WM-68
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PANT 6086

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

GREEN RIVER, UTAH

DRAFT

Completion Report

VOLUME 4C
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-01-00721-00

Calculation Cover Sheet

Contract No. 5057-05 **Discipline** UMTRA/ESCI **Calc. No.** 10-536-09-00

No. of Sheets ~~6~~7

Project

Green River, Utah UMTRA site

Feature

Durability of Rock Borrow

Item

Fremont Junction, Utah Source

~~Sources of Data~~

~~Sources of Formulae &~~ References

1. "Selection of the Best Available Rock", NRC, supplied to MKE by Ted Johnson and amended verbally 24 November 1987.
2. MKE Document 5057-GRN-K-01-00546-00, "Riprap Borrow Source Evaluation Progress Report", 28 December 1987.
3. "Additional Laboratory Rock Tests", by Chen and Associates, 3 February 1988, MKE document # 5057-GRN-L-09-00671-00.
4. "Laboratory Rock Tests", by Chen and Associates, 31 December 1987, MKE Document # 5057-GRN-L-09-00568-00.

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

0	—	Martin J. [illegible]	2/16/88	P.K. Chen	2/16/88	P.K. Chen	2/16/88
Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date

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Sheet ii
Project UMTRA - GRN
Contract No. 5057-05
File No.
Feature Durability of Rock Borrow
Designed MJG
Date 2/12/88
Item Fremont Junction, Utah Source
Checked RKC
Date 2/15/88

References (cont)

5. "Laboratory Testing, UMTRAP, Green River, Utah Site", by Chen & Associates, 5 February 1988, MKE document # 5057-GRN-C-09-00667-00.

Sheet 1/6
Project UMTRA-GRN
Contract No. 5057-05
File No.
Feature Durability of Proposed Rock Borrow
Designed MJG
Date 2/12/88
Item Fremont Junction, Utah Source
Checked pfc
Date 2/16/88

Purpose

Evaluate durability of rock from the proposed Fremont Junction, Utah borrow source using NRC rock durability scoring system (see reference # 1).

INTRODUCTION

The RAC has performed a substantial field/laboratory investigation to identify a rock borrow source that satisfies project requirements for cost, quantity, gradation, and durability. The investigation is partially summarized in the "Riprap Borrow Source Evaluation Progress Report" (Reference #2). Subsequent lab testing was performed to evaluate durability of rock from the Fremont Juntion, Utah source (see references #3, #4 and #5). This lab testing was performed on two types of samples, i.e.;

- bulk samples obtained with a backhoe from existing test pits
- hand picked samples.

Hand-picked samples were obtaned in order to provide sufficient quantities of each constituent rock type for separate testing.

Locations of the test pits are indicated on Figure #1.

PROPOSED ROCK BORROW SOURCE LIMITS - FREMONT JUNCTION

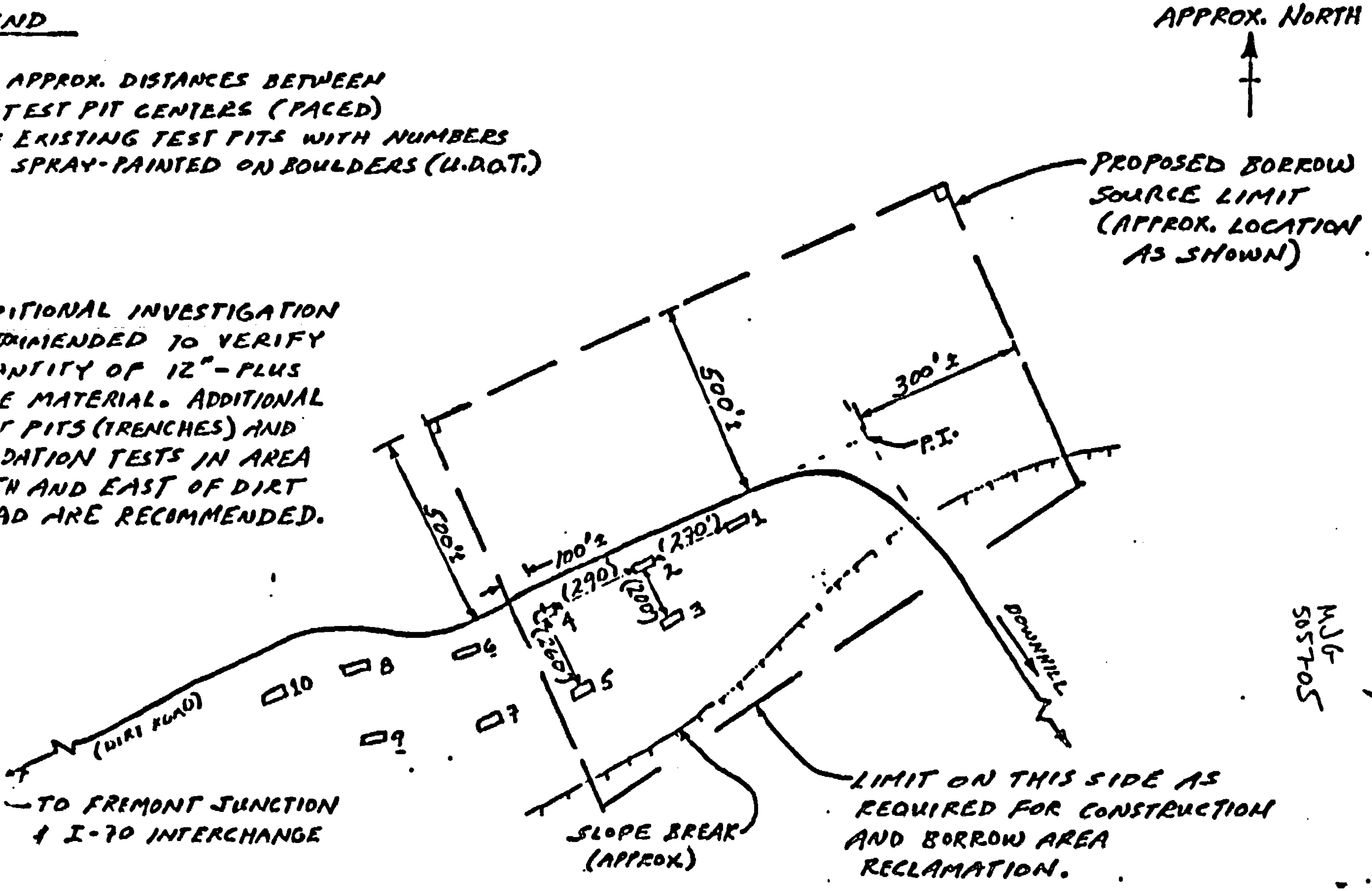
(SKETCH - NOT TO SCALE)

ND

( ) = APPROX. DISTANCES BETWEEN TEST PIT CENTERS (PACED)

▭ 10 = EXISTING TEST PITS WITH NUMBERS SPRAY-PAINTED ON BOULDERS (U.D.O.T.)

ADDITIONAL INVESTIGATION RECOMMENDED TO VERIFY QUANTITY OF 12"-PLUS SIZE MATERIAL. ADDITIONAL TEST PITS (TRENCHES) AND GRADATION TESTS IN AREA NORTH AND EAST OF DIRT ROAD ARE RECOMMENDED.



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Project UMTRA - GEN
Feature EROSION PROTECTION
Item BORROW SOURCES
Contract No. 5057
Designed FRS
Checked DKC
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Date 2/16/88

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Project UMTRA-GRN
Feature Durability of Rock Borrow
Item Fremont Junction, Utah Source
Contract No. 5057-05
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RESULTS

Calculation of durability scores is shown on Tables 1, 2 and 3.

Average durability scores are tabulated below:

Rock Type	Durability Score
Basalt	78.9
Quartzite	75.6 *
Sandstone	40.9

* based on one sample.

The following LA Abrasion tests were performed:

1. 8:1 by weight composite of basalt to quartzite (reference #4)
   LA Index = 10.1
2. 8:1:1 by weight composite of basalt: quartzite: sandstone (reference #3)
   LA index = 8.2

LA Abrasion test results were not incorporated in scoring of durability because the NRC scoring system (reference #1) does not have a procedure for scoring specimens composited from different rock categories.

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Project [illegible]
Feature [illegible] of Frozen Rock Porosity
Item [illegible] Junction, Utah [illegible]
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Sample	Rock Type	(SSD) Specific Gravity			Absorption			LA Abrasion (100 cycles)			(5 cycles) Sodium Sulfate Soundness			Schmidt Hammer[1]			Tensile strength			Score
		V	S	W	V	S	W	V	S	W	V	S	W	V	S	W	V	S	W	
TP-2A	Basalt	2.588	6.8	9	1.333	4.3	2	—	—	—	4.5	8.2	11	—	—	—	—	—	—	72.7
TP-2B	Basalt	2.568	6.4	9	1.91	3.2	2	5.5	7.7	1	1.2	9.9	11	44	5.5	3	728	6.4	10	72.5
TP-3A	Basalt & Granite	2.643	7.8	9	1.38	4.2	2	—	—	—	3.2	8.9	11	—	—	—	—	—	—	80.2
TP-3B	Basalt	2.632	7.6	9	1.76	3.5	2	—	—	—	1.7	9.6	11	—	—	—	1308	9.5	10	86.3
TP-5A	Basalt	2.651	8	9	1.986	4	2	6.4	7.2	1	3.9	8.5	11	—	—	—	—	—	—	78.6
TP-5B	Basalt/Dacite	2.585	6.9	9	1.739	3.5	2	6.7	7	1	3.7	8.6	11	48/–	6.1/–	3/–	1133/1394	8.7/10	10/10	76.7/82.
Handpicked[2]	Basalt	2.61	7.2	9	1.7	3.6	2	—	—	—	1.6	9.7	11	—	—	—	—	—	—	81.2
Handpicked[3]	Basalt	2.58	6.6	9	1.9	3.2	2	—	—	—	1.0	10	11	—	—	—	—	—	—	79.9

All test values are from reference #5 except as noted.

V = Value
S = Score
W = Weight

Notes

1. Schmidt Hardness test was performed by RAC onsite at time of sampling.
2. Reference #3
3. Reference #4

TABLE 1

Durability Scores - Basalt Samples

Sample	Rock Type	Specific Gravity (SSD)			Absorption			Sulfate Soundness (5 cycles)			Score
		V	S	W	V	S	W	V	S	W	
Handpicked[1]	Quartzite	2.61	7.2	9	1.3	4.4	2	—	—	—	——[3]
Handpicked[2]	Quartzite	2.62	7.4	9	1.1	4.8	2	4.7	8.2	11	75.6

Notes:

1. Reference #3
2. Reference #4
3. Sample was not scored because an insufficient number of tests were performed.

V = test value

S = score

W = weight

TABLE 2

Durability Scores - Quartzite Samples

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Project UMTRA-GEN
Feature Durability of Proposed Rock Borrow
Item Fremont Junction, Utah Source
Contract No. 5057-05
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Checked
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Date 2/16/88

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Project UMTRA-GRN
Feature Durability of Proposed Riprap Borrow
Item Fremont Junction, Utah Source
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Designed HJG Date 2/12/89
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SAMPLE	ROCK TYPE	Specific Gravity (SSD)			Absorption			Sulfate Soundness (5 cycles)			SCORE
		V	S	W	V	S	W	V	S	W	
Handpicked[1]	Sandstone	2.55	6.0	5	2.2	2.6	5	—	—	—	43.0
Handpicked[2]	Sandstone	2.58	6.6	5 ✓	1.8	3.5	5 ✓	38.6	0 ✓	3 ✓	38.8

Notes

1. Reference #3
2. Reference #4

V = test value
S = durability score
W = weight

TABLE 3

Durability Scores - Sandstone Samples

MKE DOCUMENT NO.5057-GRN-C-01-00888-00

Calculation Cover Sheet

Contract No. 5057-05 Discipline UMTRA - ESCI Calc. No. 10-474-01-00

No. of Sheets ~~17 + Appendix~~ 21 W

Project Green River, Utah

Feature Riprap

Item Fremont Junction Borrow Source

Sources of Data & References

1. MKE Document # 5057-GRN-R-01-00352-01

2. MKE Document # 5057-GRN-L-09-00842-00

~~Sources of Formulae & References~~

3. MKE Document # 5057-GRN-R-01-00706-00, "UMTRA Project - Green River, Utah Subcontract Documents GRN Final Design For Construction", February 1988.

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

0	—	Martin J. Goodman	5/9/88	J Carcone	5/10/88	D. K. Chan	5/11/88
Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date

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Project UMTRA - GRN
Feature Riprap
Item Fremont Junction Borrow Source

Contract No. 5057-05
Designed MJG
Checked JAC.

Sheet 1/17
File No.
Date 5/9/88
Date 5/10/88

PURPOSE

Estimate the quantity of rock available at the Fremont Junction borrow source that is suitable for use as Type 2 riprap.

INTRODUCTION

Four distinct borrow areas (Areas A, B, C and D) are present at the Fremont Junction, Utah source. These areas are described in reference 1. Gradation tests performed on samples from these areas are presented in ref 2 and appended herein. Although the samples tested were generally representative of the proposed borrow areas, the samples were not large enough to accurately represent the proportion of rocks with a nominal dimension greater than 25 inches. Therefore, a visual estimate was made of the quantity of rocks in this size range. These estimates, presented in reference 1, are repeated in Table I.

Project specifications prohibit rock with a nominal size, D, smaller than 10 inches or larger than 36 inches (ref 3). Therefore, all material smaller than D = 10" or greater than D = 36" will be separated and discarded.

Project UMTRA / GRN
Feature Riprap
Item Fremont Junction Borrow Source
Contract No. 5057-05
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ASSUMPTIONS

1. Gradation of materials with a nominal dimension D < 25" is satisfactorily represented by the following gradations:

Area	Exploration Trench *
A	MK-5
B	MK-3
C	UDOT-4
D	MK-3

* Gradations are presented in ref 2. Applicability of gradations is discussed in ref 1.

2. The total insitu volume of material at the site may be estimated using the following data:

Area	Mineable Thickness (ft)	Area (acres)	Volume (yd³) - V_T
A	4 ½	15.6	113,256
B	5	16	129,066
C	5	17	137,133
D	4.5	22	159,720

} see reference #1

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Project UMTRA - GRN
Feature Riprap
Item Fremont Junction Borrow Source

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Assumptions (cont)

3. The visual estimate (ref 1) of riprap volume for material with a nominal dimension greater than 25-inch is presented in Table I.

4. The "placed" volume of the useable portion of the insitu material will approximately equal the volume of the useable material taken from the borrow areas.

5. About 50% by weight of borrow material with a nominal dimension of $32'' < D < 48''$ has a nominal dimension $32'' < D < 36''$ inches.

6. The overall dimensions of rock at the source generally follow the ratios given below:

$D : 1.4D : 1.6D$ for $D < 25$ in

$D : 1.2D : 1.4D$ for $D > 25$ in

in which

D = minimum nominal dimension of a single rock

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Project UMTRA-GRN
Feature Riprap
Item Fremont Junction Borrow Source

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Designed [illegible]
Checked JAC

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Area	A Nominal Size Interval (in)	B Visual Estimate of Rock Volume (yd^3)[1]
A	32-48	630+
	32-36	315+ [2]
	25-32	6500
B	32-48	630+
	32-36	315+ [2]
	25-32	5500
C	32-48	630+
	32-36	315+ [2]
	25-32	5500
D	32-48	2070 [3]
	32-36	1035 [2]
	25-32	6500

NOTES

1. Visual estimates of volume are actual rock volumes (see ref 1)
2. See Assumption 5, sheet 3
3. Estimated based on 900 rocks with average nominal dimension of 40-in.

TABLE I - Visual Estimate of Rock Quantity w/ D > 25"

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Project UMTRA - GRN
Feature Riprap
Item Fremont Junction Borrow Source
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ASSUMPTIONS (cont)

6. (cont) It follows, therefore, that the volume of a rock with a nominal dimension D would be:

$$V_R = D \times 1.4D \times 1.6D / (1728 \times 27) = 4.8E\text{-}5 \times D^3 \qquad [D < 25'']$$

$$V_R = D \times 1.2D \times 1.4D / (1728 \times 27) = 3.6E\text{-}5\ D^3 \qquad [D > 25'']$$

in which $[D] = in$ and $[V_R] = yd^3$

7. The percentage by weight of material with a nominal dimension $10 < D < 12$ inches is equal to one-third of the percentage by weight of material with a nominal dimension $6 < D < 12$-inch.

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Feature Riprap
Item Fremont Junction Borrow Source
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Date 8/10/88

CALCULATIONS

- Determine percentage of each size range as follows:

A) % by volume larger than 25-in $= \frac{V_{25+}}{V_T} \times 100$

in which V_{25+} = Volume of rock larger than 25" in nominal dimension

V_T = Total volume of borrow (including voids)

B) Percentages measured in size intervals smaller than 25-inch should be adjusted to account for the percentage of particles larger than 25-inches as follows.

% in size interval = [% measured in interval] x [(100 − % larger than 25-in)/100]

in which

% measured in interval is obtained from ref 2.

Results of these calculations are presented in Tables II, III, IV and V.

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Project UMTRA-GEN
Feature Riprap
Item Fremont Junction Borrow Source
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TABLE II - AREA A

Nom Size Interval (in)	Percentage In Interval (%)	Rock Volume In Interval (yd³)[3]
36-48[1]	0.28	317[1]
32-36[1]	0.28	317[1]
25-32[1]	5.74	6500[1]
18-25	7.36	8336
15-18	6.67	7554
12-15	4.14	4689
(10-12)	(5.90)[2]	(6682)[2]
6-12	17.71	20,058
6⁻	57.82	65485

Discard

Usable Portion

Discard

Based on Visual Estimate ↑

↓ Based on Gradation Tests

Notes:
1. See Table I
2. Assume 1/3 of mat'l with $6 < D < 12"$ is contained in $10 < D < 12"$ interval
3. Volume of rock solids.

TABLE III - AREA 3

Nominal Size Interval (in)	Percentage In Interval (%)	Volume In Interval (yd³) [3]
36-48	0.24	315 [1]
32-36	0.24	315 [1]
25-32	4.26	5500 [1]
18-25	2.88	3717
15-18	2.52	3252
12-15	3.52	4543
(10-12)	(3.15) [2]	(4066) [2]
6-12	9.45	12196
6⁻	76.89	99238

NOTES: See Notes 1-3 on Table II, sheet 7.

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Project [illegible]
Feature [illegible] Coal
Item [illegible] Borrow Source
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Designed [illegible]
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Date 5/9/85
Date

TABLE IV - AREA C

Nominal Size Interval (in)	Percentage In Interval (%)	Rock Volume In Interval (yd³) [3]
36-48	0.23	315 [1]
32-36	0.23	315 [1]
25-32	4.01	5500 [1]
18-25	0	0
15-18	2.72	3730
12-15	5.08	6966
(10-12)	(5.99) [2]	(8214) [2]
6-12	17.97	24643
6-	69.76	95664

NOTES: See Notes 1-3 on Table II, sheet 7

TABLE V - AREA D

Nominal Size Interval (in)	Percentage In Interval (%)	Volume In Interval (yd³)[3]
36-48	0.65	1035[1]
32-36	0.65	1035[1]
25-32	4.07	6500[1]
18-25	2.86	4568
15-18	2.51	4009
12-15	3.49	5574
(10-12)	(3.13)[2]	(4999)[2]
6-12	9.39	14998
6⁻	76.39	122010

NOTES: See Notes 1-3 on Table II, sheet 7.

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Project [illegible]
Feature [illegible]
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Project UMTRA - GRN
Feature Riprap
Item Fremont Junction Borrow Source
Contract No. 5057-05
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Checked JAC
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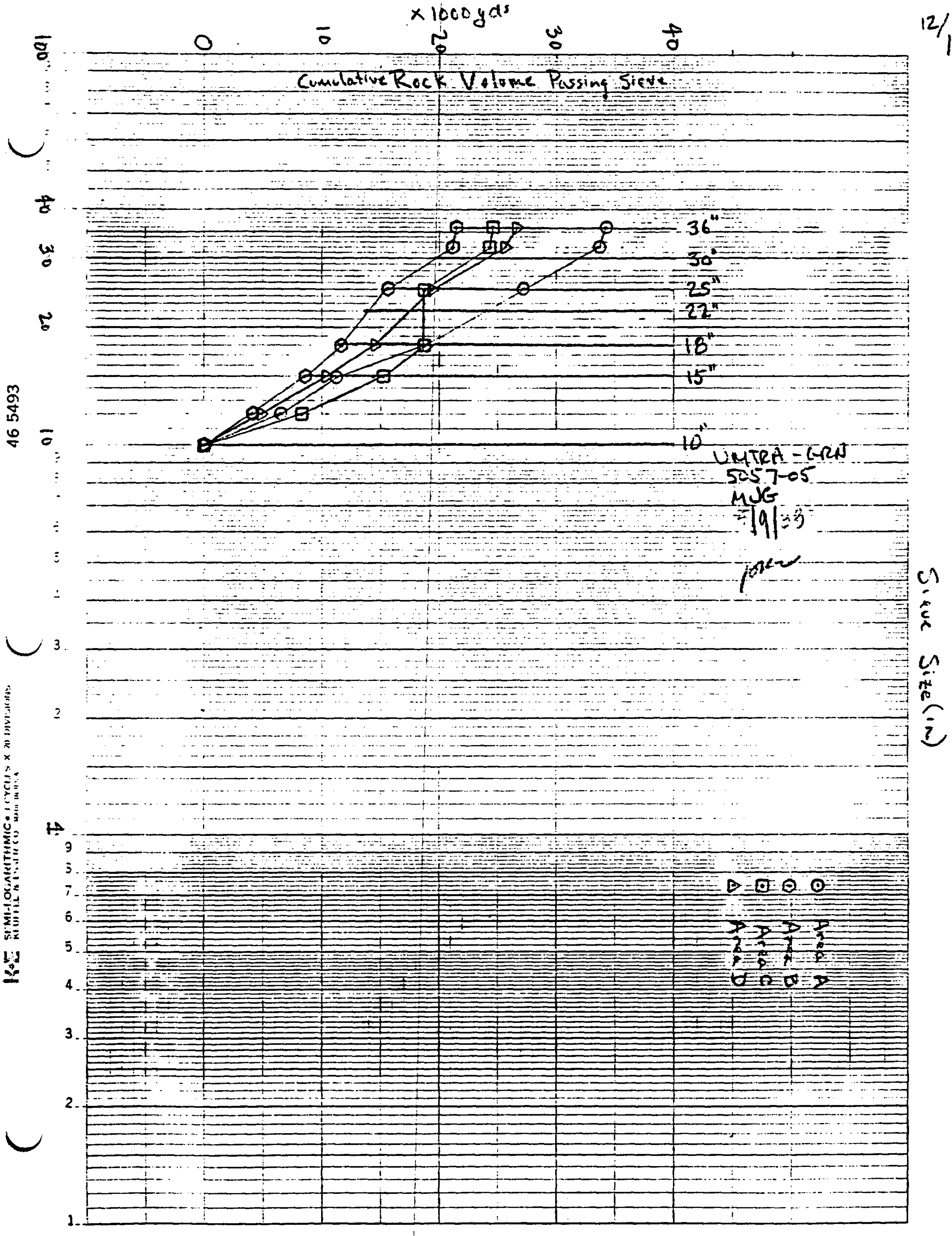
RESULTS

The quantity of suitable rock available at the Fremont Junction source is tabulated below:

AREA	SIZE INTERVAL (in)	ROCK VOLUME (yd^3)	
A	32-36	315	$\Sigma = 34078 yd^3$
	25-32	6500	
	18-25	8336	
	15-18	7554	
	12-15	4699	
	10-12	6682	
B	32-36	315	$\Sigma = 21393 yd^3$
	25-32	5500	
	18-25	3717	
	15-18	3252	
	12-15	4543	
	10-12	4066	
C	32-36	315	$\Sigma = 24725 yd^3$
	25-32	5500	
	18-25	0	
	15-18	3730	
	12-15	6966	
	10-12	8214	
D	32-36	1035	$\Sigma = 26685 yd^3$
	25-32	6500	
	18-25	4568	
	15-18	4009	
	12-15	5574	
	10-12	4999	

These data are plotted as a cumulative volume passing plot in Figure 1. Figure 1 is used to estimate the available rock volume in each size interval specified in the bid package (ref 3). These volumes are tabulated on Table VI.



UMTRA-GRN
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7/9/93

Figure 1

Sheet 13/17
Project UMTRA-GRN
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Date 5/9/88
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Nominal Size Interval (in)	Available Volume * (yd³) Area A	B	C	D	Σ
30-36	2200	1600	1500	2400	7700
25-30	4900	4500	4200	4500	18,100
22-25	3000	1500	0	1600	6100
18-22	5500	2300	0	3000	10,800
15-18	3600	3200	3200	4200	14,200
10-15	15,100	8500	15,200	10,300	49,100
Σ -	34,300	21,600	24,100	26,000	106,000

* Volume totals in this table are slightly different than those shown on sheet 11 because the volumes are estimated from Figure 1 (sheet 12).

TABLE VI - Available Rock Volume

Project UMTRA-GRN
Feature Riprap
Item Fremont Junction Borrow Source
Contract No. 5057-05
Designed [illegible]
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Date 5/10/88

The "coarse" bound gradation and the "fine" bound gradation included in project specifications (ref 3) as well as an "intermediate" gradation are used herein to evaluate if available rock volume satisfies project gradation requirements. These gradations (and the associated volumes) are presented in the following table and in Figure 2.

Nominal Dimension (in)	Coarse Bound Gradation			Intermediate Gradation			Fine Bound Gradation		
	A	B	C	A	B	C	A	B	C
36	100			100			100		
		4	748		2	374		0	0
30	96			98			100		
		34	6538		17	3179		0	0
25	62			81			100		
		16	2992		10	1870		5	935
22	46			71			95		
		14	2618		30	5610		45	8415
18	32			41			50		
		12	2244		12	2244		12	2244
15	20			29			38		
		20	3740		14	2618		28	5236
10	0			5			10		

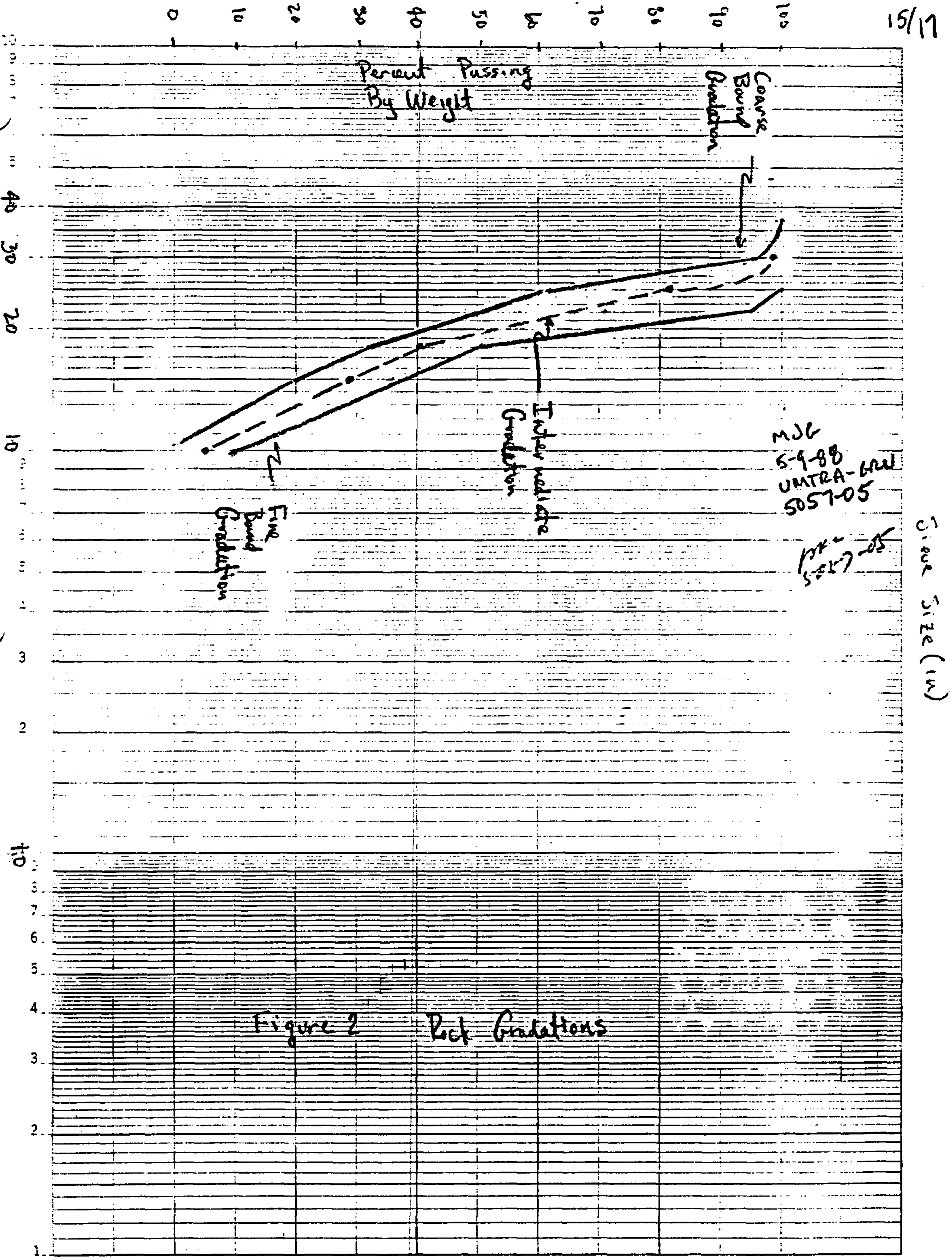
where

A = percent passing

B = percentage in interval

C = volume in interval (yd^3)

TABLE VII - Required Rock Volume



MJG
5-9-88
UMTRA-GRW
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Figure 2 Rock Gradations

Project UMTRA-GRN
Feature Riprap
Item Fremont Junction Borrow Source
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CONCLUSIONS

In order evaluate if the Fremont Junction borrow source contains sufficient material, the available volume (see Table VI) is compared to two benchmarks (1) the required rock volume (see Table VII) and (2) twice the required rock volume. [Based on UMTRA project experience, the estimated volume needs to be as much as twice the required volume to assure sufficient material is available].

- Borrow Material Satisfying coarse-bound gradation:
  1. The majority of Areas A, B, C and D will be required to produce twice the required rock volume
  2. Areas A and B alone could provide the rock volume if the 200% requirement is not applied.
- Borrow Material Satisfying Intermediate Gradation:
  1. The majority of Areas A, B, C and D will be required to produce twice the required rock volume.
  2. Area A alone can provide the required rock volume if the 200% requirement is not applied.
- Borrow Material Satisfying Fine-Bound Gradation:
  1. Due to shortage of material in the 18-in to 22-in range, only marginally more material than required by the project specifications is available at the borrow source.

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Project UMTRA - GRN
Feature Riprap
Item Fremont Junction Borrow Source

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CONCLUSIONS (cont)

Based on these individual conclusions, the borrow source should be able to provide sufficient material provided the contractor does not try to produce riprap with a gradation approaching the fine-bound gradation.

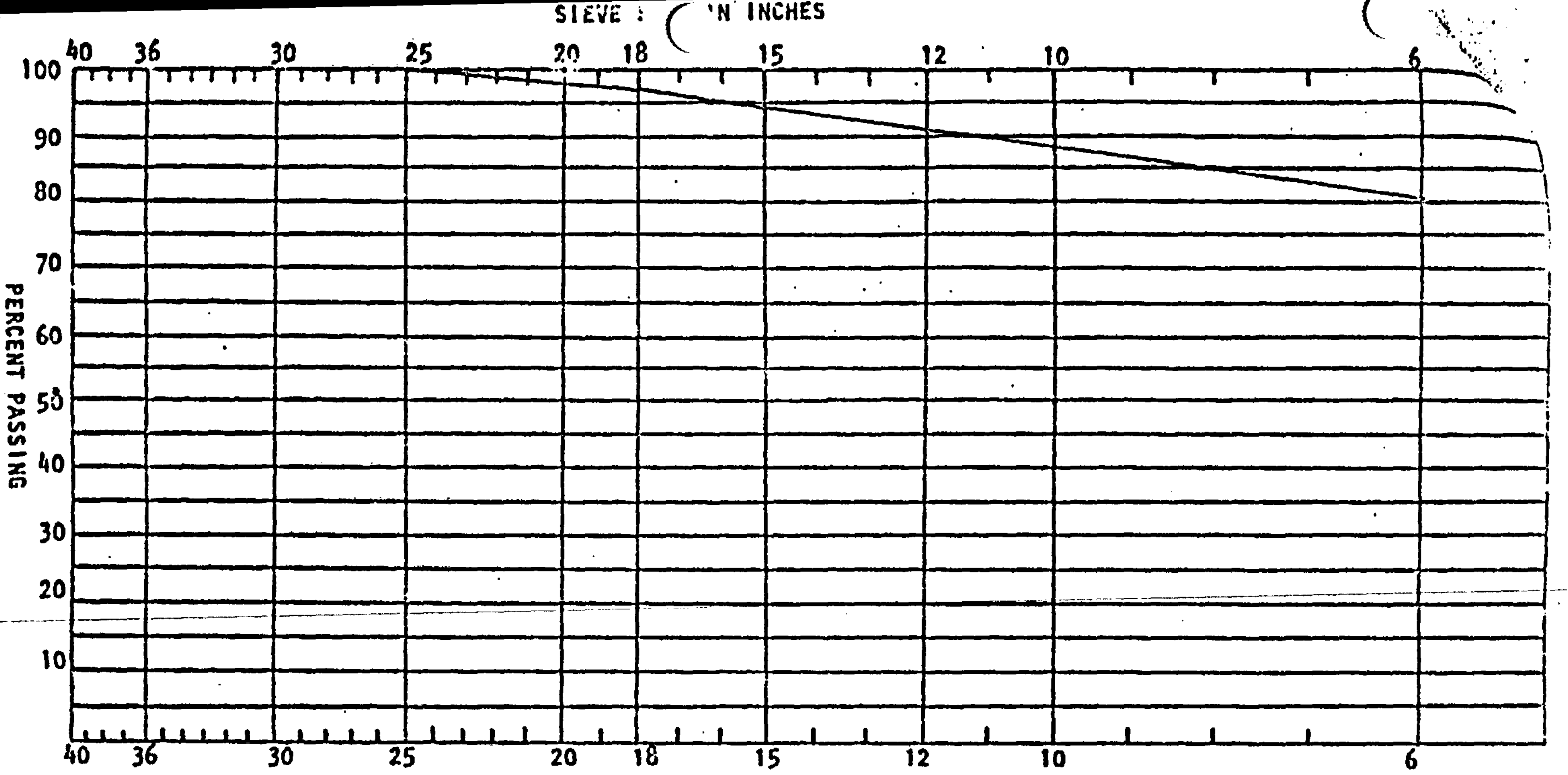
Project UMTRA-GRN
Feature Riprap
Item Fremont Junction, Borrow Source
Contract No. 6057-05
Designed MJG
Checked ✓
Sheet
File No.
Date 5 6 88
Date 5/10/88

APPENDIX

(3 pages)

Lambert and Associates

Project No.: M88026GE
Date: 4/22/88
Figure: B1



SIZE	INDIVIDUAL WEIGHT RETAINED	CUMULATIVE WEIGHT RETAINED	PERCENT PASSING
36"	0	0	
25"	0	0	100
18"	640	640	~~97~~ 96.98
15"	560	1200	~~94~~ 94.33
12"	780	1980	~~91~~ 90.64
6"	2100	4080	~~81~~ 80.72

3.02
2.65
3.69
9.92

UMTRA-GRN
5057-05
MJG
5/6/88

JHe
5/10/88

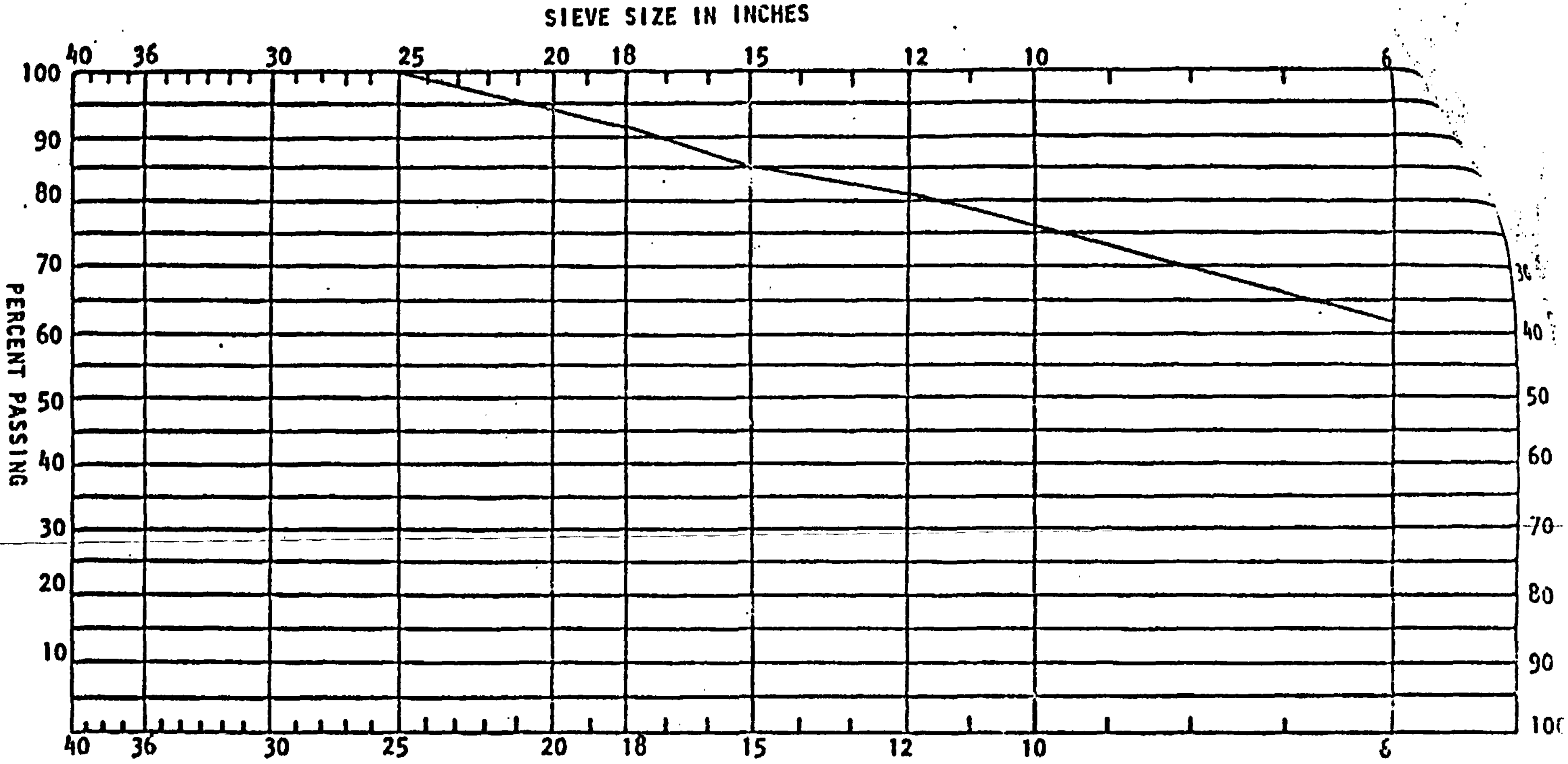
TOTAL SAMPLE WEIGHT
21,161 pounds

TEST HOLE MK-3

LABORATORY SAMPLE NUMBER: 22

Lambert and Associates

Project No.: M88026GE
Date: 4/22/88
Figure: B3



SIZE	INDIVIDUAL WEIGHT RETAINED	CUMULATIVE WEIGHT RETAINED	PERCENT PASSING
36"	0	0	
25"	0	0	100
18"	1280	1280	~~92~~ 92.15
15"	1160	2440	~~85~~ 85.03
12"	720	3160	~~81~~ 80.61
6"	3080	6240	~~62~~ 61.71

7.85
7.12
4.42
18.90

UMTRA-GRN
5057-05
MJG
6/16/93

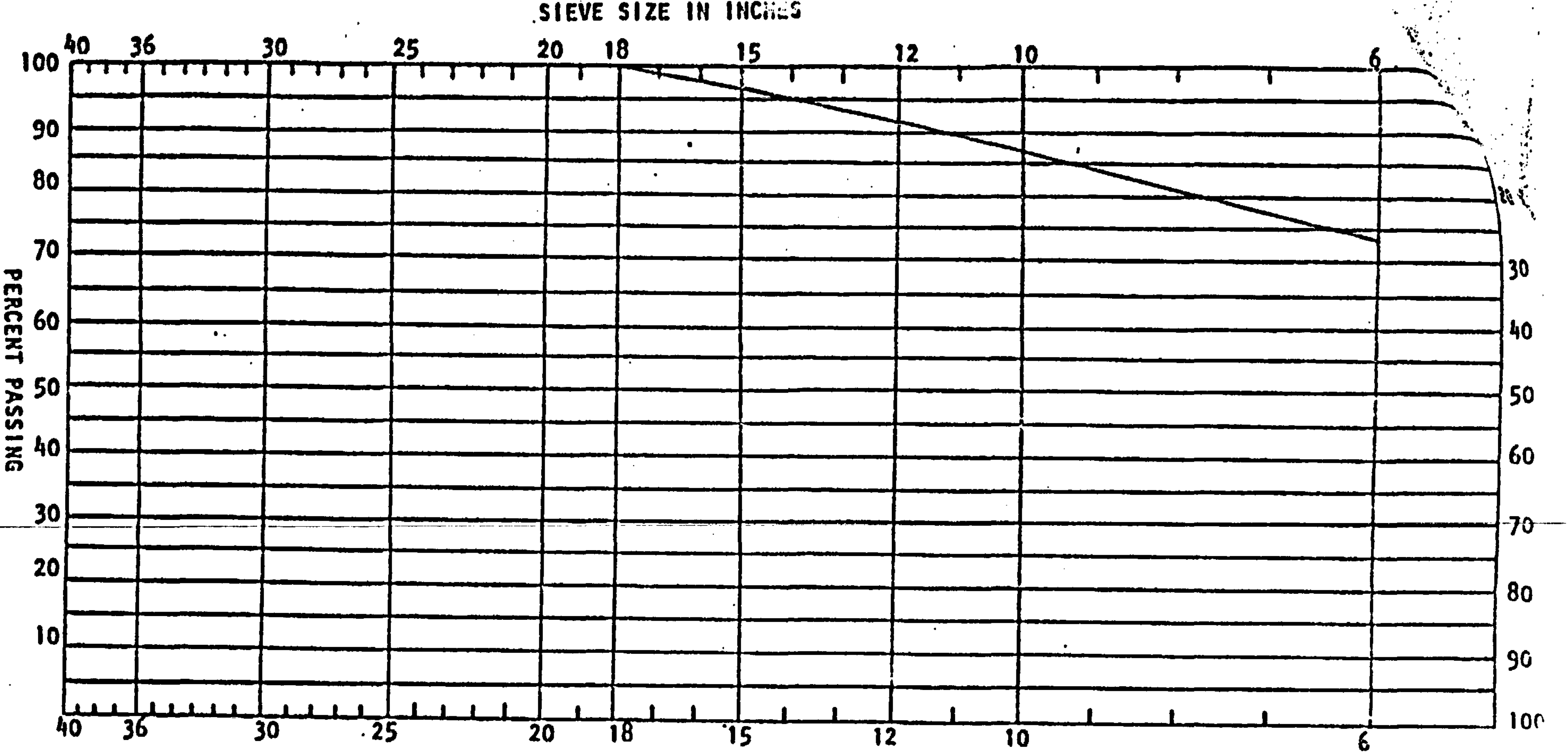
5/11/88

TOTAL SAMPLE WEIGHT
16,297 pounds

TEST HOLE MK-5

LABORATORY SAMPLE NUMBER: 2266

Lambert and Associates



SIZE	INDIVIDUAL WEIGHT RETAINED	CUMULATIVE WEIGHT RETAINED	PERCENT PASSING
36"	0	0	
25"	0	0	
18"	0	0	100
15"	460	460	~~97~~ 97.15
12"	860	1320	~~92~~ 91.83
6"	3040	4360	~~73~~ 73.02

2.85
5.32
18.81

UMTRA-GRJ
5057-05
M.T.
5/6/88

JRC
5/10/88

TOTAL SAMPLE WEIGHT
16,162 pounds

TEST HOLE UDOT 4

LABORATORY SAMPLE NUMBER: 226

Project No: MB8026GE
Date: 4/22/88
Figure: B4

Calculation Cover Sheet

Contract No. 5057-05 **Discipline** ESCI/UMTRA

Calc. No. 10-563-01-01

No. of Sheets ~~27~~ 26

(19, Appendix A/5, Appendix B/2)

Project UMTRA - GRN

Feature BEDDING MATERIAL - TOPSLOPE AND SIDESLOPES

Item GRADATION FOR MAXIMUM DRAINAGE CAPACITY WITHOUT SIGNIFICANT EROSION OF ADJACENT SOIL

Sources of Data

Sources of Formulae & References (SEE SHEET 'a' ALSO)

1. U.S. Office of Surface Mining, September 1982, Surface Mining Water Diversion Design Manual, OSM/TR-82/2, U.S. Government Printing Office, Washington D.C.
2. Israelsen, et. al., 1970, Tentative Design Procedure for Riprap-Lined Channels, NCHRP Report 108 Highway Research Board, National Academy of Sciences, Washington, D.C.
3. Morrison-Knudsen Engineers, January 1988, UMTRA Design Procedures, Rev. 6, San Francisco, California
4. U.S. Department of Energy, November, 1987, Technical Approach Document, 050425.0000, Revision 1, UMTRA Project Office, Albuquerque, New Mexico.

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

Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
1	Revised gradation to be adequate for	F.B. Guros	7-7-88	D.K. Che.	7/8/88	D.K. Che.	7/5/88
1	sideslopes (pp 1, 2, 2A 19-23, 3, 5, 7, 10, 16, 16A, & 16 B)	——		——		——	——
0	——	F.B. Guros	5-10-88	D.K. Che.	5/13/88	D.K. Che.	5/13/88

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Project UMTRA-GEN
Feature BEDDING GRADATION
Item

Contract No. 5057
Designed FBG
Checked

Sheet 9
File No.
Date 4-28-88
Date 5-5-88

REFERENCES (cont.)

5. Chow, V.T., 1959 Open-Channel Hydraulics, McGraw-Hill Book Co., New York.

6. Mitchell, J.K., 1976, Fundamentals of Soil Behavior, John Wiley and Sons, NY

7. Lambe, T.W., and Whitman, R.V., 1969 Soil Mechanics, John Wiley and Sons, New York.

8. U.S. Department of the Navy, May 1982, Soil Mechanics, NAVFAC DM-7.1, Alexandria, Virginia

9. Sherard, J.L., Dunnigan, L.P., and Talbot, J.R., June 1984, "Basic Properties of Sand and Gravel Filters", ASCE Journal of Geotechnical Engineering, Vol. 110, No. 6, p. 684.

10. Lee, D.W, et. al., November 1986, "Development of Riprap Design Criteria by Riprap Testing in Flumes: Phase I" NUREG/CR-4651, prepared by Colorado State University for U.S. Nuclear Regulatory Commission, Washington DC.

11. 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.GRNO, Albuquerque, New Mexico.

Project UMTRA- GRN
Feature BEDDING GRADATION
Item
Contract No. 5057
Designed FBG
Checked
Sheet 1*
File No.
Date 7-7-88
Date 8-1-88

REV. 1

SUMMARY: BEDDING FOR TOPSLOPES & SIDESLOPES

- The bedding material gradation given below (and shown graphically on p. 2) will significantly increase drainage capacity on the embankment slopes (top & sides) and will prevent significant erosion of adjacent soil (i.e., beneath the upper bedding layer and adjacent to the drain layer between the infiltration/radon barrier and frost barrier layer).
- Strict filter criteria are not used to determine gradation limits. (e.g. from Ref. 3). A limiting velocity analysis is used to protect against erosion and migration of soil through the bedding material.

SIZE	PERCENT PASSING
3"	100
1½"	95 - 100
½"	50 - 100
No. 4	18 - 58
No. 10	0 - 15
No. 20	0 - 5

DESIGN BEDDING MATERIAL GRADATION

<continued on sheet 1A>

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* Sheets 1, 1A, 2, & 2A supersede sheets 1 & 2 of Rev. 0
Sheets 1 & 2 of Rev. 0 have been renumbered as sheets 18A & 18B for Rev. 1.

Sheet 1A
Project UMTRA-GRN
Contract No. 5057
File No.
Feature BEDDING GRADATION
Designed FBG
Date 7-7-88
Item
Checked
Date 8-1-88

REV. 1

SUMMARY (CONT.)

- The frost protection layer is silty sand (as designed) and relatively permeable. Therefore, significant infiltration may occur into this layer regardless of the permeability of the bedding under the riprap. However, the revised bedding gradation should be used as a minimum for the drainage layer above the infiltration/radon barrier.
- This design assumes that a bedding material permeability of 0.25 cm/sec or greater provides adequate drainage, as discussed with TAC personnel.

LEGEND:

— — ⊡ - ANALYSIS CONTROL POINTS; $0.25 \le K \le 16 \frac{cm}{sec}$

— ⊗ - DESIGN CONTROL POINTS; $0.75 \le K \le 10 \frac{cm}{sec}$

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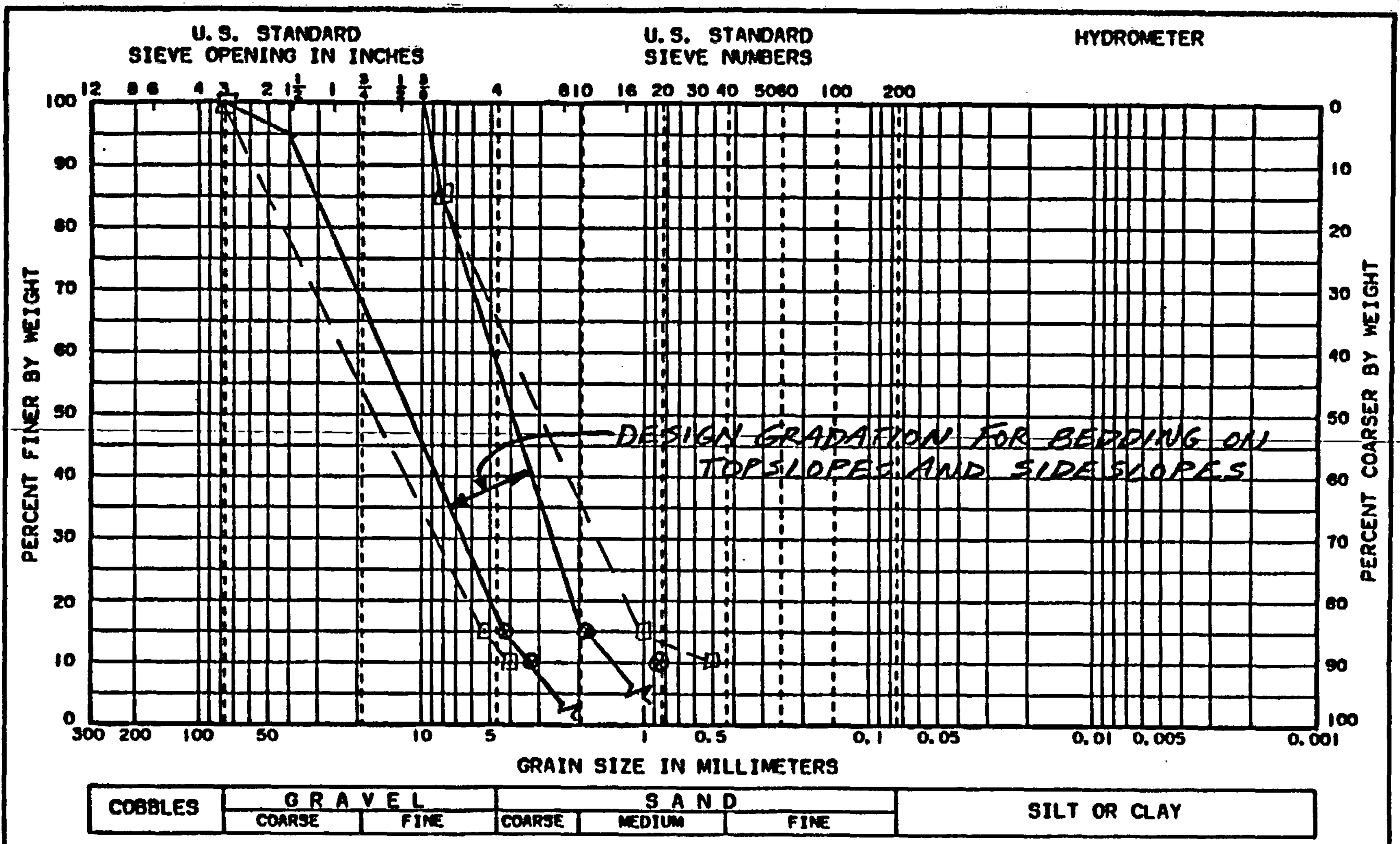
SUMMARY (cont.)

GRAIN SIZE ANALYSIS



DESIGN GRADATION FOR BEDDING ON TOPSLOPES AND SIDESLOPES

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

ANALYSIS RESULTS FOR MAXIMUM AND MINIMUM GRADATIONS FOR TOPSLOPES AND SIDESLOPES, COMPARED WITH SELECTED DESIGN GRADATION

PROJECT UMTRA-GRN
JOB NO. 5057
~~AREA~~ BEDDING GRADATION
~~HOLE NO.~~ FBG 7-7-88
DATE pkc 8-1-88

CAB110 <SEE SHEET 2A FOR ADDITIONAL DETAILS>

REV. 1

2

Sheet 2A
Project UMTRA-GRN
Contract No. 5057
File No.
Feature BEDDING GRADATION
Designed FBG
Date 7-7-88
Item
Checked
Date 8-1-88

REV. 1

SUMMARY (cont.)

PROPERTIES OF DESIGN BEDDING GRADATION:

SIZE (% FINER)	PARTICLE SIZE (mm)				PERMEABILITY (cm/sec) ②			
	ANALYSIS ①		DESIGN ①		ANALYSIS ①		DESIGN ①	
	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN
D_{10}	4	0.5	3.2	0.86	16	0.25	10	0.75
D_{15}	5.2	1.1	4.1	1.9	16	0.25	10	0.75
D_{85}	—	8	—	8	—	—	—	—

① "Analysis" refers to limits estimated by calculation. "Design" refers to values selected for design, since analysis results allow additional refinement.

② Permeability estimates using D_{10} are by Hazen's Formula. Permeability estimates using D_{15} are by data from Sherard, et. al., for sand and gravel filters (Ref. 9).

<see pp. 19-23 for details.>

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Project UMTRA-GEN
Contract No. 5057
Sheet 3
File No.
Feature BEDDING GRADATION
Designed FBG
Date 4-27-88
Item PERMEABILITY/PERMISSIBLE VELOCITY DESIGN
Checked PKC
Date 6-1-88

I. PURPOSE

This calculation presents an alternate design approach for determining riprap bedding gradation, that differs from approaches which utilize filter criteria to prevent migration of soil adjacent to a layer of bedding material.

The alternate approach is based on the observed behavior of soils subject to fluid flows that indicates that soils can withstand certain flows without significant erosion. Data are available for both open-channel flow directly on soils and for soils protected by a layer or layers of riprap or gravel.

This calculation provides a bedding material gradation that can be used for the bedding material layers on the topslope and sideslopes of the Green River final embankment.

Rev. 1: FBG 7-7-88
PKC 7-8-88

II. BACKGROUND INFORMATION

A layer of bedding material is placed beneath riprap primarily to prevent erosion of an underlying soil layer, and also to protect the soil layer from damage during riprap placement in some cases (e.g. 'thin', low permeability cover layers). Without the bedding layer, soil can migrate through the riprap and be eroded due to the following causes (after Ref. 1, pp. 5.8 - 5.9):

A) Lift and drag forces during high flows can create enough uplift pressure to draw soil particles vertically through the riprap voids,

B) Turbulent eddies and jets in the flow over the riprap can penetrate through the riprap voids and detach soil particles,

C) At all flows, but more visably at low flows, flow along the interface of the riprap and soil can cause erosion of soil if voids are large enough.

The potential for failure of the riprap layer due to base soil erosion has resulted in adoption of strict filter criteria for bedding material gradations (Ref. 1, p. 5.8; Ref. 2, p. 17, Ref. 3, and Ref. 4). Those

Project UMTRA-GEN
Feature BEDDING GRADATION
Item
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Designed FBG
Checked PKC
Sheet 5
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filter criteria essentially prevent any significant movement of soil into the bedding, even under large flow gradients from the soil into the bedding.

However, a significant potential problem has arisen with using strict filter criteria for bedding. Such filter criteria generally result in a permeability that is too small to allow adequate drainage rates on embankment ~~topslopes~~ slopes. The temporarily-retained water is thus free to infiltrate into the soil and potentially through the failings below. This could result in significant negative impacts to ground-water quality. Thus, to protect ground water, it is desireable to provide a more permeable bedding layer. To accomplish this, a rational approach is needed to provide bedding gradation criteria that are less stringent than current criteria, yet adequate to protect the riprap layer from failure due to erosion of underlying soil.

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Evidence is available which indicates that significant soil erosion can be prevented by alternative approaches. In one experiment, leaching of soil beneath a layer of uniform material was reduced to a minimum

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Feature BEDDING GRADATION
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Item
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Date 1-5-88

when the layer was three or more stones thick (Ref. 2, p.17) In an associated experiment, (Ref. 2, p.17) approximately 25% by weight of finer material was added to the uniform riprap, where the mean size of the finer material was about 1/4 the size of the riprap. In this case, leaching was reduced to a negligible rate, even when the layer thickness was one riprap stone size.

Satisfactory performance of canals designed according to criteria that limit maximum velocities or tractive forces provides further evidence that soil can sustain flows without significant erosion. (e.g. Ref. 5, pp. 164-179). In canals, flows against soil may be expected to be more uniform than water which follows a tortuous path through bedding interstices at the bedding/soil interface. On the other hand, the flow volume that passes a given point in a canal would generally be much greater than the flow volume expected on a tailings embankment cover over a 1000 year design life. Canal design criteria are expected to reliably minimize risk of erosion, due to the potentially great impact on water users and large costs required to repair damage.

Therefore, it appears promising that significant erosion of soil underlying bedding can be prevented without applying strict filter criteria, e.g., by limiting interstitial flow velocities.

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III APPROACH

A. Estimate allowable maximum velocities for soil types that may be used beneath bedding layer.

B. Determine permeability k that results in flow through bedding voids with velocity equal to allowable maximum velocity; typical slope for critical embankment ~~type~~ slope will be used to determine gradient i.

Rev. 1
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pvc 7-8-88

C. Determine gradation of bedding that will give permeability determined in 'B' above. (Note: Assume bedding D_{85} grain size must be adequate to prevent migration through riprap.)

D. Review available data from "leaching" experiments (of soil beneath riprap) for overall adequacy of bedding designed without using filter criteria to prevent significant erosion.

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Feature BEDDING GRADATION
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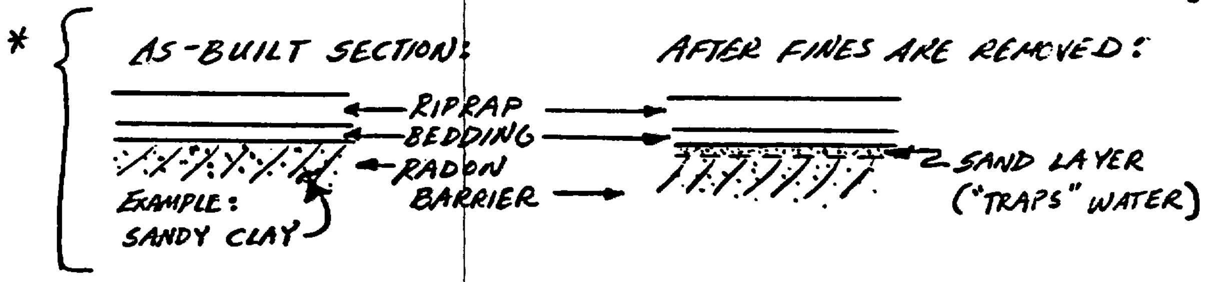
IV ALLOWABLE VELOCITIES

A. Soil Types:

Soils beneath bedding must be relatively impermeable for any advantage to be gained by maximizing bedding permeability. Thus, assume underlying soils will contain adequate silt- and clay-sized particles to ensure low permeability. Erosion of these particles will be assumed to represent failure, either by removing support for the bedding and riprap layers, or by creating a sandy layer once fines are removed* (which is the case we are attempting to avoid within the bedding, i.e., a layer that allows infiltration but inhibits lateral drainage.)



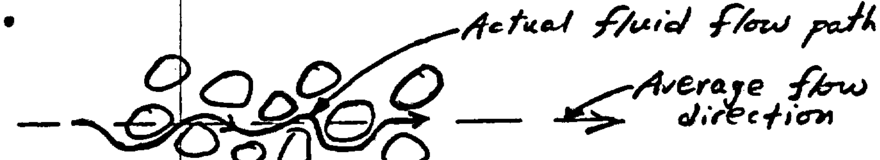
B. Allowable Velocities

1. Reference 5 contains an accumulation of data for allowable velocities and tractive forces. However, tractive force transmitted at boundaries of open-channel flow is not the same tractive force that is transmitted

to boundaries of flow within particulate media. Thus, tractive force data cannot readily be used for our purposes. Allowable velocity data indicate a range of permissible velocities depending on grain size (silt or clay) and plasticity (e.g. heavy or lean) of the soil (Attachment A, from Refs. 1 & 5).

2. For initial evaluation, select a relatively small (i.e., conservative) maximum permissible velocity of 0.5 $\frac{ft}{sec}$ (Fig. 7.3, Ref. 5 – See Attach. A).

3. Interstitial Velocity:
Permeability k is essentially an "approach velocity" under a gradient $i = 1$ (Ref. 7, p. 252). "Seepage velocity" V_s is the average velocity in the voids between two points in the average direction of flow, where $V_s = \frac{k i}{n}$ (n = porosity). Additionally, water flows in a tortuous path to get between two points along the average direction of flow. A tortuosity factor equal to about $\sqrt{2}$ applies to porous media of approximately uniform pore sizes (Ref. 6, p. 349).



HORIZONTAL SECTION AT BEDDING/SOIL INTERFACE
(SCHEMATIC)

Sheet 10
Project UMTRA-GEN
Contract No. 5057
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Feature BEDDING GRADATION
Designed FBG
Date 4-28-88
Item
Checked PKC
Date 5-8-88

The magnitude of the average instantaneous velocity vector, i.e., the actual fluid velocity "V_f", is therefore estimated as follows:

$$V_f = \frac{ki}{n}\sqrt{2}$$

For bedding, assume $n \sim 0.3$.

4. Find maximum k such that $V_f \leq 0.5$ ft/sec.
Use 5% topslope grade (Dwg. No. GRN-PS-10-0517)

$$V_f = 0.5 \text{ ft/sec} = \frac{ki}{n}\sqrt{2} = \frac{k(0.05)}{0.3}\sqrt{2}$$

$k = 2.1$ ft/sec or $k =$ <u>65 cm/sec.</u>

Therefore, bedding with a permeability of $k = 65$ cm/sec or less will limit interstitial fluid flow velocity to 0.5 ft/sec or less on a 5% slope.

$\boxed{\text{Rev. 1}}$ → For analysis and design of gradation that is suitable for topslope and sideslope, see pp. 19-24.

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PKC 7-8-88

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Checked PKC
Date 5-13-88

C. "AGING" EFFECTS

"Aging" of soil-lined canals has been observed in general to allow "old and well-seasoned" channels to stand much higher velocities than new ones, because the old channel bed is usually better stabilized, particularly with the deposition of colloidal matter (Ref. 5, p. 165). A source of such colloidal matter would be windblown materials and fines remaining in riprap and bedding after placement on the embankment. Those materials will be washed through the bedding eventually by infiltrating water.

V LIMITED DEGRADATION APPROACH

A. The maximum permeability determined in Item '4', sheet 10, is a relatively large value. In fact, such a permeability may be typical of the riprap. This could imply that →

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Designed FCG
Date 4-28-89
Checked
Date 5-5-89

a bedding layer is unnecessary. However, leaching of soils beneath riprap without a bedding layer is a possibility if excessive forces and velocities from the flow above the riprap can reach the soil (see sheet 4). Experiments were conducted to determine the protection from erosion that layer thickness and grain size of intermediate protective layers give to a non-cohesive (sand) base material (Ref. 2, pp. 66-69.). The base materials were uniform sands with grain sizes as small as 0.125 mm. The smallest-size sand classifies as a fine sand either by U.S.C.S or USDA classification systems. Permissible velocities for such a sand range from 0.8 ft/sec (Fig 7-3, Ref. 5) to 2 ft/sec (Ref. 1, Table 6.1c.). (See Attach. A).

The results of the experiments above indicated that the number of protective layers, each one grain size thick, was a significant factor in determining the erosion rate of the base material. Results indicated a transport rate of the fine sand of about 10^{-6} lb/sec-ft^2, at a total flowrate of 1.13 cfs in a 3-ft. wide channel, for either of

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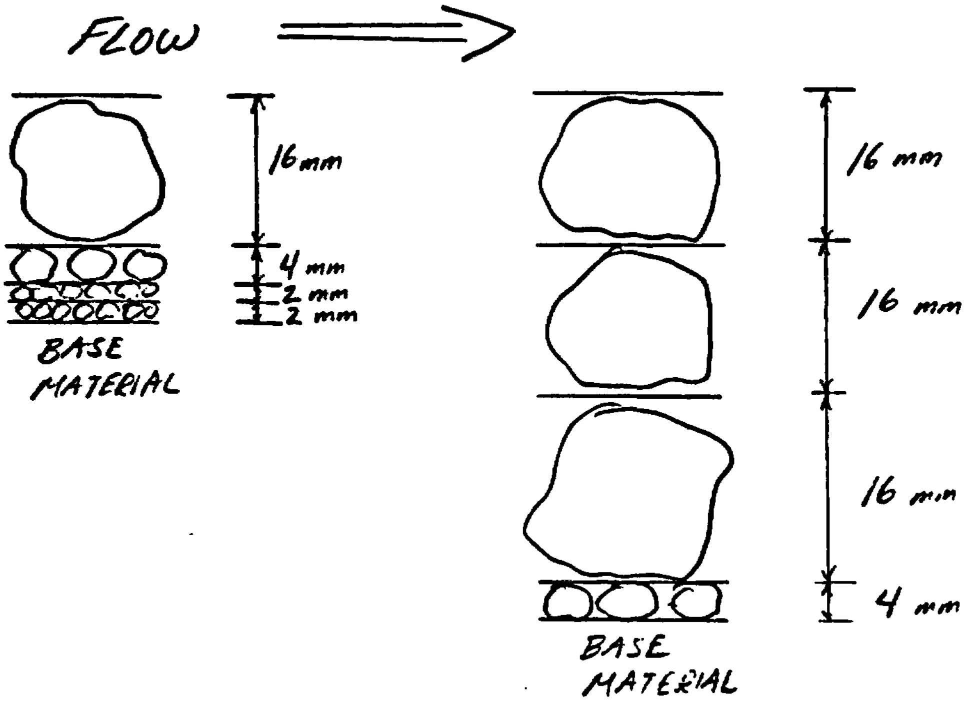
the following protective layering schemes:



Note that the effects of layer thickness and grain size are combined by referring to layers as one grain size thick. The results suggest that each layer reduced the erosion rate by 75 times, up to 4 layers (the maximum number of layers tested) (Ref. 2, p.69). Intuitively, the effect of each additional layer on the erosion rate of base soil would be less than the preceding layer. Eventually, a constant erosion rate would be attained that depends only on interstitial flow velocities that are unaffected by overlying flow (e.g. by eddies, jets, and turbulence in flow in the riprap or above the riprap). The number of layers needed to reach such a constant erosion rate would vary from case to case, due to variations in slope, flowrate, riprap size, etc.

Check number of 'layers' for present design:

Top slope = 5%
Length = 100'

Riprap* (Type A) $(D_{50})_{MAX} \simeq 3.5''$ Total thickness = 1'
Bedding* $(D_{50})_{MAX} \simeq 0.2''$ Total thickness = 0.5'
*(MKE Calc. No. 10-536-02-02, pp. C-5 & E-3)

Number of "Layers" $(D_{50})_{MAX}$ Thick:

Riprap: $1' / \left(\frac{3.5''}{12}\right) = 3.4$
Bedding: $6''/0.2'' = \underline{30}$

~ 33 Layers $(D_{50})_{MAX}$ Thick

A total of 33 layers seems to be sufficient to result in a constant erosion rate of base material, particularly since maximum flowrate and flow depth over the riprap will be relatively small.

Therefore, with an adequate number of protective layers, an allowable velocity approach (e.g. sheets 8-10) seems appropriate for determining adequate protection against excessive leaching of base soils.

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Project UMTRA-GEN
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Date 6-5-88

VI. GRADATION VS. PERMEABILITY

Permeability of sands & gravels:

MATERIAL	k cm/sec	Data Source
3/8" - 1/2" uniform gravel	29	NAVFAC DM 7.1, p. 7.1-277 (Ref. 8)
2-5 mm sand	2.7	"
2 mm - 3/4" sand/gravel	1.0	"
3 mm - 3/4" sand/gravel (dense)	8.7	Ref. 9, Table 2
9 mm - 1" sand/gravel (dense)	13.9	"
0.5 mm - 3/4" sand/gravel (dense)	1.8	"

From the table above, materials suitable for bedding are available with relatively large permeabilities (compared with 10^{-3} cm/sec for bedding designed by filter criteria for the Shiprock embankment, as reported by R. Rager of TAC.) Permeabilities above will also limit velocities to values less than allowable maximum.

Number of Layers:

Riprap: $12''/3.4'' = 3.4$
Bedding: Assume $(D_{50})_{max} \sim 1/2'' \rightarrow 6''/1/2'' = 12$
} 15 layers $(D_{50})_{max}$ thick

$\therefore$ Number of layers seems adequate. (see pp. 10-14)

VI DISCUSSION

A. A bedding material graded between 3/8" to 1/2" in size will limit interstitial velocities to less than 1/2 of allowable velocity of 0.5 ft/sec, on the embankment topslope.

B. Soils to be used beneath the riprap and bedding will be primarily silty sands (Select Fill Type A). Thus, water is likely to infiltrate to the underlying drain layer above the radon barrier. If the drain layer were constructed with a more permeable material, the additional drainage capacity could improve ground-water protection.

C. For constructability, bedding material should not be too coarse. This will reduce the amount of soil pushed into voids of the bedding material during placement and compaction.

D. Material with gradation ranging from 3 mm to 3/4" appears to have adequately large permeability of about 1-9 cm/sec (relative to 10^{-3} cm/sec)* This material should also provide adequate properties for practical constructability.

(*See "F", next sheet)

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Date 5-5-88

E. Bedding material gradation should also be adequate to prevent bedding migration through riprap. ~~Current~~ Previous bedding* design requires $(D_{85})_{MIN}$ size of about 8 mm (0.3"). (Calc. No. 10-536-02-02, p. E-3). [Riprap $(D_{50})_{MIN}$ ≈ 2.6" (MKE Calc. No. 10-536-02-02, p. C-2)]

F. The TAC has indicated that a bedding permeability k of 0.25 cm/sec or greater would provide adequate drainage on topslope for ground-water protection (per F.B. Gueros discussion R. Rager, 5-3-88).

* Rev. 1 FBG 7-7-88
PKC 7-8-88

VII CONCLUSIONS - TOPSLOPES

Rev. 1: FBG 7-7-88 PKC 7-8-88

1. The following gradation for bedding and drain layers on the embankment topslope provides adequate properties for performance and constructability:

   $D_{85} \geq 0.6"$

   Size Range: 3/4" (or slightly larger) to 2 mm.

2. The estimated permeability for this gradation is in the range of 5 to 12 cm/sec for gradation curve midway between proposed limits (see Attachment 2).

3. Other similar gradations may be suitable - the gradation for design (see 'Summary' sheets 1 & 2) is selected

by judgement to provide (a) adequate permeability for drainage (compared with required in-place minimum of 0.25 cm/sec, see sheet 17, Item II.F), (b) adequate protection of long-term erosion of the select fill and radon barrier cover layers, and (c) practical constructability.

Rev. 1 → For bedding gradation suitable for topslopes and sideslopes, see pp. 19-24

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SUMMARY -TOPSLOPE*

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The bedding gradation given below (and shown PKC 7-8-88 graphically on p. 2) will significantly increase drainage capacity on the embankment topslope and prevent significant erosion of adjacent soil (i.e., beneath the upper bedding layer and adjacent to the drain layer above the radon/infiltration barrier). Strict filter criteria are not used to relate bedding and soil gradations. Attachment B gives estimated permeability results for the gradation below.

SIZE	PERCENT PASSING
1"	98 - 100
3/4"	80 - 100
3/8"	40 - 68
No. 4	5 - 35
No. 10	0 - 2

Rev. 1: Not for design - see sheets 1-2 and 19-24
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The frost protection layer is silty sand (as designed) and relatively permeable. Therefore, significant improvement of drainage may not be achieved by using the gradation above for bedding beneath riprap. The gradation above should be used for the drainage layer above the radon barrier, as a minimum.

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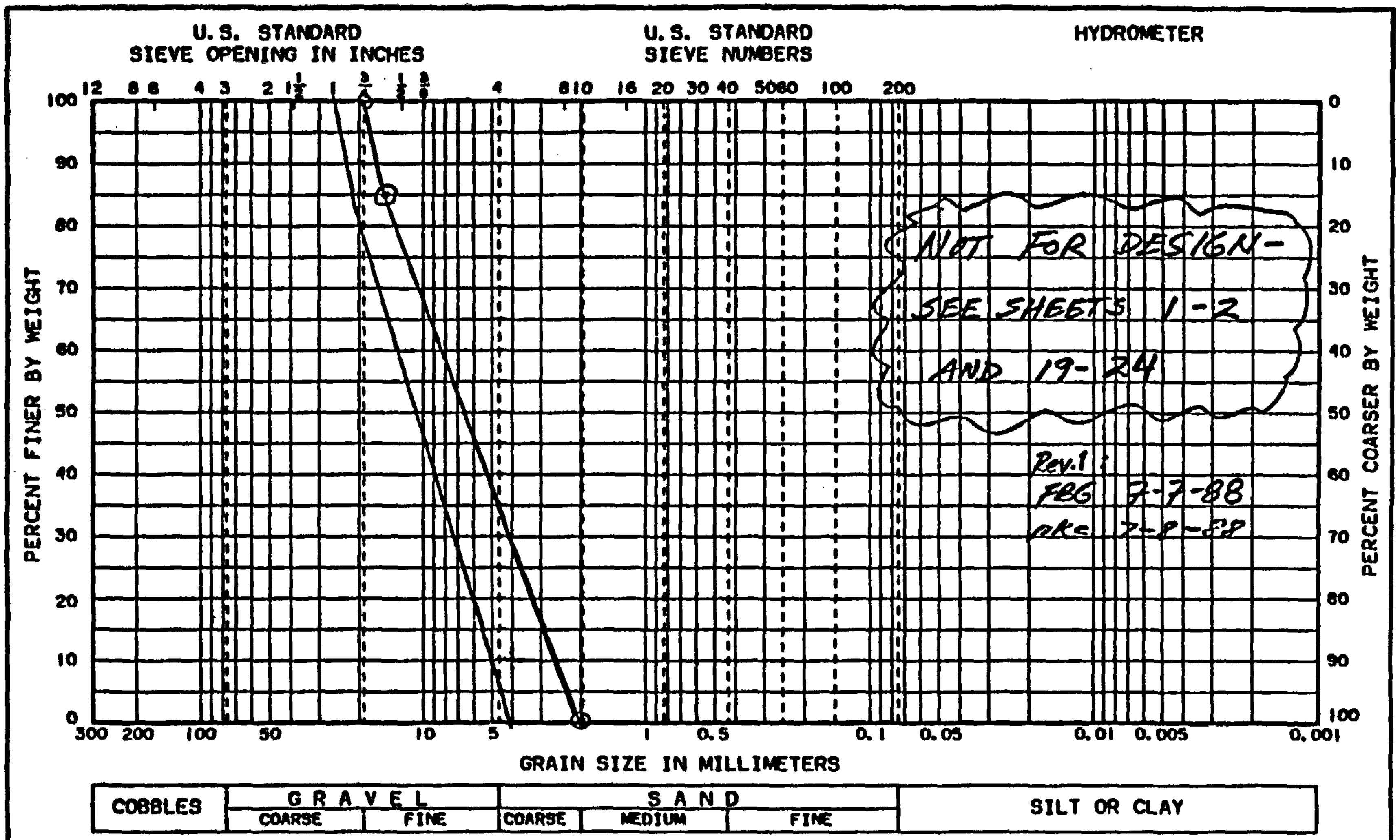

NOT FOR DESIGN - SEE SHEETS 1-2 AND 19-24

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GRAIN SIZE ANALYSIS

SAMPLE NO.	ELEV. OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
		BEDDING MATERIAL				
		- TOPSLOPE *				

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18B *

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REV. 1

VIII. SIDESLOPES

A. Find maximum allowable bedding permeability that will limit actual fluid velocity in pores to 0.5 ft/sec or less (see pp. 9-10):

$$V_f = 0.5 \frac{ft}{sec} = \frac{k i \sqrt{2}}{n} = \frac{k(0.20)\sqrt{2}}{0.3}$$

$$k_{max} = 0.53 \text{ ft/sec} \quad \text{or} \quad k_{max} = \underline{16 \text{ cm/sec}} \checkmark$$

B. Find maximum grain size distribution that will limit k to 16 cm/sec or less:

1. Method in Ref. 9:

Use upper bound equation on Fig. 8 (Ref. 9)

$$k = 0.6 (D_{15})^2$$

$$16 \text{ cm/sec} = 0.6 (D_{15})^2 \Rightarrow (D_{15})_{max} = \underline{5.2 \text{ mm}} \checkmark$$

Note: Fig. 8 is based on data in Table 2. Table 2 note states that "for specimens 11-15, the seepage was turbulent with decreasing values of $K = V/i$ with increasing gradient i. Values are for $i = 0.1$." Thus, use of upper bound curve for $i = \underline{0.2}$ is relatively conservative in two ways.

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2. Hazen's Formula

$$k\,(\text{cm/sec}) = (D_{10}\,(\text{mm}))^2$$

$$16\ \text{cm/sec} = [D_{10}(\text{mm})]^2 \qquad (D_{10})_{MAX} = \underline{4\ \text{mm}}$$

c. Revise lower bound gradation:

1. The upper bound gradation using $D_{15} = 5.2$ mm and $D_{10} = 4$ mm is smaller than the upper bound gradation selected for the topslopes previously (sheet 2). Therefore, adjust lower bound gradation to smaller sizes to facilitate production by providing wider band of acceptable gradations.

2. Method in Ref. 9:

Use approximate lower bound equation on Fig. 8. (Using lower bound equation tends to compensate for smaller value of $K = v/i$ for gradient of 0.2, relative to data for $i = 0.1$ given in Table 2 and on Fig. 8)

$$K = 0.2\,(D_{15})^2$$

$$0.25\ \text{cm/sec} = 0.2\,(D_{15})^2 \qquad (D_{15})_{MIN} = \underline{1.1\ \text{mm}}$$

↑(see p. 17, item "F".)

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3. Hazen's Formula

$$k = (D_{10}(mm))^2$$

$$0.25 \text{ cm/sec} = (D_{10}(mm))^2 \qquad (D_{10})_{MIN} = \underline{\underline{0.5 \text{ mm}}}$$

D. $(D_{85})_{MIN}$ for previous bedding design = 8 mm (see sheet 17). This size is approximately the smallest D_{85} size to prevent migration into riprap Type A ($D_{15_{MAX}}$ = 56 mm) [MKE Calc. No. 10-536-02-02, p. E-2 and Specification 02278, Rev. 0, p. 6]

E. ANALYSIS SUMMARY (NOT SELECTED DESIGN)

SIZE (% FINER)	PARTICLE SIZE (mm)	
	MAX.	MIN.
D_{10}	4	0.5
D_{15}	5.2	1.1
D_{85}	—	8
D_{100}	*	—

* 3" max. to reduce segregation (Ref. 3)

The control gradation points are plotted on sheet 2A to aid in assessing modifications that may be made to determine design gradation.

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REV. 1

F. DISCUSSION:

1. Inspection of the analysis results for maximum and minimum gradation bounds (sheet 2A) reveals a wide range of acceptable gradations.
2. A wide range of acceptable gradations is easier to satisfy during production than a narrower range (up to a point). However, the potential for "gap-grading" (including possible segregation during handling) increases as the acceptable gradation range increases.
3. A narrower range can still be produced economically by common means, and additional conservatism can be taken advantage of with respect to both maximum pore velocities and drainability.
4. Therefore, for design, select a narrower range of acceptable gradations. For the design gradation determine minimum permeability and maximum fluid velocity in the pores. (by same formulas used on sheets 19-21)

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G. DESIGN BEDDING GRADATION - TOPSLOPES AND SIDESLOPES.

1. Design gradation assumes that, for the same gradation, pore velocities on sideslopes will be critical relative to topslopes for the same maximum allowable pore velocity.

2. The gradation on sheet 2A for design was determined by trial and error to reduce the maximum possible pore velocity and increase minimum permeability. Increasing the minimum permeability was considered slightly more important than reducing maximum permeability, to provide more ground-water protection.
   Properties of the bedding gradation are summarized on sheet 2B.

It should be noted that this solution is exactly the same as the computation of the normal depth given in Solution 1 of Example 6-2. Accordingly, the solutions by trial and error and by the graphical method described in Example 6-2 can also be applied to the present problem.

Similarly, assume other suitable values of b and z, and compute the corresponding depths. The final decision on dimensions will depend on practical considerations. If the values of b and z are decided at the beginning of the computation, the depth will be computed only once.

Suppose that $b = 20$ ft, $z = 2$, and $y = 3.36$ ft are the final values. Assign a freeboard of 2 ft; the total depth of the channel is, therefore, 5.36 ft and the top width of the channel (not the width of the water surface) is 41.4 ft. The water area is 89.8 ft², and the velocity is 4.46 fps, which is greater than the minimum permissible velocity for inducing silt, if any.

When the best hydraulic section is required, substitute $A = \sqrt{3}\, y^2$ and $R = 0.5y$, obtained from Table 7-2, in $AR^{2/3} = 167.7$ and simplify; the depth is found to be $y = 6.6$ ft. Add 3 ft freeboard; the total depth is 9.6 ft. The corresponding bottom width is 7.6 ft, the top width of the channel is 18.7 ft, the water area is 75.2 ft², and the velocity is 5.32 fps. Since the best hydraulic trapezoidal section is the half hexagon, the side slopes are 1 on $\sqrt{3}/3$.

B. ERODIBLE CHANNELS WHICH SCOUR BUT DO NOT SILT

7-8. Methods of Approach. The behavior of flow in an erodible channel is influenced by so many physical factors and by field conditions so complex and uncertain that precise design of such channels at the present stage of knowledge is beyond the realm of theory.[1] The uniform-flow formula, which is suitable for the design of stable nonerodible channels, provides an insufficient condition for the design of erodible channels. This is because the stability of erodible channels, which governs the design, is dependent mainly on the properties of the material forming the channel body, rather than only on the hydraulics of the flow in the channel. Only after a stable section of the erodible channel is obtained can the uniform-flow formula be used for computing the velocity of flow and discharge.

Two methods of approach to the proper design of erodible channels are described here: the *method of permissible velocity* and the *method of tractive force*. The method of permissible velocity has been used extensively for the design of earth canals in the United States to ensure freedom from scour. The method of tractive force has sometimes been used in Europe; it is now under comprehensive investigation by the U.S. Bureau of Reclamation and is tentatively recommended for design of erodible channels. It should be noted that either method at the present stage will serve only as a guide and will not supplant experience and sound engineering judgment.

7-9. The Maximum Permissible Velocity. The *maximum permissible velocity*, or the *nonerodible velocity*, is the greatest mean velocity that will not cause erosion of the channel body. This velocity is very uncertain and variable, and can be estimated only with experience and judgment. In general, old and well-seasoned channels will stand much higher velocities than new ones, because the old channel bed is usually better stabilised, particularly with the deposition of colloidal matter. When other conditions are the same, a deeper channel will convey water at a higher mean velocity without erosion than a shallower one. This is probably because the scouring is caused primarily by the bottom velocities and, for the same mean velocity, the bottom velocities are greater in the shallower channel.

TABLE 7-3. MAXIMUM PERMISSIBLE VELOCITIES RECOMMENDED BY FORTIER AND SCOBEY AND THE CORRESPONDING UNIT-TRACTIVE-FORCE VALUES CONVERTED BY THE U.S. BUREAU OF RECLAMATION*
(For straight channels of small slope, after aging)

Material	n	Clear water		Water transporting colloidal silts	
		V, fps	τ_0, lb/ft²	V, fps	τ_0, lb/ft²
Fine sand, colloidal	0.020	1.50	0.027	2.50	0.075
Sandy loam, noncolloidal	0.020	1.75	0.037	2.50	0.075
Silt loam, noncolloidal	0.020	2.00	0.048	3.00	0.11
Alluvial silts, noncolloidal	0.020	2.00	0.048	3.50	0.15
Ordinary firm loam	0.020	2.50	0.075	3.50	0.15
Volcanic ash	0.020	2.50	0.075	3.50	0.15
Stiff clay, very colloidal	0.025	3.75	0.26	5.00	0.46
Alluvial silts, colloidal	0.025	3.75	0.26	5.00	0.46
Shales and hardpans	0.025	6.00	0.67	6.00	0.67
Fine gravel	0.020	2.50	0.075	5.00	0.32
Graded loam to cobbles when noncolloidal	0.030	3.75	0.38	5.00	0.66
Graded silts to cobbles when colloidal	0.030	4.00	0.43	5.50	0.80
Coarse gravel, noncolloidal	0.025	4.00	0.30	6.00	0.67
Cobbles and shingles	0.035	5.00	0.91	5.50	1.10

* The Fortier and Scobey values were recommended for use in 1926 by the Special Committee on Irrigation Research of the American Society of Civil Engineers.

---

[1] It has been noticed that certain channels are erodible whereas others very similar in channel geometry, hydraulics, and soil physical properties are not. As a further step in investigation, the chemical properties of the material forming the channel body should be explored. It may be that an ion exchange between water and soil or hydration of the material is providing a binder in some places and thus affecting the erosion. For a general discussion of the complexity of this problem, see [8] and [9].

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ATTACHMENT A (5 pp.)

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SOURCE:
REF. 5

Attempts[1] were made early to define a mean velocity that would cause neither silting nor scouring. From the present-day viewpoint, however, it is doubtful whether such a velocity actually exists. In 1915, Etcheverry [26] published probably the first table of maximum mean velocities that are safe against erosion. In 1925, Fortier and Scobey [27] published the well-known table of "Permissible Canal Velocities" shown in Table 7-3. The values in this table are for well-seasoned channels of small slopes and for depths of flow less than 3 ft. The table also shows

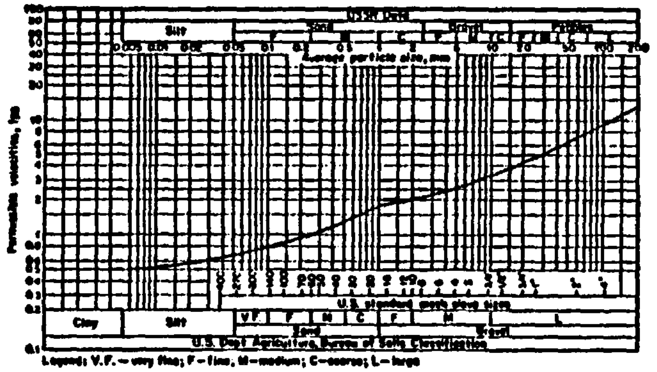

FIG. 7-3. U.S. and U.S.S.R. data on permissible velocities for noncohesive soils.

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[1] The first famous formula for this nonsilting and noneroding velocity for silt-laden water was published in 1895 by Kennedy [10]. From a study of the discharge and depth of 22 canals of the Upper Bari Doab irrigation system in Punjab, India, the Kennedy formula was developed as

$$V_0 = Cy^x \qquad (7-4)$$

where V_0 is the nonsilting and noneroding mean velocity in fps; y is the depth of flow in ft; $C = 0.84$, depending primarily on the firmness of the material forming the channel body; and $x = 0.64$, an exponent which varies only slightly. Based on later studies by other engineers, the values of C generally recommended are 0.56 for extremely fine soils such as those found in Egypt; 0.84 for fine light sand soils such as those found in the Punjab, India; 0.92 for coarse light sandy soils; 1.01 for sandy loamy silts; and 1.09 for coarse silt or hard-soil debris. For clear water, a value of $x = 0.5$ has been suggested.

For the design of canals carrying sediment-laden water, the Kennedy formula is now practically obsolete and is being replaced by methods based on Lacey's regime theory [11–16], Einstein's bed-load function [17], and Maddock-Leopold's principle of channel geometry [18]. There are voluminous writings on these methods. Comprehensive bibliographies can be found in [19] to [25].

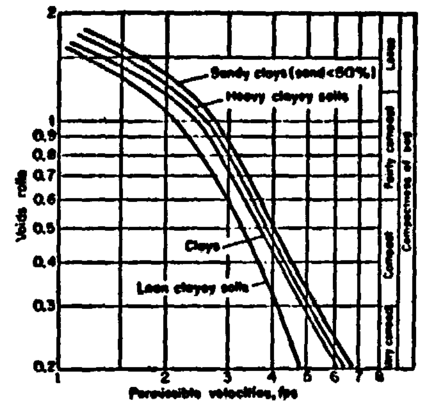

FIG. 7-4. Curves showing U.S.S.R. data on permissible velocities for cohesive soils.

suitable n values for various materials and the converted values for the corresponding permissible tractive force, which will be discussed later (Art. 7-13). In 1936, a Russian magazine [28] published values of maximum permissible velocities (Figs. 7-3 and 7-4) above which scour would be produced in noncohesive material of a wide range of particle sizes and various kinds of cohesive soil. It also gave the variation of these velocities with channel depth (Fig. 7-5).

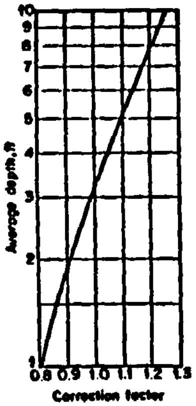

FIG. 7-5. Curves showing U.S.S.R. corrections of permissible velocity for depth for both cohesive and noncohesive materials.

The maximum permissible velocities mentioned above are with reference to straight channels. For sinuous channels, the velocities should be lowered in order to reduce scour. Percentages of reduction suggested by Lane [29] are 5% for slightly sinuous canals, 13% for moderately sinuous canals, and 22% for very sinuous canals. These percentage values, however, are very approximate, since no accurate data are available at the present time.

7-10. Method of Permissible Velocity. Using the maximum permissible velocity as a criterion, the design procedure for a channel section, assumed to be trapezoidal, consists of the following steps:

SOURCE: REF. 5

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SOURCE: REF. 1

Table 6.1a. Maximum Permissible Velocities Tables by Fortier and Scobey (1926).

		Mean velocity of canals after aging (d≤3 ft)					
Original Material Excavated For Canals	n	Clear water, no detritus ft/sec	Clear water, no detritus m/sec	Water transporting colloidal silt ft/sec	Water transporting colloidal silt m/sec	Water transporting noncolloidal silts, sands gravels or rock fragments ft/sec	Water transporting noncolloidal silts, sands gravels or rock fragments m/sec
1. Fine sand (colloidal)	0.02	1.5	0.46	2.50	0.76	1.50	0.46
2. Sandy loam (noncolloidal)	0.02	1.45	0.53	2.50	0.76	2.00	0.61
3. Silt loam (noncolloidal)	0.02	2.00	0.61	3.00	0.91	2.00	0.61
4. Alluvial silt when noncolloidal	0.02	2.00	0.61	3.50	1.07	2.00	0.61
5. Ordinary firm loam	0.02	2.50	0.76	3.50	1.07	2.25	0.69
6. Volcanic ash	0.02	2.50	0.76	3.50	1.07	2.00	0.61
7. Fine gravel	0.02	2.50	0.76	5.00	1.52	3.75	1.14
8. Stiff clay (very colloidal)	0.025	3.75	1.14	5.00	1.52	3.00	0.91
9. Graded, loam to cobbles, when noncolloidal	0.03	3.75	1.14	5.00	1.52	5.00	1.52
10. Alluvial silt when colloidal	0.025	3.75	1.14	5.00	1.52	3.00	0.91
11. Graded, silt to cobbles, when colloidal	0.03	4.00	1.22	5.50	1.68	5.00	1.52
12. Coarse gravel (noncolloidal)	0.025	4.00	1.22	6.00	1.83	6.50	1.98
13. Cobbles and shingles	0.035	5.00	1.52	5.50	1.68	6.50	1.98
14. Shales and hard pans	0.025	6.00	1.83	6.00	1.83	5.00	1.52

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Table 6.1b. Maximum Permissible Velocities Tables by Etcheverry (1916).

Material	Mean Velocity (fps)
Very light pure sand of quicksand character	0.75- 1.00
Very light loose sand	1.00- 1.50
Coarse sand or light sandy soil	1.50- 2.00
Average sandy soil	2.00- 2.50
Sandy loam	2.50- 2.75
Average loam, alluvial soil, volcanic ash soil	2.75- 3.00
Firm loam, clay loam	3.00- 3.75
Stiff clay soil, ordinary gravel soil	4.00- 5.00
Coarse gravel, cobbles, shingles	5.00- 6.00
Conglomerates, cemented gravel, soft slate, tough hard-pan, soft sedimentary rock	6.00- 8.00
Hard rock	10.00-15.00
Concrete	15.00-20.00

SOURCE: REF. 1.

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SOURCE: REF. 1

Table 6.1c. Maximum Permissible Velocities Tables[1] by U.S. Army Office (1970).

Channel Material	Mean Channel Velocity (fps)
Find sand	2.0
Coarse sand	4.0
Fine gravel[2]	6.0
Earth	
Sandy silt	2.0
Silt clay	3.5
Clay	6.0
Grass-lined earth (slopes < 5%)[3]	
Bermuda grass - sandy silt	6.0
- silt clay	8.0
Kentucky Blue Grass - sandy silt	5.0
- silt clay	7.0
Poor rock (usually sedimentary)	10.0
Soft sandstone	8.0
Soft shale	3.5
Good rock (usually igneous or hard metamorphic)*	20.0

[1] Based on TM 5-886-4 and CE Hydraulic Design Conferences of 1958-1960.

[2] For particles less than fine gravel (about 20 mm = 3/4 in.).

[3] Keep velocities less than 5.0 fps unless good cover and proper maintenance can be obtained.

*May be used with judgment in durable bedrock.

NOTE: This table is used in US Corps of Engineers EM-1110-2-1601.

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ATTACHMENT B

1. PURPOSE:

Estimate interstitial flow velocity using CSU relationship and Hazen's equation: (Compare with data on sheet 14)

<For topslope gradation only. See Rev. 1 for revised design>
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pkc 7-11-88

2. PROPOSED BEDDING PROPERTIES (sheet 2)

	D_{50} (in)	n_p	D_{60} (mm)	D_{10} (mm)	C_u
MIN	0.26	(0.3)*	8.2	2.7	1.6
MAX	0.43	0.4	14	5	5.2
AVG.	0.32**	(0.35)	11	3.5	3.1

*Assumed (CSU data show $n_p = 0.44$ for $D_{50} = 1''$ (p. 11))
** Midway between gradation bounds, sheet 2.

3. CSU RELATIONSHIP (p. 53, NUREG/CR-4651, November 1986)

$$V = 19.29\left(C_u^{-0.074} S^{0.46} n_p^{4.14}\right)^{1.064}\left(g\, D_{50}\right)^{0.5}$$

4. HAZEN'S EQUATION (Lambe & Whitman, 1969, p. 290)

$k = C_1 D_{10}^2$ k = cm/sec, D_{10} = cm $C_1 \doteq 100 - 150$ for loose uniform sands (Terzaghi & Peck, 1967, p. 50)

From Lambe & Whitman, Table 19.3, k/D_{10}^2 varies from 8 to 40 for coarse gravel (D_{10} = 0.82 mm), sandy gravel (D_{10} = 0.2 mm) and fine gravel (D_{10} = 0.3 mm).

For our purpose, assume $C_1 \sim 100$

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5. SUMMARY: ESTIMATED BEDDING PERMEABILITY

EQUATION	PERMEABILITY (cm/sec) k			FLUID VELOCITY MAGNITUDE V_f ON 5% SLOPE (ft/sec)		
	MIN.	MAX.	AVG.	MIN.	MAX.	AVG.
CSU	10. (2.1)③	50 (11)③	23 (4.9)③	0.08②	0.29②	0.15②
HAZEN	7.3	25	12	0.04①	0.19①	0.08①

① $V_f = \frac{k}{n} \cdot 0.05 \cdot \sqrt{2}$ (equation from sheet 10)

② $V_f = \frac{V}{n} \sqrt{2}$ (where V is calculated as shown in Item 3, p. B-1/2; S = 0.05)

③ First value is calculated as follows:

$k = \frac{V}{0.05}$, where $V = \frac{n V_f}{\sqrt{2}}$ (see ② above)

This value can be considered an "equivalent permeability" that gives an interstitial velocity on a 5% slope that is the same as obtain by CSU equation.

Second value shown in "( )" is calculated with CSU relationship for V, with S = 1.0. The value is shown for comparison only, not design, since CSU experiments yielded data for slopes no steeper than 20%.

Rev. 1: This sheet applies to topslope gradation only. See Rev. 1 for revised design including sideslope.
FBG 7-7-88 pxc 7-11-88

Calculation Cover Sheet

Contract No. 5057 **Discipline** Earth Sciences **Calc. No.** 10-551-02-00

No. of Sheets 25

Project UMTRA/GREEN RIVER

Feature WASTEWATER HANDLING

Item WASTEWATER ACCUMULATED VOLUME

Sources of Data

1) MKE : UMTRA/GREEN RIVER -(GRN), Calculations - Final Design for Review, Vol II - Nov. 1987. Calc # 10-531-02-00, Retention Basin.

2) Ford, Bacon, Davis Utah, Inc. "Engineering Assessment of Inactive Uranium Mill Tailings - Green River Site, Green River, Utah. Aug 1981

Sources of Formulae & References

3) NOAA Technical Report NWS 34, Mean Monthly, Seasonal, and Annual Pan Evaporation for the U.S., U.S. Dept. of Commerce, NOAA, NWS, Washington D.C., Dec. 1982. Reproduced by NTIS.

4) Rand McNally - Road Atlas of the U.S.

5) NOAA Technical Report NWS 33, Evaporation Atlas of the Contiguous 48 U.S., U.S. Dept. of Commerce, NOAA, NWS, Washington D.C., June 1982

6) Department of Commerce, NOAA, National Environmental Satellite, Data, and Information Service, National Climatic Data Center, Asheville N.C. 28801-2696 (phone: (704)-259-0682) "Climatography of the U.S. No. 20, Green River, UT" - Climatological Summary.

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

Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
0		H. Majumder.	DEC 07/87	DWLeppert	12/8/87	P.K. Chen	12/10/87

Form 42-110

Project UMTRA/GRN (Green River)
Feature WASTEWATER RUNOFF VOLUME
Item CONTENTS
Contract No. 5057
Designed HM
Checked
Sheet 1
File No.
Date DEC 03/87
Date 12/8/87

CONTENTS

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Sheet 2/
Project UMTRA/GRN
Contract No. 5057
File No.
Feature WASTEWATER RUNOFF VOLUME
Designed HM
Date Dec 04, 198
Item SUMMARY
Checked DVR
Date 12/8/87

1. SUMMARY

This calculation forms part of the wastewater handling calculations for the Green River Uranium Mills Tailings remedial action site, and specifically provides an estimate of the runoff volume into the wastewater retention basin under long-term average hydrologic conditions. The main findings of these calculations are –

(i) The mean monthly wastewater inflow into the retention basin ranges from 0.0 to 0.92 AF during the nine-month construction period of April thru December, after subtracting off evaporation losses

(ii) If these inflow volumes are allowed to accumulate, the maximum accumulated volume will be 1.98 AF over the same April thru December construction period, after subtracting off evaporation losses.

(iii) If the retention basin is designed for only a single-storm event (such as a 10-year 24-hour storm) with no provision for the mean monthly runoffs described in (i) and (ii) above, then the runoff accumulated in the retention basin would have to be withdrawn periodically to maintain enough storage space to prevent spillover during a 10-year 24-hour storm or a storm of somewhat lesser magnitude even. If this withdrawn runoff is released into natural drainages offsite, it may require treatment.

(iv) If the retention basin is designed to contain both the accumulated mean monthly runoff and the 10-year 24-hour storm runoff, no periodic withdrawals or possible treatment will be necessary during the period of construction, unless of course one or more storms greater than the 10-year 24-hour event takes place. However, at the end of the project the retention basin will contain on an average 1.9 AF of wastewater due to mean monthly flows alone, and more should the 10-year 24-hour storm occur. This water will have to be withdrawn and discharged to offsite drainage before the retention basin can be demolished. If the quality of this water does not meet the effluent limits established by the project NPDES Permit, wastewater treatment will be required.

The spreadsheet data presented on Sheet 6 provides additional data

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY
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Designed HM
Date DEC 04/87
Item RUNOFF VOLUME
Checked DWK
Date 12/8/87

to proceed with the next phase of wastewater handling design.

2. PURPOSE AND SCOPE

Wastewaters will be generated during the planned remedial action at the Green River uranium mills tailings site. A retention basin will be designed to contain the wastewaters including sediments during the construction period. Depending on the water quality, these may be treated and released into the natural drainage.

These calculations are part of the wastewater handling calculations, and specifically provides an estimate of the average runoff including snowmelt into the retention basin. The runoff and sediment volumes resulting from a more intense 10-year 24-hour storm have been estimated in a separate calculation (Ref. 1).

3. PROCEDURE

The procedure for this calculation consists of Data Collection, Analysis followed by Conclusions and Recommendations; these are described below:

Data Collection:

The long-term average precipitation and temperature data based on the 1951-80 records at the Green River, UT station are available from the Climatological Summary prepared by NOAA (Ref. 6). A two-page summary for this station is included in Appendix A. This summary also includes the mean number of days precipitation is greater than 0.1 inch. All of the above data are by months. The location of this station is Lat: 39°00'N, Long: 110°10'W, El. 4070 ft, which is considered to be close enough to the Green River remedial action site to be representative of its hydrologic condition.

Mean monthly, seasonal and ~~and~~ annual pan evaporation data are available from NOAA Tech Report # NWS 34 (Ref. 3). Mean annual and seasonal free water surface (FWS) evaporation data are available from NOAA Tech Report # NWS 33 (Ref. 5). A summary of these are included in

Sheet 4
Project UMTRA/GRN
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Appendix A.

Data on drainage area, SCS curve number, retention basin capacity and surface area for a 10-year 24-hour storm and other pertinent data are obtained from Ref. 1 and summarised below:

Total drainage area at Retention Basin = 64 Acres

Retention Basin Capacity:

Runoff	=	3.62 AF
Sediment	=	0.98 AF
Total	=	4.60 AF

Average Retention Basin Surface Area = 0.68 Acre

SCS Curve Number for Soil Cover Complex CN = 90

Construction Period = Nine Months (Ref: Ian Mouseley of MKE - Proj. Contr
Begin: April 1988
End: Dec. 1988

Sheet 5/
Project UMTRA/GRN
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File No.
Feature WASTEWATER HANDLING
Designed HM
Date Dec 03/87
Item Wastewater Volume : Analysis
Checked DWR
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Analysis:

The analysis basically consists of applying the long-term average precipitation to the drainage area, calculating the infiltration losses and the runoff. The analysis is conducted on a monthly basis. The runoff goes into the retention basin, from which the evaporation loss and any construction water (if construction usage is planned) are subtracted, subject to the minimum of (water available in the retention basin, potential evaporation loss + construction water usage). Snowmelt, depending on the monthly mean temperature, is considered.

These calculations are conveniently done on a LOTUS 1-2-3 spreadsheet, the program for which has been developed by Dennis W. Rafford of MKE. This spreadsheet performs the calculations for both the "non-accumulating" design and the "accumulating" design.

4. RESULTS

The spreadsheet analysis for the mean monthly runoff at the Green River remedial action site is presented on Sheet 6.

The top five lines include the title, drainage area and retention basin area and capacity. Columns 1 thru 7, 18, 19 and 26 are basic input data obtained in the manner described in the previous "Procedure (Data Collection)" section.

The remaining 16 columns are calculations aimed at obtaining the Surplus Water (Col. 22) under "non-accumulating" design and Accumulated Water Volume (Col. 25) under "accumulating design." These calculations are explained in Appendix B.

PROJECT: UMTRA/GRN FEATURE: WASTEWATER HANDLING ITEM: VOLUME CALC. CONTR.NO.: 5057 DESIGNED: HM DATE: Dec 04, 1987 CHECKED: DWR DATE: 12/8/87 FILE NO.: ________ SHEET: 6

TITLE: GREEN*RIVER SURFACE WATER BALANCE

DATE: 12/03/87

INPUT

RUNOFF AREA (ACRES)= 64
RETENTION BASIN CAPACITY(AC-FT)= 3.62
POND EVAP. AREA (ACRES)= 0.68
AVG ANN. LAKE EVAPORAT'N (IN.)= 40

**********************INPUT***************

<----------------------------------WATER BALANCE------------------------->
<---*NON-ACCUMULATING*---> <-----*ACCUMULATING*----->

	MONTH	SOIL SCS NO.	MEAN NO. DAYS PRECIP. >0.1" (EACH)	MEAN TEMP. DEG. F	MEAN PRECIP. (IN. WTR.)	MEAN SNOW (IN.)	SNOW (IN. WTR.)	RAIN-FALL (IN. WTR.)	SUBLIM-ATION (IN.)	ACCUM. SNOWPACK [redacted] (INCHES OF WTR.)	SNOW-MELT (IN. WTR.)	TOTAL RAINFALL & SNWMLT. (IN. WTR.)	NUMBER OF EVENTS	WATER PER EVENT (IN. WTR.)	"S" -SCS- (IN.)	TOTAL RUNOFF VOLUME (AC-FT)	*INPUT* ASSUMED CONSTR. WATER REQ'D (AC-FT)	*INPUT* ASSUMED DE-WATERING INFLOW (AC-FT)	EST. EVAPTN. (AC-FT)	ACTUAL CONSTR. WATER USAGE (AC-FT)	SURPLUS WATER (AC-FT)	EST. EVAPTN. (AC-FT)	ACTUAL CONSTR. WATER USAGE (AC-FT)	ACCUM. WTR. VOLUME (AC-FT)	*INPUT* EVAP. DISTR. FTR.
1988	APR	90	1	51.7	0.45	0	0	0.45	0	0.000	0.000	0.45	1	0.45	1.111	0.207	0	0	0.057	0.000	0.119	0.175	0.000	0.032	0.077
	MAY	90	2	61.6	0.61	0	0	0.61	0	0.000	0.000	0.61	1	0.61	1.111	0.535	0	0	0.159	0.000	0.376	0.317	0.000	0.250	0.140
	JUN	90	1	70.7	0.34	0	0	0.34	0	0.000	0.000	0.34	1	0.34	1.111	0.060	0	0	0.060	0.000	0.000	0.310	0.000	0.000	0.150
	JUL	90	1	78.0	0.38	0	0	0.38	0	0.000	0.000	0.38	1	0.38	1.111	0.105	0	0	0.105	0.000	0.000	0.105	0.000	0.000	0.157
	AUG	90	2	75.2	0.79	0	0	0.79	0	0.000	0.000	0.79	1	0.79	1.111	1.024	0	0	0.159	0.000	0.865	0.317	0.000	0.707	0.140
	SEP	90	2	65.4	0.61	0	0	0.61	0	0.000	0.000	0.61	1	0.61	1.111	0.535	0	0	0.119	0.000	0.416	0.238	0.000	1.004	0.105
	OCT	90	2	52.9	0.78	0.1	0	0.78	0	0.000	0.000	0.78	1	0.78	1.111	0.994	0	0	0.076	0.000	0.918	0.152	0.000	1.846	0.067
	NOV	90	1	38.3	0.46	0.5	0	0.46	0	0.000	0.000	0.46	1	0.46	1.111	0.224	0	0	0.043	0.000	0.180	0.086	0.000	1.984	0.038
	DEC	90	1	26.9	0.39	2.8	0.35	0.04	0.5	0.350	0.000	0.04	1	0.04	1.111	0.000	0	0	0.000	0.000	0.000	0.053	0.000	1.920	0.028
1989	JAN	90	0	0.0	0.00	0	0	0.00	0	0.000	0.000	0.00	0	0.00	1.111	0.000	0	0	0.000	0.000	0.000	0.057	0.000	1.863	0.025
COLUMNS → ①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱	⑲	⑳	㉑	㉒	㉓	㉔	㉕	㉖

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA / GRN
Feature WASTEWATER HANDLING
Item Wastewater volume calcs.
Contract No. 5057
Designed HM
Checked DWR
Sheet 7/
File No.
Date Dec 04/87
Date 12/8/87

5. CONCLUSIONS AND RECOMMENDATIONS

The mean monthly inflow into the retention basin ranges from 0.0 to to 0.92 AF during the nine month construction period, April – December – see Spreadsheet on Sheet 6. If this runoff is allowed to accumulate, the maximum accumulated volume will be 1.98 AF over the same period. These volumes are obtained after subtracting off the evaporation losses and any construction water usage (the latter = 0.0, in this case). These volumes are in addition to any runoff volume due to a more intense storm, for example, a 10-year 24-hour storm.

Should the retention basin be designed only to accomodate the runoff and sediment resulting from a 10-year 24-hour storm, (but not the mean monthly runoff), then the runoff should be released periodically to maintain enough storage space to prevent spillover. This runoff release into the natural drainage may require treatment.

If the retention basin is designed to contain both the accumulated mean monthly runoff and the 10-year 24-hour storm runoff, no periodic treatment and release will be necessary during the duration of construction, unless, of course, one or more storms greater than the 10-year 24-hour event takes place.

The spreadsheet on Sheet 6 presents sufficient information to proceed with the next phase of wastewater handling design.

Sheet A
Project UMTRA / GRN
Contract No. 5057
File No.
Feature
Designed HM
Date Dec 07, 1987
Item
Checked DWK
Date 12/18/87

APPENDIX A

MEAN MONTHLY PRECIP, TEMP AND EVAPORATION DATA

CLIMATOGRAPHY OF THE UNITED STATES NO. 20

GREEN RIVER, UT

PERIOD: 1951-80
ELEVATION: 4070 FT

CLIMATOLOGICAL SUMMARY

	TEMPERATURE (F)															PRECIPITATION TOTALS (INCHES)											
	MEANS			EXTREMES						MEAN NUMBER OF DAYS				DEGREE DAYS								SNOW			MEAN NUMBER OF DAYS		
										MAX		MIN															
	* DAILY MAXIMUM	* DAILY MINIMUM	* MONTHLY	RECORD HIGHEST	YEAR	DAY	RECORD LOWEST	YEAR	DAY	90 AND ABOVE	32 AND BELOW	32 AND BELOW	0 AND BELOW	* HEATING BASE 65	* COOLING BASE 65	* MEAN	* GREATEST MONTHLY	YEAR	GREATEST DAILY	YEAR	DAY	MEAN	MAXIMUM MONTHLY	YEAR	.10 OR MORE	.50 OR MORE	1.00 OR MORE
JAN	36.8	9.3	23.1	64+	65	31	-25+	79	30	0	10	31	8	1299	0	.40	1.67	78	.49	69	14	4.0	26.0	79	1	0	0
FEB	47.7	17.5	32.6	71+	62	11	-19+	79	5	0	2	27	2	907	0	.37	1.33	80	.45	80	19	2.0	17.0	78	1	0	0
MAR	58.1	26.1	42.1	81+	78	30	6+	65	3	0	0	24	0	710	0	.46	2.55	79	.84	79	28	.6	5.0	76	1	0	0
APR	68.6	34.8	51.7	88+	80	20	15+	75	2	0	0	11	0	399	0	.45	1.18	64	.63	53	06	.0	.3	53	1	0	0
MAY	79.0	44.2	61.6	97+	58	29	23+	75	6	3	0	1	0	142	36	.61	2.12	73	1.23	73	06	.0	.0	0	2	0	0
JUN	89.9	51.4	70.7	105+	79	29	35+	79	9	17	0	0	0	17	188	.34	1.80	69	.70	69	24	.0	.0	0	1	0	0
JUL	96.4	59.5	78.0	106+	80	19	41+	68	1	29	0	0	0	0	403	.38	1.32	75	1.08	75	30	.0	.0	0	1	0	0
AUG	93.3	57.0	75.2	107+	79	6	39+	75	29	24	0	0	0	0	316	.79	2.82	57	1.34	65	19	.0	.0	0	2	0	0
SEP	84.9	45.8	65.4	101+	79	8	25+	78	21	9	0	1	0	72	84	.61	3.41	61	1.34	61	08	.0	.0	0	2	0	0
OCT	71.2	34.5	52.9	90+	79	2	12+	75	25	0	0	12	0	375	0	.78	4.39	72	1.01	61	08	.1	2.0	71	2	0	0
NOV	53.9	22.6	38.3	74+	78	1	-6+	76	28	0	0	27	0	801	0	.46	1.97	57	.77	57	02	.5	4.0	75	1	0	0
DEC	40.9	12.8	26.9	65+	77	4	-16+	67	22	0	5	31	2	1181	0	.39	1.28	65	.75	65	10	2.8	12.7	72	1	0	0
YEAR	68.4	34.6	51.5	107	AUG 79	6	-25	JAN 79	30	82	17	165	12	5903	1027	6.04	4.39	OCT 72	1.34	AUG 65	19	10.0	26.0	JAN 79	16	0	0

*FROM 1951-80 NORMALS

ESTIMATED VALUE BASED ON DATA FROM SURROUNDING STATIONS

\+ ALSO ON EARLIER DATES.

DEGREE DAYS TO SELECTED BASE TEMPERATURES (F)

BASE	HEATING DEGREE DAYS												
BELOW	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
65	1299	907	710	399	142	17	0	0	72	375	801	1181	5903
60	1144	776	555	256	58	0	0	0	19	232	651	1026	4717
57	1051	696	462	178	25	0	0	0	7	157	561	933	4070
55	989	643	404	133	14	0	0	0	0	116	501	871	3671
50	847	517	262	53	0	0	0	0	0	42	358	716	2795

BASE	COOLING DEGREE DAYS												
ABOVE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
55	0	16	0	34	218	471	713	626	316	51	0	0	2445
57	0	13	0	19	168	411	651	564	259	30	0	0	2115
60	0	9	0	7	108	324	558	471	181	12	0	0	1670
65	0	0	0	0	36	188	403	316	84	0	0	0	1027
70	0	0	0	0	8	90	248	174	24	0	0	0	544

DERIVED FROM THE 1951-80 MONTHLY NORMALS

PROBABILITY THAT THE MONTHLY PRECIPITATION HILL BE EQUAL TO OR LESS THAN THE INDICATED PRECIPITATION AMOUNT

MONTHLY PRECIPITATION (INCHES)

PROBABILITY LEVELS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
.05	.00	.00	.00	.00	.00	.00	.02	.01	.00	.00	.00	.00
.10	.00	.00	.00	.03	.00	.00	.04	.06	.07	.02	.02	.02
.20	.04	.03	.04	.11	.13	.02	.08	.15	.19	.11	.09	.07
.30	.09	.08	.11	.18	.25	.07	.13	.26	.28	.21	.16	.13
.40	.15	.14	.19	.25	.36	.14	.19	.39	.38	.34	.23	.19
.50	.23	.22	.29	.34	.48	.21	.26	.53	.49	.49	.32	.27
.60	.34	.32	.41	.44	.61	.30	.35	.72	.61	.69	.43	.36
.70	.47	.44	.56	.56	.78	.42	.46	.95	.76	.93	.57	.48
.80	.67	.62	.78	.73	1.00	.58	.61	1.28	.96	1.29	.76	.64
.90	1.02	.93	1.15	1.01	1.35	.86	.88	1.84	1.29	1.90	1.09	.92
.95	1.37	1.25	1.52	1.29	1.70	1.14	1.15	2.41	1.61	2.52	1.41	1.20

THESE VALUES HERE DETERMINED FROM THE INCOMPLETE GAMMA DISTRIBUTION

A-1
HM Dec 02/87
CWDWK 12/8/87

423418 GREEN RIVER, UT

LAT: 39 00N (DEG MIN) LONG: 110 10W (DEG MIN)

PERIOD: 1951-80

FREEZE DATA

PROBABILITY OF LATER DATE IN SPRING (THRU JULY 31) THAN INDICATED(*)

SPRING FREEZE DATES (MO/DAY)

TEMP (F)	.90	.80	.70	.60	.50	.40	.30	.20	.10
36	5/04	5/10	5/14	5/17	5/20	5/24	5/27	5/31	6/06
32	4/20	4/26	4/30	5/03	5/06	5/09	5/13	5/17	5/22
28	4/10	4/15	4/18	4/21	4/24	4/27	4/29	5/03	5/08
24	3/26	4/01	4/06	4/10	4/13	4/17	4/20	4/25	5/01
20	3/13	3/18	3/22	3/26	3/29	4/01	4/04	4/08	4/14
16	2/24	3/03	3/08	3/12	3/16	3/20	3/24	3/29	4/05

PROBABILITY OF EARLIER DATE IN FALL (BEGINNING AUG 1) THAN INDICATED(*)

FALL FREEZE DATES (MO/DAY)

TEMP (F)	.10	.20	.30	.40	.50	.60	.70	.80	.90
36	9/12	9/16	9/19	9/22	9/24	9/27	9/30	10/03	10/07
32	9/20	9/25	9/29	10/02	10/05	10/08	10/11	10/15	10/20
28	10/02	10/07	10/10	10/13	10/16	10/19	10/22	10/26	10/30
24	10/12	10/17	10/20	10/23	10/26	10/29	10/31	11/04	11/08
20	10/22	10/26	10/30	11/02	11/05	11/07	11/10	11/14	11/19
16	10/29	11/04	11/08	11/12	11/15	11/19	11/22	11/26	12/02

PROBABILITY OF LONGER THAN INDICATED FREEZE-FREE PERIOD (DAYS)

FREEZE FREE PERIOD

TEMP (F)	.10	.20	.30	.40	.50	.60	.70	.80	.90
36	150	142	136	131	126	122	117	111	103
32	174	166	161	156	151	147	142	136	128
28	196	189	183	179	175	170	166	161	153
24	219	211	205	200	195	190	185	179	171
20	245	236	230	225	220	215	210	204	195
16	274	264	256	250	244	238	231	224	213

(*)PROBABILITY OF OBSERVING A TEMPERATURE AS COLD, OR COLDER, LATER IN THE SPRING OR EARLIER IN THE FALL THAN THE INDICATED DATE.
0/00 INDICATES THAT THE PROBABILITY OF OCCURRENCE OF THRESHOLD TEMPERATURE IS LESS THAN INDICATED PROBABILITY.

GROWING DEGREE UNITS TO SELECTED BASE TEMPERATURES (F)

BASE		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
40	M	2	20	130	360	679	930	1187	1100	768	415	65	4	5660
	S	2	22	152	512	1191	2121	3308	4408	5176	5591	5656	5660	
45	M	0	3	53	223	524	780	1032	945	618	270	19	1	4468
	S	0	3	56	279	803	1583	2615	3560	4178	4448	4467	4468	
50	M	0	0	15	114	373	630	877	790	469	148	3	0	3419
	S	0	0	15	129	502	1132	2009	2799	3268	3416	3419	3419	
55	M	0	0	2	41	234	480	722	635	323	62	0	0	2499
	S	0	0	2	43	277	757	1479	2114	2437	2499	2499	2499	
60	M	0	0	0	8	116	332	567	480	189	15	0	0	1707
	S	0	0	0	8	124	456	1023	1503	1692	1707	1707	1707	

M = MONTHLY DATA S = SUM OF MONTHLY DATA

GROWING DEGREE UNITS FOR CORN

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
CORN	M	6	44	147	286	454	571	716	678	511	342	93	8	3856
	S	6	50	197	483	937	1508	2224	2902	3413	3755	3848	3856	

NOTE: FOR CORN THE BASE IS 50, AND THE DEGREE UNITS ARE ADJUSTED FOR TEMPERATURES BELOW 50 AND ABOVE 86

OTHER CLIMATOLOGICAL DATA ARE AVAILABLE IN A VARIETY OF SUMMARIES AND FORMATS, SUCH AS THE CLIMATOGRAPHY OF THE UNITED STATES: NO. 60 - CLIMATE OF STATES; NO. 81 - MONTHLY NORMALS (AND SUPPLEMENTS: ANNUAL DEGREE DAYS TO SELECTED BASES DERIVED FROM THE 1951-80 NORMALS; AND MONTHLY PRECIPITATION PROBABILITIES, SELECTED PROBABILITY LEVELS DERIVED FROM THE 1951-80 NORMALS); NO. 84 - DAILY NORMALS; NO. 85 - DIVISIONAL NORMALS. A VARIETY OF DATA IS AVAILABLE EITHER ON MAGNETIC TAPE, MICROFICHE, OR PAPER COPY.

TO OBTAIN INFORMATION ABOUT CLIMATOLOGICAL DATA AND RELATED PUBLICATIONS, CONTACT:

DIRECTOR
NATIONAL CLIMATIC DATA CENTER
FEDERAL BUILDING
ASHEVILLE, NC 28801-2696
(OR TELEPHONE: (704) 259-0682)

DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER
ASHEVILLE, NC

USCOMM-NOAA-ASHEVILLE, NC 7/84/200

A-2

HM ccc 04/27

Chk DWK 12/8/87

TABLE I -- MEAN MONTHLY, SEASONAL, AND ANNUAL CLASS A PAN EVAPORATION (INCHES) FOR STATIONS WITH 10 YEARS OR MORE OF RECORD FOR BEST MONTH*

	State No.	Station Index No.**	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	May-Oct ***	Nov-Apr ***	Other Season ***	Annual ***	Record Began Mo/Yr	Latest Data Mo/Yr
TEXAS (continued)																				
Winter Haven Exp Station 28° 38', 99° 32'	41	9042	2.01 11 ****	3.80 12 ****	5.67 12 ****	7.30 10 ****	10 9 ****	12 9 ****	12.67 10 ****	12 9 ****	8.22 10 ****	5.92 11 ****	3.79 10 ****	2.03 9 ****	61 ****	26.08 ****	-	87 ****	3/49	3/64
Ysleta 31° 42', 106° 19'	41	9996	3.37 40 17	5.04 41 9	8.43 41 16	11.40 41 5	13.49 41 6	14.79 41 5	13.04 41 9	11.13 41 27	9.09 41 9	6.68 41 12	4.36 39 14	3.32 40 12	68.22 6	36.12 6	-	104.34 4	2/39	12/79
UTAH																				
Fish Springs Refuge 39° 51', 113° 24'	42	2832					11.48 10 ****	13.34 11 ****	16.00 13 ****	13.75 12 ****	10.10 13 ****	6 8 ****			71 ****	-	-	-	1/62	9/79
Flaming Gorge 40° 56', 109° 25'	42	2864						5.89 20 20	10.07 21 9	8.92 20 10	5.92 18 19				-	-	30.40	-	5/59	9/79
Green River Aviation 39° 00', 110° 10'	42	3418				6.31 14 ****	7.94 20 17	8.59 23 16	9.18 21 12	7.90 22 14	5.88 23 16	3.71 17 20			43.20 9	-	-		4/56	10/79
Gunnison 39° 09', 111° 49'	42	3514					7.40 12 ****	8.53 13 ****	9.91 15 ****	8.45 16 ****	6.09 16 ****	4 9 ****			44 ****	-	-	-	5/62	9/79
Logan Utah State Exp Sta 41° 46', 111° 49'	42	5190				4.27 16 ****	6.21 27 15	7.24 28 12	8.61 28 7	7.62 28 8	5.14 27 12	3.05 25 13			37.07 5	-	-	-	9/50	8/78
Moab 4 NW 38° 36', 109° 36'	42	5733				7.64 19 13	10.44 22 9	12.06 20 14	12.91 21 12	10.90 22 10	7.69 22 11	20.00 20 20			74.02 8	-	-	-	5/58	10/79
Mexican Hat 37° 09', 109° 52'	42	5582				8.00 19 12	12.02 20 11	14.35 19 15	14.45 19 14	12.06 20 34	9.10 20 34	5.71 17 13	2 5 ****		67.87 17	-	-	-	11/57	10/79
Moon Lake 40° 34', 110° 30'	42	5815						8.09 14 ****	6.82 14 ****	6 7 ****					-	-	21	-	8/41	9/55
Piute Dam 38° 19', 112° 11'	42	6897					8.97 52 12	10.84 51 11	10.59 51 10	9.11 51 17	7.41 51 14	4.91 43 16			51.83 6	-	-	-	5/18	10/70

---

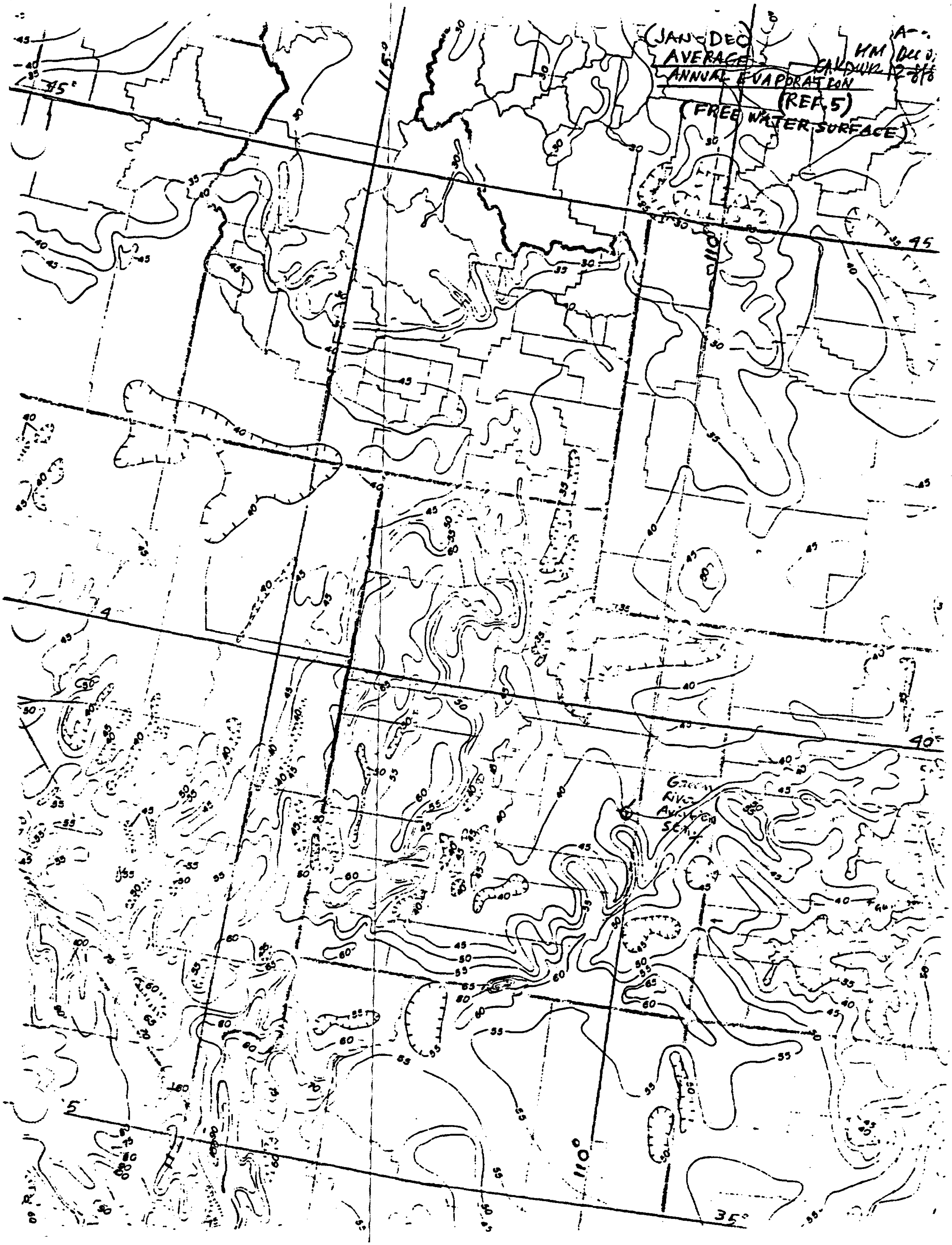
* First line of data in the table for each station is mean evaporation in inches; second line is the number of years of record per month; and third line is the coefficient of variation in percent (computed only where there are 10 years or more of record during 1956-1970).

** Climatological Data (NOAA-EDIS)

*** Sum of monthly means.

**** Insufficient data between 1956-70 to compute the coefficient of variation.

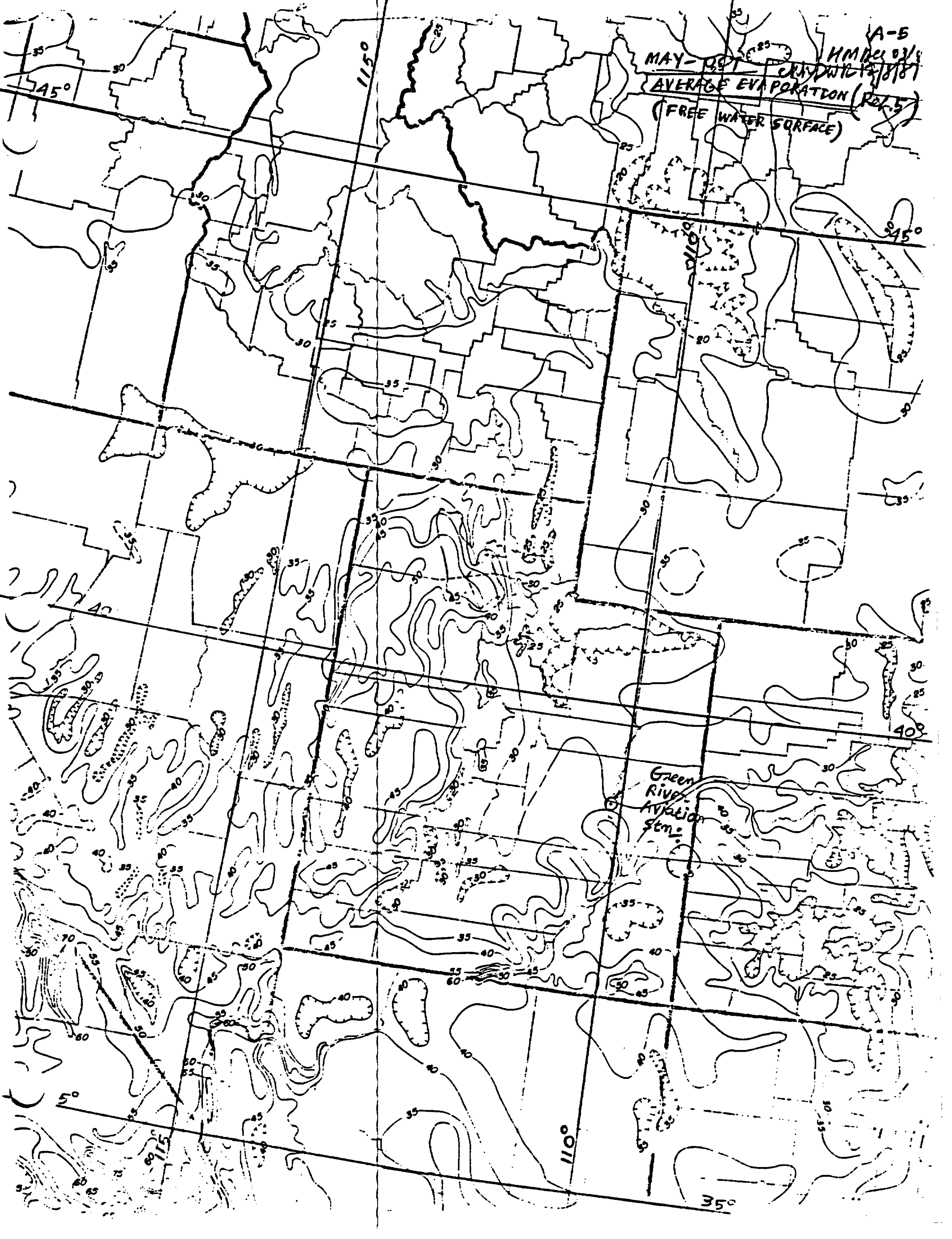
HM Dec.



(JAN-DEC) AVERAGE ANNUAL EVAPORATION (REF. 5) (FREE WATER SURFACE)

A-5

MAY-OCT AVERAGE EVAPORATION (Ref. 5)
(FREE WATER SURFACE)



MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA/GRN
Feature WASTEWATER HANDLING
Item PROCEDURE FOR EVAPORATION ESTIMATES
Contract No. 5057
Designed HM
Checked DWL
Sheet A-6
File No.
Date Dec. 03, 198
Date 12/8/87

Retention Basin Evaporation Estimates:

Evaporation data at the Green River site are available from the following sources:

NOAA Tech Report NWS 33 (Ref. 5): Shallow Lake or Free Water Surface (FWS) Evaporation — both Average Annual and Average for May thru October

NOAA Tech Report NWS 34 (Ref. 3): Average Monthly, Seasonal and Annual Class A Pan Evaporation —

Average Annual FWS Evaporation from above Ref. 5 = 40"
(See Sheet reproduced from Ref. 5)

Average Seasonal (May-Oct.) FWS Evaporation from above Ref. 5 = 30"
(See Sheet)

The 30" (May-Oct) Seasonal evaporation is distributed over these months in terms of the Pan Evaporation data obtained from Ref. 3 (see Sheet 3/).

The remaining (40-30) = 10" is distributed between the months of Nov, Dec, Jan, Feb, Mar, Apr in terms of the distribution percentages at another station (Ely, Nevada) - see Sheet 4/

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Sheet A-7
Project UMTRA / GRN
Contract No. 5057
File No.
Feature WASTEWATER HADLING
Designed HM
Date Dec. 03/87
Item EVAPORATION AT GREEN RIVER AVIATION STN.
Checked DWIL
Date 12/8/87

Month		Average Annual FWS evaporation	Monthly Distribution Percentages —
Jan	see Sheet A-9	0.10 ⊗ 10" = 1.0	0.025
Feb		0.11 ⊗ 10" = 1.1	0.027
March		0.22 ⊗ 10" = 2.2	0.065
April		0.31 ⊗ 10" = 3.1	0.077
May	see Sheet A-8	0.18 ⊗ 30" = 5.4	0.140
Jun		0.20 " " = 6.0	0.150
Jul		0.21 " " = 6.3	0.157
Aug		0.18 " " = 5.4	0.140
Sep		0.14 " " = 4.2	0.105
Oct		0.09 " " = 2.7	0.067
Nov	see sheet A-9	0.15 ⊗ 10" = 1.5	0.038
Dec		0.11 ⊗ 10" = 1.1"	0.028

Total = 40.0"

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA/GRN
Feature WASTEWATER HANDLING
Item Basic Data Collection
Contract No. 5057
Designed HM
Checked DWK
Sheet A-8
File No.
Date Dec. 02, 1987
Date 12/8/87

YEAR	MONTH	SOIL SCS NO.	MEAN NO. OF DAYS PRECIP >0.1"	MEAN TEMP. (°F)	MEAN PRECIP. (Inch)	MEAN SNOW (Inch)
1988	April	90	1	51.7	0.45	0.0
	May	90	2	61.6	0.61	0.0
	June.	90	1	70.7	0.34	0.0
	July.	90	1	78.0	0.38	0.0
	Aug.	90	2	75.2	0.79	0.0
	Sept.	90	2	65.4	0.61	0.0
	Oct.	90	2	52.9	0.78	0.10
	NOV.	90	1	38.3	0.46	0.50
basically Cleanup →	Dec.	95	1	26.9	0.39	2.80

Project UMTRA/GRN
Feature WASTEWATER HANDLING
Item Basic Data Collection
Contract No. 5057
Designed HM
Checked DWR
Sheet A-9
File No.
Date DEC 03 198
Date 12/8/87

Mean Monthly Evaporation at Green River Aviation, Lat: 39°00', Long: 110° 10' (Ref. 3)

Month	"Class A Pan Evaporation"	Monthly Percentage Distribution — In terms of (May-Oct) only
Jan	N.A. (not available)	
Feb	"	—
Mar	"	—
Apr	6.31	—
May	7.94	0.18
Jun	8.59	0.20
Jul	9.18	0.21
Aug	7.90	0.18
Sep	5.88	0.14
Oct	3.71	0.09
		1.00
Nov	N.A.	
Dec	N.A.	

May-Oct = 43.2" = Class A Pan Evaporation

These percentag
are used to
distribute the
average (May-O
FWS evaporati
- see Sheet

Pan coeff. at the above location = 0.70 (Ref. 5)

Hence (May-Oct.) FWS evaporation = 43.2 ⊗ 0.70 ≃ 30", which agrees with the (May-Oct) FWS evaporation obtained from Ref. 5.

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A MORRISON KNUDSEN COMPANY

Project UMTRA/GRN
Feature WASTEWATER HANDLING
Item Basic Data Collection
Contract No. 5057
Designed HM
Checked DWK
Sheet A·10
File No.
Date Dec. 02, 198
Date 12/8/87

Mean Monthly Evaporation at Ely, Nevada Lat: 39°16', Long: 114°15'
(Ref. 3). Elev: 6421 Ft. (Ref. 1)

Month	"Class A Pan Evaporation" (Inches)	Percentage of Total	Percentage of (Nov-Apr)
Jan.	1·62	2.5	0·10
Feb.	1·76	2.7	0·11
Mar.	3·34	5.1	0·22
Apr.	4·82	7·4	0·31
May	7·16	11·6	—
Jun.	9·31	14·3	—
Jul.	11·14	17·1	—
Aug.	9·72	15·0	—
Sept.	7·13	11·0	—
Oct.	4·63	7·1	—
Nov.	2·33	3·6	0·15
Dec.	1·66	2·6	0·11
	Annual = 65.05"	100.0 %	Total = 1·00

Total of Nov, Dec, Jan, Feb, Mar, Apr = 15·53"

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A MORRISON KNUDSEN COMPANY

Project UMTRA / GRN
Feature
Item
Contract No. 5057
Designed HM
Checked
Sheet B
File No.
Date Dec 08, 1987
Date 12/8/87

APPENDIX B

RETENTION BASIN DESIGN

RATIONAL APPROACH FOR ESTIMATING RETENTION BASIN WATER VOLUME USING MEAN CLIMATIC DATA

SHEET B-1
BY : DWL 12/8/87
CHCK'D BY: HN DEC 08,'87

RETENTION BASIN DESIGN

Retention basins collect contaminated surface water which may be either, accumulated to avoid offsite discharge or, treated and discharged to offsite on a regular basis in an effort to keep the basin relatively empty.

The minimum design volume of a retention basin is that due to a 10-year 24-hour storm.

A separate rational analysis of the retention basin water volumes should be made to evaluate surface water runoff during the life of the project using mean monthly climatic data with adjustments for basin evaporation, snowmelt, infiltration, water used for construction, and inflow due to possible dewatering. The same basic information is utilized to 1) estimate the volume of water that might accumulate over the life of the project when no offsite discharge is desired, and/or 2) to substantiate data for discharge permits. A microcomputer modeling program is available for performing such a rational analysis.

The ten year 24-hour storm volume will usually exceed the monthly runoff calculated by a rational analysis using mean climatic data. However, the monthly runoff volume by rational analysis may exceed the 10-year 24-hour storm at those sites where snow accumulation from month-to-month occurs and eventually melts.

The design volume for the retention basin shall be:

Accumulating Design

If the contaminated water is to be accumulated over the life of the project to avoid/minimize offsite discharge and water treatment, the design water volume is the sum of a 10-year 24-hour storm volume plus that maximum volume attributable to

SHEET B-2
, BY: DWK 12/8/8,
CHCKD BY: HM Dec. 08, 8

'normal' water accumulation based on a rational analysis of water usage with consideration for evaporation, construction water, dewatering, snowmelt and infiltration.

Non-Accumulating Design

Case I

If the maximum monthly net inflow volume by a rational analysis occurs during a normal construction month, the design water volume shall be the larger volume due to a 10-year 24-hour storm or as determined by a rational analysis if water in a full basin can be treated and discharged within ten days. If not, the basin should be designed for the sum of a 10-year storm plus the maximum monthly volume from a rational analysis.

Case II

If the maximum monthly net inflow volume by a rational analysis occurs during a non-construction month, the design volume shall be the sum of a 10-year 24-hour storm plus that maximum volume by a rational analysis, unless adequate water treating capacity is made available during that month.

Where high groundwater levels and/or space limitations restrict adherence to the above, additional water treating capacity may be substituted.

The need for water treatment and the water treatment plant size should be coordinated with project management because of high water treatment capital costs and possible availability problems.

Final determination of whether or not treating of water will actually be required is dependent on the degree of contamination in runoff water. The degree of contamination will likely vary with time of year (less with high volumes of snowmelt) and extent of disturbed soil due to construction.

SHEET B-3
PROJECT UMTRA /GEN CONTR. NO. 5025 FILE NO. ✓
FEATURE DESIGNED KM DATE 12-8-87
ITEM CHECKED HM DATE Dec 08, 1987

RATIONAL APPROACH FOR ESTIMATING RETENTION BASIN DESIGN WATER VOLUME USING MEAN CLIMATIC DATA

A. INTRODUCTION

THIS PROCEDURE PROVIDES THE DETAILS PRIMARILY FOR DETERMINING THE AVERAGE TOTAL MONTHLY RUNOFF VOLUME THAT SHOULD BE EXPECTED IN RETENTION BASIN(S) USING LONG TERM AVERAGE CLIMATIC DATA WITH CONSIDERATION FOR SNOWMELT CARRY-OVER. A SPREADSHEET USING LOTUS 1-2-3 SOFTWARE TO COMPUTE THE TOTAL RUNOFF VOLUME IS AVAILABLE. THE AMOUNT OF RUNOFF IS CALCULATED USING THE SOIL CONSERVATION SERVICE METHOD. SNOWMELT IS COMBINED WITH RAINFALL TO ESTIMATE THE MONTHLY TOTAL RUNOFF.

THE SPREADSHEET ALSO CALCULATES THE MONTHLY NET WATER BALANCE WITH ALLOWANCE FOR EVAPORATION AND CONSTRUCTION WATER USE, ALONG WITH THE TOTAL ANTICIPATED WATER ACCUMULATION WHICH COULD OCCUR IF WATER IS NOT DISPOSED OF MONTHLY.

THE SPREADSHEET MUST BE MODIFIED TO REFLECT THE LATEST CONSTRUCTION SCHEDULE DURING WHICH THE RETENTION BASIN WILL BE OPERATING. THE THIS PRIMARILY AFFECTS THE CALCULATED AMOUNTS OF EVAPORATION AND THE ANTICIPATED ACCUMULATED WATER VOLUMES.

B. INPUT DATA

THE REQUIRED DATA INPUT TO THE SPREADSHEET INCLUDES:

1. RUNOFF DRAINAGE AREA (ACRES): USED TO COMPUTE RUNOFF
2. RETENTION BASIN(S) CAPACITY (AC-FT): USED FOR COMPARISON PURPOSES ONLY.
3. POND EVAPORATION AREA (ACRES): FOR COMPUTING EVAPORATION
4. AVERAGE ANNUAL LAKE EVAPORATION(INCHES): USED TO DETERMINE EVAPORATION.

5. SOIL SCS CURVE NUMBER (CN): WHEN MONTHLY MEAN TEMPERATURE IS BELOW FREEZING, A MINIMUM CN=95 IS RECOMMENDED.
6. MEAN NUMBER OF DAYS PRECIPITATION IS GREATER THAN 0.1 INCHES WATER.
7. MEAN TEMPERATURE, DEGREES FAHRENHEIT
8. MEAN PRECIPITATION, INCHES
9. MEAN SNOW DEPTH, INCHES
10. CONSTRUCTION WATER DEMAND- MONTHLY AVERAGE (AC-FT). THOSE MONTHS OF NO-CONSTRUCTION MUST SHOW 'ZERO', USUALLY, DECEMBER, JANUARY, AND FEBRUARY.
11. EVAPORATION DISTRIBUTION FACTORS (DECIMALS) FOR EACH MONTH OF THE YEAR.

THE FOLLOWING INFORMATION IS USED TO COMPUTE THE TOTAL RUNOFF VOLUME: THE MEAN TEMPERATURE, MEAN SNOW DEPTH, MEAN PRECIPITATION AND THE MEAN NUMBER OF DAYS PRECIPITATION IS GREATER THAN 0.1 INCHES ARE AVAILABLE FROM THE NOAA CLIMATOGRAPHY OF THE UNITED STATES NO. 20, 1951-1980 USING THE CLOSEST RECORDING STATION TO THE SITE(S).

SHEET B-4
PROJECT UMTRA/GEN CONTR. NO. 5025 FILE NO.
FEATURE DESIGNED DWL DATE 12-8-87
ITEM CHECKED HM DATE DEC 08, 1987

ADDITIONAL INPUT FOR OVERALL WATER BALANCE ARE:

<u>AVERAGE MONTHLY CONSTRUCTION WATER DEMAND</u>: USED IN PLACING CONTAMINATED EMBANKMENT MATERIAL. APPLIES ONLY TO DISPOSAL SITE WHICH IS BEING EVALUATED, OR WHEN PROCESS SITE WATER CAN BE TRANSPORTED TO DISPOSAL SITE. TRANSPORTING OF CONTAMINATED WATER OVER PUBLIC ROADS IS NOT CONSIDERED PRACTICAL BECAUSE ADDITIONAL PERMITS MAY BE REQUIRED. DURING MONTHS OF NO CONSTRUCTION THIS EQUALS ZERO.

<u>MONTHLY EVAPORATION DISTRIBUTION FACTORS</u>: USED TO DISTRIBUTE THE TOTAL ANNUAL LAKE EVAPORATION. AVAILABLE FROM THE NOAA TECHNICAL REPORT NWS 33 OR USE AVERAGE MONTHLY EVAPORATION DATA FROM OTHER SOURCES AND LOCALS WHICH CAN BE ASSUMED TO BE REPRESENTATIVE OF THE PRESENT SITE.

<u>AVERAGE ANNUAL LAKE EVAPORATION</u>: AVAILABLE FROM CLIMATIC ATLAS OF THE UNITED STATES.

<u>POND EVAPORATION AREA</u>: FOR RECTANGULAR PONDS, USE THE POND BOTTOM AREA. WHERE DIKED RETENTION AREAS ARE USED, THE AREA MAY BE EXPRESSED AS A VARIABLE FUNCTION DEPENDENT ON POND VOLUME(SEE ATTACHED EXAMPLE). DIKED RETENTION AREAS MAY BE MODELED AS CONICAL VOLUMES. THE AVERAGE SURFACE AREA WHEN THE POND IS LESS THAN FULL IS APPROXIMATED BY:

$$A_{AVG}=KA_F(V_P/V_F)^{2/3}$$

WHERE: A_F=MAXIMUM WATER SURFACE AREA ASSOCIATED WITH V_F=VOLUME OF WATER WHEN FULL(EXCLUDING SEDIMENT)

V_P=TOTAL RUNOFF VOLUME FOR THAT MONTH

K=0.5 CONVERTS THE AREA TO AVERAGE END AREA AS THE EVAPORATION AREA GOES FROM A2 TO ZERO.

<u>NUMBER DAYS RAIN PER STORM</u>: AN EVALUATION OF HISTORICAL DAILY PRECIPITATION RECORDS OF THE SITE SHOULD BE MADE TO DETERMINE THE 'NORMAL' NUMBER OF DAYS ASSOCIATED WITH RAINFALL EVENTS WHEN DAILY PRECIPITATION IS GREATER THAN 0.1 INCHES. THE MINIMUM IS TWO. THIS DATA IS USED TO SIMULATE BACK-TO-BACK 24-HOUR STORMS.

SHEET B-5

PROJECT UMTRA / GEN CONTR. NO. 5025 FILE NO.

FEATURE DESIGNED DWN DATE 12-8-87

ITEM CHECKED HM DATE DEC 08, 1987

C. CALCULATIONS

CALCULATION OF TERMS ARE AS FOLLOWS:

DESIGN SNOW: IF AVERAGE TEMPERATURE IS LESS THAN 33 DEGREE F, SNOW IN INCHES WATER IS THE LESSER OF MEAN SNOW (INCHES OF WATER) OR MEAN PRECIPITATION. CONVERSION OF INCHES OF SNOW TO INCHES OF WATER IS BASED ON 8 INCHES SNOW EQUAL ONE INCH WATER.

RAINFALL: MEAN PRECIPITATION MINUS DESIGN SNOW (INCHES OF WATER).

ACCUMULATED SNOWPACK: IF AVERAGE TEMPERATURE IS LESS THAN 33 DEGREES F., THE SUM OF PREVIOUS MONTH SNOW PLUS NEW SNOW.

SNOWMELT: IF MEAN DAILY TEMPERATURE IS GREATER THAN 32 DEGREES F., ALL THE ACCUMULATED SNOWPACK BECOMES SNOWMELT.

TOTAL RAINFALL AND SNOWMELT: RAINFALL AND SNOWMELT ARE COMBINED TO CONSERVATIVELY SIMULATE POSSIBLE RUNOFF DURING SNOWMELT CONDITIONS.

NUMBER OF EVENTS: AVERAGE NUMBER OF BACK-TO-BACK STORMS PER MONTH DETERMINED BY DIVIDING THE TOTAL NUMBER OF DAYS PRECIPITION GREATER THAN 0.1 INCHES BY TWO DAYS RAIN PER EVENT AND ROUNDING TO THE NEAREST WHOLE NUMBER WITH A MINIMUM OF ONE.

WATER PER EVENT: TOTAL RAINFALL PLUS SNOWMELT DIVIDED BY THE NUMBER OF EVENTS.

'S': CALCULATED FROM SCS EQUATION WHERE $S=(1000/CN)-10$

TOTAL RUNOFF VOLUME: CALCULATED FROM SCS EQUATION

$$I(E)=(P-.2S)^2/(P+.8S)$$

WHERE P EQUALS THE WATER PER EVENT WHEN (P-.2S) IS GREATER THAN OR EQUAL TO ZERO, OTHERWISE EQUALS ZERO.

SHEET B-6
PROJECT UMTRA/GEN CONTR. NO. 5025 FILE NO.
FEATURE DESIGNED DWK DATE 12-8-87
ITEM CHECKED HN DATE DEC 08, 1987

EVAPORATION:

**********WITH WATER TREATMENT***********

THE LESSER VALUE OF (1) MAXIMUM POSSIBLE EVAPORATION PER MONTH DIVIDED BY A FACTOR OF SAFETY OF 2.0, OR (2) THE WATER PER EVENT.

**********NO WATER TREATMENT**************

THE LESSER VALUE OF (1) MAXIMUM POSSIBLE EVAPORATION OR (2) THE SUM OF TOTAL RUNOFF PLUS TOTAL RUNOFF MINUS EVAPORATION AND CONSTRUCTION WATER.

NOTE: THE MAXIMUM POSSIBLE EVAPORATION IS THE EVAPORATION AREA TIMES THE AVERAGE ANNUAL LAKE EVAPORATION TIMES THE MONTHLY EVAPORATION DISTRIBUTION FACTOR.

RUNOFF EXCESS: TOTAL RUNOFF MINUS EVAPORATION.

NET WATER BALANCE: RUNOFF EXCESS MINUS WATER FOR CONSTRUCTION.

ACCUMULATED WATER: THE PREVIOUS MONTHS ACCUMULATED WATER VOLUME PLUS NEW RUNOFF MINUS EVAPORATION AND CONSTRUCTION WATER. EVAPORATION IS DEDUCTED BEFORE CONSTRUCTION WATER.

MKE DOC. No.5)-GRN-C-01-01686-00

Calculation Cover Sheet

Calc. No. 10-591-03-00

Contract No. 5057 Discipline MATERIALS No. of Sheets 3

Project
UMTRA - GREEN RIVER, UTAH

Feature
BEDDING MATERIAL

Item
ROCK TYPES

Sources of Data
REFERENCE ATTACHED (2 pp.)

Sources of Formulae & References
MKES, 25 August 1989, "UMTRA Project - GRN, Bedding Material Quality Scoring" I.O.C. to MK-F Project Office (Albuquerque), San Francisco, CA (MKES Document No. 5057-GRN-I-01-01669-00)

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

—	—	F.B. Guros	8-28-89		8-28-89	F.B. Guros	9-7-89
Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date

Form 42-110

MORRISON-K DSEN ENGINEERS, INC.
A MORRISON KNUDSEN C NY

Sheet 1/3
Project UMTRA - GREEN RIVER
Contract No. 5057
File No.
Feature BEDDING MATERIAL
Designed FBG
Date 8-28-89
Item ROCK TYPES
Checked RWN
Date 8-28-89

PURPOSE :

Determine the percentage by weight of material in each of the three rock type categories used for scoring rock quality for a sample of bedding material. (Bedding material sample was produced from the Hastings Road sand and gravel source).

REFERENCE

Western Engineers, Inc., August 23, 1989, "Summary of Methods and Findings, Petrographic Analysis - Sample No. SB-DUR-001", MK-Ferguson Green River Project, Grand Junction, Colorado. (W.O. # 2263)

RESULTS

ROCK TYPE CATEGORY ①	PERCENTAGE BY WEIGHT FOR SIZE RANGE				AVERAGE % (ALL SIZES ②
	1½ - 3/4	3/4 - 3/8	3/8 - No. 4	No. 4 - No. 10	
SANDSTONE	31	20	28	24	26
LIMESTONE	34	35	39	41	37
IGNEOUS	35	45	33	35	37

① Table A, Specification Section 02278, Rev. 2

② Use averages shown for weighting rock quality scores to determine a single representative score.

UMTRA-GRN 5057
BEDDING MATERIAL

2/3

WESTERN ENGINEERS, INC.
CONSULTING ENGINEERS / LAND SURVEYORS
2150 Hwy 6 & 50, Grand Junction, CO 81505-9422 • 303/242-5202 • FAX 242-1677

COPY OF REFERENCE, p. 1/2

FBG 8-28-89
RWH 8-28-89

SUMMARY OF METHODS AND FINDINGS

PETROGRAPHIC ANALYSIS - SAMPLE NUMBER SB-DUR-001

MK-FERGUSON GREEN RIVER PROJECT

AUGUST 23, 1989

A sand and gravel sample of proposed riprap bedding was delivered to Western Engineers, Inc, in Grand Junction, Colorado, by MK-Ferguson for laboratory testing. Following laboratory testing (specific gravity, absorption, soundness, abrasion, and ASTM C-142), a request was made for identification of rock types comprising the particles of sand and gravel and also the percentages present in each size range (1 1/2 - 3/4, 3/4 - 3/8, 3/8 - No. 4, and No. 4 to No. 10) both by particle count and weight. As directed, 150 particles were identified for each size range (only 105 particles were available in the 1 1/2 to 3/4 inch sizes). The purpose of this report is to present the results of this petrographic analysis.

The sand and gravel sample was screened to obtain sufficient amounts of each of the four size ranges, and 150 particles of each size counted (except only 105 particles of 1 1/2 - 3/4 inch sizes were present). The gravel size particles (1 1/2 - No. 4) were each broken with a hammer and the rock type determined by observing hardness, texture, color, luster, cleavage, and reaction to dilute hydrochloric acid. Each rock type was separated into groups for each size range and the particles counted and weighed.

The sand sizes (No. 4 - No. 10) were identified using a binocular microscope (30 X) and essentially the same identification techniques, although breaking of each particle was not practical.

A table is attached to this report which summarizes the results of the petrographic analysis. The particles were mostly limestone, fine-grained sandstone, and quartzite with lesser amounts of siltstone, calcareous siltstone, chert, quartz, and granitic rock.

The majority of the particles examined were unweathered, hard, and dense. The softer particles were mostly composed of siltstone, calcareous siltstone, a few of sandstone, and a few of limestone. However, even much of the siltstone and calcareous siltstone was of good quality. Some of the sandstone and siltstone was fairly porous.

Prepared by:

WESTERN ENGINEERS, INC.

Joe G. Barnes
Joe G. Barnes
Consulting Geologist

[W.O.# 2203]

DIST.	ACT	INFO
J. SINGLETON	✓	
L. BIGLEY		
D. LEWIS		
D. THOMPSON		
G. STOWE		
IND. HYGIENE		
S. MARTZ	✓	
FILE.		✓

GENERAL PETROGRAPHIC ANALYSIS OF SAND AND GRAVEL

BEDDING MATERIAL - SAMPLE NO. SB-DUR-001

MK-FERGUSON GREEN RIVER PROJECT

AUGUST 1989

UMTRA-GRN 5057
BEDDING MATERIAL
ROCK TYPES

COPY OF REFERENCE, P 2/2

ROCK TYPES	Rock Type Category **	PERCENTAGE BY PARTICLE COUNT				PERCENTAGE BY WEIGHT			
		1 1/2-3/4	3/4-3/8	3/8-No.4	No.4-No.10	1 1/2-3/4	3/4-3/8	3/8-No.4	No.4-No.10
Siltstone	SS	3	1	5	2	3	2	5	2
Calcareous Siltstone	SS	7	1	8	3	5	2	6	2
Limestone	LS	32	42	42	38	34	35	39	41
Fine-Grained Sandstone	SS	25	14	16	22	23	16	17	20
Chert	IG	3	8	11	7	2	8	14	7
Quartzite	IG	25	27	11	17	28	30	11	18
Quartz	IG	3	5	3	10	3	4	3	9
Granitic Rock	IG	2	2	4	1	2	3	5	1
Number of Particles Identified		105*	150	150	150	105*	150	150	150

* Only 105 particles present in sample of 1 1/2 - 3/4 inch sizes.

Rock type of each particle determined by visual methods.

** SS = Sandstone
LS = Limestone
IG = Igneous
Rock Type Category from Table A, Specification Section 02278, Rev. 2

FBG 8-28-89
RWN 8-28-89

MKE DOC. 5057-GRN C-01-01678-00

Calculation Cover Sheet

Calc. No. 10-591-02-00

Contract No. 5057-05 **Discipline** MKES **No. of Sheets** 69

Project

UMTRA - GREEN RIVER (GRN)

Feature

INFILTRATION

Item

'UNSAT2' ANALYSIS - INPUT & OUTPUT

Sources of Data

SEE SH 1

Sources of Formulae & References

SEE SH 1

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

Rev. No.	Revision	Calculation By	Date	Checked By	Date	Approved By	Date
0	——	M. PICHEL P. Y. LI	7-28-89 7/28/89	P. LI M. PICHEL	7/28/89 7-28-89		8-1-89

Form 42-110

Sheet 1
Project UMTRA/GRN
Contract No. 5057-05
File No.
Feature Infiltration
Designed PYL
Date 7/27/89
Item 'UNSAT2' Analysis - Input & 'Output
Checked MSP
Date 7-28-89

REFERENCES & SOURCES OF DATA

1. MKE calc # UMTRA-GEN "INFILTRATION OF CONSTRUCTION WATER"
(IN PROGRESS (8-9-89) PYL MSP

2. "RETC" program decription MKE DOC # 4005-GEN-R-04-06697-00

3. NRC. "UMTRA - Green River - Comments on Green River RAIP"
MKE Doc. No. 5057-GRN-L-09-01585-00, June 22, 1989

4. NRC. "Documentation and User's Guide: UNSAT2 - Variably Saturated Flow Model", Final Report. NUREG/CR-3390

5. MKE. "UMTRA - Green River - Memorandum Report, Disposal Cell Seepage Evaluation", August 1989. MKE Doc. No. 5057-GRN-R-01-01628-00

6. El-Kadi, Aly I. "A Computer Program to Estimate the Parameters of Soil Hydraulic Properties: 'SOIL'" International Ground Water Modeling Center. April 1985, Butler University
Indianapolis, Indiana

MORRISON-KNUDSEN ENGINEERS, INC.
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Sheet 2
Project UMTRA / GREEN RIVER
Contract No. 5057-05
File No.
Feature Infiltration
Designed PYL
Date 7/27/89
Item 'UNSAT2' Analysis - Input & Output
Checked JKSP
Date 7-28-89

PURPOSE & SCOPE

This calculation describes the several-step process that is required to compile the necessary input data to run 'UNSAT2', and presents the results of 'UNSAT2' analysis. 'UNSAT2' analysis was performed in response to NRC comments on Green River RAIP. (Ref. 3). 'UNSAT2' is a finite element computer model for evaluating groundwater flow through variably saturated media (Ref. 4). The input data required to use 'UNSAT2' are the paired values of relative hydraulic conductivity (Krel) and volumetric moisture content (θ), paired values of suction head (in feet) and volumetric moisture content (θ), saturated hydraulic conductivity, porosity and placement moisture content of the materials. The materials involved are placed tailings, windblown / offsite material, and buffer material.

Basic Soil Properties and Capillary Moisture Test Data

A summary table of basic soil properties is included in REF 5 and also on sh. 15. Capillary moisture test data available were discussed in Ref. 5. Appropriate or representative capillary moisture curves (or water retention curves) for each material selected to be used in 'UNSAT2' analysis were also discussed in Ref. 5, and mentioned in summary table on sh. 15-17.

Sheet 3
Project UMTRA / GREEN RIVER
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Date 7/24/89
Item 'UNSAT2' Analysis – 'Input & Output
Checked MSP
Date 7-28-89

(See SH 4 for discussion of Hydraulic properties using "RETC" program)

Hydraulic Properties using 'SOIL' program (Ref. 6)

'SOIL' uses a non-linear least-square analyses to estimate the soil-water characteristic function, $\theta(h)$, and unsaturated hydraulic fraction, $K(\theta)$, where volumetric moisture content (θ) is a function of suction head, h, and hydraulic conductivity is a function of volumetric moisture content. The $\theta(h)$ form proposed by Brooks & Corey ((1964) was used here. Data values from selected water retention curves mentioned in the last section were used as 'SOIL' input. (See 'SOIL' printout in the App. for input data used)

Values of hydraulic properties were desired for all data in the range of moisture contents from saturated to residual. However, 'SOIL' does not output hydraulic properties for all values in this range. Therefore, hand computation of hydraulic properties utilizing the same functions, in this case 'Brooks & Corey' for $\theta(h)$ with estimated $K(\theta)$ function using the series parallel model of Childs and Collis-George, is necessary.
The calculation is shown on the 'SOIL' output on SH. 22

— — — — — — — — —

Fitted water retention curves using 'SOIL' & 'RETC' are presented on sh 9-11. Relative hydraulic conductivity vs. θ curves generated are presented on sh 12-14. The average of "RETC" & "SOIL" curves for K_{rel} vs θ are used for all 3 materials in 'UNSAT2'. As for water retention curves, the actual curves were used for tailings and offpile material, and the 'RETC' fitted curve was used for buffer material since it fits good with actual data in our working moisture range.

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Sheet 4
Project UMTRA-GRN
Contract No. 5057-05
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Date 7-27-89
Item UNSAT2 - input & output
Checked PYL
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Hydraulic Properties using "RETC" program

The "RETC" program (see sh 4 & 5 for program description) was also run to estimate $\theta(h)$ & $K_{UNSAT}(\theta)$. The Van Genuchten equation was used to estimate $\theta(h)$. Mualem's predictive conductivity model was used to estimate $K_{UNSAT}(\theta)$. ($\ell = 0.5$ in the Mualem equation*; $m = 1 - 1/n$ in the Van Genuchten equ.; see ref 1, SH 2 for a discussion of these parameters.)

The "RETC" runs use the same inputs as the "SOIL" runs.

---

*Mualem suggests $\ell \cong 0.5$ REF 2 PG 2 (see sh 6)

UMTRA-
GEN - INFILTRATION

SH 5

JHK

From REF 2

MSP 7-27-89
PYL 7/28/89

PROGRAM: RETC.F77

PURPOSE: To analyze observed soil water retention and hydraulic conductivity data.

DESCRIPTION: This program can be used to fit several analytical functions to observed retention and unsaturated hydraulic conductivity or diffusivity data. The soil water retention curve can be described with equations proposed by Brooks and Corey (1964) or van Genuchten (1980). Analytical functions for the unsaturated hydraulic conductivity (K) or diffusivity (D) were obtained by using the retention functions in conjunction with the predictive hydraulic models of Burdine (1953) and Mualem (1976). As in an earlier version of this program (van Genuchten, 1978), the computer code can be used to predict the unsaturated hydraulic conductivity from observed soil water retention data, assuming the conductivity at saturation (K_s) to be known. In addition, the program allows the analytical functions to be fitted simultaneously to observed retention and conductivity data. As before, the least-squares optimization process is based on Marquardt's maximum neighborhood method (Marquardt, 1963).

The soil water retention curves are given by

$$\theta = \theta_r + \frac{\theta_s - \theta_r}{[1 + (\alpha h)^n]^m} \qquad [1]$$

Van Genuchten

$$\theta = \theta_r + \frac{\theta_s - \theta_r}{(\alpha h)^n} \qquad [2]$$

Brooks & Corey

where θ is the volumetric soil water content, θ_r is the residual water content, θ_s is the saturated water content, h is the pressure head (for notational convenience taken positive for unsaturated soils), and where α, n and m are empirical constants. The inverse of α in Eq. [2] is frequently referred to as the air entry value or bubbling pressure. For a detailed discussion of Eqs. [1] and [2], see van Genuchten and Nielsen (1985).

Mualem's predictive conductivity model is given by

$$K = K_s S_e^{\ell} [f(S_e)/f(1)]^2 \qquad [3]$$

UMTRA-GAN
INFILTRATION

SH6

From REF 2

AHSI 7-27-89
PYL 7/28/89

where

$$f(S_e) = \int_0^{S_e} \frac{1}{h(S'_e)} dS'_e \qquad [4]$$

and S_e is a reduced water content: $S_e = (\theta-\theta_r)/(\theta_s-\theta_r)$. Burdine's model can be expressed in a similar form as folows

$$K = K_s S_e^{\ell} g(S_e)/g(1) \qquad [5]$$

where

$$g(S_e) = \int_0^{S_e} \frac{1}{h^2(S'_e)} dS'_e \qquad [6]$$

Note that both models contain two unknown coefficients: the saturated hydraulic conductivity, K_s, and an unknown parameter ℓ. Mualem (1976) concluded from an analysis of several soils that ℓ in his model should be about 0.5. We will keep ℓ as a potentially unknown coefficient in the program, thus adding more flexibility for fitting different types of data sets. The same is also done for Burdine's model; the parameter ℓ in that model was originally fixed at 2 (Burdine, 1953; Brooks and Corey, 1964).

Choice of a particular retention and conductivity or diffusivity function in the program is governed by the input parameter MTYPE. This parameter determines the type of retention model (e.g., Eq. [1] or [2]) and the type of model used for calculating the hydraulic conductivity (Mualem or Burdine) as follows

MTYPE	Type of Retention model	K is predicted with
1	Eq. [1] with variable m and n	Mualem's model (Eqs. [3] and [4])
2	Eq. [1] with variable m and n	Burdine's model (Eqs. [5] and [6])
3	Eq. [1] with $m = 1-1/n$	Mualem's model
4	Eq. [1] with $m = 1-2/n$	Burdine's model
5	Eq. [2]	Mualem's model
6	Eq. [2]	Burdine's model

Sheet 7
Project UMTRA / GRN
Contract No. 5057-05
File No.
Feature Infiltration
Designed PYL
Date 7/27/89
Item 'UNSATZ' Analysis - Input & Output
Checked MJS
Date 7-28-89

'UNSATZ' ANALYSIS

- Finite Element Mesh was developed as shown on sh. 8, based on Ref. 5, p. 3.
- Cases Studied

  6 Cases were studied Ⓐ through Ⓕ (see sh 15-17), with case Ⓐ being the "nominal" case.
- Boundary Conditions for each case are mentioned in summary tables on sh. 15-17.
- Simulation period is 100 years for all cases
- Initial (Placement) moisture contents θ of the materials were obtained from Ref. 5 and also presented on sh. 15-17.

Hydraulic gradients i, were calculated from the 'UNSATZ' output for selected locations of the modelled soil column (see sh 15-17 for the locations selected) to assess flux velocity there and then seepage velocity. Time for θ' travel through buffer was also assessed.
The value of θ at $t = 100$ years was assumed for the cross-section of flow in order to calculate seepage velocity.
Detailed calculations of i for each print out time step are presented in the Appendix. Values of flux velocity, seepage velocity and travel time at steady-state condition were shown in summary tables on sh. 15-17.

Complete 'UNSATZ' output files are available for inspection at the offices of MK-Environmental Services in San Francisco.

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Project UMTRA-GRN
Feature Infiltration
Item 'UNSAT2' analysis

Contract No. 5037.05
Designed MSP
Checked P/L

Sheet 7A
File No.
Date 7-28-89
Date 7/28/89

- a plot of time to travel thru 6" of buffer vs. cover flux is shown on SH 18

The cover flux corresponding to a 200 yr travel time ≅ 6.6×10^{-9} cm/s

- Conclusions drawn from the unsat 2 runs are discussed in REF 5

- Sheet 18a lists values of hydraulic gradient (i) @ top of buffer for all time steps.

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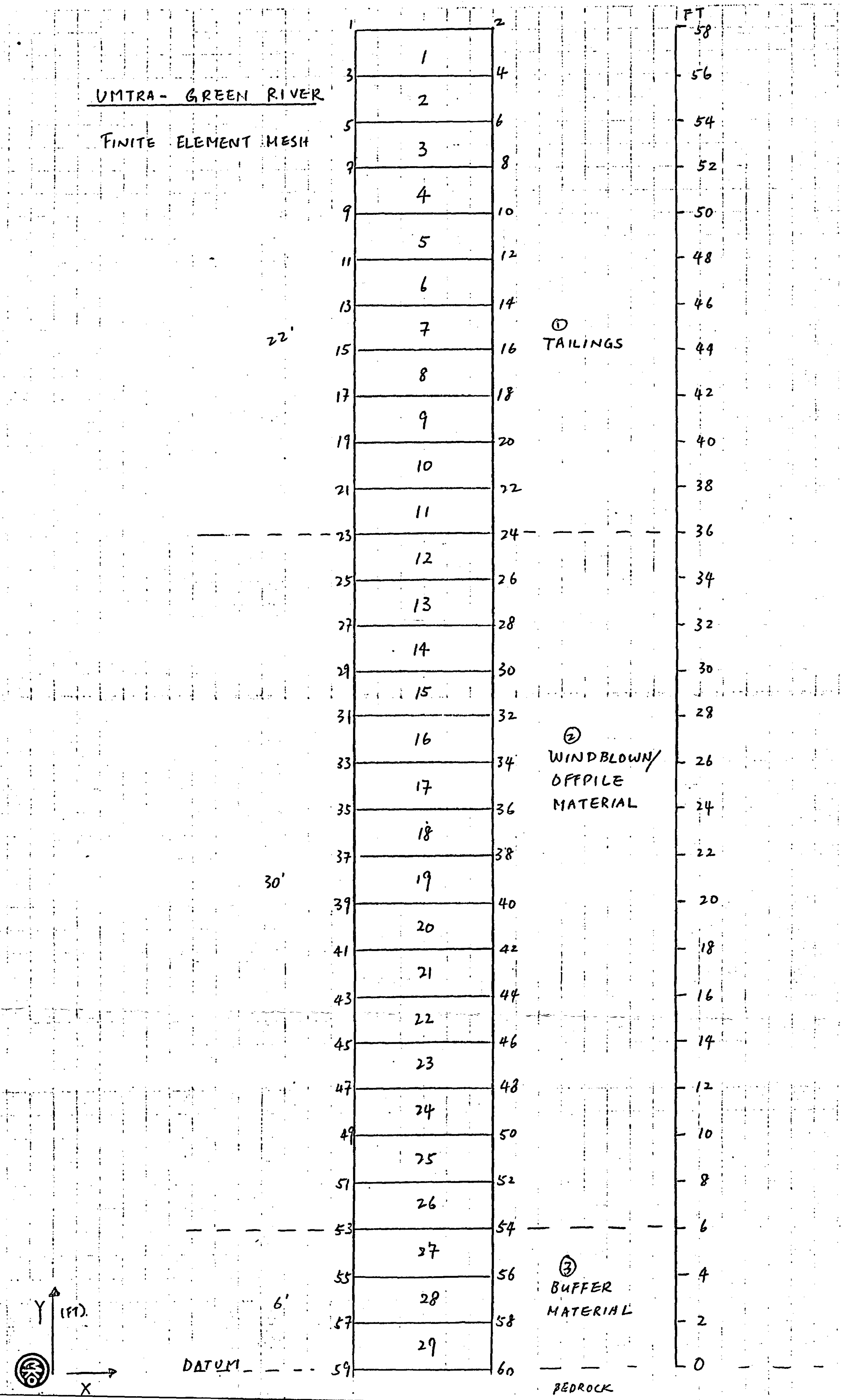
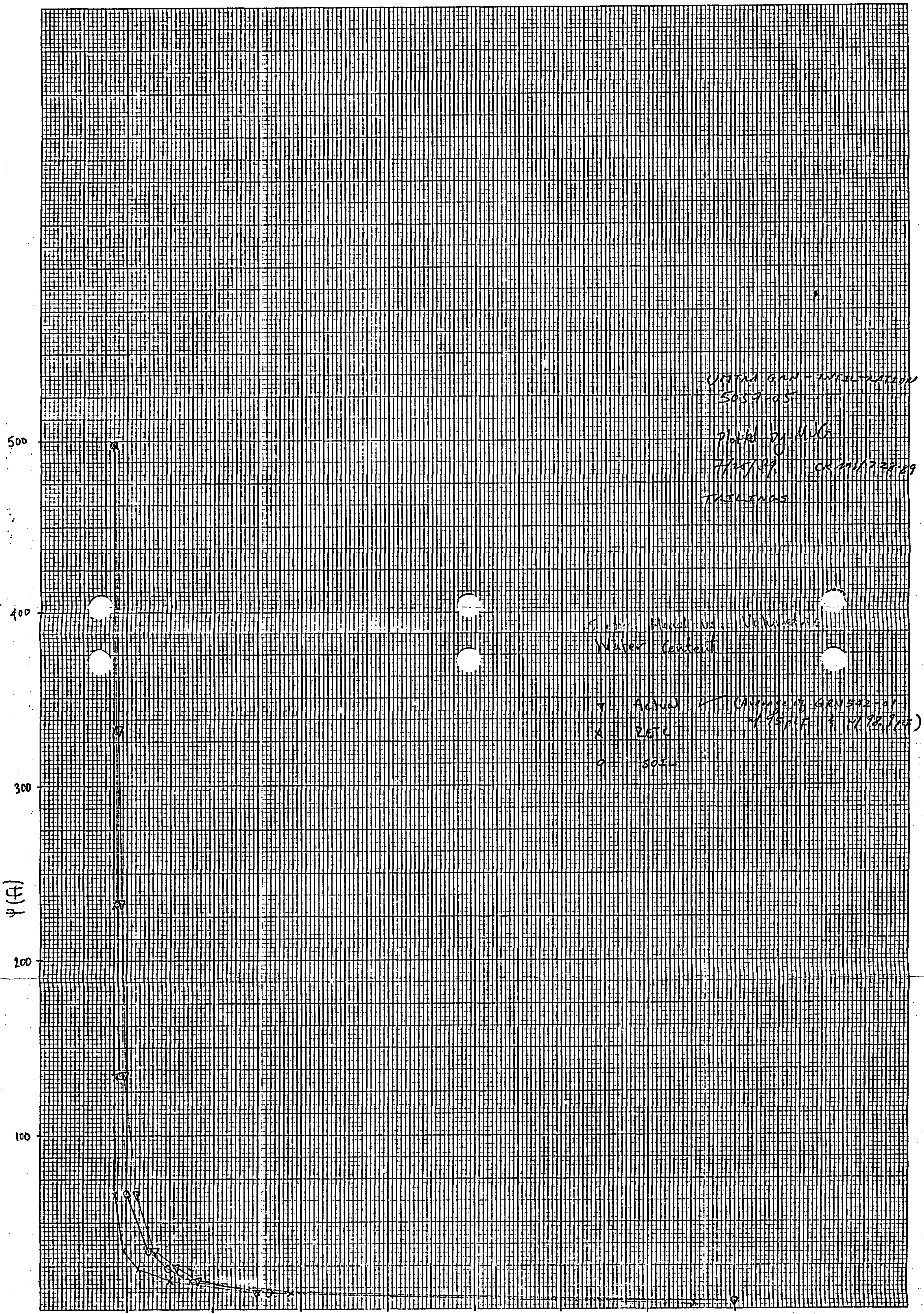
Project UMTRA / GRN
Feature Infiltration
Item 'UNSAT2' Analysis
Contract No. 5057-05
Designed PYL
Checked [illegible]
Sheet 8
File No.
Date 7/26/89
Date 7-25-89

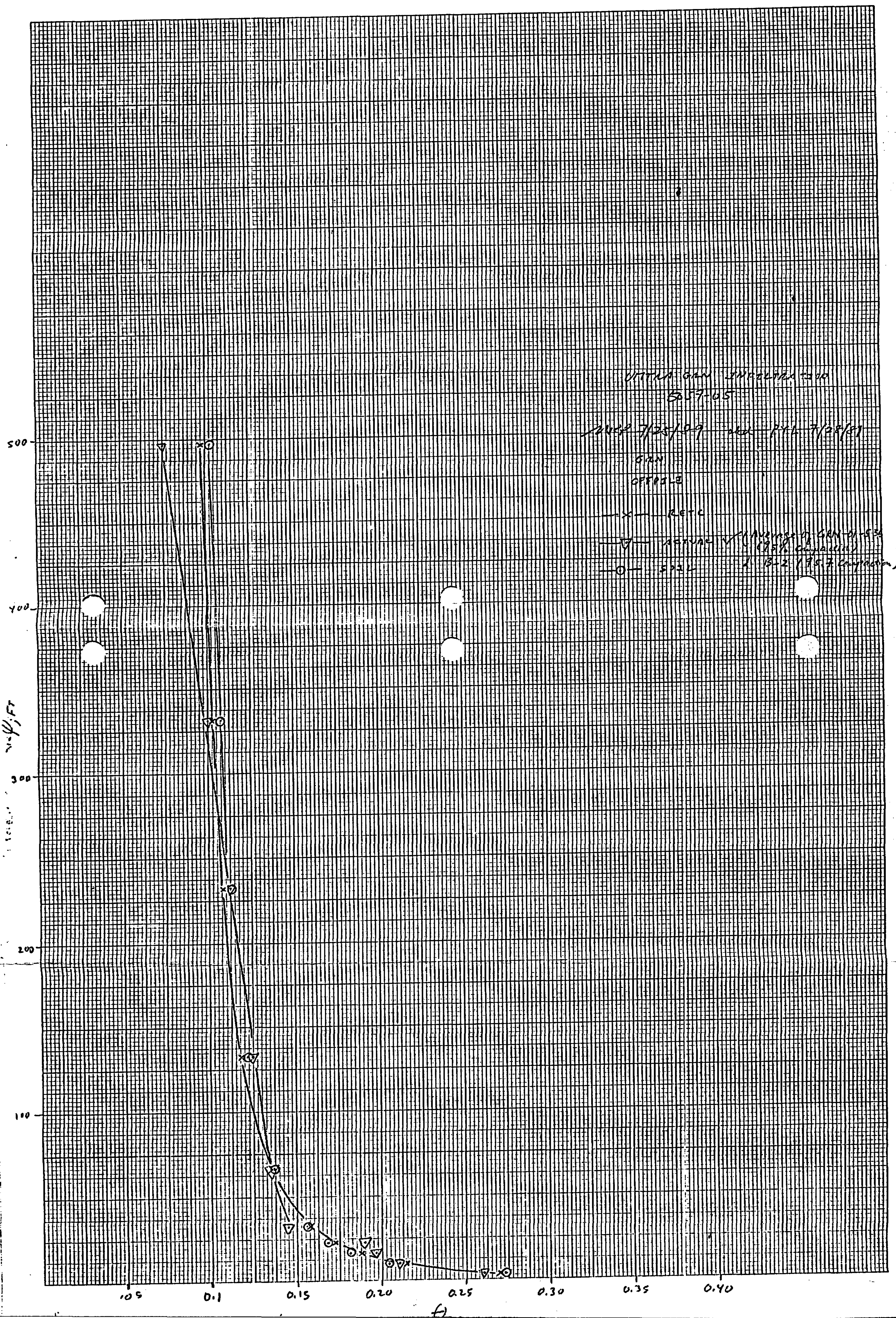
UMTRA- GREEN RIVER

FINITE ELEMENT MESH




UMTRA GRN - INFILTRATION
5057-05
Plotted by MVG
7/25/89 CK [illegible] 7-28-89
TAILINGS
Suction Head vs. Volumetric Water Content
▽ Actual ← (Average of GRN 542-91 w/ 95 pcf & w/ 98.9 pcf)
X RETC
o SOIL
ψ (ft)
500
400
300
200
100
0.05
0.10
0.15
0.20
.25
0.30
0.35
0.40

SH 9


UTTRA GRN INSTALLATION
5057-65
TAUCH 7/25/89 chk PYL 7/28/89
GRN
OFFPILE
—x— RETC
—▽— ACTUAL ✓ (Average of GRN-01-S34 (95% Compaction)
& 13-2 (95.7 Compaction))
—○— SOIL
500
400
300
200
100
ψ, FT
.05
0.1
0.15
0.20
0.25
0.30
0.35
0.40
θ

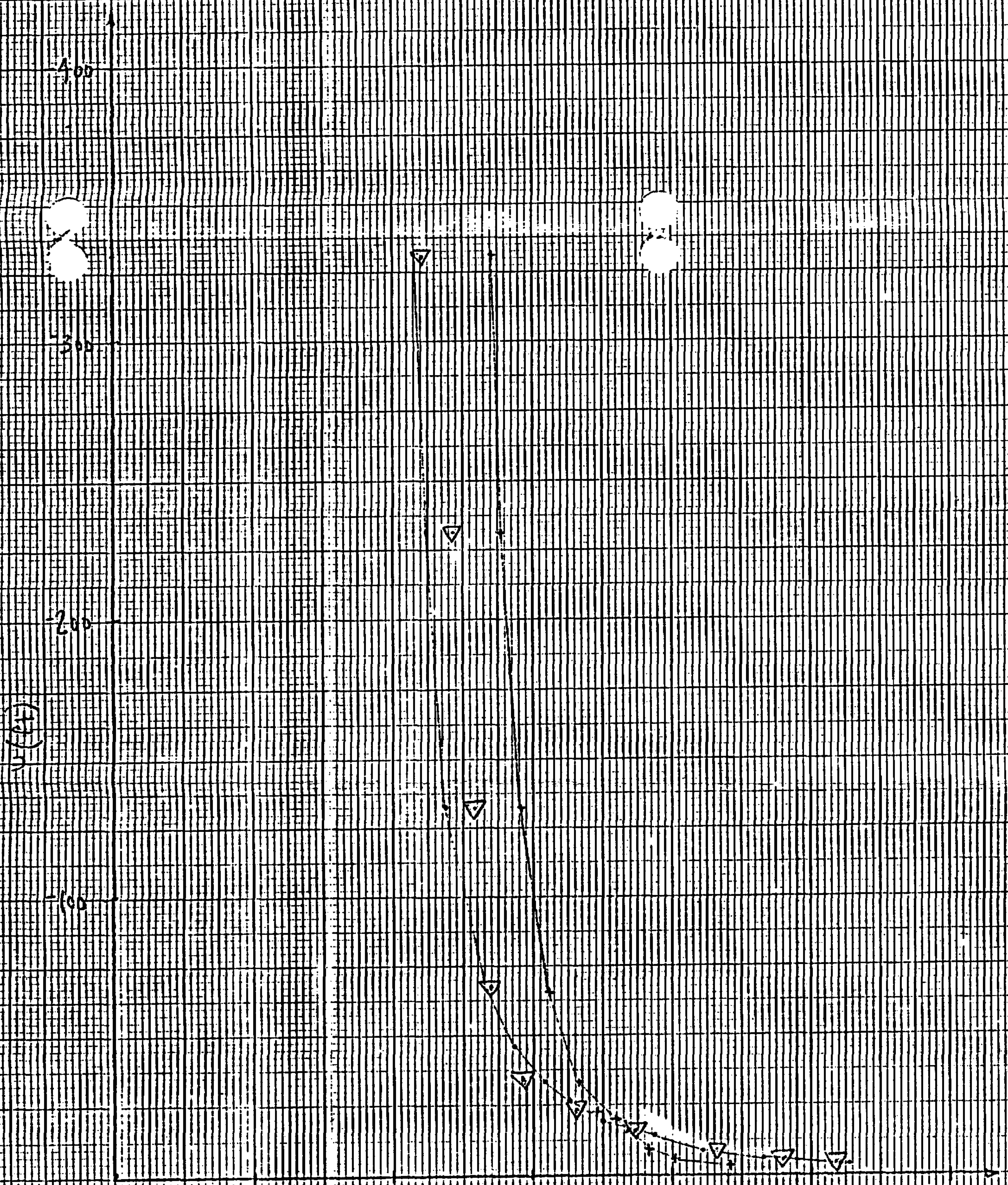
SH 10

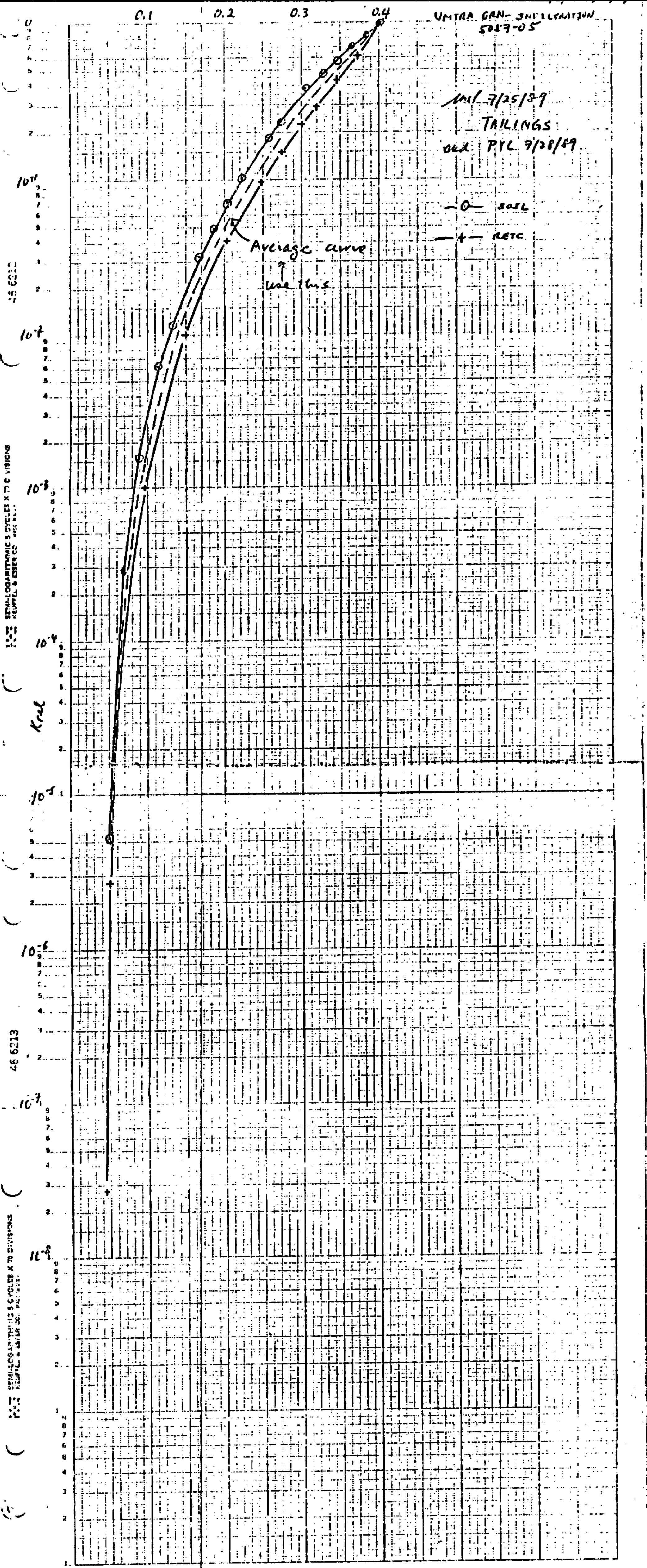
UMTRA GRN INFILTRATION
5057-05

B-1, B-2 BUFFER
UMTRA-GRN
19 July 89
• "RETC" output (fit)
+ "SOIL" output (fit)

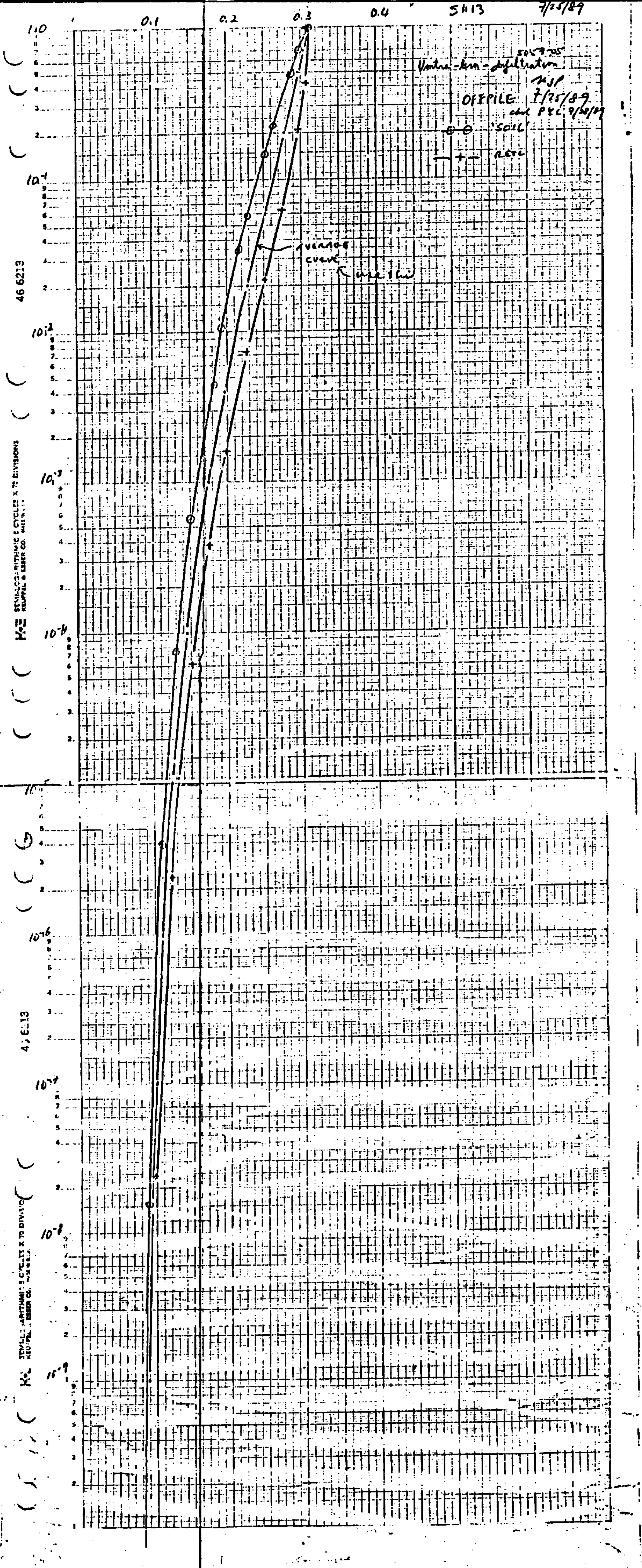
▽ ACTUAL DATA AYL 7/28/89

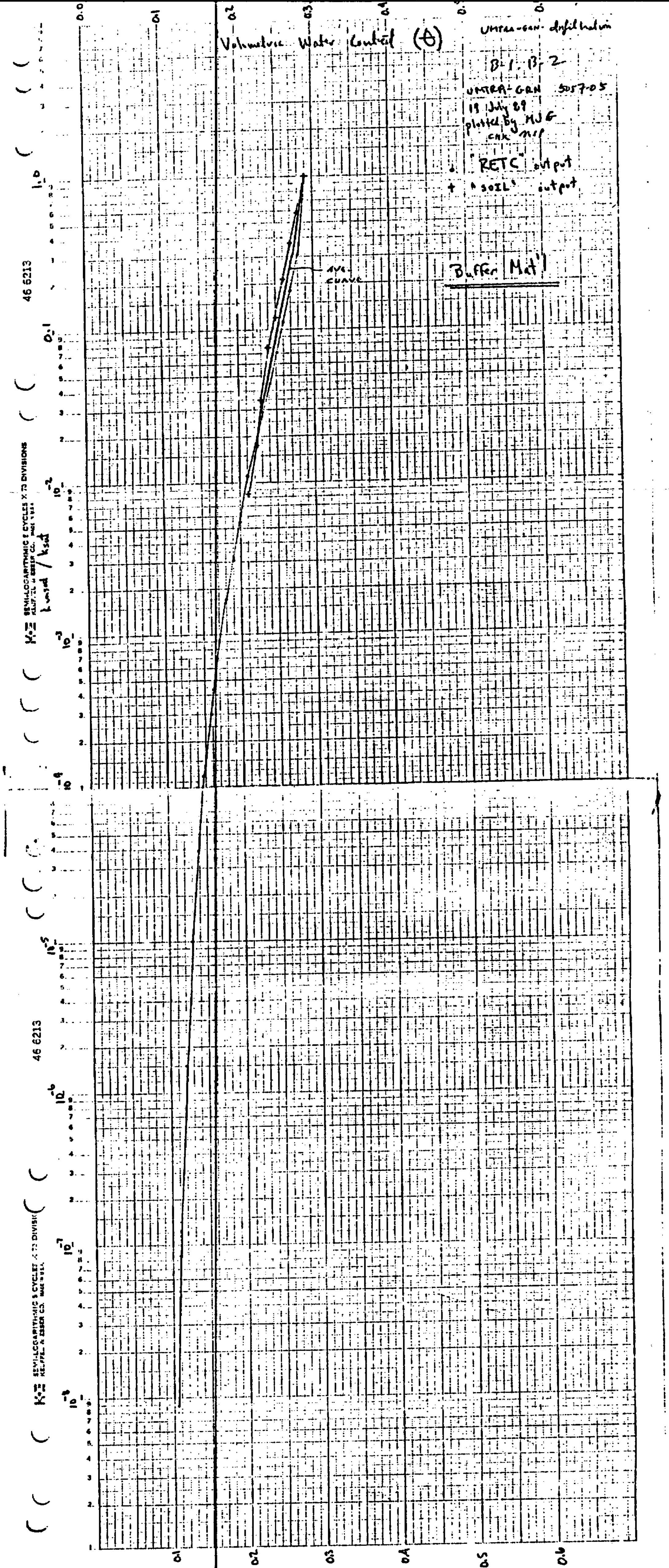
CHK MSB 7-28-89




0.1
0.2
0.3
0.4
UMTRA GRN- INFILTRATION
5057-05
MKL 7/25/89
TAILINGS
CKd PYC 7/28/89
—O— SOSL
—+— RETC
Average curve
use this
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
Krel
46 6213
SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

5113 7/25/89


0.1
0.2
0.3
0.4
1.0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
5057.05
[illegible]-[illegible]-infiltration
MSP
OFFFILE 7/25/89
chk PXL 7/28/89
'SOIL'
ROCK
AVERAGE CURVE
use this
46 6213
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO.


Volumetric Water Content (θ)
UMTRA-GRN-infiltration
B-1, B-2
UMTRA-GRN 5057-05
19 July 89
plotted by MJG
chk MJP
• "RETC" output
+ "SOIL" output
Buffer Mat'l
ave. curve
k_{unsat}/k_{sat}
1.0
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0.0
0.1
0.2
0.3
0.4
0.5
0.6
K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO.
46 6213

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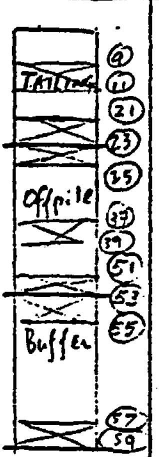
Project UMTRA / GRN
Feature Infiltration
Item SUMMARY OF 'UNSAT2' ANALYSIS
Contract No. 5057-05
Designed PYC
Checked MSP
Sheet 15
File No.
Date 7/25/89
Date 7-26-89

INPUT

RUN #	SAMPLE USED	(FITTED) CURVES USED			Sat. K (cm/s)	n.	Initial θ	BOUNDARY CONDITIONS	
		ψ vs. θ	Krel vs θ	residual θ_r				Top	Bottom
NOMINAL CASE Ⓐ (GRN.A OUT)	TAILINGS AVG. OF 542-01 G=95pcf & 98.9pcf	USE ACTUAL DATA	AVG. OF 'SOIL' & 'RETC'	0.042	5.8×10^{-4}	0.40	0.07	W/ COVER FLUX 2.0×10^{-8} cm/s	FIX ψ @ bottom = -14'
	OFFPILE (AVG. OF GRN-01-536 (95%) & B-2 (95.7))	USE ACTUAL DATA	AVG. OF 'SOIL' & 'RETC'	0.075	4.5×10^{-4}	0.31	0.108		
	BUFFER (B-1 & B-2) (green)	ACTUAL DATA ('RETC')	AVG. OF 'RETC' & 'SOIL'	0.095	2.7×10^{-4}	0.29	0.158		
Ⓑ (GRN B. OUT)	TAILINGS SAME AS Ⓐ	USE ACTUAL DATA	AVG. OF 'SOIL' & 'RETC'	0.042	5.8×10^{-4}	0.40	0.07	W/O COVER FLUX	SAME AS Ⓐ ψ_{bottom} = -14'
	OFFILE SAME AS Ⓐ	USE ACTUAL DATA	AVG. OF 'SOIL' & 'RETC'	0.075	4.5×10^{-4}	0.31	0.108		
	BUFFER SAME AS Ⓐ	ACTUAL DATA ('RETC')	AVG. OF 'SOIL' & 'RETC'	0.095	2.7×10^{-4}	0.29	0.158		

OUTPUT



RUN #		Time (yr.)	Hyd. grad. i (See App.)	$\theta_{AVG.}$	(1) Rel K.	(2) Unsat. K (cm/s)	Flux (3) Velocity (cm/s)	Seepage (4) Velocity (ft/yr)	Time for (5) 6' Travel Thru buffer (year)
Ⓐ		95.6	0.56	0.0612					
		95.6	0.3253	0.0633					
		95.6	0.5021	0.14266	8.0×10^{-5}	3.6×10^{-8}	1.8×10^{-8}	0.131	
		95.6	0.407	0.145					
		95.6	0.0135	0.19255	3.6×10^{-3}	1.62×10^{-6}	2.19×10^{-8}	0.118	
		95.6	0.0415	0.17824	1.6×10^{-3}	4.32×10^{-7}	1.79×10^{-8}	0.104	58
		95.6	0.0225	0.19	3.2×10^{-3}	8.64×10^{-7}	1.9×10^{-8}	0.103	
Ⓑ	TAILINGS	95.6	0	0.0606					
	OFFPILE	95.6	0	0.14	6×10^{-5}	2.7×10^{-8}	0	0	
		95.6	0	0.192	3×10^{-3}	1.35×10^{-6}	0	0	
	Buffer	95.6	0	0.178	1.6×10^{-3}	4.32×10^{-7}	0	0	∞
		95.6	0	0.190	3.2×10^{-3}	8.64×10^{-7}	0	0	

FOR DISCUSSION OF THE SOIL PROPERTIES SEE REF 5

NOTES:
(1) From Krel vs. θ plots
(2) $K_{unsat} = K_{rel} \times K_{sat}$
(3) Flux velocity = $i \cdot K_{unsat}$
(4) Seepage velocity = $\frac{\text{Flux velocity}}{\theta}$ & converted to ft/yr.
(5) Travel time = $\frac{6'}{\text{Seepage Velocity}}$

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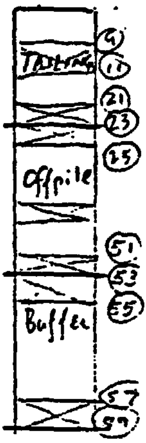
Sheet 16
Project UMTRA / GRN
Contract No. 5057-05
File No.
Feature Infiltration
Designed PTC
Date 7/25/89
Item SUMMARY OF 'UNSAT2' ANALYSIS
Checked 1nsl
Date 7-26-89

RUN#	INPUT									OUTPUT								
	SAMPLE USED	FITTED CURVES USED*			Sat. K (cm/s)	n.	Initial θ	BOUNDARY CONDITIONS			Time (yr.)	Hyd. grad. i	θ	Rel K.	Unsat. K (cm/s)	Flux Velocity (cm/s)	Seepage Velocity (ft/yr.)	Time for 6' Travel Thru (year)
		Ψ vs. θ	Krel vs θ	θr				Top	Bottom									
(C) (GRN.C OUT)	TAILINGS SAME AS (A)			0.042	5.8×10⁻⁴	0.40	0.05	w/ COVER FLUX	FIX ψ @ bottom = -14'		95.6	0.56	0.0612					
											95.6	0.3233	0.0633					
											95.6	0.5021	0.14266	8.0×10⁻⁵	3.6×10⁻⁸	1.8×10⁻⁸	0.131	
	OFFPILE	SAME AS (A)		0.075	4.5×10⁻⁴	0.31	0.108				95.6	0.407	0.145					
											95.6	0.0135	0.19255	3.6×10⁻³	1.62×10⁻⁶	2.19×10⁻⁸	0.118	
	BUFFER			0.095	7.7×10⁻⁴	0.29	0.158				95.6	0.0415	0.17824	1.6×10⁻³	4.32×10⁻⁷	1.79×10⁻⁸	0.104	58
												0.0225	0.19	3.2×10⁻³	2.64×10⁻⁷	1.9×10⁻⁸	0.103	
(D) (GRN D. OUT)	TAILINGS SAME AS (A)	SAME AS (A)		0.042	5.8×10⁻⁴	0.40	0.07	w/ Cover flux	Fix Ψ bottom = -7'		95.6	0.4458	0.062					
										TAILINGS	95.6	0.267	0.0643					
	OFFPILE									OFFPILE	95.6	0.478	0.1437	9×10⁻⁵	4.05×10⁻⁸	1.9×10⁻⁸	0.139	
				0.075	4.5×10⁻⁴	0.31	0.108				95.6	0.0542	0.1695					
											95.6	0.0668	0.202	5×10⁻³	2.25×10⁻⁶	1.53×10⁻⁸	0.078	
	BUFFER									BUFFER	95.6	0.01105	0.202	6.4×10⁻³	1.73×10⁻⁶	1.91×10⁻⁸	0.0978	61
				0.095	2.7×10⁻⁴	0.29	0.158				95.6	0.0029	0.224	2×10⁻²	5.4×10⁻⁶	1.57×10⁻⁸	0.0725	

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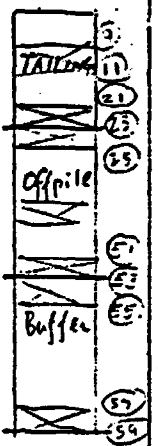
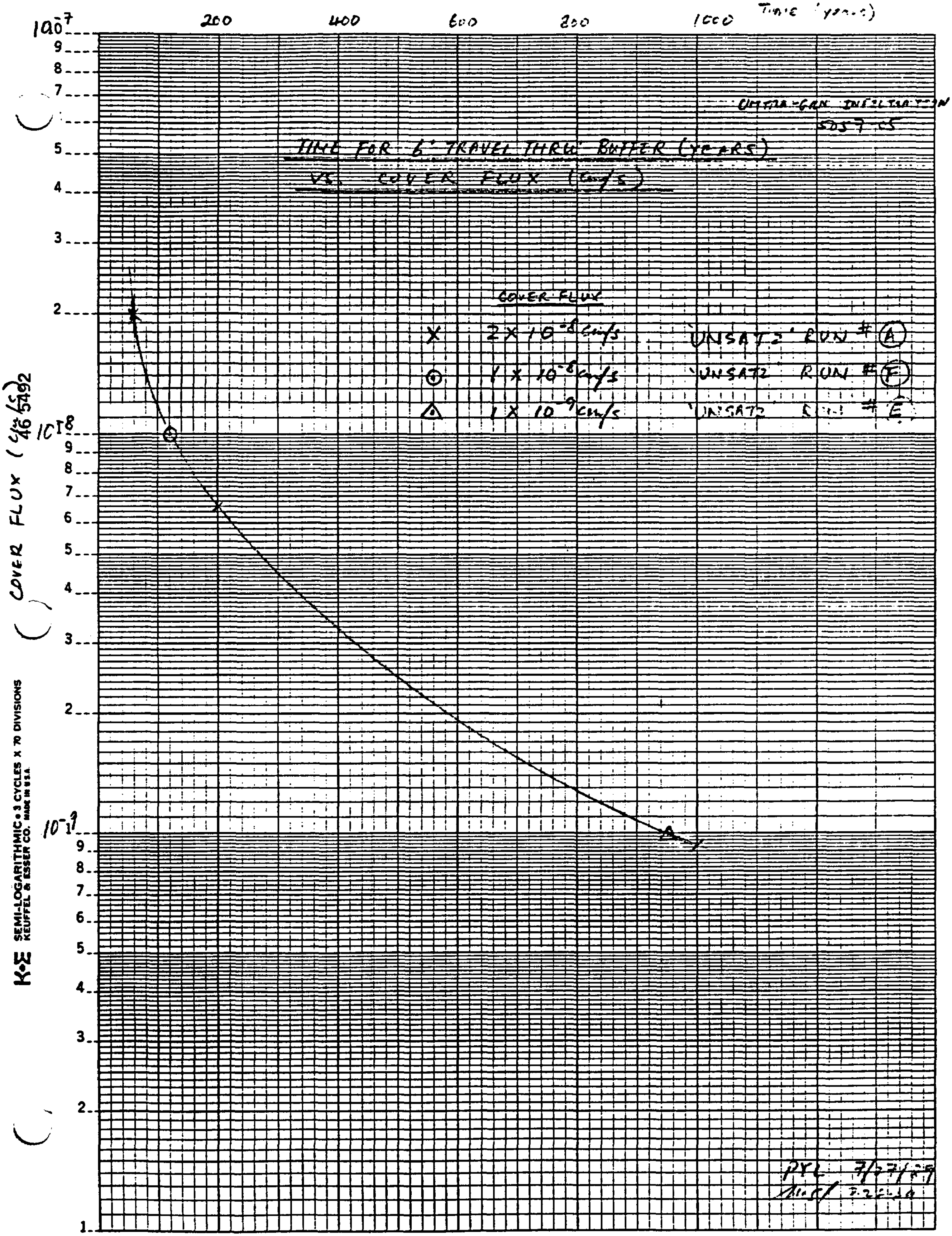
Sheet 17
Project UMTRA / GRN
Contract No. 5057-05
File No.
Feature Infiltration
Designed PTC
Date 7/25/89
Item SUMMARY OF 'UNSAT2' ANALYSIS
Checked MSP
Date 7-27-89

RUN#	INPUT									OUTPUT								
	SAMPLE USED	FITTED CURVES USED			Sat. K (cm/s)	n.	Initial θ	BOUNDARY CONDITIONS			Time (yr.)	Hyd. grad. i	θ	Rel. K.	Unsat. K (cm/s)	Flux Velocity (cm/s)	Seepage Velocity (ft/yr.)	Time for 6' Travel Thru (year)
		Ψ vs. θ	Kel vs θ	θr				Top	Bottom									
Ⓔ	TAILINGS	SAME AS Ⓐ			5.8×10^{-4}	0.40	0.07	w/ COVER FLUX $= 1 \times 10^{-9}$ cm/s	$\Psi_{bottom} = -14'$		95.6	0.013	0.0573					
											95.6	0.034	0.06076					
(GRN E. OUT)											95.6	0.028	0.14035	6.4×10^{-4}	2.88×10^{-8}	8.06×10^{-10}	0.0059	
	OFFPILE				4.5×10^{-4}	0.31	0.108					0.023	0.1444					
											95.6	0.0005	0.19234	3×10^{-3}	1.35×10^{-6}	6.75×10^{-10}	0.00363	
	BUFFER				2.7×10^{-4}	0.29	0.158				95.6	0.0025	0.1779	1.6×10^{-3}	4.32×10^{-7}	1.08×10^{-9}	0.00628	$\boxed{955}$ ←
											95.6	0.0010	0.1899	3.2×10^{-3}	8.64×10^{-7}	8.64×10^{-10}	0.00471	
Ⓕ	TAILINGS	SAME AS Ⓐ			5.8×10^{-4}	0.40	0.07	w/ COVER FLUX $= 1 \times 10^{-8}$ cm/s	$\Psi_{bottom} = -14'$		95.6	0.5129	0.0597					
										TAILINGS	95.6	0.2181	0.0620					
	OFFPILE				4.5×10^{-4}	0.31	0.108			OFFPILE	95.6	0.2658	0.1415	6.8×10^{-5}	3.06×10^{-8}	8.13×10^{-9}	0..059	
											95.6	0.2305	0.1447					
											95.6	0.007	0.19245	3.1×10^{-3}	1.40×10^{-6}	9.8×10^{-9}	0.053	
	BUFFER				2.7×10^{-4}	0.29	0.158			BUFFER	95.6	0.021	0.17803	1.6×10^{-3}	4.32×10^{-7}	9.07×10^{-9}	0.053	$\boxed{114}$
											95.6	0.011	0.1899	3.2×10^{-3}	8.64×10^{-7}	9.5×10^{-9}	0.052	

11


UMTRA-GRN INFILTRATION
5057.05
TIME FOR 6' TRAVEL THRU BUFFER (YEARS)
VS. COVER FLUX (cm/s)
COVER FLUX
× 2 X 10⁻⁸ cm/s 'UNSAT2' RUN # Ⓐ
⊙ 1 X 10⁻⁸ cm/s 'UNSAT2' RUN # Ⓕ
△ 1 X 10⁻⁹ cm/s 'UNSAT2' RUN # Ⓔ
TIME (YEARS)
200
400
600
800
1000
COVER FLUX (cm/s)
10⁻⁷
10⁻⁸
10⁻⁹
1
2
3
4
5
6
7
8
9
K+E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 5492

PYL 7/27/79

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project [illegible]
Feature Infiltration
Item

Contract No. 5157.05
Designed [illegible]
Checked PYL

Sheet 18a
File No.
Date 7-28-89
Date 7/28/89

VALUES OF HYDRAULIC GRADIENT (i) @ TOP OF BUFFER (NODE 53→55)

CASE	TIME (yr). 0	13	30	46	62.7
A	-114	.0340	.0410	.0415	SAME →
B	-114	-.004	-.0005	0	SAME →
C	-114	.0115	.041	.0145	SAME →
D	-114	.01045	.01105	SAME	→
E	-114	-.002	.002	.0025	SAME →
F	-114	.0145	.0205	.0210	SAME →

Sheet 19
Project UMTRA-GRN
Contract No. 5057-05
File No.
Feature INFILTRATION
Designed PYL
Date 7-27-87
Item 'UNSATZ' ANALYSIS
Checked JHS
Date 7-27-87

APPENDIX

4

UMTRA - GRN Infiltration
5057-05

PYC 7/25/89
MSP 7-28-89

SOIL' OUTPUT - TAILINGS

```
        --------------------------------
        NON-LINEAR LEAST SQUARE ANALYSIS
        --------------------------------

  LTS FOR RUN #  2

<<<  UMTRA -- GREEN RIVER -- TAILINGS <BROOKS & COREY>7/25/89  >>>

INPUT PARAMETERS
================
MODEL NUMBER.............................   6
NUMBER OF OBSERVATIONS...................   10
NUMBER OF COEFFICIENTS...................   2
RESIDUAL WATER CONTENT.................       0.0420
SATURATED WATER CONTENT................       0.4000  = n
SATURATED HYDRAULIC CONDUCTIVITY.......       2.0880  cm/hr = 5.8 x 10^-4 cm/s


OBSERVED DATA
=============
 I        X(I)          Y(I)

 1    15150.0000      0.0420
 2    10100.0000      0.0450
 3     7070.0000      0.0460
 4     4040.0000      0.0480
 5     2020.0000      0.0560
 6     1010.0000      0.0660
 7      707.0000      0.0780
        505.0000      0.0910
        303.0000      0.1240
        101.0000      0.4000

ITERATION NO    WCR        ALPHA          N          SSQ

     0        0.0420   1033.041000    0.3148     0.972248
     1        0.0420    486.313600    0.3244     0.535129
     2        0.0420    215.711900    0.3623     0.242669
     3        0.0420     68.120120    0.4668     0.043375
     4        0.0420    104.719800    0.8326     0.009498
     5        0.0420     98.423460    1.0995     0.000732
     6        0.0420    100.921300    1.2328     0.000167
     7        0.0420    100.766700    1.2526     0.000156
     8        0.0420    100.776100    1.2539     0.000156
     9        0.0420    100.776100    1.2539     0.000156
```

Untra-Gro - Infiltration
5057-05

21
PYL 7/28/89
CK MS 7-28-89

```
CORRELATION MATRIX
==================

              1             2

  1        1.0000
  2        0.2856        1.0000

NON-LINEAR LEAST-SQUARE ANALYSIS: FINAL RESULTS
===============================================

                                                    95% CONFIDENCE LIMITS

VARIABLE       VALUE       S.E. COEFT.    T-VALUE       LOWER         UPPER

ALPHA        100.7761  hp   0.9913       101.6623      98.4903      103.0620
N              1.2539  λ    0.0311        40.2644       1.1821        1.3257

    --------ORDERED BY COMPUTER INPUT--------

                                 MOISTURE CONTENT:
  NO.      PRESSURE          OBSERVED      FITTED        RESIDUAL

   1     15150.0000          0.0420        0.0427        -0.0007
   2     10100.0000          0.0450        0.0431         0.0019
   3      7070.0000          0.0460        0.0437         0.0023
   4      4040.0000          0.0480        0.0455         0.0025
   5      2020.0000          0.0560        0.0503         0.0057
   6      1010.0000          0.0660        0.0619         0.0041
           707.0000          0.0780        0.0731         0.0049
           505.0000          0.0910        0.0895         0.0015
           303.0000          0.1240        0.1320        -0.0080
  10       101.0000          0.4000        0.3990         0.0010

    --------ORDERED BY RESIDUALS--------------

                                 MOISTURE CONTENT:
  NO.      PRESSURE          OBSERVED      FITTED        RESIDUAL

   5      2020.0000          0.0560        0.0503         0.0057
   7       707.0000          0.0780        0.0731         0.0049
   6      1010.0000          0.0660        0.0619         0.0041
   4      4040.0000          0.0480        0.0455         0.0025
   3      7070.0000          0.0460        0.0437         0.0023
   2     10100.0000          0.0450        0.0431         0.0019
   8       505.0000          0.0910        0.0895         0.0015
  10       101.0000          0.4000        0.3990         0.0010
   1     15150.0000          0.0420        0.0427        -0.0007
   9       303.0000          0.1240        0.1320        -0.0080
```

Untra-Gen-Infiltration
5057-05

PTC 7/25/89
ck MSP 7-28-89

SOIL HYDRAULIC PROPERTIES

PRESSURE (cm)	Pt	WC	K (cm/hr)	RELATIVE K	SD
100.7761	3.31	0.4000	2.0880	1.0000	1.0000
104.9841	3.44	0.3821	1.7556	0.8408	0.9500
109.6100	3.6	0.3642	1.4632	0.7008	0.9000
114.7222	3.76	0.3463	1.2076	0.5784	0.8500
120.4052	3.95	0.3284	0.9859	0.4722	0.8000
126.7648	4.16	0.3105	0.7952	0.3808	0.7500
133.9353	4.39	0.2926	0.6325	0.3029	0.7000
142.0898	4.66	0.2747	0.4954	0.2372	0.6500
151.4560	4.97	0.2568	0.3810	0.1825	0.6000
162.3393	5.33	0.2389	0.2870	0.1375	0.5500
175.1601	5.75	0.2210	0.2110	0.1010	0.5000
190.5143	6.25	0.2031	0.1506	0.0721	0.4500
209.2776	6.87	0.1852	0.1038	0.0497	0.4000
232.7944	7.64	0.1673	0.0684	0.0328	0.3500
263.2473	8.64	0.1494	0.0427	0.0204	0.3000
304.4476	9.99	0.1315	0.0247	0.0118	0.2500
363.7476	11.93	0.1136	0.0129	0.0062	0.2000

SD $= S_e = \frac{\theta - \theta_r}{n - \theta_r}$

θ

PARAMETERS OF THE K-FUNCTION

ASSUMING THE RELATIONSHIP OF THE RELATIVE HYDRAULIC CONDUCTIVITY AND THE EFFECTIVE SATURATION TO BE A GHT LINE ON A LOG-LOG PAPER, THE AVERAGE SLOPE IS:

SATK= 2.088 cm/hr N= 3.198141

500.4	16.42	0.09	0.0016	0.13408
769.2	25.24	0.07	0.0002886	0.0782
2088.5	68.5	0.05	5.3×10^{-6}	0.02235

Assumed straight line relationship of Krel and Se on a log-log paper:

$$\text{Rel } K = \log^{-1}\{(\log Se)\cdot N\} ;$$

where N = 3.198141

'Brooks & Corey' function:

$$\text{Pressure } h = \frac{h_p}{(Se)^{1/\lambda}}$$

where $h_p = 100.7761$ (see previous sheet

$\lambda = 1.2539$

④

Untra - Grn - Infiltration SH23
5037-05

PYL 7/25/89
MP 7-28-89

'SOIL 'OUTPUT - OFFPILE MATERIAL

```
 -------------------------------
 NON-LINEAR LEAST SQUARE ANALYSIS
 -------------------------------

  JLTS FOR RUN #  1
                                    OFFPILE
<<<  UNTRA -- GREEN RIVER --[redacted] < BROOKS & COREY>7/25/89  >>>

INPUT PARAMETERS
================
MODEL NUMBER..............................  6
NUMBER OF OBSERVATIONS....................  10
NUMBER OF COEFFICIENTS....................  2
RESIDUAL WATER CONTENT.................      0.0750
SATURATED WATER CONTENT................      0.3100   = n
SATURATED HYDRAULIC CONDUCTIVITY.......      1.6200   Cm/hr = 4.5x10^-4 cm/s


OBSERVED DATA
=============
  I        X(I)         Y(I)

  1     15150.0000      0.0750
  2     10100.0000      0.0995
  3      7070.0000      0.1115
  4      4040.0000      0.1250
  5      2020.0000      0.1345
  6      1010.0000      0.1450
  7       707.0000      0.1900
          505.0000      0.1965
          303.0000      0.2100
          101.0000      0.2600

ITERATION NO    WCR        ALPHA          N          SSQ

       0       0.0750    3922.185000    0.2010     0.486175
       1       0.0750    1261.909000    0.1950     0.247231
       2       0.0750     197.544200    0.2121     0.064864
       3       0.0750      40.566790    0.2624     0.006012
       4       0.0750      68.694530    0.3807     0.002063
       5       0.0750      64.543800    0.3882     0.001937
       6       0.0750      64.410750    0.3875     0.001937
       7       0.0750      64.436010    0.3876     0.001937
```

Mentua-Gun-Infiltration

PYL 7/25/89
CK MSP 7-28-89

```
CORRELATION MATRIX
==================

            1           2

  1      1.0000
  2      0.7938      1.0000

NON-LINEAR LEAST-SQUARE ANALYSIS: FINAL RESULTS
===============================================

                                                   95% CONFIDENCE LIMITS

VARIABLE     VALUE     S.E. COEFT.    T-VALUE       LOWER       UPPER

ALPHA       64.4360     14.1130        4.5657      31.8923     96.9798
N            0.3876      0.0428        9.0573       0.2889      0.4863


     --------ORDERED BY COMPUTER INPUT--------

                          MOISTURE CONTENT:
  NO.     PRESSURE        OBSERVED     FITTED        RESIDUAL

   1    15150.0000        0.0750       0.1033        -0.0283
   2    10100.0000        0.0995       0.1081        -0.0086
   3     7070.0000        0.1115       0.1130        -0.0015
   4     4040.0000        0.1250       0.1223         0.0027
   5     2020.0000        0.1345       0.1368        -0.0023
         1010.0000        0.1450       0.1559        -0.0109
          707.0000        0.1900       0.1679         0.0221
          505.0000        0.1965       0.1808         0.0157
          303.0000        0.2100       0.2040         0.0060
  10      101.0000        0.2600       0.2724        -0.0124

     --------ORDERED BY RESIDUALS--------------

                          MOISTURE CONTENT:
  NO.     PRESSURE        OBSERVED     FITTED        RESIDUAL

   7      707.0000        0.1900       0.1679         0.0221
   8      505.0000        0.1965       0.1808         0.0157
   9      303.0000        0.2100       0.2040         0.0060
   4     4040.0000        0.1250       0.1223         0.0027
   3     7070.0000        0.1115       0.1130        -0.0015
   5     2020.0000        0.1345       0.1368        -0.0023
   2    10100.0000        0.0995       0.1081        -0.0086
   6     1010.0000        0.1450       0.1559        -0.0109
  10      101.0000        0.2600       0.2724        -0.0124
   1    15150.0000        0.0750       0.1033        -0.0283
```

Untra-Grn-Infiltration

PYL 7/25/89
CK 7-28-89

SOIL HYDRAULIC PROPERTIES

PRESSURE (cm)	ft	WC	K (cm/hr)	RELATIVE K	SD
64.4360	2.11	0.3100	1.6200	1.0000	1.0000
73.5534	2.413	0.2983	1.1508	0.7104	0.9500
84.5640	2.774	0.2865	0.8034	0.4959	0.9000
98.0012	3.215	0.2748	0.5501	0.3396	0.8500
114.5939	3.760	0.2630	0.3687	0.2276	0.8000
135.3559	4.441	0.2513	0.2412	0.1489	0.7500
161.7275	5.306	0.2395	0.1535	0.0947	0.7000
195.8042	6.424	0.2278	0.0947	0.0585	0.6500
240.7188	7.90	0.2160	0.0564	0.0348	0.6000
301.3052	989	0.2042	0.0322	0.0199	0.5500
385.3026	12.64	0.1925	0.0175	0.0108	0.5000
505.6600	16.57	0.1808	0.0089	0.0055	0.4500

PARAMETERS OF THE K-FUNCTION

ASSUMING THE RELATIONSHIP OF THE RELATIVE HYDRAULIC CONDUCTIVITY AND THE EFFECTIVE SATURATION TO BE A STREIGHT LINE ON A LOG-LOG PAPER, THE AVERAGE SLOPE IS:

SATK= 1.62 cm/hr N= 6.533814

1227.4	40.3	0.15	5.74×10^{-4}	0.3191
-73236	89.6	0.13	7.56×10^{-5}	0.2340
70.88	287.8	0.11	3.94×10^{-6}	0.1489
103	7562.9	0.09	1.55×10^{-8}	0.0638
		0.08	1.19×10^{-11}	

$$\text{Rel } K = \log^{-1}\{(\log S_e)\cdot N\}$$

where $N = 6.533814$

$$h = \frac{h_p}{(S_e)^{1/\lambda}}$$

where $h_p = 14.1130$

$\lambda = 0.0428$

Umtra-Grn-Infiltration 26

PYL 7/18/89

AMSI 7-28-89

'SOIL' OUTPUT

```
        ------------------------------
        NON-LINEAR LEAST SQUARE ANALYSIS
        ------------------------------

    LTS FOR RUN # 3
```

[illegible] β-1, β-2

```
<<<  UMTRA -- GREEN RIVER -- BUFFER < BROOKS & COREY >  >>>

INPUT PARAMETERS
================
MODEL NUMBER..............................   6
NUMBER OF OBSERVATIONS....................   11
NUMBER OF COEFFICIENTS....................   2
RESIDUAL WATER CONTENT.................       0.0950
SATURATED WATER CONTENT................       0.2900
SATURATED HYDRAULIC CONDUCTIVITY.......       0.9720
```

= n

cm/hr = 2.7 x10^{-4} cm/s

```
OBSERVED DATA
=============
  I        X(I)          Y(I)

  1      10.1000        0.2900
  2     101.0000        0.2600
  3     202.0000        0.2400
  4     303.0000        0.2150
  5     505.0000        0.1850
  6     707.0000        0.1650
  7    1010.0000        0.1445
       2020.0000        0.1355
       4040.0000        0.1285
       7070.0000        0.1210
      10100.0000        0.1110

ITERATION NO    WCR        ALPHA          N          SSQ

        0      0.0950    232.480800     0.2085     0.088590
        1      0.0950    100.728400     0.2144     0.041373
        2      0.0950     18.082870     0.2262     0.007035
        3      0.0950     17.223210     0.2481     0.006532
        4      0.0950     16.829040     0.2452     0.006529
        5      0.0950     16.886840     0.2457     0.006529
        6      0.0950     16.885330     0.2457     0.006529
```

Unutra-bu-Infiltration

27
PYL 7/18/89
CL [illegible] 7-28-89

```
CORRELATION MATRIX
=================

             1            2

    1      1.0000
    2      0.6100       1.0000

NON-LINEAR LEAST-SQUARE ANALYSIS: FINAL RESULTS
=============================================

                                                   95% CONFIDENCE LIMITS

VARIABLE     VALUE      S.E. COEFT.    T-VALUE     LOWER        UPPER

ALPHA       16.8853      6.9669        2.4237      1.1254      32.6453
N            0.2457      0.0392        6.2721      0.1571       0.3343


     --------ORDERED BY COMPUTER INPUT--------

                          MOISTURE CONTENT:
  NO.      PRESSURE      OBSERVED     FITTED        RESIDUAL

   1   .33  10.1000      0.2900       0.3162       -0.0262
   2 3.31  101.0000      0.2600       0.2207        0.0393
   3 6.63  202.0000      0.2400       0.2010        0.0390
   4 9.94  303.0000      0.2150       0.1909        0.0241
   5 16.57 505.0000      0.1850       0.1796        0.0054
   6 23.2  707.0000      0.1650       0.1729       -0.0079
     33.14 1010.0000     0.1445       0.1664       -0.0219
     66.28 2020.0000     0.1355       0.1552       -0.0197
     12.55 4040.0000     0.1285       0.1458       -0.0173
  10 [illegible] 7070.0000  0.1210    0.1392       -0.0182
  11 [illegible] 10100.0000 0.1110    0.1355       -0.0245

     --------ORDERED BY RESIDUALS--------------

                          MOISTURE CONTENT:
  NO.      PRESSURE      OBSERVED     FITTED        RESIDUAL

   2      101.0000       0.2600       0.2207        0.0393
   3      202.0000       0.2400       0.2010        0.0390
   4      303.0000       0.2150       0.1909        0.0241
   5      505.0000       0.1850       0.1796        0.0054
   6      707.0000       0.1650       0.1729       -0.0079
   9     4040.0000       0.1285       0.1458       -0.0173
  10     7070.0000       0.1210       0.1392       -0.0182
   8     2020.0000       0.1355       0.1552       -0.0197
   7     1010.0000       0.1445       0.1664       -0.0219
  11    10100.0000       0.1110       0.1355       -0.0245
   1       10.1000       0.2900       0.3162       -0.0262
```

Umtra-Grn-Infiltration 28

PYL 7/18/89
CK MSP 7-28-89

SOIL HYDRAULIC PROPERTIES

② PRESSURE (cm)	(ft)	WC	K (cm/hr)	① RELATIVE K	SD
16.8853	0.554	0.2900	0.9720	1.0000	1.0000
20.8054	0.6826	0.2802	0.5979	0.6151	0.9500
25.9266	0.8506	0.2705	0.3587	0.3690	0.9000
32.7175	1.0734	0.2608	0.2093	0.2153	0.8500
41.8737	1.374	0.2510	0.1184	0.1218	0.8000
54.4528	1.787	0.2413	0.0647	0.0665	0.7500
72.1062	2.366	0.2315	0.0340	0.0349	0.7000
97.4916	3.199	0.2218	0.0170	0.0175	0.6500
135.0366	4.430	0.2120	0.0081	0.0084	0.6000

PARAMETERS OF THE K-FUNCTION

ASSUMING THE RELATIONSHIP OF THE RELATIVE HYDRAULIC CONDUCTIVITY AND THE EFFECTIVE SATURATION TO BE A STREIGHT LINE ON A LOG-LOG PAPER, THE AVERAGE SLOPE IS:

SATK= .972 cm/hr N= 9.377619

209.754	6.88	0.20	3×10^{-3}	0.5385
495.70	16.26	0.18	4.15×10^{-4}	0.4359
2913.25	95.64	0.15	7.02×10^{-6}	0.2821
-248	601.98	0.13	1.01×10^{-7}	0.1795
1668	2368	0.12	4.3×10^{-9}	0.1282

① Rel $K = \log^{-1}\{(\log Se) \cdot N\}$

where $N = 9.377619$

② $h = \frac{h_p}{(Se)^{1/\lambda}}$;

$h_p = 16.8853$

$\lambda = 0.7457$

Illustra. Grn-Infiltration RE 11.2N MSI 7-25-89

chd PYL 7/28/89 TAILINGS

```
 2    1    7
  EXAMPLE 1: CALCULATE CURVE WITH KNOWN PARAMETER VALUES      GREENRIVER  TAIL
 1    0    0    3    2    1    0    0    8   30
  .0420     .4000     .0100      3.00      0.50       0.5   0.00058
  EXAMPLE 5: GREEN RIVER; TAILINGS
 1   10   10    3    2    1    0    1    8   30
  0.042   -0.4000    0.010       3.00      0.50       0.5   0.00058
 0    0    1    1    1    1    0
     101      .400
     303      .124
     505      .091
     707      .078
    1010      .066
    2020      .056
    4040      .048
    7070      .046
   10100      .045
   15150      .042
```

Untr Grn - Infiltration RC11.IN 30

MSL 7-25-89

Ckd. PXL 7/28/89

```
**********************************************************************
*                                                                    *
*     ANALYSIS OF SOIL HYDRAULIC PROPERTIES                          *
*                                                                    *
*     EXAMPLE 1: CALCULATE CURVE WITH KNOWN PARAMETER VALUES         *
*                                                                    *
*     MUALEM-BASED RESTRICTION, M=1-1/N                              *
*     MTYPE= 3     METHOD= 2                                         *
*                                                                    *
**********************************************************************


INITIAL VALUES OF THE COEFFICIENTS
==================================
NO      NAME      INITIAL VALUE   INDEX
 1       WCR           .0420        0
 2       WCS           .4000        0
 3      ALPHA          .0100        0
 4        N           3.0000        0
 5        M            .6667        0
 6       EXPO          .5000        0
 7      CONDS          .0006        0


SOIL HYDRAULIC PROPERTIES (MTYPE = 3)
=====================================
   WC        P          LOGP       COND       LOGK        DIF        LOGD
 .0442   .1265D+04   3.102   .4976D-11 -11.303   .1407D-05   -5.852
 .0465   .8940D+03   2.951   .5632D-10 -10.249   .5633D-05   -5.249
 .0510   .6316D+03   2.800   .6377D-09  -9.195   .2259D-04   -4.646
 .0599   .4455D+03   2.649   .7232D-08  -8.141   .9102D-04   -4.041
 .0689   .3626D+03   2.559   .2999D-07  -7.523   .2068D-03   -3.685
 .0778   .3129D+03   2.495   .8239D-07  -7.084   .3718D-03   -3.430
 .0868   .2786D+03   2.445   .1807D-06  -6.743   .5885D-03   -3.230
 .0957   .2531D+03   2.403   .3437D-06  -6.464   .8599D-03   -3.066
 .1047   .2331D+03   2.367   .5926D-06  -6.227   .1189D-02   -2.925
 .1136   .2167D+03   2.336   .9511D-06  -6.022   .1581D-02   -2.801
 .1226   .2030D+03   2.308   .1445D-05  -5.840   .2039D-02   -2.691
 .1315   .1913D+03   2.282   .2104D-05  -5.677   .2569D-02   -2.590
 .1405   .1810D+03   2.258   .2958D-05  -5.529   .3178D-02   -2.498
 .1494   .1720D+03   2.235   .4041D-05  -5.393   .3872D-02   -2.412
 .1584   .1638D+03   2.214   .5391D-05  -5.268   .4659D-02   -2.332
 .1673   .1565D+03   2.194   .7047D-05  -5.152   .5548D-02   -2.256
 .1763   .1497D+03   2.175   .9052D-05  -5.043   .6551D-02   -2.184
 .1852   .1435D+03   2.157   .1145D-04  -4.941   .7681D-02   -2.115
 .1942   .1377D+03   2.139   .1430D-04  -4.845   .8952D-02   -2.048
 .2031   .1322D+03   2.121   .1766D-04  -4.753   .1038D-01   -1.984
 .2121   .1271D+03   2.104   .2157D-04  -4.666   .1199D-01   -1.921
 .2210   .1223D+03   2.087   .2612D-04  -4.583   .1380D-01   -1.860
 .2300   .1177D+03   2.071   .3137D-04  -4.503   .1585D-01   -1.800
 .2389   .1132D+03   2.054   .3740D-04  -4.427   .1816D-01   -1.741
 .2479   .1090D+03   2.037   .4430D-04  -4.354   .2079D-01   -1.682
 .2568   .1048D+03   2.020   .5217D-04  -4.283   .2378D-01   -1.624
 .2658   .1008D+03   2.003   .6112D-04  -4.214   .2721D-01   -1.565
 .2747   .9684D+02   1.986   .7127D-04  -4.147   .3116D-01   -1.506
 .2837   .9296D+02   1.968   .8276D-04  -4.082   .3574D-01   -1.447
 .2926   .8911D+02   1.950   .9576D-04  -4.019   .4109D-01   -1.386
 .3016   .8527D+02   1.931   .1104D-03  -3.957   .4740D-01   -1.324
 .3105   .8141D+02   1.911   .1270D-03  -3.896   .5495D-01   -1.260
 .3195   .7751D+02   1.889   .1458D-03  -3.836   .6410D-01   -1.193
 .3284   .7353D+02   1.866   .1671D-03  -3.777   .7539D-01   -1.123
 .3374   .6942D+02   1.841   .1912D-03  -3.718   .8964D-01   -1.047
 .3463   .6511D+02   1.814   .2188D-03  -3.660   .1082D+00    -.966
 .3553   .6053D+02   1.782   .2504D-03  -3.601   .1333D+00    -.875
 .3642   .5553D+02   1.745   .2872D-03  -3.542   .1693D+00    -.771
 .3732   .4987D+02   1.698   .3307D-03  -3.481   .2256D+00    -.647
```

Unitra Grn - Infiltration

```
 .3821     .4308D+02  1.634    .3835D-03   -3.416      .3280D+00    -.484
 .3911     .3383D+02  1.529    .4520D-03   -3.345      .5878D+00    -.231
 .3955     .2671D+02  1.427    .4980D-03   -3.303      .1006D+01     .003
 .4000     .0000D+00           .5800D-03   -3.237

END OF PROBLEM
==============
```

MSP 7-25-89

ckd PYC 7/28/89

Uintra - Green - Infiltration MSP 7-25-89 32
ckd PYC 7/28/89

```
***********************************************************************
*                                                                     *
*     ANALYSIS OF SOIL HYDRAULIC PROPERTIES                           *
*                                                                     *
*     EXAMPLE 5: GREEN RIVER; TAILINGS                                *
*                                                                     *
*     MUALEM-BASED RESTRICTION, M=1-1/N                               *
*     ANALYSIS OF RETENTION DATA ONLY                                 *
*     MTYPE= 3      METHOD= 2                                         *
*                                                                     *
***********************************************************************


INITIAL VALUES OF THE COEFFICIENTS
==================================
NO       NAME           INITIAL VALUE   INDEX
 1        WCR                 .0420       0
 2        WCS                 .4000       0
 3       ALPHA                .0100       1
 4         N                 3.0000       1
 5         M                  .6667       0
 6        EXPO                .5000       0
 7       CONDS                .0006       0


NIT      SSQ      ALPHA       N
 0     .02279     .0100   3.0000
 1     .01175     .0045   2.5523
 2     .00390     .0060   2.6576
 3     .00309     .0049   3.1924
 4     .00245     .0054   3.2086
 5     .00236     .0051   3.4617
 6     .00233     .0052   3.4365
 7     .00233     .0051   3.5118
15     .00233     .0052   3.5082


CORRELATION MATRIX
==================
         1          2
 1   1.0000
 2   -.8060     1.0000


RSQUARED FOR REGRESSION OF OBSERVED VS FITTED VALUES =   .98595953
=====================================================================


NONLINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS
===============================================
                                                       95% CONFIDENCE LIMITS
VARIABLE      VALUE      S.E.COEFF.      T-VALUE      LOWER         UPPER
 ALPHA        .00516      .00062           8.35        .0037         .0066
   N         3.50816      .51443           6.82       2.3219        4.6944

                                   ∇ ACTUAL        Y CALC
OBSERVED AND FITTED DATA
========================
NO            P           LOG-P      WC-OBS      WC-FIT      WC-DIF
 1      .1010D+03 3.3    2.0043      .4000       .3761       .0239
 2      .3030D+03 9.9    2.4814      .1240       .1440      -.0200
 3      .5050D+03 16.6   2.7033      .0910       .0737       .0173
 4      .7070D+03 23.2   2.8494      .0780       .0558       .0222
 5      .1010D+04 33.1   3.0043      .0660       .0477       .0183
 6      .2020D+04 66.3   3.3054      .0560       .0430       .0130
```

Unsat-Zone-Infiltration

MSP 7-25-89 33
ckd PYC 7/28/89

```
 7      .4040D+04 132.5 3.6064     .0480      .0422      .0058
 8      .7070D+04 232.  3.8494     .0460      .0420      .0040
 9      .1010D+05 331.  4.0043     .0450      .0420      .0030
10      .1515D+05 497.  4.1804     .0420      .0420      .0000

SUM OF SQUARES OF OBSERVED VERSUS FITTED VALUES
===============================================
                      UNWEIGHTED   WEIGHTED
RETENTION DATA          .00233      .00233
COND/DIFF DATA          .00000      .00000
      ALL DATA          .00233      .00233

SOIL HYDRAULIC PROPERTIES (MTYPE = 3)
=====================================
   WC         P         LOGP      COND       LOGK        DIF       LOGD
 .0442    .1466D+04   3.166   .1600D-10 -10.796    .4185D-05   -5.378
 .0465    .1112D+04   3.046   .1574D-09  -9.803    .1563D-04   -4.806
 .0510    .8426D+03   2.926   .1549D-08  -8.810    .5848D-04   -4.233
 .0599    .6374D+03   2.804   .1527D-07  -7.816    .2201D-03   -3.657
 .0689    .5404D+03   2.733   .5834D-07  -7.234    .4810D-03   -3.318
 .0778    .4800D+03   2.681   .1512D-06  -6.820    .8419D-03   -3.075
 .0868    .4372D+03   2.641   .3170D-06  -6.499    .1306D-02   -2.884
 .0957    .4046D+03   2.607   .5810D-06  -6.236    .1877D-02   -2.726
 .1047    .3785D+03   2.578   .9708D-06  -6.013    .2562D-02   -2.591
 .1136    .3568D+03   2.552   .1516D-05  -5.819    .3367D-02   -2.473
 .1226    .3384D+03   2.529   .2249D-05  -5.648    .4301D-02   -2.366
 .1315    .3224D+03   2.508   .3203D-05  -5.494    .5373D-02   -2.270
 .1405    .3082D+03   2.489   .4415D-05  -5.355    .6595D-02   -2.181
 .1494    .2955D+03   2.471   .5923D-05  -5.227    .7979D-02   -2.098
 .1584    .2840D+03   2.453   .7768D-05  -5.110    .9542D-02   -2.020
 .1673    .2735D+03   2.437   .9995D-05  -5.000    .1130D-01   -1.947
 .1763    .2637D+03   2.421   .1265D-04  -4.898    .1328D-01   -1.877
 .1852    .2547D+03   2.406   .1578D-04  -4.802    .1549D-01   -1.810
 .1942    .2461D+03   2.391   .1945D-04  -4.711    .1798D-01   -1.745
 .2031    .2381D+03   2.377   .2370D-04  -4.625    .2076D-01   -1.683
 .2121    .2304D+03   2.363   .2861D-04  -4.544    .2389D-01   -1.622
 .2210    .2231D+03   2.349   .3423D-04  -4.466    .2741D-01   -1.562
 .2300    .2161D+03   2.335   .4064D-04  -4.391    .3137D-01   -1.504
 .2389    .2093D+03   2.321   .4792D-04  -4.320    .3584D-01   -1.446
 .2479    .2027D+03   2.307   .5615D-04  -4.251    .4091D-01   -1.388
 .2568    .1962D+03   2.293   .6542D-04  -4.184    .4668D-01   -1.331
 .2658    .1899D+03   2.279   .7585D-04  -4.120    .5327D-01   -1.273
 .2747    .1837D+03   2.264   .8754D-04  -4.058    .6086D-01   -1.216
 .2837    .1775D+03   2.249   .1006D-03  -3.997    .6966D-01   -1.157
 .2926    .1713D+03   2.234   .1152D-03  -3.938    .7994D-01   -1.097
 .3016    .1650D+03   2.218   .1316D-03  -3.881    .9207D-01   -1.036
 .3105    .1587D+03   2.201   .1498D-03  -3.824    .1066D+00    -.972
 .3195    .1523D+03   2.183   .1702D-03  -3.769    .1242D+00    -.906
 .3284    .1456D+03   2.163   .1929D-03  -3.715    .1459D+00    -.836
 .3374    .1387D+03   2.142   .2184D-03  -3.661    .1734D+00    -.761
 .3463    .1314D+03   2.119   .2471D-03  -3.607    .2092D+00    -.679
 .3553    .1235D+03   2.092   .2796D-03  -3.553    .2579D+00    -.589
 .3642    .1148D+03   2.060   .3166D-03  -3.499    .3281D+00    -.484
 .3732    .1047D+03   2.020   .3594D-03  -3.444    .4387D+00    -.358
 .3821    .9244D+02   1.966   .4102D-03  -3.387    .6421D+00    -.192
 .3911    .7520D+02   1.876   .4736D-03  -3.325    .1169D+01     .068
 .3955    .6145D+02   1.789   .5144D-03  -3.289    .2044D+01     .310
 .4000    .0000D+00           .5800D-03  -3.237

END OF PROBLEM
==============
```

Uintha-Gw·Infiltration RE/2.2N

```
 2    1    7
 EXAMPLE 1: CALCULATE CURVE WITH KNOWN PARAMETER VALUES     GREEN RIVER OFF-PILE MATERIAL
 1    0    0    3    2    1    0    0    8   30
  1750     .3100     .0100      3.00       0.50        0.5   0.00045
 EXAMPLE 5: GREEN RIVER; OFF-PILE MATERIAL
    10   10    3    2    1    0    1    8   30
 0.075    0.3100     0.010      3.00       0.50        0.5   0.00045
 0    0    1    1    1    1    0
   101      .260
   303      .210
   505      .197
   707      .190
  1010      .145
  2020      .135
  4040      .125
  7070      .112
 10100      .100
 15150      .075
```

~~7-19-89~~ 7-25-89 MSP

ckd PYC 7/28/89

Untra-Drn-Infiltration RE 12.IN

MSP 7-25-89
Ckd PYC 7/28/89

```
******************************************************************
*                                                                *
*    ANALYSIS OF SOIL HYDRAULIC PROPERTIES                       *
*                                                                *
*    EXAMPLE 1: CALCULATE CURVE WITH KNOWN PARAMETER VALUES      *
*                                                                *
*    MUALEM-BASED RESTRICTION, M=1-1/N                           *
*    MTYPE= 3     METHOD= 2                                      *
*                                                                *
******************************************************************


INITIAL VALUES OF THE COEFFICIENTS
==================================
NO      NAME       INITIAL VALUE   INDEX
 1       WCR           .0750         0
 2       WCS           .3100         0
 3      ALPHA          .0100         0
 4        N           3.0000         0
 5        M            .6667         0
 6       EXPO          .5000         0
 7       CONDS         .0005         0


SOIL HYDRAULIC PROPERTIES (MTYPE = 3)
=====================================
    WC         P        LOGP      COND       LOGK        DIF        LOGD
  .0765    .1265D+04  3.102   .3861D-11 -11.413    .1663D-05   -5.779
  .0779    .8940D+03  2.951   .4369D-10 -10.360    .6658D-05   -5.177
  .0809    .6316D+03  2.800   .4948D-09  -9.306    .2670D-04   -4.573
  .0868    .4455D+03  2.649   .5611D-08  -8.251    .1076D-03   -3.968
  .0926    .3626D+03  2.559   .2327D-07  -7.633    .2444D-03   -3.612
  .0985    .3129D+03  2.495   .6392D-07  -7.194    .4394D-03   -3.357
  .1044    .2786D+03  2.445   .1402D-06  -6.853    .6956D-03   -3.158
  .1103    .2531D+03  2.403   .2667D-06  -6.574    .1016D-02   -2.993
  .1161    .2331D+03  2.367   .4598D-06  -6.337    .1406D-02   -2.852
  .1220    .2167D+03  2.336   .7379D-06  -6.132    .1869D-02   -2.728
  .1279    .2030D+03  2.308   .1121D-05  -5.950    .2410D-02   -2.618
  .1338    .1913D+03  2.282   .1632D-05  -5.787    .3037D-02   -2.518
  .1396    .1810D+03  2.258   .2295D-05  -5.639    .3756D-02   -2.425
  .1455    .1720D+03  2.235   .3135D-05  -5.504    .4576D-02   -2.340
  .1514    .1638D+03  2.214   .4183D-05  -5.379    .5506D-02   -2.259
  .1573    .1565D+03  2.194   .5467D-05  -5.262    .6558D-02   -2.183
  .1631    .1497D+03  2.175   .7023D-05  -5.153    .7743D-02   -2.111
  .1690    .1435D+03  2.157   .8887D-05  -5.051    .9078D-02   -2.042
  .1749    .1377D+03  2.139   .1110D-04  -4.955    .1058D-01   -1.976
  .1808    .1322D+03  2.121   .1370D-04  -4.863    .1227D-01   -1.911
  .1866    .1271D+03  2.104   .1674D-04  -4.776    .1417D-01   -1.849
  .1925    .1223D+03  2.087   .2027D-04  -4.693    .1631D-01   -1.787
  .1984    .1177D+03  2.071   .2434D-04  -4.614    .1873D-01   -1.727
  .2043    .1132D+03  2.054   .2902D-04  -4.537    .2147D-01   -1.668
  .2101    .1090D+03  2.037   .3437D-04  -4.464    .2457D-01   -1.610
  .2160    .1048D+03  2.020   .4048D-04  -4.393    .2811D-01   -1.551
  .2219    .1008D+03  2.003   .4742D-04  -4.324    .3216D-01   -1.493
  .2278    .9684D+02  1.986   .5530D-04  -4.257    .3683D-01   -1.434
  .2336    .9296D+02  1.968   .6421D-04  -4.192    .4224D-01   -1.374
  .2395    .8911D+02  1.950   .7429D-04  -4.129    .4856D-01   -1.314
  .2454    .8527D+02  1.931   .8569D-04  -4.067    .5603D-01   -1.252
  .2513    .8141D+02  1.911   .9856D-04  -4.006    .6495D-01   -1.187
  .2571    .7751D+02  1.889   .1131D-03  -3.946    .7576D-01   -1.121
  .2630    .7353D+02  1.866   .1296D-03  -3.887    .8911D-01   -1.050
  .2689    .6942D+02  1.841   .1484D-03  -3.829    .1060D+00    -.975
  .2748    .6511D+02  1.814   .1697D-03  -3.770    .1279D+00    -.893
  .2806    .6053D+02  1.782   .1943D-03  -3.712    .1576D+00    -.803
  .2865    .5553D+02  1.745   .2228D-03  -3.652    .2001D+00    -.699
  .2924    .4987D+02  1.698   .2565D-03  -3.591    .2667D+00    -.574
```

Unter-Gm-Infiltration

MSP 7-25-89
Ckd PYL 7/28/89

```
 .2983   .4308D+02  1.634   .2976D-03  -3.526   .3877D+00   -.411
 .3041   .3383D+02  1.529   .3507D-03  -3.455   .6948D+00   -.158
 .3071   .2671D+02  1.427   .3864D-03  -3.413   .1190D+01    .075
 .3100   .0000D+00          .4500D-03  -3.347

END OF PROBLEM
==============
```

Untra. Grn - Infiltration

MSP 7-25-89
Ckd PTC 7/28/89

```
*****************************************************************
*                                                               *
*     ANALYSIS OF SOIL HYDRAULIC PROPERTIES                     *
*                                                               *
*     EXAMPLE 5: GREEN RIVER; OFF-PILE MATERIAL                 *
*                                                               *
*     MUALEM-BASED RESTRICTION, M=1-1/N                         *
*     ANALYSIS OF RETENTION DATA ONLY                           *
*     MTYPE= 3     METHOD= 2                                    *
*                                                               *
*****************************************************************


INITIAL VALUES OF THE COEFFICIENTS
=================================
NO      NAME         INITIAL VALUE   INDEX
 1       WCR              .0750        0
 2       WCS              .3100        0
 3      ALPHA             .0100        1
 4        N              3.0000        1
 5        M               .6667        0
 6      EXPO              .5000        0
 7      CONDS             .0005        0


NIT      SSQ     ALPHA      N
 0     .05107    .0100   3.0000
 1     .00995    .0094   1.7170
 2     .00420    .0096   1.3611
 3     .00135    .0082   1.4652
 4     .00126    .0083   1.4844
 5     .00126    .0084   1.4823
 6     .00126    .0084   1.4823
 7     .00126    .0084   1.4823


CORRELATION MATRIX
=================
         1          2
 1    1.0000
 2    -.8909     1.0000


RSQUARED FOR REGRESSION OF OBSERVED VS FITTED VALUES =   .95840519
===============================================================


NONLINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS
=============================================
                                               95% CONFIDENCE LIMITS
VARIABLE    VALUE     S.E.COEFF.    T-VALUE     LOWER       UPPER
 ALPHA      .00837      .00210        3.98       .0035       .0132
   N       1.48226      .06134       24.16      1.3408      1.6237


OBSERVED AND FITTED DATA
=======================
NO          P          LOG-P    WC-OBS    WC-FIT    WC-DIF
 1      .10100+03     2.0043     .2600     .2698    -.0098
 2      .30300+03     2.4814     .2100     .2145    -.0045
 3      .50500+03     2.7033     .1970     .1881     .0089
 4      .70700+03     2.8494     .1900     .1725     .0175
 5      .10100+04     3.0043     .1450     .1578    -.0128
 6      .20200+04     3.3054     .1350     .1348     .0002
 7      .40400+04     3.6064     .1250     .1179     .0071
```

Untra - Grn - Infiltration

MSP 7-25-89
ckd PYC 7/28/89

```
  8    .70700+04    3.8494     .1120      .1078      .0042
  9    .10100+05    4.0043     .1000      .1026     -.0026
 10    .15150+05    4.1804     .0750      .0977     -.0227


SUM OF SQUARES OF OBSERVED VERSUS FITTED VALUES
===============================================
                        UNWEIGHTED   WEIGHTED
RETENTION DATA            .00126      .00126
COND/DIFF DATA            .00000      .00000
      ALL DATA            .00126      .00126


SOIL HYDRAULIC PROPERTIES (MTYPE = 3)
=====================================
    WC         P        LOGP      COND       LOGK        DIF       LOGD
  .0765    .4444D+07   6.648   .1064D-18  -18.973    .6673D-09   -9.176
  .0779    .1056D+07   6.024   .1066D-16  -16.972    .7944D-08   -8.100
  .0809    .2508D+06   5.399   .1069D-14  -14.971    .9459D-07   -7.024
  .0868    .5958D+05   4.775   .1071D-12  -12.970    .1126D-05   -5.948
  .0926    .2570D+05   4.410   .1586D-11  -11.800    .4797D-05   -5.319
  .0985    .1415D+05   4.151   .1074D-10  -10.969    .1342D-04   -4.872
  .1044    .8901D+04   3.949   .4736D-10  -10.325    .2981D-04   -4.526
  .1103    .6094D+04   3.785   .1593D-09   -9.798    .5726D-04   -4.242
  .1161    .4421D+04   3.646   .4443D-09   -9.352    .9952D-04   -4.002
  .1220    .3347D+04   3.525   .1081D-08   -8.966    .1608D-03   -3.794
  .1279    .2616D+04   3.418   .2370D-08   -8.625    .2457D-03   -3.610
  .1338    .2097D+04   3.322   .4787D-08   -8.320    .3594D-03   -3.444
  .1396    .1715D+04   3.234   .9050D-08   -8.043    .5077D-03   -3.294
  .1455    .1426D+04   3.154   .1620D-07   -7.790    .6969D-03   -3.157
  .1514    .1202D+04   3.080   .2771D-07   -7.557    .9343D-03   -3.030
  .1573    .1025D+04   3.011   .4561D-07   -7.341    .1228D-02   -2.911
  .1631    .8828D+03   2.946   .7263D-07   -7.139    .1586D-02   -2.800
  .1690    .7663D+03   2.884   .1124D-06   -6.949    .2021D-02   -2.694
  .1749    .6698D+03   2.826   .1696D-06   -6.770    .2542D-02   -2.595
  .1808    .5890D+03   2.770   .2505D-06   -6.601    .3165D-02   -2.500
  .1866    .5205D+03   2.716   .3629D-06   -6.440    .3905D-02   -2.408
  .1925    .4618D+03   2.664   .5170D-06   -6.287    .4781D-02   -2.320
  .1984    .4112D+03   2.614   .7254D-06   -6.139    .5816D-02   -2.235
  .2043    .3672D+03   2.565   .1004D-05   -5.998    .7037D-02   -2.153
  .2101    .3286D+03   2.517   .1374D-05   -5.862    .8477D-02   -2.072
  .2160    .2944D+03   2.469   .1861D-05   -5.730    .1018D-01   -1.992
  .2219    .2641D+03   2.422   .2498D-05   -5.602    .1219D-01   -1.914
  .2278    .2369D+03   2.375   .3326D-05   -5.478    .1457D-01   -1.836
  .2336    .2125D+03   2.327   .4397D-05   -5.357    .1742D-01   -1.759
  .2395    .1903D+03   2.279   .5782D-05   -5.238    .2083D-01   -1.681
  .2454    .1700D+03   2.231   .7568D-05   -5.121    .2494D-01   -1.603
  .2513    .1515D+03   2.180   .9871D-05   -5.006    .2997D-01   -1.523
  .2571    .1343D+03   2.128   .1285D-04   -4.891    .3617D-01   -1.442
  .2630    .1183D+03   2.073   .1672D-04   -4.777    .4395D-01   -1.357
  .2689    .1033D+03   2.014   .2178D-04   -4.662    .5392D-01   -1.268
  .2748    .8916D+02   1.950   .2846D-04   -4.546    .6701D-01   -1.174
  .2806    .7561D+02   1.879   .3745D-04   -4.427    .8483D-01   -1.071
  .2865    .6247D+02   1.796   .4985D-04   -4.302    .1104D+00    -.957
  .2924    .4949D+02   1.695   .6763D-04   -4.170    .1499D+00    -.824
  .2983    .3626D+02   1.559   .9503D-04   -4.022    .2194D+00    -.659
  .3041    .2191D+02   1.341   .1442D-03   -3.841    .3820D+00    -.418
  .3071    .1349D+02   1.130   .1919D-03   -3.717    .6099D+00    -.215
  .3100    .0000D+00           .4500D-03   -3.347


END OF PROBLEM
==============
```

Jn 39

MSP 7-25-89

Umtra-Gen-Infiltration

RE 7.IN 7-18-89 mjl

chd PYL 7/20/89

B-1, B-2

```
2    1    7
 EXAMPLE 1: CALCULATE CURVE WITH KNOWN PARAMETER VALUES     GREEN RIVER BUFFER MATERIAL
1    0    0    3    2    1    0    0    8   30
 .0950     .2900     .0100      3.00      0.50        0.5    0.00027
 EXAMPLE 5: GREEN RIVER: BUFFER MATERIAL
1   13   13    3    2    1    0    1    8   30
 0.095     0.2900    0.010      3.00      0.50        0.5    0.00027
0    0    1    1    1    1    0
   101       .263
   202       .238
   303       .217
   404       .198
   505       .184
   606       .171
   808       .155
  1010       .145
  1414       .140
  2020       .136
  4040       .129
  7070       .121
 10100       .111
```

Unter-Gm-Infiltration RET. IN -MSP 7-18-89 CRA PTC 7/28/89 5H 40

```
*********************************************************************
*                                                                   *
*     ANALYSIS OF SOIL HYDRAULIC PROPERTIES                         *
*                                                                   *
*     EXAMPLE 1: CALCULATE CURVE WITH KNOWN PARAMETER VALUES        *
*                                                                   *
*     MUALEM-BASED RESTRICTION, M=1-1/N                             *
*     MTYPE= 3      METHOD= 2                                       *
*                                                                   *
*********************************************************************


INITIAL VALUES OF THE COEFFICIENTS
==================================
NO       NAME          INITIAL VALUE   INDEX
 1        WCR               .0950        0
 2        WCS               .2900        0
 3       ALPHA              .0100        0
 4         N               3.0000        0
 5         M                .6667        0
 6        EXPO              .5000        0
 7        CONDS             .0003        0


SOIL HYDRAULIC PROPERTIES (MTYPE = 3)
=====================================
   WC          P         LOGP       COND       LOGK         DIF       LOGD
 .0962     .1265D+04   3.102    .2317D-11  -11.635     .1203D-05   -5.920
 .0974     .8940D+03   2.951    .2622D-10  -10.581     .4814D-05   -5.317
 .0999     .6316D+03   2.800    .2969D-09   -9.527     .1931D-04   -4.714
 .1048     .4455D+03   2.649    .3367D-08   -8.473     .7779D-04   -4.109
 .1096     .3626D+03   2.559    .1396D-07   -7.855     .1767D-03   -3.753
 .1145     .3129D+03   2.495    .3835D-07   -7.416     .3177D-03   -3.498
 .1194     .2786D+03   2.445    .8411D-07   -7.075     .5030D-03   -3.298
 .1243     .2531D+03   2.403    .1600D-06   -6.796     .7349D-03   -3.134
 .1291     .2331D+03   2.367    .2759D-06   -6.559     .1016D-02   -2.993
 .1340     .2167D+03   2.336    .4428D-06   -6.354     .1351D-02   -2.869
 .1389     .2030D+03   2.308    .6728D-06   -6.172     .1743D-02   -2.759
 .1438     .1913D+03   2.282    .9794D-06   -6.009     .2196D-02   -2.658
 .1486     .1810D+03   2.258    .1377D-05   -5.861     .2716D-02   -2.566
 .1535     .1720D+03   2.235    .1881D-05   -5.726     .3309D-02   -2.480
 .1584     .1638D+03   2.214    .2510D-05   -5.600     .3981D-02   -2.400
 .1633     .1565D+03   2.194    .3280D-05   -5.484     .4742D-02   -2.324
 .1681     .1497D+03   2.175    .4214D-05   -5.375     .5599D-02   -2.252
 .1730     .1435D+03   2.157    .5332D-05   -5.273     .6564D-02   -2.183
 .1779     .1377D+03   2.139    .6659D-05   -5.177     .7650D-02   -2.116
 .1828     .1322D+03   2.121    .8220D-05   -5.085     .8872D-02   -2.052
 .1876     .1271D+03   2.104    .1004D-04   -4.998     .1025D-01   -1.989
 .1925     .1223D+03   2.087    .1216D-04   -4.915     .1180D-01   -1.928
 .1974     .1177D+03   2.071    .1460D-04   -4.836     .1354D-01   -1.868
 .2023     .1132D+03   2.054    .1741D-04   -4.759     .1552D-01   -1.809
 .2071     .1090D+03   2.037    .2062D-04   -4.686     .1777D-01   -1.750
 .2120     .1048D+03   2.020    .2429D-04   -4.615     .2033D-01   -1.692
 .2169     .1008D+03   2.003    .2845D-04   -4.546     .2326D-01   -1.633
 .2218     .9684D+02   1.986    .3318D-04   -4.479     .2663D-01   -1.575
 .2266     .9296D+02   1.968    .3853D-04   -4.414     .3054D-01   -1.515
 .2315     .8911D+02   1.950    .4458D-04   -4.351     .3512D-01   -1.455
 .2364     .8527D+02   1.931    .5141D-04   -4.289     .4051D-01   -1.392
 .2413     .8141D+02   1.911    .5914D-04   -4.228     .4696D-01   -1.328
 .2461     .7751D+02   1.889    .6787D-04   -4.168     .5478D-01   -1.261
 .2510     .7353D+02   1.866    .7777D-04   -4.109     .6443D-01   -1.191
 .2559     .6942D+02   1.841    .8901D-04   -4.051     .7661D-01   -1.116
 .2608     .6511D+02   1.814    .1018D-03   -3.992     .9246D-01   -1.034
```

Uinta-Grn-Infiltration

SH 41
MSP-7-19-89
ckd PYL 7/28/89

```
 .2705     .5553D+02  1.745    .1337D-03  -3.874     .1447D+00    -.840
 .2754     .4987D+02  1.698    .1539D-03  -3.813     .1928D+00    -.715
 .2803     .4308D+02  1.634    .1785D-03  -3.748     .2803D+00    -.552
 .2851     .3383D+02  1.529    .2104D-03  -3.677     .5024D+00    -.299
 .2876     .2671D+02  1.427    .2318D-03  -3.635     .8601D+00    -.065
 .2900     .0000D+00           .2700D-03  -3.569

END OF PROBLEM
==============




 ***********************************************************************
 *                                                                     *
 *     ANALYSIS OF SOIL HYDRAULIC PROPERTIES                           *
 *                                                                     *
 *     EXAMPLE 5: GREEN RIVER: BUFFER MATERIAL                         *
 *                                                                     *
 *     MUALEM-BASED RESTRICTION, M=1-1/N                               *
 *     ANALYSIS OF RETENTION DATA ONLY                                 *
 *     MTYPE= 3     METHOD= 2                                          *
 *                                                                     *
 ***********************************************************************


 INITIAL VALUES OF THE COEFFICIENTS
 ==================================
 NO       NAME        INITIAL VALUE   INDEX
  1        WCR             .0950        0
  2        WCS             .2900        0
  3       ALPHA            .0100        1
  4         N             3.0000        1
  5         M              .6667        0
  6       EXPO             .5000        0
  7       CONDS            .0003        0
```

```
 0    .05331    .0100   3.0000   Unitra-Grn                 5442
 1    .01641    .0088   1.9880                                 MIP. 7-19-9
 2    .00502    .0069   1.4323    Infiltration           ded PYC 7/28/89
 3    .00058    .0068   1.5717
 4    .00043    .0060   1.6392
 5    .00041    .0060   1.6499
 6    .00041    .0060   1.6515
 7    .00041    .0060   1.6517
 8    .00041    .0060   1.6517

CORRELATION MATRIX
==================
        1          2
1    1.0000
2    -.8959     1.0000

RSQUARED FOR REGRESSION OF OBSERVED VS FITTED VALUES =   .98533596
=================================================================

NONLINEAR LEAST-SQUARES ANALYSIS: FINAL RESULTS
===============================================
                                                   95% CONFIDENCE LIMITS
VARIABLE      VALUE     S.E.COEFF.     T-VALUE      LOWER        UPPER
 ALPHA        .00600      .00060        10.08        .0047        .0073
   N         1.65170      .04583        36.04       1.5508       1.7526

OBSERVED AND FITTED DATA
========================
NO  (ft)    P (cm)       LOG-P      WC-OBS     WC-FIT     WC-DIF
 1  3.31  .1010D+03     2.0043      .2630      .2640     -.0010
 2  6.63  .2020D+03     2.3054      .2380      .2336      .0044
 3  9.94  .3030D+03     2.4814      .2170      .2115      .0055
 4 13.25  .4040D+03     2.6064      .1980      .1958      .0022
 5 16.57  .5050D+03     2.7033      .1840      .1843     -.0003
 6 19.88  .6060D+03     2.7825      .1710      .1754     -.0044
 7 26.51  .8080D+03     2.9074      .1550      .1628     -.0078
 8 33.14  .1010D+04     3.0043      .1450      .1541     -.0091
 9 46.39  .1414D+04     3.1504      .1400      .1428     -.0028
10 66.27  .2020D+04     3.3054      .1360      .1331      .0029
11 132.55 .4040D+04     3.6064      .1290      .1194      .0096
12 231.96 .7070D+04     3.8494      .1210      .1119      .0091
13 331.36 .1010D+05     4.0043      .1110      .1084      .0026

SUM OF SQUARES OF OBSERVED VERSUS FITTED VALUES
===============================================
                    UNWEIGHTED    WEIGHTED
RETENTION DATA        .00041       .00041
COND/DIFF DATA        .00000       .00000
      ALL DATA        .00041       .00041

                                                  Kunsat
SOIL HYDRAULIC PROPERTIES (MTYPE = 3)
=====================================
Vol. WC        P        LOGP      COND       LOGK         DIF       LOGD
 .0962    .4016D+06   5.604   .2234D-16  -16.651    .1129D-07   -7.947
 .0974    .1386D+06   5.142   .1060D-14  -14.975    .9254D-07   -7.034
 .0999    .4786D+05   4.680   .5034D-13  -13.298    .7583D-06   -6.120
 .1048    .1652D+05   4.218   .2390D-11  -11.622    .6215D-05   -5.207
 .1096    .8861D+04   3.947   .2287D-10  -10.641    .2129D-04   -4.672
 .1145    .5693D+04   3.755   .1136D-09   -9.945    .5105D-04   -4.292
```

```
.1243    .3046D+04  3.484    .1090D-08  -8.963    .1756D-03  -3.755
.1291    .2399D+04  3.380    .2578D-08  -8.589    .2815D-03  -3.551
.1340    .1949D+04  3.290    .5440D-08  -8.264    .4242D-03  -3.372
.1389    .1620D+04  3.210    .1052D-07  -7.978    .6101D-03  -3.215
.1438    .1373D+04  3.138    .1900D-07  -7.721    .8460D-03  -3.073
.1486    .1180D+04  3.072    .3246D-07  -7.489    .1139D-02  -2.943
.1535    .1026D+04  3.011    .5301D-07  -7.276    .1498D-02  -2.825
.1584    .9015D+03  2.955    .8335D-07  -7.079    .1931D-0   -2.7
.1633    .7984D+03  2.902    .1269D-06  -6.897    .2449D-0   -2.6
.1681    .7119D+03  2.852    .1879D-06  -6.726    .3063D-02  -2.514
.1730    .6385D+03  2.805    .2718D-06  -6.566    .3786D-02  -2.422
.1779    .5754D+03  2.760    .3851D-06  -6.414    .4633D-02  -2.334
.1828    .5206D+03  2.717    .5358D-06  -6.271    .5621D-02  -2.250
.1876    .4727D+03  2.675    .7337D-06  -6.134    .6771D-02  -2.169
.1925    .4303D+03  2.634    .9906D-06  -6.004    .8108D-02  -2.091
.1974    .3926D+03  2.594    .1321D-05  -5.879    .9659D-02  -2.015
.2023    .3588D+03  2.555    .1742D-05  -5.759    .1146D-01  -1.941
.2071    .3283D+03  2.516    .2275D-05  -5.643    .1355D-01  -1.868
.2120    .3005D+03  2.478    .2946D-05  -5.531    .1599D-01  -1.796
.2169    .2752D+03  2.440    .3785D-05  -5.422    .1884D-01  -1.725
.2218    .2519D+03  2.401    .4832D-05  -5.316    .2218D-01  -1.654
.2266    .2304D+03  2.362    .6134D-05  -5.212    .2612D-01  -1.583
.2315    .2103D+03  2.323    .7749D-05  -5.111    .3079D-01  -1.512
.2364    .1915D+03  2.282    .9752D-05  -5.011    .3638D-01  -1.439
.2413    .1739D+03  2.240    .1224D-04  -4.912    .4313D-01  -1.365
.2461    .1571D+03  2.196    .1533D-04  -4.814    .5141D-01  -1.289
.2510    .1411D+03  2.150    .1920D-04  -4.717    .6170D-01  -1.210
.2559    .1257D+03  2.099    .2406D-04  -4.619    .7477D-01  -1.126
.2608    .1108D+03  2.044    .3023D-04  -4.520    .9182D-01  -1.037
.2656    .9606D+02  1.983    .3818D-04  -4.418    .1149D+00   -.940
.2705    .8135D+02  1.910    .4866D-04  -4.313    .1477D+00   -.831
.2754    .6633D+02  1.822    .6297D-04  -4.201    .1982D+00   -.703
.2803    .5041D+02  1.702    .8374D-04  -4.077    .2868D+0    -.5
.2851    .3221D+02  1.508    .1182D-03  -3.927    .4945D+0    -.3
.2876    .2089D+02  1.320    .1489D-03  -3.827    .7895D+00   -.103
.2900    .0000D+00           .2700D-03  -3.569

END OF PROBLEM
==============
```

Ksat

S#43
msl
7-19-89
Uintah-Basin
Infiltration
Ded PRL 7/28/89

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Sheet 43a
Project UMTRA - GRN
Contract No. 5057-05
File No.
Feature Infiltration
Designed PTL
Date 7/28/89
Item 'UNSATZ' Analysis
Checked RLP
Date 7-28-89

<u>Calculations of</u>
<u>Hydraulic gradient i for each printout time-step.</u> (sh. 44-67)

H = total head in feet (from 'UNSATZ' output)

i = hydraulic gradient $= \dfrac{H_n - H_{n+1}}{d}$

where n = node number

d = spacing between 2 nodes = 2 ft.

θ = volumetric moisture content (from 'UNSATZ' output)

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

Project UMTRA - GRN
Feature INFILTRATION
Item 'UNSATZ' Analysis

Contract No. 5057-05
Sheet 44
File No.
Designed MSP
Date 7.26.89
Checked PYL
Date 7/28/89

Case A (Refer to sh. 15)
GRNA.OUT;1

θ = %

Time (yr.)		NODE 23		25
0	H	6.0		-226
	i		116	
	θ			
~ 13	H	-6.2582		-7.2020
	i		.4719	
	θ	.14224		.14250
~ 30	H	-5.3958		-6.393[illegible]
	i		.5015	
	θ	.14250		.142[illegible]
~ 46	H	-5.3798		-6.324[illegible]
	i		.5021	
	θ	.14251		.14281
~ 62.7	H	-5.3796		[illegible]
	i		.5021	
	θ	.14251		.14281
~ 79.1	H	-5.3796		-6.3[illegible]38
	i		SAME	
	θ	.14251		.14231
~ 95.6	H		SAME	
	i			
	θ			
	H			
	i			
	H			
	i			

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project: UMTRA - GRN
Feature: INFILTRATION
Item: 'UNSATZ' Analysis
Contract No.: ~~[illegible]~~ 5057-05
Designed: RJSP
Checked: TYL
Sheet: 45
File No.:
Date: 7-26-89
Date: 7/26/89

Case A

GRNA.OUT;1

θ = %

Time (yr.)		NODE 51		53
0	H	-252		-254
	i		1	
	θ			
~ 13	H	-13.821		-13.543
	i		.011	
	θ	.19146		.19356
~ 30	H	-13.783		-13.816
	i		.0135	
	θ	.19150		.19360
~ 46	H	-13.732		-13.809
	i		.0135	
	θ	.19150		.19366
~ 62.7	H	-13.782		-13.809
	i		SAME	
	θ	.19150		.19360
~ 79.1	H		SAME	
	i			
	θ			
~ 95.6	H		SAME	
	i			
	θ			
	H			
	i			
	H			
	i			

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA - GRN
Contract No. 5057-05
Sheet 46
File No.
Feature INFILTRATION
Designed PKSP
Date 7-26-89
Item 'UNSATZ' analysis
Checked PYL
Date 7/26/89

Case A θ = %

Time (yr.)			NODE 53		55
0	H		-254		-26
	i			-114	
	θ				
~ 13	H		-13.843		-13.911
	i				
	θ		.17555	.0342	.18076
~ 30	H		-13.810		-13.892
	i				
	θ		.17564	.0410	.18082
~ 46	H		-13.809		-13.892
	i				
	θ		.17565	.0415	.18082
~ 62.7	H		-13.809		-13.892
	i			SAME	
	θ		.17565		.18082
~ 79.1	H			SAME	
	i				
	θ				
~ 95.6	H				
	i			SAME	
	θ				
	H				
	i				
	H				
	i				

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA GRN. Contract No. 5057-05 Sheet 47
Feature INFILTRATION File No.
Item 'UNSAT2' Analysis
Designed MSP Date 7-26-89
Checked PYL Date 7/26/89

Case A: GRNA.OUT;1

NODE 23 → 25 top of stpile element.

@ Time (t) = 95.6 yr

$i = .5021$ $\theta_{ave(2+2)} = .14266$

$K_{rel} = 8.0 \times 10^{-5}$

$K_{unsat} = (8.0 \times 10^{-5})(4.5 \times 10^{-4}) = 3.6 \times 10^{-8}$ cm/s

flux velocity = $i * K_{unsat} = 1.8 \times 10^{-8}$ cm/s

seepage vel = .131 ft/yr

NODE 51 → 53 bottom of stpile element

@ t = 95.6 yr , $i = .0135$

$\theta_{ave} = .19255$ $K_{rel} = 3.6 \times 10^{-3}$

$K_{unsat} = (3.6 \times 10^{-3})(4.5 \times 10^{-4}) = 1.62 \times 10^{-6}$ cm/s

flux velocity = $i * K = 2.19 \times 10^{-8}$

seepage vel = .118 ft/yr

NODE 53 → 55 top of buffer

@ t = 95.6 $i = .0415$

$\theta_{av} = .17824$ $K_{rel} = 1.6 \times 10^{-3}$

$K_{unsat} = (1.6 \times 10^{-3})(2.7 \times 10^{-4}) = 4.32 \times 10^{-7}$ cm/s

flux velocity = 1.79×10^{-8} cm/s

seepage vel = .104 ft/yr

58 yrs to travel thru 6' of buffer

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA-GRN
Feature INFILTRATION
Item 'UNSAT2' Analysis W/O FLUX

Contract No. 5057-05
Designed PYL
Checked MSP
Sheet 48
File No.
Date 7/26/89
Date 7-26-89

Case B (Refer to sh. 15)

GRNB.UT;1

$\theta_{tailings}$ = 7.0 %

Time (min.)		㉓		㉕
0	H	6		-226
	i		116	
	θ			
13 yr.	H	-14.656		-14.597
	i		-0.0295	
	θ	0.13971		0.14033
30 yr.	H	-14.026		-14.0[illegible]
	i		-0.001	
	θ	0.13990		0.14050
46 yr.	H	-14.001		-14.001
	i		0	
	θ	0.13991		0.14051
62.7 yr.	H	-14.000		-14.000
	i		0	
	θ	0.13991		0.14051
79.1 yr.	H	-14.000		-14.000
	i		0	
	θ	0.13991		0.14051
95.6 yr.	H	-14.000		-14.000
	i		0	
	θ	0.13991		0.14051
	H			
	i			
	H			
	i			

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Project UMTRA-GJN
Feature INFILTRATION
Item 'UNSATZ' analysis
Contract No. 5057-01 ~~[illegible]~~
Designed PYL
Checked [illegible]
Sheet 49
File No.
Date 7/26/89
Date 7·26·89

Case B :

θ = %

Time (min.)		(51)		(53)
0	H	-252		-254
	i		1	
13 yr.	H	-14.021		-14.019
	i		-0.001	
	θ	0.19125		0.19332
30 yr.	H	-14.001		-14.001
	i		0	
	θ	0.19127		0.19339
46 yr.	H	-14.000		-14.000
	i		0	
	θ	0.19127		0.19339
62.7 yr.	H	-14.000		-14.000
	i		0	
	θ	0.19127		0.19339
79.1 yr.	H	-14.000		-14.000
	i		0	
	θ	0.19127		0.19339
95.6 yr.	H	-14.000		-14.000
	i		0	
	θ	0.19127		0.19339
	H			
	i			
	H			
	i			

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Project UMTRA-[illegible]
Feature INFILTRATION
Item 'UNSAT2' analysis
Contract No. 5057-05 ~~5025-41~~
Designed PYL
Checked [illegible]
Sheet 50
File No.
Date 7/26/79
Date 7-26-79

Case B :

θ = %

Time (~~min.~~)		⑤③		⑤⑤
0.	H	-254		-26
	i		-114	
	θ			
13 yr.	H	-14.019		-14.011
	i		-0.004	
	θ	0.17517		0.18050
30 yr.	H	-14.001		-14.000
	i		-0.001	
	θ	0.17521		0.18052
46 yr.	H	-14.000		-14.000
	i		0	
	θ	0.17521		0.18052
62.7 yr.	H		SAME	
	i			
	θ			
79.1 yr.	H		SAME	
	i			
95.6 yr.	H		SAME	
	i		0	
	H			
	i			
	H			
	i			

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA /GRN
Feature Infiltration.
Item 'UNSAT2' analysis

Sheet 51
Contract No. 5C57-05
File No.
Designed PTL
Date 7/26/89
Checked MSP
Date 7-26-89

Case B:

Node ㉓ → ㉕ Top of Offpile mat.

@ $t = 95.6$ yr.

$i = 0$

$\theta_{avg} = 0.14$

$K_{rel.} = 6 \times 10^{-5}$

$K_{sat} = 4.5 \times 10^{-4}$ cm/s

$K_{unsat.} = 2.7 \times 10^{-8}$ cm/s

flux velocity = $i \cdot K_{unsat} = 0$

Seepage velocity = 0

Node (51) → (53) . bottom of offpile material

@ $t = 95.6$ yr.
$i = 0$
$\theta_{avg} = 0.192$
$K_{rel.} = 3 \times 10^{-3}$
$K_{sat.} = 4.5 \times 10^{-4}$ cm/s
$K_{unsat} = 1.35 \times 10^{-6}$ cm/s
flux velocity = $i \cdot K_{unsat} = 0$
Seepage velocity = 0

Node (53) → (55) Top of buffer material

@ $l = 95.6$ yr.
$i = 0$
$\theta_{avg} = 0.178$
$K_{rel} = 1.6 \times 10^{-3}$
$K_{sat} = 2.7 \times 10^{-7}$ cm/s

$K_{unsat} = 4.32 \times 10^{-7}$ cm/s.

flux velocity = $i \cdot K_{unsat} = 0$

Seepage Velocity = 0

Time for 6' Travel thru buffer = ∞

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA - GRN	**Contract No.** 5057-05 ~~[illegible]~~	**Sheet** 52
Feature INFILTRATION	**Designed** MSP	**Date** 7.20.89
Item 'UNSAT2' analysis	**Checked** PYL	**Date** 7/26/89

Case C: (Refer to sh. 16) GRNC.OUT; 1

θ = %

Time (yrs.)		NODE 23		25
0	H	−79.0		−226
	i		73.5	
	θ			
~ 13	H	−9.24[illegible]		−9.99[illegible]
	i		.37[illegible]	
	θ	.14134		.14172
~ 30	H	−5.4443		−6.4439
	i		.4499	
	θ	.14247		.14279
~ 46	H	−5.3[illegible]7		−6.3249
	i		.5021	
	θ	.14251		.14281
~ 62.7	H	−5.3746		−6 [illegible]
	i		.5021	
	θ	.14251		.14281
~ 79.1	H	−5.3796		−6.3838
	i		SAME	
	θ	.14251		.14281
~ 95.6	H			
	i		SAME	
	θ			
	H			
	i			
	H			
	i			

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA - GRN
Contract No. ~~[illegible]~~ 5057-05
Sheet 53
File No.
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Designed MSP
Date 7-26-89
Item 'UNSAT2' analysis
Checked PYL
Date 7/26/89

GRNC.OUT;1

Case C:

θ = %

Time (yr.)		NODE 51		53
0	H	-252.0		-254.0
	i		1	
	θ			
~ 13	H	-13.939		-13.947
	i		.024	
	θ	.19134		.19345
~ 30	H	-13.765		-13.811
	i		.0136	
	θ	.19150		.19359
~ 46	H	-13.782		-13.809
	i		.0135	
	θ	.19150		.19360
~ 62.7	H	-13.782		-13.809
	i		SAME	
	θ	.19150		.19360
~ 79.1	H		SAME	
	i			
	θ			
~ 95.6	H		SAME	
	i			
	θ			
	H			
	i			
	H			
	i			

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA - GRN
Feature INFILTRATION
Item 'UNSATZ' analysis
Contract No. ~~[illegible]~~ 5057-05
Designed MHSP
Checked PYL
Sheet 54
File No.
Date 7-26-89
Date 7/26/89

(c) Case C: GRNC.OUT§1

θ = %

Time (yr.)		NODE 53		55
0	H	-254.0		-200
	i		-114	
	θ			
~ 13	H	-13.947		-13.970
	i			
	θ	.17531	.0115	.18[illegible]
~ 30	H	-13.811		-13.843
	i			
	θ	.17564	.041	.18031
~ 46	H	-13.809		-13.842
	i			
	θ	.17565	.0415	.18082
~ 62.7	H	-13.809	SAME	-13.842
	i			
	θ	.17565		.18082
~ 79.1	H		SAME	
	i			
	θ			
~ 95.6	H		SAME	
	i			
	θ			
	H			
	i			
	H			
	i			

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA GRN
Feature Infiltration
Item 'UNSATZ' analysis
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Date 7-26-89
Date 7/26/89

GRNC.OUT;1

(C) Case C :

NODE 23→25 top of tailings element.

@ Time (t) = 95.6 yr

$i = .5021$ $\theta_{AVE(23+25)} = .14266$

$K_{rel} = 8.0 \times 10^{-5}$

$K_{unsat} = (8.0 \times 10^{-5})(4.5 \times 10^{-4}) = 3.6 \times 10^{-8}$ cm/s

flux velocity = $i * k$ = 1.8×10^{-8} cm/s

seepage vel = .131 FT/yr

NODE 51→53 bottom of tailings element

@ $t = 95.6$ yr , $i = .0135$

$\theta_{AVE} = .19255$ $K_{rel} = 3.6 \times 10^{-3}$

$K_{unsat} = (3.6 \times 10^{-3})(4.5 \times 10^{-4}) = 1.62 \times 10^{-6}$ cm/s

flux velocity = $i * k$ = 2.19×10^{-8} cm/s

seepage vel = .118 FT/yr

NODE 53→55 top of buffer

@ $t = 95.6$ $i = .0415$

$\theta_{AV} = .17824$ $K_{rel} = 1.6 \times 10^{-3}$

$K_{unsat} = (1.6 \times 10^{-3})(2.7 \times 10^{-4}) = 4.32 \times 10^{-7}$ cm/s

flux velocity = 1.79×10^{-8} cm/s

seepage vel = .104 FT/yr

58 yrs to travel 6 FT thru Buffer

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA - GRN
Contract No. ~~[illegible]~~ 5057-05
Sheet 56
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Designed PYL
Date 7/26/89
Item UNSAT2' analysis
Checked MSP
Date 7-26-89

Ⓓ Case D: (Refer to sh. 16) $\Psi = -7'$, w/ cover fine GRND.OUT;1

θ = %

Time (yr.)		NODE 23		25
0	H	6		-226
	i		116	
	θ			
~ 13	H	-2.1048		-3.0323
	i		0.464	
	θ	0.14349		0.14382
~ 30	H	-1.9134		-2.8696
	i		0.478	
	θ	0.14355		0.14386
~ 46	H	-1.9127		-2.8690
	i		0.478	
	θ	0.14355		0.14386
~ 62.7	H	-1.9127		-2.8690
	i		0.478	
	θ	0.14351		0.14386
~ 79.1	H			
	i		SAME	
	θ			
~ 95.6	H			
	i		SAME	
	θ			
	H			
	i			
	H			
	i			

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Contract No. 5037-05 ~~[illegible]~~
Sheet 57
File No.
Feature INFILTRATION
Designed PYL
Date 7/26/89
Item 'UNSATZ' Analyses
Checked MSP
Date 7·26·89

Ⓓ Case D :

θ = %

Time (yr.)		NODE (51)		(53)
0	H	-252		-254
	i		1	
	θ			
~ 13	H	-6.9482		-6.9610
	i		0.0064	
	θ	0.2002		0.20406
~ 30	H	-6.9451		-6.9587
	i		0.0068	
	θ	0.20021		0.20407
~ 46	H	-6.9451		-6.9587
	i		0.0068	
	θ	0.20021		0.20407
~ 62.7	H			
	i		SAME	
	θ			
~ 79.1	H			
	i		SAME	
	θ			
~ 95.6	H			
	i		SAME	
	θ			
	H			
	i			
	H			
	i			

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA - GRN
Feature INFILTRATION
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Sheet 58
File No.
Date 7/26/89
Date 7 2 [illegible]

Ⓓ Case D:

θ = %

Time (yr.)		NODE (53)		(55)
0	H	-254		-26
	i		-114	
	θ			
~ 13	H	-6.961		-6.9819
	i		0.01045	
	θ	0.19737		0.2065
~ 30	H	-6.9587		-6.9808
	i		0.01105	
	θ	0.19738		0.20651
~ 46	H			
	i		SAME	
	θ			
~ 62.7	H			
	i		SAME	
	θ			
~ 79.1	H			
	i		SAME	
	θ			
~ 95.6	H			
	i		SAME.	
	θ			
	H			
	i			
	H			
	i			

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Project UMTRA /GRN
Feature Infiltration.
Item 'UNSAT2' analysis
Contract No. 505705
Designed PYC
Checked MSP
Sheet 59.
File No.
Date 6/29
Date 7-21-9

Ⓓ Case D:

Node ㉓ → ㉕ Top of Offpile mat.

@ $t = 95.6$ yr.
$i = 0.478$
$\theta_{avg} = 0.1437$
$K_{rel.} = 9 \times 10^{-5}$
$K_{sat} = 4.5 \times 10^{-4}$ cm/s
$K_{unsat.} = 4.05 \times 10^{-8}$ cm/s.

flux velocity $= i \cdot K_{unsat} = 1.9 \times 10^{-8}$ cm/s.
Seepage velocity $= 0.139$ ft/yr.

Node (51) → (53) . bottom of offpile material

@ $t = 95.6$ yr.
$i = 0.0068$
$\theta_{AVG} = 0.202$
$K_{rel.} = 5 \times 10^{-3}$
$K_{sat.} = 4.5 \times 10^{-4}$ cm/s
$K_{unsat} = 2.25 \times 10^{-6}$ cm/s
flux velocity $= i \cdot K_{unsat} = 1.53 \times 10^{-8}$ cm/s
Seepage velocity $= 0.078$ ft/yr.

Node (53) → (55) Top of buffer material

@ $t = 95.6$ yr.
$i = 0.01105$
$\theta_{AVG} = 0.202$
$K_{rel} = 6.4 \times 10^{-3}$
$K_{sat} = 2.7 \times 10^{-4}$ cm/s
$K_{unsat} = 1.728 \times 10^{-6}$ cm/s

flux velocity $= i \cdot K_{unsat} = 1.91 \times 10^{-8}$ cm/s
Seepage Velocity $= 0.0978$ ft/yr.
Time for 6' Travel thru buffer = <u>61 yr.</u>

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA - GRN
Feature INFILTRATION
Item 'UNSAT2' analysis
5057-05 Contract No. ~~5020-71~~
Designed PYL
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Sheet 60
File No.
Date 7/26/89
Date 7.27

Ⓔ Case E: (Refer to sh. 17) GRNE.OUT

$\theta_{tailing} = 7\ \%$, $\psi_{bottom} = -14'$, cover flux = 1×10^{-9} cm/s

Time (yr.)		NODE (23)		(25)
0	H	6		-226
	i		110	
	θ			
~ 13	H	-14.224		-14.220
	i		-0.002	
	θ	0.13984		0.14045
~ 30	H	-13.555		-13.609
	i		0.027	
	θ	0.14004		0.14063
~ 46	H	-13.530		-13.586
	i		0.028	
	θ	0.14005		0.14064
~ 62.7	H	-13.529		-13.585
	i		0.028	
	θ	0.14005		0.14064
~ 79.1	H			
	i		SAME	
	θ			
~ 95.6	H			
	i		SAME	
	θ			
	H			
	i			
	H			
	i			

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Project UMTRA - GRN
Feature INFILTRATION
Item 'UNSAT2' analysis
Contract No. 5057-05 ~~[illegible]~~
Sheet 61
File No.
Designed PYC
Date 7/26/89
Checked [illegible]
Date 7.27.89

Case E.

Ⓔ θ = %

Time (yr.)		NODE (51)		(53)
0	H	-252		-254
	i		1	
	θ			
~ 13	H	-14.012		-14.010
	i		-0.001	
	θ	0.19126		0.19338
~ 30	H	-13.990		-13.991
	i		0.0005	
	θ	0.19128		0.19340
~ 46	H	-13.989		-13.990
	i		0.0005	
	θ	0.19128		0.19340
~ 62.7	H		SAME	
	i			
	θ			
~ 79.1	H		SAME	
	i			
	θ			
~ 95.6	H		SAME	
	i			
	θ			
	H			
	i			
	H			
	i			

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Project UMTRA - GRN
Feature INFILTRATION
Item GRNE.OUT
Contract No. 5057-05
Designed PYL
Checked VMF
Sheet 62
File No.
Date 7/26/89
Date 7·27·90

(I) Case E:

θ = %

Time (yr.)		NODE ⑤③		⑤⑤
0	H	-254		-26
	i		-114	
	θ			
~ 13	H	-14.010		-14.006
	i		-0.002	
	θ	0.17519		0.18051
~ 30	H	-13.991		-13.995
	i		0.002	
	θ	0.17523		0.18054
~ 46	H	-13.990		-13.995
	i		0.0025	
	θ	0.17523		0.18054
~ 62.7	H			
	i		SAME	
	θ			
~ 79.1	H		SAME	
	i			
	θ			
~ 95.6	H	-13.990		-13.995
	i		0.0025	
	θ	0.17523		0.18054
	H			
	i			
	H			
	i			

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Project UMTRA /GRN
Feature Infiltration.
Item 9PNE. CUT
Contract No. 505705
Designed PYC
Checked MS
Sheet 63
File No.
Date 7/26/89
Date 7-27-89

Case E:

Node ㉓ → ㉕ Top of Offpile mat.

@ $t = 95.6$ yr.
$i = 0.028$
$\theta_{avg} = 0.140345$
$K_{rel.} = 6.4 \times 10^{-4}$
$K_{sat} = 4.5 \times 10^{-4}$ cm/s
$K_{unsat.} = 2.88 \times 10^{-8}$ cm/s
flux velocity $= i \cdot K_{unsat} = 8.06 \times 10^{-10}$ cm/s.
Seepage velocity $= 0.0059$ ft/yr.

Node (51) → (53) : bottom of offpile material

@ $t = 95.6$ yr.
$i = 0.0005$
$\theta_{avg} = 0.19234$
$K_{rel.} = 3 \times 10^{-3}$
$K_{sat} = 4.5 \times 10^{-4}$ cm/s
$K_{unsat} = 1.35 \times 10^{-6}$ cm/s
flux velocity $= i \cdot K_{unsat} = 6.75 \times 10^{-10}$ cm/s.
Seepage velocity $= 3.63 \times 10^{-3}$ ft/yr.

Node (53) → (55) Top of buffer material

@ $t = 95.6$ yr.
$i = 0.0025$
$\theta_{avg} = 0.1779$
$K_{rel} = 1.6 \times 10^{-3}$
$K_{sat} = 2.7 \times 10^{-4}$ cm/s
$K_{unsat} = 4.32 \times 10^{-7}$ cm/s
flux velocity $= i \cdot K_{unsat} = 1.08 \times 10^{-9}$ cm/s
Seepage Velocity $= 0.00628$ ft/yr.
Time for 6' Travel thru buffer $= \boxed{955 \text{ yr.}}$

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA - GRN
Feature INFILTRATION
Item 'UNSATZ' analysis
Contract No. 5057-05
Designed MSP
Checked PYL
Sheet 64
File No.
Date 7.27.89
Date 7/28/89

Ⓕ Case F : (Refer to Sh. 17) GRNF.OUT;1

θ = %

Time (yr.)		NODE 23		25
0	H	6.0		-220
	i		116	
	θ			
~ 13	H	-10.389		-10.954
	i		.2329	
	θ	.14100		.14146
~ 30	H	- 9.4895		- 10.020
	i		.2653	
	θ	.14127		.14171
~ 46	H	- 9.4679		- 9.[illegible]
	i		.2659	
	θ	.14127		.14172
~ 62.7	H	-9.4675		-9.9991
	i		.2658	
	θ	.14127		.14172
~ 79.1	H	-9.4675		-9.9991
	i		SAME	
	θ	.14127		.14172
~ 95.6	H		SAME	
	i			
	θ			
	H			
	i			
	H			
	i			

Project	UMTRA - GRN	Contract No. 5057-05 ~~[illegible]~~	Sheet	65
Feature	INFILTRATION	Designed PMP	Date	7-27-89
Item	'UNSATZ' analysis	Checked PYL	Date	7/28/89

(I) Case F : GRNF.OUT;1

θ = %

Time (yr.)		NODE 51		53
0	H	-252		-254
	i			
	θ			
~ 13	H	-13.924		-13.934
	i		.005	
	θ	.19135		.19346
~ 30	H	-13.891		-13.905
	i		.007	
	θ	.19139		.19350
~ 46	H	-13.890		-13.904
	i		.007	
	θ	.19139		.19350
~ 62.7	H	-13.890		-13.904
	i		SAME	
	θ	.19139		.19350
~ 79.1	H		SAME	
	i			
	θ			
~ 95.6	H		SAME	
	i			
	θ			
	H			
	i			
	H			
	i			

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA - GRN
Feature INFILTRATION
Item 'UNSAT2' Analysis
Contract No. 5057-05
Sheet
File No.
Designed MSP
Date 7-28 89
Checked PYL
Date 7/28/89

Case F: GRNF.OUT, 1

θ = %

Time (yr.)		NODE 53		55
0	H	-254		-26
	i		-228	
	θ			
~ 13	H	-13.934		-13.963
	i		.0145	
	θ	.17534		.18063
~ 30	H	-13.905		-13.946
	i		.0205	
	θ	.17539		.18067
~ 46	H	-13.904		-13.946
	i		.0210	
	θ	.17539		.18067
~ 62.7	H	-13.904		-13.946
	i		SAME	
	θ	.17539		.18067
~ 79.1	H		SAME	
	i			
	θ			
~ 95.6	H		SAME	
	i			
	θ			
	H			
	i			
	H			
	i			

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Sheet 67
Project UMTRA GJN
Contract No. 5057-05
File No.
Feature Infiltration
Designed MSP
Date 7-27-89
Item 'UNSAT2' analysis
Checked PYL
Date 7/28/89

(F) Case F: GRVF.OUT, 1

NODE 23 → 25 top of offpile elements.

@ TIME (t) = 95.6 yr

$i = .2658$ $\theta_{AVE(23+25)} = .14150$

$K_{rel} = 6.8 \times 10^{-5}$

$K_{unsat} = (6.8 \times 10^{-5})(4.5 \times 10^{-4}) = 3.06 \times 10^{-8}$ cm/s

flux velocity = $i * k$ = 8.13×10^{-9} cm/s

seepage vel = .059 FT/YR

NODE 51 → 53 bottom of offpile element

@ t = 95.6 yr , $i = .007$

$\theta_{AVE} = .19245$ $K_{rel} = 3.1 \times 10^{-3}$

$K_{unsat} = (3.1 \times 10^{-3})(4.5 \times 10^{-4}) = 1.40 \times 10^{-6}$ cm/s

flux velocity = $i * k$ = 9.8×10^{-9} cm/s

seepage vel = .053 FT/YR

NODE 53 → 55 top of buffer

@ t = 95.6 $i = .0210$

$\theta_{AV} = .17803$ $K_{rel} = 1.6 \times 10^{-3}$

$K_{unsat} = (1.6 \times 10^{-3})(2.7 \times 10^{-4}) = 4.32 \times 10^{-7}$ cm/s

flux velocity = 9.07×10^{-9} cm/s.

seepage vel = .053 FT/YR

114 yrs to travel thru 6' of buffer

Calculation Cover Sheet

Calc. No. 10-591-01-00

Contract No. 5057-05 **Discipline** ESCI **No. of Sheets** 3

Project UMTRA-GRN

Feature Tailings, Off-pile, Buffer Materials

Item In-place Parameter Characterization

Sources of Data

1. MKE document # 5057-GRN-R-02-01587-00, "Contaminated Materials and Type "A" Fill Test Results", supplied by MK-F.

~~Sources of Formulae & References~~

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

0	——	Martin Goodman	7/27/89	N.O. CHAN	7/28/89	G.B. Guros	8-16-89
Rev. No.	**Revision**	**Calculation By**	**Date**	**Checked By**	**Date**	**Approved By**	**Date**

Sheet A-0
Project UMTRA - GRN
Contract No. 5057-05
File No.
Feature Tailings, Offpile, Buffer Materials
Designed MJG
Date 27 July 89
Item Inplace Parameter Characterization
Checked WOC
Date 7-27-89

SUMMARY

Based on available construction data, in-place buffer and contaminated material mean water content and density values are as follows (see Table 4):

MAT'L TYPE	W(%)	γ_d (pcf)	θ (%)
Tailings	4.6	99.0	7.0
Offpile	5.5	115.2	10.8
Buffer	8.3	119.2	15.8

Mean values of optimum water content and maximum dry density of D-698 compaction tests used to control placement of tailings, "windblown" and buffer materials are presented in Table 10, sheet A-29.

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA-GRN
Feature Tailings, offpile, Buffer Mat'ls
Item Inplace Parameter Characterization
Contract No. 5057-05
Designed MJL
Checked WOC
Sheet A-1
File No.
Date 26 July 89
Date 7/28/89

PURPOSE

Estimate inplace (as-compacted) mean values of the following parameters for the tailings, offpile contaminated material ("windblown" and vicinity property) and buffer materials:

- gravimetric water content (W)
- dry density (γ_d)
- volumetric water content (θ).

PROCEDURE

1. W and γ_d test data for tailings, offpile and buffer materials presented in ref. 1, are reproduced in Tables 1-3, respectively.
2. Data from tests designated as "failed" or from tests performed on tailings/native soil mixtures are excluded from the data base.
3. Mean and standard deviation values of water content and dry density tests in the data base are then estimated for the tailings, offpile and buffer materials. It is assumed these mean test values are approximately equivalent to mean inplace values because tests were performed at an approximate frequency dictated by specifications in the projects Subcontract Documents. [The same remark also applies to the volumetric water content, θ].

...

<PROCEDURE CONTINUED ON p. A-20>...

MJG
7/26/89
UMTRA-GRN
5057-05
CKD. WOC 7/28/89

A-2

TAILINGS*

* All data compacted in-place.

SAMPLE #	ω(%) / θ(%)	γ_d (pcf)	
MKE - 038	~~5.9~~	~~104.2~~	tailings mixture
- 039	~~3.3~~	~~104.9~~	" "
- 040	~~5.5~~	~~106.9~~	" "
- 041	2.9 / (4.8)	102.3	
- 042	4.4 / 7.0	99.4	
- 043	4.7 / 7.5	100.0	
- 044	3.7 / 5.8	97.1	
- 045	3.9 / 6.0	96.2	
- 046	2.8 / 4.4	97.8	
- 047	3.3 / 5.2	98.8	
- 048	3.0 / 4.9	102.0	
- 049	5.3 / 8.5	99.6	
- 050	3.9 / 6.3	101.2	
- 051	4.1 / 6.4	97.6	
- 052	3.4 / 5.4	98.8	
- 053	5.1 / 7.8	95.7	
- 054	6.3 / 9.7	96.3	
- 055	3.3 / 5.2	99.2	
- 056	3.3 / 5.2	99.1	
- 057	6.1 / 9.6	97.9	
- 058	3.2 / 5.0	97.0	
- 059	4.0 / 6.2	96.8	
- 060	3.7 / 5.8	98.1	
- 061	5.8 / 9.5	101.9	
- 062	5.4 / 8.9	103.1	
- 063	1.9 / 3.0	98.7	
- 064	6.7 / 10.5	98.1	
- 065	5.3 / 8.3	97.5	
- 066	4.1 / 6.5	98.4	
- 067	5.3 / 8.6	101.0	
- 068	6.7 / 11.2	104.4	
- 069	4.8 / 7.9	102.9	
- 070	3.9 / 6.2	99.5	
- 071	5.0 / 7.8	96.8	

TABLE 1
(adapted from ref 1)

MJG
26 July 89
UMTRA-GRN
5057-05 CKD. WOC. 7/28/89

TAILINGS

Sample #	In Place		
	W% / θ%	γ_d (pcf)	
MK-E-072	~~3.9~~	~~109.9~~	mixture
-073	3.9 /6.1	97.9	
-074	4.2 / 6.4	95.2	
-075	5.9 / 9.3	98.7	
-076	5.2 / 8.2	98.7	
CM-M-142	4.6	—	
-143	3.1	—	
-144	3.4	—	
-145	5.7		
-146	3.8		
-147	6.7		
-148	5.0		
-149	3.8		
-150	6.9		
-151	4.8		
-152	2.5		
-153	2.0		
-154	3.5		
-155	3.7		
-156	3.6		
-157	3.2		
-158	3.8		
-159	3.3		
-160	4.0		
-161	6.0		
-162	4.3		
-163	3.9		
-164	4.2		
-165	4.3		
-166	2.7		
-167	5.2		
-168	8.0		
-169	6.3		
-170	5.0		
-171	4.5		

TABLE 1 (cont)

(adapted from ref 1)

TAILINGS

MJG
26 July 89
UMTRA GRN
5057-05
ckd. WOC 7/28/89

Sample#	w(%)
CM-M-172	3.1
-173	2.5
-174	4.0
-175	4.8
-176	4.6
-177	3.3
-178	7.4
-179	5.4
-180	4.1
-181	5.2
-182	3.4
-183	4.7
-184	4.1
-185	3.0
-186	2.6
-187	2.2
-188	2.6
-189	3.0
-190	2.4
-191	2.5
-192	2.5
-193	3.9
-194	4.0
-195	3.8
-196	4.1
-197	5.7
-198	6.6
-199	4.3
-200	3.9
-201	1.1
-202	3.9
-203	3.4
-204	3.0
-205	5.3
-206	3.2

Sample #	w(%)
CM-M-207	3.1
-208	3.3
-209	4.5
-210	4.9
-211	5.7
-212	5.1
-213	5.0
-214	6.9
-215	4.8
-216	3.5
-217	5.1
-218	5.6
-219	4.0
-220	3.9
-221	5.1
-222	4.4
-223	6.7
-224	4.4
-225	5.2
-226	5.5
-227	6.0
-228	5.3
-229	5.6
-230	8.0
-231	9.2
-232	7.4
-233	5.9
-234	6.9
-235	8.0
-236	5.5
-237	5.5
-238	4.0
-239	5.4
-240	5.6
-241	7.0

Sample #	w(%)	
CM-M-242	5.0	
-243	6.1	
-244	6.0	
-245	~~7.8~~	Fail
-245-R1	~~5.7~~	Mixture
-246	~~6.0~~	mix
-247	~~4.6~~	mix

θ (summary)
$n = 35$
$\bar{x} = \underline{7.0}$
$\sigma_x = 1.91$
$v = \frac{\sigma_x}{\bar{x}} = 0.27$

TABLE 1 (cont)

(adapted from ref 1)

13 July 89
MJC
5057-05
UMTRA-GRN

MJG
7/27/89
UMTRA-GRN
5057-05
Ckd. Woc 7/28/89

OFFPILE

Sample #	In-place		
	$\omega(\%)/\theta(\%)$	γ_d (pcf)	
MKE -001	5.5 / 9.6	108.7	
-002	5.6 /10.2	113.4	
-003	6.3 /10.6	105.2	
-004	5.6 /10.1	112.2	
-005	6.8 /12.4	114.1	
-006	5.6 /10.6	118.2	
-007	4.1 / 7.9	120 7	
-008	7.0 / 13.3	118.7	
-009	5.4 /10.1	117.2	
-010	~~4.7~~	~~110.6~~	Failed
-010 R1	5.1 /9.7	118.1	
-011	7.5 / 14.1	117.2	
-012	5.7 /10.5	115.0	
-013	6.3 / 11.8	116.8	
-014	4.4 /8.1	115.3	
-015	6.0/ 11.5	119.5	
-016	5.0 /9.5	119.0	
-017	6.6 / 12.2	115.6	
-018	7.0/ 12.5	111.2	
-019	6.8 /12.8	117.0	
-020	6.0/11.4	118.1	
-021	6.6/11.8	111.7	
-022	7.6 /14.5	119.3	
-023	5.8 / 10.6	114.2	
-024	4.8/ 9.1	117.8	
-025	6.4 /12.4	121.3	
-026	5.8 /10.6	114.5	
-027	5.7 /10.5	114.6	
-028	4.8/9.2	119.7	
-029	5.3 /9.6	113.1	
-030	5.3/9.6	113.0	
-031	6.3/ 10.6	105.2	
-032	4.7/ 8.7	114.9	
-033	7.0/ 12.8	114.0	
-034	7.7 /14.2	115.1	

TABLE 2
(adapted from ref 1)

MJG
7/27/89
UMTRA-GRN
5057-05
CKD. WOC 7/28/89

Off pile

TABLE 2 (cont)
(adapted from ref 1)

Sample #	In-Place W% / θ%	In-Place γ_d (pcf)	
MK-E-035	5.7 / 10.9	119.4	
-036	4.1 / 7.8	119.2	
-037	5.4 / 9.1	105.5	
-077	4.9 / 5.5	108.7	
-078	6.1 / 11.3	115.1	
-079	5.7 / 11.0	120.0	
CM-M-001	7.4		
-002	7.2		
-003	~~10.~~		FAIL
-004	5.4		
-005	~~9.4~~		FAIL
-006	6.3		
-007	~~10.2~~		FAIL
-008	7.7		
-005-R1	4.0		
-003-R1	6.7		
-009	~~8.0~~		FAIL
-009-R1	5.7		
-010	5.5		
-011	5.8		
-012	5.7		
-007-R1	6.2		
-013	5.5		
-014	7.3		
-015	7.0		
-016	7.7		
-017	5.9		
-018	5.4		
-019	5.6		
-020	6.5		
-021	6.2		
-022	5.9		
-023	5.8		
-024	5.1		
-025	5.3		

MJG
7/27/89
UMTRA-GRN
5057-05
Ckd. WOC 7/28/89

OFFPILE

SAMPLE #	INPLACE w (%)	
CM-M-026	6.3	
-027	5.6	
-028	4.9	
-029	4.8	
-030	5.6	
-031	4.6	
-032	3.7	
-033	5.0	
-034	5.9	
-035	6.8	
-036	4.6	
-037	5.6	
-038	4.1	
-039	4.2	
-040	~~5.3~~	Fail
-041	3.9	
-042	~~5.5~~	Fail
-043	5.7	
-040-R1	4.2	
-042-R1	4.3	
-044	5.5	
-045	5.0	
-046	5.4	
-047	4.0	
-048	4.7	
-049	5.4	
-050	4.4	
-051	4.0	
-052	5.4	
-053	4.6	
-054	5.2	
-055	4.9	
-056	6.8	
-057	5.7	
-058	6.5	

Sample #	Inplace w(%)
CM-M-059	6.7
-060	6.7
-061	5.9
-062	6.1
-063	5.5
-064	6.3
-065	5.5
-066	4.8
-067	4.0
-068	5.2
-069	6.0
-070	7.6
-071	6.0
-072	4.8
-073	4.3
-074	7.0
-075	5.8
-076	5.9
-077	4.6
-078	5.8
-079	6.0
-080	7.1
-081	6.5
-082	5.7
-083	6.7
-084	4.7
-085	6.5
-086	6.0
-087	6.7
-088	6.3
-089	6.4
-090	6.1
-091	5.7
-092	5.9
-093	6.2

TABLE 2 (cont) (adapted from ref 1)

MJG
7/27/89
UMTRA-GRN
5057-05
CKg. WOC 7/28/89

A-8

OFFPILE

SAMPLE #	Inplace W(%
CM-M-094	7.0
-095	4.9
-096	6.9
-097	4.9
-098	4.9
-099	6.0
-100	5.4
-101	5.9
-102	5.4
-103	5.2
-104	7.2
-105	7.3
-106	6.1
-107	5.5
-108	5.8
-109	4.7
-110	5.5
-111	5.1
-112	4.7
-113	5.7
-114	5.4
-115	~~8.5~~ F
-116	~~10.4~~ F
-115-R1	5.5
-116-R1	5.8
-117	7.5
-118	5.4
-119	4.9
-120	4.3
-121	4.8
-122	5.6
-123	4.1
-124	6.0
-125	5.6
-126	5.9

Sample #	Inplace W%
CM-M-127	6.6
-128	6.5
-129	5.4
-130	4.2
-131	1.9
-132	3.6
-133	2.8
-134	2.8
-135	3.3
-136	4.4
-137	3.9
-138	3.5
-139	2.0
-140	5.1
-141	3.6
-248	5.3
-249	3.6
-250	7.8
-251	6.3
-252	4.2
-253	1.9
-254	3.6

θ (summary)

$n = 40$

$\bar{X} = \underline{10.8}$

$\sigma_x = 1.70$

$v = \frac{\sigma_x}{\bar{x}} = 0.16$

TABLE 2 (cont)

(adapted from ref 1)

MJG
7/27/89
UMTRA-GRN
5057-05
CKD. Woe 7/28/89

BUFFER MAT'L
(i.e., Type A Special Fill)

	(data)		(calculated)	
TEST #	γ_d (pcf)	w (%)	θ (%)	
SFA-S-004	118.9	5.1	9.72	
-005	120.0	6.7	12.88	
-006	122.2	4.7	9.20	
-007	123.0	4.6	9.07	
SFA-N-008	} see attached sheets			
↓				
061				
SFA-S-062	~~116.4~~	~~6.0~~		Fail
-062-R1	117.5	6.0	11.30	
-062-R2	118.3	9.2	17.44	
-063	~~116.0~~	~~5.8~~		Fail
-063-R1	119.0	6.6	12.59	
-064	119.0	6.3	12.01	
-065	123.4	6.6	13.05	
-066	125.3	7.5	15.06	
-067	118.0	7.7	14.56	
-068	121.1	7.3	14.17	
-069	119.8	10.1	19.39	
-070	124.8	8.1	16.2	
-071	122.6	8.9	17.49	
-072	~~116.4~~	~~5.0~~		Fail
-072-R1	120.2	9.3	17.91	
-073	120.1	7.8	15.01	
-074	123.6	8.0	15.85	
-075	125.0	7.0	14.02	
-076	119.1	10.0	19.09	
-077	123.4	9.5	18.79	
-078	121.0	8.9	17.26	
-079	123.3	7.6	15.02	

TABLE 3
(adapted from ref 1)

ORIGINAL

JOB: ~~[illegible]~~ GREEN RIVER

DATE: ~~3/29/89~~ ~~CONTRACT # 3050~~

GREEN RIVER, UTAH

TY REQUIREMENTS
DM 3/30/89
QA ENTRY NO. 617

TEST SPECIFICATIONS: 02200 REV. 2 - 95% OF A D698
02200 REV. 2 OPT. MOISTURE TO -4% OF OPT. MOISTURE

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	% OF MAX. DRY DENSITY	PASS/ FAIL
SFA-N-008	N59,450 E58850 ELEV 4099 1ST 12" LEFT	SFA-4-001	SILTY SAND	124.9	8.7	130.2	121.3	7.3 14.19	SD 3-89 97.X2	PASS
SFA-N-009	N59,330 E58,978 ELEV 4099 1ST 12" LEFT	SFA-4-001	SILTY SAND	124.9	8.7	124.7	119.1	4.8 9.16	95.4	PASS
* ** SFA-N-010	N59,390 E59,052 ELEV 4099 1ST 12" LEFT	SFA-4-004	SILTY SAND	(ONE-POINT) 127.8	SDM 3/27/89 10.1 ~~8.7~~	130.2	122.1	6.7 13.11	95.5	PASS
SFA-N-011	N59,482 E58,955 ELEV 4099 1ST 12" LEFT	SFA-4-004	SILTY SAND	127.8	10.1	129.7	122.3	6.1 11.96	95.7	PASS
SFA-N-012	N59,528 E58,891 ELEV 4100 2ND 12" LEFT	SFA-4-004	SILTY SAND	~~127.8~~	~~10.1~~	~~128.3~~	~~119.1~~	~~7.7~~	~~93.2~~	~~FAIL~~
(RETEST) SFA-N-012-R1	N59,528 E58,891 ELEV 4100 2ND 12" LEFT	SFA-4-004	SILTY SAND	127.8	10.1	132.7	121.7	9.0 17.55	SD 3-89 95.X2	PASS
** SFA-N-013	N59,408 E58,890 ELEV 4100 2ND 12" LEFT	SFA-4-005	CLAYEY SILT	(FOUR POINT) 125.4	10.8	127.7	119.5	6.9 13.21	SD 3-89 95.X3	PASS
SFA-N-014	N59,414 E59,058 ELEV 4100 2ND 12" LEFT	SFA-4-005	CLAYEY SILT	125.4	10.8	130.3	119.3	9.2 17.59	95.1 ~~97.0~~ SDM 3/[illegible]	PASS
SFA-N-015	N59,302 E59,012 ELEV 4100 2ND 12" LEFT	SFA-4-005	CLAYEY SILT	125.4	10.8	131.2	122.2	7.4 14.99	97.4	PASS

(TROXLER 3440 CS-50 5337 AM-4711737)

TABLE 3 (cont) {adapted from ref 1}

MJG 7/27/89
UMTRA-GRN
5057-05
Cod. w/o 7/27/89

OPERATOR: [illegible]

REVIEWED BY: Steve Dike

COMMENTS: * SAND CONE CORRELATION CONDUCTED ** ONE-POINT OR FOUR POINT CONDUCTED

MK-FER COMPANY

ORIGINAL
CONTRACT # 3050
GREEN RIVER, UTAH

JOB: ~~950~~ Green River

DATE: ~~3-30-89~~

REQUIREMENT BY: 4 3/31/89
QA ENTRY NO. 631

TEST SPECIFICATIONS: 02200 Rev 2 -95% of A D698
02200 Rev C. Opt. Moisture to -4% of opt. Moisture

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	θ	% OF MAX. DRY DENSITY	PASS/ FAIL
SFA-N-016	N59635 E58964 Elev. 4099	SFA-4-005	Clayey Silt	125.4	10.8	132.5	122.2	8.4	16.45	97.4	PASS
SFA-N-017	N59633 E59097 Elev. 4099	SFA-4-005	Clayey Silt			130.3	119.9	8.7	16.78	95.6	PASS
* ** SFA-N-018	N59500 E59111 Elev. 4099	SFA-4-005				131.9	121.5	8.6	16.75	96.9	PASS
SFA-N-019	N59475 E59212 Elev. 4099	SFA-4-005				131.7	120.5	9.3	17.96	96.1	PASS
SFA-N-020	N59585 E59135 Elev. 4099	SFA-4-005	Clayey Silt	125.4	10.8	131.1	119.4	9.8	18.75	95.2	PASS
SFA-N-021	N59355 E59050 Elev. 4101	SFA-4-005	Clayey Silt	125.4	10.8	131.2	120.7	8.7	16.83	96.3	PASS
SFA-N-022	N59360 E59125 Elev. 4101	SFA-4-005	Clayey Silt	125.4	10.8	130.5	119.7	9.0	17.26	95.5	PASS
** SFA-N-023	N59380 E58975 Elev. 4101	SFA-4-003	Silty sand	123.9	10.0	132.3	120.8	9.5	18.39	97.5	PASS
SFA-N-024	N59450 E58960 Elev. 4101	SFA-4-003	Silty Sand			132.9	120.9	9.9	19.18	97.6	PASS
* ~~SFA-N-025~~	N59490 E58810 ~~Elev. 4101~~	SFA ~~4-003~~	Silty ~~Sand~~	123.9	10.0	134.4	121.4	10.7	20.62	98.0	FAIL
(TROX	LER 3440	CS-	50 50	5337	AM-47	11737)				UMTRA-GRN 5057-05 ccd. rec. 7/31/89	MJG 7/31/89
				TABLE 3	(cont)	{adapted from ref 1}					

OPERATOR: Steve Dike

REVIEWED BY: Steven Mat

COMMENTS: * Sandcone correlation conducted ** One-point or four-point conducted

A-11

MK-FERGUSON COMPANY

ORIGINAL
CONTRACT # 3056
GREEN RIVER, UTAH

JOB: ~~5050~~ Green River

DATE: ~~3-31-89~~

REQUIREMENTS 4/3/89

QA ENTRY NO. 643

TEST SPECIFICATIONS: 02200 Rel 2 - 95% of A D698
02200 Rel C. opt. Moisture to -4% of opt. Moisture

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	Ø	% OF MAX. DRY DENSITY	PASS/ FAIL
SFA-N-C25-R1	N59490 E58810 Elev. 4101	SFA-4-003	Silty Sand	123.9	10.0	133.4	122.0	9.4	18.38	98.5	PASS
SFA-N-026	N59637 E58963 Elev. 4100	SFA-4-003	Silty Sand	123.9	10.0	125.0	117.9	6.1	11.53	95.2	PASS
SFA-N-027	N59568 E59062 Elev. 4100	SFA-4-003	Silty Sand	123.9	10.0	133.4	122.6	8.8	17.29	99.0	SD 4-89 PASS
SFA-N-028	N59460 E59160 Elev. 4100	SFA-4-003	Silty Sand	123.9	10.0	131.6	122.1	7.7	15.07	98.5	PASS
* SFA-N-029	N59470 E59258 Elev. 4100	SFA-4-003	Silty Sand	123.9	10.0	131.2	120.3	9.0	17.35	97.1	PASS

(TROXLER 3440 CS-505337 AM-4711737)

TABLE 3 (cont)

(adapted from ref 1)

MJG 7/27/89
UMTRA-GRN 5057-05

Cea. WOC 7/28/89

OPERATOR: Steve Dike

REVIEWED BY: Steven Mast

COMMENTS: * A sandcone correlation and a one-point conducted (See SFA-C-026)

MK-FERGU[illegible] COMPANY

TY REQUIREMENTS
OM 4/3/89
QA ENTRY NO. 641

ORIGINAL
~~CONTRACT # 3050~~
GREEN RIVER, UTAH

JOB: ~~050~~ Green River DATE: ~~3/31/89~~

TEST SPECIFICATIONS: 02200 Rel 2 -95% OF A D698
02200 Rel C. OPT. MOISTURE TO -4% OF OPT. MOISTURE

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE		% OF MAX. DRY DENSITY	PASS/ FAIL
SFA-N-030	N 59,560 E 59,180 @ ELEV 4100	SFA-4 -002	SILTY SAND	123.9	10.0	129.7	119.5	8.5	16.28	96.4	PASS
SFA-N-031	N 59,696 E 59,065 @ ELEV 4100	SFA-4 -003	SILTY SAND	123.9	10.0	128.1	118.2	8.4	15.91	95.4	PASS
SFA-N-032	N 59,444 E 58,830 @ ELEV 4102	SFA-4 -003	SILTY SAND	123.9	10.0	132.4	121.7	8.8	17.16	98.2	PASS
SFA-N-033	N 59,365 E 58,918 @ ELEV 4102	SFA-4 -003	SILTY SAND	123.9	10.0	130.8	120.7	8.4	16.25	97.4	PASS
* SFA-N-034	N 59,270 E 59,020 @ ELEV 4102	SFA-4 -005	CLAYEY SILT	125.4	10.8	129.4	120.4	7.5	14.47	96.0	PASS
SFA-N-035	N 59,505 E 58,922 @ ELEV 4102	SFA-4 -005	CLAYEY SILT	125.4	10.8	132.1	122.3	8.0	15.68	97.5	PASS
SFA-N-036	N 59,394 E 59,038 @ ELEV 4102	SFA-4 -005	CLAYEY SILT	125.4	10.8	133.2	122.3	8.9	17.44	97.5	PASS

SFA-C-001
SFA-C-002

(TROXLER 3440 CS-50 5337 AM 471178)

CED. WOC 7/28/89

7/27/89
UMTRA-GRN
5057-05

MJG

TABLE 3 (cont)

(adapted from ref 1)

OPERATOR: & STEVE OAKE REVIEWED BY:

COMMENTS: * 1 SAND CONE VERIFICATION AND A ONE POINT CONDUCTED (SEE SFA-C-001)

* - 3

MK-FER COMPANY

ORIGINAL

JOB: ~~3050~~ -GREEN RIVER DATE: ~~4/3/89~~ ~~CONTRACT # 3050~~

GREEN RIVER, UTAH

REVIEWED FOR REQUIREMENTS BY SDM 4/4/89

QA ENTRY NO. 662

TEST SPECIFICATIONS: 95% of A Dens 02200 Rev 2
02200 Rev C Opt. Moisture to -4% of Optimum Moisture

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	% OF MAX. DRY DENSITY	PASS/FAIL
~~SFA-N-037~~	N59635 E58990 Elev. 4101	SFA- ~~4-006~~	Silty Sand	** ~~118.2~~	~~12.3~~	~~116.0~~	~~109.5~~	~~5.9~~ 10.35	~~92.6~~	FAIL
SFA-N-038	N59640 E59100 Elev. 4101			~~118.2~~	~~12.3~~	~~115.1~~	~~109.6~~	~~5.0~~	~~92.7~~	~~FAIL~~
* SFA-N-039	N59515 E59100 Elev. 4104 SD 4/3/89			118.2	12.3	132.2	118.0	12.0 22.69	99.8	PASS
SFA-N-037-R1	N59635 E58990 Elev. 4101			~~118.2~~	~~12.3~~	~~122.9~~	109.4 ~~113.2~~	~~8.6~~	92.6 ~~95.8~~	FAIL ~~PASS~~
SFA-N-038R1	N59640 E59100 Elev. 4101			~~118.2~~	~~12.3~~	~~126.7~~	112.2 ~~116.1~~	~~9.1~~	94.9 ~~98.2~~	FAIL ~~PASS~~
SFA-N-040	N59545 E59215 Elev. 4104 SD 4/3/89			~~118.2~~	~~12.3~~	~~122.8~~	109.2 ~~113.0~~	~~8.7~~	92.4 ~~95.6~~	FAIL ~~PASS~~
SFA-N-041	N59255 E59050 Elev. 4103	SFA- 4-006	Silty Sand	~~118.2~~	~~12.3~~	~~124.5~~	110.2 ~~114.0~~	~~9.2~~	93.2 ~~96.4~~	FAIL ~~PASS~~
* SFA-N-042	N59320 E58965 Elev. 4103	SFA- 4-007	Silty Sand	** ~~117.2~~	~~11.7~~	~~126.7~~	110.1 ~~113.9~~	~~11.2~~	93.9 ~~97.2~~	FAIL ~~PASS~~

SEE SAND CONE CORRELATION SFA-C-009. TEST NUMBERS SFA-N-037-R1, SFA-N-038-R1, SFA-N-040, SFA-N041 AND SFA-N-042 WERE RETESTED ON 4/4/89. SEE DENSITY EVALUATION FOR SAND CONE CORRELATION SFA-C-009. (SEE SFA-DE-009)

JG 7/27/89

TABLE 3 (cont) {adapted from ref 1}

UMTRA-GRN 5057-05 ccj. Noc 7/18/89

OPERATOR: Steve Dike REVIEWED BY: Steven Mack

COMMENTS: * A sand cone correlation conducted ** A one point or four point conducted

MK-FERGUSON COMPANY

JOB: ~~3050~~ GREEN RIVER

DATE. 4/2/89

ORIGINAL

~~CONTRACT # 3050~~

GREEN RIVER, UTAH

QA APPROVED FOR
Q REQUIREMENTS
BY 4/4/89
QA ENTRY NO. 665

TEST SPECIFICATIONS: 02200 REV 2 - 95% OF D 0698
02200 REV C OPT. MOISTURE TO -4% OF OPT. MOISTURE

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	Ø	% OF MAX. DRY DENSITY	PASS/ FAIL
SFA-N-043	N59460 E59040 Elev. 4103	SFA-4 -007	SILTY SAND	117.2	11.7	122.3	112.4	8.8	15.85	95.9	PASS
SFA-N-044	N59,615 E58,880 @ ELEV 4103	SFA-4 -007	SILTY SAND	117.2	11.7	124.0	114.1	8.7	15.91	97.4	PASS
SFA-N-045	N59,430 E58,930 @ ELEV 4103	SFA-4 -007	SILTY SAND	117.2	11.7	123.5	112.8	9.5	17.17	96.2	PASS
SFA-N-046	N59,620 E58,965 @ ELEV 4102	SFA-4 -007	SILTY SAND	117.2	11.7	125.1	115.0 SD 1/89	8.7	16.05	SD 1/89 98.2	PASS
* SFA-N-047	N59,440 E59,195 @ ELEV 4102	SFA-4 -007	SILTY SAND	117.2	11.7	126.1	SD 1/89 113.7	10.9	19.86	SD 1/89 97.0 ~~96.9~~	PASS

(TROXLER 3440 AM-4711737 CS-50 5337)

TABLE 3 (cont)

(adapted from ref 1)

MJG 7/27/89

UMTRA-GRN
5057-05
CEO. NOC 7/28/89

OPERATOR: Steve Dike

REVIEWED BY:

COMMENTS: * A SAND CONE CORRELATION WAS CALCULATED.

ORIGINAL

JOB: ~~50~~ Green River DATE. ~~1-4-89~~ ~~CONTRACT # 3050~~

GREEN RIVER, UTAH

QU REQUIREMENTS BY 4/5/89
QA ENTRY NO. 624

TEST SPECIFICATIONS: 02200 Rev 2 - 95% of A D698
02200 Rev C. OPT. MOISTURE TO -4% OF OPT. MOISTURE

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	∅	% OF MAX. DRY DENSITY.	PASS/ FAIL
SFA-N-037-R2	N59635 E58990 Elev. 4101	SFA-4-006	Silty Sand	118.2	12.3	128.9	118.1	9.2	17.91	99.9	PASS
SFA-N-038-R2	N59640 E59100 Elev. 4101	)	)	)	)	124.8	113.0	10.4	18.83	95.6	PASS
SFA-N-040-R1	N59545 E59215 Elev. 4101	)	)	)	)	128.9	116.9	10.3	19.3	98.9	PASS
SFA-N-041-R1	N59255 E59050 Elev. 4103	)	)	)	)	123.9	113.6	9.1	16.57	96.1	PASS
*SFA-N-042-R1	N59320 E58965 Elev. 4103	SFA-4-006	Silty Sand	~~118.2~~ 117.2 sm 4/1/89	~~12.3~~ 11.7	125.9	114.34 SP 4-1-89	10.1	18.50	sm 4/4/89 97.6 ~~96.8~~	PASS
SFA-N-048	N59505 E59255 Elev. 4102	SFA-4-007	Silty Sand	117.2	11.7	124.9	115.2	8.4	15.51	98.3	PASS
SFA-N-049	N59565 E59060 Elev. 4102	)	)	)	)	126.8	116.3	9.0	16.77	99.2	PASS
SFA-N-050	N59590 E58980 Elev. 4103	)	)	)	)	127.8	116.9	9.3	17.42	99.7	PASS
SFA-N-051	N59430 E58860 Elev. 4104	SFA-4-007	Silty Sand	117.2	11.7	126.7	116.2	9.0	16.76	99.1	PASS
*SFA-N-052	N59535 E58930 Elev. 4104	SFA-4-002	Silty Sand	**119.2	10.8	130.1	119.9	8.5	16.33	100.6	PASS

** - MAX DEN SAME ORIGINAL CURVE FOR ALL RETESTS.

TABLE 3 (cont)

UMTRA-GRN
5057-05
80.40C 7/26/89

MJG
7/31/89

OPERATOR: Steve Dike

REVIEWED BY: Steve Mart

COMMENTS: * A sandcone correlation was conducted ** A one point or four point was conducted.

A-16

MK-FER COMPANY

ORIGINAL

JOB: ~~3050~~ Green River

DATE: ~~4-4-89~~ ~~CONTRACT # 3050~~

GREEN RIVER, UTAH

BY SDM 4/5/89

QA ENTRY NO. 625

TEST SPECIFICATIONS: 02200 BELT. - 95% OF A D698

02200 REV C. - OPT. MOISTURE TO -4% OF OPT. MOISTURE

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	Ø	% OF MAX. DRY DENSITY	PASS/ FAIL
STA-N-053	N59675 E59080 Elev. 4103	STA-4-002	Silty Sand	119.2	10.8	122.8	114.2	7.5	13.73	95.8	PASS
STA N-054	N59380 E59020 Elev. 4104	)	)	)	)	126.6	115.4	9.7	17.94	96.8	PASS
STA-N-055	N59350 E59140 Elev. 4104	)	)	)	)	126.8	115.9	9.4	17.46	97.2	PASS
STA-N-056	N59490 E59155 Elev. 4103	STA-4-002	Silty Sand	119.2	10.8	127.2	117.5	8.3	15.63	98.6	PASS

(TROXLER 3440 CS-50 5337 AM-471737)

UMTRA-GRN 5057-05

Ceg. Noc 7/27/89

MJG 7/27/89

TABLE 3 (cont)

(adapted from ref 1)

OPERATOR: Steve Dike

REVIEWED BY: Steve Mast

COMMENTS: [illegible]

MK-FER COMPANY

ORIGINAL

REVIEWED FOR REQUIREMENTS BY: [illegible] 4/6/89

QA ENTRY NO. 692

JOB: ~~3050~~ Green River

DATE: ~~4-5-89~~ CONTRACT # 3050

GREEN RIVER, UTAH

TEST SPECIFICATIONS: 02200 - F.6.2 95% OF A D698.
02200 - F.6.c. OPT. MOISTURE TO -4% OF OPT. MOISTURE

TEST NO.	LOCATION	CURVE ENTRY NO.	TYPE OF MATERIAL	MAX. DRY DENSITY	OPTIMUM MOISTURE	WET DENSITY	DRY DENSITY	PERCENT MOISTURE	Ø	% OF MAX. DRY DENSITY.	PASS/ FAIL
* SFA-N-057	N59570 E59175 Elev. 4103	SFA-4-002	Silty Sand	119.2	10.8	127.9	117.1	9.2	12.26	98.~~5~~ 7 SDM 4/5/89	PASS
SFA-N-058	N59500 E59280 Elev. 4104					124.5	116.~~8~~ 4 SP 4-5-89	7.0	13.06	97.7	PASS
SFA-N-059	N59460 E59115 Elev. 4104					126.0	115.9	8.7	16.16	97.2	PASS
SFA-N-060	N59610 E59115 Elev. 4104					123.5	114.5	7.9	14.5	96.~~0~~ 6 SDM 4/5/89	PASS
* SFA-N-061	N59680 E58980 Elev. 4104	SFA-4-002	Silty Sand	119.2	10.8	122.5	114.4	7.1	13.02	96.0	PASS

(TROXLER 3440 CS-50 5337 AM-471737)

TABLE 3 (cont)

(adapted from ref 1)

UMTRA-GRN 5057-05 Geo. Doc. 7/31/89

MJG 7/27/89

OPERATOR: Steve Dike

REVIEWED BY: Steve Martz

COMMENTS: * A sandcone correlation was conducted.

Project UMTRA-GRN
Feature Tailings, Offpile, Buffer Mat'ls
Item Inplace Parameter Characterization
Contract No. 5057-05
Designed MJG
Checked WOC
Sheet A19
File No.
Date 26 July 89
Date 7/28/89

INPLACE BUFFER (summary)

77 data pts (see sheets A-9 through A-18)

	γ_d (pcf)	W (%)	θ (decimal)
$\bar{x}$	119.2	8.3	15.8
σ	3.18	1.43	2.64
$J = \sigma/x$	0.027	0.173	0.167

TABLE 3 (cont)

Procedure (cont)

4. Calculate θ for each (w, γ_d) data pair for each material type using the following formula:

$$\theta = w \frac{\gamma_d}{\gamma_w}$$

where $\gamma_w = 62.4$ pcf.

5. The mean value (and the standard deviation) of θ for each of the materials is calculated from the individual θ's in the data base (see step 4, above).

RESULTS

Mean values of w, γ_d and θ for the tailings, offpile and buffer materials are presented in Table 4.

Standard deviation, σ, and coefficient of variation, $V = \sigma/\text{mean}$ of θ for the above materials are presented in Table 5.

Mean values and standard deviations of the water content data sets used to estimate w and θ are presented in Table 6.

Sheet A-21
Project UMTRA-GRN
Contract No. 5057-05
File No.
Feature Tailings, Offpile, Buffer Materials
Designed MJK
Date 26 July 89
Item Inplace Parameter Characterization
Checked WOC
Date 7/28/89

MAT'L TYPE	$\bar{w}$ (%)	$\bar{\gamma}_d$ (pcf)	$\bar{\theta}$ (%)	
			Method ① 1	Method ② 2
Tailings	4.56	98.96	7.0	7.2
Offpile	5.52	115.19	10.8	10.2
Buffer	8.30	119.2	15.8	15.9

NOTES

① $\bar{\theta}$ estimated as mean value of individual θ values, i.e.,

$$\bar{\theta} = \frac{1}{n\gamma_w} \sum_{i=1}^{n} w_i \gamma_{d_i}$$

where: (w_i, γ_{d_i}) are (water content, dry density) measurements on one test specimen;
n = number of (w_i, γ_{d_i}) pairs

② $\bar{\theta}$ estimated from mean w and γ_d values, i.e.,

$$\bar{\theta} = \frac{1}{\gamma_w} (\bar{w}) (\bar{\gamma}_d)$$

where $\bar{w}$ and $\bar{\gamma}_d$ are the mean values of w and γ_d on test specimens for which both w and γ_d data are available

TABLE 4

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA-GRN
Feature Tailings, Offpile Buffer Mat'ls
Item Inplace Parameter Characterization

Contract No. 5057-05
Designed MJG
Checked WOC

Sheet A-22
File No.
Date 7/27/89
Date 7/28/89

MATL TYPE	θ (%) ①		
	Mean	σ	ν ②
Tailings	7.0	1.91	0.27
Offpile	10.8	1.70	0.16
Buffer	15.8	2.64	0.17

NOTES

① See data summaries, Tables 1-3.
② $\nu = \sigma / \text{mean}$

TABLE 5

Project UMTRA-GRN
Feature Tailings, Offpile, Buffer Mat'ls
Item Inplace Parameter Characterization
Contract No. 5057-05
Designed MJG
Checked WOC
Sheet A-23
File No.
Date 27 July 89
Date 7/21/89

COMPLETE DATA SET

MAT'L	# Data Points	Grav. Water Content	
		Mean	σ
Tailings	138	4.56	1.43
Offpile	188	5.52	1.13

TABLE 6a

SUBSET USED TO ESTIMATE θ

MAT'L	# Data Points	Grav. Water Content	
		Mean	σ
Tailings	35	4.41	1.19
Offpile	40	5.85	0.91

TABLE 6b

MORRISON-KNUDSEN ENGINEERS, INC.
A MORRISON KNUDSEN COMPANY

Project UMTRA-GRN
Feature Tailings, Offpile, Buffer Materials
Item Inplace Parameter Characterization

Contract No. 5357-05
Designed MJG
Checked WOC

Sheet A-24
File No.
Date 26 July 89
Date 7/28/89

DISCUSSION

1. The mean values of θ estimated herein are not significantly different than would be estimated using mean values of W and γ_d (see Table 4)

2. Although fewer γ_d tests were performed than W tests, based on a comparison of the mean value and standard deviation of all water contents measured and of the mean and standard deviation of water contents for which γ_d data are also available (see Table 6), it can be seen that compacted water content (and presumably γ_d) of the data set used to estimate θ is not significantly different than compacted water content (and γ_d) of the complete data set.

Project UMTRA-GRN
Feature Tailings, Offpile, Buffer Materials
Item Inplace Parameter Characterization

Contract No. 5057-05
Designed MJG
Checked WOC

Sheet A-25
File No.
Date 27 July 89
Date 7/28/89

SUPPLEMENT

PURPOSE

Determine the mean values of optimum water content (OMC) and maximum dry density ($\gamma_{d\max}$) based on ASTM D-698 of compaction tests used to control compaction of tailings, offpile and buffer materials.

Procedure

1. OMC and $\gamma_{d\max}$ test data from ref. 1 are reproduced in Tables 7-9.
2. Mean values of OMC and $\gamma_{d\max}$ are calculated using coventional formulae. Results are presented in Table 10.

Discussion

1. Mean OMC and $\gamma_{d\max}$ values of offpile materials are similar to those of the buffer materials. This corroborates that the buffer material is composed of the same materials as the offpile materials.

TAILINGS

CONTROL CURVE	D-698 *		
	OMC (%)	$\gamma_{d\max}$ (pcf)	
CM4 -001	18.2	97.6	
no - number	14.9	103.6	
CM4 - 002	16.5	99.5	
CM4 - 024	14.8	103.0	
CM-4-025	14.1	105.1	
CM-4-026	14.0	104.8	
CM-4-027	13.9	103.5	
CM-4-028	15.8	99.6	
CM-4-029	15.2	102.3	
CM-4-032	~~13.5~~	~~107.3~~	← 95% tailings (not included in avg)
CM-4-033	13.5	104.4	
CM-4-034	13.8	103.5	
CM-4-035	14.5	102.0	
CM-4-036	13.1	107.6	
CM-4-037	15.0	101.0	
CM-4-038	15.0	102.3	
CM-4-039	13.7	104.2	
CM -4 - 040	14.8	103.1	
CM -4 -041	13.8	101.2	
CM-4-042	~~13.3~~	~~110.~~	← (unknown amount of insitumat'l do not include in avg.)
CM-4-043	~~12.7~~	~~115.6~~	
CM-4-044	~~9.4~~	~~123.0~~	
$n =$	18	18	does not include tailings mixed w/ other mat'l.
$\bar{X} =$	14.70	102.7	
$\sigma_x =$	1.22	2.34	
$v = \sigma/\bar{X} =$	0.083	0.023	

* 4-pt compaction tests

TABLE 7

(adapted from ref 1)

MJG
5057-05
12 July 89
UMTRA-GRN
ckd. WOC 7/28/89

Offpile

Control Curve	D-698 *	
	OMC (%)	$\gamma_{d\,max}$ (pcf)
CM-4-004	10.8	124.4
CM-4-003	10.3	127.7
CM-4-005	9.7	126.8
CM-4-006	13.1	118.8
CM-4-007	10.9	125.7
CM-4-008	10.9	120.6
CM-4-009	10.9	124.7
CM-4-010	10.7	124.2
CM-4-011	10.2	125.2
CM-4-012	10.0	124.7
CM-4-013	10.0	125.6
CM-4-014	12.5	112.8
CM-4-015	15.4	105.8
CM-4-016	12.0	119.3
CM-4-017	11.7	117.7
CM-4-018	10.8	121.7
CM-4-019	13.2	111.2
CM-4-020	11.9	116.5
CM-4-021	7.9	130.9
CM-4-022	10.6	123.4
CM-4-023	12.3	114.8
CM-4-030	10.9	123.0
CM-4-031	12.2	116.1
n =	23	23
$\bar{x}$ =	11.26	120.94
σ_x =	1.50	6.00
$v = \sigma/\bar{x}$ =	0.133	0.050

* 4-pt compaction tests

TABLE 8

(adapted from ref 1)

Project UMTRA-GRN
Feature Tailings, Offpile, Buffer Materials
Item Inplace Parameter Characterization
Contract No. 5057-05
File No.
Designed MJG
Date 1/27/89
Checked
Date 2/28/89

TYPE A SELECT FILL
(BUFFER)

CONTROL CURVE	D-698*	
	γ_d max (pcf)	OMC (%)
SFA-N-001	124.9	8.7
SFA-N-010	127.8	10.1
SFA-N-013	125.4	10.8
SFA-N-023	123.9	10.0
SFA-N-037	118.2	12.3
SFA-N-043	117.2	11.7
SFA-N-052	119.2	10.8
Mean	122.4	10.6
Std. dev.	4.1	1.2

* Data taken from field density tests; compaction test data are not available in ref. 1.

TABLE 9

(adapted from ref 1)

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA-GRN
Feature Tailings, Offpile, Buffer Mat'ls
Item Inplace Parameter Characterization

Contract No. 505705
Designed MJG
Checked WOC

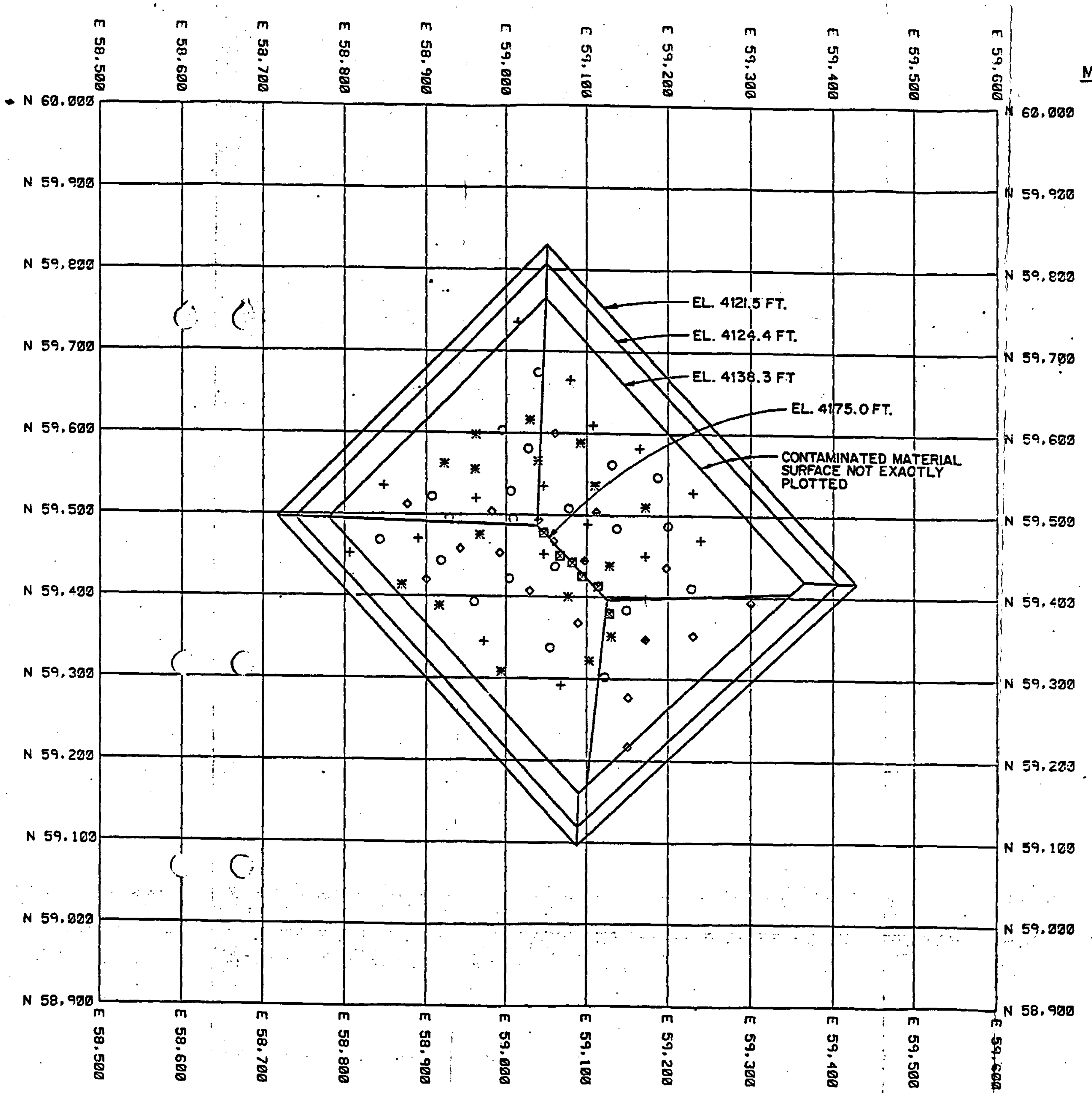
Sheet A-29
File No.
Date 27 July 89
Date 7/28/89

MATERIAL	MEAN D-698 Compaction Variables*	
	γ_d max (pcf)	OMC (%)
Tailings	102.7	14.7
Offpile	120.9	11.3
Buffer	122.4	10.6

* based on data in Tables 7-9.

TABLE 10

MOISTURE CONTENT/DENSITY TEST LOCATIONS



LEGEND:

TEST LOCATION ELEVATION RANGES (FT.)

4108 ≤ + ≤ 4119
4119 < ✳ ≤ 4130
4130 < ○ ≤ 4141
4141 < ◇ ≤ 4152
4152 < ◆ ≤ 4163
4163 < ⊠ ≤ 4174

FIGURE 1

100 0 100 200
SCALE FEET

MKE DOC. 5057-GRN-C-01-01761-00

Calculation Cover Sheet

Contract No. 5057-05 **Discipline** UMTRA/ES&I **Calc. No.** 10-536-10-0
No. of Sheets 11

Project

UMTRA-GRN

Feature Compaction of Contaminated Materials

Item Statistical Evaluation of degree of compaction

~~**Sources of Data**~~

Sources of Formulae & References

1. "Mechanics of Particulate Media", Milton E. Harr, published by McGraw Hill, 1977.
2. "Contaminated Material Moisture Content, Density and Compaction Data - Green River, Utah", prepared by MK-ES (in progress).

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

0	—	Martin Goodman	25 Oct 89	Rick Stauber	10-30-89	D.K. Chen	12-21-89
Rev. No.	**Revision**	**Calculation By**	**Date**	**Checked By**	**Date**	**Approved By**	**Date**

Form 42-110

Sheet 1/7
Project UMTRA-GRN
Contract No. 5057-05
File No.
Feature Compaction of Contaminated Materials
Designed MJG
Date 25 Oct 89
Item Statistical Evaluation
Checked RMS
Date 10/30/89

PURPOSE

Using constrution data, evaluate the likelihood that contaminated materials were compacted to less than 90% compaction.

APPROACH

In-place compacted density (and percentage compaction) are random variables. An upper bound to the probability that these random variables will be outside a specified range can be estimated using the Chebyshev Inequality(1) which states:

$$P(|x-\bar{x}| > n\sigma_x) \le 1/n^2 \qquad \text{(Ref 1, pg 121)}$$

in which:

x = a random variable
$\bar{x}$ = mean value of random variable
σ_x = standard deviation of the random variable
n = the number of σ-bounds of the random variable beyond the mean of the random variable

P = probability

$$0 \le P \le 1$$

The Chebyshev Inequality applies regardless of the probability density function of the random variable, however, if the probability density function is approximately symmetric and has a finite upper bound*, the probability that the value of a random variable being more than n-standard deviations beyond its mean reduces to:

$$P\left(|x-\bar{x}| > n\sigma_x\right) \leq \frac{4}{9n^2} \qquad \text{(ref 1, pg. 123)}$$

For symmetric distributions, the probability that the value of a random variable will exceed n-standard deviations beyond its mean value on one side of the mean can be taken to be one-half the probability the value of the random variable will be more than n-standard deviations beyond its mean on both sides, i.e.,

$$P\left[(x-\bar{x}) > n\sigma_x\right] \leq \frac{2}{9n^2} \qquad \text{for} \quad x \geq \bar{x}$$

$$P\left[(\bar{x}-x) > n\sigma_x\right] \leq \frac{2}{9n^2} \qquad \text{for} \quad x \leq \bar{x}$$

* Percentage Compaction is inherently has a finite upper bound determined from the zero-voids condition.

The symmetry assumption may be checked by calculating the skewness of the random variable data set. The coefficient of skewness is calculated as follows:

$$\beta_1 = \frac{(1/n)\sum_{1}^{n}(x_i-\bar{x})^3}{\sigma_x^3}$$

where β_1 = coefficient of skewness
n = number of random variable data points
x_i = i^{th} random variable observation
$\bar{x}$ = mean value of random variable
σ_x = standard deviation of random variable

Generally, probability density functions with $-0.5 < \beta_1 < 0.5$ may be considered to be symmetric, although if the distribution is skewed towards the bound whose exceedance probability is being evaluated, the resulting estimate of exceedance probability may be somewhat underconservative.

For the case of the % compaction values of the Green River disposal cell, the random variable is the %-compaction at a random location measured at regular volume intervals. Therefore, the Chebyshev Inequality may be used to estimate the upper bound on the probability that the %-compaction at any random location will be less than 90% compaction.

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Sheet 4/7
Project UMTRA-GRN
Contract No. 5057-05
File No.
Feature Compaction of Contaminated Materials
Designed MJG
Date 26 Oct 89
Item Statistical Evaluation
Checked RMS
Date 10/30/89

Since probability can not be less than zero, the actual probability that compaction at any random location will be less than 90% may be estimated as one-half the upper bound probability. This value is more reasonable for design purposes because the joint probability that many of the lifts will have densities less than 90% is considerably smaller than the probability that just one lift will have a density smaller than 90% compaction.

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Project UMTRA-GEN
Feature Compaction of Contaminated Materials
Item Statistical Evaluations
Contract No. 5057-05
Designed MJL
Checked RMS
Sheet 5/7
File No.
Date 26 Oct 89
Date 10/30/89

CALCULATIONS

- Tailings % Compaction

a) Demonstration of symmetry

calculate coefficient of skew $\beta_1 = \dfrac{(1/n)\sum_{1}^{n}(x_i-\bar{x})^3}{\sigma^3}$

$\beta_1 = -0.265^{*} > -0.5$ * (see appended data)

∴ distribution function of percent compaction is approximately symmetric.

b) Determination of n-σ bounds

for percent compaction:

mean = 95.65 %
σ = 2.16 %
} (see appended data)

for x = design compaction percentage, i.e., 90%

$n = (\bar{x} - x) / \sigma$ for $x < \bar{x}$

$= (95.65 - 90)/2.16$

$= 2.62$

c) Calculation of Probability of noncompliance.

$$P(x < 90\%) \leq \frac{2}{9n^2} = \frac{2}{9(2.62^2)} = \underline{0.033}$$

i.e, the theoretical upper bound probability that %- compaction will be less than 90% at any random location is about 3.3%.

MORRISON-KNUDSEN ENGINEERS, INC.
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Project UMTRA- GRN
Feature Compaction of Contaminated Materials
Item Statistical Evaluation

Contract No. 5057-05
Designed MJG
Checked RMS

Sheet 6/7
File No.
Date 26 Oct 89
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– Offpile Contaminated Materials % Compaction

a) demonstration of symmetry

$\beta_1 = -0.215^{*} > -0.5$ * see appended data

∴ distribution function of percentage compaction ~ symmetric.

b) n- σ bounds

for percent compaction %

mean = 94.67 %
σ = 2.71 %
} see appended data

$n = (\bar{x} - x)/\sigma$ for $x < \bar{x}$
$= (94.67 - 90)/2.71$
$= 1.72$

c) Calculation of Probability of Noncompliance

$$P(x < 90\%) \leq \frac{2}{9n^2} = \frac{2}{9(1.72^2)} = \underline{0.075}$$

i.e., the theoretical upper bound probability that % compaction is less than 90% at any random location is about 7.5%.

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Project UMTRA-GRN
Feature Compaction of Contaminated Materials
Item Statistical Evaluation
Contract No. 5057-05
Designed MJC
Checked RMS
Sheet 7/7
File No.
Date 26 Oct 89
Date 10/30/89

CONCLUSIONS

The theoretical upper bound probabilities of noncompliance for percent compaction of tailings and off-pile contaminated materials at any random location in the disposal cell are 3.3% and 7.5%, respectively.

The "actual" probabilities of noncompliance for percent compaction at a random location, which are estimated to be approximately one-half of the theoretical upper bound values, agree well with the 1 in 79 noncompliance rate achieved using the Method Specification in the Subcontract Documents.

Martin J Goodman
UMTRA-GRN
5057-05
31 Oct 89

A1/4

Checked 10/31/89

~~TABLE 3A~~

OFF-PILE CONTAMINATED MATERIAL **
(Sheet 1 of 2)

Sample No.*	Dry Density (pcf)	Percent Compaction	Moisture Content(%)	Percent Dryer than OMC
MKE-001	108.7	97.8	5.5	7.6
MKE-002	113.4	91.3	5.6	5.1
MKE-003	105.2	90.3	6.3	5.6
MKE-004	112.2	90.3	5.6	5.1
MKE-005	114.1	91.1	6.8	3.4
MKE-006	118.2	94.4	5.6	4.6
MKE-007	120.7	92.2	4.1	3.8
MKE-008	118.7	94.5	7.0	3.0
MKE-009	117.2	94.4	5.4	5.3
MKE-010-R1	118.1	95.1	5.1	5.6
MKE-011	117.2	96.3	7.5	3.3
MKE-012	115.0	94.5	5.7	5.1
MKE-013	116.8	96.0	6.3	4.5
MKE-014	115.3	94.7	4.4	6.4
MKE-015	119.5	96.8	6.0	4.6
MKE-016	119.0	96.4	5.0	5.6
MKE-017	115.6	93.7	6.6	4.0
MKE-018	111.2	96.9	7.0	5.3
MKE-019	117.0	94.8	6.8	3.8
MKE-020	118.1	95.7	6.0	4.7
MKE-021	111.7	90.5	6.6	4.0
MKE-022	119.3	96.1	7.6	3.1
MKE-023	114.2	91.9	5.8	4.9
MKE-024	117.8	96.8	4.8	6.0
MKE-025	121.3	99.7	6.4	4.4
MKE-026	114.5	98.3	5.8	6.1
MKE-027	114.6	98.4	5.7	6.2
MKE-028	119.7	96.2	4.8	6.0
MKE-029	113.1	91.1	5.3	5.9
MKE-030	113.0	97.0	5.3	6.6

*Note: 1 failed point not included.

** Data are extracted from ref. 2.

Martin J Goodman
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A2/4

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~~TABLE 3A~~

OFF-PILE CONTAMINATED MATERIAL **
(Sheet 2 of 2)

Sample No.*	Dry Density (pcf)	Percent Compaction	Moisture Content(%)	Percent Dryer Than OMC
MKE-031	105.2	90.3	6.3	5.6
MKE-032	114.9	98.6	4.7	7.2
MKE-033	114.0	91.6	7.0	3.8
MKE-034	115.1	92.5	7.7	3.1
MKE-035	119.4	97.1	5.7	5.2
MKE-036	119.2	96.9	4.1	6.8
MKE-037	105.5	90.9	5.4	7.1
MKE-077	108.7	96.4	4.9	7.6
MKE-078	115.1	92.7	6.1	4.6
MKE-079	120.0	96.6	5.7	5.0
MEAN	115.19 ✓	94.67 ✓	5.85 ✓	5.14 ✓
STANDARD DEVIATION	4.19 ✓	2.71 ✓	0.91 ✓	1.25 ✓
Coefficient of Variation	.0364 ✓	0.0286 ✓	0.1560 ✓	0.2435 ✓
Coefficient of Skewness	--	-0.215 ✓	--	--

*Note: 1 failed point not included.

** Data are extracted from reference 2.

Martin J. Goodman A3/4
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31 Oct 89

~~TABLE 3B~~

TAILINGS *
(Sheet 1 of 2)

Sample No.	Dry Density (pcf)	Percent Compaction	Moisture Content(%)	Percent Dryer Than OMC
MKE-038	104.2	93.7	5.9	7.4
MKE-039	104.9	94.3	3.3	9.9
MKE-040	106.9	90.0	5.5	7.7
MKE-041	102.3	98.0	2.9	10.6
MKE-042	99.4	95.2	4.4	9.1
MKE-043	100.0	95.8	4.7	8.8
MKE-044	97.1	95.2	3.7	10.8
MKE-045	96.2	95.2	3.9	11.1
MKE-046	97.8	96.8	2.8	12.2
MKE-047	98.8	96.6	3.3	11.7
MKE-048	102.0	99.7	3.0	12.2
MKE-049	99.6	97.4	5.3	9.9
MKE-050	101.2	97.1	3.9	10.4
MKE-051	97.6	93.5	4.1	9.4
MKE-052	98.8	94.6	3.4	10.1
MKE-053	95.7	91.7	5.1	8.3
MKE-054	96.3	93.0	6.3	7.5
MKE-055	99.2	95.8	3.3	10.5
MKE-056	99.1	95.7	3.3	10.5
MKE-057	97.9	96.9	6.1	8.9
MKE-058	97.0	96.0	3.2	11.8
MKE-059	96.8	95.8	4.0	11.0
MKE-060	98.1	95.2	3.7	11.1
MKE-061	101.9	98.8	5.8	8.9
MKE-062	103.1	100.0	5.4	9.4
MKE-063	98.7	97.7	1.9	13.1
MKE-064	98.1	97.1	6.7	8.9
MKE-065	97.5	96.5	5.3	9.7
MKE-066	98.4	91.4	4.1	9.0
MKE-067	101.0	93.9	5.3	7.8

* Data are extracted from reference 2.

Martin J. Goodman A4/4
UMTRA-GRN
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31 Oct 89

~~TABLE 3B~~ 2

TAILINGS *
(Sheet 2 of 2)

Sample No.	Dry Density (pcf)	Percent Compaction	Moisture Content(%)	Percent Dryer Than OMC
MKE-068	104.4	95.0	6.7	6.6
MKE-069	102.9	99.4	4.8	9.0
MKE-070	99.5	96.1	3.9	10.2
MKE-071	96.8	93.5	5.0	8.8
MKE-072	109.9	95.1	3.9	8.8
MKE-073	97.9	96.9	3.9	11.1
MKE-074	95.2	94.3	4.2	10.8
MKE-075	98.7	95.7	5.9	8.9
MKE-076	98.7	95.7	5.2	9.6
MEAN	99.73 ✓	95.65 ✓	4.44 ✓	9.78 ✓
STANDARD DEVIATION	3.21 ✓	2.16 ✓	1.18 ✓	1.46 ✓
COEFFICIENT OF VARIATION	0.0321 ✓	0.0226 ✓	0.2654 ✓	0.1494 ✓
Coefficient of Skewness	--	-0.265 ✓	--	--

* Data are extracted from reference 2.