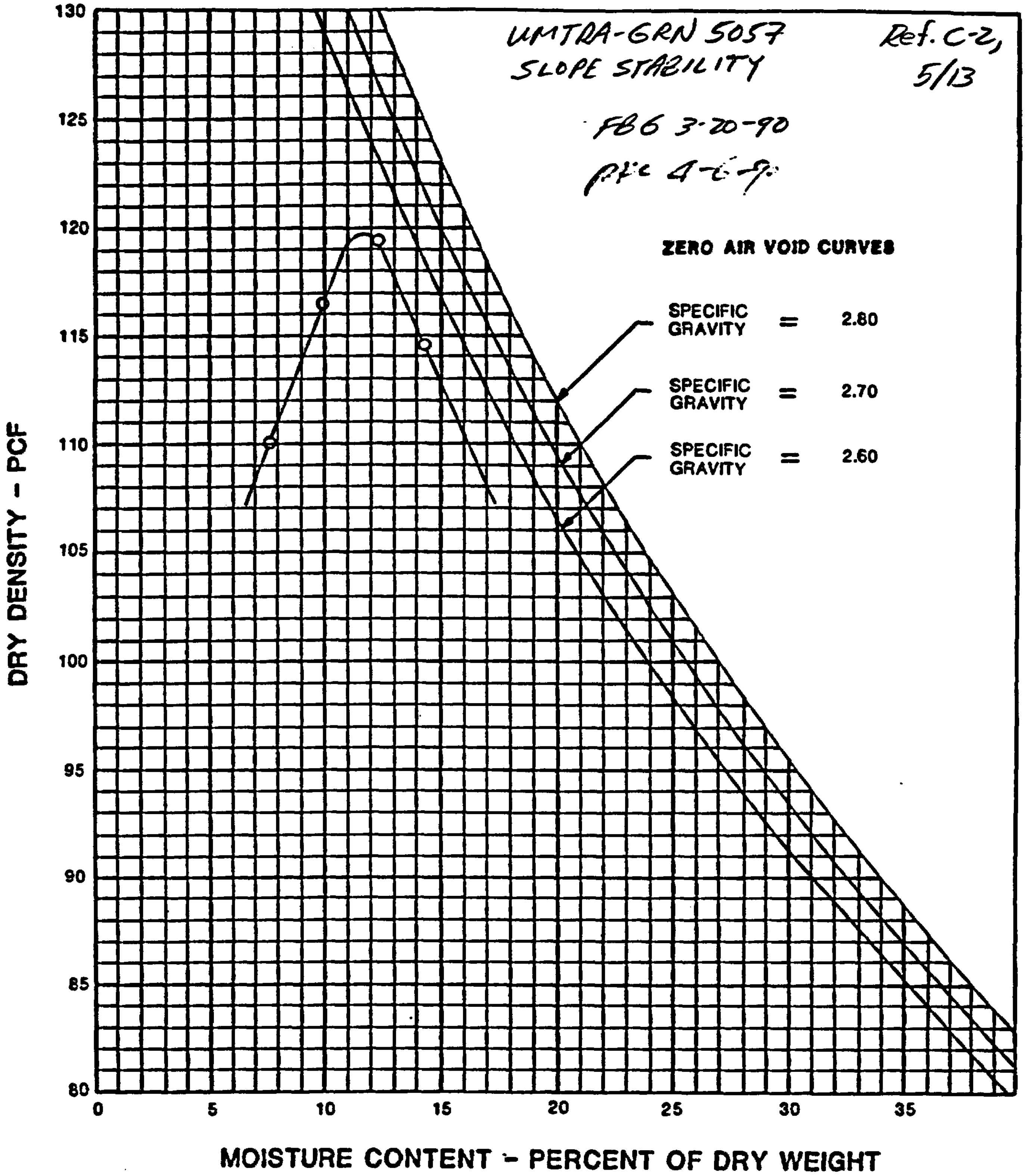
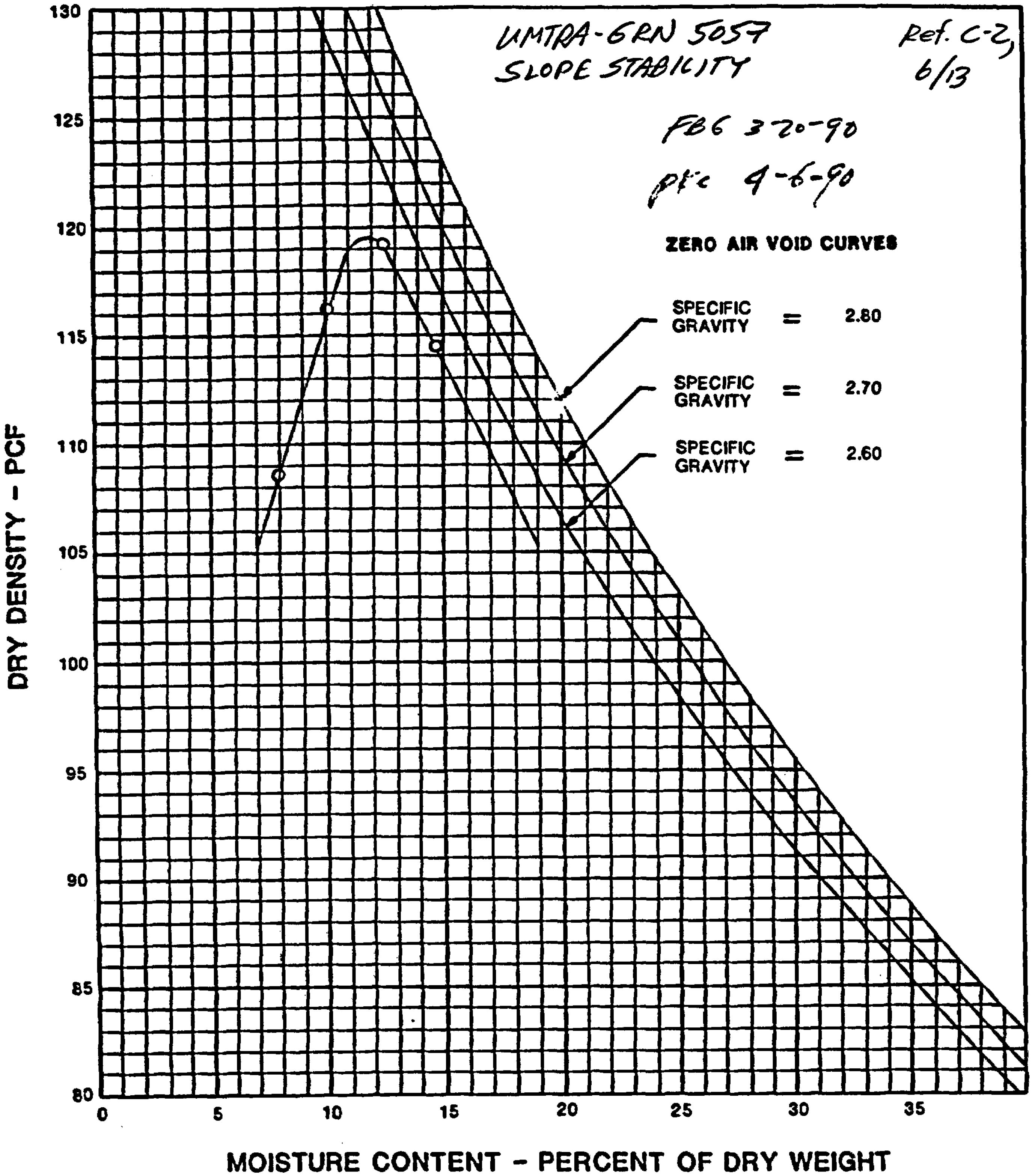
SLOPE STABILITY

Ref. C-2, 5/13

FBG 3-20-90
PKC 4-6-9?

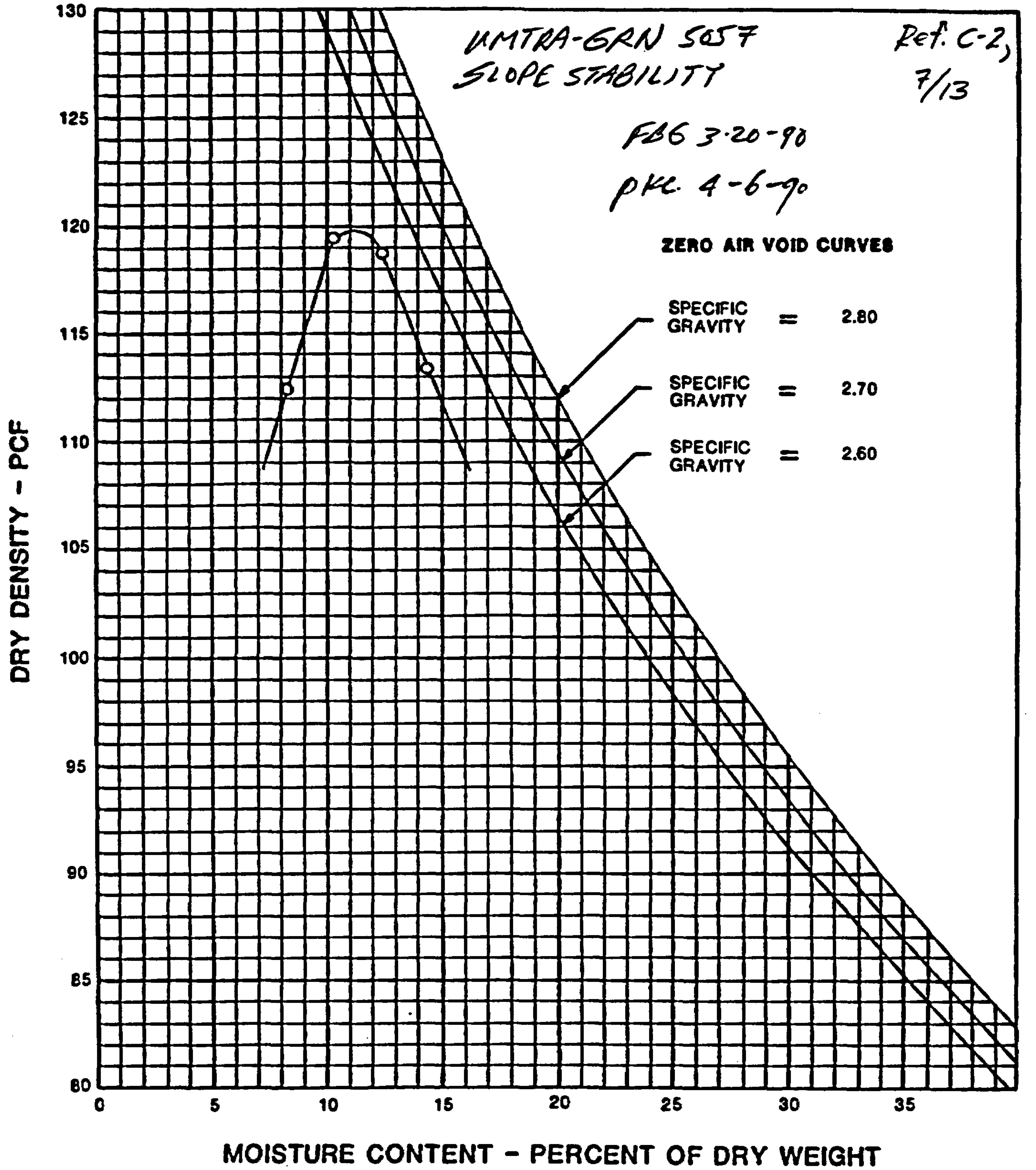


LOCATION : Test Pit 2 DEPTH : 5.0 SAMPLE NO. :	MOISTURE-DENSITY RELATIONSHIPS	
SOIL DESCRIPTION : Sandy silty clay- CL-ML	Chen & Associates	
MAX. DRY DENSITY : 119.8 PCF OPT. MOIST. CONTENT : 11.8 %	PROCEDURE : ASTM D698-78, Method A	
LIQUID LIMIT : 21 PLASTICITY INDEX : 6	JOB NO. : 1 620 87	FIG. NO.
GRAVEL : 0 % SAND : 40 % SILT AND CLAY (-200) : 60 %	DATE : 9-21-87	6

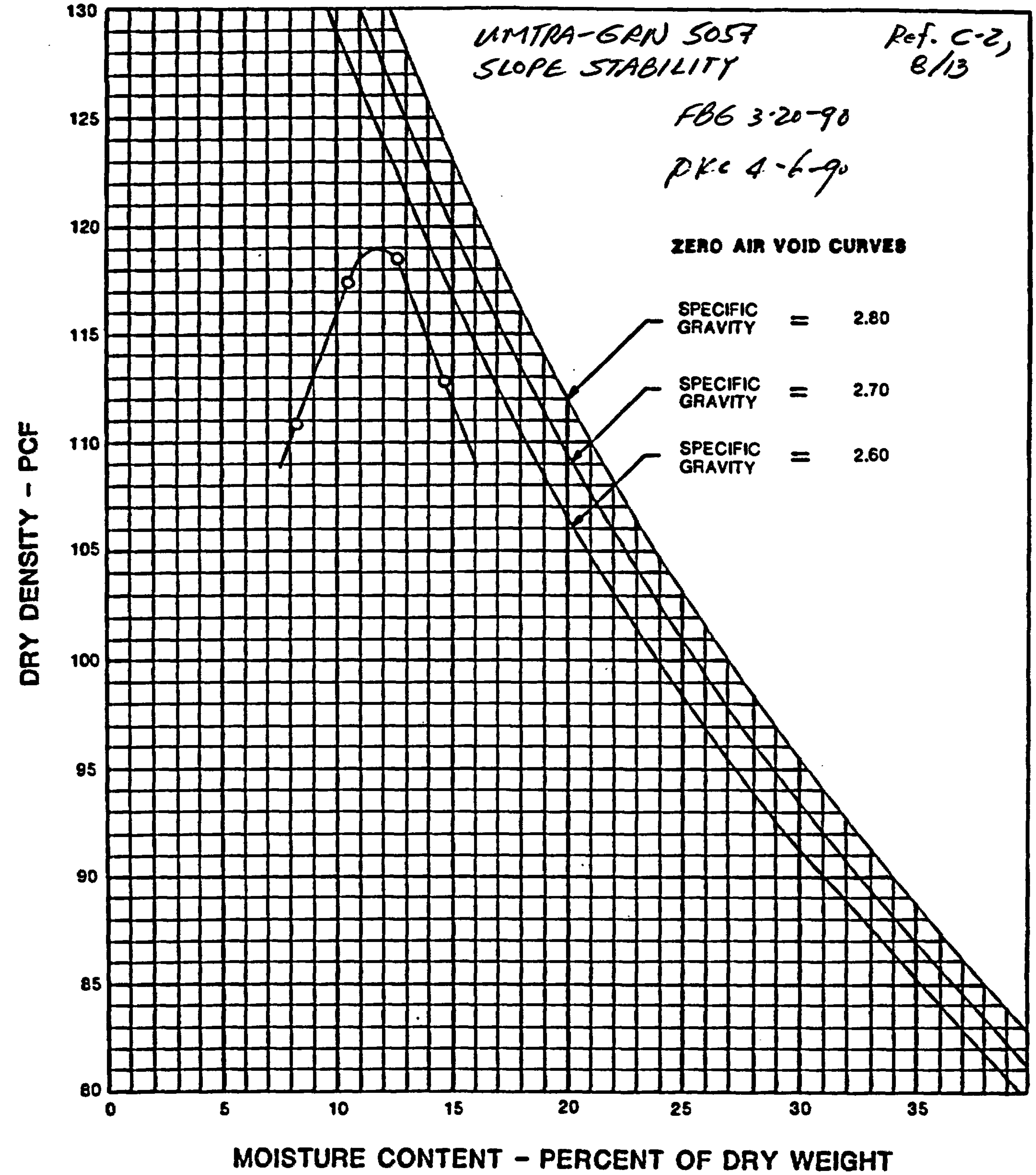


Gs = 2.706
e = 0.41

LOCATION: Test Pit 3 DEPTH: 5.0 SAMPLE NO.:	MOISTURE-DENSITY RELATIONSHIPS
SOIL DESCRIPTION: Sandy silty clay - CL-ML	Chen & Associates
MAX. DRY DENSITY: 119.4 PCF OPT. MOIST. CONTENT: 11.9 %	PROCEDURE: ASTM D698-78, Method A
LIQUID LIMIT: 20 PLASTICITY INDEX: 6	JOB NO.: 1 620 87 — FIG. NO 7
GRAVEL: 0 % SAND: 30 % SILT AND CLAY (-200): 70 %	DATE: 9-21-87



LOCATION:		MOISTURE-DENSITY RELATIONSHIPS
Test Pit 6 DEPTH: 8.0 SAMPLE NO.:		
SOIL DESCRIPTION: Sandy silty clay- CL-ML		Chen & Associates
MAX. DRY DENSITY: 119.9 PCF	OPT. MOIST. CONTENT: 11.2 %	PROCEDURE: ASTM D698-78, Method A
LIQUID LIMIT: 19	PLASTICITY INDEX: 4	JOB NO.: 1 620 87 / FIG. NO.
GRAVEL: 0 % SAND: 45 %	SILT AND CLAY (-200): 55 %	DATE: 9-21-87 / 8



LOCATION :	MOISTURE-DENSITY RELATIONSHIPS
Test Pit 7 DEPTH : 8.0 SAMPLE NO. :	
SOIL DESCRIPTION : Silty clay with sand- CL-ML	Chen & Associates
MAX. DRY DENSITY : 118.9 PCF OPT. MOIST. CONTENT : 11.8 %	PROCEDURE : ASTM D698-78,Method A
LIQUID LIMIT : 21 PLASTICITY INDEX : 6	JOB NO. : 1 620 87 — FIG. NO.
GRAVEL : 0 % SAND : 28 % SILT AND CLAY (-200) : 72 %	DATE : 9-21-87 — 9

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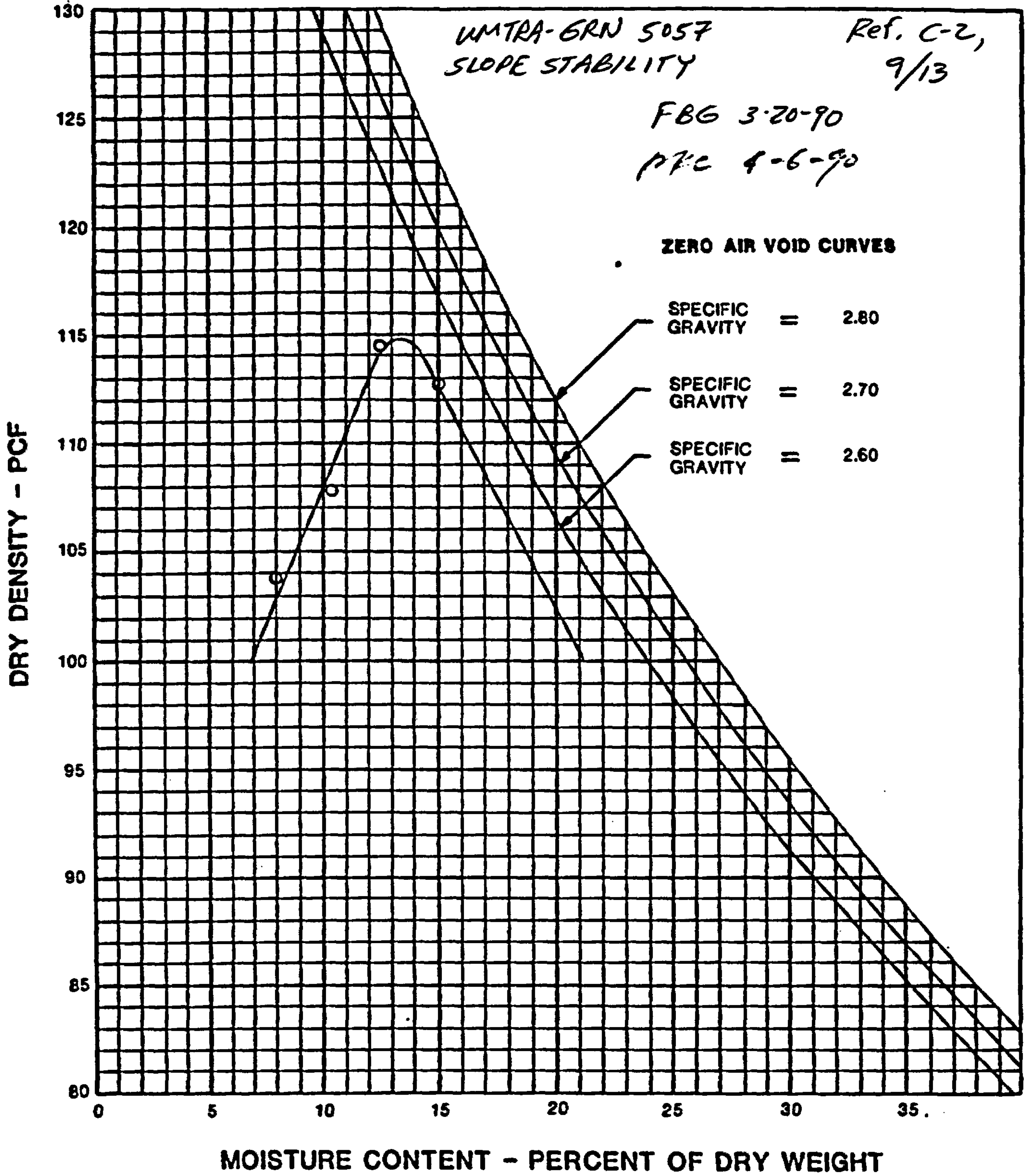
FBG 3-20-90
PKC 4-6-90



Gs = 2.713
e = 0.27

LOCATION :	MOISTURE-DENSITY RELATIONSHIPS
Test Pit 9 DEPTH : 8.0 SAMPLE NO. :	
SOIL DESCRIPTION : Lean clay - CL	Chen & Associates
MAX. DRY DENSITY : 114.9 PCF OPT. MOIST. CONTENT : 13.3 %	PROCEDURE : ASTM D698-78, Method A
LIQUID LIMIT : 28 PLASTICITY INDEX : 13	JOB NO. : 1 620 87 — FIG. NO.
GRAVEL : 0 % SAND : 14 % SILT AND CLAY (-200) : 86 %	DATE : 9-21-87 — 10

UMTRA-GRN 5057
SLOPE STABILITY
FGG 3-20-90

C-27

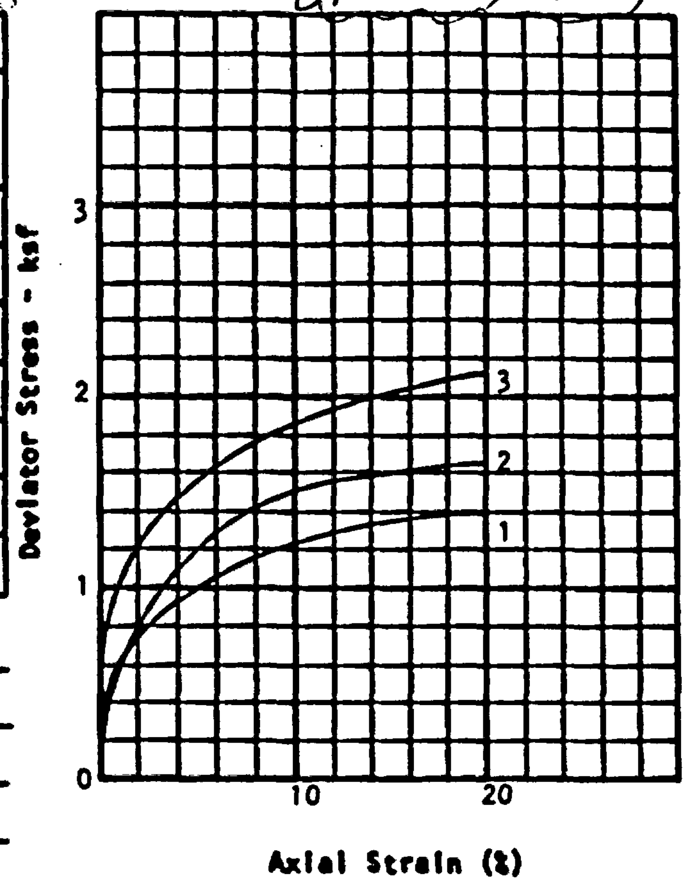
CHEN AND ASSOCIATES

Consulting Soil and Foundation Engineers

GREEN RIVER, UTAH

Ref. C-2, 10/13

TEST NUMBER	1	2	3	4
LOCATION	6-RAD BOR			
HEIGHT - INCH	3.876	3.925	3.914	
DIAMETER - INCH	1.876	1.876	1.876	
WATER CONTENT - %	13.7	13.9	14.0	
DRY DENSITY - pcf	113.1	113.3	113.4	
$\sigma_1 - \sigma_3$	1.420	1.630	2.130	
σ_1 - ksf	1.564	2.350	3.570	
σ_3 - ksf	0.144	0.720	1.440	



TYPE OF SPECIMEN: Remolded

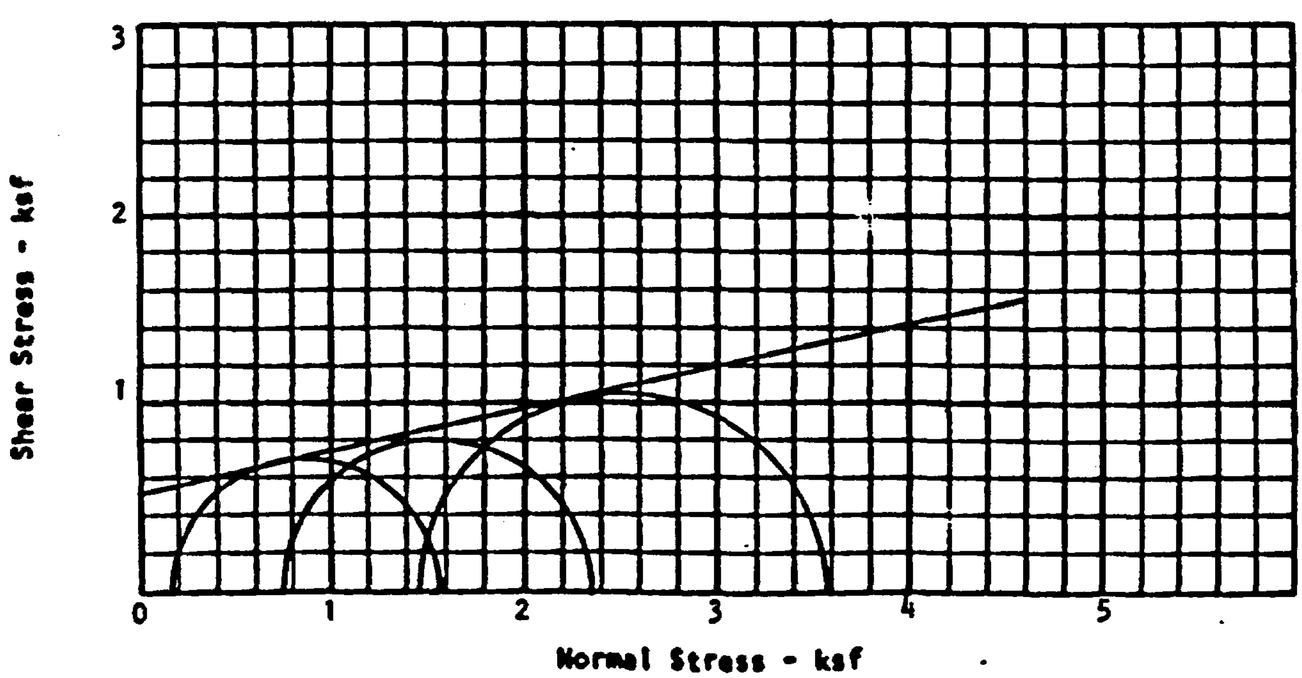
SOIL DESCRIPTION: Sandy silty clay

TYPE OF TEST: Unsaturated, Unconsolidated, Undrained

TAN ϕ: 0.22

ϕ: 12.6°

COHESION - ksf: 0.52



TRIAXIAL SHEAR TEST RESULTS

Fig. 11

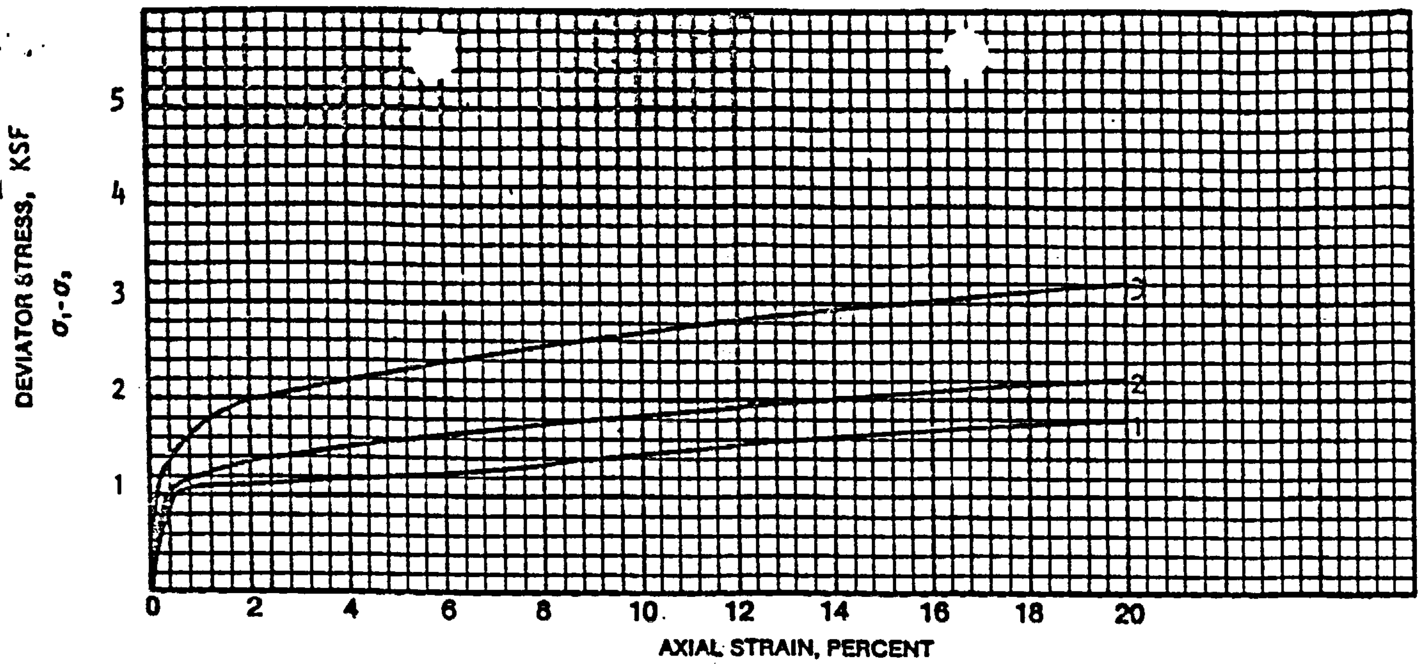
SHEAI‾TRENGTH OF SOIL IN TRIAXIAL COMPRESSION

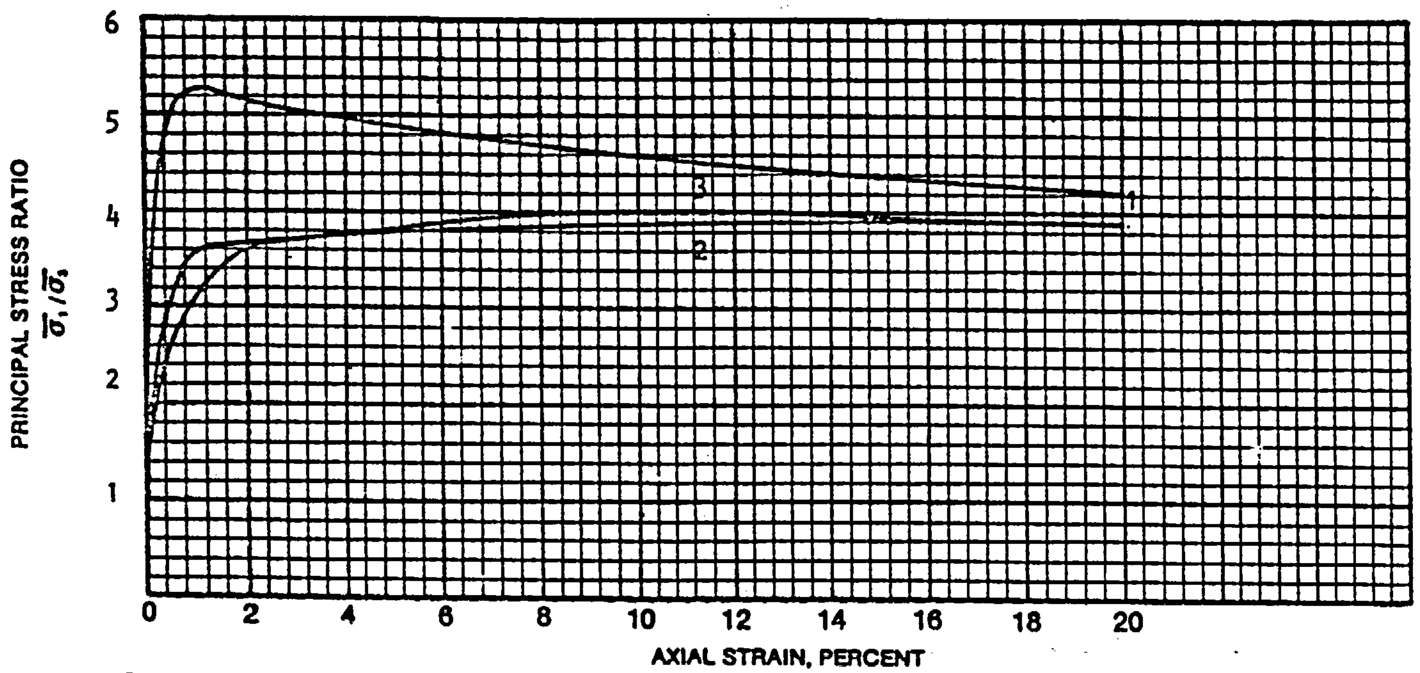
C-28

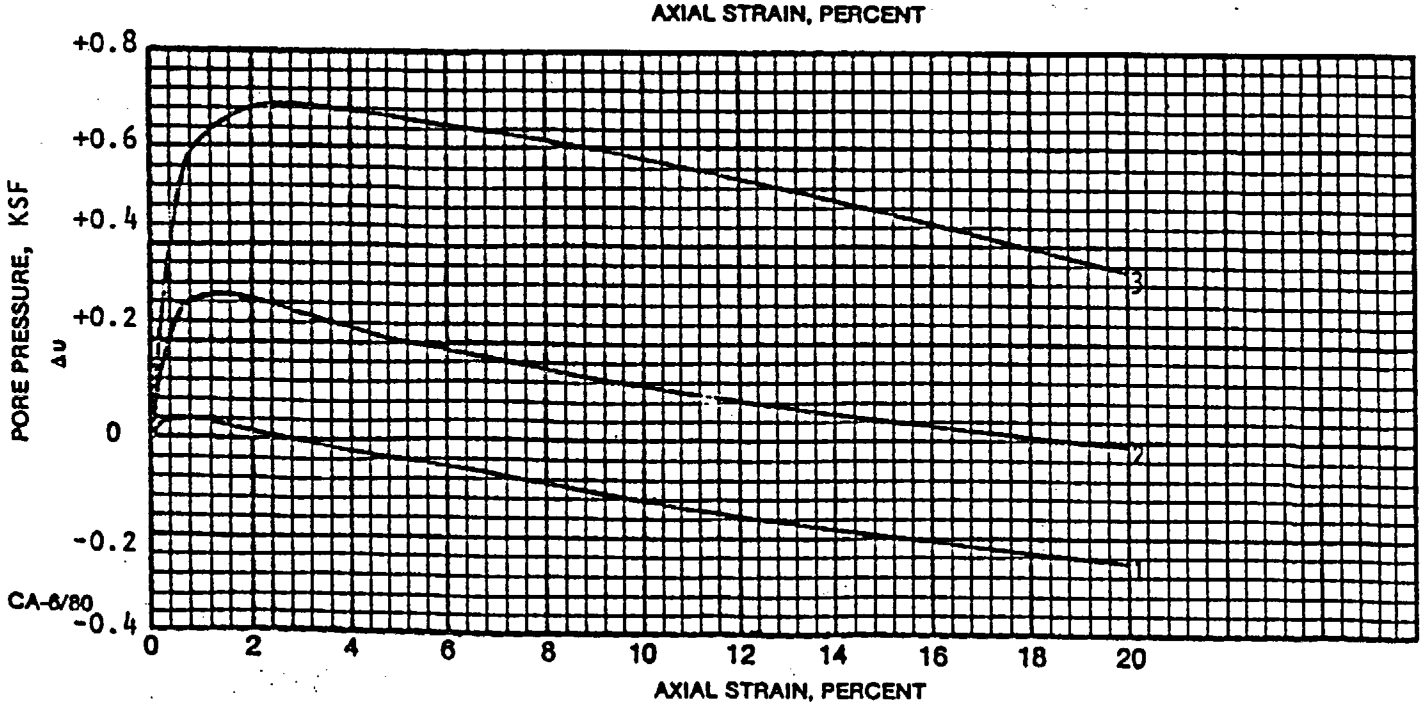
GREEN RIVER, UTAH

UMTRA-GRN, 5057
SLOPE STABILITY
Ref. C-2,
FRG 3-20-90 ΠKL 4-6-90 11/13

Job No. 1 620 87
Date 10-21-87
Type of Test Saturated, consolidated, undrained, with pore pressure measurements

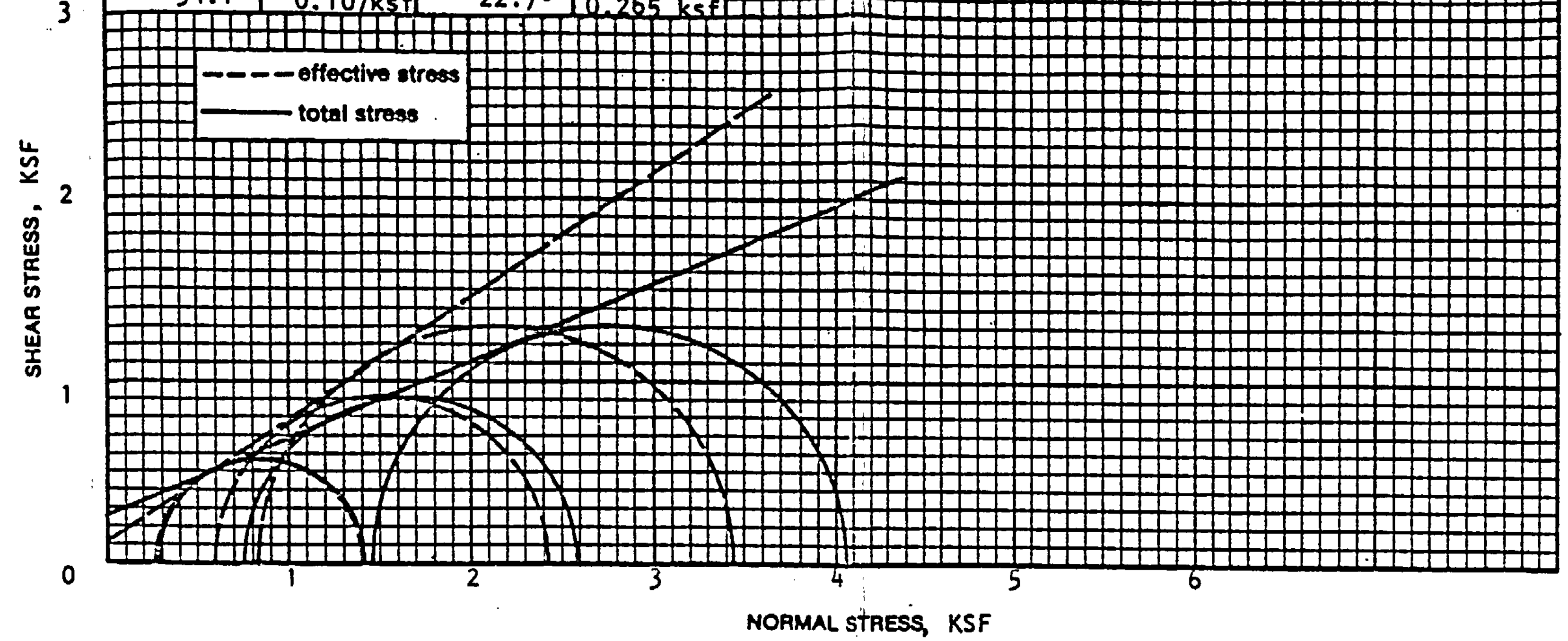






CA-6/80

SHEAR VALUES			
Effective Stresses		Total Stresses	
$\bar{\phi}$ = 34.1°	$\bar{C}$ = 0.107ksf	ϕ = 22.7°	C = 0.265 ksf



Specimen Number	Specimen Location		Initial Specimen Data					Soil Description
	Boring Number	Depth (Ft)	Sample Type	Length (in)	Diameter (in)	Dry Density (P.C.F.)	Moisture Content (%)	
1	6 RAD BOR		Remolded	3.924	1.876	113.1	14.1	Sandy silty clay
2	6 RAD BOR		Remolded	3.916	1.876	113.0	14.2	Sandy silty clay
3	6 RAD BOR		Remolded	3.924	1.876	113.0	14.2	Sandy silty clay

Specimen Number	"B" Parameter	TEST VALUES AT MAXIMUM EFFECTIVE STRESS RATIO							Remarks
		Total Confining Stress σ_3	Total Axial Stress σ_1	Deviator Stress $\sigma_1-\sigma_3$	Effective Lateral Stress $\bar{\sigma}_3$	Effective Axial Stress $\bar{\sigma}_1$	Pore Pressure μ	Percent Strain ϵ%	
1	0.98	0.288	1.417	1.129	0.259	1.388	0.029	2.599	Units in ksf
2	0.95	0.763	2.574	1.811	0.605	2.416	0.158	9.007	Units in ksf
3	0.96	1.454	4.059	2.605	0.835	3.440	0.619	9.082	Units in ksf

Remarks:

Fig. 12

UMTRA-GRN 5057 SLOPE STABILITY FEB 3-20-90

CHEN AND ASSOCIATES

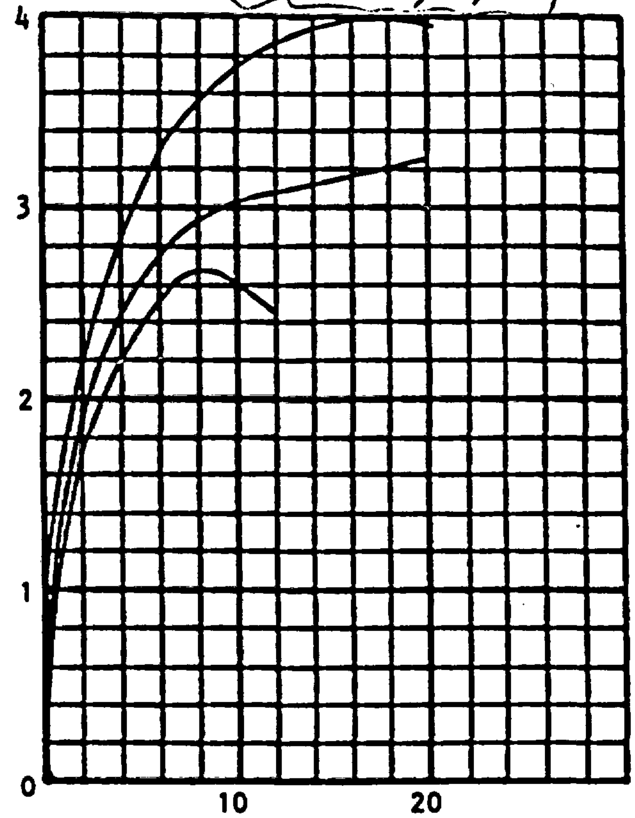
Consulting Soil and Foundation Engineers

GREEN RIVER, UTAH

C-29

Ref. C-2, 12/13

TEST NUMBER	1	2	3	4
LOCATION	9-RAD BOR			
HEIGHT - INCH	3.920	3.930	3.920	
DIAMETER - INCH	1.876	1.876	1.880	
WATER CONTENT - %	16.2	16.0	15.9	
DRY DENSITY - pcf	108.5	108.4	108.4	
$\sigma_1 - \sigma_3$	2.65	3.25	4.00	
σ_1 - ksf	2.79	3.97	5.44	
σ_3 - ksf	0.14	0.72	1.44	



TYPE OF SPECIMEN: Remolded

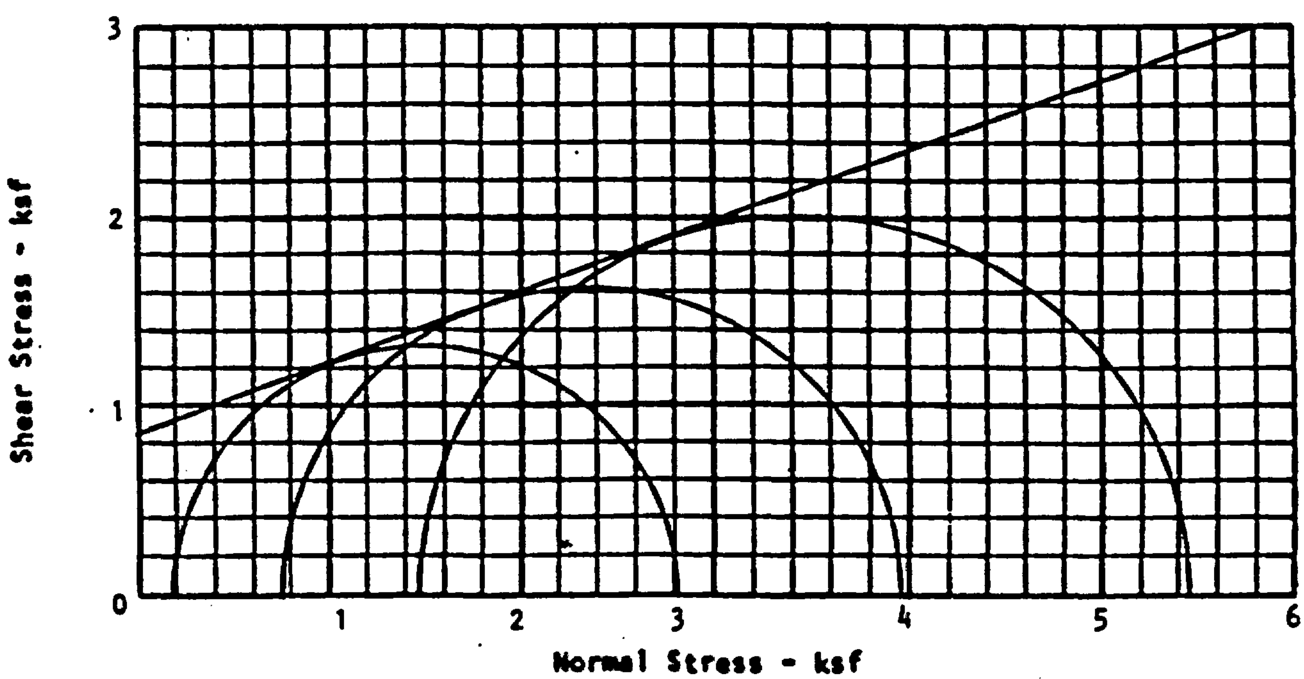
SOIL DESCRIPTION: Clayey silt

TYPE OF TEST: Unsaturated, Unconsolidated, Undrained

TAN Ø: 0.36

Ø: 20.0°

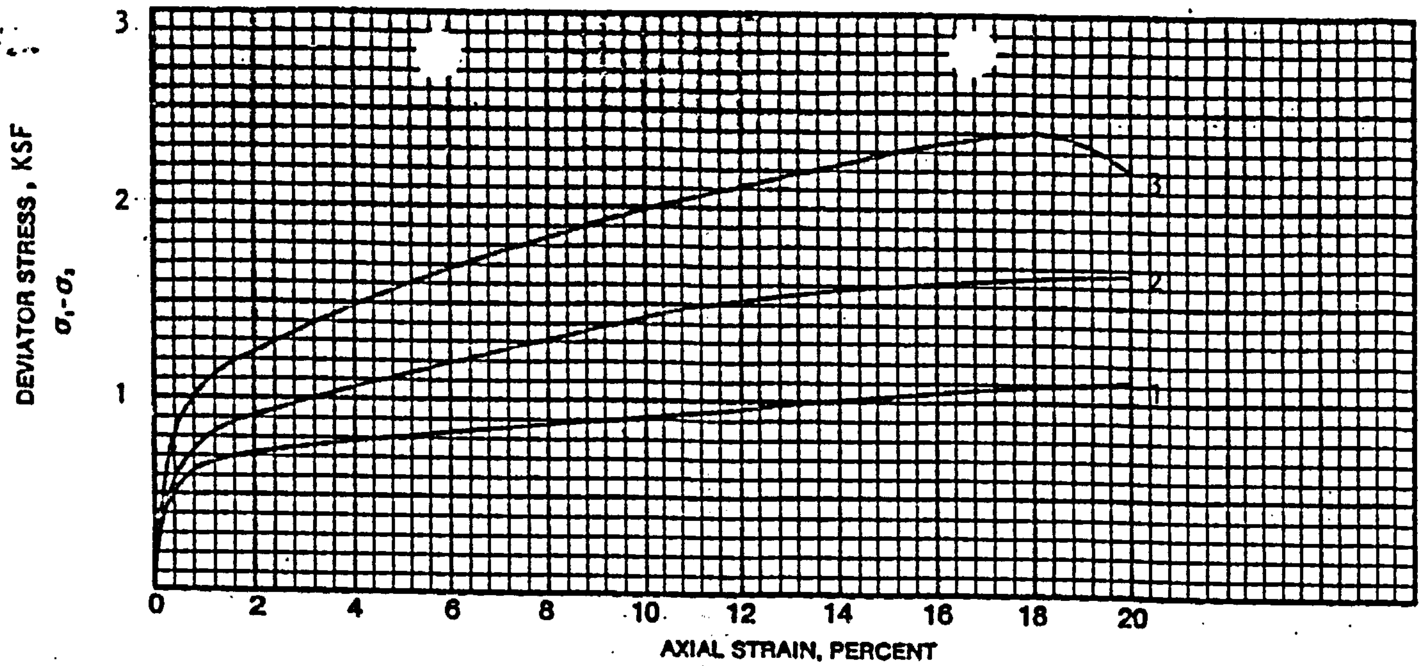
COHESION - ksf: 0.88

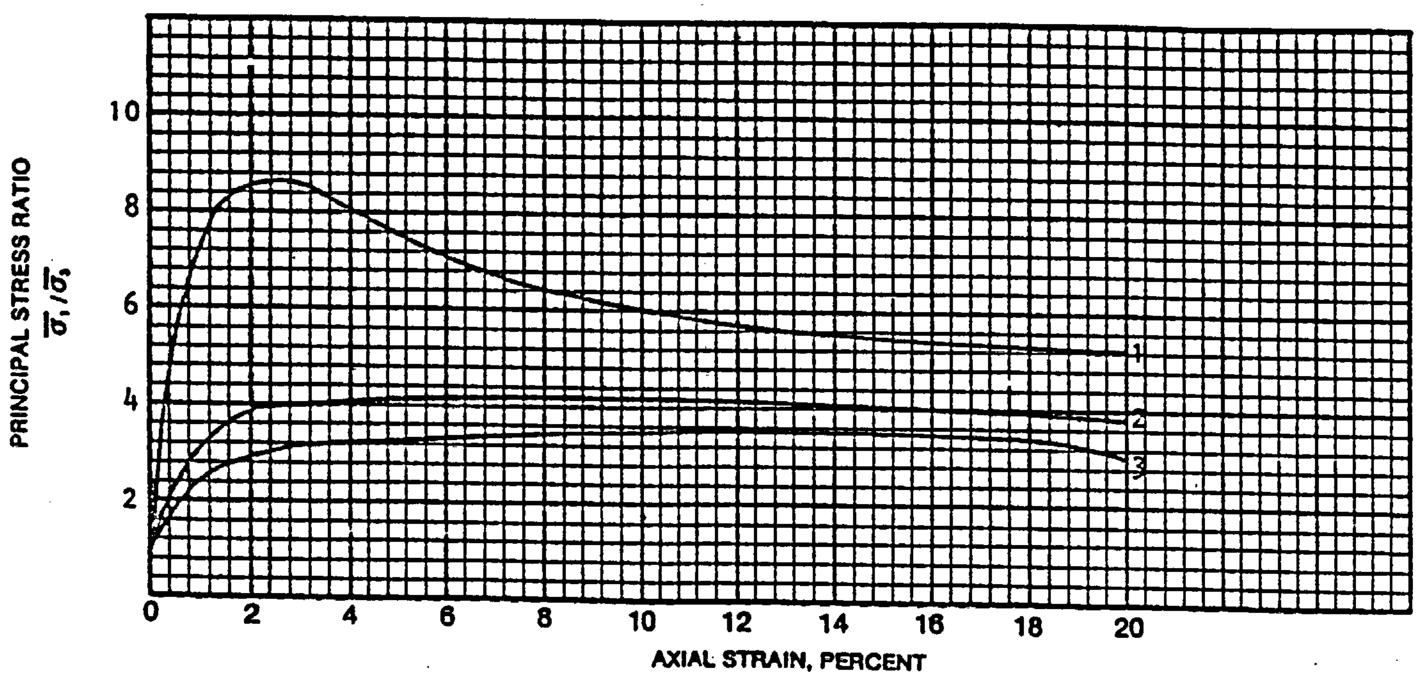


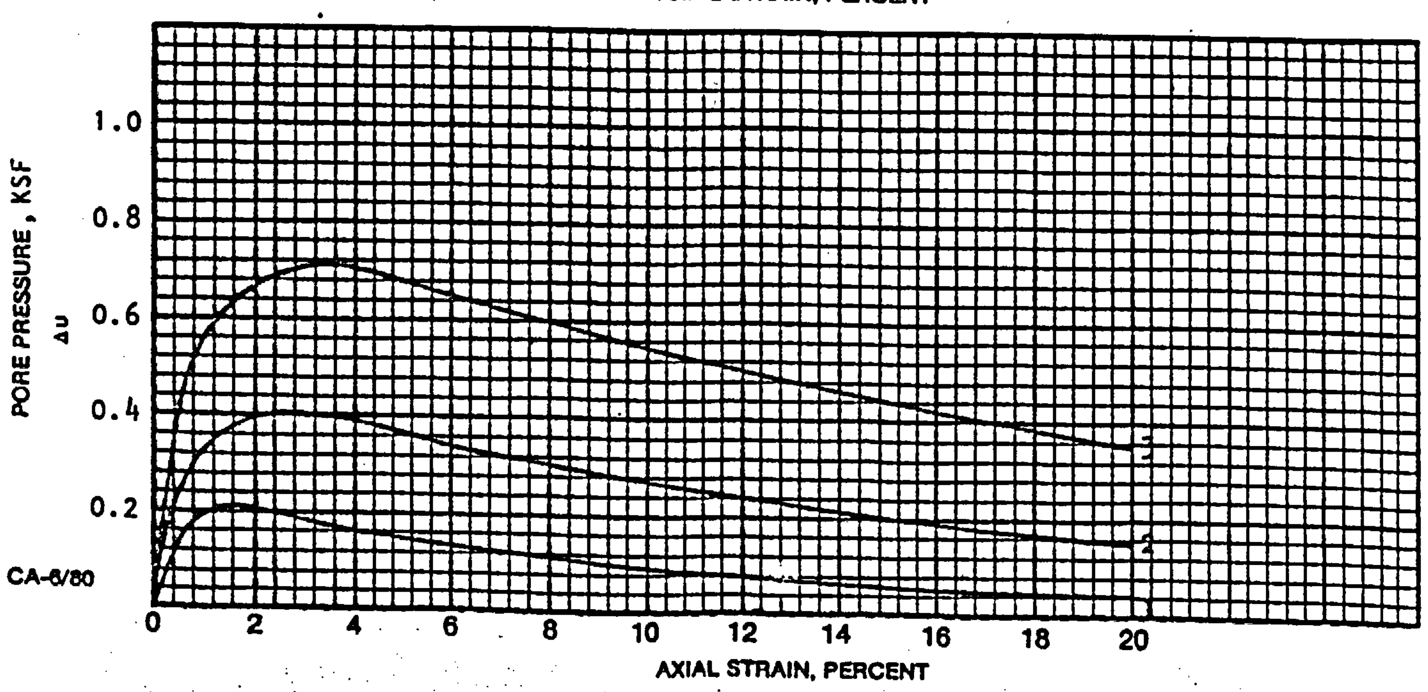
1 620 87

TRIAXIAL SHEAR TEST RESULTS

Fig. 13







CA-6/80

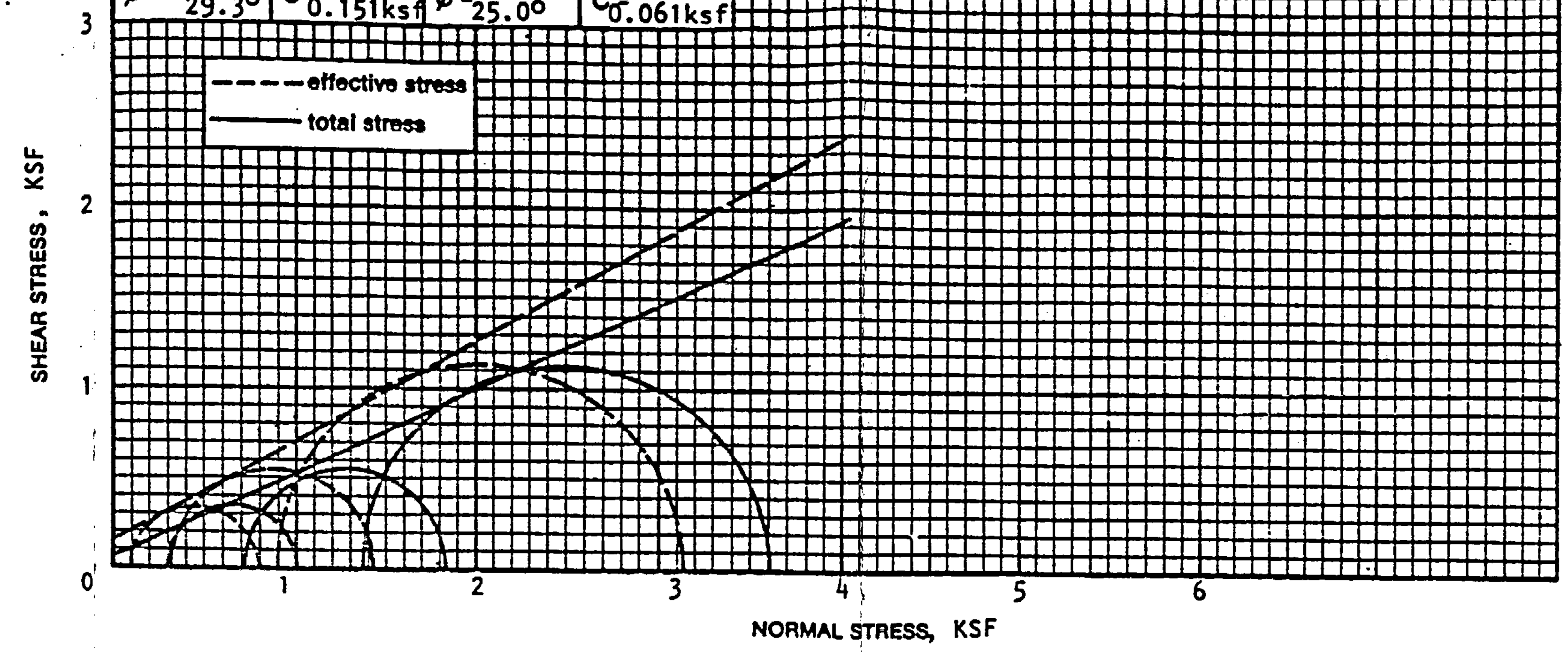
SHEAR STRENGTH OF SOIL IN TRIAXIAL COMPRESSION

C-30

Job No. 1 620 87
Date 10-21-87
Type of Test Saturated, consolidated, undrained, with pore pressure measurements

GREEN RIVER, UTAH
UMTRA-GRN 5057
SLOPE STABILITY
FBG 3-20-90 ... 4-6-90
Ref. C-2, 13/13

SHEAR VALUES			
Effective Stresses		Total Stresses	
$\bar{\phi}$ = 29.3°	$\bar{C}$ = 0.151ksf	ϕ = 25.0°	C = 0.061ksf



Specimen Number	Specimen Location: Boring Number	Specimen Location: Depth (Ft)	Initial Specimen Data: Sample Type	Length (in)	Diameter (in)	Dry Density (P.C.F.)	Moisture Content (%)	Soil Description
1	9 RAD BOR		Remolded	3.930	1.880	107.6	16.3	Lean clay
2	9 RAD BOR		Remolded	3.905	1.876	108.8	16.1	Lean clay
3	9 RAD BOR		Remolded	3.910	1.880	108.3	16.0	Lean clay

Specimen Number	"B" Parameter	Test Values at Maximum Effective Stress Ratio: Total Confining Stress σ_3	Total Axial Stress σ_1	Deviator Stress $\sigma_1-\sigma_3$	Effective Lateral Stress $\bar{\sigma}_3$	Effective Axial Stress $\bar{\sigma}_1$	Pore Pressure μ	Percent Strain ϵ%	Remarks
1	1.00	0.288	1.004	0.716	0.086	0.802	0.202	2.194	Units in KSF
2	0.95	0.734	1.837	1.103	0.331	1.435	0.403	4.506	Units in KSF
3	0.96	1.368	3.612	2.244	0.893	3.137	0.475	14.271	Units in KSF

Remarks:

Fig. 14

C-31

Chen & Associates
Consulting Geotechnical Engineers

96 South Zuni
Denver, Colorado 80223
303/744-7105

Casper
Colorado Springs
Ft. Collins
Glenwood Springs
Phoenix
Rock Springs
Salt Lake City
San Antonio

UMTRA-GRN 5057
SLOPE STABILITY

FBG 3-20-90
MKC 4-6-90

Ref. C-3
1/3

REF. C-3 (3pp.

February 15, 1988

Subject: Laboratory Testing, Radon Barrier Materials, UMTRA Project, Green River, Utah
PO # 3050-511-9502 C.O.5
Job No. 1 104 88

Mr. Mark Thompson
MK-Ferguson Company
P.O. Box 9136
Albuquerque, New Mexico 87119

Dear Mr. Thompson:

As requested, we have performed consolidated, undrained triaxial shear strength tests on samples 3-RADBOR and 7-RADBOR from the subject site. The test samples were compacted with three percent bentonite to approximately 100% of the standard Proctor density. The results are presented on Figures 8 and 9, enclosed. All requested testing for this change order has been completed.

If you have any questions regarding this submittal, please call.

Sincerely,

CHEN & ASSOCIATES, INC.

By Sally K. Miller
Sally K. Miller, A.E.T.
Soils Laboratory Supervisor

SKM/djb
Rev. By: KRC
cc: Mr. Frank Guros
Morrison-Knudsen Engineers, Inc.

ATTACHMENT: 5057-GRN-C-09-00710-00

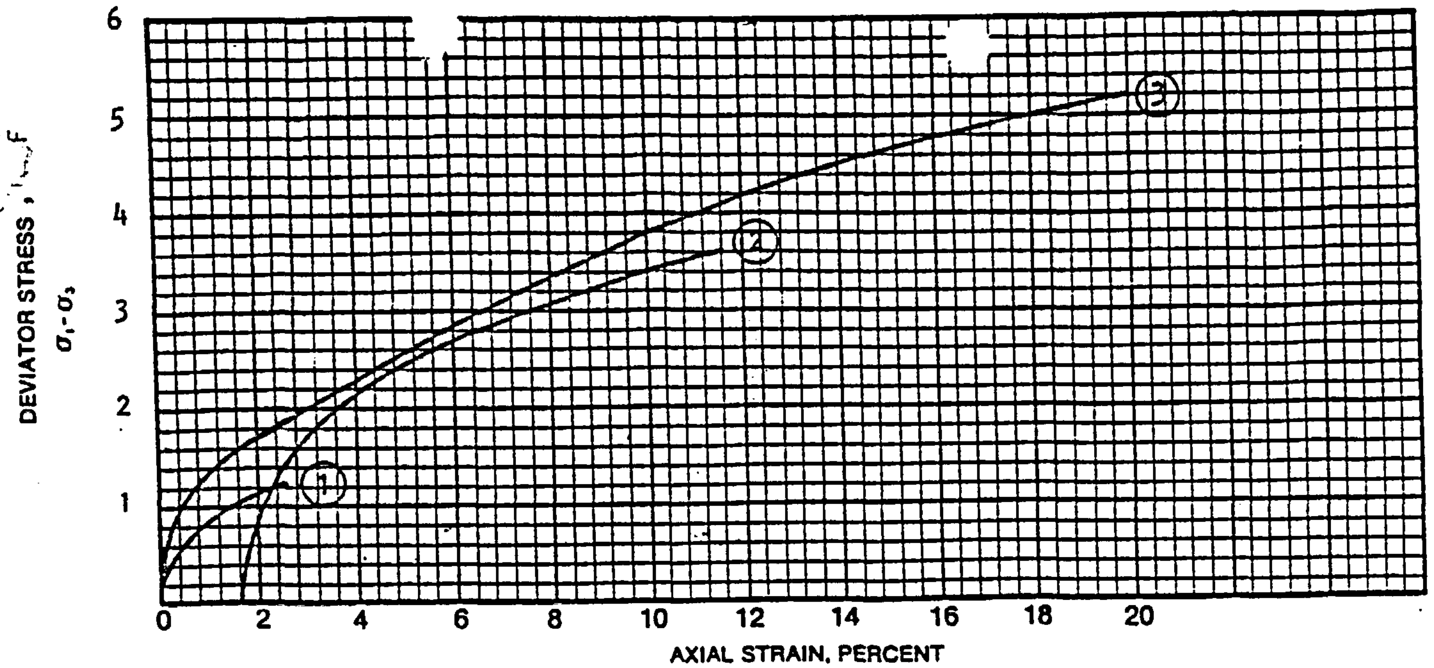
RECEIVED-MKE
FEB 17 1988
UMTRA-S.F.

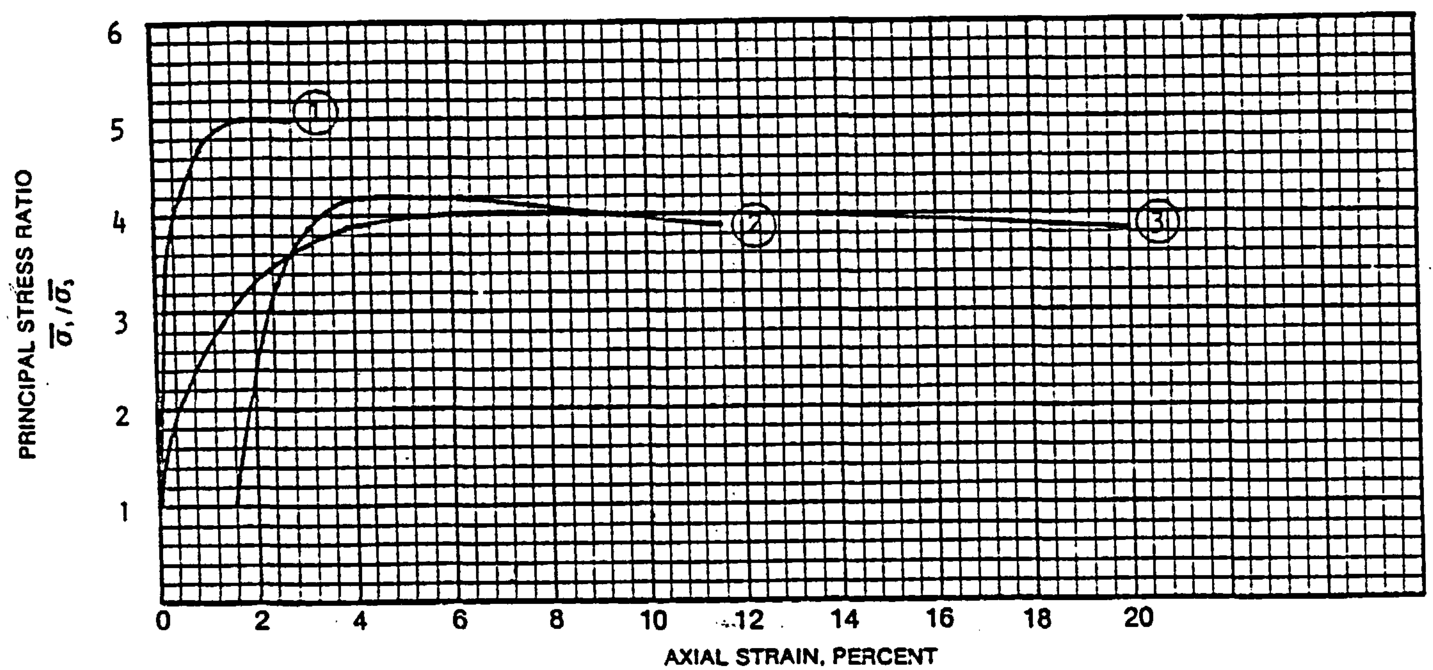
MKE DOCUMENT NO.5057-GRN-C-09-00710-00 C-32

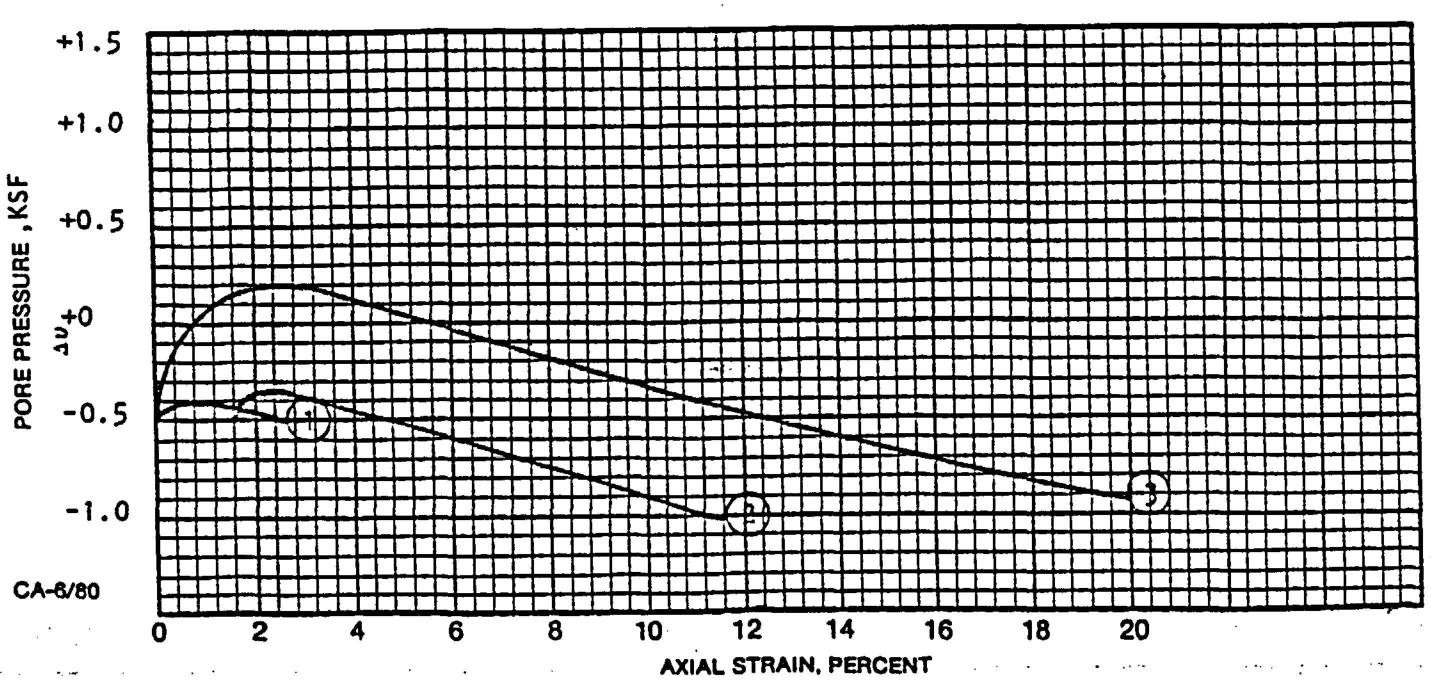
SHEAR STRENGTH OF SOIL IN TRIAXIAL COMPRESSION

FBG 3-20-90
UMTRA-GRN 5057 SLOPE STABILITY Ref. C-3, 2/3

Job No. 1 104 88
Date 2-9-88
Type of Test Multi-staged,* saturated, consolidated, undrained with pore pressure measurements

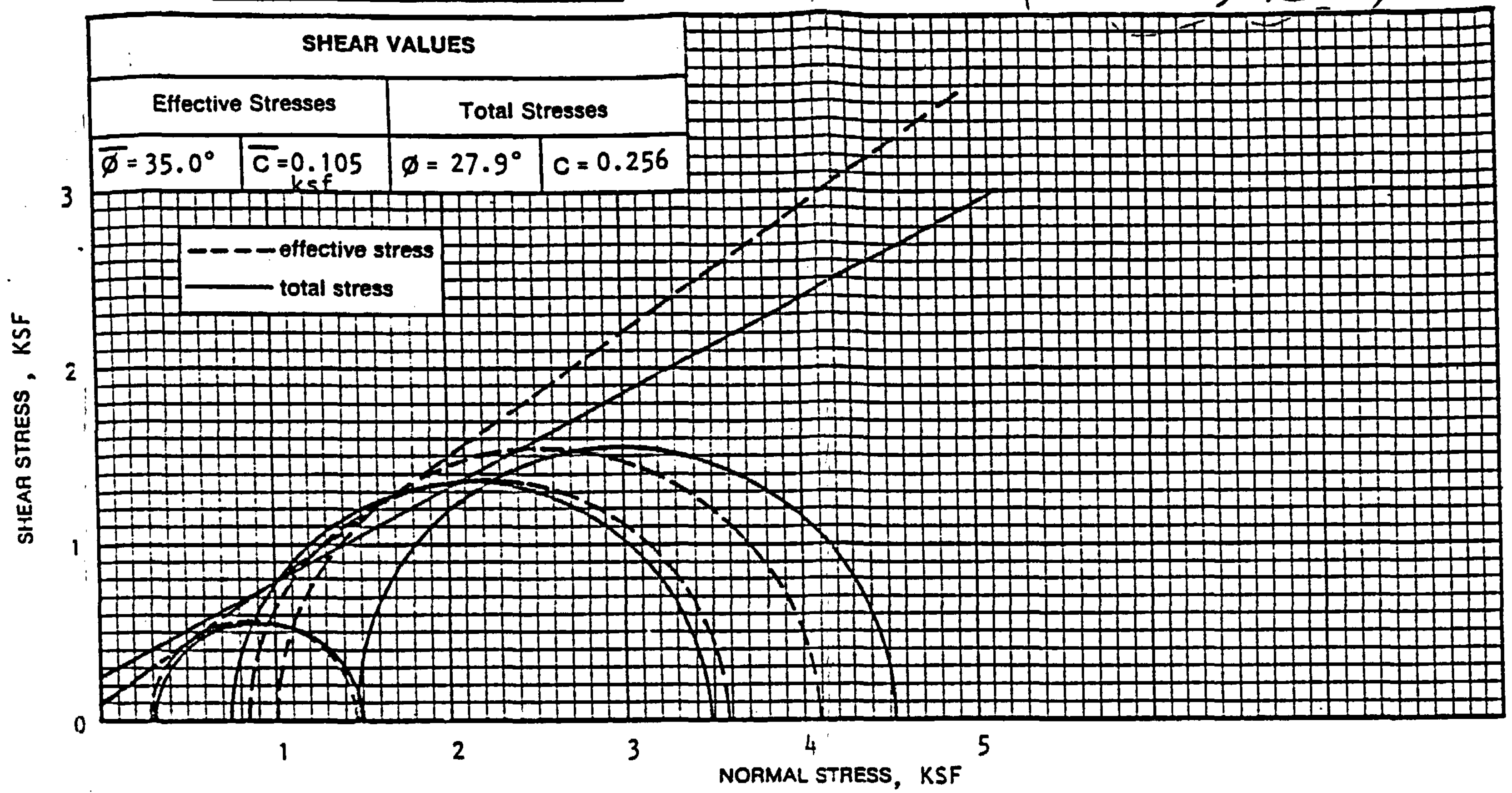






CA-6/80

SHEAR VALUES			
Effective Stresses		Total Stresses	
$\bar{\phi}$ = 35.0°	$\bar{c}$ = 0.105 ksf	ϕ = 27.9°	c = 0.256



Stage Number	Specimen Location: Boring Number	Depth (Ft)	Initial Specimen Data: Sample Type	Length (in)	Diameter (in)	Dry Density (P.C.F.)	Moisture Content (%)	Soil Description
1	TP-3		Remolded	3.960	1.878	116.2	15.2	Sandy, silty clay with 3% bentonite
2	TP-3		—	—	—	—	—	Sandy, silty clay with 3% bentonite
3	TP-3		Remolded	3.952	1.878	116.6	15.3	Sandy, silty clay with 3% bentonite

Stage Number	"B" Parameter	Test Values at Maximum Principal Stress Ratio: Total Confining Stress σ_3	Total Axial Stress σ_1	Deviator Stress $\sigma_1-\sigma_3$	Effective Lateral Stress $\bar{\sigma}_3$	Effective Axial Stress $\bar{\sigma}_1$	Pore Pressure μ	Δ * Percent Strain ε%	Remarks
1	0.95	0.317	1.487	1.170	0.288	1.458	0.029	2.205	Units in ksf
2	—	0.749	3.466	2.717	0.850	3.566	-0.101	4.508	Units in ksf
3	0.97	1.454	4.538	3.084	1.008	4.092	0.446	6.997	Units in ksf

Remarks: * First two stages only. Third stagr run separately.

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FEB 17 1988

Fig. 8

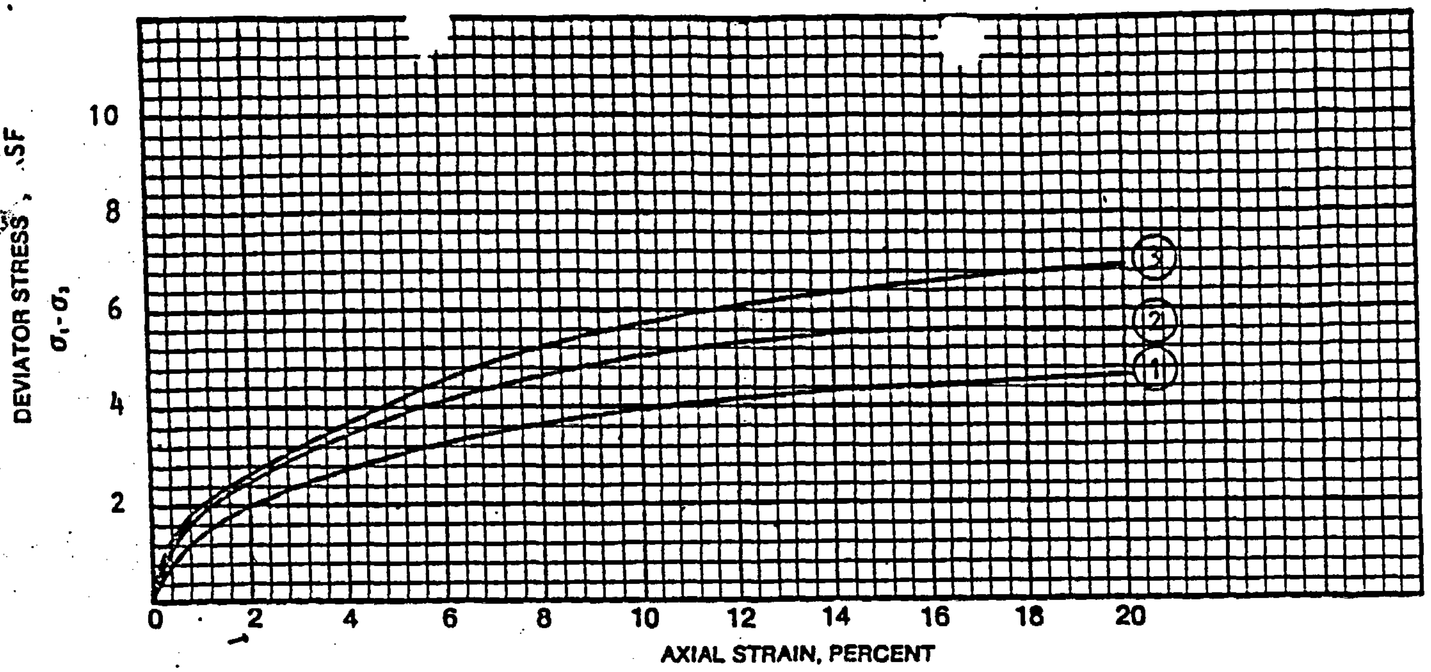
SHEAR STRENGTH OF SOIL IN TRIAXIAL COMPRESSION

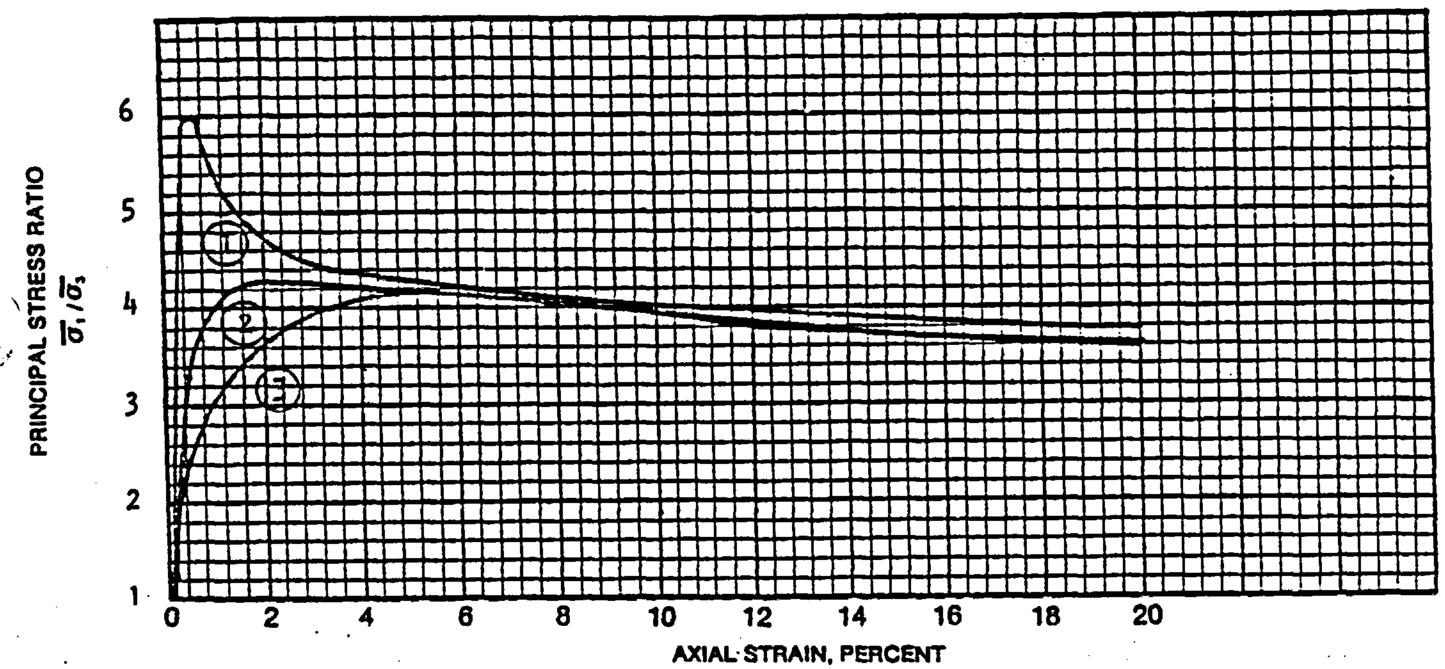
C-33

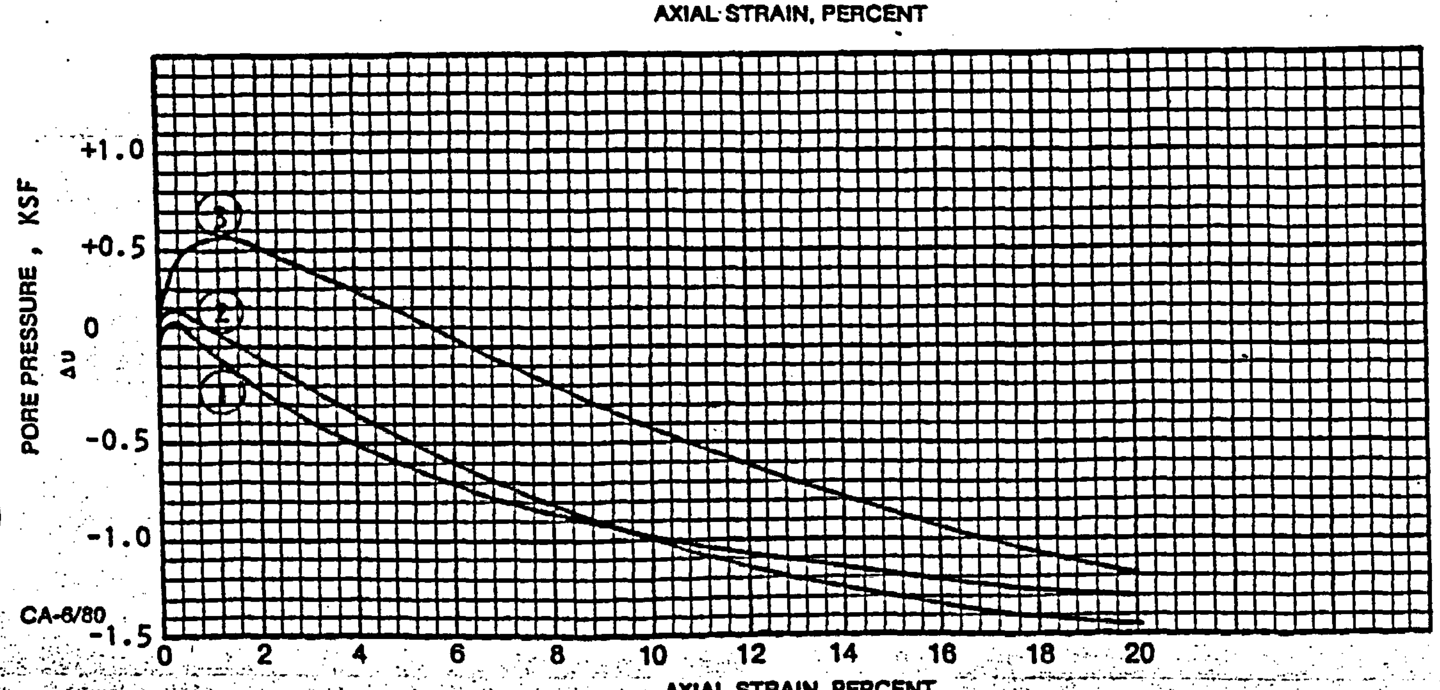
UMTRA-GRN 5057
SLOPE STABILITY
Ref. C-3, 3/3

FB6 3-20-90

Job No. 1 104 88
Date 2-12-88.
Type of Test Saturated, consolidated, undrained with pore pressure measurements

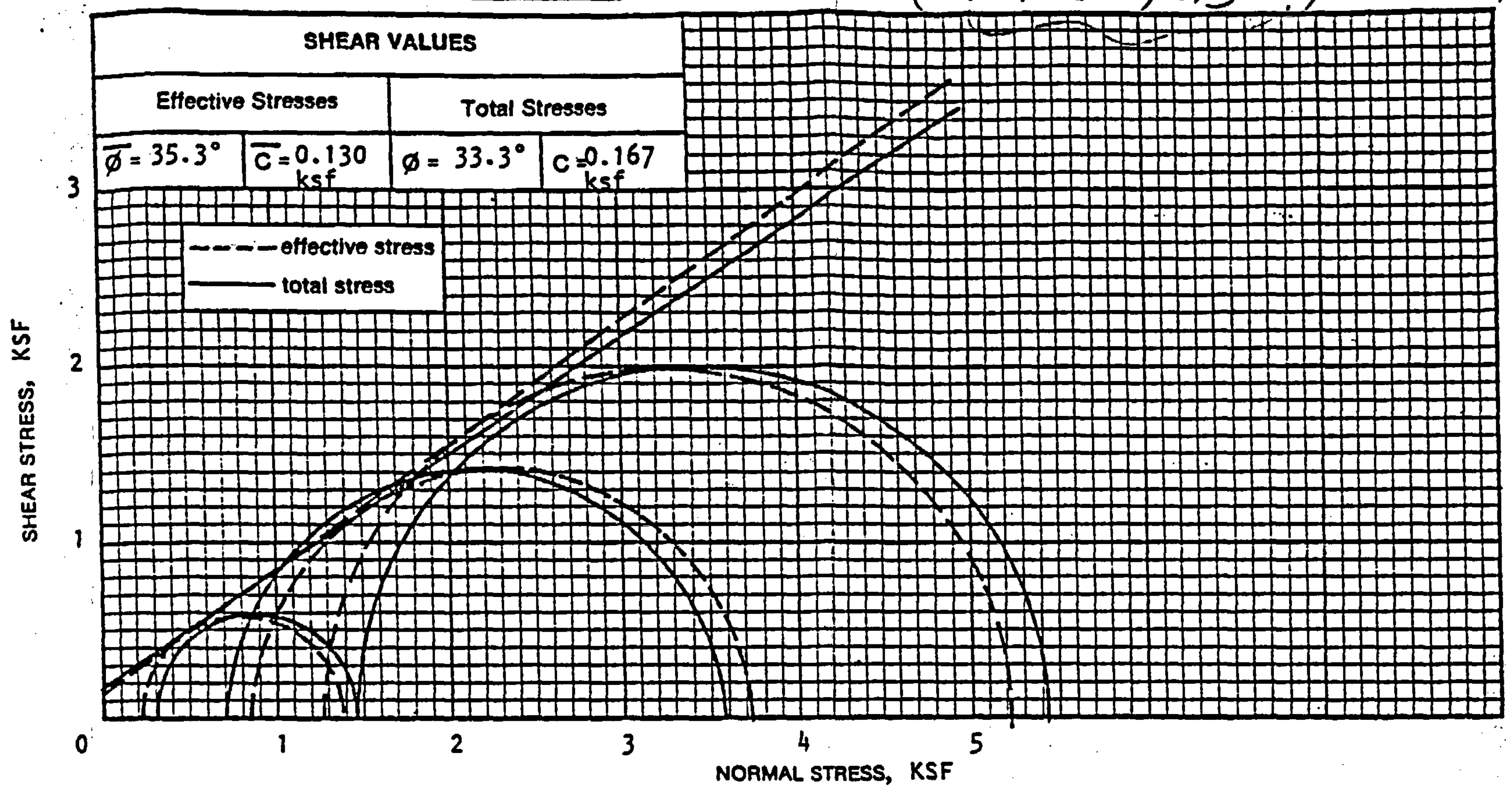






CA-6/80

SHEAR VALUES			
Effective Stresses		Total Stresses	
$\bar{\phi}$ = 35.3°	$\bar{c}$ = 0.130 ksf	ϕ = 33.3°	c = 0.167 ksf



Stage Number	Specimen Location: Boring Number	Specimen Location: Depth (Ft)	Initial Specimen Data: Sample Type	Length (in)	Diameter (in)	Dry Density (P.C.F.)	Moisture Content (%)	Soil Description
1	TP-7		Remolded	3.903	1.884	117.3	14.0	Silty clay with sand with 3% bentonite
2	TP-7		Remolded	3.898	1.885	117.0	14.2	Silty clay with sand with 3% bentonite
3	TP-7		Remolded	3.884	1.884	117.2	14.4	Sandy clay with sand 3% bentonite

Stage Number	"B" Parameter	Test Values at Maximum Principal Stress Ratio: Total Confining Stress σ_3	Total Axial Stress σ_1	Deviator Stress $\sigma_1-\sigma_3$	Effective Lateral Stress $\bar{\sigma}_3$	Effective Axial Stress $\bar{\sigma}_1$	Pore Pressure μ	Percent Strain ϵ%	Remarks
1	0.96	0.317	1.469	1.152	0.230	1.383	0.086	0.589	Units in ksf
2		0.720	3.548	2.828	0.864	3.692	-0.144	2.608	Units in ksf
3		1.469	5.433	3.964	1.253	5.217	0.216	4.991	Units in ksf

Remarks:

Fig. 9

C-34

Chen & Associates
Consulting Geotechnical Engineers

96 South Zuni
Denver, Colorado 80223
303/744-7105

Casper
Colorado Springs
Ft. Collins
Glenwood Springs
Phoenix
Rock Springs
Salt Lake City
San Antonio

UMTRA-GRN 5057
SLOPE STABILITY

FBG 3-20-90
[illegible] 4-6-90

Ref. C-4
1/9

Ref. C-4 (9 pp.)

January 27, 1988

Subject: Laboratory Testing, Radon Barrier Materials, UMTRA Project, Green River, Utah
PO # 3050-511-9502 C.O.5
Job No. 1 104 88

Mr. Mark Thompson
MK-Ferguson Company
P.O. Box 9136
Albuquerque, New Mexico 87119

Dear Mr. Thompson:

As requested, we have performed standard Proctor compaction and triaxial permeability tests on the following samples: 1-RADBOR, 2-RADBOR, 3-RADBOR, 4-RADBOR, 5-RADBOR, 6-RADBOR, and 7-RADBOR from the subject site. The permeability test samples were compacted with varying percentages of bentonite to approximately 100% of the standard Proctor density. The results are presented on Table II and Figures 1 through 7, enclosed.

If you have any questions regarding this submittal, please call.

Sincerely,

CHEN & ASSOCIATES, INC.

By Sally K. Miller
Sally K. Miller, A.E.T.
Soils Laboratory Supervisor

SKM/djb
Rev. By: KRC
cc: Mr. Frank Guros
Morrison-Knudsen Engineers, Inc.

ATTACHMENT NO: 5057-GRN-C-09-00636-00

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JAN 28 1988
UMTRA-S.E.

January 27, 1988
Green River,
Utah
Job No. 1 104 88

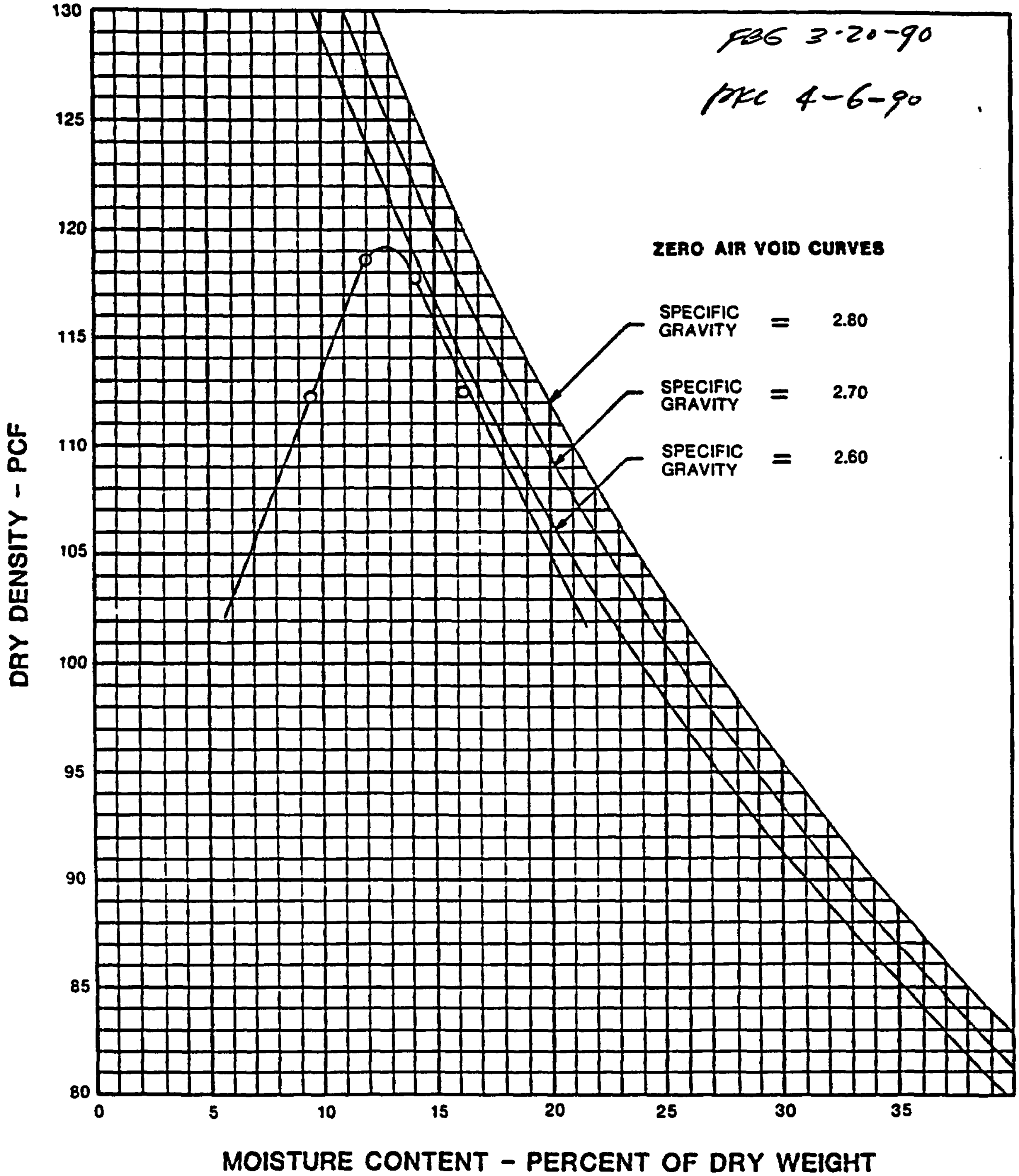
UMTRA-GRN 5057
SLOPE STABILITY

CHEN AND ASSOCIATES

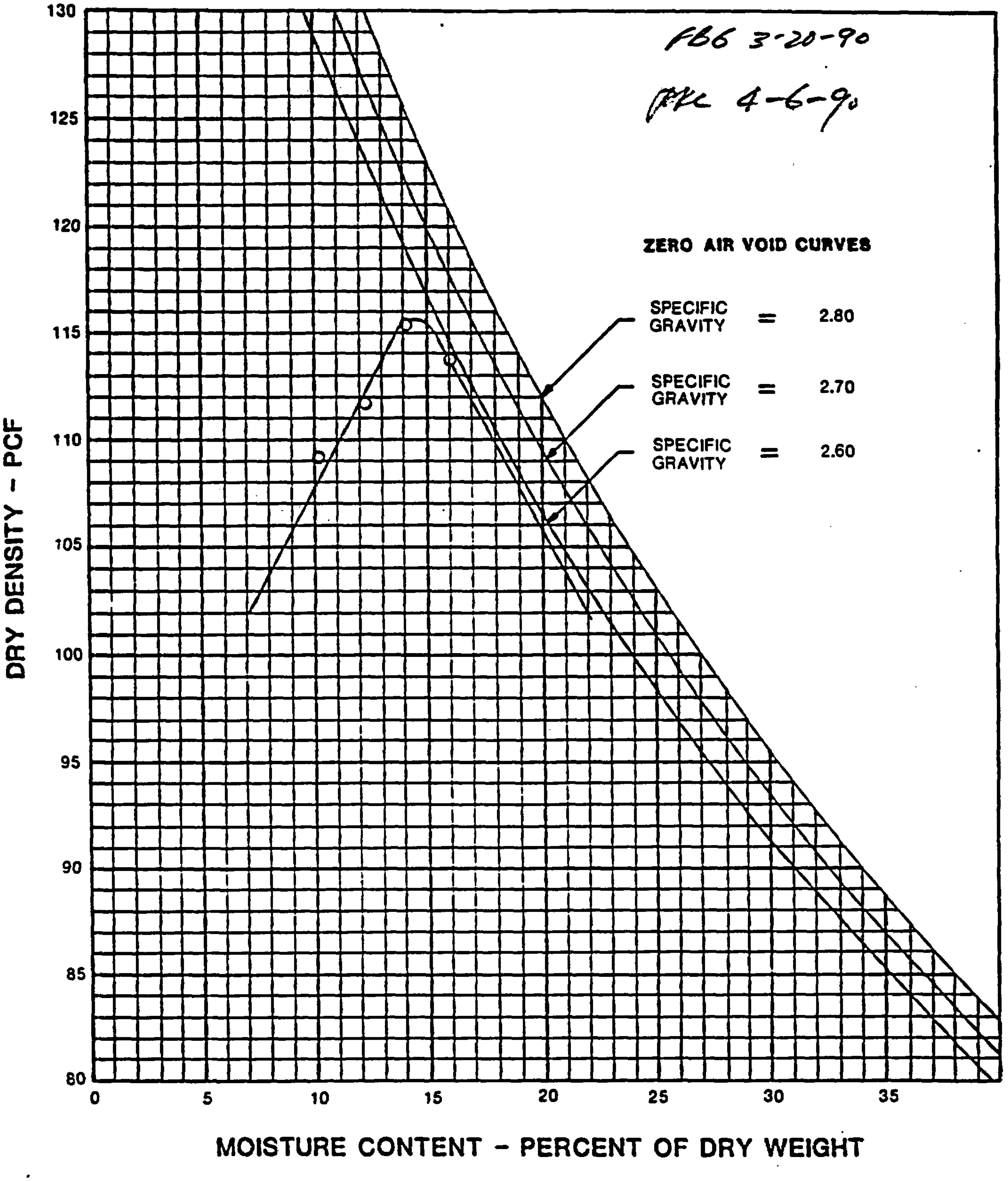
TABLE II

SUMMARY OF PERMEABILITY TEST RESULTS

Test Pit	Bentonite Added	Initial Moisture Content, %	Initial Dry Density, psf	Initial Compaction, %	Final Moisture Content, %	Final Dry Density, pcf	Coefficient of Permeability, cm/sec
1	1%	14.8	118.8	99.7	16.6	116.5	2.6×10^{-8}
2	6%	16.3	115.1	99.6	19.2	110.8	9.2×10^{-9}
3	3%	15.7	116.7	98.8	17.6	114.5	2.0×10^{-8}
4	1%	16.8	114.2	98.5	19.2	112.1	6.7×10^{-8}
5	3%	17.2	112.6	99.0	19.1	112.0	1.5×10^{-8}
6	6%	16.6	114.7	98.6	17.9	113.2	1.0×10^{-8}
7	3%	15.1	115.8	98.9	16.6	116.4	3.4×10^{-8}



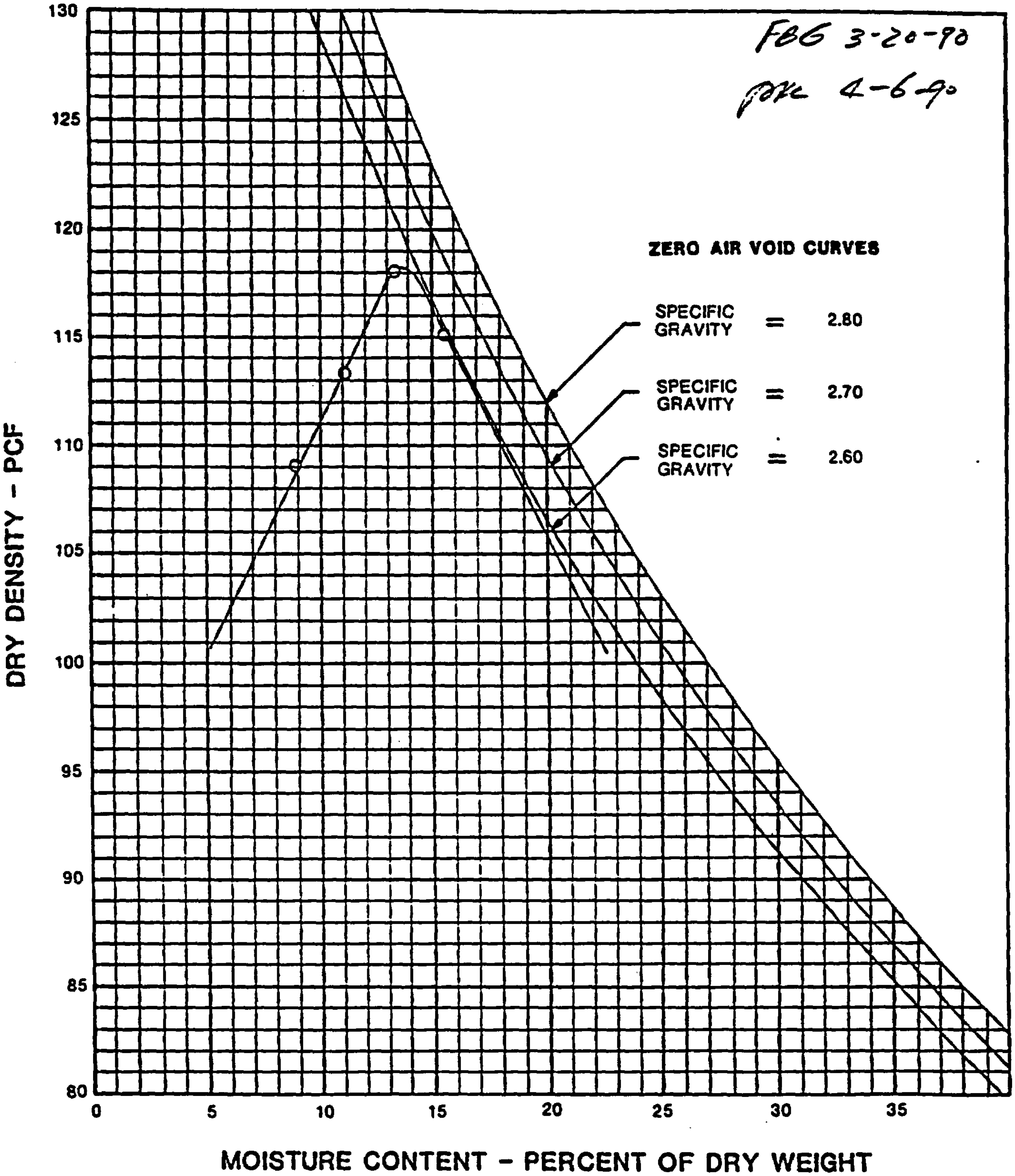
LOCATION : Green River, Utah	MOISTURE-DENSITY RELATIONSHIPS
Test Pit 1 DEPTH : 4.0 SAMPLE NO. :	
SOIL DESCRIPTION : Lean clay with sand with 1% Bentonite	Chen & Associates
MAX. DRY DENSITY : 119.1 PCF OPT. MOIST. CONTENT : 13.0 %	PROCEDURE : ASTM D698-78, Method A
LIQUID LIMIT : 22 PLASTICITY INDEX : 8	JOB NO. : 1 104 88 — FIG. NO. 1
GRAVEL : 0 % SAND : 25 % SILT AND CLAY (-200) : 75 %	DATE : 1-5-88



LOCATION : Green River, Utah	MOISTURE-DENSITY RELATIONSHIPS
Test Pit 2 DEPTH : 5.0 SAMPLE NO. :	
SOIL DESCRIPTION : Sandy silty clay with 6% Bentonite	Chen & Associates
MAX. DRY DENSITY : 115.5 PCF OPT. MOIST. CONTENT : 14.5 %	PROCEDURE :ASTM D698-78, Method A
LIQUID LIMIT : 21 PLASTICITY INDEX : 6	JOB NO. : 1 104 88 — FIG. NO. 2
GRAVEL : 0 % SAND : 40 % SILT AND CLAY (-200) : 60 %	DATE : 1-5-88

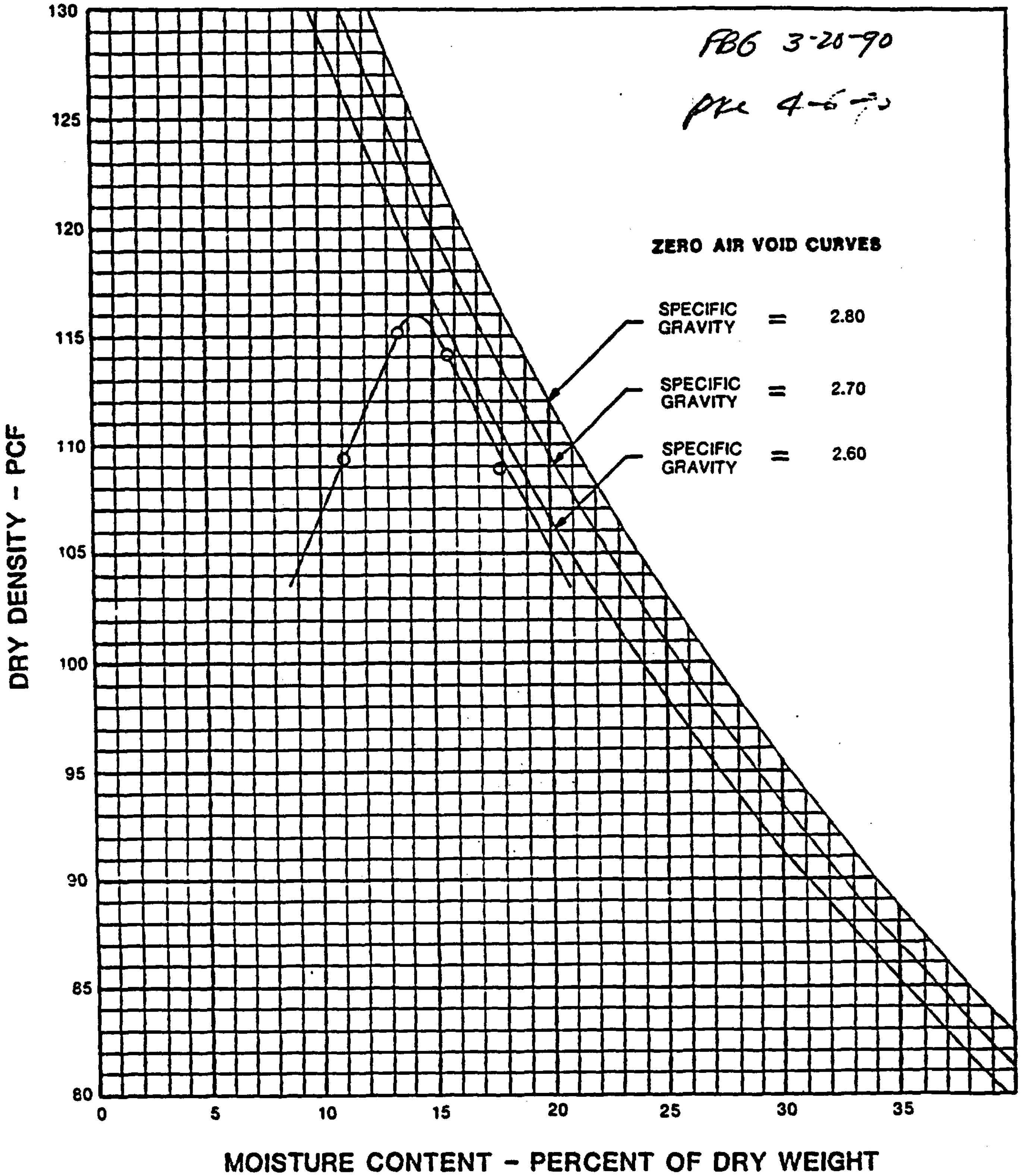
UMTRA-GRN 5057 SLOPE STABILITY (Ref. C-4, 5/9) C-38

FBG 3-20-90
[initials] 4-6-90

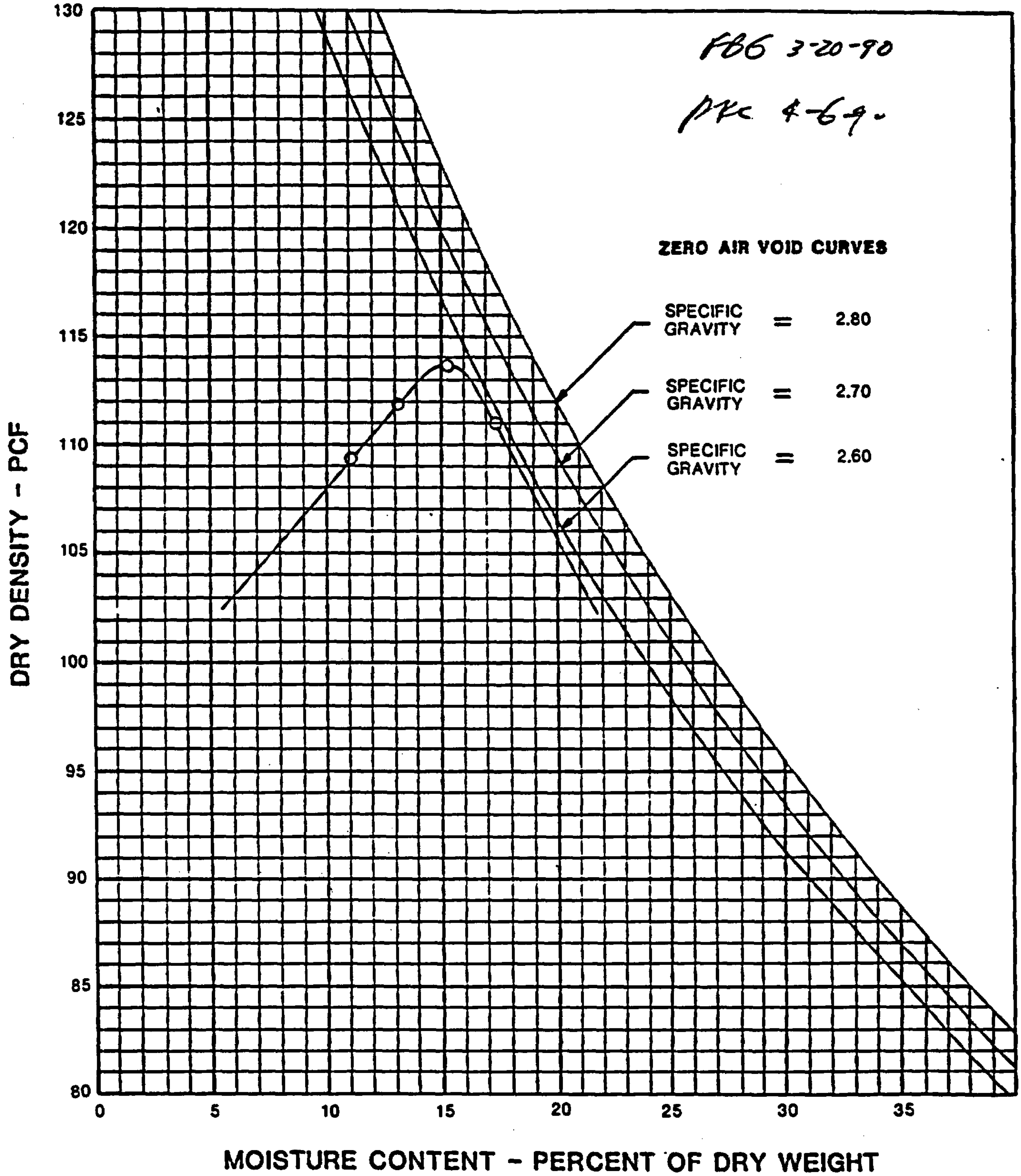


LOCATION : Green River, Utah	MOISTURE-DENSITY RELATIONSHIPS
Test Pit 3 DEPTH : 5.0 * SAMPLE NO. :	
SOIL DESCRIPTION : Sandy silty clay with 3% Bentonite	**Chen & Associates**
MAX. DRY DENSITY : ? PCF OPT. MOIST. CONTENT : ? %	PROCEDURE : ASTM D698-78, Method A
LIQUID LIMIT : 118.1 PLASTICITY INDEX : 13.9	JOB NO. : 1 104 88 FIG. NO. 3
GRAVEL : 0 % SAND : 30 % SILT AND CLAY (-200) : 70 %	DATE : 1-5-88

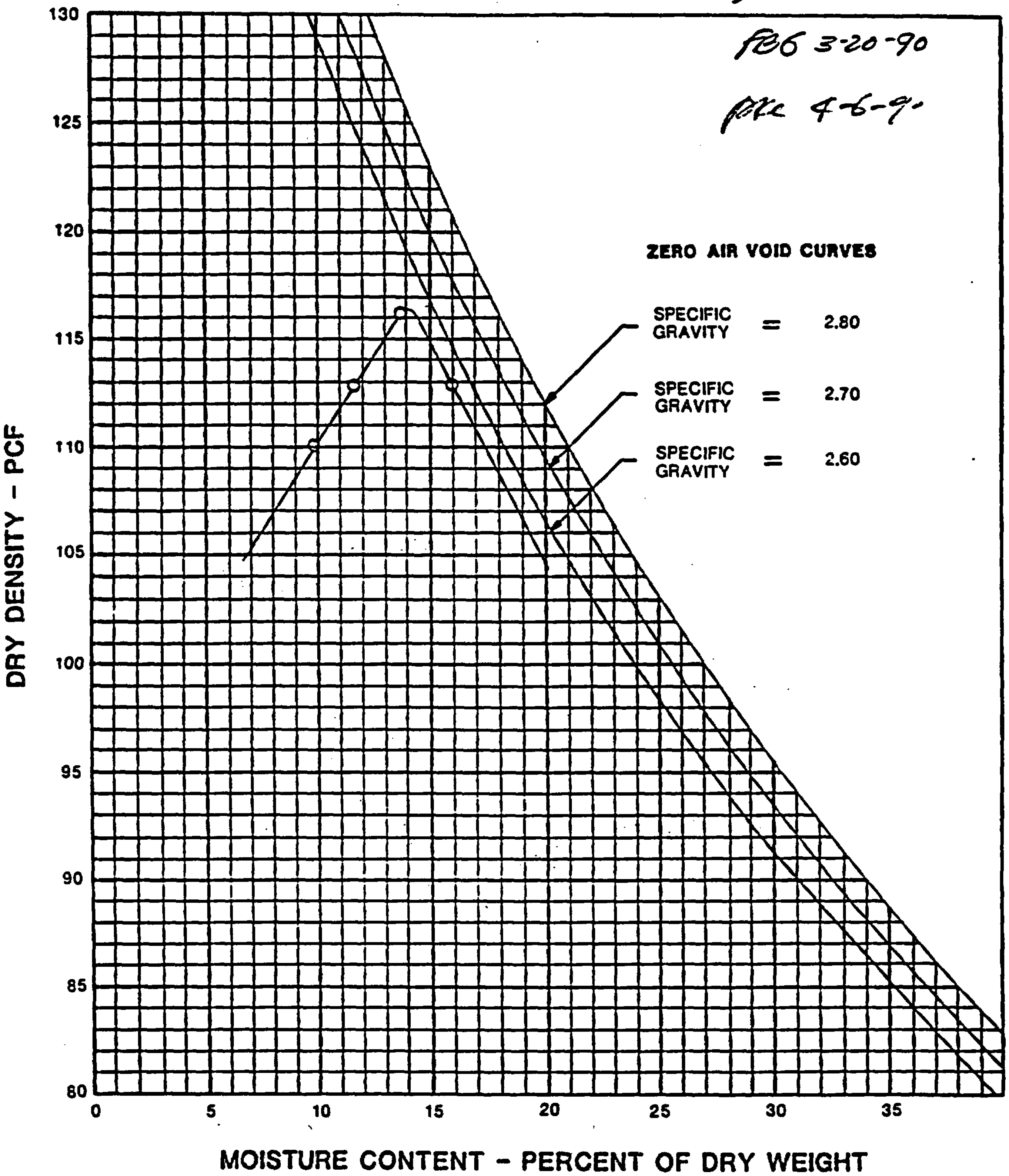
FBG 3-20-90
PKC 4-6-90



LOCATION : Green River, Utah	**MOISTURE-DENSITY RELATIONSHIPS**
Test Pit 4 DEPTH : 7 SAMPLE NO. :	
SOIL DESCRIPTION : Lean clay with sand with 1% Bentonite	**Chen & Associates**
MAX. DRY DENSITY : 115.9 PCF OPT. MOIST. CONTENT : 14.4 %	PROCEDURE : ASTM D698-78, Method A
LIQUID LIMIT : 25 PLASTICITY INDEX : 9	JOB NO. : 1 104 88 — FIG. NO. 4
GRAVEL : 0 % SAND : 20% SILT AND CLAY (-200) : 80 %	DATE : 1-5-88

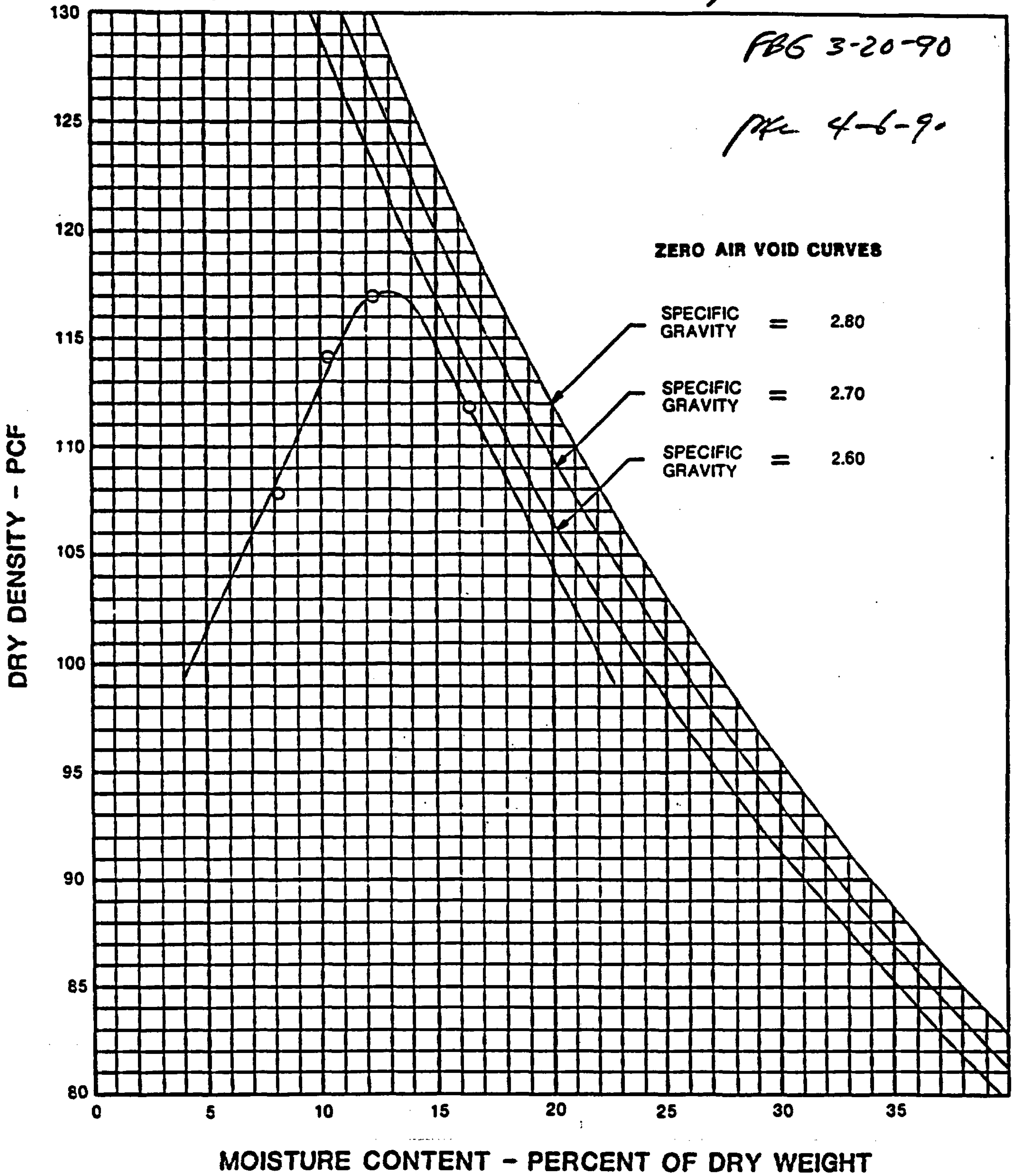


LOCATION : Green River, Utah	MOISTURE-DENSITY RELATIONSHIPS
Test Pit 5 DEPTH : 6 SAMPLE NO. :	
SOIL DESCRIPTION : Lean clay with sand with 3% Bentonite	Chen & Associates
MAX. DRY DENSITY : 113.7 PCF OPT. MOIST. CONTENT : 15.3 %	PROCEDURE : ASTM D698-78, Method A
LIQUID LIMIT : 25 PLASTICITY INDEX : 9	JOB NO. : 1 104 88 / FIG. NO.
GRAVEL : % SAND : % SILT AND CLAY (-200) : %	DATE : 1-5-88 / 5



LOCATION : Green River, Utah			MOISTURE-DENSITY RELATIONSHIPS
Test Pit 6	DEPTH : 8.0	SAMPLE NO. :	
SOIL DESCRIPTION : Sandy silty clay with 6% Bentonite			Chen & Associates
MAX. DRY DENSITY : 116.3 PCF		OPT. MOIST. CONTENT : 14.2 %	PROCEDURE : ASTM D698-78, Method A
LIQUID LIMIT : 19		PLASTICITY INDEX : 4	JOB NO. : 1 104 88 — FIG. NO. 6
GRAVEL : 0 %	SAND : 45 %	SILT AND CLAY (-200) : 55 %	DATE : 1-5-88

UMTRA-GRN, 5057, SLOPE STABILITY (Ref. C-4, 9/9) C-42



LOCATION : Green River, Utah			MOISTURE-DENSITY RELATIONSHIPS
Test Pit 7	DEPTH : 8.0	SAMPLE NO. :	
SOIL DESCRIPTION : Silty clay with sand with 3% Bentonite			Chen & Associates
MAX. DRY DENSITY : 117.1 PCF	OPT. MOIST. CONTENT : 13.0 %		PROCEDURE : ASTM D698-78, Method A
LIQUID LIMIT : 21	PLASTICITY INDEX : 6		JOB NO. : 1 104 88 / FIG. NO.
GRAVEL : 0 %	SAND : 28 %	SILT AND CLAY (-200) : 72 %	DATE : 1-5-88 / 7

MKE DOCUMENT NO. 5057-GRN-C-01-00279-04

Calculation Cover Sheet

04 ~~03~~ ~~02~~

Contract No. 5057-05 Discipline Earth Sciences Calc. No. 10-536-02-~~01~~ ~~00~~

No. of Sheets ~~15~~ + Appendix ~~17~~ 40 incl. app/ N

-MJG 1/25/88

Project

UMTRA / GRN Green River, Utah

Feature

TAILINGS EMBANKMENT

Item

EROSION PROTECTION

~~Sources of Data~~

3	Deleted Appendix E (Superseded by Calc. No. 10-563-01-01)	F.B. Guros	3-14-90	[illegible]	3/14/90	F.B. Guros	3-14-90
4	Added new Appendix E (verify riprap size)	JC PORTER	17 APR 90	R.M. STAUBER	4/18/90	F.B. Guros	4-18-90

Sources of Formulae & References 1/2

1. (MKE) "UMTRA DESIGN PROCEDURES MANUAL", May 1987
2. (MKE) "Calculation # 10-539-01-00", April 23, 1987
3. "Stevens, M.A., Simons, D.B., and Lewis, G.L.," Safety Factors For Riprap Protection", ASCE Journal of the Hydraulics Division, Vol. 102, No HY5, May 1976, pp 637-655.
4. Stephenson, D, "Rockfill in Hydraulic Engineering", Elsevier Scientific Publishing Company, NY, 1979.
5. Draft "Remedial Action Plan and Site Conceptual Design For Stabilization of the Inactive Uranium Mill Tailings at Green River, Utah" January 1987

(CONTINUED)

Preliminary Calc. ☐ Final Calc. ☒ Supersedes Calc. No. ——

Revisions continued ↑

Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
2	Added Appendices C, D & E & Summary Sheet 1a.	—	—	F.B. Guros	1-26-88	[illegible]	2/3/88
2	Revised Type A and Bedding Gradation / replace filter w/ Type A	Martin Gorden	1/25/88			—	—
1	Change to Final Calc	Martin Gorden	11/11/87	[illegible]	11/11/87	[illegible]	11/11/87
0	Riprap, Filter, & Bedding Gradations	[illegible]	9/24/87	Martin Gorden	9-24-87	[illegible]	9-24-87
0	Stable Rock sizes for embankment	Martin Gorden	9-24-87	F.B. Guros	9-24-87	[illegible]	9-24-87

Form 42-110

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA/GRN Contract No. 5057-05 Sheet Refs. 2/2
Feature Tailings Embankment Designed MJG File No.
Item Riprap Checked FBG Date 9-26-87 Date 9-23-87

Referances (Cont)

6. Andersen, A.G., Paintal, A.S., Davenport, J.T, "Tentative Design Procedure For Riprap-Lined Channels", NCHRP Report 108, 1970.

7. Calculation # 10-536-05-00 (MKE)

8. "Selection of the Best Available Rock", dated 11/19/87, including verbal amendments from Ted Johnson (NRC), 12/18/87.

FBG 1-26-88
MJG 1-26-88

Summary

The design gradations for erosion protection materials that will be placed over the radon barrier are presented in this calculation as follows:

MATERIAL	PAGE	
	D_{50} Calculation	Gradation Spec
Type A Riprap	5/13	C-3
Type B Riprap	Calc#10-536-05-01	8/13
Bedding	—	E-2

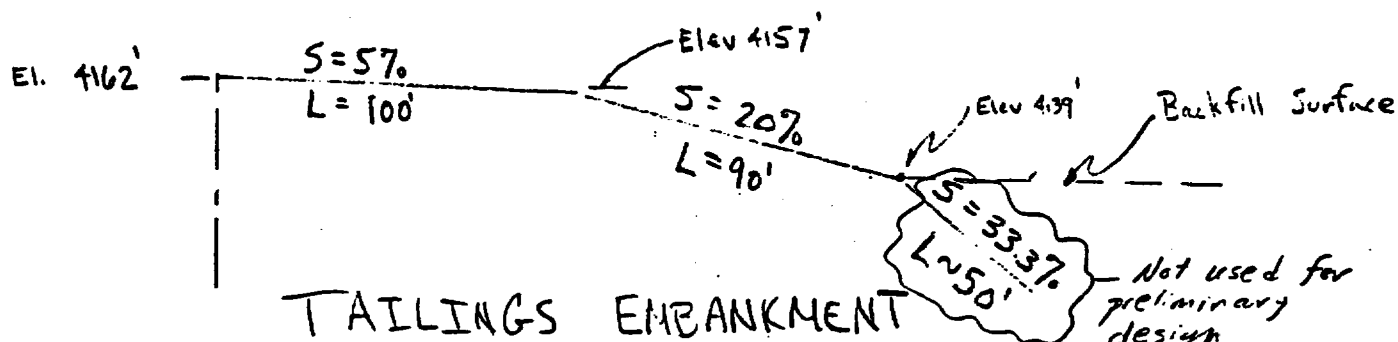
MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project GRN / UMTRA Contract No. 5057-05 Sheet 1/13
Feature Tailings Embankment Designed MJG File No.
Item Riprap Checked FBG Date 8-26-87 Date 9-23-87

Purpose: Calculate the minimum allowable riprap D_{50} (without oversizing) for the Green River, Utah site tailings embankment, for sideslopes and topslopes, and gradation for all riprap types and bedding. MJG 1/25/88 FBG 1-26-88

Assumptions:

1. The riprap will be designed for sheet flow on the following critical section (see section A, Figure 1)



2. Backfill that covers the toe of the embankment ~~i.e., the L=50', S=33%~~ ~~slope segment)~~ may erode during the design life of the embankment and expose the embankment toe protection. Therefore the toe protection material must be designed as riprap. (see calc No. 10-536-05-01) (MJG 1/25/88, FBG 1-26-88)

3. The minimum allowable riprap D_{50} may be calculated (for embankment sideslopes) using Stephensons method for slopes steeper than 10% (ref 4) and using the safety factor method for slopes flatter than 10% (ref. 3). An MKE computer program, "RPRPSFST" was employed to calculate minimum stable rock sizes. The program iterates to obtain compatability between ① rock size, flow depth and Mannings 'n', and ② time of concentration and rainfall intensity. (MJG 1-25-88, FBG 1-26-88)

5057-05
UMTRA/GRN
8-26-87
MJG
FBG 9-23-87

2/13

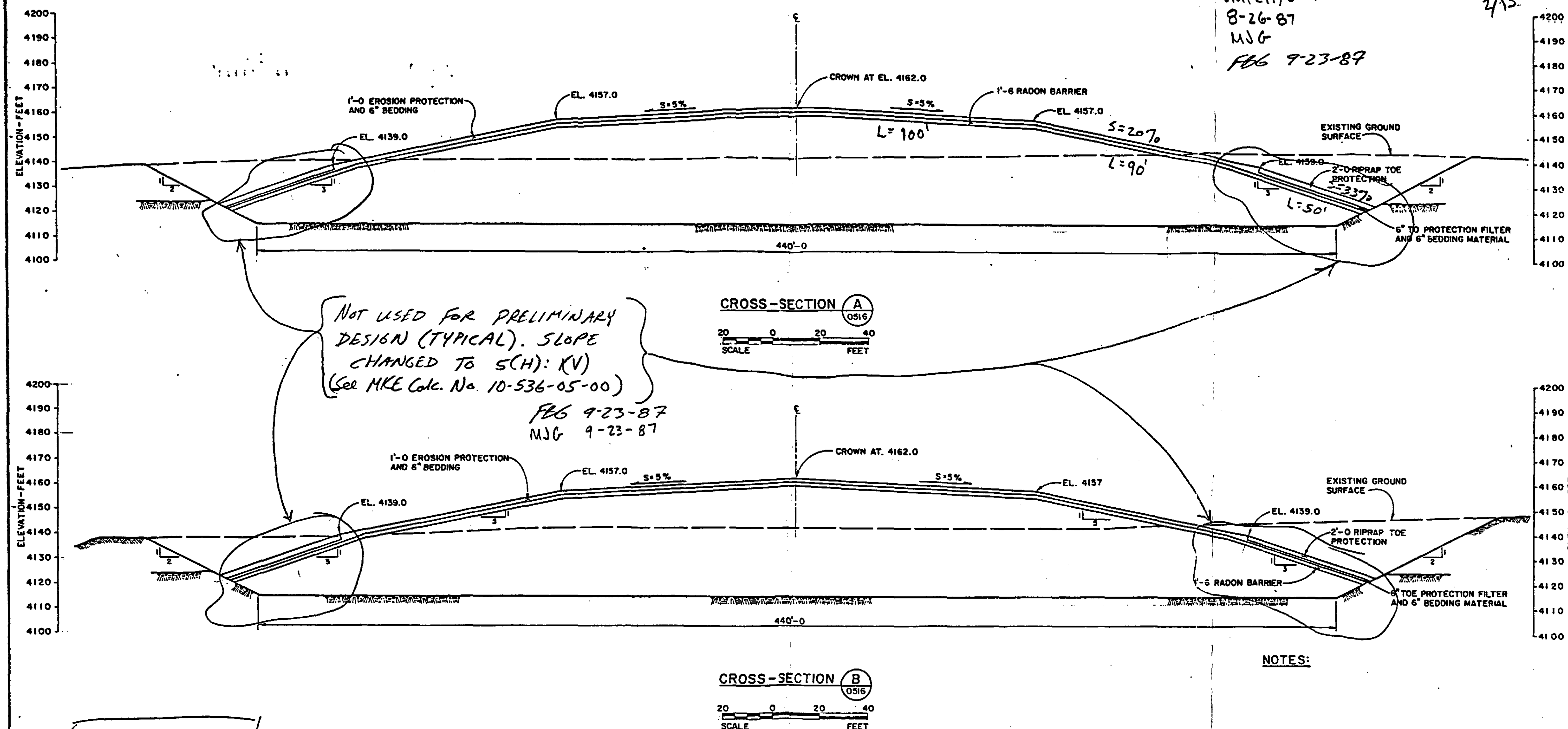


Figure 1

NOTES:

REFERENCE DRAWINGS:

GRN-PS-10-0516, TAILINGS EMBANKMENT -FINAL GRADING PLAN

Note: This is an in-progress, unchecked working drawing for design purposes only

QA MK-F	NO.	DATE	REVISIONS	BY	CK	E&D MGR	CHIEF ENG.	T&C REV.	DOE APP.
	△								
	△								
	△								
	△		~~ISSUED FOR PRELIMINARY REVIEW~~	—	—	—	—	—	—

U. S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

DESIGNED | DRAWN | CHECKED | INSPECTED | RECOMMENDED | APPROVED | DATE | DOE PROJECT ENGINEER | DATE

GREEN RIVER SITE
GREEN RIVER, UTAH

TAILINGS EMBANKMENT AND FINAL GRADING SECTIONS

MORRISON-KNUDSEN ENGINEERS, INC.
UMTRA PROJECT

PROJECT NO. DE-AC04-83AL18796

DRAWING NO. GRN-PS-10-0517 REV.

4. Riprap should resist sheetflow associated with a PMF event as a minimum, for embankment sideslopes and topslopes. MJG 1-25-88 FBG 1-26-88

Intensity of PMP, I_{PMP} is defined by the following equation:

$$I_{PMP} = 10^{[1.81 - 0.31(\log t)^{1.77}]}$$ (see reference #2)

in which

t = storm duration (minutes)

I_{PMP} = intensity of PMP storm (in/hr)

5. Riprap will have the following properties:

specific gravity, G_s = 2.49*

porosity, n = 0.3

friction angle, ϕ = 37° **

{ G_s for rock sources currently under consideration is greater than 2.49, but G_s = 2.49 is suitably for slightly conservative design on this basis. FBG 1-26-88 MJG 1-26-88

non-granitic rock ⇒ C in Stephenson's procedure = 0.22

* Based on single sample GRN07-02/02 (p D-238, Ref 5.)+

** Riprap friction angle is conservatively estimated from angle of repose correlation (see Figure 2, page 4)

PROCEDURE

1. Conservatively estimate the minimum allowable D_{50} for rock sizes on each segment using program RPRPSFST and assuming that there is no through-flow in the riprap pores. The computer output that shows this calculation is presented in Appendix A.

+Note: Additional data indicates G_s as small as 2.48; G_s = 2.49 is adequate for this analysis.
FBG 9-23-87
MJG 9-23-87

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA GJT	Contract No. 5057-05	Sheet 4/13	File No.
Feature: Tailings Embankment	Designed HJS	Date 5-26-87	
Item: Riprap	Checked FBG	Date 9-23-87	

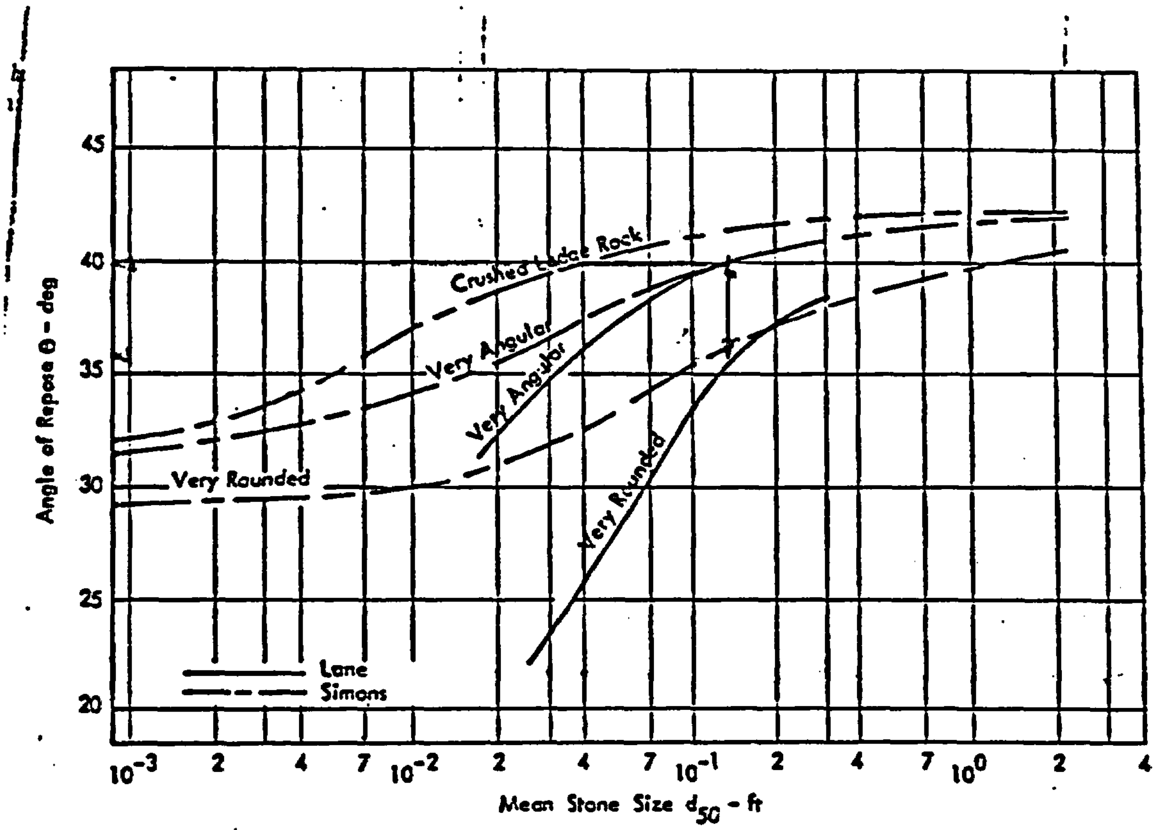


Figure 16. Angle of repose of stones of different angularity for various sizes (10, 21).

Reference #6

Figure 2 - Determination of Riprap Friction Angle

2. Repeat the calculation described above assuming through flow occurs in the riprap pores. The computer output for this calculation is presented in Appendix B.

CONCLUSIONS:

- There is essentially no difference in D_{50} regardless of whether through-flow in the riprap pores is considered or not.

- Minimum allowable D_{50} values for ~~embankment~~ riprap (on embankment sideslopes and topslopes) are as follows: (1-25-88 MJG; FBG 1-26-88)

Segment	D_{50} (in)	Sheet No.
5%	1.5	A-4/5
20%	2.0	A-4/5
~~33%~~	~~4.7~~	~~A-4/5~~

→ Not used for preliminary design
FBG 9-23-87
MJG 9-23-87

- The D_{50} values tabulated above assume no "oversizing" to account for weight loss. Also, the D_{50} values have been calculated on the assumption of sheet flow. Other criteria may neccessitate a greater D_{50} value, however.

MJG 1-25-88

Note: See Calc. No. 10-536-05-01 for minimum D_{50} of riprap toe protection (Type B).

Gradation for Type B riprap is determined on sheet 8/13 herein.

* FBG 1-26-88

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA/GRN	Contract No. 5057-05	Sheet 6/13	
Feature Tailings Embankment	Designed MJG	File No.	Date 9-23-87
Item Riprap	Checked FBG	Date 9-23-87	

Gradation of Riprap, Bedding ~~and Filter~~ Superceded (Appendix D) MJG 1-25-88 FBG 1-26-88

1. Because the cost of riprap with a $D_{50} = 2.0"$ is not significantly greater than riprap with $D_{50} = 1.5"$, a single riprap gradation is selected for use on the topslopes as well as the sideslopes of the tailings embankment.

superceded by Appendix C MJG 1-25-88 FBG 1-26-88

~~To account for potential long-term riprap degradation on the exposed embankment surface, $D_{50} = 6"$ is used for riprap placed there. This is the largest material that can be placed in a 12-inch thick layer, which does not result in a significant cost increase.~~

Riprap with $(D_{50})_{min} = 6"$ and $(D_{50})_{min} = 18"$ are referred to as Type A and Type B respectively. Riprap gradation is determined according to the procedure described in Ref 1.

Migration of the radon barrier fines through the riprap is prevented by constructing a bedding layer, designed according to Ref. 1, between the radon barrier and the riprap.

superceded by Appendices C&D MJG 1-25-88 FBG 1-26-88

~~Although Riprap Type A could be used as the required filter between the bedding and Riprap Type B, a 12-inch thick layer would be needed. To reduce costs, a separate filter gradation is determined to permit use of a 6-inch thick filter.~~

Riprap

Following the Corps of Engineers criteria, the graduation limit for riprap will be determined as follows:

Compute $W_{50(min)} = \pi G_s \gamma_w \frac{D_{50(min)}^3}{6}$

then $W_{100(min)} = 2 W_{50(min)}$

$W_{100(max)} = 5 W_{50(min)}$

$W_{25(min)} = W_{100(max)} / 16$

Combining the above

$D_{100(max)} = 1.71\ D_{50(min)}$

$D_{100(min)} = 1.26\ D_{50(min)}$

$D_{25(min)} = 0.68\ D_{50(min)}$

The layer thickness will be determined by the following Corps of Engineers Criteria:

$T_{min} \geq 1.9\ D_{50(min)}$

$T_{min} \geq 1.5\ D_{50(max)}$ } Use largest value

$T_{min} \geq 12$ inches

Superceded by Appendix C
MJG 1-25-88
FB6 1-26-88

~~(1) For $D_{50(min)} = 6''$ (Type A)~~

~~Particle Size~~

~~$D_{100(max)} = 1.71 \times 6 = 10.3''$~~

~~$D_{100(min)} = 1.26 \times 6 = 7.6''$~~

~~$D_{25(min)} = 0.68 \times 6 = 4.1''$~~

~~$T_{min} = 1.9 \times 6 = 11.4'' < 12''$~~

~~Say $T_{min} = 12''$~~

~~$D_{50(max)} = \frac{12}{1.5} = 8''$~~

~~Gradation~~

Sieve Opening	% Passing by Wt.
10 - inch	93 - 100
8 - inch	50 - 100
7½ - inch	45 95
6 - inch	30 - 50
4 - inch	0 - 24
3 - inch	0 - 5

(2) For $D_{50(min)} = 18''$ (Type B)

Particle Size

$D_{100(max)} = 1.71 \times 18 = 30.8''$

$D_{100(min)} = 1.26 \times 18 = 22.7''$

$D_{25(min)} = 0.68 \times 18 = 12.3''$

$T_{min} = 1.9 \times 18 = 34.2'' > 12''$

Say $T_{min} = 35''$

$D_{50(max)} = \frac{35}{1.5} = 23.4''$

Gradation

Sieve Opening	% Passing by Wt.
30 - inch	96 - 100
25 - inch	62 - 100
22 - inch	46 - 95
18 - inch	32 - 50
15 - inch	20 - 38
10 - inch	0 - 10

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA / GRN
Feature Tailings Embankment
Item Riprap

Sheet 9/13
Contract No. 5057-05 File No.
Designed WYL Date 9/18/87
Checked MJG Date 9/23/87

Bedding / Filter

Between the riprap and the radon barrier (or in situ soils) and among the ripraps a bedding / filter material will be needed to prevent the migration of the fine particles through the ripraps.

The following design criteria for bedding / filter will be used

Subgrade Soil Group No.	Subgrade Soil Percent Fines*	Design Criteria**
1	40 - 100	$D_{15})_f \leq 0.7$ mm, except where base soil is dispersive or cohesionless, for which special study is required
2	0 - 15	$D_{15})_f / D_{85})_b \leq 4$ where base material is radon barrier, or ≤ 7.5 otherwise+
3	15 - 40	Interpolate linearly with percent fines between sizes required by criteria for groups 1 and 2

Notes:

* By weight, smaller than No. 200 sieve.

** D_{15} and D_{85} are sizes for which 15 percent and 85 percent of the particles are smaller, respectively. "f" denotes filter and "b" denotes base.

\+ Page 10 of the reference recommends $D_{15})_f / D_{85})_b \leq 4$, but p. 14 states that this results in a factor of safety of about 2, whereas $D_{15})_f / D_{85})_b \leq 7.5$ still results in a factor of safety ≥ 1.

For filter material $D_{15})_f / D_{85})_b \leq 4$

To avoid internal movement of fines, Bedding / filter material should have no more than 5% by wt passing No. 200 sieve.

Bedding $D_{max} \leq 3$ inch

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA / GRN
Feature: Tailings Embankment
Item: Riprap

Sheet: 10 / 13
Contract No.: 5057-05
File No.:
Designed: WYL Date: 9/18/87
Checked: MJG Date: 9/23/87

(1) Bedding Between Radon Barrier / in situ soils and Riprap Type A

Radon Barrier / in situ soils D_{85} (radon barrier) = 0.03 mm = 0.001"

Riprap Type A D_{15} (riprap A) = 4.9"

(a) to prevent migration of the radon barrier / in situ soils through the bedding

D_{15} (bedding) ≤ 0.7 mm

(b) to prevent migration of the bedding through the riprap type A

D_{85} (bedding) ≥ D_{15} (riprap A) / 7.5 = 4.9 / 7.5 = 0.65" = 16.51 mm

Gradation

Sieve opening	% passing by wt
3 - inch	100
1½ - inch	87 - 99
¾ - inch	74 - 88
No. 4	48 - 67
No. 40	6 - 32
No. 200	0 - 5

$T_{min} = 1.1 \times D_{100})_{max} = 1.1 \times 3 = 3.3" < 6"$ Say 6"

Superceded by Appendix E

MJG 1-25-88 FBG 1-26-88

(2) Filter Between Bedding and Riprap Type B

Bedding D_{85}(bedding) = 0.67" (~0.65" : ck MJG)

Riprap Type B D_{15}(riprap B) = 13.9"

(a) to prevent migration of the bedding through the filter

D_{15}(filter) ≤ 4 × D_{85}(bedding) = 4 × 0.67 = 2.68"

(b) to prevent migration of the filter through the riprap type B

D_{85}(filter) ≥ D_{15}(riprap B) / 4 = 13.9 / 4 = 3.48"

Gradation

sieve opening	% passing by wt
5½ - inch	95 - 100
4½ - inch	50 - 100
3½ - inch	33 - 85
3 - inch	23 - 50
2½ - inch	11 - 38
1½ - inch	0 - 4

T_{min} = 1.1 × D_{100})max = 1.1 × 5.75 = 6.33" Say 7"

Superceded by Appendix D

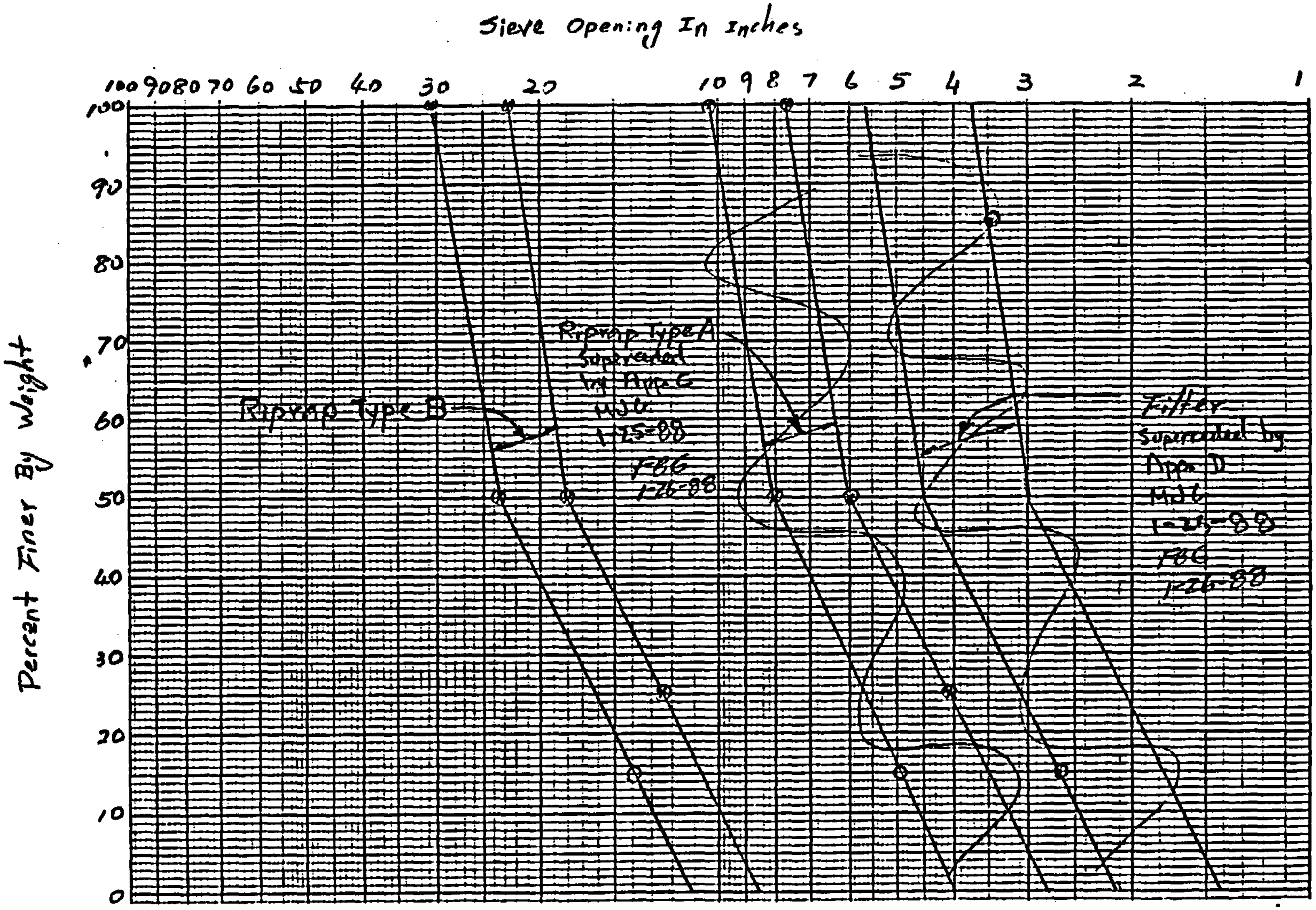
MJG 1-25-88

FBG 1-26-88

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA/GRN
Feature Tailings Embankment
Item Riprap

Contract No. 5054 7-05
Designed WYL Checked MJG
Sheet 12/13
File No.
Date 9/18/87
Date 9/23/87

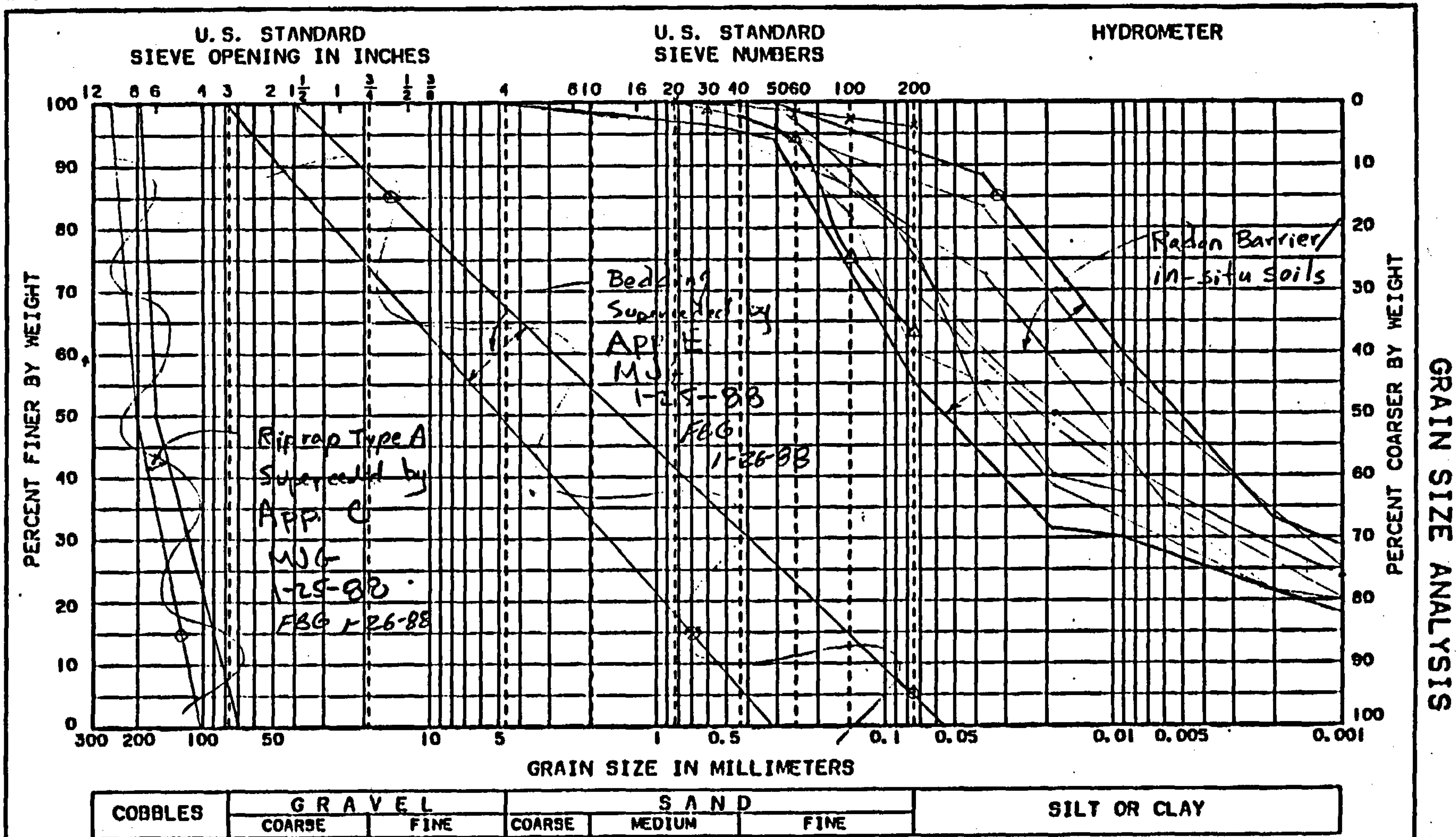


GRADATION OF RIPRAP

M.J.G. 9/23/87

UMTRA /GRN
WYL 9/18/87

INTERNATIONAL ENGINEERING COMPANY, INC.



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT	UMTRA /GRN
JOB NO.	5057
AREA	
HOLE NO.	
DATE	

CA8110

13/13

APPENDIX A

RPRPSFST COMPUTER RUN

- NO THROUGHFLOW

5057-05
UMTRA-GRN
8-26-87
MJG
FBG 9-23-87

A-2/5

INPUT FILE PRINTOUT

UMTRA - GREEN RIVER SITE - TAILINGS EMBANKMENT RIPRAP DESIGN

```
             25 AUG1987
 1.810   .310 1.770 2.490   .220       A   .002 1.0
  3    0
  0    0    0
 10   10    5
TOP       100.0   5.0    .30   37.0   FS
MIDDLE     90.0  20.0    .30   37.0   ST
BOTTOM     50.0  33.3    .30   37.0   ST
 .1250     .5   .00833
 .1250     .5   .00833
 .1250     .5   .00833
```

* * * * * * * * * * * END INPUT DATA * * * * * * * * * * * *

UMTRA - GREEN RIVER SITE - TAILINGS EMBANKMENT RIPRAP DESIGN

UMTRA/ RUN I.D.= DATE=25 AUG1987

SAFETY FACTOR/STEPHENSON METHOD FOR EMBANKMENT EROSION PROTECTION

* * * * * * * * * * * INPUT DATA * * * * * * * * * * * * * *

COEFFICIENTS FOR INTENSITY DURATION CURVE -
IPMP=10**(G-H*(LOGT)**Z):

G= 1.810 H= .310 Z=1.770

RIPRAP STONE SP.GRAVITY= 2.49 C IN STEPHENSONS EQN= .22

--- EMBANKMENT ---

AREA (LOCATION IN PLAN)	SEGMENT	LENGTH (FT)	SLOPE (%)	POROSITY	FRICTION ANGLE (DEG)	
A	TOP	100.	5.	.30	37.	SAFETY FACTOR
A	MIDDLE	90.	20.	.30	37.	STEPHENSONS
A	BOTTOM	50.	33.	.30	37.	STEPHENSONS

* * * * * * * * * * * END INPUT DATA * * * * * * * * * * * *

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

5057-05
UMTRA-GRN
8-26-87
MJG

A-3/5

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

FBG 9-23-87

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

DETAILED CALC TABLE WITH FINAL ROCK SIZE

SEGMENT=TOP LENGTH= 100. FT. SLOPE= 5.%

ASSUMED D50= .1250FT. AT D/S END OF SEGMENT
CORRESPONDING Q= .595CFS/FT AT SEGMENT END BY FS METHOD

LOPED DISTANCE FROM (FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL
0.	10.	.060	.000	.060	1.17	.05	.040	.14	.14
10.	20.	.119	.000	.119	1.67	.07	.035	.10	.24
20.	30.	.179	.000	.179	2.04	.09	.033	.08	.32
30.	40.	.238	.000	.238	2.34	.10	.031	.07	.39
40.	50.	.298	.000	.298	2.60	.11	.030	.06	.46
50.	60.	.357	.000	.357	2.83	.13	.030	.06	.52
60.	70.	.417	.000	.417	3.04	.14	.029	.05	.57
70.	80.	.476	.000	.476	3.24	.15	.029	.05	.62
80.	90.	.536	.000	.536	3.42	.16	.028	.05	.67
90.	100.	.595	.000	.595	3.59	.17	.028	.05	.72

RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L (INCH/HR)	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**Z)) (INCH/HR)
259.35	56.15

DETAILED CALC TABLE WITH FINAL ROCK SIZE

SEGMENT=MIDDLE LENGTH= 90. FT. SLOPE= 20.%

ASSUMED D50= .1667FT. AT D/S END OF SEGMENT

5057-05
UMTRA-GRN
8-26-87
MJG

FBG
9-23-87

CORRESPONDING Q= .263CFS/FT AT SEGMENT END-BY STEPHENSONS METHOD

SLOPED ISTANCE FROM (FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL
0.	10.	.014	.000	.014	.52	.03	.060	.32	.32
10.	20.	.028	.000	.028	.78	.04	.048	.21	.53
20.	30.	.042	.000	.042	.97	.04	.043	.17	.71
30.	40.	.055	.000	.055	1.13	.05	.041	.15	.85
40.	50.	.069	.000	.069	1.27	.05	.039	.13	.99
50.	60.	.083	.000	.083	1.39	.06	.037	.12	1.10
60.	70.	.097	.000	.097	1.51	.06	.036	.11	1.22
70.	80.	.111	.000	.111	1.61	.07	.035	.10	1.32
80.	90.	.125	.000	.125	1.71	.07	.035	.10	1.42
90.	100.	.138	.000	.138	1.80	.08	.034	.09	1.51
0.	9.	.151	.000	.151	2.42	.06	.044	.06	1.57
9.	18.	.163	.000	.163	2.53	.06	.043	.06	1.63
18.	27.	.176	.000	.176	2.63	.07	.042	.06	1.69
27.	36.	.188	.000	.188	2.73	.07	.041	.06	1.74
36.	45.	.201	.000	.201	2.82	.07	.041	.05	1.80
45.	54.	.213	.000	.213	2.91	.07	.040	.05	1.85
54.	63.	.226	.000	.226	3.00	.08	.040	.05	1.90
63.	72.	.238	.000	.238	3.08	.08	.039	.05	1.95
72.	81.	.251	.000	.251	3.16	.08	.039	.05	1.99
81.	90.	.263	.000	.263	3.24	.08	.039	.05	2.04

RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L (INCH/HR)	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**Z)) (INCH/HR)
60.29	56.15

DETAILED CALC TABLE WITH FINAL ROCK SIZE

SEGMENT=BOTTOM LENGTH= 50. FT. SLOPE= 33.%

ASSUMED D50= .3916FT. AT D/S END OF SEGMENT
CORRESPONDING Q= .312CFS/FT AT SEGMENT END-BY STEPHENSONS METHOD

SLOPED DISTANCE FROM (FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL
0.	10.	.013	.000	.013	.50	.03	.061	.33	.33
10.	20.	.026	.000	.026	.75	.03	.049	.22	.55
20.	30.	.039	.000	.039	.94	.04	.044	.18	.73
30.	40.	.052	.000	.052	1.09	.05	.041	.15	.88
40.	50.	.065	.000	.065	1.23	.05	.039	.14	1.02
50.	60.	.078	.000	.078	1.35	.06	.038	.12	1.14
60.	70.	.091	.000	.091	1.46	.06	.037	.11	1.26
70.	80.	.104	.000	.104	1.56	.07	.036	.11	1.36
80.	90.	.117	.000	.117	1.66	.07	.035	.10	1.47

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90.	100.	.130	.000	.130	1.74	.07	.034	.10	1.56
0.	9.	.142	.000	.142	2.34	.06	.044	.06	1.62
9.	18.	.153	.000	.153	2.45	.06	.043	.06	1.69
18.	27.	.165	.000	.165	2.54	.06	.043	.06	1.74
27.	36.	.177	.000	.177	2.64	.07	.042	.06	1.80
36.	45.	.189	.000	.189	2.73	.07	.041	.05	1.86
45.	54.	.200	.000	.200	2.82	.07	.041	.05	1.91
54.	63.	.212	.000	.212	2.90	.07	.040	.05	1.96
63.	72.	.224	.000	.224	2.98	.08	.040	.05	2.01
72.	81.	.235	.000	.235	3.06	.08	.040	.05	2.06
81.	90.	.247	.000	.247	3.14	.08	.039	.05	2.11
0.	10.	.260	.000	.260	2.76	.09	.066	.06	2.17
10.	20.	.273	.000	.273	2.84	.10	.065	.06	2.23
20.	30.	.286	.000	.286	2.92	.10	.064	.06	2.29
30.	40.	.299	.000	.299	2.99	.10	.063	.06	2.34
40.	50.	.312	.000	.312	3.07	.10	.062	.05	2.40

RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**Z))
(INCH/HR)	(INCH/HR)
56.64	56.15

*******RESULTS SUMMARY******* AREA=A

SEGMENT	LENGTH (FT)	SLOPE (%)	D50 (INCH)	Q AT D/S END (CFS/FT) *	TC (MINUTES)	STARTING ROCK D50 (INCH)	METHOD OF CALC.
TOP	100.	5.0	1.5	.595	2.5	1.50	SAFETY FACTOR
MIDDLE	90.	20.0	2.0	.263	2.5	1.50	STEPHENSON
BOTTOM	50.	33.3	4.7	.312	2.5	1.50	STEPHENSON

* Checker's Comment:

This Q is total Q that rock can withstand, and may be greater than Q based on actual estimated PMP.

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APPENDIX B

RPRPSFST COMPUTER RUN

- WITH THROUGHFLOW INCLUDED

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INPUT FILE PRINTOUT

UMTRA - GREEN RIVER SITE - TAILINGS EMBANKMENT RIPRAP DESIGN

```
            25 AUG1987
 1.810  .310 1.770 2.490  .220      A  .002 1.0
  5    0
  1    0    1    1    1
  5    1    4    9    5
top_50   50.0   5.0   .30  37.0  FS
top_10   10.0   5.0   .30  37.0  FS
top_40   40.0   5.0   .30  37.0  FS
MIDDLE   90.0  20.0   .30  37.0  ST
BOTTOM   50.0  33.3   .30  37.0  ST
 .1250    .5  .00833
 .1250    .5  .00833
 .1250    .5  .00833
 .1250    .5  .00833
 .1250    .5  .00833
```

* * * * * * * * * * * END INPUT DATA * * * * * * * * * * *

UMTRA - GREEN RIVER SITE - TAILINGS EMBANKMENT RIPRAP DESIGN

UMTRA/ RUN I.D.= DATE=25 AUG1987

*SAFETY FACTOR/STEPHENSON METHOD FOR EMBANKMENT EROSION PROTECTION***

* * * * * * * * * * * INPUT DATA * * * * * * * * * * * * *

COEFFICIENTS FOR INTENSITY DURATION CURVE -
IPMP=10**(G-H*(LOGT)**Z):

G= 1.810 H= .310 Z=1.770

RIPRAP STONE SP.GRAVITY= 2.49 C IN STEPHENSONS EQN= .22

- - - EMBANKMENT - - -

AREA (LOCATION IN PLAN)	SEGMENT	LENGTH (FT)	SLOPE (%)	POROSITY	FRICTION ANGLE (DEG)	
A	top_50	50.	5.	.30	37.	SAFETY FACTOR
A	top_10	10.	5.	.30	37.	SAFETY FACTOR
A	top_40	40.	5.	.30	37.	SAFETY FACTOR
A	MIDDLE	90.	20.	.30	37.	STEPHENSONS
A	BOTTOM	50.	33.	.30	37.	STEPHENSONS

* * * * * * * * * * * END INPUT DATA * * * * * * * * * * *

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NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

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NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

Note: This prints out for each iteration where $T_c < 2.5$ minutes.
(This sheet included for completeness, but not used otherwise)

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NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

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NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

DETAILED CALC TABLE WITH FINAL ROCK SIZE

SEGMENT=top_50 LENGTH= 50. FT. SLOPE= 5.%

ASSUMED D50= .1250FT. AT D/S END OF SEGMENT
CORRESPONDING Q= .664CFS/FT AT SEGMENT END BY FS METHOD

LOPED DISTANCE FROM (FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL

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0.	10.	.133	.069	.064	1.22	.05	.039	.14	.14	5057-05
10.	20.	.266	.069	.197	2.14	.09	.032	.08	.21	UMTRA-GRN
20.	30.	.398	.069	.330	2.73	.12	.030	.06	.28	8-26-87
30.	40.	.531	.069	.463	3.19	.14	.029	.05	.33	
40.	50.	.664	.069	.595	3.59	.17	.028	.05	.37	MJG

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RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**Z))
(INCH/HR)	(INCH/HR)
578.57	56.15

DETAILED CALC TABLE WITH FINAL ROCK SIZE

SEGMENT=top_10 LENGTH= 10. FT. SLOPE= 5.%

ASSUMED D50= .1250FT. AT D/S END OF SEGMENT
CORRESPONDING Q= .595CFS/FT AT SEGMENT END BY FS METHOD

SLOPED DISTANCE FROM (FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL
0.	10.	.099	.069	.031	.82	.04	.047	.20	.20
10.	20.	.198	.069	.130	1.74	.07	.034	.10	.30
20.	30.	.298	.069	.229	2.30	.10	.031	.07	.37
30.	40.	.397	.069	.328	2.73	.12	.030	.06	.43
40.	50.	.496	.069	.427	3.08	.14	.029	.05	.49
0.	10.	.595	.000	.595	3.59	.17	.028	.05	.53

RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**Z))
(INCH/HR)	(INCH/HR)
432.25	56.15

DETAILED CALC TABLE WITH FINAL ROCK SIZE

SEGMENT=top_40 LENGTH= 40. FT. SLOPE= 5.%

ASSUMED D50= .1250FT. AT D/S END OF SEGMENT
CORRESPONDING Q= .664CFS/FT AT SEGMENT END BY FS METHOD

SLOPED DISTANCE FROM FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL
0.	10.	.066	.066	.000	.00	.00	.000	.00	.00
10.	20.	.133	.069	.064	1.22	.05	.039	.14	.14
20.	30.	.199	.069	.131	1.75	.07	.034	.10	.23

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30.	40.	.266	.069	.197	2.14	.09	.032	.08	.31
40.	50.	.332	.069	.263	2.45	.11	.031	.07	.38
0.	10.	.398	.000	.398	2.97	.13	.029	.06	.43
0.	10.	.465	.069	.396	2.96	.13	.029	.06	.49
10.	20.	.531	.069	.463	3.19	.14	.029	.05	.54
20.	30.	.598	.069	.529	3.40	.16	.028	.05	.59
30.	40.	.664	.069	.595	3.59	.17	.028	.05	.64

RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**Z))
(INCH/HR)	(INCH/HR)
289.28	56.15

DETAILED CALC TABLE WITH FINAL ROCK SIZE

SEGMENT=MIDDLE LENGTH= 90. FT. SLOPE= 20.%

ASSUMED D50= .1583FT. AT D/S END OF SEGMENT
CORRESPONDING Q= .243CFS/FT AT SEGMENT END-BY STEPHENSONS METHOD

SLOPED DISTANCE FROM (FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL
0.	10.	.013	.013	.000	.00	.00	.000	.00	.00
10.	20.	.026	.026	.000	.00	.00	.000	.00	.00
20.	30.	.038	.038	.000	.00	.00	.000	.00	.00
30.	40.	.051	.051	.000	.00	.00	.000	.00	.00
40.	50.	.064	.064	.000	.00	.00	.000	.00	.00
0.	10.	.077	.000	.077	1.34	.06	.038	.12	.12 *
0.	10.	.090	.069	.021	.67	.03	.052	.25	.37
10.	20.	.103	.069	.034	.87	.04	.046	.19	.57
20.	30.	.115	.069	.047	1.03	.05	.042	.16	.73
30.	40.	.128	.069	.059	1.17	.05	.040	.14	.87
0.	10.	.141	.141	.000	.00	.00	.000	.00	.87
10.	20.	.154	.154	.000	.00	.00	.000	.00	.87
20.	30.	.167	.163	.003	.18	.02	.170	.95	1.82
30.	40.	.179	.163	.016	.65	.02	.088	.26	2.08
40.	50.	.192	.163	.029	.96	.03	.070	.17	2.25
50.	60.	.205	.163	.042	1.21	.03	.061	.14	2.39
60.	70.	.218	.163	.054	1.42	.04	.056	.12	2.51
70.	80.	.231	.163	.067	1.60	.04	.053	.10	2.61
80.	90.	.243	.163	.080	1.76	.05	.050	.09	2.71

RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**Z))
(INCH/HR)	(INCH/HR)
55.82	54.93

DETAILED CALC TABLE WITH FINAL ROCK SIZE

* No through-flow assumed on the 1st segment to compensate for excessive t_c increment that would be calculated by the computer program

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B-7/7

SEGMENT=BOTTOM LENGTH= 50. FT. SLOPE= 33.%

ASSUMED D50= .3916FT. AT D/S END OF SEGMENT
'ORRESPONDING Q= .312CFS/FT AT SEGMENT END-BY STEPHENSONS METHOD

SLOPED DISTANCE FROM (FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL	
0.	10.	.013	.013	.000	.00	.00	.000	.00	.00	
10.	20.	.026	.026	.000	.00	.00	.000	.00	.00	
20.	30.	.039	.039	.000	.00	.00	.000	.00	.00	
30.	40.	.052	.052	.000	.00	.00	.000	.00	.00	
40.	50.	.065	.065	.000	.00	.00	.000	.00	.00	
0.	10.	.078	.000	.078	1.35	.06	.038	.12	.12	*
0.	10.	.091	.069	.022	.69	.03	.051	.24	.37	
10.	20.	.104	.069	.035	.89	.04	.045	.19	.55	
20.	30.	.117	.069	.048	1.05	.05	.042	.16	.71	
30.	40.	.130	.069	.061	1.19	.05	.040	.14	.85	
0.	10.	.143	.143	.000	.00	.00	.000	.00	.85	
10.	20.	.156	.156	.000	.00	.00	.000	.00	.85	
20.	30.	.169	.163	.006	.28	.02	.127	.60	1.45	
30.	40.	.182	.163	.019	.72	.03	.083	.23	1.68	
40.	50.	.195	.163	.032	1.02	.03	.068	.16	1.84	
50.	60.	.208	.163	.045	1.26	.04	.060	.13	1.98	
60.	70.	.221	.163	.058	1.46	.04	.055	.11	2.09	
70.	80.	.234	.163	.071	1.64	.04	.052	.10	2.19	
80.	90.	.247	.163	.084	1.81	.05	.049	.09	2.28	
0.	10.	.260	.260	.000	.00	.00	.000	.00	2.28	
10.	20.	.273	.273	.000	.00	.00	.000	.00	2.28	
20.	30.	.286	.286	.000	.00	.00	.000	.00	2.28	
30.	40.	.299	.299	.000	.00	.00	.000	.00	2.28	
40.	50.	.312	.312	.000	.00	.00	.000	.00	2.28	

RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L (INCH/HR)	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**Z)) (INCH/HR)
56.64	56.15

*******RESULTS SUMMARY******* AREA=A

SEGMENT	LENGTH (FT)	SLOPE (%)	D50 (INCH)	Q AT D/S END (CFS/FT)	TC (MINUTES)	STARTING ROCK D50 (INCH)	METHOD OF CALC.
op_50	50.	5.0	1.5	.664	2.5	1.50	SAFETY FACTOR
cop_10	10.	5.0	1.5	.595	2.5	1.50	SAFETY FACTOR
top_40	40.	5.0	1.5	.664	2.5	1.50	SAFETY FACTOR
MIDDLE	90.	20.0	1.9	.243	2.7	1.50	STEPHENSON
BOTTOM	50.	33.3	4.7	.312	2.5	1.50	STEPHENSON

* See note on page B-6.

APPENDIX C

TYPE A RIPRAP GRADATION

APPENDIX C

PURPOSE

Select upper and lower bound gradations for riprap Type A.

METHOD

A) Determination of D_{50}

- Lower bound gradation

Assume the riprap has a durability score of 80 or more based on reference 2. Consequently, D_{50} is not oversized.

- Upper bound gradation

Assume the riprap has a durability score of 50.

The percent oversizing of the mean rock dimension, D_{50}, would be (80 − score) %, i.e., 30% (see reference 8, pg. 3)

B) Selection of Gradation (from Reference 1, pg. 5-13)

$D_{100\,min} = 1.26\ D_{50\,min}$

$D_{100\,max} = 1.71\ D_{50\,min}$

$D_{25\,min} = 0.68\ D_{50\,min}$

CALCULATIONS

A) Lower Bound Gradation (see Figure 1)

$D_{50_{min}} = 2.0"$ (see pg. 5/13)

$G_s = 2.49$ (assumed in stability calc)

D_{100} min $= 1.26 \times 2 = \underline{2.52"}$

D_{100} max $= 1.71 \times 2 = \underline{3.42"}$

D_{25} min $= 0.68 \times 2 = \underline{1.36"}$

B) Upper Bound Gradation (see Figure 2)

D_{50} min $= 1.3 \times D_{50} = 2.6"$

$G_s = 2.49$ (assumed)

D_{100} min $= 1.26 \times 2.6 = \underline{3.28"}$

D_{100} max $= 1.71 \times 2.6 = \underline{4.45"}$

D_{25} min $= 0.68 \times 2.6 = \underline{1.77"}$

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		Sheet	C-3
Project	UMTRA-GJN	Contract No. 5057-05	File No.
Feature	Riprap Type A	Designed MJG	Date 1/6/92
Item	Gradation	Checked [illegible]	Date 1-8-92

CONCLUSIONS

A) Lower Bound Gradation (For Comparitive Purposes Only)

Sieve Size (in)	Percent Finer By Weight
3 1/2	100
3	79 to 100
2	32 to 50
1 1/2	17 to 35
1	0 to 5
3/4	0

B) Upper Bound Gradation (For Design - See Note Below)

Sieve Size (in)	Percent Finer By Weight
4 1/2	100
4	70 to 100
3	39 to 88
2	8 to 32
1 1/2	0 to 17
1	0

Note: Upper bound gradation is selected for design to ensure against changing gradation during construction due to minor variations in design and physical test results for rock durability.

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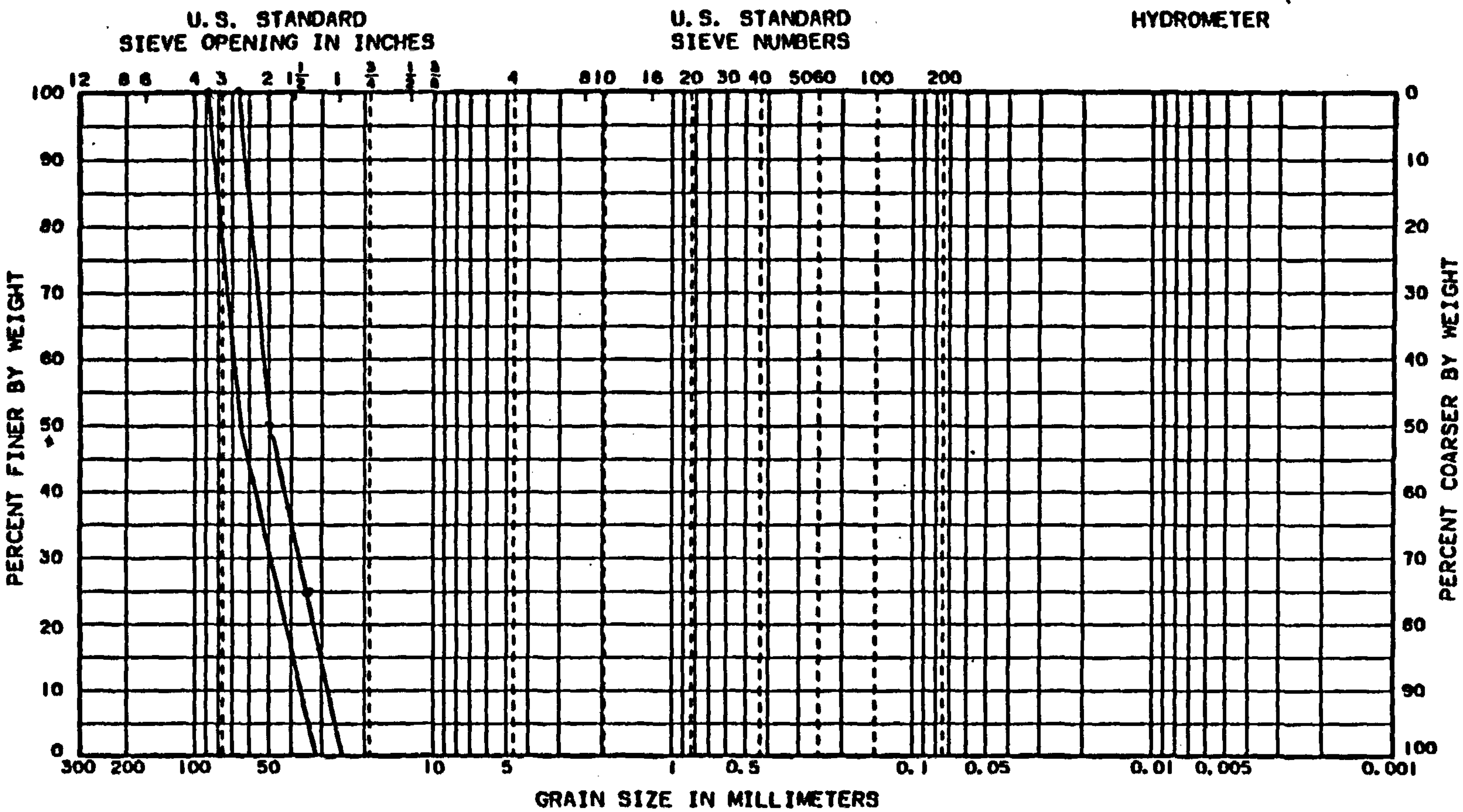
A MORRISON-KNUDSEN COMPANY

GRAIN SIZE ANALYSIS



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI	
							PROJECT
							JOB NO.
							AREA
							HOLE NO.
							DATE

CAB110

Figure 1 - Lower Bound Gradation

UMTA-GRN 5057-05 MJG 1/6/68

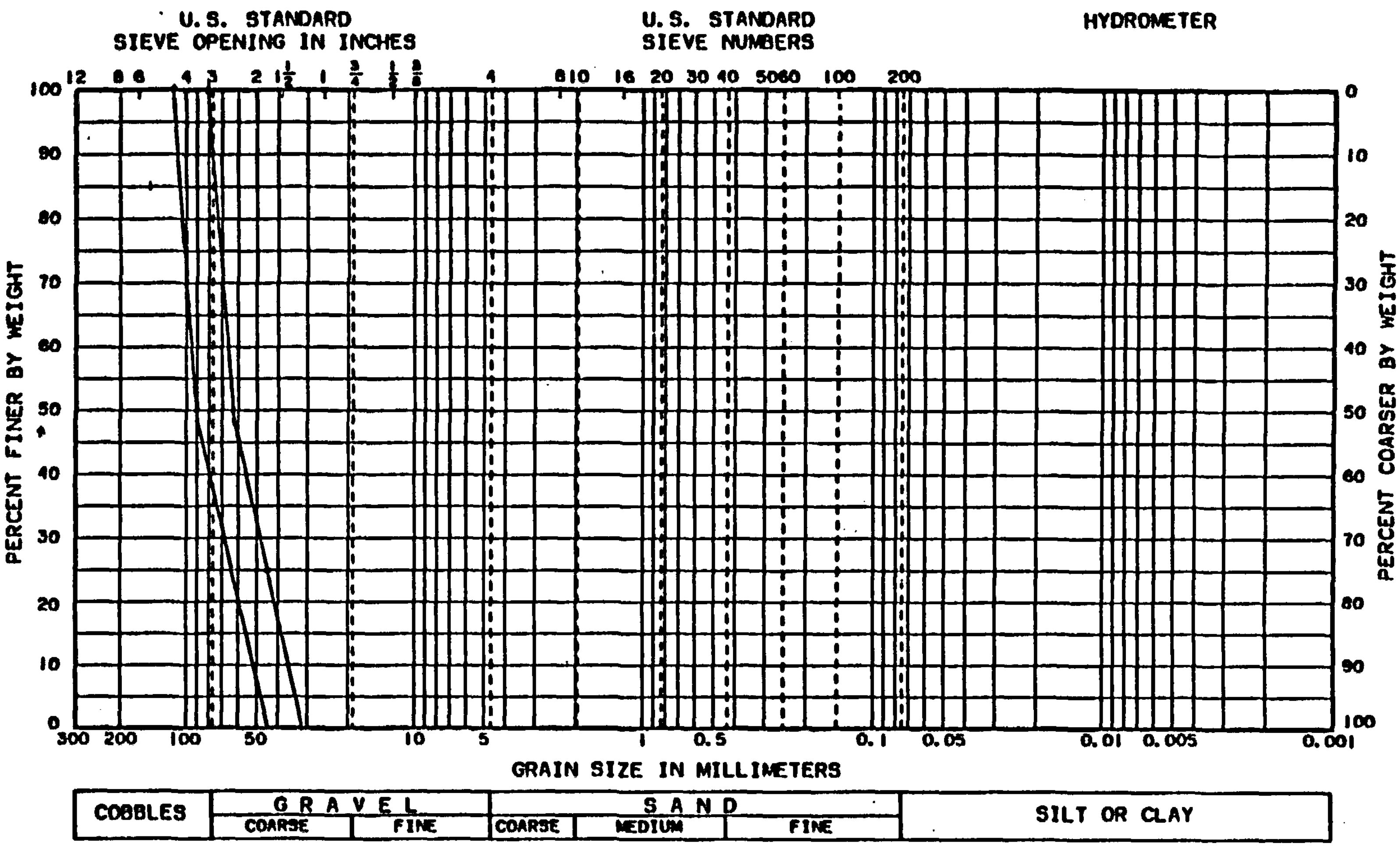
Riprap Type A Gradation

1-8-??

C-4

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON-KNUDSEN COMPANY

GRAIN SIZE ANALYSIS



SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI	
							PROJECT
							JOB NO.
							AREA
							HOLE NO.
							DATE

CAB110

Figure 2 - Upper Bound Gradation

DMTRA-GRN
5057-05
1/6/88

Riprap Type A Gradation

C-5

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA-GRN	Contract No. 5057-05	Sheet D-1a	File No.
Feature Disposal Embankment	Designed MJC	Date 1-25-93	
Item Use of Type A Riprap for Filter	Checked FBG	Date 4-25-90	

APPENDIX D

Replacing Filter with Type A Riprap

APPENDIX D

Purpose

Determine if Riprap Type A "upper bound" gradation* is acceptable for use as a filter between Riprap Type B and Bedding Materials (* see page C-5)

Method

Prevent migration of fine-grained material into coarser material by maintaining the following ratio;

$$D_{15})_f / D_{85})_b \leq 7.5 \qquad \text{(Ref. 1)}$$

in which

f - indicates the coarser-grained material (i.e. "filter") that prevents migration of finer-grained material.

b - indicates the finer-grained material (or "base" material)

Data

Material	D_{15} (in)	D_{85} (in)
Riprap Type B [1]	11 to 13.8	21 to 29
Riprap Type A	1.5 to 2.2	3.0 to 4.2
Bedding [1]	0.006 to 0.028	0.6 to 1.4

1. Calc. 10-536-02-00 pp. 12-13

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA · GRN

Feature Disposal Embankment

Item Use of Riprap Type A For Filter

Contract No. 5057-05 | Sheet D-2 | File No.
Designed MJG | Date 1/11/88
Checked FBG | Date 1-26-88

Calculations

- check migration of bedding into filter, i.e., type A riprap

$$D_{15_f} / D_{85_b} = 2.2 / 0.6 = 3.7 \leq 7.5 \quad \therefore OK^{*}$$

- check migration of filter, i.e., Type A riprap, into Type B riprap.

$$D_{15_f} / D_{85_b} = 13.8 / 3 = 4.6 \leq 7.5 \quad \therefore OK$$

CONCLUSIONS

- Riprap Type A may be substituted for the filter that would separate Riprap Type B from bedding materials.
- The maximum size of Riprap Type A for the gradation used above will allow use of the minimum layer thickness of 6" between Riprap TYPE B and bedding.

MJG 1-26-88
FBG 1-12-88

* Checker's Comment: A decrease in the largest size ranges of bedding may be allowable if gradation for Riprap Type A used above is used for construction.

FBG 1-12-88
MJG 1-26-88

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA - GRN
Feature EMBANKMENT EROSION PROTECTION
Item VERIFY ADEQUACY OF AS-BUILT COND.
Contract No. 5057
Designed JCP
Checked RMS
Sheet E-1
File No.
Date 3 APRIL 90
Date 4/11/90

APPENDIX E

PURPOSE: TO VERIFY THE ADEQUACY OF THE MINIMUM ALLOWABLE RIPRAP TYPE A D_{50} BASED UPON AS-BUILT GEOMETRY OF THE GREEN RIVER TAILINGS EMBANKMENT. (MINOR PORTIONS OF THE SOUTHEASTERN SIDE OF THE EMBANKMENT ARE STEEPER THAN 5(H):1(V).)

METHOD: COMPUTER PROGRAM RPRP/SFST IS USED TO VERIFY MINIMUM ALLOWABLE RIPRAP TYPE A D_{50}.

SUMMARY: COMPUTED MINIMUM ALLOWABLE RIPRAP D_{50} BASED ON AS-BUILT GRADES ON SOUTHEASTERN SIDE OF EMBANKMENT IS 2.0 INCHES WHICH AGREES WITH D_{50} CALCULATED IN APPENDIX A.

∴ RIPRAP TYPE A MINIMUM ALLOWABLE D_{50} CALCULATED PREVIOUSLY (SHEET 5/13) IS ADEQUATE FOR EMBANKMENT SLOPES AS-BUILT.

REFERENCES (IN ADDITION TO REFERENCES CITED ON CALCULATION COVER SHEET):

9. MK-F EROSION PROTECTION SCORING RESULTS, MKES DOC # 5057-GRN-R-02-01809-00

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Sheet E-2
Project UMTRA - GRN Contract No. 5057 File No.
Feature EMBANKMENT EROSION PROTECTION Designed JCP Date 4 APR 90
Item VERIFY ADEQUACY OF AS-BUILT COND. Checked RMS Date 4/11/90

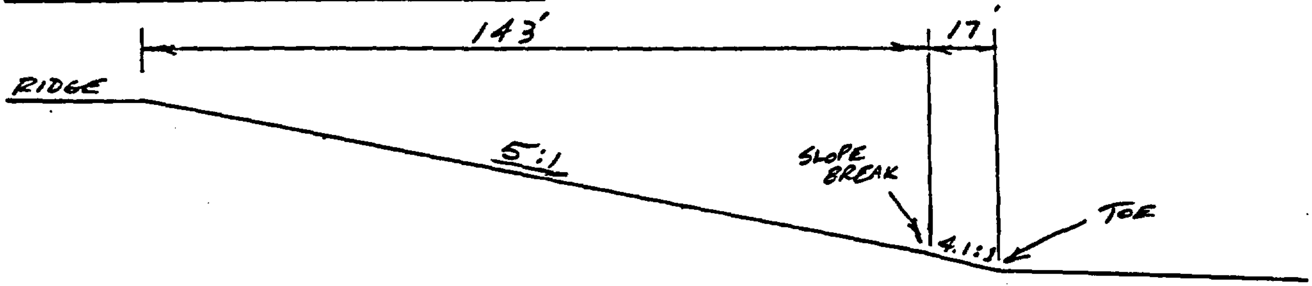
10. FAX FROM J SINGLETON, MK-F, TO F GUROS, MKES, MKES DOC # 5057-GRN-R-02-1863-00

11. "TYPICAL CENTER LINE CROSS-SECTIONS, GREEN RIVER REMEDIAL ACTION PROJECT," MKES DOC # 5057-GRN-D-69-01835-00

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN | Contract No. 5057 | Sheet E-3 | File No.
Feature: EMBANKMENT EROSION PROTECTION | Designed JCP | Date 4 APRIL 90
Item: VERIFY ADEQUACY OF AS-BUILT COND. | Checked RMS | Date 4/11/90

EMBANKMENT GEOMETRY



AS-BUILT EMBANKMENT GEOMETRY DATA PROVIDED BY ART BARKER AND ASSOCIATES, WELLINGTON, UTAH. SLOPE BREAK & TOE LOCATION DATA PROVIDED BY ROLAND ENGINEERING, GRAND JUNCTION, CO.

MAXIMUM WATERSHED FLOWLINE LENGTH IS USED TO CALCULATE MINIMUM ALLOWABLE RIPRAP D_{50} (REF 11). A CHANGE IN SLOPE FROM 5(H):1(V) TO 4.1(H):1(V) AND 4.3(H):1(V) OCCURS ON EITHER SIDE OF THE MAXIMUM FLOWLINE LENGTH (REF 10). A SLOPE CHANGE OF 4.1(H):1(V) IS PROJECTED ONTO THE MAXIMUM FLOWLINE LENGTH TO PROVIDE A CONSERVATIVE MODEL OF EXISTING CONDITIONS AND ALSO REFLECT THE UNCERTAINTY OF EXISTING SLOPE CHANGE CONDITIONS ALONG THE MAXIMUM FLOWLINE CHOSEN.

ADDITIONAL INPUT DATA.

COMPUTER PROGRAM RPRP/SFST WILL BE RUN USING THE SAME INPUT PARAMETERS USED BY MJG IN APPENDIX A FOR NO THROUGHFLOW CONDITIONS. A SPECIFIC GRAVITY VALUE OF 2.49 IS AGAIN USED FOR CONVENIENCE SINCE REPRESENTATIVE SAMPLING & TESTING OF PLACED RIPRAP YIELDED SPECIFIC GRAVITIES GREATER THAN AFOREMENTIONED (SEE REF 9).

THE FOLLOWING PARAMETERS WERE CHANGED FOR THE FOLLOWING REASONS:

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

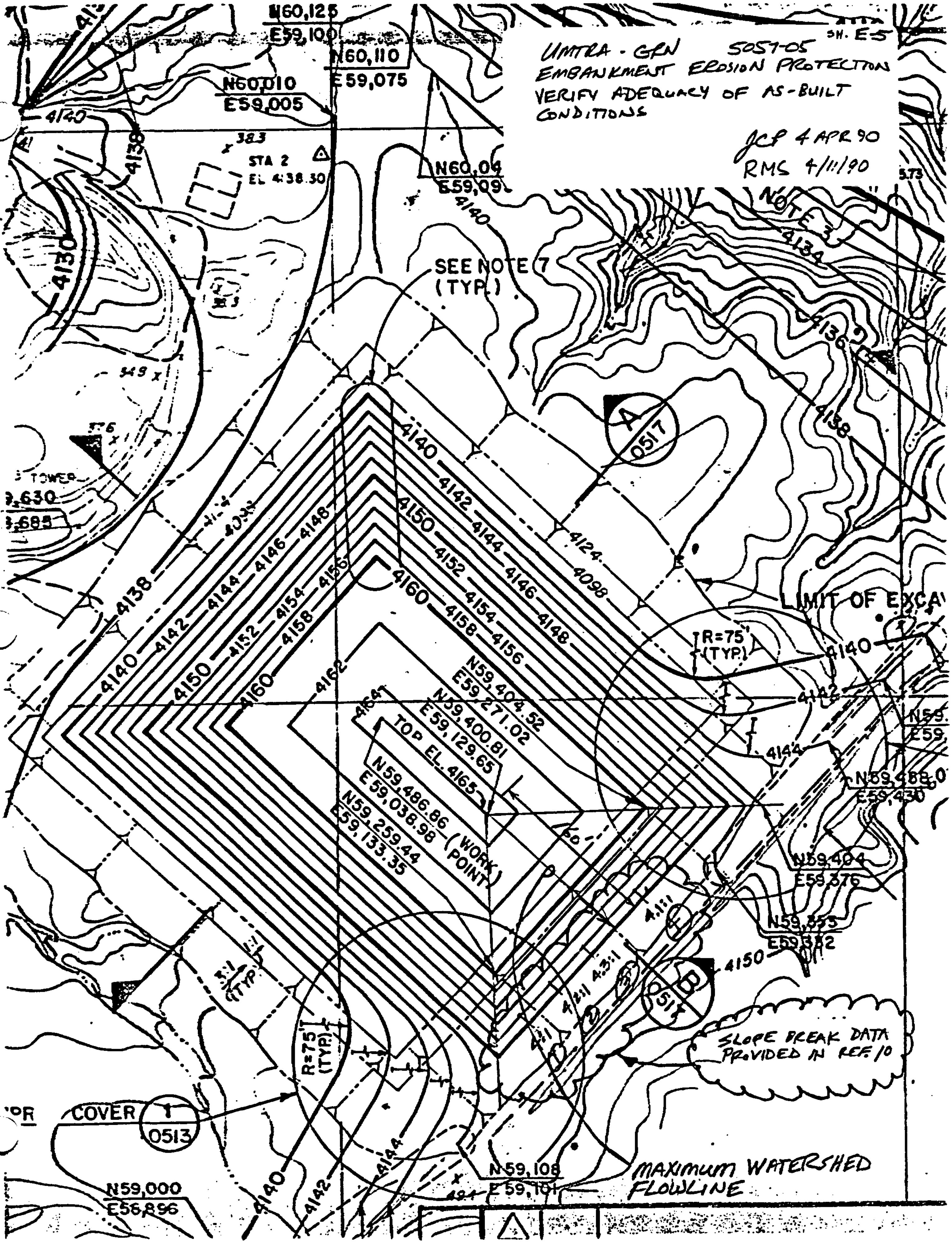
Project UMTRA - GRN
Feature EMBANKMENT EROSION PROTECTION
Item VERIFY ADEQUACY OF AS-BUILT COND.

Sheet E-4
Contract No. 5057
File No.
Designed JCP
Date 4 APR 90
Checked RMS
Date 4/11/90

1) EMBANKMENT GEOMETRY (ADDRESSED ON PREVIOUS PAGE)

2) INPUT PARAMATER "C".

INPUT PARAMETER C WAS CHANGED FROM 0.22 (FOR GRAVELS & PEBBLES) TO 0.27 (FOR CRUSHED GRANITE) BECAUSE THE RIPRAP IS CRUSHED BASALT.


UMTRA - GRN 5057-05
SH. E-5
EMBANKMENT EROSION PROTECTION
VERIFY ADEQUACY OF AS-BUILT CONDITIONS
JCF 4 APR 90
RMS 4/11/90
N60,125
E59,100
N60,110
E59,075
N60,010
E59,005
STA 2
EL 4138.30
SEE NOTE 7 (TYP.)
NOTE 3
LIMIT OF EXCA
R=75' (TYP.)
N59,404.52
E59,271.02
N59,400.81
E59,129.65
TOP EL. 4165
N59,486.86 (WORK POINT)
E59,038.98
N59,259.44
E59,133.35
N59,404
E59,376
N59,353
E59,382
N59,488.0
E59,430
SLOPE BREAK DATA PROVIDED IN REF. 10
COVER
0513
0517
N59,108
E59,101
N59,000
E58,896
MAXIMUM WATERSHED FLOWLINE

SH. E-6

UMTRA - GRN 5057-05
EMBANKMENT EROSION PROT.
VERIFICATION OF AS-BUILT
ADEQUACY

JCP 4 APR 90
RMS 4/11/90

```
**INPUT FILE PRINTOUT**

UMTRA-GREEN RIVER, EMBANKMENT RIPRAP TYPE A VERIFICATION

GRN   EROPROAPR04 1990
  1.810  .310 1.770 2.490  .270      A  .002 1.0
   2    0
   0    0
   6    2
 SIDE     143.0  20.0   .30  37.0  ST
 BREAK     17.0  24.4   .30  37.0  ST
  .1250     .5   .00833
  .1250     .5   .00833

 * * * * * * * * * * * * END INPUT DATA * * * * * * * * * * * *
```

UMTRA-GREEN RIVER, EMBANKMENT RIPRAP TYPE A VERIFICATION

UMTRA/GRN RUN I.D.=EROPRO DATE=APR04 1990

SAFETY FACTOR/STEPHENSON METHOD FOR EMBANKMENT EROSION PROTECTION

* * * * * * * * * * * * INPUT DATA * * * * * * * * * * * * * *

COEFFICIENTS FOR INTENSITY DURATION CURVE -
IPMP=10**(G-H*(LOGT)**Z):

G= 1.810 H= .310 Z=1.770

RIPRAP STONE SP.GRAVITY= 2.49 C IN STEPHENSONS EQN= .27

- - - EMBANKMENT - - -

AREA (LOCATION IN PLAN)	SEGMENT	LENGTH (FT)	SLOPE (%)	POROSITY	FRICTION ANGLE (DEG)	
A	SIDE	143.	20.	.30	37.	STEPHENSONS
A	BREAK	17.	24.	.30	37.	STEPHENSONS

* * * * * * * * * * * * END INPUT DATA * * * * * * * * * * * *

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

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NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

E-7

UMTRA - GRN 5057-05
EMBANKMENT EROSION PROT.
VERIFY AS-BUILT ADEQUACY

JCP 4 APR 90
RMS 4/11/90

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

NOTE-TIME OF CONC. IS SET AS MINM.= 2.5MINUTES

DETAILED CALC TABLE WITH FINAL ROCK SIZE

SEGMENT=SIDE LENGTH= 143. FT. SLOPE= 20.%

ASSUMED D50= .1250FT. AT D/S END OF SEGMENT
CORRESPONDING Q= .196CFS/FT AT SEGMENT END-BY STEPHENSONS METHOD

SLOPED DISTANCE FROM (FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL
0.	24.	.035	.000	.035	1.20	.03	.056	.33	.33
24.	48.	.070	.000	.070	1.77	.04	.045	.22	.56
48.	72.	.105	.000	.105	2.20	.05	.041	.18	.74
71.	95.	.140	.000	.140	2.55	.05	.039	.16	.89
95.	119.	.175	.000	.175	2.86	.06	.037	.14	1.03
119.	143.	.210	.000	.210	3.14	.07	.036	.13	1.16

RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L (INCH/HR)	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**2)) (INCH/HR)
63.86	56.15

DETAILED CALC TABLE WITH FINAL ROCK SIZE

SEGMENT=BREAK LENGTH= 17. FT. SLOPE= 24.%

ASSUMED D50= .1667FT. AT D/S END OF SEGMENT
CORRESPONDING Q= .219CFS/FT AT SEGMENT END-BY STEPHENSONS METHOD

SLOPED DISTANCE FROM (FT)	TO (FT)	*****FLOWS(CFS/FT)**** ALLOC.	PORES	ROCK	VEL. (FPS)	DEPTH (FT)	MANNING N	TIME OF CONC(MIN) INT.	TOTAL
0.	24.	.033	.000	.033	1.15	.03	.057	.35	.35
24.	48.	.065	.000	.065	1.71	.04	.046	.23	.58
48.	72.	.098	.000	.098	2.12	.05	.042	.19	.77
71.	95.	.131	.000	.131	2.47	.05	.039	.16	.93
95.	119.	.163	.000	.163	2.77	.06	.037	.14	1.07
119.	143.	.196	.000	.196	3.03	.06	.036	.13	1.20
0.	9.	.208	.000	.208	3.01	.07	.041	.05	1.25
9.	17.	.219	.000	.219	3.10	.07	.041	.05	1.29

RAINFALL INTENSITY THAT ASSUMED D50 CAN WITHSTAND BASED ON THE EQN I=Q/CA= (43560*Q)/L (INCH/HR)	RAINFALL INTENSITY BASED ON CALCULATED TIME OF CONC.AND USING INTERPOLATING FUNCTION I=10**(G-H*((LOGT)**2)) (INCH/HR)
59.75	56.15

UMTRA – GRN 5057-05
EMBANKMENT EROSION PROT.
VERIFY AS-BUILT ADEQUACY

JCP 4 APR 90
RMS 4/11/90

*******RESULTS SUMMARY******* AREA=A

SEGMENT	LENGTH (FT)	SLOPE (%)	D50 (INCH)	Q AT D/S END (CFS/FT)	TC (MINUTES)	STARTING ROCK D50 (INCH)	METHOD OF CALC.
SIDE	143.	20.0	1.5	.210	2.5	1.50	STEPHENSON
BREAK	17.	24.4	2.0	.219	2.5	1.50	STEPHENSON

$(D_{50})_{min} = 2.0''$ ✓

MKE DOCUMENT NO. 5057-GRN-C-01-00280-01

Calculation Cover Sheet

Contract No. 5057 Discipline ESCI/UMTRA Calc. No. 10-536-05-~~00~~ 01 No. of Sheets ~~57~~ 52

Project
UMTRA-GRN (GREEN RIVER SITE, UTAH)

Feature
EMBANKMENT

Item
RIPRAP TOE PROTECTION AND SITE DRAINAGE IMPROVEMENTS

Sources of Data

1. Chen and Associates, September 11, 1987, "Additional Laboratory Test Results, Green River, Utah", Job No. 1-620-87 (P.O. No. 3050-511-9502) Denver, Colorado

Sources of Formulae & References

1. U.S. Department of Energy, January 1987, Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings Site at Green River, Utah Draft, UMTRA-DOE/AL-050510.GRN0, UMTRA Project Office, Albuquerque, N.M.
2. Morrison-Knudsen Engineers, May 1986, UMTRA Design Procedures Manual, MKE Doc. No. 4005-GEN-Q-01-00571-02, Copy No. 28.
3. Stephenson, D. 1979 Rockfill in Hydraulic Engineering, Developments in Geotechnical Engineering 27, Elsevier Scientific Publishing Co., NY
4. Stevens, M.A., Simons, D.B., and Lewis, G.L., May 1976, "Safety Factors for Riprap Protection", ASCE Jour. Hydraulics Division vol. 102, No. HY-5

[CONTINUED, SHEET "REF-2"]

Preliminary Calc. ☐ Final Calc. ☒ Supersedes Calc. No. ———

Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
1	Change to Final Calc	M.J. Gordman	11-11-87	P.K. Chen	11/11/87	P.K. Chen	11/17
0	Attachment B: Upslope Area PMF	JC PORTER	9-18-87	FB Guros	9-18-87	P.K. Chen	[illegible]
0	———	F.B. Guros	9-18-87	[illegible]	9/24/87	———	

Form 42-110

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA-GRN | Contract No. 5057 | Sheet REF-2
Feature EMBANKMENT | Designed FBG | File No.
Item RIPRAP TOE PROTECTION | Checked WYL | Date 9-18-87 | Date 9/23/87

REFERENCE LIST (continued)

5. U.S. Corps of Engineers, 1 July 1970, Hydraulic Design of Flood Control Channels, EM 1110-2-1601, Reprint with Changes 1-4 included (15 Sept. 1982)

6. Anderson, A.G., Paintal, A.S., and Davenport, J.T., 1970, Tentative Design Procedure for Riprap-Lined Channels, NCHRP Report No. 108, Highway Research Board, Washington, D.C.

7. U.S. Bureau of Reclamation, 1974, Design of Small Dams, U.S. Government Printing office, Washington, D.C.

8. Israelsen, C.E., et al, April 1980, Erosion Control During Highway Construction: Manual on Principles and Practices NCHRP Report No. 221, Transportation Research Board, Washington D.C.

9. Chow, V.T, 1959, Open-Channel Hydraulics, McGraw Hill, NY

10. Morrison-Knudsen, Engineers, September 1987, "UMTRA-GRN, Tailings Embankment, Erosion Protection", MKE Calc. No. 10-536-02-00.

11. Morrison-Knudsen Engineers, September 1987, "UMTRA-GRN, PMP For Erosion Protection, S.O.S. Disposal Site", MKE Calc. No. 10-539-01.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA-GRN | Contract No. 5057 | Sheet A
Feature EMBANKMENT | Designed FBG | Date 9-23-87 | File No.
Item RIPRAP TOE PROTECTION | Checked WYL | Date 9/23/87

SUMMARY

(SEE P. 1. FOR CONTENTS OF CALCULATION)

I. SITE DRAINAGE IMPROVEMENTS

A. Provide apron at embankment toe to facilitate sheet flow away from embankment.

B. Abandon existing culverts to reduce runoff flows near the embankment.

C. Drain southeast side of embankment to existing ditch across road

D. Fill existing gullies with gravel, i.e., erosion-resistant materials that promote sheet flow, not gully formation.

E. Design final grades to promote sheet flow. Do not allow shale bedrock excavated materials to be used as fill around embankment to reduce gully formation potential.

F. Final boundary should be adequate to prevent alterations to site grading and gravel fill around embankment.

II. RIPRAP TOE PROTECTION

A. Riprap size $(D_{50})_{MIN}$ = 1.5'
(For design gradation, see Ref. 10)

SUMMARY (continued)

B. Provide riprap end protection on southeast side of embankment to protect against potential PMF flow, in the event the site road is abandoned or is washed away by a PMF.

C. Provide riprap toe protection on southwest, northwest, and northeast sides of embankment. This will provide protection against relatively large potential future flow concentrations. Long-term soil loss on these sides is estimated at 4'-7'; therefore, provide toe protection through maximum depth of soil (~ 18').

D. See preliminary design drawings for construction details.

NOTE: Riprap quality and final riprap source selection will be the subject of a separate detailed evaluation.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA-GRN	Contract No. 5057	Sheet 1	File No.
Feature EMBANKMENT	Designed FBG	Date 9-23-87	
Item RIPRAP TOE PROTECTION/SITE DRAINAGE	Checked WYL	Date 9/23/87	

CONTENTS

PURPOSE

This calculation presents the following:

1. Rationale for site drainage improvements that reduce the possibility that long-term erosion will undermine or erode into the tailings embankment.
2. Design of riprap toe protection

METHOD

1. Section 1 of this calculation describes site drainage improvements and conditions that will reduce erosion potential on and near the site. The rational supporting the expected effectiveness of each improvement is given.

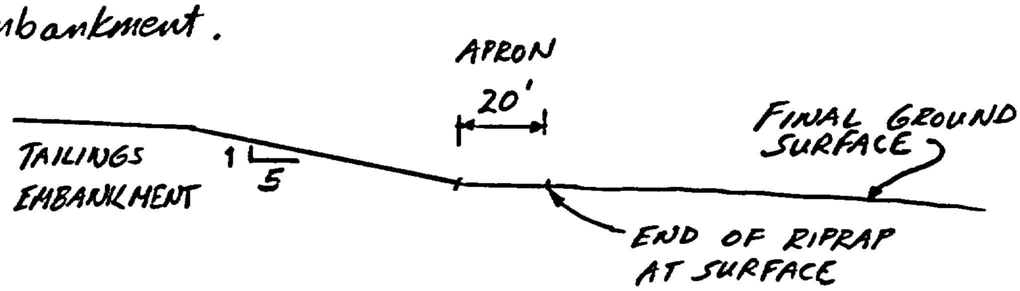
2. Section 2 presents riprap toe protection design, including the following elements:
   - A. Criteria for design, based on expected erosion potential including consideration of site drainage improvements given in Section 1.
   - B. Analysis of riprap stability, including methods, assumptions, and final rock sizes.

   [Riprap gradation(s) is given in Ref. 10]

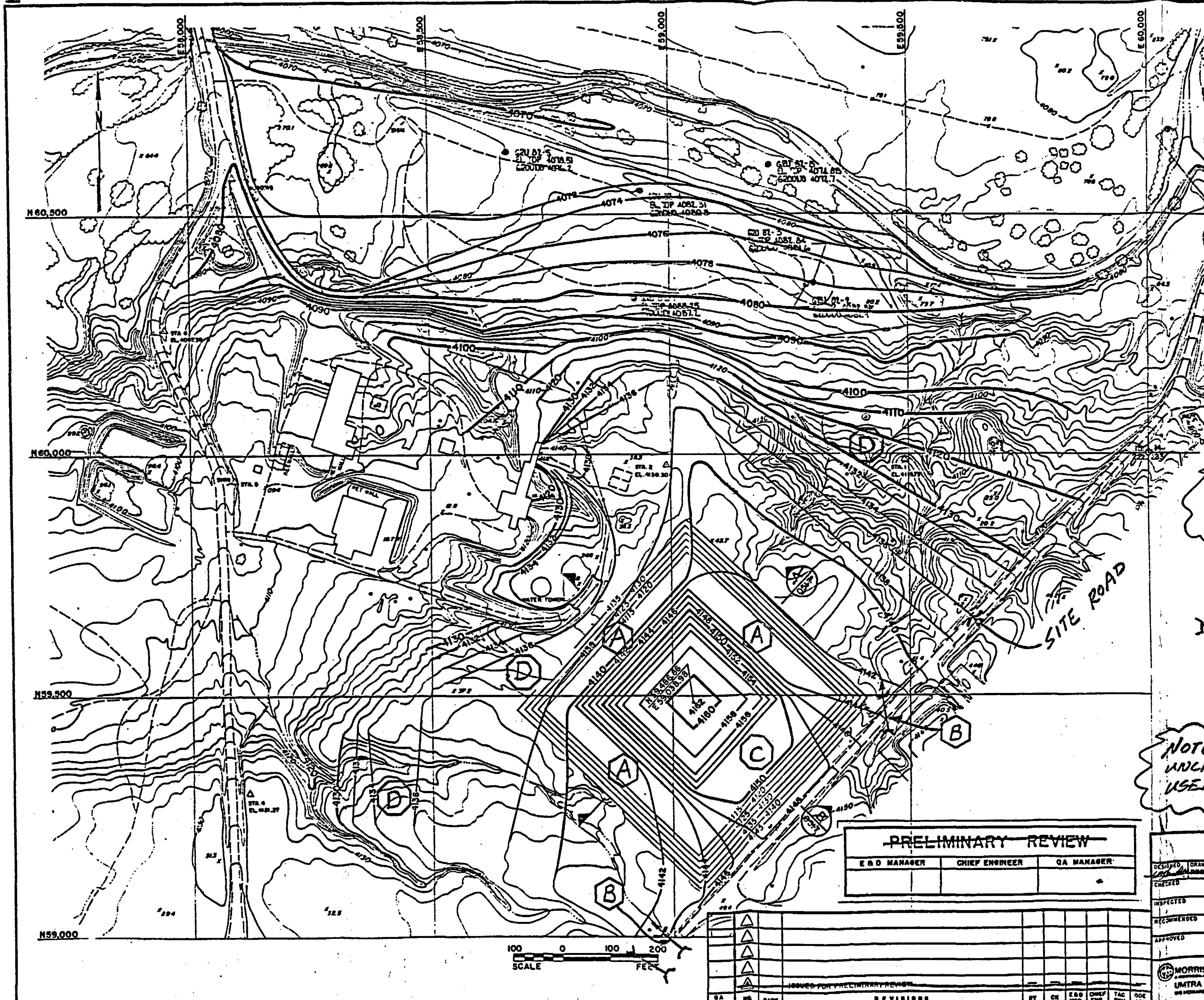
SECTION 1: SITE DRAINAGE IMPROVEMENTS

1. Refer to the plan on sheet 4 for locations of site drainage improvements discussed below. Locations for particular improvements are labelled "(A), (B)," etc.

2. (A): An apron will be provided on the SW, NW, and NE sides of the embankment where the 5(H):1(V) embankment sideslopes meet adjacent site grading. (see below) The apron will consist of riprap and will decrease velocity of sheet flow from the embankment to site grades without riprap. This eliminates potential for scour and depressions that would form at the toe of the sideslope and the potential for gullies beginning in selective flow paths that could form to drain any ponding in those depressions. The apron also ensures that sheet flow will continue a minimum distance away from the embankment.



SECTION
(NOT TO SCALE



SHEET 4

UMTRA-GRN 5057
EMBANKMENT
RIPRAP TOE PROTECTION

FBG 9-18-87
WYL 9/23/87

NOTES:

1. FOR SEQUENCE OF EXCAVATION AND PLACEMENT OF CONTAMINATED MATERIALS SEE DWG. NO. GRN-PS-10-0512.
2. FINAL EMBANKMENT TOP SLOPE ELEVATIONS SHALL BE ADJUSTED TO ACCOMMODATE ACTUAL QUANTITIES OF MATERIALS PLACED UPON THE APPROVAL OF THE CONTRACTOR.

(A) = LOCATION OF SITE DRAINAGE IMPROVEMENT DISCUSSED IN CALCULATION SECTION 1

REFERENCE DRAWINGS:

GRN-PS-10-0512 CONTAMINATED MATERIAL EXCAVATION PLAN (SHEET 2 OF 2)
GRN-PS-10-0517 TAILINGS EMBANKMENT & FINAL GRADING SECTIONS

CULVERT WITH FLOW DIRECTION

LEGEND:

4150 — EXISTING SITE FEATURES & CONTOURS (JULY 1982 SURVEY)
4160 — FINAL CONTOURS
N60,500 — CONSTRUCTION GRID COORDINATE

NOTE: THIS DRAWING IS AN IN-PROGRESS UNCHECKED WORKING DRAWING USED FOR DESIGN PURPOSES ONLY.

~~PRELIMINARY REVIEW~~

E&D MANAGER	CHIEF ENGINEER	QA MANAGER

QA	NO.	DATE	REVISIONS	BY	CK	E&D MGR.	CHIEF ENG.	TAC REV.	DOE APP.
	△								
	△								
	△								
	△								
	△		ISSUED FOR PRELIMINARY REVIEW						

U. S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

GREEN RIVER SITE
GREEN RIVER, UTAH

TAILINGS EMBANKMENT AND FINAL SITE GRADING SECTIONS

DESIGNED / DRAWN / CHECKED / INSPECTED / RECOMMENDED / APPROVED / DATE / DOE PROJECT ENGINEER / DATE

MORRISON-KNUDSEN ENGINEERS, INC.
UMTRA PROJECT

PROJECT NO. DE-AC04-83AL18796
DRAWING NO. GRN-PS-10-0516
REV. A

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA-GRN	Contract No. 5057	Sheet 5
Feature EMBANKMENT	Designed FBG	File No.
Item SITE DRAINAGE IMPROVEMENTS	Checked WYL	Date 9-18-87 / Date 9/23/87

3. (B) Two existing culverts will be abandoned to reduce on-site flows. These culverts currently drain beneath the site road.

Flows that currently drain into the culvert south of the embankment location will be diverted into another culvert farther from the embankment. The gully that drains the farther culvert has a lower base level than the nearer gully – thus, it is unlikely that the diverted flow will attempt to reestablish a channel at its previous location closer to the gully (e.g., in the event the culvert to remain becomes clogged.)

Flows that currently drain into the culvert east of the embankment will be diverted into an existing ditch that runs along the southeast side of the site road. The ditch will be improved to ensure that major storm flows up to the PMF will not overtop the road near the embankment (See MKE Calc. No. 10-539-03-00)

4. (C) Site grading on the southeast side of the embankment will be covered with erosion protection that will withstand the PMP. Flows will be diverted across the site road and into the ditch. (continued →)

4. (cont.) This design prevents flows from the southeast side from concentrating along the northwest side of the site road, and draining as concentrated flow onto on-site grades below the embankment. Thus, the potential for these flows to initiate gullies near the embankment is nearly eliminated. (Riprap end protection for this area is designed in Section 2). [Note: Existing site road is surfaced with bituminous surface treatment, and thus should not erode easily due to sheet flow from embankment]

5. (D) Existing gullies will be filled with cohesionless, erosion-resistant gravels (details are given in preliminary design subcontract documents). This type of material promotes infiltration and facilitates continued sheet flow, two important factors in reducing gully erosion potential. (As-constructed site grading is designed to promote sheet flow and avoid flow concentrations as well.) Gravels will be placed only up to a given maximum elevation in some areas to ensure that the gravel fill does not act as a future obstacle to sheet flow after long-term erosion of other site soils. This reduces possibility of sheet flow concentrating and flowing around the gravel fill areas.

6. Site Grading: Site grading is designed to promote sheet flow. Additionally, shale bedrock from required

embankment excavation will be prohibited from placement within the final site boundary, since such fill would be more susceptible to gully formation.

7. Upslope Area: The drainage area upslope of the embankment location is bounded by 2 embankments of I-70 to the southeast and existing drainages northeast and southwest of the area. (See Ref. 1, Appendix D, Plate D.7.3, Aerial Photograph)*. Primary direction of flow from the upslope area is to the north towards Browns Wash. Thus, a strong potential exists for gullies northeast of the upslope drainage area to enlarge and divert flow into them. This would reduce the actual drainage area contributing flow to areas closer to the embankment, resulting in decreased erosion potential near the embankment. (*See sheet B-3)

8. Final Site Boundary: The final site boundary is proposed to include areas of site grading where sheet flow reduces gully erosion potential and areas of gravel fill. Since the former millsite may become an active commercial/industrial development in the near future, future occupants may want to

modify nearby site grades or possibly borrow gravel fill imported to the site (for gully fill). Thus, ownership by the State of Utah as part of the disposal site is the only assurance that such activities would be prevented.

SECTION 2: RIPRAP TOE PROTECTION

PURPOSE:

This section presents design of riprap toe protection, including rock size and construction details.
Two types of protection are differentiated and are labeled for convenience as follows:

A. Riprap Toe Protection: This protects SW, NW, and SE sides of the embankment from long-term erosion, either sheet & rill erosion or moderate gully erosion.

B. Riprap End Protection: This protects SE side of embankment from upslope drainage area. Drainage from that area could eventually flow against the embankment if long-term erosion washes out the site road in the event the site road is abandoned, or if a PMP washes out the road.

METHOD

A. Protection is provided against flows due to PMP. [Assumptions regarding PMF flowrate due to PMP are given for each type of protection (toe or end) below.] Embankment T_c is less than 2.5 minutes, so use $I = 56.15$ in/hr.

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B. Stable Rock Size: Design follows general methodology in Ref. 2, as follows:

1. Riprap Toe Protection: Compare results of following 3 methods and select rock size using judgement.

   a) Stephenson's Method for Flow down embankment slope. (Ref. 3)
   b) Stephenson's Method for Stones in Flowing Water (Ref. 3, p.41)
   c) Safety Factor Method (Ref. 4)

2. Upslope PMF Diversion: Use Safety Factor Method (Ref. 4)
   Use Safety Factor = 1.0

C. Riprap/Rock Properties

$\phi = 40°$

$G_s = 2.48$ (minimum value of 8 total samples of rock type proposed for use)

$C = 0.22$ (For Stephenson's Method only, most conservative C-value from available data)

D. Hydraulic Parameters

1. Flow depth by Mannings Formula
2. Mannings 'n' by USCE Formula (Ref. 5)

$$n = R^{1/6} / (23.85 + 21.95 \log R/k)$$

3. Maximum shear stress on side or bottom of channel:

See Sheet 11:
- Ref. 6, Fig. 11 (Side of trapezoidal channel)
- Ref. 6, Fig. 12 (Bottom of trapezoidal channel)
- Ref. 6, Fig. 10 (Side of triangular channel)

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EMBANKMENT, RIPRAP TOE PROTECTION

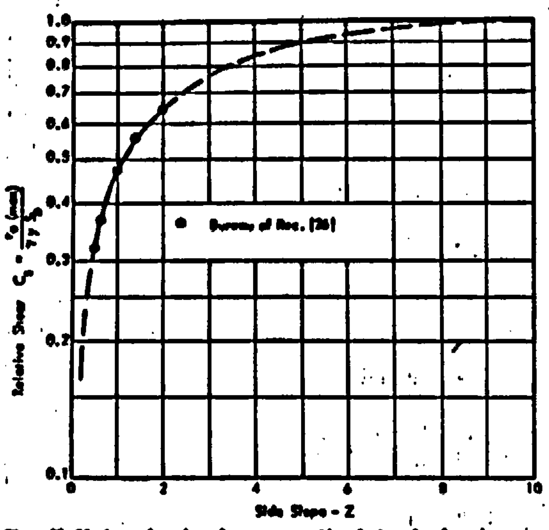

Figure 10. Maximum boundary shear stress on sides of triangular channels.

SOURCE : REF. 6

side slopes. As the channel gets narrower (less than 1:2) the shear on the bed decreases, whereas that on the sides tends to increase relative to the mean. Because the trapezoidal channels of interest have values of B/y greater than 2 and side slopes steeper than 1:4 the value of maximum shear can be conservatively approximated as

$$\tau_{s(max)} = 1.5\,\gamma R S_o \qquad (23)$$

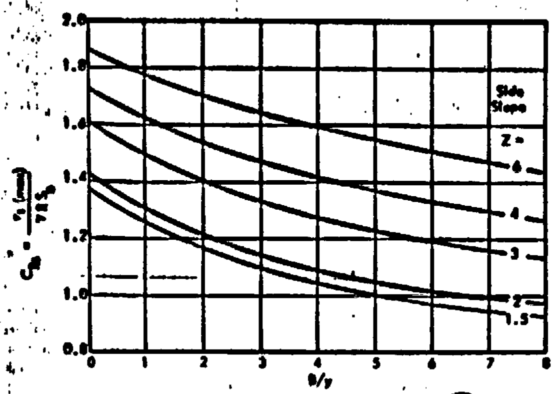

Figure 11. Maximum boundary shear stress on sides of trapezoidal channels.

SHEET 11

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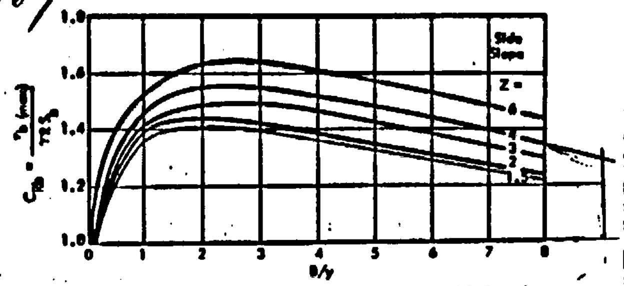

Figure 12. Maximum boundary shear stress on bottom of trapezoidal channels.

This is further substantiated by measurements (28) of the shear distribution in trapezoidal channels of relatively steep side slopes reproduced in Figure 13. The range of data for the several channels is included in the shaded portion. From this diagram it also appears that the maximum shear on the bed may be taken as 1.5 times the mean shear on the entire wetted perimeter.

The stability of the riprap lining of a trapezoidal channel implies that the riprap on the sloping sides of the channel will be as resistant to motion as that on the bottom. The ratio of the maximum shear on the sides to the maximum shear on the bed can be determined from Figures 11 and 12 for corresponding side slopes and values of B/y. These data are plotted in Figure 14, which further shows that except for the smaller values of B/y the maximum bed shear is greater than the maximum side shear. Again, considering the range of values of side slope and B/y of concern the ratio of these shears can be approximated by a single value as being representative of a large number of channels. This representative value can be taken, somewhat arbitrarily in view of the approximations used in establishing the curves, as

$$\frac{\tau_{s(max)}}{\tau_{b(max)}} = 0.8 \qquad (24)$$

Not USED

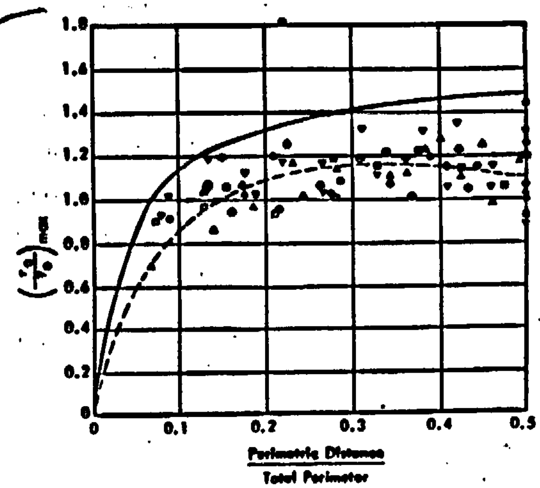

Figure 13. Distribution of boundary shear stress in trapezoidal channels.

SHEET 11

E. Long-Term Soil Loss (Appendix A)

Long-term soil loss due to sheet and rill erosion is estimated using method in Ref. 7. Parameters, site-specific values, and calculations are given in Appendix B.

This long-term soil loss is a rough estimate for sheet and rill erosion on the SW, NW, and NE sides of the embankment only.

F. Upslope PMF Flowrate: (Appendix B)

Area is only 11± ac., so Rational Formula is used with C = 1. $Q = CIA = (1.)IA = IA$

Time of concentration is estimated to determine appropriate value of I. See Appendix B for details.

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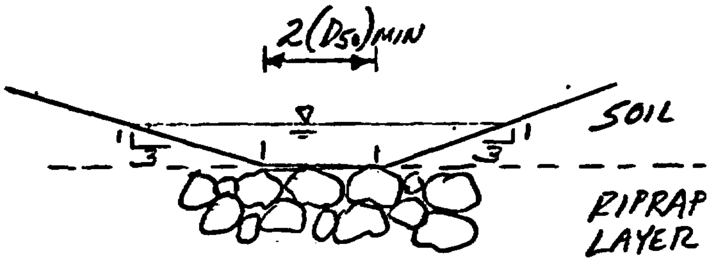
CALCULATIONS

A. RIPRAP TOE PROTECTION: STABLE ROCK SIZE

1. The SW, NW, and NE sides of embankment may be subject to flow concentrations due to irregular erosion beyond the embankment, including minor gullies. Gullies that may form should be limited in depth at the end of the riprap, since site grading is design to promote sheet flow. Additionally, existing gullies on the site that drain much larger areas than can occur on site in the future are limited in total depth, particularly near the embankment location.

2. Rock size versus flowrate will be determined below to judge the sensitivity of stability to flow concentration on the riprap toe protection. Then, a design rock size will be selected, based on those results and judgement.

3. Assumed gully shape for flow concentration on the riprap toe protection is as follows:



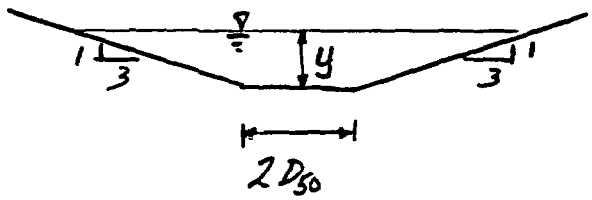
SECTION
(NTS)

a) Assume rock cannot be significantly displaced until bottom width = $2(D_{50})_{MIN}$

b) Assume 3(H):1(V) gully sideslopes. This is approximately the same as existing sideslopes in deeper portions of existing gullies.

4. Assume 5(H): 1(V) slope for riprap toe protection, same as embankment sideslope.

5. Hydraulic Properties of Flow Cross-Section



$$A = y(2D_{50}) + 3y^2$$

$$R = \left[y(2D_{50}) + 3y^2\right] / \left[2D_{50} + 2\sqrt{10}\, y\right]$$

6. Assume flow depth is controlled by Mannings n for rock (This will give relatively conservative flow depth, since n for soil sideslopes is less than n for rock)

7. $$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

$$AR^{2/3} = \left[y(2D_{50}) + 3y^2\right]\left[\frac{y(2D_{50}) + 3y^2}{2D_{50} + 2\sqrt{10}\, y}\right]^{2/3}$$

B. Rock Stability Equations: Safety Factor Method

Use equations for rock stability with flow down a plane sloping bed. (Ref. 4)

$$SF = \frac{\cos\alpha \tan\phi}{\eta \tan\phi + \sin\alpha}$$

$\alpha = \tan^{-1}(1/5) = 11.31°$

$\phi = 40°$

$$\eta = \frac{21\,\tau_s}{(S_s - 1)\gamma K}$$

$\gamma = 62.4 \ lb/ft^3$

S_s = specific gravity = 2.48

$K = D_{50}$ (ft)

$$\tau_s = C_{Rb}\,\gamma R \sin\alpha$$

$\sin\alpha$ = energy gradient*

R = hydraulic radius

C_{Rb} = maximum shear stress factor for bottom of trapezoidal channel (riprap location)

Combining & rearranging equations above (for SF = 1.0):

$$SF = 1.0 = \cos\alpha \tan\phi \Big/ \left\{\left[\frac{21\,C_{Rb}\,\gamma R \sin\alpha}{(S_s - 1)\gamma K}\right]\tan\phi + \sin\alpha\right\}$$

$$\frac{(S_s - 1)\gamma K}{21\,C_{Rb}\,\gamma R \sin\alpha} = \frac{\tan\phi}{\cos\alpha \tan\phi - \sin\alpha}$$

$$K = 21\,C_{Rb}\,R \sin\alpha \tan\phi \Big/ (S_s - 1)(\cos\alpha \tan\phi - \sin\alpha)$$

*Energy Gradient: The energy gradient will decrease as flow moves from the 5(H):1(V) side slope into the assumed gully at the toe. Use $\sin\alpha$ as a relatively conservative estimate of energy gradient.

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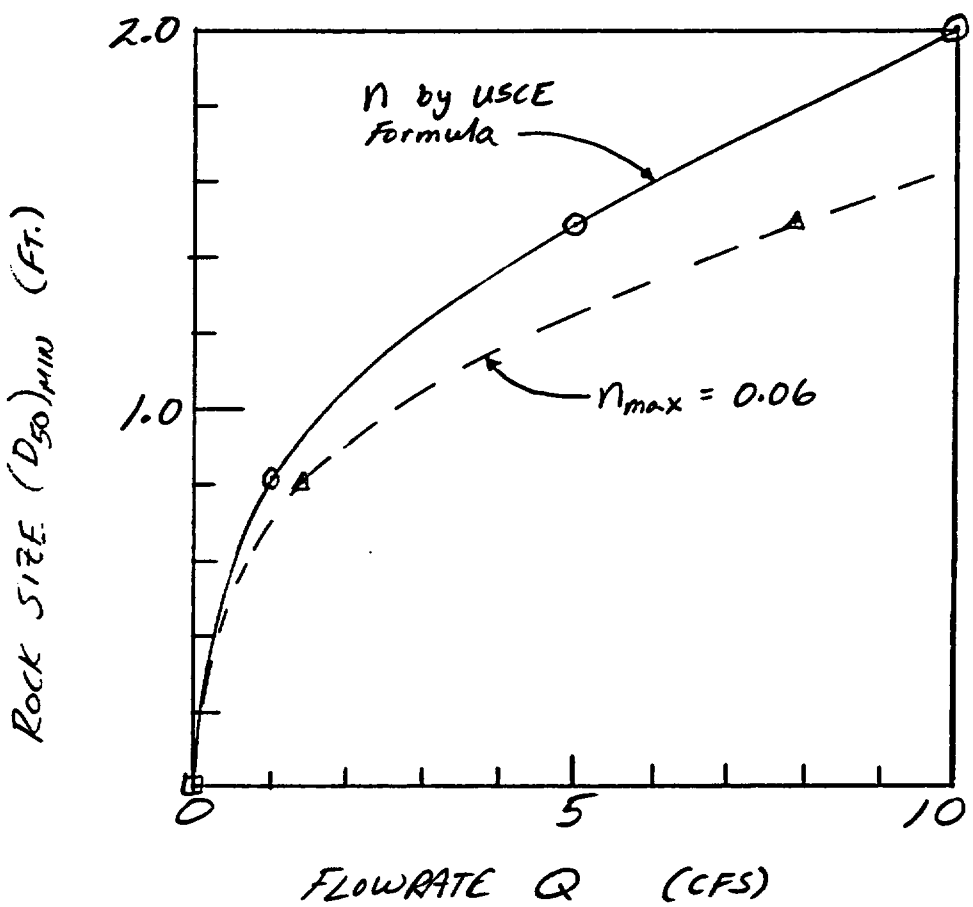
Rock Size Vs. Flow Rate:

Safety Factor Method and USCE Formula For Manning's n



"( )" = Results for maximum n = 0.06 (for comparison)

Q (ft³/sec)	n	y (ft)	R (ft)	C_{Rb}	D_{50} (ft)
1.0 (1.48)	0.088 (0.06)	0.21	0.16	1.35	0.81
5.0 (7.92)	0.095 (0.06)	0.39	0.30	1.35	1.49
10.0 (16.7)	0.10 (0.06)	0.52	0.40	1.35	2.00

9. Evaluation of Safety Factor Method

The riprap sizes calculated by the method above with the Safety Factor method appear to be conservatively large. The Safety Factor method has been found to be conservative for rock sizes on slopes steeper than 10% under sheet flow. Flow conditions calculated above are essentially the same as sheet flow, as evidenced by the following:

a) Maximum shear stress by $C_{Rb} \gamma R S \simeq \gamma y S$, i.e., where $\gamma y S$ is maximum shear stress for sheet flow.

b) Inspection of sketches drawn to scale (sheet 18) of flow depth and channel cross sections.

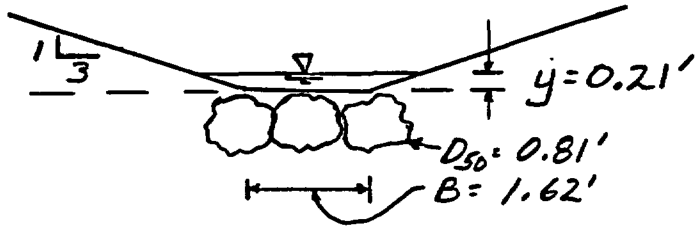
Thus, other methods should be used to determine a more reasonable rock size that will be stable.

SCALE* DRAWINGS OF FLOW IN CHANNEL SECTIONS

SAFETY FACTOR METHOD, USCE FORMULA FOR MANNINGS 'n', AND BOTTOM WIDTH = 2 (D_{50})

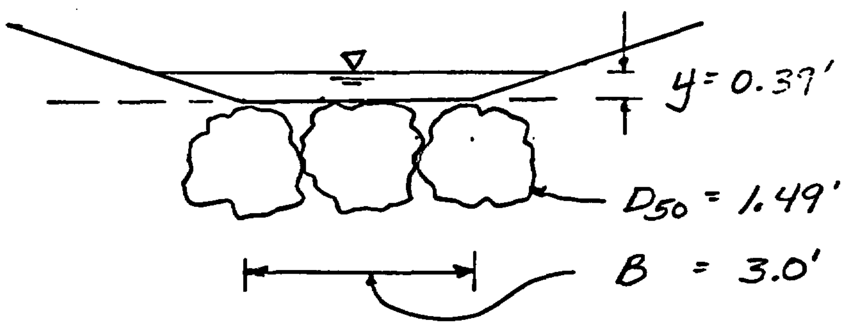
$Q = 1.0$ cfs

[$Q = 1.48$ for $n_{max} = 0.06$]



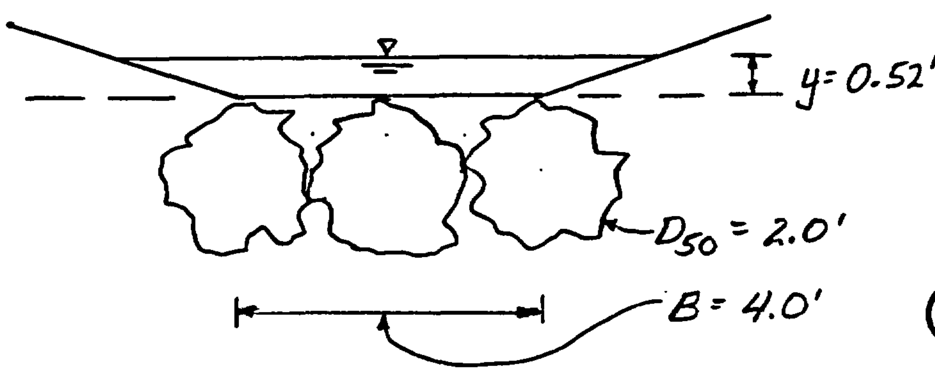
$Q = 5.0$ cfs

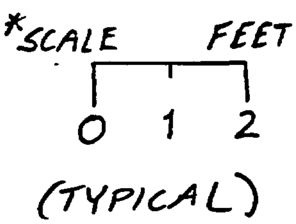
[$Q = 7.92$ for $n_{max} = 0.06$]



$Q = 10$ cfs

[$Q = 16.7$ for $n_{max} = 0.06$]





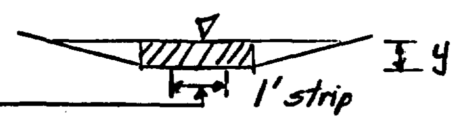
10. METHOD 1:
Stable Rock Size: Stephenson's Method For Flow Down an Embankment Slope (Ref. 3, p. 51)

$$d = \left\{ \frac{q^*(\tan\theta)^{7/6} n^{1/6}}{C g^{1/2}\left[(1-n)(G_s-1)\cos\theta(\tan\phi-\tan\theta)\right]^{5/3}} \right\}^{2/3}$$

q^*: flowrate (ft³/sec) for sheet flow above riprap
θ: slope angle $= \tan^{-1}(1/5)$
G_s = specific gravity → use 2.48
ϕ: riprap friction angle → use 40°
C = factor 0.22 - 0.27 → use 0.22
n = porosity → use 0.30 (approximate)

q^* (ft³/sec/ft)	Q (ft³/sec)①	d (ft)
0.5	0.31	0.22
1.0	1.0	0.35
2.0	3.1	0.55
5.0	14.5	1.0
10.0	45.5	1.6
20.0		2.6

These are considered minimum allowable sizes for stability in any future flow concentration that may form on riprap toe protection.



Note: q^* is portion of total flow that approximates sheet flow immediately above riprap in a 1' wide strip

① Total flowrate Q in assumed gully is determined on sheet 20.

Total flowrate is determined in this manner to be consistent with flowrate by other methods in this calculation.

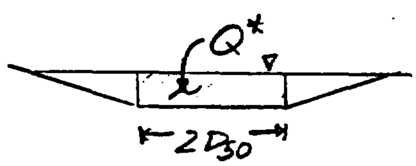
GIVEN							
q^* cfs/ft	d (ft)	Q^* ② ft³/sec	n ①	y (ft)	V ft/sec	A ③ (ft²)	Q ④ (ft³/sec)
0.5	0.22	0.22	0.044	0.13	2.9	0.11	0.31
1.0	0.35	0.70	0.048	0.21	3.6	0.28	1.0
2.0	0.55	2.2	0.052	0.33	4.5	0.69	3.1
5.0	1.0	10.	0.057	0.61	6.2	2.3	14.5
10.0	1.6	32.	0.062	0.96	7.8	5.8	45.5

① Use USCE formula using R for flow channel

② Q^* = flow portion immediately above bottom of flow channel (width = $2(D_{50})$)

③ Trapezoidal channel with $B = 2(D_{50})$ and 3(H):1(V) side slopes

④ Q: See Appendix C for method of obtaining total Q that is compatible with Q^*



II. METHOD 2:

Stable Rock Size: Stephenson's method for "Stones in Flowing Water" (Ref. 3, p. 41)

a) $d = 0.25\,V^2 / [g(G_s - 1)\cos\theta(\tan\phi - \tan\theta)]$

V = flow velocity : 1) Complete slope movement @ V = Q/A
2) Individual stone movement at velocities as small as ½(Q/A)

Results of this method will be used for analysis and comparison to results of other methods.

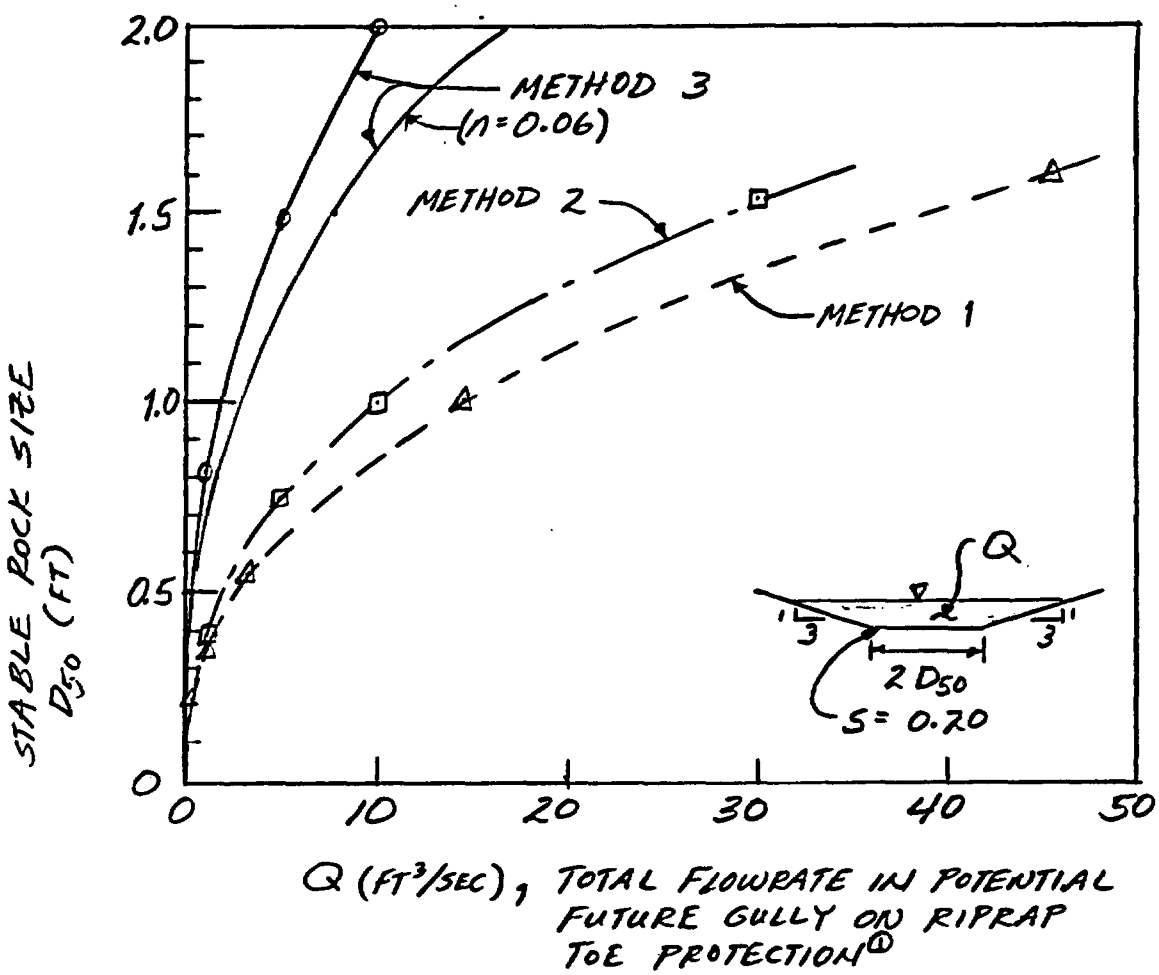
b) Calculate stable rock size using $2 \times V = 2 \times (Q/A)$ to ensure against any stone movement (per discussion in Ref. 3, p. 41, para. 3). Use USCE formula to calculate Mannings 'n'.

Q (ft^3/sec)	n	y (ft)		V (ft/sec)	d ft
1.0	0.052	0.21		3.42	0.39
5.0	0.057	0.39		4.73	0.75
10.0	0.061	0.52		5.40	1.0
30	0.065	0.81		6.72	1.54

Note: The same assumptions regarding flow cross section are used above as were used for Safety Factor method approach [e.g. Trapezoidal channel, $B = 2 \times D_{50}$, side slopes = 3(H):1(V)]

12. COMPARISON OF RESULTS FOR STABLE ROCK SIZE BY THREE METHODS (RIPRAP TOE PROTECTION)

(See Sheet 22 for Tabular Summary)



METHOD 1 : Rock size for Stephenson's Method for Flow Down an Embankment Slope (These rock sizes are considered the minimum allowable for a given flowrate Q)

METHOD 2 : Rock size for Stephenson's method for Stones in Flowing Water (Using V = 2 (Q/A) to ensure against any movement of stones)

METHOD 3 : Rock size by Safety Factor Method (Research at Colorado State University indicates that this method is conservative for sheet flow down slopes steeper than 10%)

13. TABULAR SUMMARY: FLOW CONDITIONS IN POTENTIAL FUTURE GULLY ON RIPRAP TOE PROTECTION AND STABLE ROCK SIZES BY THREE METHODS

METHOD & CALC. PAGES	Q ft³/sec	n	y (ft)	V ft/sec	D_{50} (ft)
STEPHENSON: FLOW DOWN AN EMBANKMENT SLOPE (pp. 19-20)	0.31	0.044	0.13	2.9	0.22
	1.0	0.048	0.21	3.6	0.35
	3.1	0.052	0.33	4.5	0.55
	14.5	0.057	0.61	6.2	1.0
	45.5	0.062	0.96	7.8	1.6
STEPHENSON: STONES IN FLOWING WATER (pp. 20-21)	1.0	0.052	0.21	3.42	0.39
	5.0	0.057	0.39	4.73	0.75
	10.	0.061	0.52	5.40	1.00
	30.	0.065	0.81	6.72	1.54
SAFETY FACTOR METHOD (pp. 15-18)	1.0 (1.48)	0.088 (0.06)	0.21	2.1	0.81
	5.0 (7.92)	0.095 (0.06)	0.39	3.1	1.49
	10.0 (16.7)	0.10 (0.06)	0.52	3.5	2.0

14. Discussion: Stable Rock Size

a) Comparison of three methods indicates a wide range of results for stable rock size for a given flowrate in an assumed gully on the 5(H):1(V) slope. (sheet 22)

b) Stephensons method for flow down an embankment slope (Method 1) has been shown to give satisfactory rock sizes under sheet flow conditions on similar slopes.* Rock sizes based on this method are considered the minimum sizes for the toe protection, since flow conditions in a potential future gully will likely be more turbulent than for sheet flow.

c) The Safety Factor method (Method 3) has been shown to be conservative for slopes steeper than 10% * for sheet flow. This probably helps explain the relatively (very) large rock sizes from this method compared with the other two methods.

d) Stephenson's method for stones in flowing water (Method 2) determines stable rock sizes needed to form an underwater embankment by dumping rock into a flowing channel. This condition is less stable for riprap than flow over a packed riprap layer constructed in the dry. Results of this method

[* Recent research at Colorado State University, Fort Collins, CO] give larger rock sizes than Method 1, which is appropriate

e) Methods are not available that apply strictly to assumed flow conditions in potential future gullies on the riprap toe protection.
However, based on results above, rock sizes determined by Method 2 appear adequate for estimating resistance of rock in riprap toe protection against movement.

15. Rock size selection

a) As an initial estimate, assume $D_{50} = 1.5'$.
This results in a maximum rock size for riprap of approximately 32"-36". Rock larger than this is very costly to place and may be excessively difficult or costly to produce from available sources nearby (based on inspection of photographs of potential rock sources nearby).

b) Cursory inspection of physical test results (Data Source 1) indicates that rock quality may be marginal for locations subject to occassional saturation and weathering forces at the ground surface. Thus, some oversizing should be provided to account for long-term weight loss of riprap due to weathering. Two factors will tend to reduce weathering of the riprap toe protection, as follows:

- Toe protection will be overlain by fill for site grading. This fill will provide initial protection against some weathering. As long-term erosion proceeds, the 5(H):1(V) slope will be exposed. However, the longer any given elevation is exposed, the greater long-term erosion in adjacent site grades will be. Thus, the potential for greater flow concentrations will diminish. (Sizes required for protection against sheet flow are relatively small, on the order of 2", Ref. 10).

- Riprap toe protection is not located in a floodplain or ditch. Runoff from the embankment will drain rapidly to the bottom of the riprap toe protection and into the adjacent silty sands, which have a relatively large permeability. Thus, the frequency of actual saturation of the riprap pieces will be seldom at most.

c) Riprap with D_{50} = 1.5 ft will resist flow down the 5(H): 1(V) slope up to approximately 28 cfs in a potential future gully (Sheet 22, Method 2)

Maximum sheet flow rate at the lowest elevation on the toe protection is estimated as follows:

PMP intensity ~ 56.15 in/hr (Ref. 11)

Flow path ~ 100' + 90' + 18' depth (5) ~ 280'

[From Ref. 10, p. 1/5, adjusted for 5(H): 1(V) slope.]

$$Q = CIA = 1.0\,(56.15)\,(280' \times 1' / 43560) = \underline{0.36}\ ft^3/sec./ft$$

Therefore, flow concentrations on the order of $(28 / 0.36) \simeq 77$ times can be resisted by D_{50} = 1.5' rock.

This translates to a 77 ft-wide section of the entire embankment concentrating flow in a single gully. Since long-term sheet and rill erosion will proceed along with any future gully erosion, total gully depth (and thus, the ability to concentrate flow) will be limited. Additionally, the PMP would have to occur close to the point in time of maximum gully depth.

d) Assuming a future gully depth of 5', the maximum PMF flowrate intercepted by the 3:1 sideslopes would be $[(5' \times 3) + (5' \times 3)] \times 0.36 \frac{cfs}{ft} = 11 \text{ cfs} < 28 \text{ cfs}$

(For Q = 11 cfs, riprap size $D_{50} \simeq 1.1'$ would be needed)

Thus, $D_{50} = 1.5'$ will provide adequate protection.

e) Summary:

1) $D_{50} = 1.5'$ is adequate for resistance to relatively severe flow concentrations for PMP runoff. Even smaller sizes will protect against moderate flow concentrations.

2) Buried riprap should not weather excessively. As riprap is exposed by long-term erosion, sheet flow will continue farther down the slope and the potential for flow concentrations at any elevation will decrease

For Design, select $D_{50} = 1.5'$

B. RIPRAP END PROTECTION : STABLE ROCK SIZE

1. After a long period of time, runoff from the small watershed (9.1± ac) upslope of the embankment may erode the site road on the southeast side of the embankment. Riprap end protection will be provided between the site road and embankment on the SE side to prevent continued erosion towards the embankment.

2. As discussed in Section 1, Item 7., drainage of this upslope area trends to the north and not directly towards the embankment. The area of this "upslope" area could decrease with time, since active gullies farther to the northeast could cut into this area. Thus, the possibility of the full PMF intersecting the rock on the riprap end protection from the existing upslope area is considered very small.

3. For purpose of this calculation, it is considered relatively conservative to assume that the entire PMF flows along the riprap end protection before being diverted around the embankment. The full PMF flowrate is calculated as 475 ft^3/sec. (See Appendix B for calculation and plan of watershed).

4. Assumed Channel Geometry:

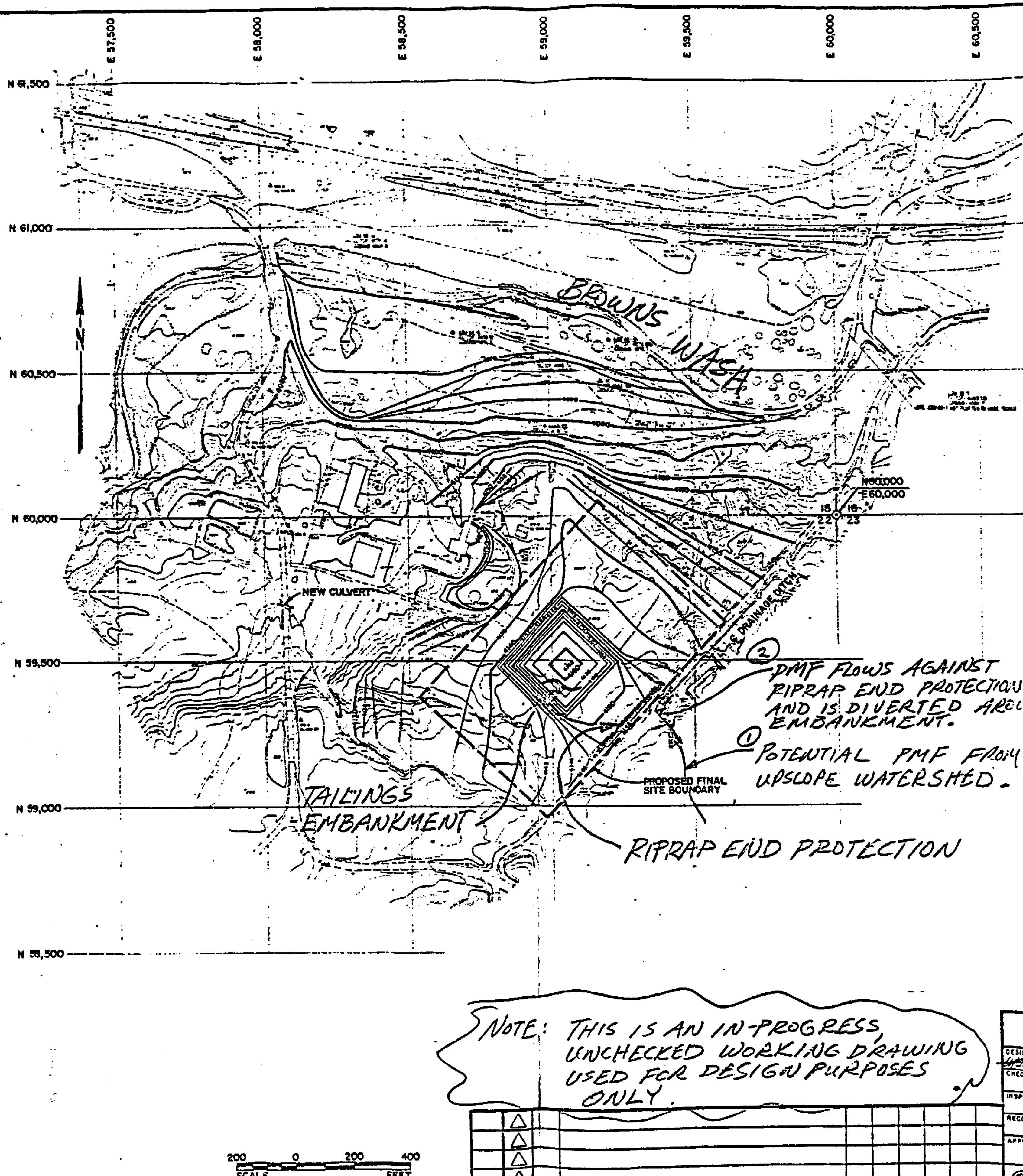
a) Assuming the road is eroded as far as the riprap end protection, runoff would flow against the end protection and be diverted around the embankment. A possible scenario is shown on the next sheet. (Fig. 8-1)

b) For design purposes, use existing gradients of gullies or ditches in the vicinity of the embankment area to estimate gradient of potential future diversion channel. From contours on Fig. 8-2, existing gully or ditch gradients are as follows:

GULLY LOCATION NEAR EMBANKMENT	AVERAGE GRADIENT, %
IMMEDIATELY SOUTHEAST OF EMBANKMENT	3.1 ±
SECOND GULLY SOUTHEAST OF EMBANKMENT	2.0 ±
GULLY NORTHEAST OF EMBANKMENT LOCATION THAT CROSSES SITE ROAD	2.7 ±
DITCH NORTHEAST OF EMBANKMENT ALONG NORTHEAST SIDE OF EMBANKMENT	3.3 ±
AVERAGE: USE FOR ASSUMED GRADIENT OF POTENTIAL FUTURE DIVERSION	2.8%

c. Side slopes and bottom width of the assumed future diversion channel will be governed by potential future erosion. One side slope will be controlled by stable slope of rock on riprap end protection. Bottom width and remaining side slope will be (continued)→

FIGURE B-1 / SHEET 31



NOTES:

1. TOPOGRAPHY TAKEN FROM OLYMPUS AERIAL SURVEYS, INC., SALT LAKE CITY, UTAH ON JULY 10, 1982.
2. THE SUBCONTRACTOR SHALL DETERMINE FINAL SITE BOUNDARY COORDINATES WITH RESPECT TO SALT LAKE BASE AND MERIDIAN COORDINATE SYSTEM.

UMTRA-GRN 5057
EMBANKMENT
RIPRAP END PROTECTION

FIGURE B-1

WYL 9/23/87

REFERENCE DRAWINGS:

GRN-PS-10-0503	DEMOLITION & TEMPORARY FENCING PLAN
GRN-PS-10-0511	CONTAMINATED MATERIAL EXCAVATION PLAN (SHEET 1 OF 2)
GRN-PS-10-0512	CONTAMINATED MATERIAL EXCAVATION PLAN (SHEET 2 OF 2)
GRN-PS-10-0516	TAILINGS EMBANKMENT & FINAL GRADING PLAN

LEGEND:

- EXISTING SITE FEATURES & CONTOURS (JULY 19, 1982 SURVEY)
- 4090 FINAL CONTOURS
- N61,500 CONSTRUCTION GRID COORDINATE
- DRAINAGE DITCH

PRELIMINARY REVIEW		
E & D MANAGER	CHIEF ENGINEER	QA MANAGER

NOTE: THIS IS AN IN-PROGRESS, UNCHECKED WORKING DRAWING USED FOR DESIGN PURPOSES ONLY.

QA MK-F	NO.	DATE	REVISIONS	BY	CK	E&D MGR	CHIEF ENG.	TAC REV.	DOE APP
	△								
	△								
	△								
	△								
	△		~~ISSUED FOR PRELIMINARY REVIEW~~	—	—	—	—	—	—

U. S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

GREEN RIVER SITE
GREEN RIVER, UTAH

FINAL SITE PLAN

DESIGNED | DRAWN | CHECKED | INSPECTED | RECOMMENDED | APPROVED | DATE | DOE PROJECT ENGINEER | DATE

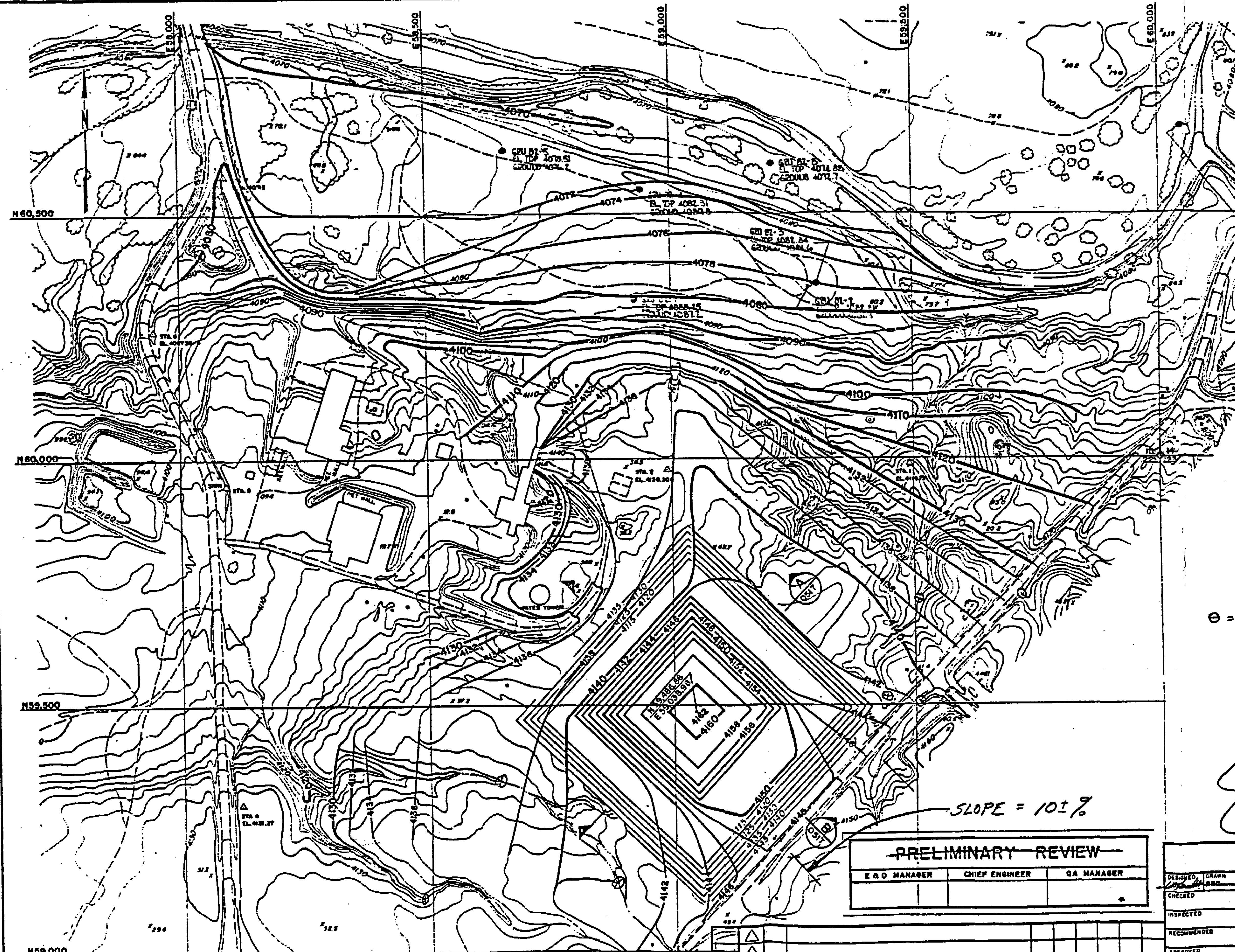
MORRISON-KNUDSEN ENGINEERS, INC.
UMTRA PROJECT

PROJECT NO. DE-AC04-83AL18796

DRAWING NO. GRN-PS-10-0504

SHEET 32

FIGURE B-2



UMTRA-GRN 5057
EMBANKMENT
RIPRAP END PROTECTION
FIGURE B-2

FBG 9-19-87
WYL 9/23/87

NOTES:

1. FOR SEQUENCE OF EXCAVATION AND PLACEMENT OF CONTAMINATED MATERIALS SEE DWG. NO. GRN-PS-10-0512.
2. FINAL EMBANKMENT TOP SLOPE ELEVATIONS SHALL BE ADJUSTED TO ACCOMMODATE ACTUAL QUANTITIES OF MATERIALS PLACED UPON THE APPROVAL OF THE CONTRACTOR.

REFERENCE DRAWINGS:

GRN-PS-10-0512	CONTAMINATED MATERIAL EXCAVATION PLAN (SHEET 2 OF 2)
GRN-PS-10-0517	TAILINGS EMBANKMENT & FINAL GRADING SECTIONS

⊖ = Endpoints of gully segments used to determine existing gradients in embankment area.

LEGEND:

- 4150 — EXISTING SITE FEATURES & CONTOURS (JULY 1982 SURVEY)
- 4160 — FINAL CONTOURS
- N60,500 — CONSTRUCTION GRID COORDINATE

NOTE: THIS IS AN IN-PROGRESS UNCHECKED WORKING DRAWING USED FOR DESIGN PURPOSES ONLY.

~~PRELIMINARY REVIEW~~

E&O MANAGER	CHIEF ENGINEER	QA MANAGER

U. S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

GREEN RIVER SITE
GREEN RIVER, UTAH

TAILINGS EMBANKMENT
AND FINAL SITE GRADING SECTIONS

DESIGNED | DRAWN RBC
CHECKED
INSPECTED
RECOMMENDED
APPROVED | DATE | DOE PROJECT ENGINEER | DATE

MORRISON-KNUDSEN ENGINEERS, INC.
UMTRA PROJECT

PROJECT NO. DE-AC04-83AL18796

DRAWING NO. GRN-PS-10-0516 | REV.

QA	NO.	DATE	REVISIONS	BY	CK	E&O MGR.	CHIEF ENG.	TAC REV.	DOE APP.
			~~ISSUED FOR PRELIMINARY REVIEW~~	—	—	—	—	—	—

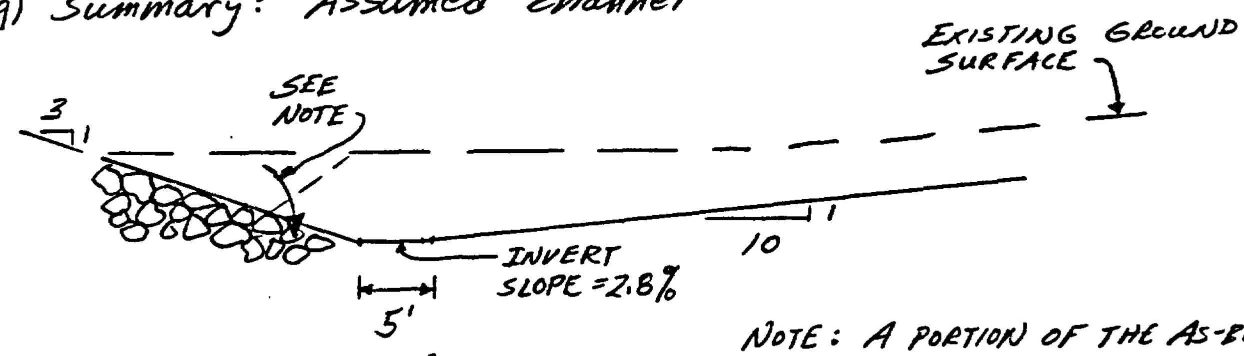
determined by conditions that form if long-term erosion erodes the site road.

d) For design, assume riprap end protection adjusts to a 3(H):1(V) side slope. (This is flattest slope, by judgement, that rock can adjust to and still remain a continuous, intact barrier to flow)

e) Assume long-term erosion gradually erodes the site road due to flows in the existing ditch. This would advance the ditch towards the embankment, leaving a slope similiar to the existing slope southeast of the existing ditch. This slope is approximately 10%.

f) Assume a nominal channel bottom width of at least 5 ft., considered conservatively narrow. Existing gullies are rounded and equivalent trapezoidal sections should have at least this large a bottom width.

g) Summary: Assumed channel



SECTION
(NOT TO SCALE)

NOTE: A PORTION OF THE AS-BUILT RIPRAP END PROTECTION CAN ADJUST TO LONG-TERM EROSION. (SEE REF. 5, PLATE 37 FOR USCE TYPICAL SECTION FOR THIS CASE)

5. Stable Rock Size: Equations

Safety Factor method for stable rock size. (Ref. 4)
Use general case: and Safety factor = 1.0:

$$SF = \frac{\cos\theta \tan\phi}{\eta' \tan\phi + \sin\theta \cos\beta}$$

$$\eta' = \frac{\eta}{2}\left(1 + \sin(\lambda + \beta)\right) \qquad \eta = \frac{21\,\tau_s}{(G_s - 1)\gamma K}$$

$$\tau_s = C_{RS}\,\gamma\, y\, S_e \qquad S_e = \sin\alpha$$

$$\beta = \tan^{-1}\left(\frac{\cos\lambda}{\left(\frac{2\sin\theta}{\eta\tan\phi}\right) + \sin\lambda}\right)$$

$$\lambda = \sin^{-1}(\sin\alpha / \sin\theta)$$

SF = Safety Factor → use 1.0
θ = side slope angle → use $\tan^{-1}(1/3)$
ϕ = rock friction angle → use 40°
G_s = rock specific gravity → use 2.48

y = maximum flow depth (ft)
S_e = energy slope = $\sin\alpha$ for uniform flow
α = channel invert slope → 0.028 ft/ft (sheet)
K = rock size (ft)
γ = unit weight of water (62.4 lb/ft³)
C_{RS} = shear factor for maximum local boundary shear on rock: Use Fig. 11 (sheet 11) for 3(H):1(V) side slope.
τ_s = shear stress on riprap

6. Mannings 'n' : Assume flow depth is controlled primarily by roughness on soil, since the wetted perimeter will comprise primarily soil. From Chow, 1959 (Ref. 9), Table 5-6, select n for "Excavated or Dredged, Earth, winding & sluggish, earth bottom and rubble sides"

$n = \underline{0.030}$

7. Channel Hydraulic Properties

$$A = 5y + \tfrac{1}{2}(10y^2 + 3y^2)$$

$$R = (A) / (5 + \sqrt{10}\, y + \sqrt{101}\, y)$$

8. Stable Rock Size: Results

Q (ft³/sec)	n	y (ft)	R (ft)	C_{RS}	D_{50} (ft)	NOTES
475	0.030	2.35	1.32	1.40	0.96	FULL PMF
238	0.030	1.74	1.01	1.35	0.44	½ PMF (FOR COMPARISON)

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Project UMTRA-GRN	Contract No. 5057	Sheet A-1	File No.
Feature EROSION	Designed FRG	Date 9-11-87	
Item	Checked WYL	Date 9/22/87	

APPENDIX A

1. PURPOSE:

This calculation estimates long-term sheet and rilling erosion at the Green River site around the tailings embankment.

2. SUMMARY OF RESULTS

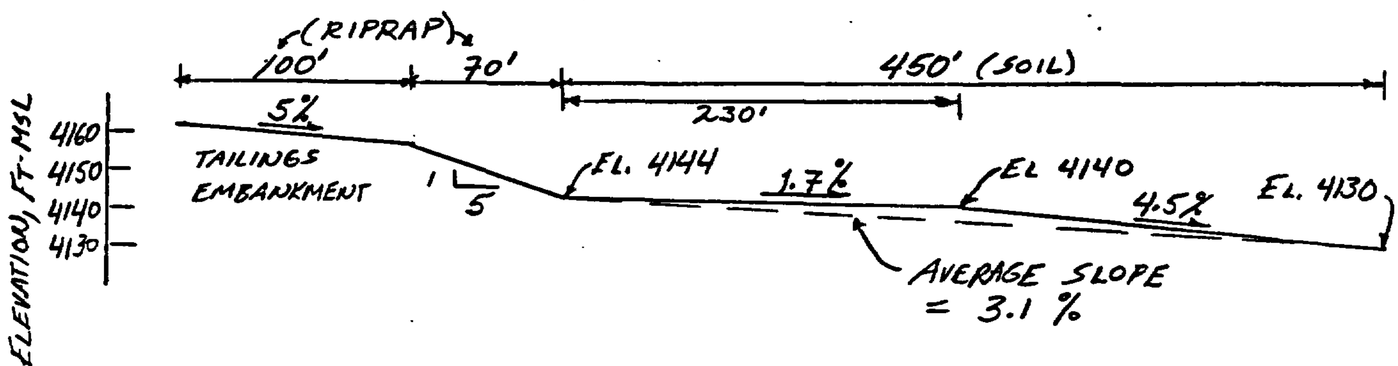
A. Soil loss depth due to sheet and rill erosion soils around embankment is estimated to be on the order of 4' - 7' after 1000 years

3. METHOD

A. Use method in Ref. B

B. Estimate long-term erosion for the slope between the embankment side slope (5H:1V) and the bluff or drop-off in gully fill.

C. Use the following representative slope, taken from the grading plan for in-progress preliminary design. (This should provide reasonable estimate even if minor changes are made to the grading plan, since the estimate is approximate in any case.) This slope is the longest slope between the embankment and bluff, approximately.:



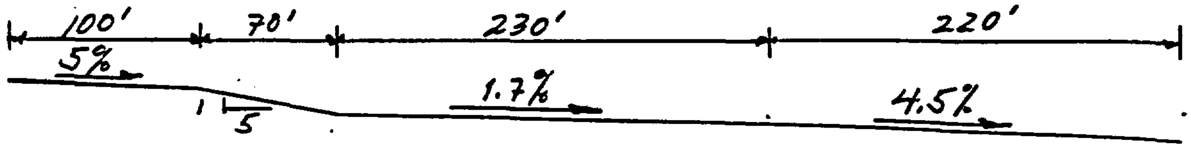
SECTION
(NTS)

D. The calculated weight loss of soil per year will be divided by an average unit weight of 80 pcf (assumed) to obtain volume of soil lost from slope (lower unit weight is relatively conservative for this calculation)

Then, the loss will be assumed distributed evenly over the slope to estimate the depth of soil loss.

4. CALCULATIONS

A. SLOPE SEGMENTS USED FOR CALCULATION OF 'LS':



SECTION
(NTS)

CALCULATION TABLE:
(Format is after Table C-2, Ref.)

(1) Slope Segment	(2) S_n %	(3) ℓ (ft)	(4)* λ_n (ft)	(5)⊕ λ_{n-1} (ft)	(6)* $L_{\lambda_n} S_{S_n}$	(7)⊕ $L_{\lambda(n-1)} S_{S(n-1)}$	(8) (6)x(4)	(9) (7)x(5)	(10) (8)-(9)	(11) (10)÷(3)	(12) Σ(10) $(LS)_n$	13 (12)÷(4) $LS_Σ$
1	5	100	100	0	0.53	0	53	0	53	0.53	53	0.53
2	20	70	170	100	5.31	4.08	903	408	495	7.1	548	3.2
3	1.7	230	400	170	0.26	0.21	104	36	68	0.30	616	1.5
4	4.5	220	620	400	1.08	0.89	670	356	314	1.4	930	1.5

Note: LS value from column (13) (cumulative effect of LS) is greater than individual LS values (column (11)) for slope segments of interest (segments 3 & 4 not covered with riprap)

For this calculation, use LS = 1.5

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Project [illegible]	Contract No. 5057	Sheet A-4	File No.
Feature Site Grading	Designed FBG	Date 9-13-87	
Item Erosion	Checked WYL	Date 9/22/87	

B. VALUE OF 'K' FOR SOIL

Site-specific grain size distribution curves are available for disposal area soils (Attachment A1). Soils are generally classified by U.S.C.S. as SM (15 samples), SC-SM (4 samples), SC (3 samples), SP-SC (1 sample), SW-SM (2 samples), SW-SC (1 sample), CL-ML (2 samples) CL (1 sample), GP (1 sample), GP-GM (1 sample) & GW-GM (1 sample).

The primary soils are thus sands with 12-50% low plasticity fines.

1) For purposes of this calculation, use the following ranges of sand (0.1 - 2.0 mm) and silt plus very fine sand (0.002 - 0.1 mm). (Silt sizes are roughly extrapolated from grain size data available to 0.074 mm only):

Sand	Silt plus Very Fine Sand	From inspection of grain size curve envelopes:
55	45	= Relatively finer-grained site soils
40	25	= Relatively coarser-grained site soils

2) Organic Matter: Assume 0% (for Figure 2.2)

3) Permeability: Finer-grained soils: Assume #4, "Slow to Moderate"

Coarser-grained soils: Assume #3, "Moderate"

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Project	UMTRA-GRN	Sheet	A-6
Contract No.	5C57	File No.	
Feature	SITE GRADING	Designed	FBG
Date	9-13-87	Item	EROSION
Checked	WYL	Date	9/22/87

4) Soil Structure:

Finer-grained soils: Assume No. 1 "very fine granular"

Coarser-grained soils: Assume No. 2 "Fine granular"

5) K-values (from Fig. 2-2, Ref.)

SITE SOIL TYPE	K
Finer-grained	0.40
Coarser-grained	0.21

C. VALUE OF 'R'

From Fig 5-2, R = 14* (Average of R = 12 and R = 16 contours near City of Green River)

D 'VM' FACTOR (From Table 2-2, Ref)

Assume that vegetation will essentially be absent, but also that ground will not be filled (similar to existing condition).

Assume "Compacted Fill" average VM = 1.5

(This is essentially average of 'worst-case' VM condition)

E. SOIL LOSS

$A = R \cdot K \cdot LS \cdot VM = (14) \cdot K \cdot (1.5) \cdot (1.5)$ (For This Calculation)

A = Tons/Acre/Year

For 1000 years and soil of 80 pcf, average depth of soil lost is as follows

$$A\ (\text{ton/acre/yr.}) \times 1000\ \text{yr.} \times \left[\frac{\text{Slope Length} \times 1'\ \text{wide}}{43560\ \text{ft}^2/\text{a}}\right] = (\text{Loss})_{1000}\ (\text{tons})$$

$$(\text{Loss})_{1000}\ (\text{tons}) \left(\frac{1}{(\text{Slope Length} \times 1'\ \text{wide})\ 80\ \frac{\text{lb}}{\text{ft}^3}}\right) 2000\ \frac{\text{lb}}{\text{ton}} = (D_n)_{1000}\ (\text{ft})$$

where $(D_n)_{1000}$ = soil loss depth in ft. for slope segment 'n' after 1000 yr.

SLOPE SEGMENT & LENGTH		K	SOIL LOSS IN TONS AFTER 1000 YR.	$(D_n)_{1000}$ (ft)
3	230'	0.40	66.5	7.2
	230'	0.21	34.9	3.8
4	220'	0.40	63.6	7.2
	220'	0.21	33.4	3.8

Round off, since this estimate is very approximate after 1000 yr.

Say depth of soil loss estimate ranges from

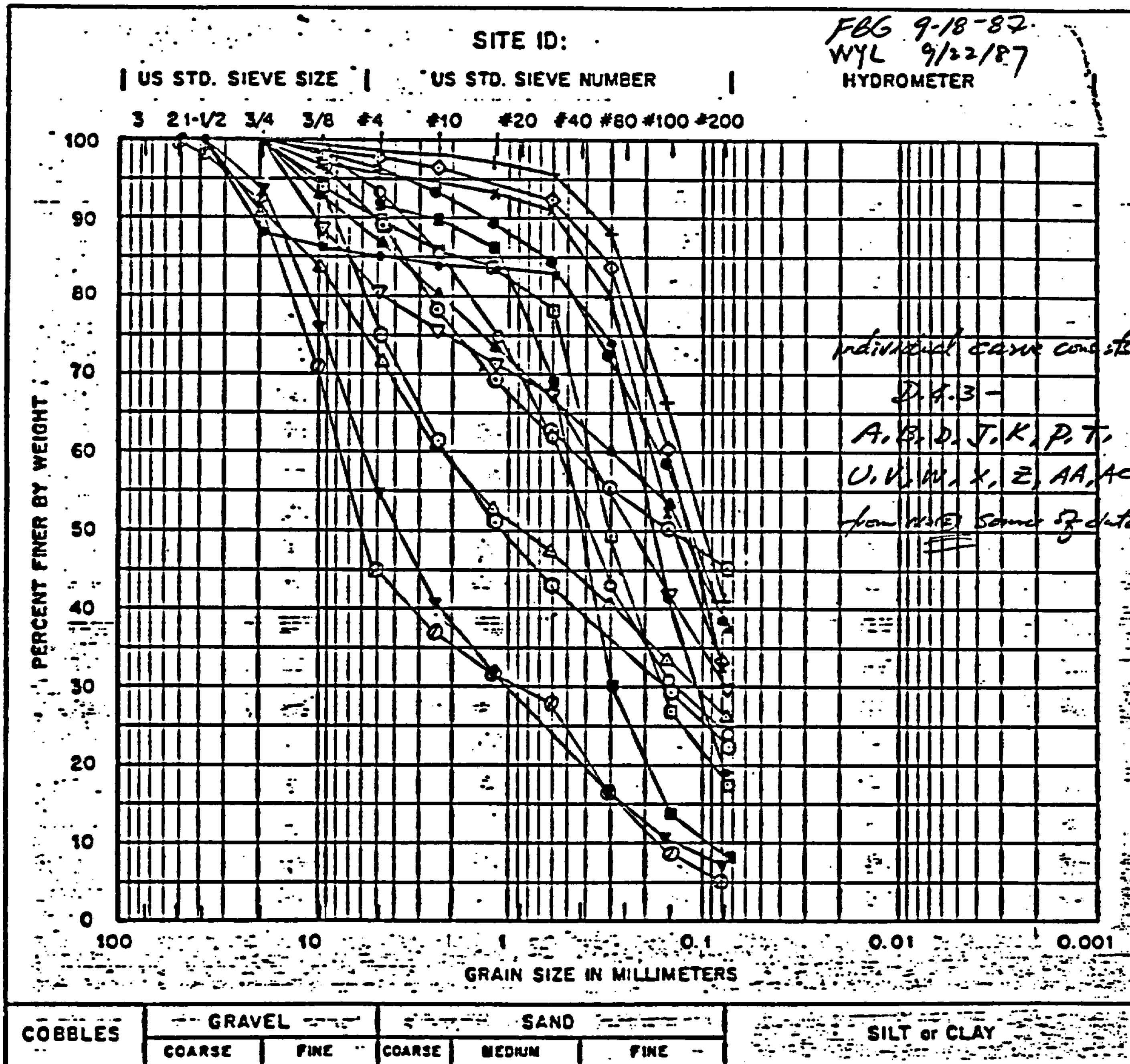
4' - 7'

UMTRA - GRN 5057
GEOTECHNICAL DESIGN PARAMETERS

ATTACHMENT A1 (1/3)

PRC 4/15/87
FBG 5-20-87

39/63

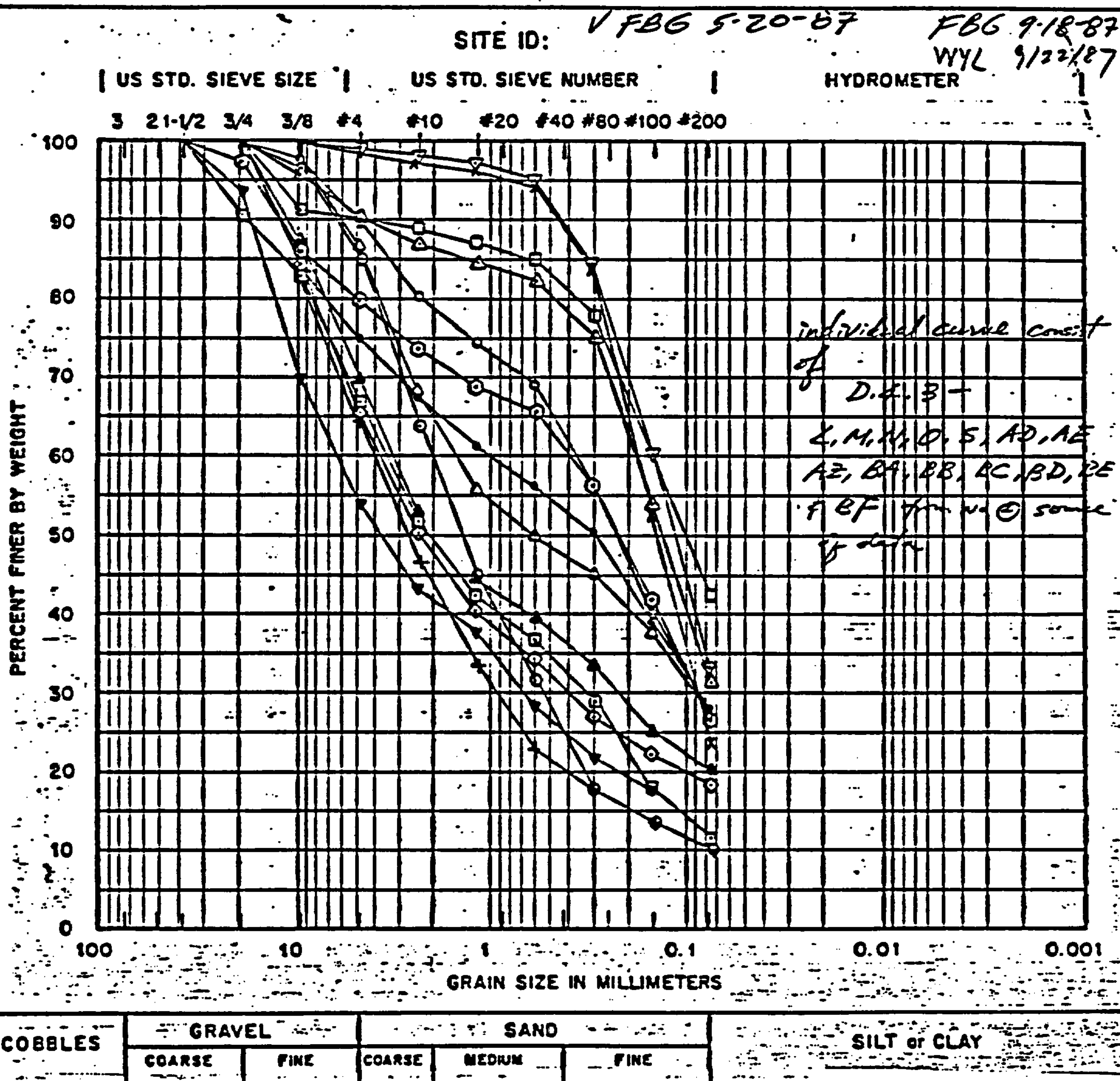


SYMBOL	BORING No.	DEPTH (FT)	CLASSIFICATION	SYMBOL	BORING No.	DEPTH (FT)	CLASSIFICATION
•	53501	1-1.5	SILTY SAND W/GRAVEL (SM)	⊙	56805	10-11	SILTY SAND W/GRAVEL (SM)
+	53503	4-5	SILTY CLAYEY SAND (SC-SM)	■	56806	13-14	SAND W/CLAY (SP-SC)
⊘	53603	8-9.5	GRAVEL ... (GP)	◇	56902	3-4	SILTY SAND (SM)
×	53801	8-8.5	SILTY SAND (SM)	△	56904	8-9	CLAYEY SAND W/GRAVEL (SC)
○	56207	10-11	SILTY SAND (SM)	▲	57002	3-4	CLAYEY SAND (SC)
⊙	56209	12-14	SILTY SAND (SM)	▼	57004	7-8	SAND WITH SILT & GRAVEL (SW-SM)
⊡	56708	15-16	SILTY SAND (SM)	●	57101	0.5-1	CLAYEY SAND (SC-SM)
▽	56803	5-6	SILTY CLAYEY SAND W/GRAVEL (SC-SM)				

FIGURE 2 (SHEET 1/3): DISPOSAL SITE SOILS GRAIN SIZE DISTRIBUTION CURVES

UMTRA-GRN 5057
GEOTECHNICAL DESIGN PARAMETERS | pec 4/15/87

ATTACHMENT A1 (2/3)



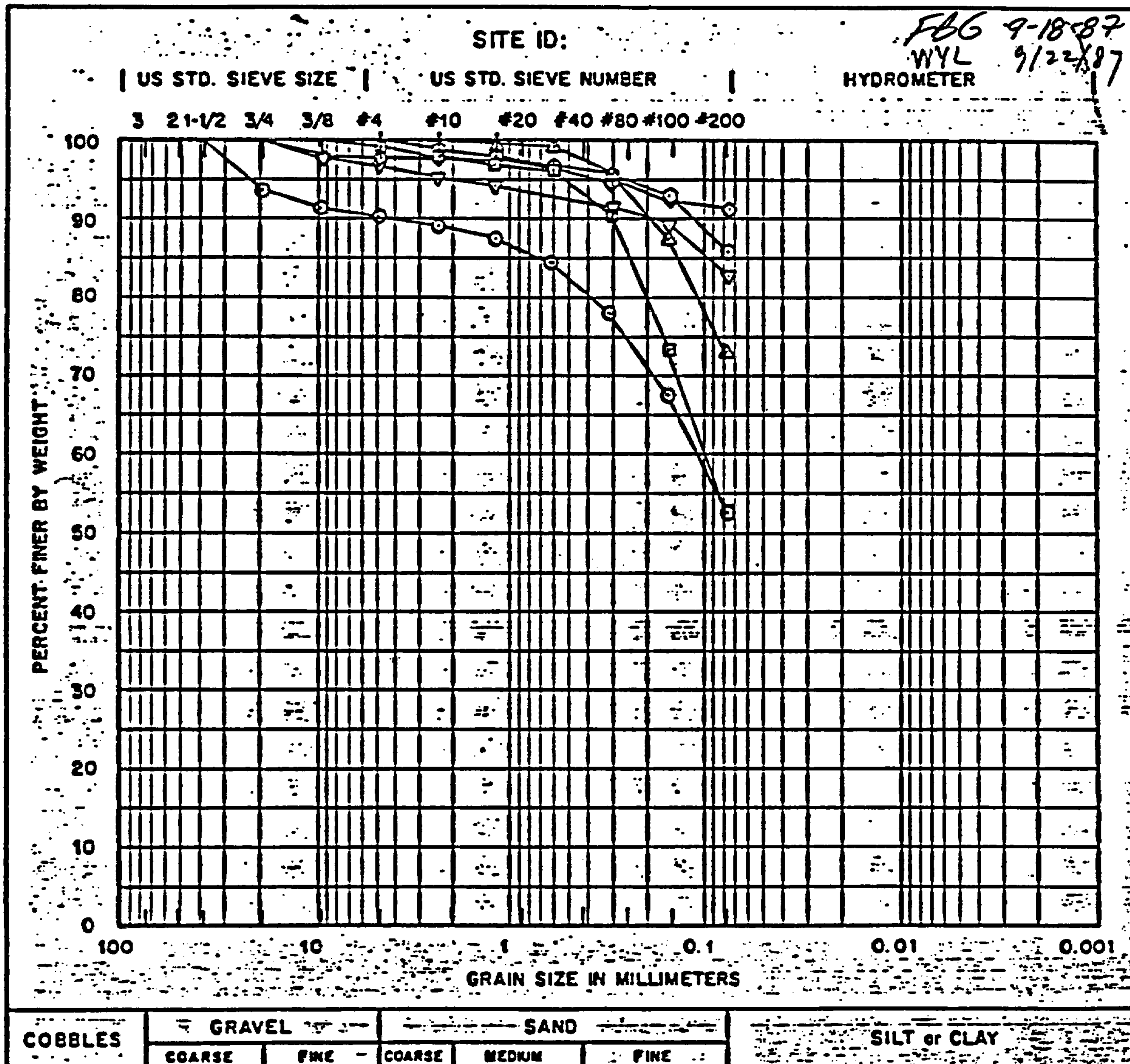
SYMBOL	BORING No	DEPTH (FT)	CLASSIFICATION	SYMBOL	BORING No	DEPTH (FT)	CLASSIFICATION
⊟	56211	16-17	SAND WITH SILT & GRAVEL (SP-SM)	×	57601	0.5-1	SILTY SAND (SM)
△	56702	4-4.5	SILTY SAND (SM)	○	57602	3-4	CLAYEY SAND WITH GRAVEL (SC)
⊙	56705	8-9	SILTY SAND WITH GRAVEL (SM)	⊙	57603	6-6.5	SAND WITH CLAY AND GRAVEL (SW-SC)
◇	56707	13-14	SILTY SAND WITH GRAVEL (SM)	▲	57605	10-11	SILTY SAND WITH GRAVEL (SM)
◆	56709	17-18	GRAVEL WITH SILT & SAND (GP-GM)	□	57701	0.5-1.5	SILTY CLAYEY SAND (SM)
▽	56801	0.5-1	SILTY SAND (SM)	△	57703	3.5-4.5	SILTY CLAYEY SAND (SC-SM)
•	57103	5.5-6.5	SILTY SAND WITH GRAVEL (SM)	▼	57705	10-10.8	SAND WITH SILT & GRAVEL (GW-GM)
+	57105	10-11	SAND WITH SILT & GRAVEL (SW-SM)				

FIGURE 2 (SHEET 2/3): DISPOSAL SITE SOILS GRAIN SIZE DISTRIBUTION CURVES

UMTRA-GRN 5057 PFC 4/15/87 ATTACHMENT A1 3/3

GEOTECHNICAL DESIGN PARAMETERS √FBG 5-21-87

FBG 9-18-87
WYL 9/22/87



SYMBOL	BORING NUMBER	DEPTH (feet)	CLASSIFICATION
O	53601	2 - 2.5	BROWN SANDY SILTY CLAY (CL-ML)
▣	56201	1 - 2	LIGHT BROWN SANDY CLAY (CL)
△	56203	4 - 5	BROWN SILTY CLAY WITH SAND (CL-ML)
⊙	56710	20 - 21	LIGHT GREY CLAY (CH) - [WEATHERED CLAYSTONE OVERLYING BEDROCK]
◇	56911	25.5	LIGHT GREY CLAY (CL) [SHALE]
▽	57006	13 - 14	GREY CLAY WITH SAND (CL) [SHALE]
		Reference individual curve	D.4.3 C, H, I, R, Y, & AB from no ② source & data

FIGURE 2 (SHEET 3/3): DISPOSAL SITE FOUNDATION
GRAIN SIZE DISTRIBUTION CURVE

MORRISON-KNUDSEN ENGINEERS, INC.
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Project	UMTRA - GRN	Contract No. 5057	Sheet B-1
Feature	PMP CALCULATION	Designed JCP	File No.
Item	PURPOSE, METHODS, SUMMARY	Checked FBG	Date 8-27-87
			Date 9-18-87

APPENDIX B

PURPOSE

THE PURPOSE OF THIS CALCULATION IS TO DETERMINE THE QUANTITY OF FLOW FROM PROBABLE MAXIMUM PRECIPITATION (P.M.P.) THAT WILL DRAIN INTO THE TAILINGS EMBANKMENT AREA.

METHODS

DUE TO THE SMALL SIZE OF THE WATERSHED CONSIDERED, THE RATIONAL METHOD IS USED TO OBTAIN THE DESIGN FLOW. TWO WATERSHED AREAS CONTRIBUTE FLOW HAVING AREAS OF 1.53 ACRES TO THE WEST AND 9.08 ACRES TO THE EAST OF THE EASTERN SITE ROAD. THIS WATERSHED AREA DIFFERS FROM THE "RAP" WATERSHED AREA BECAUSE THE EXISTING I-70 FREEWAY IS CONSIDERED AS A WATER BARRIER. ANY FLOW UPLAND FROM THE FREEWAY WILL BE DIVERTED AWAY FROM THE PROPOSED EMBANKMENT AND NOT CONTRIBUTE TO FLOW IN THAT AREA. ONLY THE AREA BELOW I-70 DIRECTLY CONTRIBUTES FLOW TOWARD THE TAILINGS EMBANKMENT AREA. (THE T.A.C. WAS CONTACTED AND AGREED WITH THIS ASSUMPTION.)

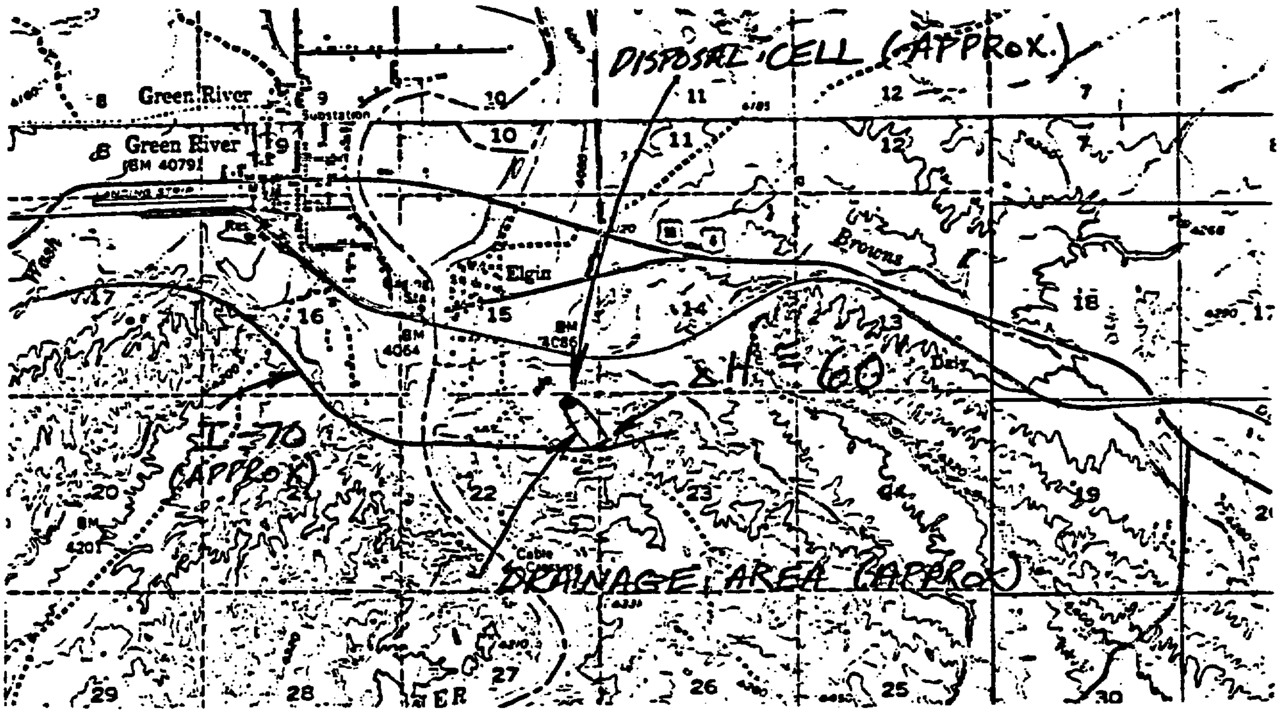
SUMMARY

PMP TOTAL FLOW = 475 ft^3/sec

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN
Feature: SITE DRAINAGE
Item: ΔH FOR WATERSHED 2
Contract No. 5057
Designed: JCP
Checked: EBG
Sheet: B-2
File No.
Date: 8-11-8
Date: 9-18-85

EAST WATERSHED



USGS 15 MINUTE QUADRANGLE (TOPOGRAPH) GREEN RIVER, UTAH
SCALE : 1:62,500 CONTOUR INTERVAL 40 FEET
1954 DMA 3961 I-SERIES V797

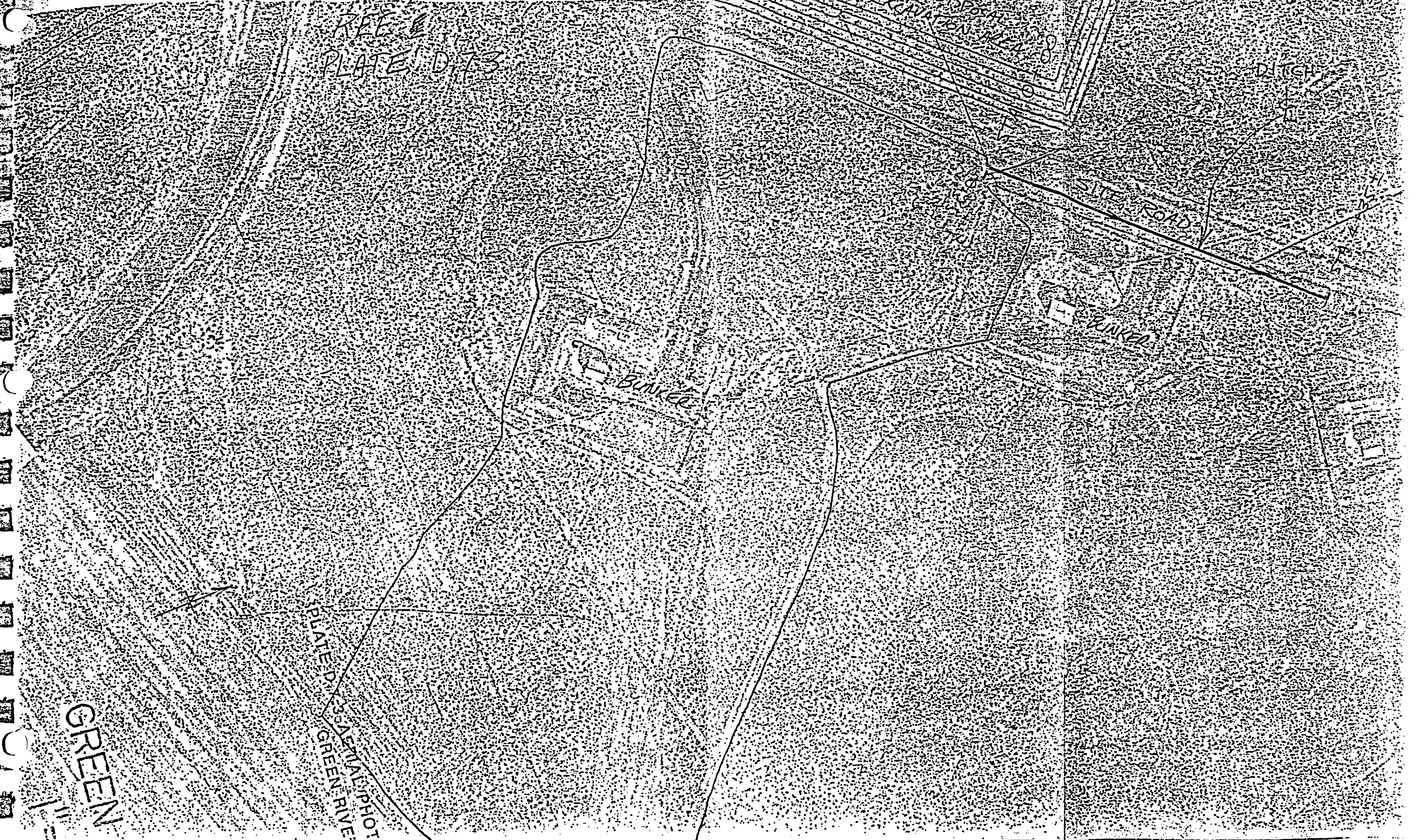
$\Delta H \approx 60'$ *

* THIS VALUE IS A CONSERVATIVE APPROXIMATION. NO TOPOS WITH SMALLER CONTOUR INTERVALS IS AVAILABLE TO THE DESIGNER AT THIS TIME

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project	UMTRA - GRN	Contract No.	5057
Feature	DRAINAGE	Designed	JCP
Item	WATERSHED EAST OF SITE ROAD	Checked	FBG
Sheet	B-3	File No.	
Date	8-19-87	Date	3-14-90

B-3

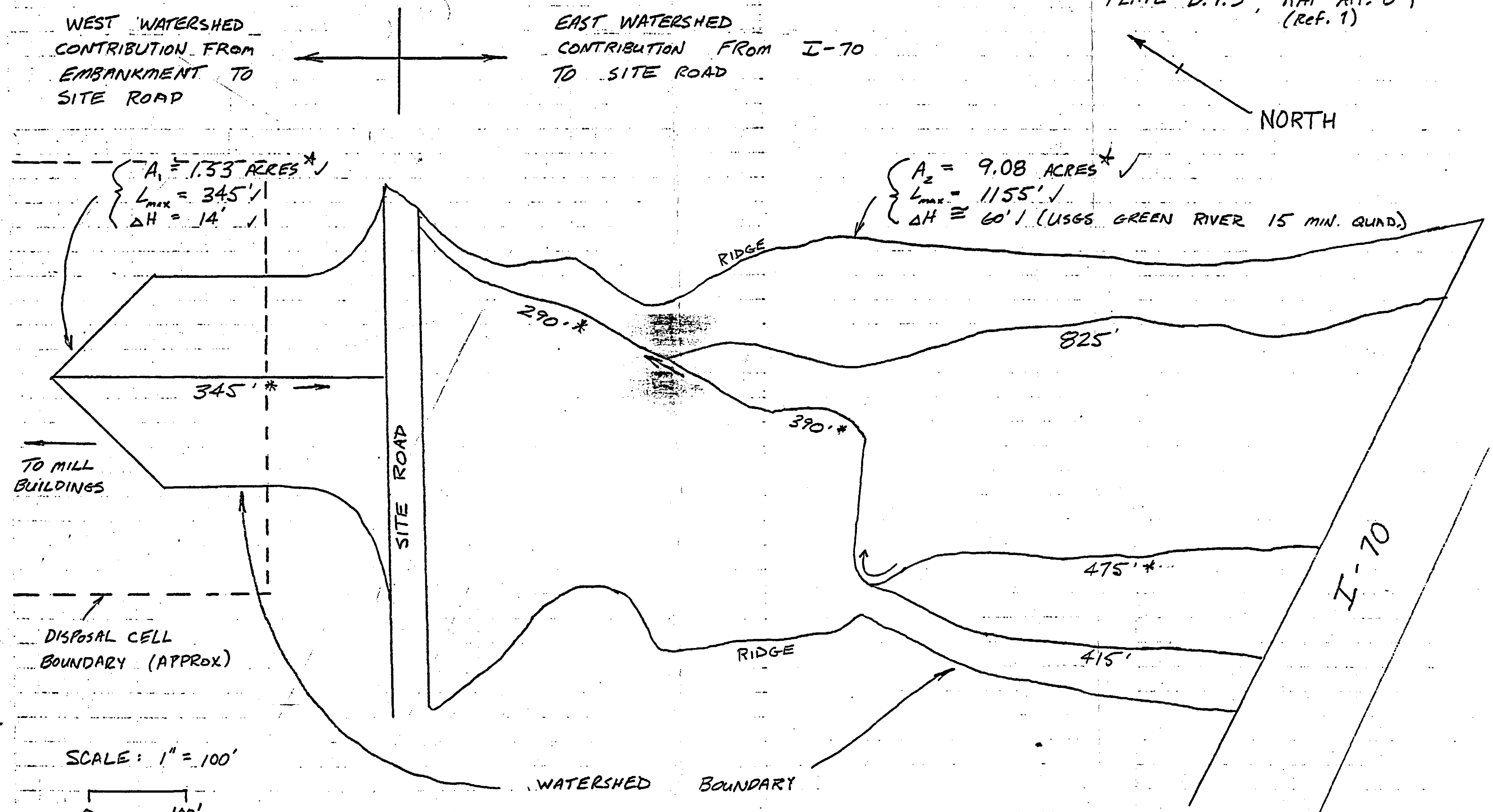


MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN
Feature: SITE DRAINAGE
Item: WATERSHEDS USED IN RATIONAL FORMULA
Contract No. 5057
Designed: JCP
Checked: FBG
Sheet: B-4
File No.
Date: 8-11-87
Date: 9-18-87

WATERSHED USED FOR CALCULATING Q

(TRACED FROM AREAL PHOTO, GREEN RIVER SITE, UTAH PLATE D.7.3, RAP APP. D) (Ref. 1)



* ⇒ LONGEST DRAINAGE PATH
* ⇒ BY PLANIMETER

IN CALCULATING Q, THE WATERSHED IS DIVIDED INTO TWO AREAS, ONE REPRESENTING THE CONTRIBUTION FROM THE DISPOSAL CELL AND ONE REPRESENTING THE FLOW FROM I-70 TO THE SITE ROAD UPSTREAM FROM THE DISPOSAL CELL. THE TWO Q VALUES ARE THEN ADDED SINCE THEY DRAIN INTO THE SAME DITCH. THE RATIONAL FORMULA IS USED TO CALCULATE Q SINCE THE SIZE OF THE WATERSHED IS SMALL (1.53 ACRES AND 9.08 ACRES RESPECTIVELY). ✓

WEST WATERSHED

AREA = 1.53 ACRES

L_{max} = 345' = 0.0653 MILES

ΔH = 14'

$$T_c = \left[11.9\ L^3/\Delta H\right]^{0.385}$$ (REF. 7)

WHERE T_c = TIME OF CONCENTRATION [HOURS]
L = LONGEST DRAINAGE PATH [MILES]
ΔH = DIFFENCE IN ELEVATION OF LONGEST DRAINAGE PATH [FEET]

$$T_c = \left[11.9(0.0653)^3/14\right]^{0.385} = 0.040\ \text{HRS} = 2.4\ \text{MINUTES}$$ ✓

FROM RAINFALL INTENSITY FREQUENCY DURATION CURVE FOR LOCAL PMP (MKE CALC NO. 10-539-01-00, SHEET 10) WITH T_c = 2.4 MINUTES:

RAINFALL INTENSITY, I = 56.3 IN./HR (FOR MINIMUM ALLOWABLE T_c = 2.5 MIN.)

RATIONAL FORMULA: $Q = CIA$

WHERE: Q = FLOW [C.F.S.]
C = RUNOFF COEFFICIENT
I = RAINFALL INTENSITY [IN/HR]
A = WATERSHED AREA [ACRES]

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Project UMTRA – GRN | Contract No. 5057 | Sheet 8-6 | File No.
Feature DRAINAGE | Designed JCP | Date 8-11-87
Item CALCULATION OF Q | Checked FBG | Date 9-18-87

CHOICE OF RUNOFF COEFFICIENT, C :

DURING THE DESIGN LIFE OF 200 – 1000 YEARS, THERE IS A POSSIBILITY OF THE PMP OCCURING WHEN THE SOIL IS SATURATED. FOR THIS REASON AND THE LENGTH OF THE DESIGN LIFE LET C = 1.0, THE MOST CONSERVATIVE ESTIMATE.

$Q_w = CIA_w = 1.0(56.3)(1.53)$

$\underline{Q_w = 86.2 \text{ C.F.S.}}$ ✓

EAST WATERSHED

AREA = 9.08 ACRES
L_{max} = 1,155 FT = 0.2188 MILES
$\Delta H \cong 60$ FT *

$T_c = [11.9 \, L^3/\Delta H]^{0.385}$

$= [11.9 (0.2188)^3/60]^{0.385} = 0.0927$ HRS = 5.6 MINUTES ✓

FROM RAINFALL INTENSITY FREQUENCY DURATION CURVE FOR LOCAL PMP (MKE CALC NO 10-539-01-00, SHEET 10) WITH T_c = 5.6 MINUTES

RAINFALL INTENSITY, I = 42.8 IN/HR ✓

$Q_E = CIA_E = 1.0(42.8)(9.08)$

$\underline{Q_E = 388.6 \text{ CFS.}}$ ✓

* THIS VALUE WAS OBTAINED FROM THE USGS 15 MINUTE QUAD MAP OF GREEN RIVER, UTAH. NO OTHER TOPOS OF THE WATERSHED WERE AVAILABLE. ✓ ok, good enough

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Project: UMTRA – GRN	Contract No. 5057	Sheet D-5	
Feature: DRAINAGE	Designed JCP	Date 8-11-87	File No.
Item: CALCULATION OF Q,	Checked FBG	Date	

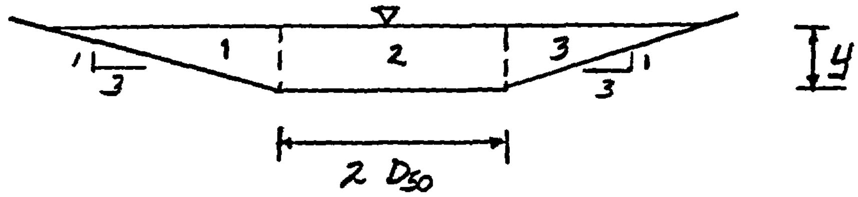
$$Q_{TOT} = Q_W + Q_E = 86.2 + 388.6$$

$$Q_{TOT} = 474.8 \text{ CFS}$$

$$Q_{TOT} \cong 475 \text{ CFS}$$ ✓

APPENDIX C

CONVEYANCE RATIO OF CHANNEL



$$A_1 = A_3 = \tfrac{3}{2} y^2 \qquad W_{P1} = W_{P3} = \sqrt{10}\, y$$

$$A_2 = 2 y D_{50} \qquad W_{P2} = 2 D_{50}$$

$$A_T = 3y^2 + 2y D_{50} \qquad W_{PT} = 2\sqrt{10}\, y + 2 D_{50}$$

From Chow, 1959 (Ref.), pp. 138-140, use conveyance factors assuming a channel of compound sections to determine total Q of section if Q^* (flowrate in middle section #2 above) is known.

$$Q = AV = \left(\sum_1^N K_N\right) S^{1/2} \qquad K_N = \frac{1.489}{n}\left(AR^{2/3}\right)_N$$

For practical purposes, assume velocity distribution coefficients α and β can be ignored.

① $$Q = K_T S^{1/2} = \frac{1.486}{n} S^{1/2} \left(3y^2 + 2y D_{50}\right)\left[\frac{3y^2 + 2y D_{50}}{2\sqrt{10}\, y + 2 D_{50}}\right]^{2/3}$$

② $$Q_1 + Q_3 = 2 K_1 S^{1/2} = 2\left(\frac{1.486}{n}\right) S^{1/2} \left(\frac{3}{2} y^2\right)\left[\frac{3/2\, y^2}{\sqrt{10}\, y}\right]^{2/3}$$

③ $$Q^* = K_2 S^{1/2} = \frac{1.486}{n} S^{1/2} \left(2y D_{50}\right)\left[\frac{2y D_{50}}{2 D_{50}}\right]^{2/3}$$

$$= \frac{1.486}{n} S^{1/2}\, 2 y^{5/3} D_{50}$$

Assume Q^* is given or otherwise known. Find Q.

$$Q = Q^* + 2\left(\frac{1.486}{n}\right) S^{1/2} \left(\frac{3}{2} y^2\right) \left[\frac{\frac{3}{2} y^2}{\sqrt{10}\, y}\right]^{\frac{2}{3}}$$

A solution for Q and y is found as follows:

1. Assume Q
2. Calculate compatible y and n values using conveyance for entire section, $Q = K_T S^{1/2}$
3. Check Q^* by equation for conveyance of middle section

$$Q^* = \frac{1.486}{n} S^{1/2}\, 2 D_{50}\, y^{5/3}$$

MKE DOCUMENT NO. 5057-GRN-C-01-00270-01

Calculation Cover Sheet

Contract No. 5057 Discipline EARTH SCI Calc. No. 10-539-03-01 No. of Sheets 14

Project

UMTRA-GRN

Feature

PERMANENT DRAINAGE

Item

DIVERSION DITCH ALONG SITE ROAD

Sources of Data

1. M.K.E. CALC NO. 10-539-01-00
2. M.K.E. CALC NO. 10-536-05-00

5. "DESIGN OF SMALL DAMS", U.S. DEPARTMENT OF THE INTERIOR, 1972

Sources of Formulae & References

1. DOE, REMEDIAL ACTION PLAN AND SITE CONCEPTUAL DESIGN FOR STABILIZATION OF THE INACTIVE URANIUM MILL TAILINGS AT GREEN RIVER, UTAH, VOLUMES I AND II - APPENDIX D, DRAFT, JANUARY, 1987
2. MKE DOC. NO. 4005-GEN-Q-01-00. UMTRA DESIGN PROCEDURES MANUAL, REVISED MAY, 1986
3. "OPEN CHANNEL HYDRAULICS", V.T. CHOW, McGRAW-HILL, 1959
4. "WATER RESOURCES ENGINEERING", R.K. LINSLEY & J.B. FRANZINI, THIRD EDITION, McGRAW-HILL, 1979

Preliminary Calc. ☒ Final Calc. ☐ Supersedes Calc. No. ______

Rev No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
1	Change to Final Calc	M.J. Carlson	[illegible]	[signature]	11/11/87	[signature]	[illegible]
0	——	J.C. PORTER	8-28-87	[signature]	8/30/87	PK Chan	9/18/87

Form 42-110

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA - GRN	Contract No. 5057	Sheet 1	File No.
Feature DIVERSION DITCH	Designed JLP	Date 8-28-87	
Item TABLE OF CONTENTS	Checked UWC	Date 8-30-87	

CONTENTS

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN	Contract No. 5057	Sheet 2	File No.
Feature: DIVERSION DITCH	Designed JCP	Date 8-27-87	
Item: PURPOSE, METHODS	Checked [illegible]	Date 8-30-87	

PURPOSE

THE PURPOSE OF THIS CALCULATION IS TO DESIGN A DITCH TO DIVERT THE UPLAND FLOW AWAY FROM THE PROPOSED TAILINGS EMBANKMENT. THIS IS TO PROVIDE AN ADDITIONAL SAFETY FEATURE AGAINST FAILURE OF THE RIPRAP EROSION PROTECTION DURING THE DESIGN LIFE AND TO MINIMIZE THE FLOW IMPACT TO THE SITE DURING CONSTRUCTION.

METHODS

DITCH DESIGN

SEVERAL FACTORS INFLUENCED DITCH DESIGN, MOST NOTABLY SPACE LIMITATIONS. THE DITCH WAS DESIGNED TO LEAVE A MINIMUM OF 5' SHOULDER WIDTH ALONG THE SITE ROAD AND NOT DISPLACE THE MILITARY BUNKERS TO THE EAST. CONSTRUCTABILITY WAS ANOTHER FACTOR. A TRAPEZOIDAL CHANNEL WITH 8' BOTTOM WIDTH WAS CHOSEN DUE TO THE HIGH AVAILABILITY OF 8' WIDE BLADES FOR TRACTOR UNITS. IN ORDER TO MAKE THE BUNKERS ACCESSIBLE IN THE FUTURE, THE ROAD LEADING INTO THE BUNKER WILL BE GRADED INTO A V-SHAPED SWALE WITH 8(H):1(V) SIDESLOPES TO PROMOTE FLOW ACROSS THE ROAD AND ALLOW VEHICLE

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA - GRN	Contract No. 5057	Sheet 3	File No.
Feature DIVERSION DITCH	Designed JCP	Date 8-27-87	
Item METHODS	Checked [illegible]	Date 8-30-87	

ACCESS. A TRANSITION WAS DESIGNED TO ACCOMPLISH THIS CHANGE IN SHAPE AND THEN RETURN THE DITCH TO ITS ORIGINAL TRAPEZOIDAL GEOMETRY.

AS DESIGNED, THE DITCH WILL CARRY "PMP" FLOW APPROXIMATELY 150' DOWNSTREAM FROM THE TAILINGS EMBANKMENT. AT THAT POINT A PORTION OF THE FLOW WILL OVERTOP THE SITE ROAD AND DISCHARGE ONTO THE GRADED AREA BETWEEN BROWN'S WASH AND THE EMBANKMENT. DURING PMP FLOW AN EROSIVE VELOCITY WILL EXIST, HOWEVER THE CHANNEL WILL PARALLEL TO THE SITE ROAD AND NOT CUT INTO THE CELL. IT SHOULD BE NOTED AT THIS POINT THAT THE TOE PROTECTION RIPRAP IS DESIGNED TO PROTECT THE EMBANKMENT FROM PMP DISCHARGE. IN THE EVENT THAT ALL THE SOIL ERODES AWAY, THE CELL WILL BE PROTECTED. THIS DITCH IS A SECONDARY SAFETY FACTOR AND SHOULD NOT BE TREATED AS THE PRIMARY PROTECTION FOR THE TAILINGS EMBANKMENT. FOR THIS REASON, AND THE FACT THAT THE PMP DOES NOT OCCUR OFTEN IN THE DESIGN LIFE, IT IS JUDGED THAT THE DITCH WILL ADEQUATELY SERVE ITS PURPOSE AND NOT CONTRIBUTE TO UNDERMINING THE EMBANKMENT.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA - GRN	Contract No. 5057	Sheet 4	File No.
Feature DIVERSION DITCH	Designed J.C.P.	Date 8-27-87	
Item METHODS, SUMMARY	Checked [illegible]	Date 8-30-87	

EXCAVATION QUANTITY

THE EXCAVATION QUANTITY WAS CALCULATED USING THE AVERAGE END AREA METHOD FOR CALCULATING VOLUMES. THIS IS A ROUGH APPROXIMATION IN THAT THE ACTUAL END OF THE DITCH WILL BE DETERMINED BY TOPOGRAPHY, I.E. WHEN THE DITCH MEETS "DAYLIGHT". ALSO, GRADING TO PROMOTE POSITIVE DRAINAGE WILL EFFECT THE FINAL VOLUME.

SUMMARY

DESIGN CAPACITY = 475 cfs.*

LENGTH ≈ 435' ±

EXCAVATION VOLUME ≈ 930 C.Y.

STARTING POINT OF DITCH ℄ : N 59382.5
E 59414.0

BEARING : N 42° 45' 00" E

* DATA SOURCE 2

MORRISON-KNUDSEN ENGINEERS, INC.
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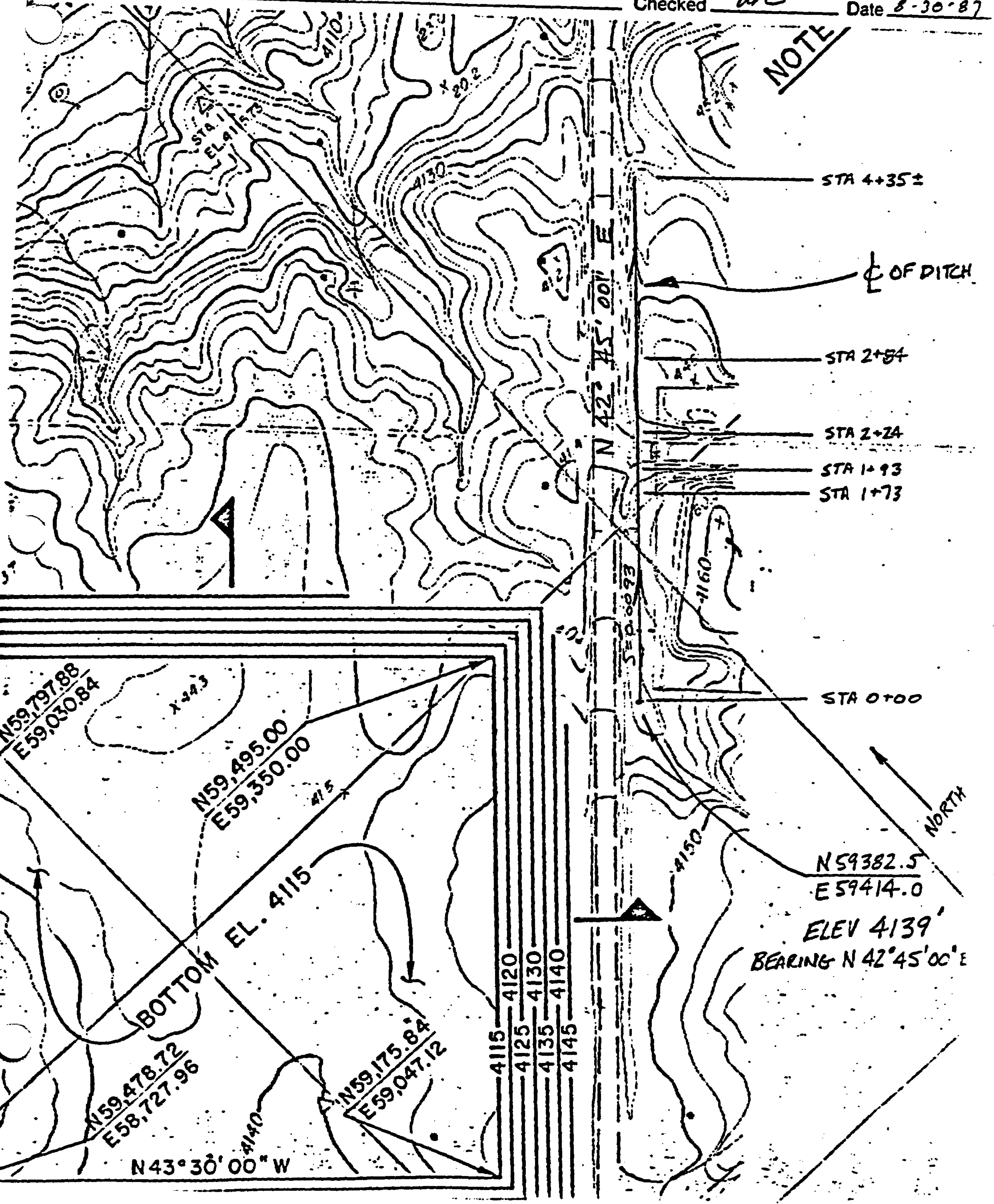
Project UMTRA - GRN
Feature DRAINAGE
Item DITCH PLAN VIEW

Contract No. 5057
Designed JCP
Checked [illegible]

Sheet 5
File No.
Date 8-14-8[illegible]
Date 8-30-87

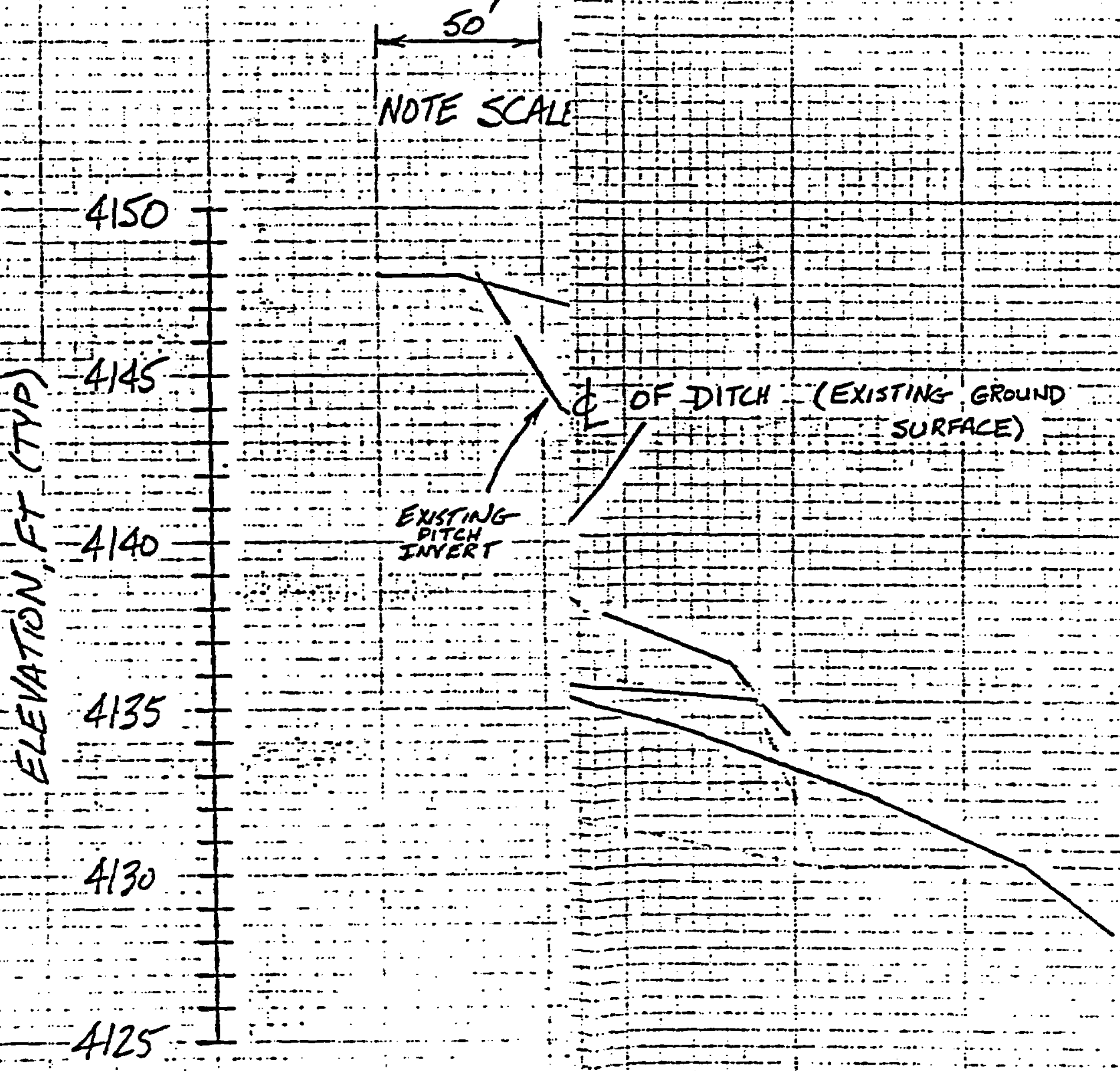


MORRISON-KNUDSEN ENGINEERS
A MORRISON KNUDSEN COMPANY

Project UMTRA - GRN

Feature DRAINAGE

Item DITCH PROFILE



MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN
Feature: DRAINAGE
Item: SECTION PROFILE
Contract No. 5057
Designed: JLP
Checked: [illegible]
Sheet 7
File No.
Date 8-14-8
Date 8-30-8

STA 0+00

MORRISON-KNUDSEN ENGINEERS, INC.
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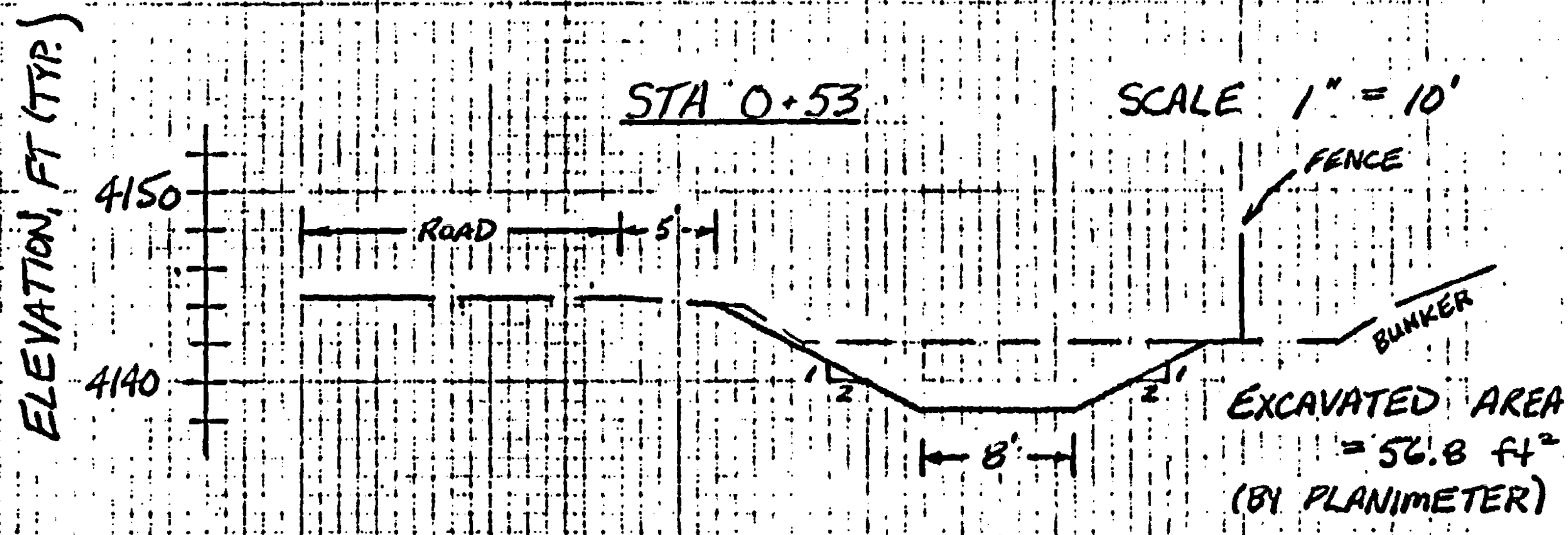
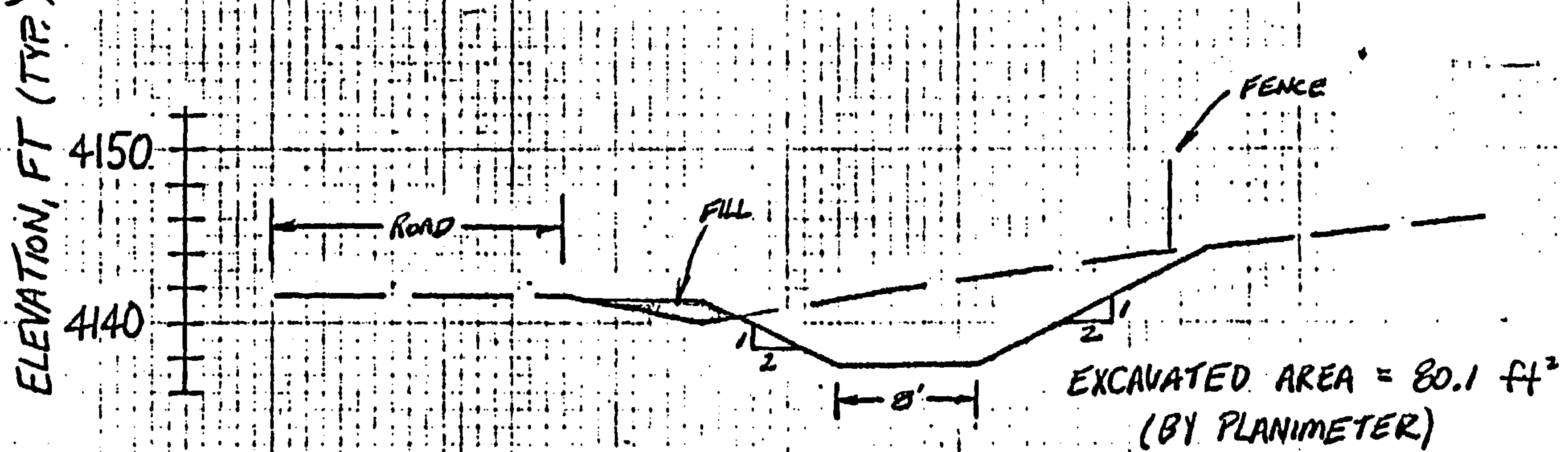
Project UMTRA - GRN
Feature DRAINAGE
Item PROFILES
Contract No. 5057
Designed JCP
Checked [illegible]
Sheet 8
File No. [illegible]
Date 8-14-87
Date 8-30-87

STA 0+53 SCALE 1" = 10'



STA 1+53 SCALE 1" = 10'



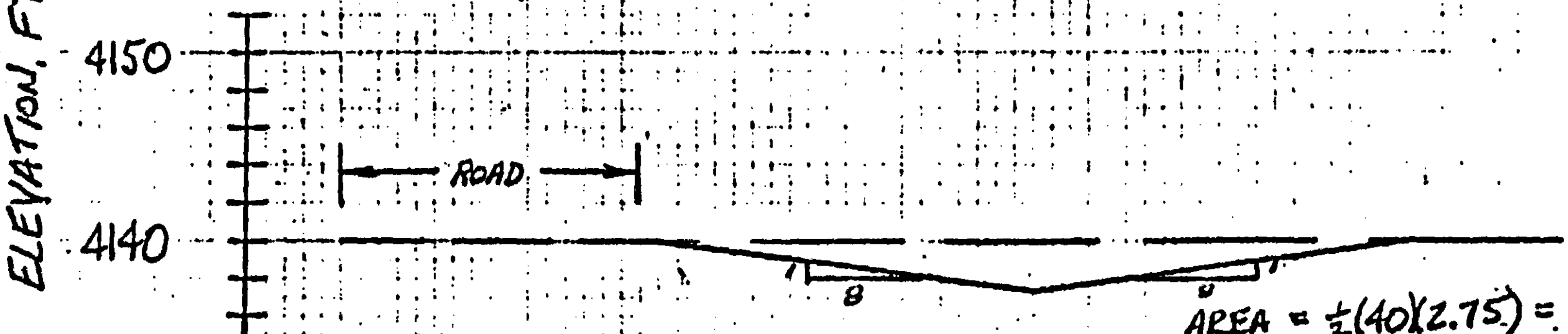
MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN
Feature: DRAINAGE
Item: PROFILES
Contract No.: 5057
Designed: JLP
Checked: UWC
Sheet: 9
File No.:
Date: 8-14-8
Date: 8-8?-8

STA 1+73 SCALE 1" = 10'

EXCAVATED AREA = 71.3 ft²
(BY PLANIMETER)

STA 1+93 SCALE 1" = 10'



AREA = ½(40)(2.75) = 55.0 ft²

MORRISON-KNUDSEN ENGINEERS, INC.
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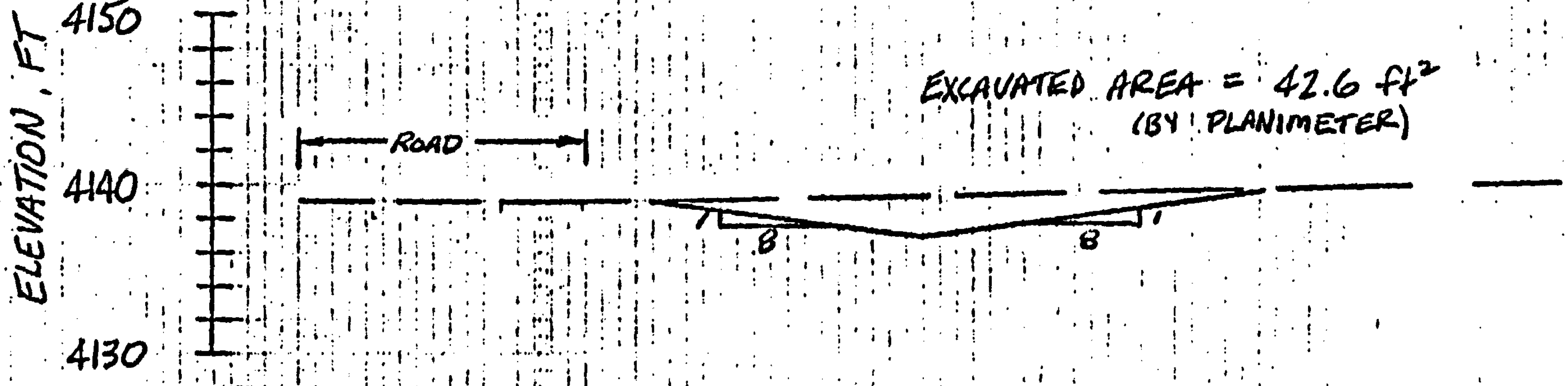
Project UMTRA - GRN
Feature DRAINAGE
Item PROFILES

Contract No. 5057
Designed JCP
Checked WC

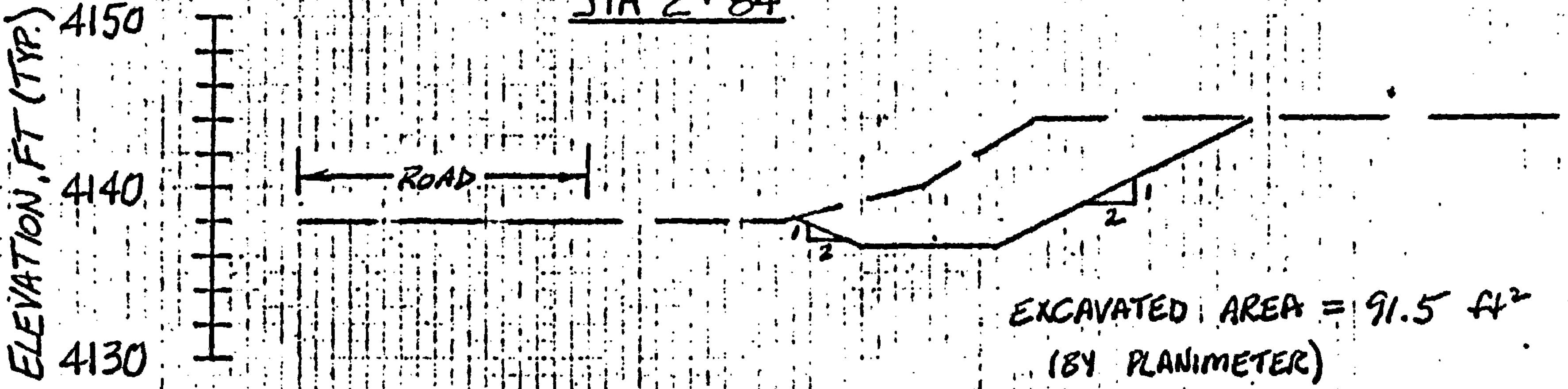
Sheet 10
File No. 8-14-8
Date 8-30-8
Date

STA 2+24

SCALE 1"=10'



STA 2+84



$Q = 475$ cfs

$Q = VA$

$V = \frac{1.49}{n} R^{2/3} S^{1/2}$ WHERE $R = \frac{A}{P}$

$n = 0.024$ (REF 4)
$S = 0.0093$

DETERMINE DEPTH OF FLOW AT EACH STATION FOR GIVEN Q BY TRIAL AND ERROR.*

STATIONS 0+53 AND 1+53

y [ft]	A [ft²]	P [ft]	R [ft]	V [ft/s]	Q [ft³/s]
3	42	21.42	1.96	9.38	394
3.5	52.5	23.65	2.22	10.19	535
3.3	48.2	22.76	2.12	9.87	(476)

CLOSE ENOUGH

∴ $y = 3.3'$ AND RUNOFF WILL NOT FLOW OVER SITE ROAD ✓

* STATION 0+00 WAS NOT CONSIDERED HERE BECAUSE OF THE LARGE FLOODPLAIN AREA, I.E. IT WILL NEVER OVERTOP THE SITE ROAD WITH Q = 475 cfs.

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Project: UMTRA - GRN	Contract No. 5057	Sheet 12	File No.
Feature: DRAINAGE	Designed J.C.P.	Date 8-18-87	
Item: DITCH CAPACITY	Checked WC	Date 8-30-87	

STATION 1+73

A_{max} BEFORE OVERTOPPING ROAD = 55.8 ft^2 (BY PLANIMETER)

$y_{max} = 3.3'$

$P_{max} = 31.97'$

$R = \frac{A}{P} = \frac{55.8}{31.97} = 1.745'$

$V = \frac{1.49}{n} R^{2/3} S^{1/2} = \frac{1.49}{.024} (1.745)^{2/3} (.0093)^{1/2} = 8.68$ fps

$Q = VA = 8.68(55.8) = 484$ cfs > 475 cfs

∴ PMF RUNOFF WILL BE CONTAINED IN DITCH AND NOT OVERTOP SITE ROAD.

STATION 1+93

$A_{max} = \frac{1}{2}(40)(2.75) = 55.0$ ft^2

$P_{max} = 40.38'$

$R = \frac{A}{P} = \frac{55.0}{40.38} = 1.362'$

$V = \frac{1.49}{n} R^{2/3} S^{1/2} = \frac{1.49}{.024} (1.362)^{2/3} (.0093)^{1/2} = 7.36$ fps

$Q = VA = 7.36(55.0) = 405$ cfs

∴ PMF RUNOFF WILL OVERTOP SITE ROAD BETWEEN STA 1+73 AND STA 1+93

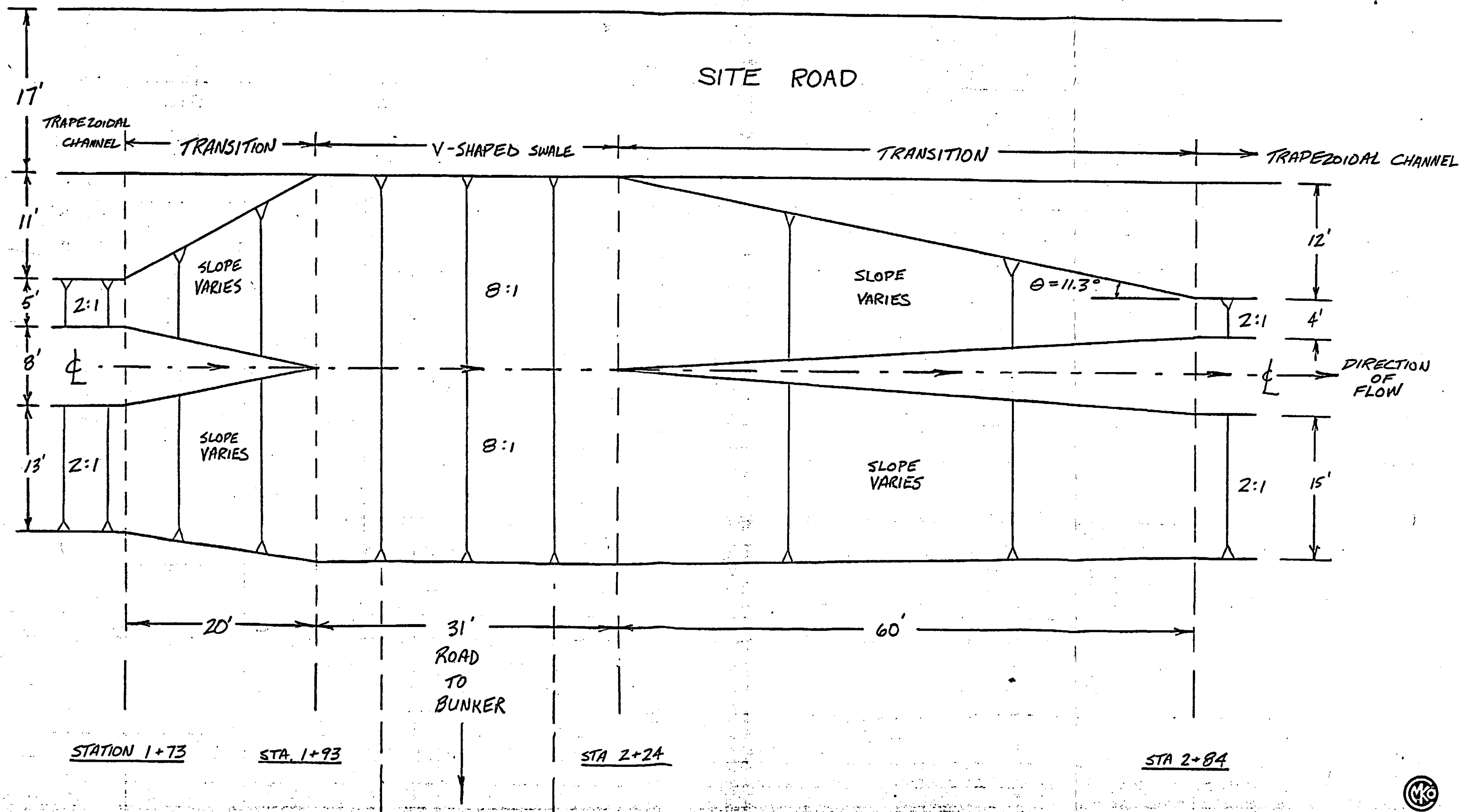
MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN	Contract No. 5057	Sheet 13	
Feature: DRAINAGE	Designed JCP	File No.	Date 8-17-87
Item: BUNKER ROAD CROSSING: TRAP TO V-SWALE TO TRAP. CHANNEL	Checked wc		Date 8-20-87

PLAN VIEW

SCALE : 1" = 10'

$\theta = \tan^{-1}\left(\frac{12}{60}\right) = 11.3°$



MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA - GRN
Feature DRAINAGE
Item EXCAVATION QUANTITIES

Contract No. 5057
Designed JCP
Checked [illegible]

Sheet 14
File No.
Date 8-17-8
Date 8-30-8

EXCAVATION QUANTITIES WILL BE CALCULATED USING THE AVERAGE END AREA METHOD FOR CALCULATING VOLUMES.

STATION	AREA [ft^2]	AVERAGE AREA [ft^2]	SPACING [ft]	VOLUME [yd^3]
0+00	43.4			
		50.1	53	98.3
0+53	56.8			
		68.5	100	253.7
1+53	80.1			
		75.7	20	56.1
1+73	71.3			
		63.2	20	46.8
1+93	55.0			
		48.8	31	56.0
2+24	42.6			
		67.1	60	149.1
2+84	91.5			
		47.8	148	262.0
4+32	0			
			VOLUME = 922 C.Y.	

EXCAVATION VOLUME ≅ 930 C.Y.

NOTE: THIS IS A ROUGH APPROXIMATION IN THAT THE ACTUAL END OF THE DITCH WILL BE DETERMINED BY THE TOPOGRAPHY, I.E. WHEN THE DITCH MEETS "DAYLIGHT". ALSO, GRADING TO PROMOTE POSITIVE DRAINAGE WILL ALSO EFFECT THE FINAL VOLUME.

MKE DOCUMENT NO.5057-GRN-C-01-00271-01

Calculation Cover Sheet

Calc. No. 10-534-03-01
No. of Sheets 6/rw

Contract No. 5057 Discipline ESCI

Project

UMTRA / GREEN RIVER

Feature

SITE DRAINAGE

Item

CULVERT (CMP.) DESIGN

Sources of Data

Sources of Formulae & References

1). MKE Calc. # 10-534-02-00 "Retention Basin" Storm Intensity. July 1987.

2) Handbook of Steel Drainage & Highway Construction Product, 3rd ed. 1983.

Preliminary Calc. ☐ Final Calc. ☒ Supersedes Calc. No. ____

1	Change to Final Calc	M. J. Goodman	11-11-87	D. K. Chen	11/11/87	D. K. Chen	11/11/87
—	————	V.P. Chantalitan	9-1-87	JC Porter	9-2-87	D. K. Chen	9/18/87
Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date

Form 42-110

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project	UMTRA / GREEN RIVER	Contract No. 5057	Sheet 1
Feature	SITE DRAINAGE	Designed WC	File No.
Item	CULVERT DESIGN	Checked JCP	Date 9-1-87 / Date 9-2-87

PURPOSE:

This calculation is to select the culvert size to carry the 10-yr, 24-hr storm away from the mill building area.

METHOD:

The watershed that will contribute the run-off to the southern most gully and the culvert consists of the areas bound by the freeway I-70 and the bunker, and south of the final embankment area and the surrounding site road.

The rational method is used to estimate the run off since the watershed area is relatively small.

MORRISON-KNUDSEN ENGINEERS, INC.
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Project	UMTRA / GREEN RIVER	Sheet	2
		Contract No. 5057	File No.
Feature	SITE DRAINAGE	Designed	Date 9-1-87
Item	CULVERT DESIGN	Checked JCP	Date 9-2-87

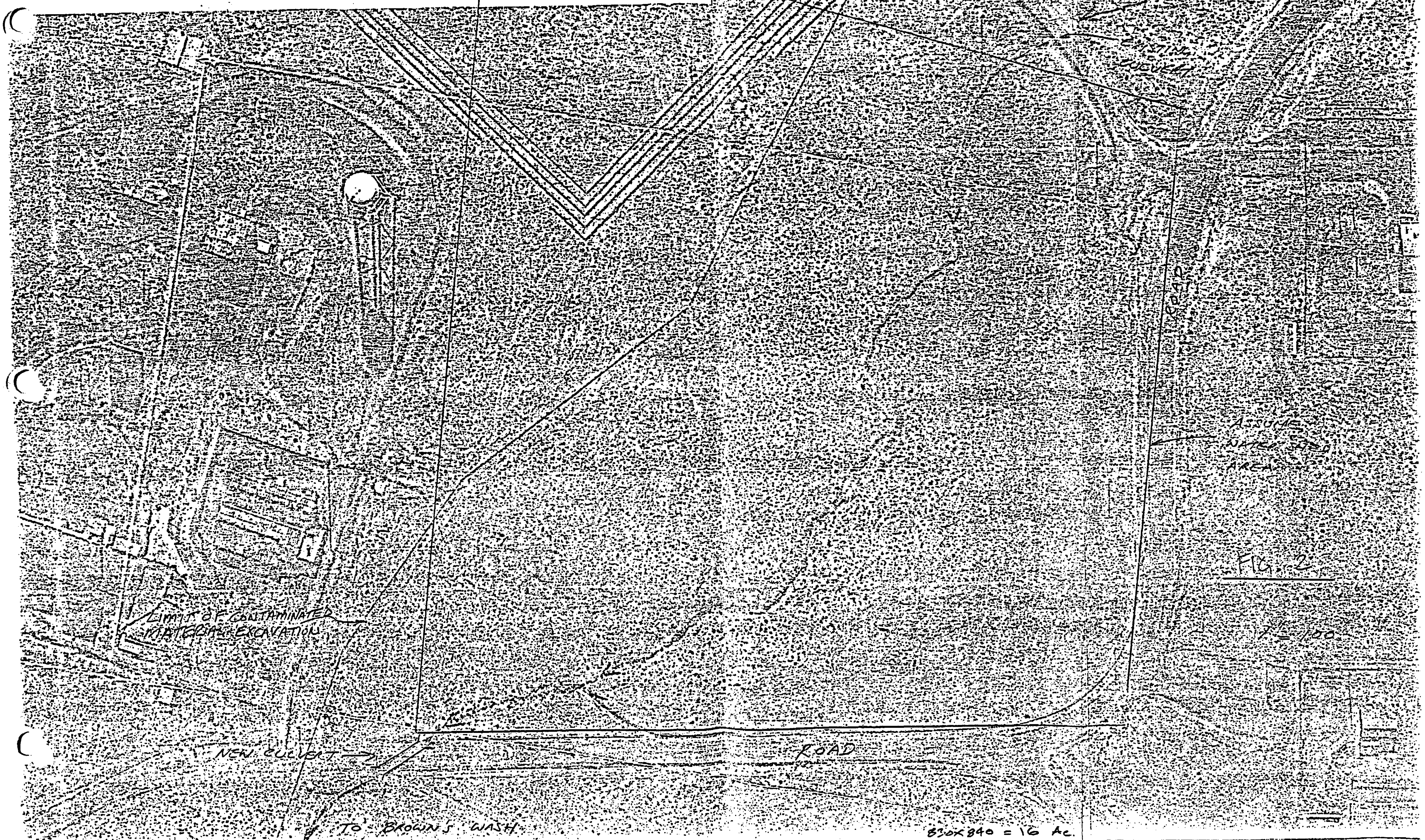
830 x 450 = 8.6 Ac.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA / GREEN RIVER
Feature: SITE DRAINAGE
Item: CULVERT DESIGN

Contract No. 5057
Designed UPC
Checked JCP

Sheet 3
File No.
Date 9-1-87
Date 9-2-87



METHOD: (CON'T)

Watershed area contributes to the gully flow and flow through the culvert.

Fig. 1 Fig. 2

$(830 \times 450) + (830 \times 840) = 8.6 + 16$

$= 24.6$ Ac.

From Ref. 1 P. 12 ; 10 yr. - 24 hr storm.

$i = 1.5''$ ✓

REF. 2, P. 164

Table 4-2 Values of Relative Imperviousness[1]

Type of Surface	Factor C
For all watertight roof surfaces	0.75 to 0.95
For asphalt runway pavements	0.80 to 0.95
For concrete runway pavements	0.70 to 0.90
For gravel or macadam pavements	0.35 to 0.70
*For impervious soils (heavy)	0.40 to 0.65
*For impervious soils, with turf	0.30 to 0.55
*For slightly pervious soils	0.15 to 0.40
*For slightly pervious soils, with turf	0.10 to 0.30
*For moderately pervious soils	0.05 to 0.20
*For moderately pervious soils, with turf	0.00 to 0.10

*For slopes from 1% to 2%

Modifications to the rational method have been proposed in order that the C coefficient may account for antecedent precipitation conditions. Recommended Antecendent Precipitation Factors are listed below. The rational formula now includes a new variable: $Q = C\,C_a\,I\,A$

Recommended Antecedent Precipitation Factors for the Rational Formula[6]

Recurrence Interval (Years)	C_a
2 to 10	1.0
25	1.1
50	1.2
100	1.25

NOTE: The product of $C \times C_a$ should not exceed 1.

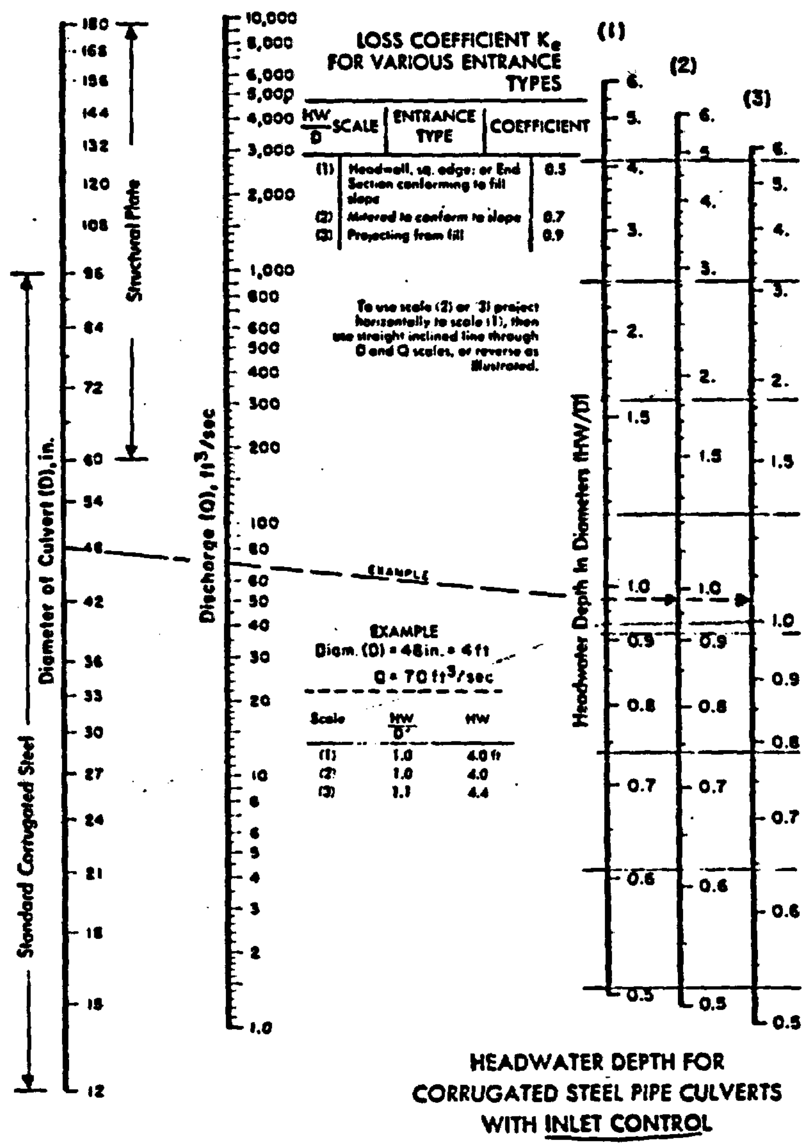
Project UMTRA / GREEN RIVER
Feature SITE DRAINAGE
Item CULVERT DESIGN

Contract No. 5057
Designed WR
Checked JCP

Sheet 5
File No.
Date 9-1-87
Date 9-2-87

METHOD : (CON'T)

REF. 2



FHWA HEC 5

Figure 4-28 *Inlet control* nomograph for corrugated steel *pipe* culverts. The manufacturers recommended keeping *HW/D* to a maximum of 1.5 and preferably to no more than 1.0.

METHOD (CON'T)

Design $Q = C_a CIA$

$= 1.0 \times 0.3 \times 1.5 \times 24.6$

$= 11.07$ cfs.

① Assume Inlet control

② $HW/D = 1.0$ ✓

③ Culvert Project from fill w/o Headwall.

From Chart FHWA HEC 5, fig 4-20 Ref 2

$D = 24$ inches //

$HW = 2$ ft.

$L = 70$ ft.

MKE DOCUMENT NO. 5057-GRN-C-01-00253-01

Calculation Cover Sheet 1/2

Contract No. 5057-05 **Discipline** ESCI/UMTRA **Calc. No.** 10-534-02-01 **No. of Sheets** 48

Project UMTRA / Green River

Feature Retention Basin

Item

Sources of Data

Sources of Formulae & References (continued sheet 2/2)

1. UMTRA PROJECT - GRN, Design Basis Memorandum No. 11-534-00, Retention Basin, document 5057-GRN-V-01-00113-00.
2. HEC-1, Flood Hydrograph Package, Users Manual, revised January 1985
3. NOAA Atlas 2, "Precipitation-Frequency Atlas of the Western United States, Volume VI Utah", J.F. Miller, R.H. Frederick & R.J. Tracy
4. NCHRP Report 221, "Erosion Control During Highway Construction, Manual on Principles and Practices, April 1980.

Preliminary Calc. ☐ Final Calc. ☒ Supersedes Calc. No. ——

Rev No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
1	Change to Final Calc	Martin J. [illegible]	11-11-87	[illegible]	[illegible]	[illegible]	[illegible]
0	——	[illegible]	7-31-87	[illegible]	7-30-87	[illegible]	8-11-8[illegible]

Form 42-110

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA/GRN
Feature Retention Basin
Item

Contract No. 5057-CS
Designed MJG
Checked [illegible]

Sheet 1
File No.
Date 7/21/87
Date 7-2[illegible]-87

References (cont)

5. "A Guide to Hydrologic Analysis Using SCS Methods", Richard H. McCuen, 1982.

6. "Design of Small Dams", US Department of Interior, Bureau of Land Management.

7. Draft, "Urban Hydrology for Small Watersheds, Technical Release 55", pg. 2-18 to 2-21, revised 6/17/85.

8. Draft, "Remedial Action Plan and Site Conceptual Design for Stabilization of the Inactive Uranium Mill Tailings At Green River, Utah", Volume II, Appendix D, January, 1987

9. "Engineering Assessment of Inactive Uranium Mill Tailings, Green River Site, Green River, Utah", prepared by Ford, Bacon and Davis Utah Inc., August 1981

10. Handbook of Hydraulics, 6th Edition; E.F. Brater and H.W. King

MORRISON-KNUDSEN ENGINEERS, INC.
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Project [illegible]	Contract No. 5057-05	Sheet 2	File No.
Feature Retention Basin	Designed KJG	Date 7/21/87	
Item	Checked [illegible]	Date 7-22-87	

CONTENTS

MORRISON-KNUDSEN ENGINEERS, INC.
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Project: GRN / UMKH — Sheet: 3
Feature: Retention Basin — Contract No.: 5357-05 — File No.:
Item: — Designed: MJG — Date: 7/21/87
Checked: CWC — Date: 7-22-87

CONTENS (cont)

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA / GREEN RIVER
Feature RETENTION BASIN DESIGN
Item

Sheet 4
Contract No. 5057
File No.
Designed [illegible]
Date 8-11-87
Checked [illegible]
Date 9-24-87

SUMMARY : RETENTION BASIN DESIGN

A. DESIGN HYDROLOGIC PARAMETER, FLOWRATE & VOLUME.

Soil Type : Silty Sand - loose to medium dense

Land Use : Range, Sage Brush grass.

Moisture Condition : Saturated

Ground Surface : 30% vegetation cover.

Drainage Area : 64 - Acre / 0.1 Sq. Mile.

CN : 90

STORM EVENT	Tc (min.)	Total Rainfall (inch)	Run Off (Ac.ft.)	Peak Flow (cfs)
10 yr - 24 hr	22.12	1.50	3.62	(54)
25 yr - 24 hr.	22.12	1.88	(5.26)	74

B: RETENTION BASIN & SPILLWAY

Design Capacity (Ac-ft)		Average Basin Area (Ac.)	Design Depth (Ft.)				Berm Crest to Spillway (Ft.)
Run Off	Sediment		No Discharge	Spillway Flow Depth	Free Board	Total	
3.62	0.98	0.68	7.0	0.95	1.0	9.0	2.0

1.0 PURPOSE

- These calculations present the design for the retention basin at the Green River Site. The retention basin will control surface water runoff in contaminated areas and other waste water generated during site cleanup.

- The retention basin is designed to perform the following functions (see Reference #1)

  A) Provide sufficient volume to store the following items without discharge:

     1) Surface water runoff from contaminated areas resulting from a 10-yr, 24-hr storm.

     2) Sediment produced in drainage basin for the entire clean-up period.

     3) Wastewater resulting from decontamination of equipment and personnel, clothing washwater and dewatering (if necessary).

  B) Provide sufficient surface area to facilitate evaporation [illegible] 10-yr, 24-hr storm by the end of each clean-up season.

     Evaporation is intended to be the primary means of removal of waste water without releasing contaminants.

  C) Provide emergency spillway capacity to route the peak flow from a 25 yr, 6-hr storm that occurs at a time when the retention basin is already full. To account for uncertainties in characterization of runoff at the site, a 25 yr, 24-hr storm was selected for design purposes.

  D) Prevent leakage or seepage of contaminants from retention basin.

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Project UMTRA/GEN			Sheet 6
		Contract No. 5057-05	File No.
Feature Retention Basin		Designed M.K.	Date 7/21/87
Item		Checked [illegible]	Date 7.22.87

E) Allow for removal of sediment if and when accumulated sediment exceeds 60% the design capacity of retention basin

F) Remain stable and intact throughout cleanup operations.

2.0 METHODS OF ANALYSIS SUMMARY

2.1 The HEC-1 computer program is used to evaluate the following item: (Reference 2)

A) the 10-yr, 24-hr storm

B) the minimum spillway dimensions necessary to route a 24-hr, 25-yr storm through the retention basin at a time when the retention basin is already full.

2.2 The rainfall hyetographs for 10-yr, 24 hr and 25-yr, 24-hr storms were generated using the procedure presented in the NOAA Precipitation-Frequency Atlas (reference # 3).

2.3 Sediment quantities are determined base on erosion rate calculated with Modified Universal Soil Loss Equation (reference # 4).

3.0 RUNOFF VOLUME AND FLOWRATE

Let P_{x-y} = x-year, y-hour precipitation [in]
All precipitation calculations follow the procedure described in the NOAA Atlas (Reference 3)

3.1. Rainfall Distribution

3.1A. 10-year, 24-hr Precipitation (P_{10-24})

Coordinates: E110° 07' N 38° 55' ⟹ Zone = 1

$X_1 = P_{2-6} = 0.7''$ (Fig 19, Ref 3)

$X_3 = P_{100-6} = 1.8''$ (Fig 24, Ref 3)

$X_2 = P_{2-24} = 0.9''$ (Fig 25, Ref 3)

$X_4 = P_{100-24} = 2.4''$ (Fig 30, Ref 3)

* $Y_2 = P_{2-1} = -0.011 + 0.942 X_1^2 / X_2 = 0.502''$

$Y_{100} = P_{100-1} = 0.494 + 0.755 X_3^2 / X_4 = 1.513''$

* eqs from Table 11, pg 15, Ref 3.

Estimate P_{10-1} from P_{2-1} and P_{100-1} using copy of Figure 6, ref 3 shown on following page.

$P_{10-1} \sim$ <u>0.95"</u>

P_{10-6} = <u>1.2"</u> (fig 21, ref 3)

P_{10-24} = <u>1.5"</u> (fig 27, ref 3)

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Project UMTRA / GRN
Feature Retention Basin
Item

Contract No. 5057-05
Designed MJG
Checked [illegible]

Sheet 9
File No.
Date 7-29-87
Date 7-29-87

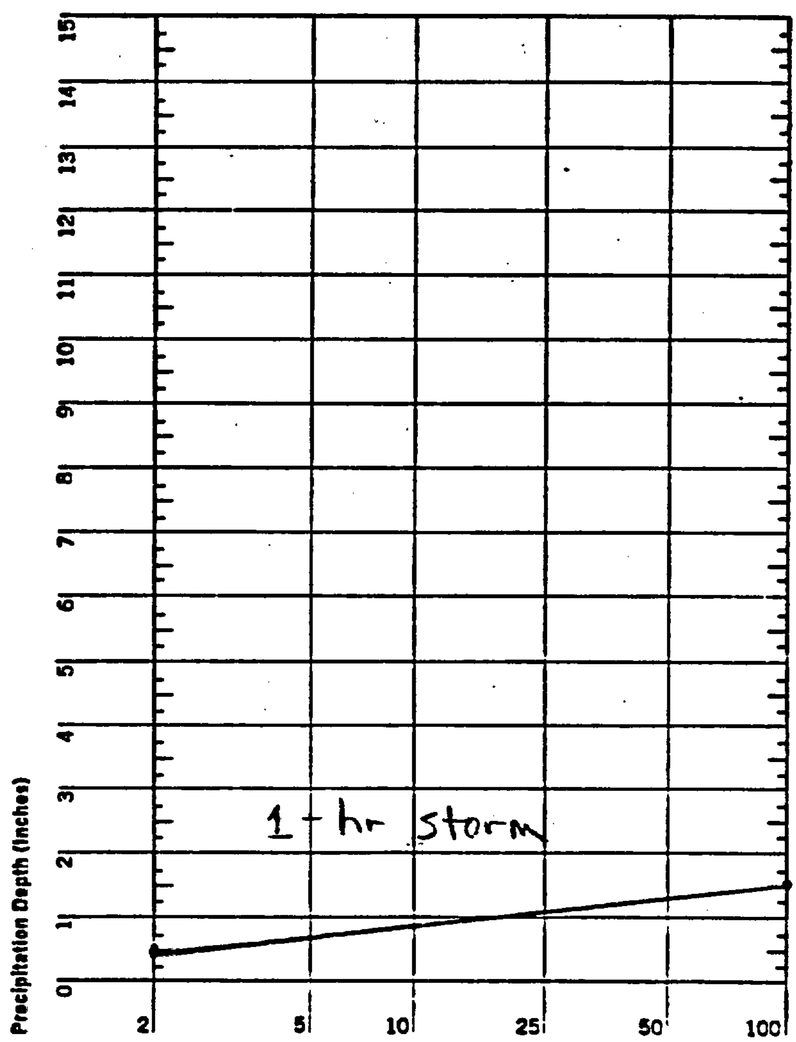

fig 6, ref 3

Intensities of 10-year storm (1 hr)

P_{10-2} = 1.02" }
P_{10-3} = 1.10" } fig 15, ref 3 (see following page)

P_{10-12} = 1.3 fig 16, ref 3 (see page 8/43)

Precipitation Duration (min)	Precipitation* (in)
5	0.28 ⇐ 0.29 × 0.95" = 0.28"
10	0.43
15	0.54
30	0.75

* see Table 12, ref 3.

Summary: NOAA P_{10-24} Duration - Precipitation Relation

Partial Duration (hrs)	Cumulative Rainfall (in)	5-min Intensity (in)
5 min	0.28	0.28
10 min	0.43	0.15
15 min	0.54	0.11
30 min	0.75	0.07
1 hr	0.95	0.03
2	1.02	0.0058
3	1.1	0.006
6	1.20	0.0028
12	1.30	0.0014
24	1.50	0.0014

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Project UMTRA/GRN
Feature Retention Basin
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Contract No. 5057-05
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Checked
Sheet 11
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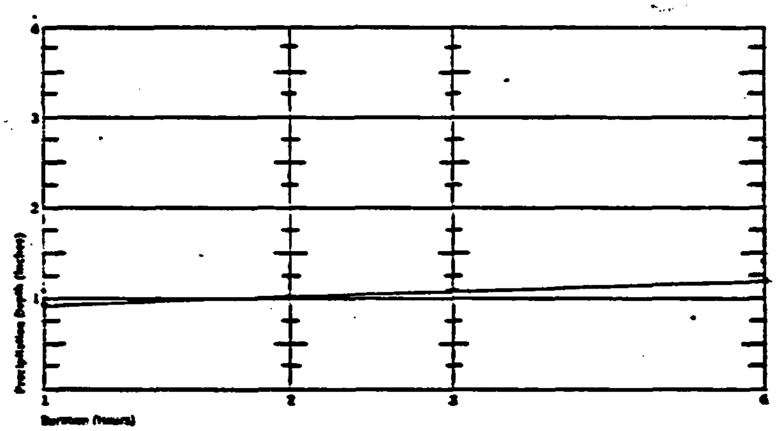
Date 7-29-87
Date 7-29-87



(A)

Figure 15. *Precipitation depth-duration diagram (1- to 6-hr).*
Ref 3
a. Utah south of the Unita Mountains, east of the Wasatch Range, and east and south of the Boulder and Pine Valley Mountains. (Region 1, fig. 18).

Determination of 2-hr and 3-hr 10-year Storms

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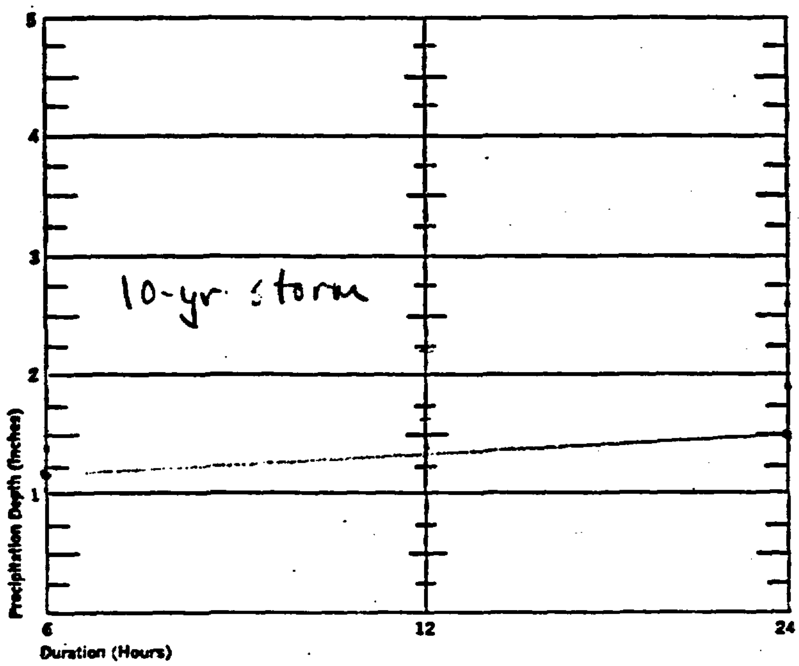
Project UMTRA / GRN	Contract No. 5c57-05	Sheet 12	File No.
Feature Retention Basin	Designed MJG	Date 7-29-87	
Item	Checked 6RL	Date 7-29-87	

RF3

Figure 16. *Precipitation depth-duration diagram (6- to 24-hr).*



Determination of 12-hr, 10-year storm

MORRISON-KNUDSEN ENGINEERS, INC.
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Project: GRN / UMTRA	Contract No. 5157-CS	Sheet 13	File No.
Feature: Retention Basin	Designed MJG	Date 7/21/87	
Item	Checked CWC	Date 7-21-87	

The following supplemental calculation sheet has been added to demonstrate that the NOAA partial duration vs. cumulative precipitation relationship is more critical than the corresponding SCS relationship.

As will be shown in section 3.3, the time of concentration, t_c, for the design drainage basin is about 22 minutes.

The duration closest to t_c at which cumulative rainfall can be determined using the SCS method is 30 minutes.

For a SCS Type II storm with P_{10-24},

$$P_{10-0.5} = (0.6632 - 0.2833) \times 1.5'' = 0.57'' \quad *$$

* (see ref 5, pg. 8)

It is evident that the SCS Method calculated precipitation in a period approximately equal to t_c, is less than that calculated using the NOAA procedure.

Therefore, the NOAA duration-rainfall relation is selected for design.

3.1B 25-Year, 24 hour Precipitation (P_{25-24})

Zone = 1

P_{2-6} = X_1 = 0.7"
P_{100-6} X_2 = 1.8"
P_{2-24} X_3 = 0.9"
P_{100-24} X_4 = 2.4"

P_{2-1} Y_2 = .502"
P_{100-1} Y_{100} = 1.513"

Estimate P_{10-1} from P_{2-1} and P_{100-1}, using Fig 6, ref 3 (see next page)

P_{25-1} = 1.1"

P_{25-6} = 1.4" (Fig 22, ref 3)

P_{25-24} = 1.9" (Fig 28, ref 3)

P_{25-2} = 1.2"
P_{25-3} = 1.26"
} fig 15a, ref 3 (copy on page 11)

P_{25-12} = 1.65" fig 16, ref 3. (copy on page 11)

Precipitation Duration (in)	Precipitation (in) *
5	0.32
10	0.50
15	0.63
30	0.87

* See Table 12, ref 3.

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Project UMTRA / GRN			Sheet 15
Feature Retention Basin	Contract No. 505705		File No.
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	Checked		Date 7-29-87

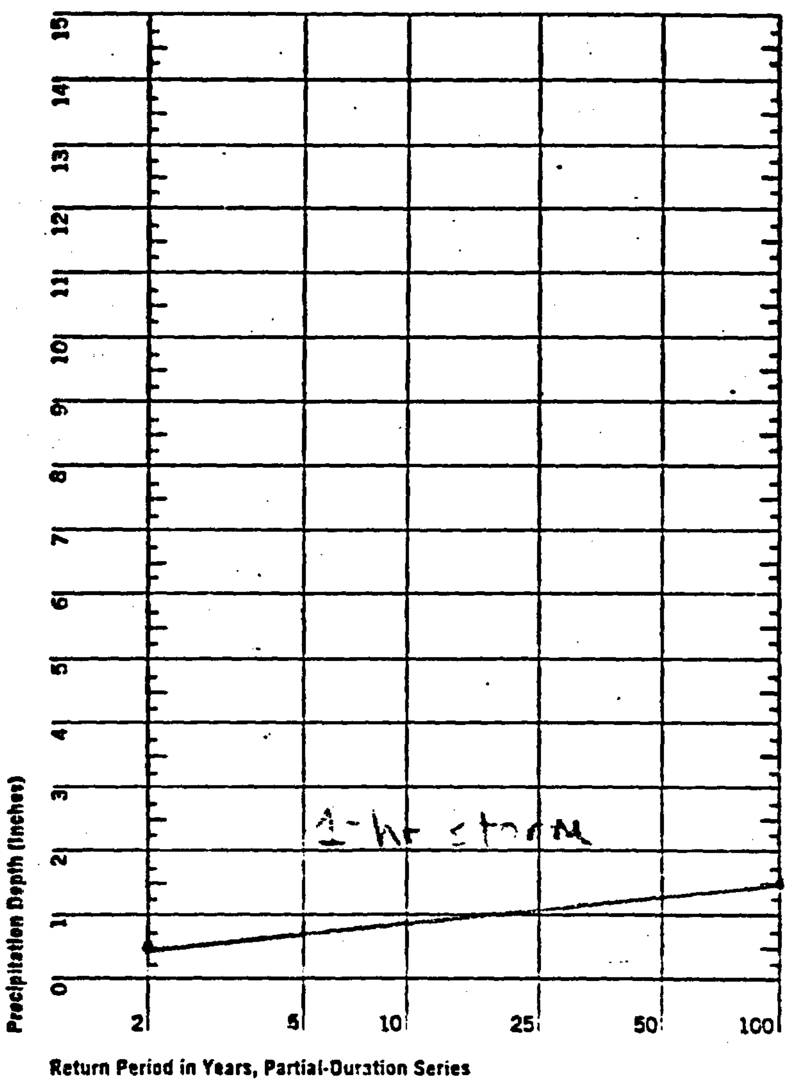

Figure 6. *Precipitation depth versus return period for partial-duration series.*
Ref 3

... of 25 year storm (1-hr)

MORRISON-KNUDSEN ENGINEERS, INC.
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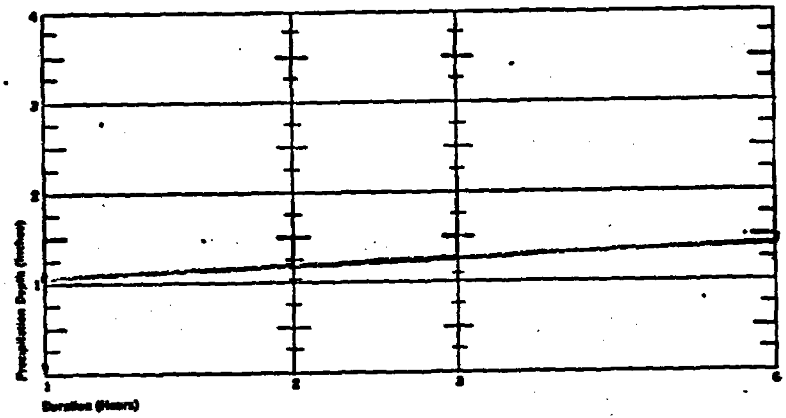
Project	UMTRA / GRN	Contract No. 5057-05	Sheet 16
Feature	Retention Basin	Designed MJG	File No.
Item		Checked cwc	Date 7-29-87 / Date 7-29-87



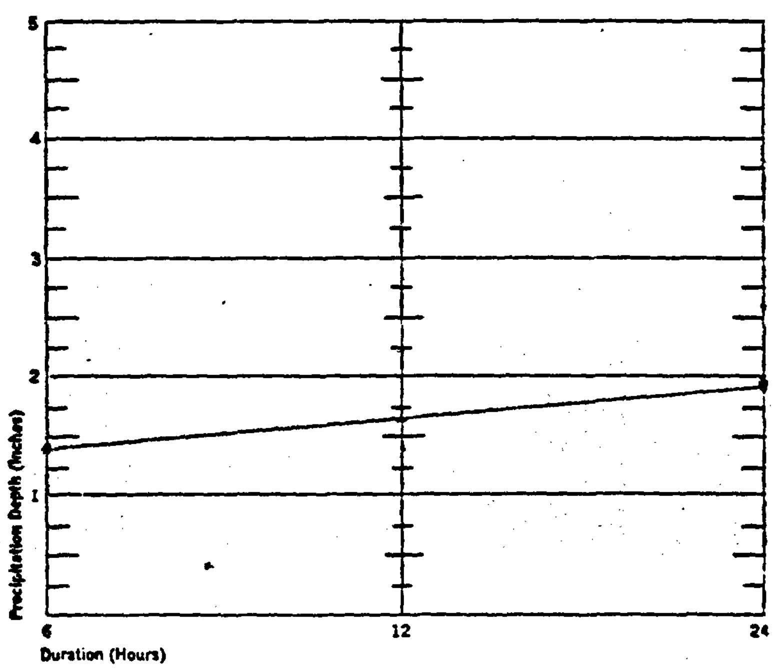
(A)

Figure 15. *Precipitation depth-duration diagram (1- to 6-hr).*
Ref 3 *a. Utah south of the Unita Mountains, east of the Wasatch Range, and east and south of the Boulder and Pine Valley Mountains. (Region 1, fig. 18).*

Determination of 2-hr and 3-hr 25-year storms

Ref 3

Figure 16. *Precipitation depth-duration diagram (6- to 24-hr).*



Determination of 12-hr, 25-year storm

Summary: NOAA P_{25-24} Duration Precipitation Relation

Partial Duration (hrs)	Cumulative Rainfall (in)	5-min Intensity (in)
5 min	0.32	0.32
10 min	0.50	0.18
15 min	0.63	0.13
30 min	0.87	0.08
1 hr	1.10	0.038
2	1.20	0.0083
3	1.26	0.005
6	1.40	0.0039
12	1.65	0.0035
24	1.90	0.0017

3.1C Procedure for Synthesizing Rainfall Hyetographs

(See paragraph #2, pg 6, reference #5)

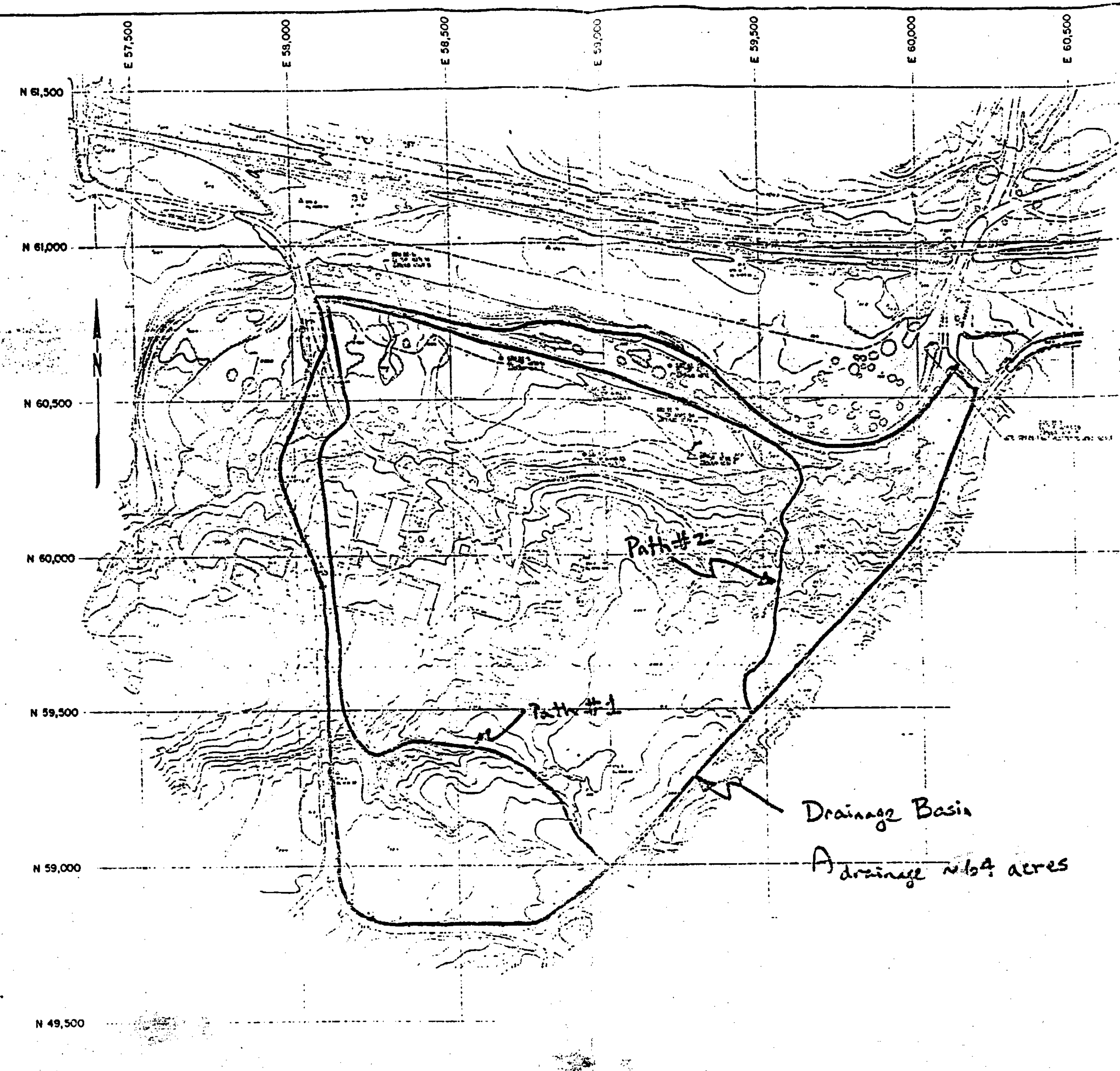
Rainfall Hyetographs are listed in HEC1 computer outputs.
(See sections 3.5 and 7.2).

3.2 Drainage Basin

The retention basin will be designed to store surface water runoff and sediment from the contaminated areas located south of Browns Wash. This drainage basin is shown on appended copy of Project drawing GRN-PS-10-0504.

Surface water runoff and sediment will be intercepted and diverted from the site during cleanup operations.

The area of the drainage basin, obtained by planimetering, is approximately 64 acres (0.1 mile^2).



200 0 200 400
SCALE FEET

NOTES:

REFERENCE DRAWINGS:

LEGEND:

7-29-87
MJG , 7-29-87
5057/05
1" = 400'

QA	NO	DATE	REVISIONS	BY	CH	ENG MGR	CHIEF ENG	TAC REV	DOE APP
	△								
	△								
	△								
	△								
	A		ISSUED FOR PRELIMINARY REVIEW	—	—	—	—	—	—

U. S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

GREEN RIVER SITE
GREEN RIVER UTAH
PHASE I CONSTRUCTION

SITE PLAN

DESIGNED | DRAWN | CHECKED | INSPECTED | RECOMMENDED | APPROVED | DATE | DOE PROJECT ENGINEER | DATE

MORRISON-KNUDSEN ENGINEERS, INC.
UMTRA PROJECT
SAN FRANCISCO, CA

PROJECT NO. DE-AC04-83AL18795
DRAWING NO. GRN-PS-10-0504
REV A

3.3 Lag Time

3.3A Estimate time of concentration, t_c, using procedure presented on pg. 47 of reference #6., ie,

$$t_c = \left[11.9 \frac{L^3}{H} \right]^{0.385}$$ ✓

in which

L = path length (miles)
H = elevation drop (ft)
t_c = time of concentration (hrs)

The paths in question are shown on page 15/43.

Path	Elevation Interval (ft)	H (ft)	L (ft)	t_c (minutes)
1	4136 - 4142	6	250	3.40
	4114 - 4136	22	750	4.97
	4070 - 4114	44	1450	8.15
				Σ = 16.52
2	4150 - 4090	60	850	3.9
	4090 - 4080	10	1600	16.16
				Σ = 20.06 min.

t_c = maximum travel time in the drainage basin

= 20.06 minutes

3.3B Estimate time of concentration, t_c, on drainage basin, using Figure 8 (pg. 22) of Reference 5,

in which,

$$t_c = \frac{l}{V}$$

Drainage Path Type	Description
A	Alluvial Fans Western Mountain Regions
B	Small Upland Gullies.

Path*	Type	Elev Diff (ft)	Length (ft)	Slope (%)	Velocity (ft/sec)	t_c (min)
1	A	6	350	1.71	1.4	4.17
	B	22	750	2.90	3.5	3.57
	A	44	1450	3.03	1.75	13.81
						Σ = 21.55 min
2	A	60	850	7.06	2.6	5.45
	B	10	1600	0.63	1.6	16.67
						Σ = 22.12 min

t_c = max travel time in basin = **22.12 min**

* Drainage paths are shown in sheet 15/43.

MORRISON-KNUDSEN ENGINEERS, INC.
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Project GEN TUMIRA
Feature [illegible]
Item

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Contract No. 5057-05
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Designed MJG
Date 7/21/87
Checked [illegible]
Date 7-22-87

. 3.3C

Lag Time Calculation

Method of calculating t_c in reference #5 produces a higher (i.e, more conservative) t_c value. Therefore, use

$$t_c = \underline{22.12 \text{ minutes}}$$

$$\text{Lag time} = 0.6\, t_c = 0.6(22.12) = 13.2 \text{ min}$$

$$= \underline{0.22 \text{ hrs}}$$

3.4 Curve Number

The curve number used to quantify the effect of soil conditions on runoff is estimated using the procedure described in Reference # 5 and modified in reference # 7.

- less than 30% of ground surface has vegetal cover

  ⟹ hydrologic condition = poor

- surficial soils in drainage basin generally are loose to medium dense, silty SANDS or silty clayey SANDS

  ⟹ Soil Group = B

- Land Use = Range, sagebrush grass

⟹ the curve number, CN = 67
(see ref #7)

To account for possible saturation of ground prior to design storm, use moisture condition 3.

⟹ CN = 85 (ref 5, pg. 15)

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Project: Green / UMTRA	Contract No. 5057-05	Sheet 24	File No.
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Item	Checked	Date 7.24.87	

To account for reduction of perviousness of site surface by construction operations, the design curve number was increased to

$CN = 90.$

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Project	GRN- UMIRA	Contract No. 5157-05	Sheet 25
Feature	Retention Basin	Designed MJG	File No.
			Date 7/21/87
Item		Checked [illegible]	Date 7.22.87

3.5 RESULTS

- The runoff that would reach the lowest point in the drainage basin as a result of the design storm was estimated using the HEC-1 computer program (output on sheets 15, 16, 17).

- Based on the computer run, the volume of rainfall runoff for which the retention basin should be designed/sized is 3.62 acre-ft.

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UMTRA / GREEN RIVER

7/11/87

****

FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985

U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616

****

6/30/87
5057-05
Green River Retention Basin Capacity Estimate
MJG

7-22-87

THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3

```
                                HEC-1 INPUT                                  PAGE 1

LINE      ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

** FREE ***
  1       ID   UMTRA/GRN  -  DETENTION BASIN DESIGN
  2       ID   10-YEAR, 24-HOUR PMP.
  3       ID   5-MINUTE INTERVALS
  4       ID   ~~JUNE 16, 1987~~
  5       IT       5       0       0     288       0    1440
  6       IO       3       1

  7       KK       ZDRAINAGE BASIN FOR PROPOSED DETENTION BASIN
  8       BA     0.1
  9       PB       0
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 40       UD    0.22
 41       ZZ
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7/21/87

UMTRA/GRN - DETENTION BASIN DESIGN
10-YEAR, 24-HOUR PMP
5-MINUTE INTERVALS
~~JUNE 16, 1987~~

6/30/87
5057-05
MJG
Green River Retention Basin Capacity Estim

ac 7-22-87

6 IO OUTPUT CONTROL VARIABLES

IPRNT	3	PRINT CONTROL
IPLOT	1	PLOT CONTROL
QSCAL	0.	HYDROGRAPH PLOT SCALE

IT HYDROGRAPH TIME DATA

NMIN	5	MINUTES IN COMPUTATION INTERVAL
IDATE	1 0	STARTING DATE
ITIME	0000	STARTING TIME
NQ	288	NUMBER OF HYDROGRAPH ORDINATES
NDDATE	1 0	ENDING DATE
NDTIME	2355	ENDING TIME

COMPUTATION INTERVAL .08 HOURS
TOTAL TIME BASE 23.92 HOURS

ENGLISH UNITS

*** ***

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              **************
              *            *
7 KK          *        2   *     DRAINAGE BASIN FOR PROPOSED DETENTION BASIN
              *            *
              **************
```

SUBBASIN RUNOFF DATA

8 BA SUBBASIN CHARACTERISTICS
TAREA .10 SUBBASIN AREA sq.mi

PRECIPITATION DATA

9 PB STORM 1.50 BASIN TOTAL PRECIPITATION

10 PI INCREMENTAL PRECIPITATION PATTERN

.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
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.00	.00	.00	.00	.00	.00	.01	.01	.01	.01
.01	.01	.01	.01	.01	.01	.01	.01	.03	.03
.03	.07	.11	.28	.15	.07	.07	.03	.03	.03

.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00			

38

7/24/87

39 LS SCS LOSS RATE

STRTL	.22	INITIAL ABSTRACTION
CRVNBR	90.00	CURVE NUMBER
RTIMP	.00	PERCENT IMPERVIOUS AREA

6/30/87
WJG
5257-05
Green River Retention Basin Capacity Estimate

[illegible] 7-24-87

40 UD SCS DIMENSIONLESS UNITGRAPH

TLAG .22 LAG

***

WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

UNIT HYDROGRAPH
15 END-OF-PERIOD ORDINATES

39.	133.	184.	163.	105.	60.	37.	22.	13.	8.
5.	3.	2.	1.	0.					

*** *** *** *** ***

HYDROGRAPH AT STATION 2

TOTAL RAINFALL = 1.50, TOTAL LOSS = .82, TOTAL EXCESS = .68

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	23.92-HR
+ (CFS)	(HR)					
		(CFS)				
+ 54.	12.25		6.	2.	2.	2.
		(INCHES)	.596	.679	.679	.679
		(AC-FT)	3.	4.	4.	4.

CUMULATIVE AREA = .10 SQ MI

0.679" × [illegible] = [illegible] acre-ft

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+	HYDROGRAPH AT									
		2	54.	12.25	6.	2.	2.	.10		

*** NORMAL END OF HEC-1 ***

4.0 Sediment Inflow

4.1 Design Assumptions

- All sediment from the site will be directed into the retention basin. Sediment originating outside of the site will be diverted from the site.
- Construction / cleanup will require as much a 2 years.
- The topography of the site may be represented by an average slope and a single soil type.
- The Modified Universal Soil Loss Equation (MUSLE) may be used to estimate erosion in the drainage basin.

4.2 Calculations

- MUSLE (see reference #4)

$$A = R \cdot K \cdot LS \cdot VM$$

in which

- A = computed <u>amount</u> of soil loss per unit area for the time interval represented by factor R, generally expressed as tons per acre per year
- R = <u>rainfall</u> factor
- K = soil erodibility factor in tons per acre per year per unit of R
- LS = topographic factor (<u>length</u> and <u>steepness</u> of slope) (dimensionless)
- VM = erosion control factor (<u>vegetative</u> and <u>mechanical</u> measures) (dimensionless)

- Follow procedure described on pages 10-14 of reference #4.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: Green River UMTRA	Contract No.	Sheet: 30	File No.
Feature: Retention Basin	Designed: MJG	Date: 7-21-87	
Item: Sediment Storage Capacity	Checked: [illegible]	Date: 7-22-87	

1. Site Location: E 110° 07'
   N 38° 55'

2. Annual R-Value for site:

   from Figure 5-2, R = 12

3. Time of Exposure to Erosion:

   Assume time = 2 years

4. Estimate R value for 2 year construction period:

   If recurrence interval for EI is 2 years, there is a 50 % probability of exceedance of EI in one year.

   Similarly, if the recurrence interval for EI is 4 years, there is a 50 % probability of exceeding EI in 2 years.

   Therefore the design annual EI / R ratio is 1.3 (see Figure 2 in reference 4, reproduced on the following page).

   $$R_{design} = (R_{annual})(EI/R_{annual})(\#\text{ of years})$$
   $$= 12(1.3)(2) = \underline{31.2}$$

MORRISON-KNUDSEN ENGINEERS, INC.
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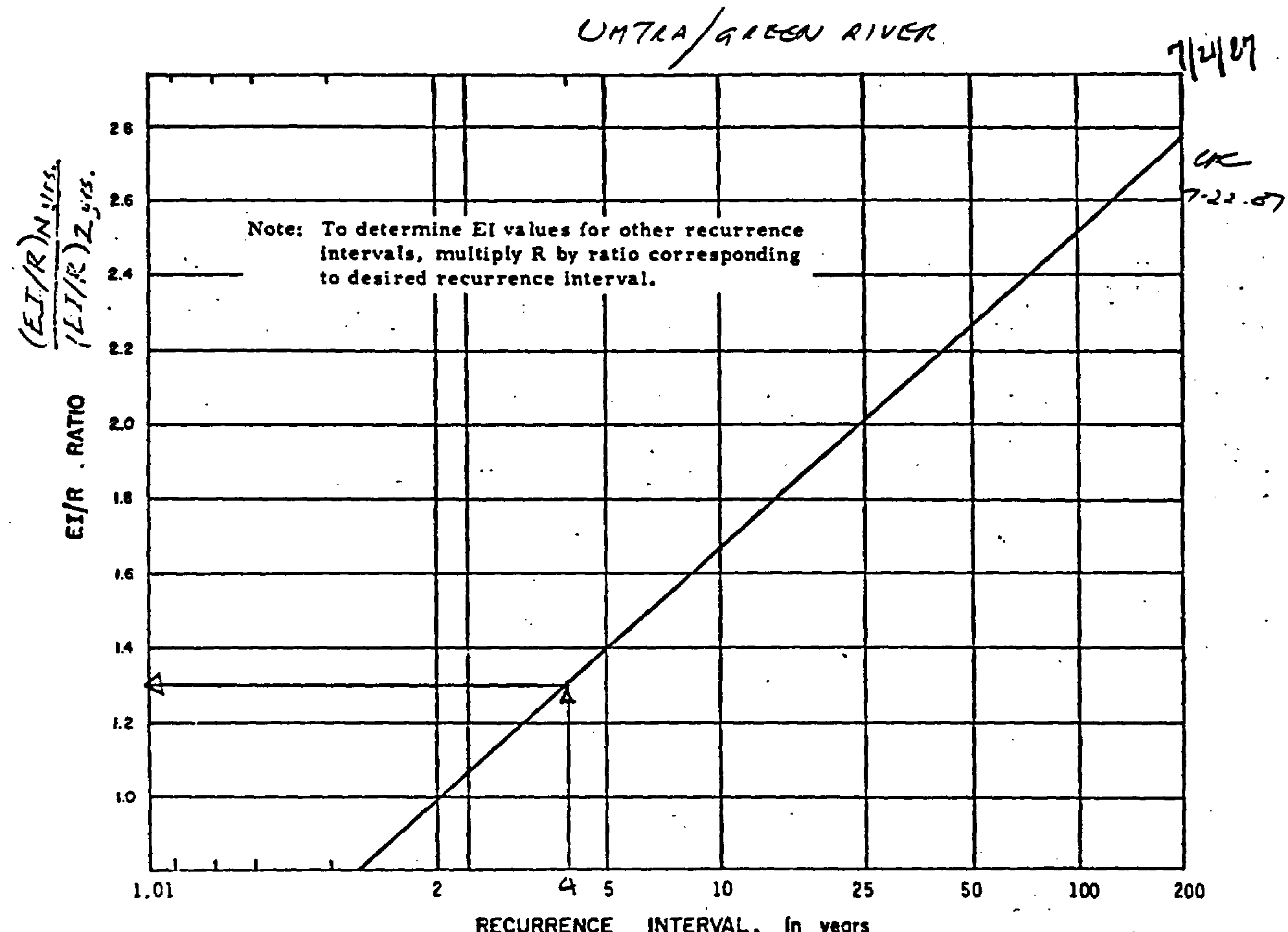
Sheet 31

Project UMTRA / GRN   Contract No. 5057-05   File No.

Feature Retention Basin   Designed MJG   Date 7-29-85

Item   Checked   Date



Ref-4

Figure 2-1. The relationship between the EI/R ratio and recurrence interval.

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Project [illegible]	Contract No. 5057-05	Sheet 32	
Feature [illegible] Basin	Designed [illegible]	File No.	Date 7/21/87
Item Sediment Storage Capacity	Checked [illegible]	Date 7-22-87	

5. Soil Factor K

The following data were taken from the gradation test results contained in reference 8.

Drill Hole	(ft) Sample Depth	% Between .002mm and 0.1 mm	% Between 0.1 mm and 2.0mm	Soil Type	K
562	1-2	—	37	CL	—
569	0.5-1	44	52	SM	0.[illegible]
571	0.5-1	46	41	SC	0.3
573	0.5	23	77	SC	0.[illegible]
574	2.5	14	86	SP-SM	0.12
575	2.5-3.0	14	86	SP-SM	0.1[illegible]
576	0.5-1.0	34	62	SM	0.[illegible]
577	0.5-1.0	49	37	SC-SM	0.35
578	2.0-3.0	19	81	SP-SM	0.16

[illegible] of the soil samples contained organic materials

Using figure 2-2 from reference 4 (reproduced on the following page), the soil erodability factor, K was evaluated for each of the near-surface soil samples listed above. [[illegible] structure and permeability [illegible]]

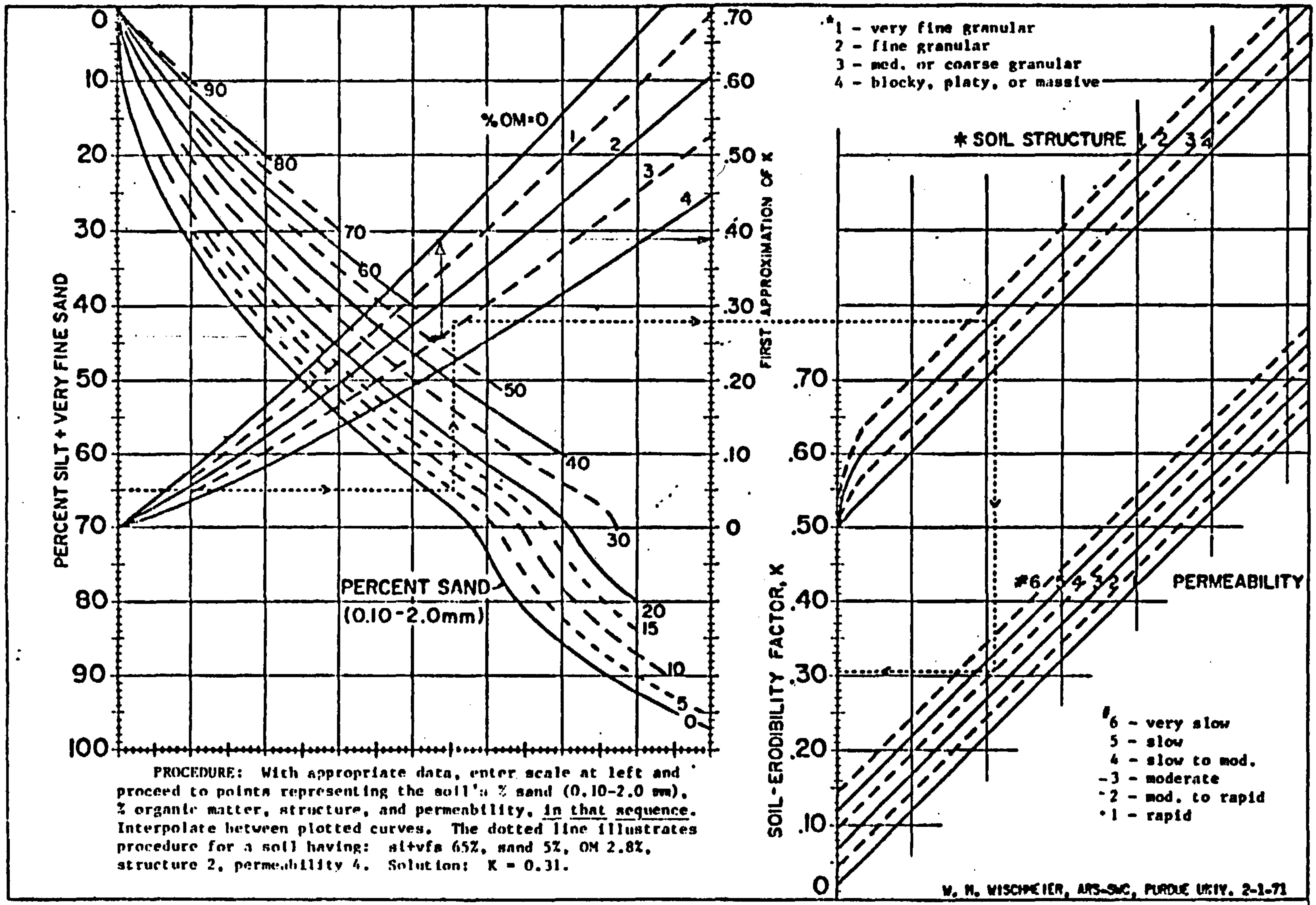


Figure 2-2. Nomograph for determining soil erodibility factor K.

To be conservative, the maximum K value obtained in any of the samples tested (K=.39*, drill hole # 562, depth = 1' to 2') was selected to estimate erosion at the site.

* K=.39 is more conservative than 0.1< K< 0.2 shown on figure 5-9 of reference 4.

6. Slope Steepness S

It can be seen in Figure 1 that the site generally slopes downward from southeast to northwest.

The average drainage length appears to be about 1400 ft and the elevation difference between the ends of the drainage path is about 70 feet (4070' to 4140')

$$\Rightarrow \text{slope} = \frac{70}{1400} \times 100 = \underline{5.0\%}$$

7. Slope Length (SL):

$$SL \approx \sqrt{70^2 + 1400^2} \approx \underline{1402'}$$

8. Calculate LS factor

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{65.41 s^2}{s^2 + 10{,}000} + \frac{4.56 s}{\sqrt{s^2 + 10{,}000}} + 0.065\right)$$

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: Green River / UMTRA	Contract No. 5057-05	Sheet 35	File No.
Feature: Infiltration Basin	Designed: MJG	Date 9/21/87	
Item:	Checked:	Date 7-22-87	

In which l = slope length (ft)

s = steepness in percent

M = 0.5 (because slope $\geq$ 5%)

$$LS = \left(\frac{1400}{72.6}\right)^{0.5}\left[\frac{65.41(5)^2}{5^2+10{,}000} + \frac{(4.56)(5)}{(5^2+10{,}000)^{1/2}} + 0.065\right]$$

$$= 4.39\left[\frac{1635.25}{10{,}025} + \frac{(4.56)(5)}{100.12} + .065\right]$$

$$= \underline{2.0}$$

10. Table 2.2 (Ref. 4)

VM_{max} = 1.3 for soil compacted with a bulldozer

Substituting R, K, LS and VM from #'s 4, 5, 6 and 8 above into MUSLE:

$$A = R \cdot K \cdot LS \cdot VM$$

$$= (31.2)(.039)(2)(1.3) = \underline{31.64 \text{ tons / acre}}$$

Assume average density of eroded soil = 95 pcf

Volume of eroded soil, V_s = $31.64 \frac{ton}{acre} \times 64 \text{ acres} \times \frac{2000\#}{ton} \times \frac{1 ft^3}{95\#}$

$= 42,626 \; ft^3$

$= \underline{0.98 \text{ acre-ft.}}$

Conclusion:

If 0.98 acre-ft are provided in retention basin for sediment, it will not be necessary to clean sediment from the retention basin during the 2-year construction period.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project	[illegible]	Contract No. 5157-CS	Sheet 37
Feature	Retention Basin	Designed MTC	File No.
			Date 7/21/87
Item		Checked [illegible]	Date 7.22.87

5.0 Evaporation

- The average annual rate of evaporation at the site is about 60"/year. (reference 9, pg. 2-5)
- Because the design 10-yr, 24-hr storm would store 84" of water in the retention basin, as much as 24" to 48" of water could remain unevaporated in the retention pond at the end of a construction year.
- Construction should be sequenced to account for potential unevaporated water.

6.0 Minimum Basin Volume

Assuming that water produced by dewatering and miscellaneous cleaning tasks will evaporate prior to design storms, the minimum required volume of the retention basin

$$= Volume_{sediment} + Volume_{runoff}$$

$$= 3.62 + 0.98$$

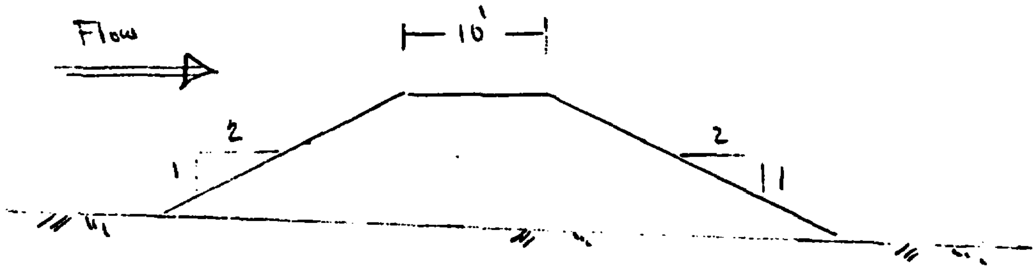
$$= \underline{4.6 \text{ acre-ft}}$$

The retention basin (project drawing GJN-PS-10-C508) actually provides 4.81 acre-ft of storage (This figure assumes that the average elevation of the bottom of the retention basin is 4072'. It is likely that the bottom will have a lower elevation and that the basin storage will be correspondingly higher).

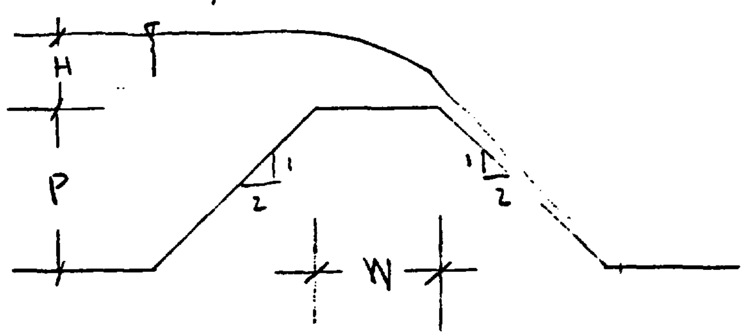
7.0 SPILLWAY DESIGN

7.1 Design Inflow

- The runoff of a 24-hr, 25-yr storm on the basin must be routed through the retention basin at a time when the basin is full (elevation 4079')
- Spillway will be lined with geomembrane to control erosion.



- Embankment will have sideslopes 2:1 (H:V) or flatter and 10-ft wide crest or wider.
- Discharge coefficient, C, to be used to estimate spillway discharge in $Q = CLH^{1.5}$ may be estimated from Tables 5-9, 5-10 in reference #10.



The discharge coefficient, C, should be selected for the value of H that will make the prototype geometry dimensionally similar to the model on which tables 5-10 and 5-11 are based.

The significant geometric variables for the prototype spillway are

$H/W = 1'/10' = \underline{0.1}$

$H/P = 1'/7' = \underline{0.14}$

The corresponding discharge coefficient, C, is

Criteria	C
H/W	2.68
H/P	3.02

For design purposes an average C-value may be used.

$C_{avg} = (2.68 + 3.02)/2 = \underline{2.85}^{*}$

* In the actual design calculations, c = 2.80 was used. This will result in overestimating the spillway width by about 2%.

7.2 Storm Routing

- The HEC1 computer program was used to calculate the stage (pool elevation) in the retention basin that would be produced by a 25 year, 24 hour storm for spillways of varying width.
- The level pool procedure of reservoir routing was employed.
- 1-ft. of freeboard was provided above maximum pool elevation (elevation 4081', assuming max pool elevation is one foot above spillway elevation)
- Output of the HEC1 program used to size the spillway is appended on the following sheets.
- It was assumed the retention basin is full to elevation 4079 and that the ground surface is saturated prior to start of 25-year, 24 hour storm

42

UMTRA/GREEN RIVER 7/2

urc 9-22-87

```
1                                         ****
                FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
       U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
                                          ****




      THIS HEC-1 VERSION CONTAINS ALL OPTIONS EXCEPT ECONOMICS, AND THE NUMBER OF PLANS ARE REDUCED TO 3


1                                      HEC-1 INPUT                                              PAGE  1

      LINE         ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 *** FREE ***
         1         ID  UMTRA/GRN  -  SPILLWAY DESIGN
         2         ID  25-YEAR. 24-HOUR RAIN
         3         ID  5-MINUTE INTERVALS
         4         ID  JULY 17, 1987
         5         IT       5       0       0     288       0    1440
         6         IO       3       1

         7         KK       1DRAINAGE BASIN
         8         BA     0.1
         9         PB       0
        10         PI  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017
        11         PI  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017
        12         PI  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017
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        14         PI  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017
        15         PI  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017
        16         PI  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017
        17         PI  0.0017  0.0017  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035
        18         PI  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035
        19         PI  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035
        20         PI  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0039  0.0039
        21         PI  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039
        22         PI  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039   0.005   0.005   0.005   0.005
        23         PI   0.005   0.005 0.00083  0.0083  0.0083  0.0083  0.0083  0.0083   0.038   0.038
        24         PI   0.038    0.08    0.13    0.32    0.18    0.08    0.08   0.038   0.038   0.038
        25         PI 0.00083  0.0083  0.0083  0.0083  0.0083  0.0083   0.005   0.005   0.005   0.005
        26         PI   0.005   0.005  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039
        27         PI  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039  0.0039
        28         PI  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035  0.0035
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        37         PI  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017
        38         PI  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017  0.0017
        39         LS       0      90
        40         UD    0.22
```

41 KK RETENTION BASIN
42 RS 1 ELEV 4079.0 0
43 SA 0.8 0.875
44 SE 4079.0 4081.0
45 SS 4079.0 25.0 2.8 1.5
46 ZZ

UMTRA / GREEN RIVER

WC 7-22-87

43

1

****
FLOOD HYDROGRAPH PACKAGE HEC-1 (IBM XT 512K VERSION) -FEB 1,1985
U.S. ARMY CORPS OF ENGINEERS, THE HYDROLOGIC ENGINEERING CENTER, 609 SECOND STREET, DAVIS, CA. 95616
****

UMTRA/GRN - SPILLWAY DESIGN
25-YEAR, 24-HOUR RAIN
5-MINUTE INTERVALS
JULY 17, 1987

6 IO OUTPUT CONTROL VARIABLES
IPRNT 3 PRINT CONTROL
IPLOT 1 PLOT CONTROL
QSCAL 0. HYDROGRAPH PLOT SCALE

IT HYDROGRAPH TIME DATA
NMIN 5 MINUTES IN COMPUTATION INTERVAL
IDATE 1 0 STARTING DATE
ITIME 0000 STARTING TIME
NQ 288 NUMBER OF HYDROGRAPH ORDINATES
NDDATE 1 0 ENDING DATE
NDTIME 2355 ENDING TIME

COMPUTATION INTERVAL .08 HOURS
TOTAL TIME BASE 23.92 HOURS

ENGLISH UNITS

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        **************
        *            *
 7 KK   *      1     *    DRAINAGE BASIN
        *            *
        **************
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SUBBASIN RUNOFF DATA

8 BA SUBBASIN CHARACTERISTICS
TAREA .10 SUBBASIN AREA

PRECIPITATION DATA

9 PB STORM 1.88 BASIN TOTAL PRECIPITATION

10 PI INCREMENTAL PRECIPITATION PATTERN *

.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

44
7/21/8

.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.01	.01	.01	.01	.01	.04	.04
.04	.08	.13	.32	.18	.08	.08	.04	.04	.04
.00	.01	.01	.01	.01	.01	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
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.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.00	.00	.00	.00	.00	.00	.00			

```
39 LS        SCS LOSS RATE
                  STRTL        .22  INITIAL ABSTRACTION
                  CRVNBR     90.00  CURVE NUMBER
                  RTIMP        .00  PERCENT IMPERVIOUS AREA
```

UINTA / GREEN RIVER
WC 7-22-87

```
40 UD        SCS DIMENSIONLESS UNITGRAPH
                  TLAG         .22  LAG
```

***

WARNING *** TIME INTERVAL IS GREATER THAN .29*LAG

UNIT HYDROGRAPH
15 END-OF-PERIOD ORDINATES

39.	133.	184.	163.	105.	60.	37.	22.	13.	8.
5.	3.	2.	1.	0.					

*** *** *** *** ***

HYDROGRAPH AT STATION 1

TOTAL RAINFALL = 1.88, TOTAL LOSS = .89, TOTAL EXCESS = .99

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW 6-HR	24-HR	72-HR	23.92-HR
+ (CFS)	(HR)					
		(CFS)				
+ 74.	12.25		9.	3.	3.	3.
		(INCHES)	.848	.986	.986	.986
		(AC-FT)	5.	5.	5.	5.

$V = 0.986'' \times \frac{1 ft}{12''} \times 64$ acres
$= 5.26$ acre-ft

CUMULATIVE AREA = .10 SQ MI

*** ***

```
          **************
          *            *
41 KK     *         2  *   RETENTION BASIN
          *            *
          **************
```

HYDROGRAPH ROUTING DATA

UINTA / GREEN RIVER

WC 7-22-87

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42 RS STORAGE ROUTING

NSTPS	1	NUMBER OF SUBREACHES
ITYP	ELEV	TYPE OF INITIAL CONDITION
RSVRIC	4079.00	INITIAL CONDITION
X	.00	WORKING R AND D COEFFICIENT

43 SA AREA .8 .9

44 SE ELEVATION 4079.00 4081.00

45 SS SPILLWAY

CREL	4079.00	SPILLWAY CREST ELEVATION
SPWID	25.00	SPILLWAY WIDTH
COQW	2.80	WEIR COEFFICIENT
EXPW	1.50	EXPONENT OF HEAD

***

COMPUTED STORAGE-ELEVATION DATA

STORAGE	.00	1.67
ELEVATION	4079.00	4081.00

COMPUTED OUTFLOW-ELEVATION DATA

OUTFLOW	.00	.00	.03	.27	.92	2.18	4.24	7.33	11.65	17.38
ELEVATION	4079.00	4079.00	4079.01	4079.02	4079.06	4079.10	4079.15	4079.22	4079.30	4079.40
OUTFLOW	24.75	33.94	45.18	58.67	74.59	93.17	114.58	139.06	166.79	197.99
ELEVATION	4079.50	4079.62	4079.75	4079.89	4080.04	4080.21	4080.39	4080.58	4080.78	4081.00

COMPUTED STORAGE-OUTFLOW-ELEVATION DATA

STORAGE	.00	.02	.04	.08	.12	.18	.24	.32	.40	.50
OUTFLOW	.00	.27	.92	2.18	4.24	7.33	11.65	17.38	24.75	33.94
ELEVATION	4079.00	4079.02	4079.06	4079.10	4079.15	4079.22	4079.30	4079.40	4079.50	4079.62
STORAGE	.61	.73	.85	1.00	1.15	1.31	1.49	1.67		
OUTFLOW	45.18	58.67	74.59	93.17	114.58	139.06	166.79	197.99		
ELEVATION	4079.75	4079.89	4080.04	4080.21	4080.39	4080.58	4080.78	4081.00		

*** *** *** *** ***

HYDROGRAPH AT STATION 2

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	23.92-HR
+ (CFS)	(HR)					
		(CFS)				
+ 65.	12.33		9.	3.	3.	3.
		(INCHES)	.843	.977	.977	.977
		(AC-FT)	4.	5.	5.	5.

PEAK STORAGE	TIME	MAXIMUM AVERAGE STORAGE			
		6-HR	24-HR	72-HR	23.92-HR
(AC-FT)	(HR)				
1.	12.33	0.	0.	0.	0.

PEAK STAGE	TIME	MAXIMUM AVERAGE STAGE			
		6-HR	24-HR	72-HR	23.92-HR
+ (FEET)	(HR)				
4079.95	12.33	4079.21	4079.07	4079.07	4079.07

CUMULATIVE AREA = .10 SQ MI

UMTRA / GREEN RIVER

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7/21/8

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+ HYDROGRAPH AT	1	74.	12.25	9.	3.	3.	.10		
+ ROUTED TO	2	65.	12.33	9.	3.	3.	.10	4079.95	12.33

*** NORMAL END OF HEC-1 ***

7.3 RESULTS

- A 25' wide spillway may be used for the proposed retention basin.

  For design purposes, the spillway width should be rounded up to 30'.

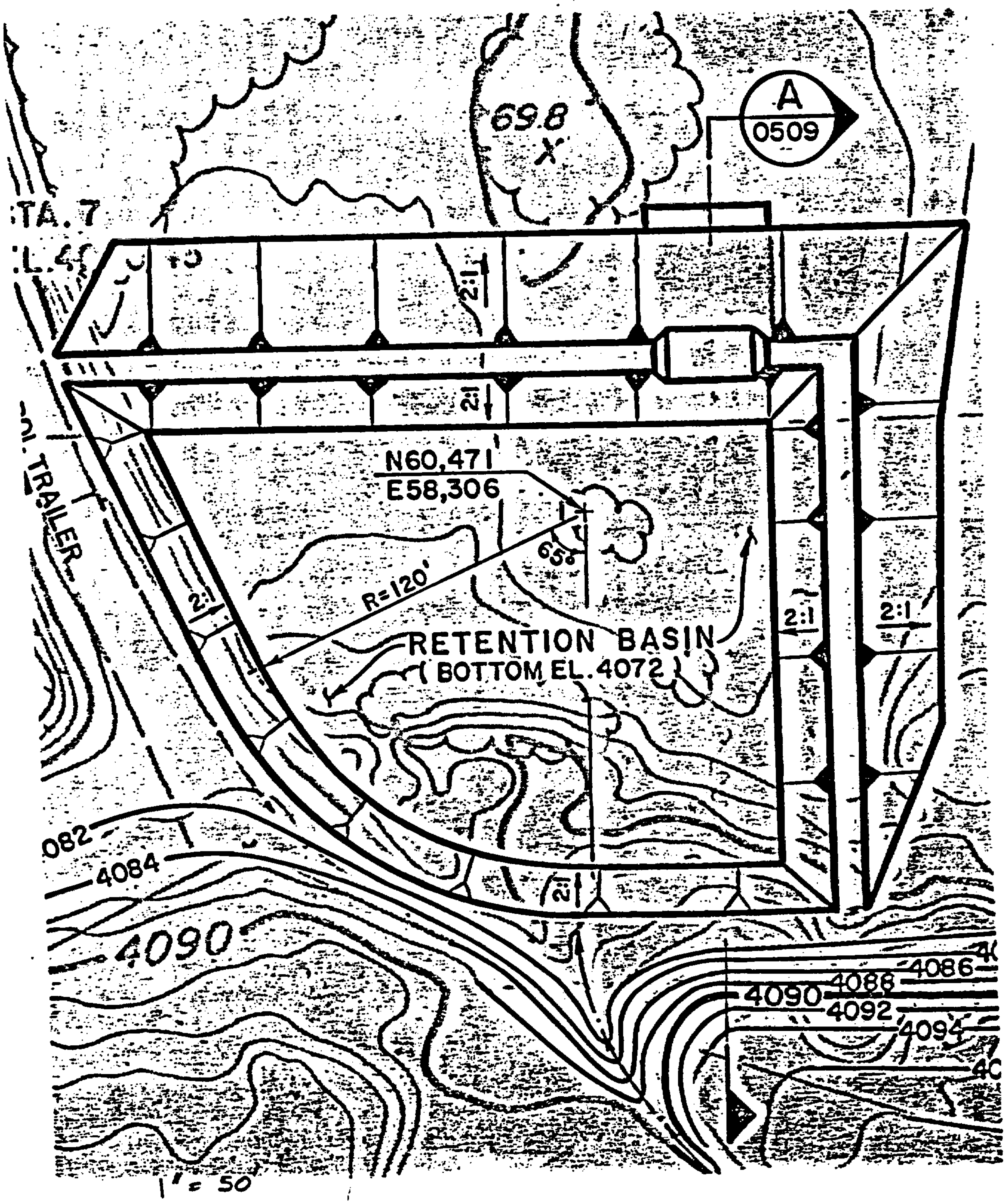
- The maximum elevation of water in the retention basin is 1.0 foot above spillway elevation. Including 1-ft of freeboard, the embankment crest of the retention basin should be at elevation 4081'.

MEMBRANE LINER:

5200 SY.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Sheet 48
File No.
Project UMTRA / GREEN RIVER
Contract No. 5057
Feature RETENTION BASIN
Designed WE
Date 8-26-87
Item
Checked JCP
Date 8-26-87



Calculation Cover Sheet

Contract No. 5057-05 **Discipline** ESCI / UMTRA **Calc. No.** 10-550-01-00
No. of Sheets 14

Project Green River, Utah

Feature Decontamination Pad

Item PCC Pavement Design

Sources of Data

Sources of Formulae & References

1. Jim Porter (oral communication)
2. (MKE) Calculation 10-536-08-00, "Tailings Embankment: Layout, Quantities and Capacity".
3. Draft RAP, "Remedial Action Plan for Stabilization of the Inactive Uranium Mill Tailings Site at Green River, Utah", January 1987.
4. E. J. Yoder and M. W. Witczak, "Principles of Pavement Design, 2nd edition, John Wiley and Sons Publishing Company, 1975.

Preliminary Calc. ☐ Final Calc. ☒ Supersedes Calc. No. ______

Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
0	—	M. J. Jordan	11-6-87	P. K. Chen	11-6-87	P. K. Chen	11-6-87

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project		Contract No. 5057-05	Sheet 1/14
Feature	Decon Pad	Designed	File No.
Item	PCC Pavement Design	Checked	Date 10-16-87 / Date 11-6-87

Summary

1. Use a 6-inch minimum thickness PCC Pavement.
2. Joint spacing ≤ 30 feet.
3. Use $f'_c \geq 2600$ psi
4. Use 4x4 W1.4xW1.4 welded wire fabric for temperature/warping effects.
5. Use 1"-diameter, 18-inch long steel (f_y = 65 ksi) dowels @ 12" spacings to transfer wheel loads across joints.
6. Allowable bearing pressure of dowel on concrete controls design.

Purpose:

a) Select PCC pavement thickness for decontamination pad.

b) Specify temperature steel and dowels.

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA-GRN | Contract No. 5057-05 | Sheet 3|4
Feature: Decon Pad | Designed: MJG | Date: 10-16-87 | File No.
Item: PCC Pavement Design | Checked: [signature] | Date: 11-6-87

Assumptions

1. Decontamination pad pavement should be designed to have a Present Serviceability Index (PSI) of at least 2.5 after being subjected to the loadings of all vehicles that will be decontaminated.

2. The principal vehicles that will be decontaminated will be unloaded haul vehicles used to import of soil materials. (No water will be imported).

3. The volumes of the import are as follows:

Item	Volume (yd^3)	Reference #
Gully fill	69,100	1
Riprap		
- Type 1	7,400	2
- Type 3	16,700	2
Bedding	5,400	2
Filter	1,700	2
Radon Barrier	12,800	2
Total	113,100	

4. About 18 yd^3 of import will be hauled on each truck. Therefore, the number of haul truck passes over the decontamination pad is:

Passes = 113,100 / 18 = 6283 passes

5. The density of the import (during hauling) is about 100 pcf. Therefore, the weight of the import on a truck is

$18\ yd^3 \times 27 ft^3/yd^3 \times 100\ lb/ft^3 = 48.6^k$

6. Assuming the haul trucks, when loaded, will have a 10^k single-axle and two 36^k tandem axles (total weight = 82^k), the truck weight after unloading is 33.4^k.

7. Construction will occur between April and December. Because freezing conditions will not occur until near the end of construction, no measures need be taken to protect the pavement against frost action. (see ref 3).

9. Near-surface site soil generally is loose to medium dense silty SAND. Therefore the coefficient of vertical subgrade reaction may conservatively be estimated to be 200 pci (see ref. 4 pg. 601).

10. Tensile strength of concrete may be conservatively estimated as $8\sqrt{f'_c}$ (see ref 4, pg. 259).

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Sheet 5/14

Project UMTRA-GRN | Contract No. 5057-05 | File No.
Feature Decon Pad | Designed MJG | Date 10-16-87
Item PCC Pavement Design | Checked [illegible] | Date 11-6-87

Calculations

- Determine Equivalent Axle Loads (EAL) of each pass of haul truck

single axle load ~ $\frac{33.4}{82} \times 10^k = 4.07^k$

tandem axle load ~ $\frac{33.4}{82} \times 36 = 14.66^k$

Axle Load (kips)	Equivalence Factor *
14.66	0.06
4.07	0.002

EAL / pass of unloaded haul truck = 2 x 0.06 + .002 = 0.122

* See Table 1 (slab thickness = 7 in assumed. Calculation is not revised because bearing pressure of dowel on concrete controls).

AASHO Equivalence Factors - Rigid Pavement

TABLE 4.10. (continued)

Single Axles, $p_t = 2.5$

Axle Load (kips)	D—Slab Thickness (in.) 6	7	8	9	10	11
2	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
4	0.003	0.002	0.002	0.002	0.002	0.002
6	0.01	0.01	0.01	0.01	0.01	0.01
8	0.04	0.04	0.03	0.03	0.03	0.03
10	0.10	0.09	0.08	0.08	0.08	0.08
12	0.20	0.19	0.18	0.18	0.18	0.17
14	0.38	0.36	0.35	0.34	0.34	0.34
16	0.63	0.62	0.61	0.60	0.60	0.60
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.51	1.52	1.55	1.57	1.58	1.58
22	2.21	2.20	2.28	2.34	2.38	2.40
24	3.16	3.10	3.23	3.36	3.45	3.50
26	4.41	4.26	4.42	4.67	4.85	4.95
28	6.05	5.76	5.92	6.29	6.61	6.81
30	8.16	7.67	7.79	8.28	8.79	9.14
32	10.81	10.06	10.10	10.70	11.43	11.99
34	14.12	13.04	12.94	13.62	14.59	15.43
36	18.20	16.69	16.41	17.12	18.33	19.52
38	23.15	21.14	20.61	21.31	22.74	24.31
40	29.11	26.49	25.65	26.29	27.91	29.90

Tandem Axles, $p_t = 2.5$

Axle Load (kips)	D—Slab Thickness (in.) 6	7	8	9	10	11
10	0.01	0.01	0.01	0.01	0.01	0.01
12	0.03	0.03	0.03	0.03	0.03	0.03
14	0.06	0.05	0.05	0.05	0.05	0.05
16	0.10	0.09	0.08	0.08	0.08	0.08
18	0.16	0.14	0.14	0.13	0.13	0.13
20	0.23	0.22	0.21	0.21	0.20	0.20
22	0.34	0.32	0.31	0.31	0.30	0.30
24	0.48	0.46	0.45	0.44	0.44	0.44
26	0.64	0.64	0.63	0.62	0.62	0.62
28	0.85	0.85	0.85	0.85	0.85	0.85
30	1.11	1.12	1.13	1.14	1.14	1.14
32	1.43	1.44	1.47	1.49	1.50	1.51
34	1.82	1.82	1.87	1.92	1.95	1.96
36	2.29	2.27	2.35	2.43	2.48	2.51
38	2.85	2.80	2.91	3.04	3.12	3.16
40	3.52	3.42	3.55	3.74	3.87	3.94
42	4.32	4.16	4.30	4.55	4.74	4.86
44	5.26	5.01	5.16	5.48	5.75	5.92
46	6.36	6.01	6.14	6.53	6.90	7.14
48	7.64	7.16	7.27	7.73	8.21	8.55

Table 1 (Ref #4, pg 167.)

- Calculate total EAL's

0.122 × 6283 passes = 767 EAL's

- Calculate stress ratio

From table 3, the stress ratio is about 0.73.

- Calculate tensile stress in slab, required tensile strength and design cylinder strength

Slab Thickness (in)	Tensile Stress[1] (psi)	Tensile Strength[2] (psi)	f'_c[3] (psi)
4	330	452	3192
5	250	342	1828
6	170	233	848

Table 2

Notes

1. See Figure 1 (values are extrapolated).
2. Tensile strength = tensile stress / stress ratio
3. f'_c = (tensile strength / 8)^2 - see assumption # 10

TABLE 17.1. Stress Ratios Allowable Load Repetitions[a]

Stress[b] Ratio	Allowable Repetition	Stress Ratio	Allowable Repetition
0.51[c]	400,000	0.69	2,500
0.52	300,000	0.70	2,000
0.53	240,000	0.71	1,500
0.54	180,000	0.72	1,100
0.55	130,000	0.73	850
0.56	100,000	0.74	650
0.57	75,000	0.75	490
0.58	57,000	0.76	360
0.59	42,000	0.77	270
0.60	32,000	0.78	210
0.61	24,000	0.79	160
0.62	18,000	0.80	120
0.63	14,000	0.81	90
0.64	11,000	0.82	70
0.65	8,000	0.83	50
0.66	6,000	0.84	40
0.67	4,500	0.85	30
0.68	3,500		

[a] From Portland Cement Association.
[b] Load stress divided by modulus of rupture.
[c] Unlimited repetitions for stress ratios of 0.50 or less.

Table 3

(Reference 4, pg. 603)

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN — Contract No. 5057-05 — Sheet 9/14 — File No.

Feature: Decon Pad — Designed: M.J.C. — Date: 10-16-87

Item: PCC Pavement Design — Checked: [signature] — Date: 11-6-87

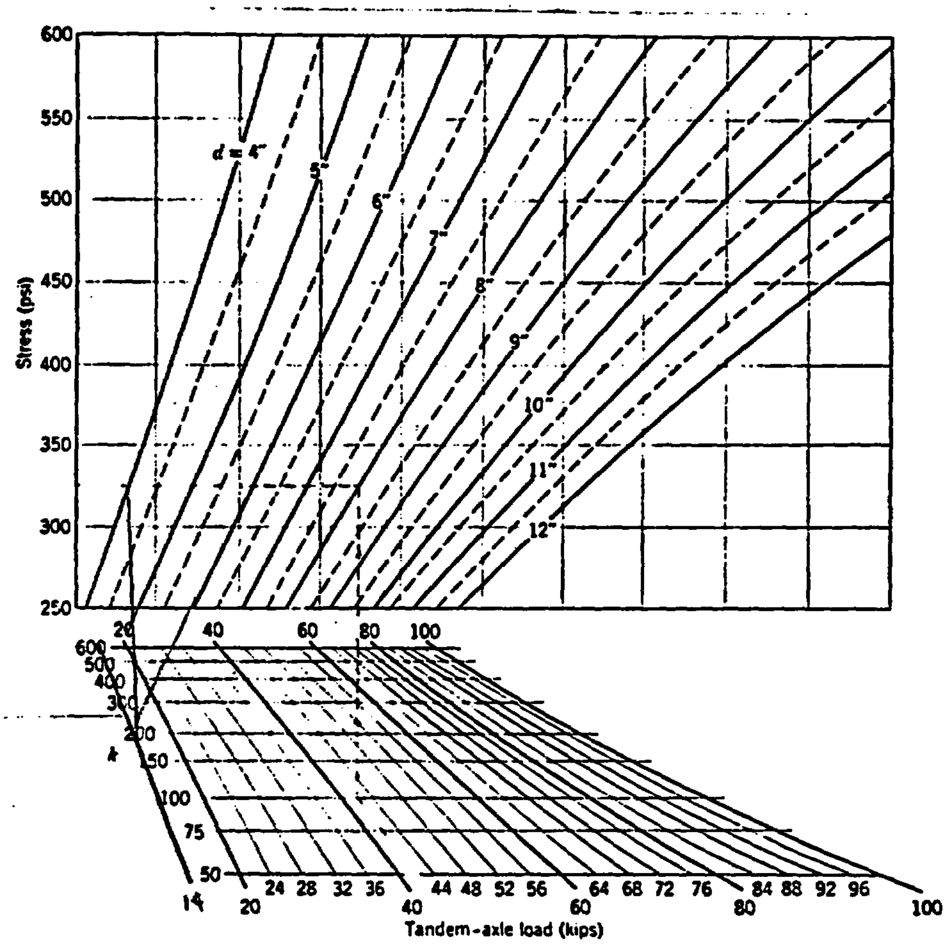


Figure 17.3. Design chart for tandem-axle truck loads. (From Portland Cement Association.)

Figure 1

(Reference 4, page 605)

- Select Temperature Reinforcement

$$A_s = \frac{W f L}{2 f_s}$$ (ref. 4, p. 91)

in which

A_s : required steel area (in² / ft of slab width)

W = weight of slab (lb / ft² of surface area)

f = 1.5

L = greatest uncracked slab dimension (ft)

f_s = allowable steel stress (psi)

Assume:

$$W = \frac{6''}{12''}[145 \text{ psf}] = 72.5 \text{ lb/ft}^2$$

L = 30'

f_s = 43000 psi (f_y = 65 ksi)

$$A_s = \frac{(96.7)(1.5)(30)}{(2)(43{,}000)} = 0.038 \text{ in}^2$$

Use 4x4 W1.4xW1.4 weld wire fabric* (0.04 in² / ft of width

* Note maximum spacing of joints shall not exceed 30 feet

- Size dowels

$$l = \left(\frac{EH^3}{12(1-\mu^2)k} \right)^{1/4}$$

in which

E = concrete modulus

H = pavement thickness

μ = Poissons ratio of concrete

k = subgrade modulus

Assume:

E = 3×10^6 psi

H = 6"

μ = 0.15

k = 200 pci

$$l = \left[\frac{(3\times10^6)(6)^3}{12(1-.15^2)(200)} \right]^{1/4} = 22.93"$$ (ref 4, pg 83)

$1.8 l$ = 41.27"

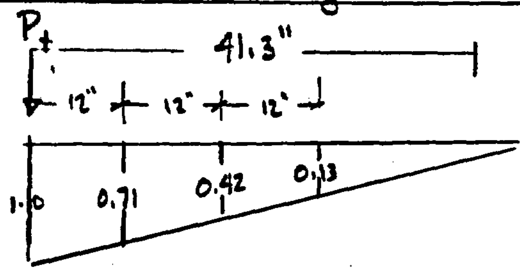
Assume 50% load transfer by dowels across joints:

Therefore, design load on dowel is $\frac{1}{2}^{*}\left[\frac{1}{2}(14.66^k)\right] = 3.67^k$

Assume dowel spacing = 12"

dowel diameter = 1.0"

* ½ of axle load



$1.0 + 0.71 + 0.42 + 0.13 = 2.26$ equivalent dowels

P_t = Load on edge dowel = $3.67^k / 2.26 = 1.62^k$

$$\beta = \left[\frac{Kb}{4EI}\right]^{1/4}$$ (ref 4 pg. 98)

in which

K = dowel modulus of support

b = dowel diameter

E = dowel modulus

I = dowel moment of inertia

assume

$K = 1.5 \times 10^6$ psi
$b = 1.0"$
$E = 29 \times 10^6$ psi

$I = \pi r^4/4 = 3.14\left(\frac{1}{2}\right)^4/4 = .0491 \text{ in}^4$

$$\beta = \left[\frac{(1.5 \times 10^6)(1.0)}{4(29 \times 10^6)(.0491)}\right]^{1/4} = \underline{0.7164} \text{ in}^{-1}$$

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UNTEA- GEN		Sheet: 14/14	
Feature: Lecon Pad	Contract No. 5057-05	File No.	
Item: PCC Pavement Design	Designed: MJG	Date: 10-16-87	
	Checked: p.k Ch	Date: 11-6-87	

$$y_0 = \frac{P_t}{4\beta^3 EI}(2+\beta z)$$ (Ref 4, pg. 99)

in which

z = joint width

assume $z = 0.25"$

$$y_0 = \frac{1.62}{4(.716)^3(29{,}000)(.049)}\left[2+(.716)(.25)\right] = 0.00169$$

← applied bearing pressure of dowel on concrete.

$\sigma = K y_0$ (Ref 4, pg. 99)

$= (1.5\times10^6)(.00169)$

$= 2538$ psf

- allowable bearing pressure of dowel on concrete

$f_b = \left(\frac{4-b}{3}\right) f'_c$ (ref 4, pg. 103)

therefore minimum $f'_c \geq \left(\frac{3}{4-b}\right) f_b = \frac{3}{4-1}(2538) \cdot$ 2538 psf

⟹ use 1"-diam, 18" long dowels @ 12" spacing.

pavement slab shall be at least 8" thick and

shall use $f'_c \geq 2600$ psi

(For length of dowels, see ref 4, pg 102)