Agua Fria River
SLA Calculations
(Quantities, Scour, Etc.)

Simons, Li and Assoc..

1984

Summary of Calculations

1) Quantity Estimate ISRB to Camelback Road With Siphon Alternative
2) Quantity Estimate Thomas Road to ISRB with Siphon Alternative
3) Quantity Estimate I-10 to Thomas Road with Siphon Alternative
4) Quantity Estimate Buckeye Rd. to I-10 with Siphon Alternative
5) Quantity Estimate ISRB to Camelback Road without Siphon Alternative
6) Quantity Estimate Thomas Road to ISRB without Siphon Alternative
7) Quantity Estimate I-10 to Thomas Road without Siphon Alternative
8) Quantity Estimate Buckeye Road to I-10 without Siphon Alternative
9) Local Scour around bridge piers for SPF
10) Local Scour around SPRR for 100 yr + SPF existing conditions
11) Local Scour around transmission towers SPF
12) Summary of Dynamic Equilibrium Slope Computations
13) Summary of Static Equilibrium Slope Computations
14) Summary of short-term + long-term bed response for reaches
15) Antidune heights near bridges
16) General Regional Scour at Contractions
17) RID flume survey of foundation supports
18) ROW upstream of ISRB
19) Levee slope stability Analysis
20) Siphon Computations.

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CLIENT FCD of MC | JOB NO. AZ-MC-05 | PAGE 1/3
PROJECT SPF Design | DATE CHECKED | DATE 2/1/84
DETAIL ISRB to Camelback Road | CHECKED BY | COMPUTED BY MJB

Quantity and Costs. with span

Property of
Flood Control District of MC Library
Please Return to
2801 W. Durango
Phoenix, AZ 85009

1) Channel Quantities

1:1 SS West Levee Fill	8,120 yd³
3:1 SS West Levee Fill	9050 yd³
Channel Excavation	477,850 yd³

2) Transverse Dike # 2

Riprap	20,780 yd³
Filter Fabric	23,800 yd²
Common Fill	33,250 yd³
Soil Cement	21,205 yd³
Common Fill	6,925 yd³

3) Transverse Dike # 1

Riprap	8170 yd³
Filter Fabric	9330 yd²
Common Fill	12,445 yd³
Soil Cement	8320 yd³
Common Fill	2590 yd³

4) West Bank Transverse Dike

Riprap	3170 yd³
Filter Fabric	3160 yd²
Common Fill	4650 yd³
Soil Cement	2820 yd³
Common Fill	3840 yd³

5) Spur Dike.

Riprap	4870 yd³
Filter Fabric	4870 yd²
Common Fill	8000 yd³
Soil Cement	4340 yd³
Common Fill	2240 yd³

6) Land Acquisition
157.5 acres — 157.5 acres

7) Floodwall on ISR.

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CLIENT FCD of MC
PROJECT SPF Design
DETAIL ISRB to Camelback
JOB NO. AZ-MC-05
DATE CHECKED
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PAGE 1/A
DATE 2/8/94
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Quantity and Costs.

8) Levee Bank Protection

Soil Cement	13650 yd^3
Riprap	18660 yd^3
Filter Fabric	5110 yd^2

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PROJECT SPF Design | DATE CHECKED | DATE 2/2/84
DETAIL ISRB to Camelback Road | CHECKED BY | COMPUTED BY MJB

Quantity and Cost Estimates

1) Channel Quantities

1:1ss Common Fill	Levee	8120 yd³ @ 1.25/yd³	$ 10,150.0
3:1ss Common Fill	Levee	16,050 yd³ @ $1.25/yd³	$ 20,065.0
Drainage Excavation		477,850 yd³ @ .90/yd³	$ 430,065.0

2) TRANVERSE DIKE # 2

Riprap	20,780 yd³	@ $22.00/yd³	$ 457,160
Filter Fabric	23,800 yd²	@ $ 1.50/yd²	35,700
Common Fill	33,250 yd³	@ $ 1.25/yd³	41,560
		subtotal	$ 534,420
Soil Cement	21,205 yd³	@ $22.50/yd³	$ 477,110
Common Fill	6,925 yd³	@ 1.25/yd³	8660
			$ 485,770

3) Transverse Dike #1

Riprap	8170 yd³	@ $22.00/yd³	$ 179,740
Filter Fabric	9330 yd²	@ $ 1.50/yd²	14,000
Common Fill	12,445 yd³	@ $ 1.25/yd³	15560
		subtotal	$ 209,295
Soil Cement	8320 yd³	@ $22.50/yd³	187,200
Common Fill	2590 yd³	@ $ 1.25/yd³	3,240
		subtotal	$ 190,440

4) West Bank Transverse Dike

Riprap	3170 yd³	@ $22.0/yd³	$ 69,740
Filter Fabric	3160 yd²	@ $1.50/yd²	4,740
Common Fill	4650 yd³	@ $1.25/yd³	5,810
		subtotal	$ 80,290
Soil Cement	2820 yd³	@ $22.50/yd³	$ 63450
Common Fill	3840 yd³	@ 1.25/yd³	$ 4800
		subtotal	$ 68,250

5) Spur Dike

Riprap	4870 yd³	@ $22.00/yd³	$ 107,140
Filter Fabric	4370 yd²	@ 1.50/yd²	7,305
Common Fill	8000 yd³	@ 1.25/yd³	$ 10,000
		subtotal	$ 124,445
Soil Cement	4340 yd³	@ $22.50/yd³	$97,650
Common Fill	2240 yd³	@ 1.25/yd³	2,800

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CLIENT: FCD of MC | JOB NO. AZ-MC-05 | PAGE 3/3
PROJECT: SPF Design | DATE CHECKED: | DATE 2/2/84
DETAIL: ISRB to Camelback Road | CHECKED BY: | COMPUTED BY MJB

Cost Estimates

6) Land Acquisition
157.5 acres @ $5000/acre $ 787,500

7) Flood Wall along ISR 155,360

8) Levee Protection

Soil Cement	13650 yd³ @ 22.50/yd³		$ 307,125
RiPrap	18,660 yd³ @ 22.00/yd³		$ 410,520
Filter Fabric	5,110 yd² @ 1.50/yd²		$ 7,665

Cost Soil Cement W/o Floodwall $ 1,747,610
10% contingencies + construction super 174,760

$ 1,922,370
land acquisition 787,500

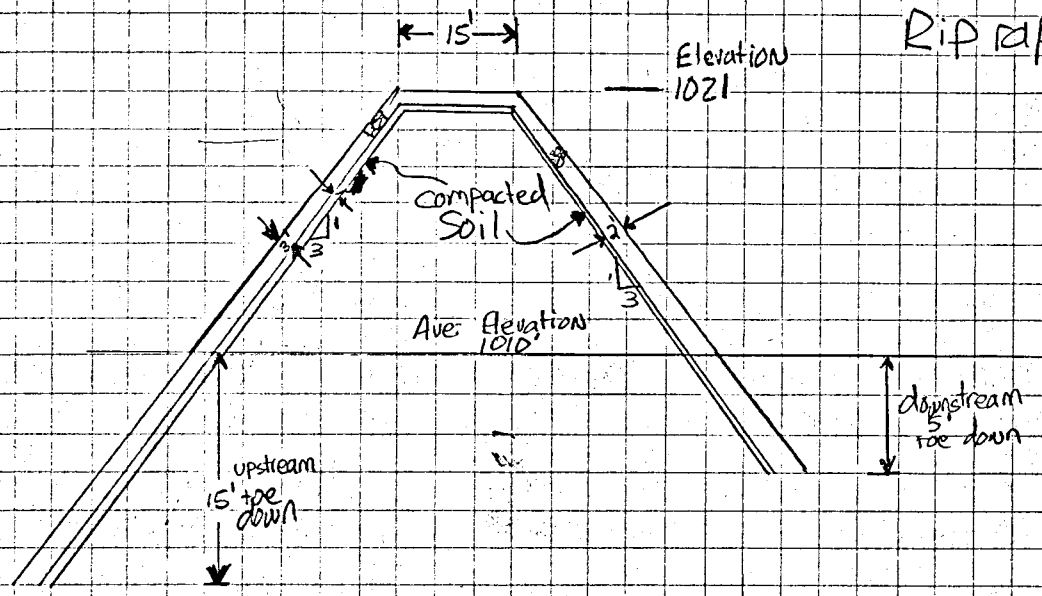
$ 2,709,870

TRANSVERSE Dike #2 Rip rap protection

W.S. Elevation 1017.66 for SPF

with 3' of freeboard elevation top of transverse dike #2 is 1021 ft.

Rip rap protection.



Area

Compacted Soil $= \left[\left(\frac{15+81}{2}\right)(11)\right] = 528\ ft^2$

Filter fabric $= 1700\left[(26')(3) + (16')(3)\right] = 214{,}200\ ft^2$

Riprap $= (2')(3)(16') + (3')(3)(26) = 330\ ft^2$

Length of Dike 1630 ft say 1700 ft with ends

Volume of Compacted fill $= (528\ ft^2)(1700\ ft) = 897{,}600\ ft^3$ or $33259\ yd^3$

filter fabric $= 214{,}200\ ft^2$ or $23{,}800\ yd^2$

Riprap $= (330\ ft^2)(1700\ ft) = 561{,}000\ ft^3$ or $20{,}780\ yd^3$

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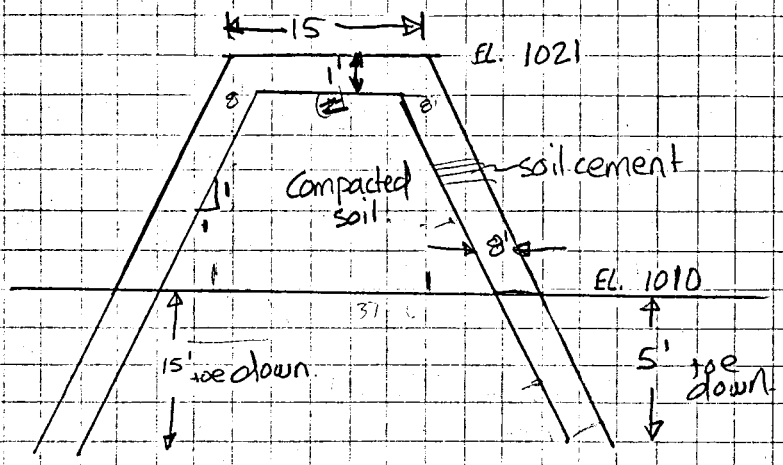
CLIENT: FCD of Maricopa County
PROJECT: SPF Design
DETAIL: ISRB to Camelback Rd.
JOB NO.: AZ-MC-05
DATE CHECKED:
CHECKED BY:
PAGE: 2/8
DATE: 2/1/84
COMPUTED BY: MJB

Transverse Dike #2 Soil Cement Protection



Volume Compacted Soil $\left(\frac{1' + 21'}{2}\right)(10')(1700') = 187{,}000\ ft^3$ or $6925\ yd^3$

height

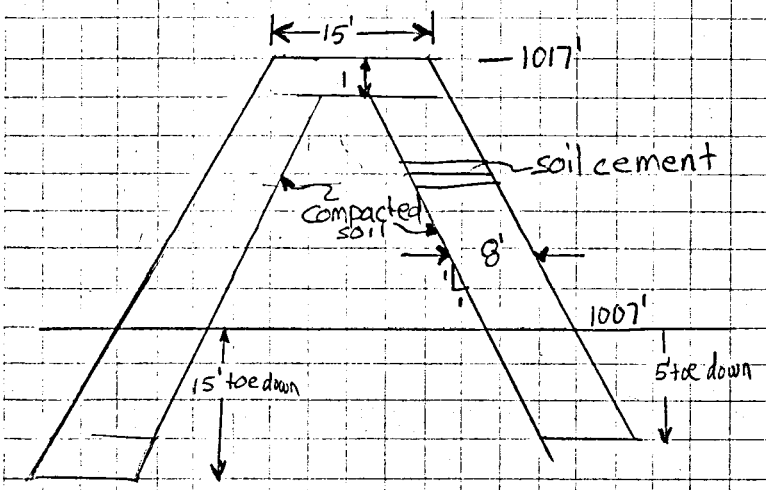
Volume Soil Cement $= (5.67')(22.6')(1700') + (5.67')(36.8')(1700')$

$= 572{,}560\ ft^3$ or $21{,}205\ yd^3$

TRANSVERSE Dike #1 Soil Cement Protection

SPF Water Surface Elevation 1013.5 ft.

with 3.5 ft of freeboard top elevation = 1017ft.



Areas

Compacted Soils = $\left(\frac{1' + 19'}{2}\right)(10') = 100 ft^2$ ✓

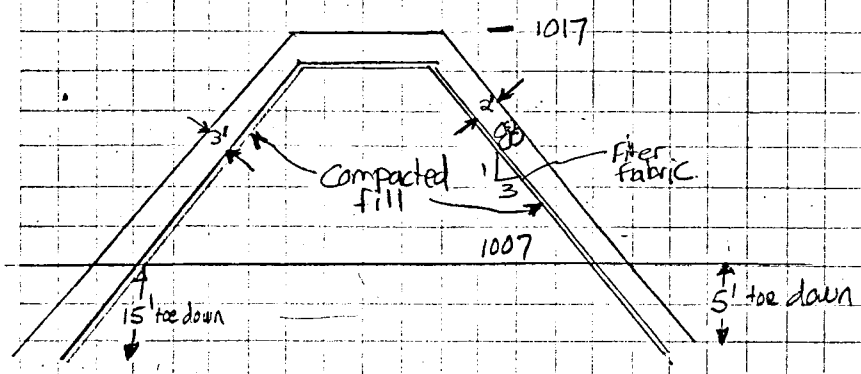
Soil Cement = $(5.67')(21.2') + (5.67')(35.4') = 320.9 ft^2$ ✓

Volume

Compacted Soil = $(700')(100 ft^2) = 70000 ft^3$ or $\underline{2590 yd^3}$

Soil Cement = $(321 ft^2)(700 ft) = 224,700 ft^3$ or $\underline{8320 yd^3}$

Transverse Dike #1 Riprap Protection



Area

Riprap = $(2')(15')(3) + (25')(3)(3') = 315 ft^2$

Filter Fabric = $700'[(15')3 + (25')(3)] = 84000 ft^2$

Compacted Soil = $\left(\frac{15' + 81'}{2}\right)(10') = 480 ft^2$

Volume

Riprap = $(315 ft^2)(700 ft) = 200,500 ft^3$ or $\underline{8,170 yd^3}$

Filter fabric = $84000 ft^2$ or $\underline{9330 yd^2}$

Compacted Soil = $(480 ft^2)(700') = 336,000 ft^3$ or $\underline{12,450 yd^3}$

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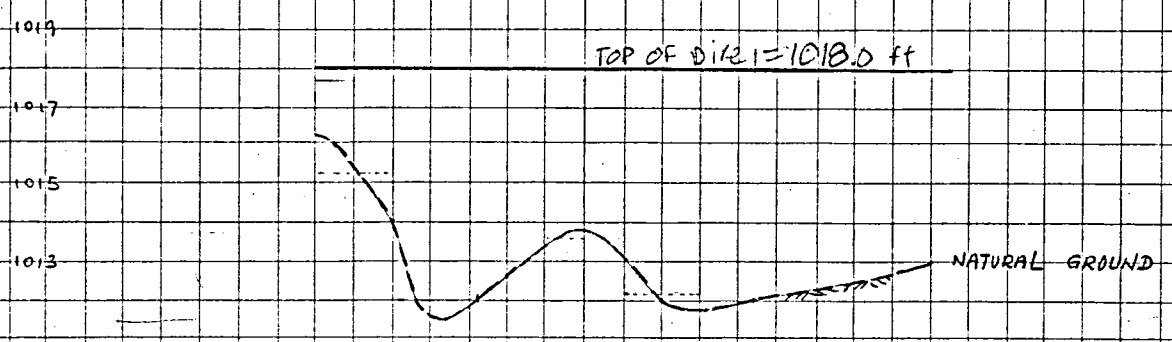
CLIENT: FCD of MC | JOB NO. AZ-MC-05 | PAGE 5/8
PROJECT: SPF Design | DATE CHECKED | DATE 6/13/83
DETAIL: QUANTITY for West Bank Dike upstream of ISRB | CHECKED BY | COMPUTED BY VHC

TRANSVERSE DIKE NEAR ISRB west bank.



DISTANCE (100FT)	8 7.5	7	6	5	4	3	2	1	0
AVG. HEIGHT (FT)	2.8	6.0	5.4	4.4	5.80	6.05	5.65	5.3	AVG. = 5.20'

ASSUMING TOP WIDTH OF 15' & S.S. = 3:1

FILL VOL. (CY)	121	733	624	460	696	743	669	607	= 4653 yd³

§ LOCAL SCOUR :

LIU : $S = 1.1\, d \left(\frac{a}{d}\right)^{0.4} F_r^{0.33}$

$$F_r = \frac{u}{\sqrt{g \cdot d}} = \frac{8.93}{\sqrt{32.2 \times 6.67}} = 0.609$$

$$S = 1.1 \times 6.67 \times (3)^{0.4} (0.609)^{0.33} = 9.7 \text{ ft}$$

RIP-RAP TYPE E FOR DIKE PROTECTION. (3.0' THICK)

§ RIP-RAP + TOE DOWN :

0 ~ 200' : TOE DOWN = 12'
200 ~ 750' : TOE DOWN = 5'

	7.5	7	6	5	4	3	2	1	0
AVG. TOTAL HEIGHT (FT)	7.8	11.0	10.4	9.4	10.8	11.05	17.65	17.3	
RIP-RAP (CY) FACE	47	200	180	147	193	202	188	176	1333 } 3167 yd³
TOE DOWN	83	167	167	167	167	283	400	400	1834
Filter Fabric Area. (yd²)	130	367	347	313	360	478	588	577	3160 yd²

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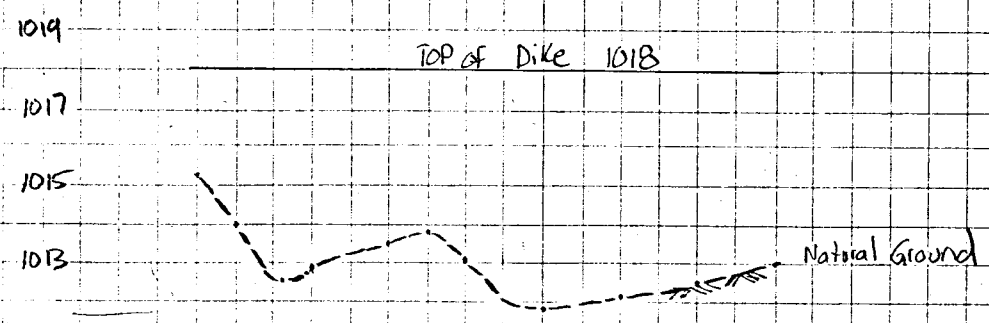
CLIENT FCD of MC JOB NO. AZ-MC-05 PAGE 6B
PROJECT SPF Design DATE CHECKED DATE 2/1/84
DETAIL West Bank Transverse Dike CHECKED BY COMPUTED BY MJB

West Bank Transverse Dike U/S of ISRB

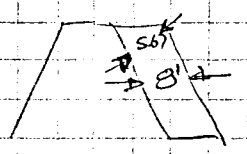


Distance (100 ft.)	7.5	7	6	5	4	3	2	1	0
Avg. Height	2.8	6.0	5.4	4.4	5.8	6.05	5.65	5.3	

Assuming Top Width = 15' S.S. = 1:1 front face 3:1 back face

Fill Volume	107	600	516	388	571	607	550	503	= 3842 yd³

Soil Cement and Toe Down.



	7.5	7	6	5	4	3	2	1	0
Avg. total height	7.8	11.0	10.4	9.4	10.8	11.05	17.65	17.3	

Soil Cement

Face	42	178	160	131	172	180	168	157	1188	2820 yd³
toe down	74	148	148	148	148	252	356	356	1630	

SPUR DIKE EAST OVERBANK

USE AT BRIDGE 1012.4

Upstream end of Spur Dike Elevation 1013.0

Height of Spur Dike 1016.0

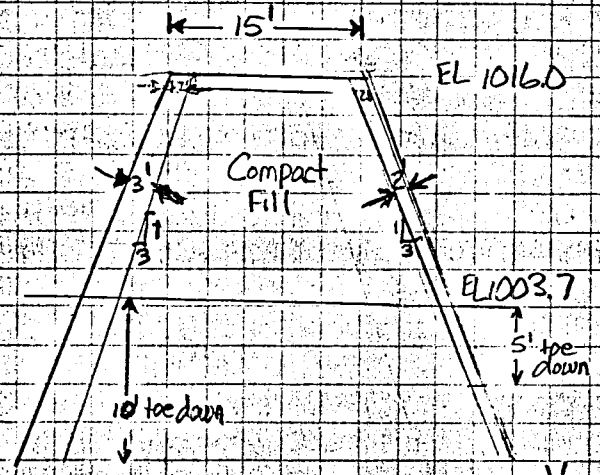
Average Height of Ground 1003.7 ft.

Length of Dike 350' say 400'

Nose has 15' toe down

shank has 10' toe down

Riprap with 3:1 side slopes.



Area Compact Fill

$A_{cf} = \left(\frac{7' + 80.8'}{2}\right)(12.3') = 540.0\ ft^2$

$V_{cf} = (540\ ft^2)(400') = 216{,}000\ ft^3$ or $8000\ yd^3$

Volume Rip Rap

$V_{RR} = (300')(22.3')(3)(3') + (100')(27.3')(3)(3') + (300')(17.3')(3')(3)$

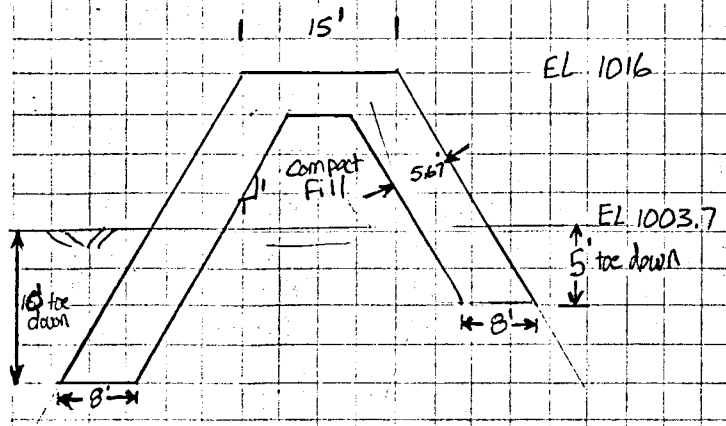
$V_{RR} = 131{,}490\ ft^3$ or $4870\ yd^3$

Area Filter fabric

$A_{FF} = (300')(22.3')(3) + (100')(27.3')(3) + (300')(17.3')(3)$

$A_{FF} = 43{,}830\ ft^2$ or $4870\ yd^2$

SPUR DIKE WITH soil Cement Protection



Volume of Compact Fill

$$V_{CF} = \left(\frac{1' + 23.6'}{2}\right)(12.3')(400')$$

$$V_{CF} = 60{,}520\ ft^3 \quad \text{or} \quad \underline{2240\ yd^3}\ \checkmark$$

Volume of Soil Cement

$$V_{SC} = (100')(38.6')(5.67') + (300')(31.5')(5.67') + (300')(24.5')(5.67$$

$$V_{SC} = 117{,}140\ ft^3 \quad \text{or} \quad \underline{\underline{4340\ yd^3}}\ \checkmark$$

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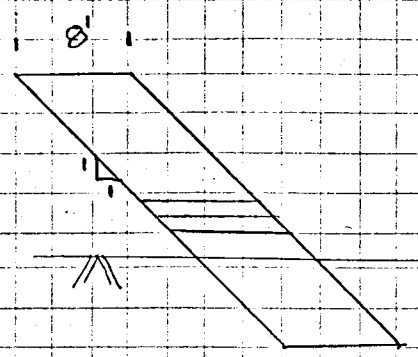
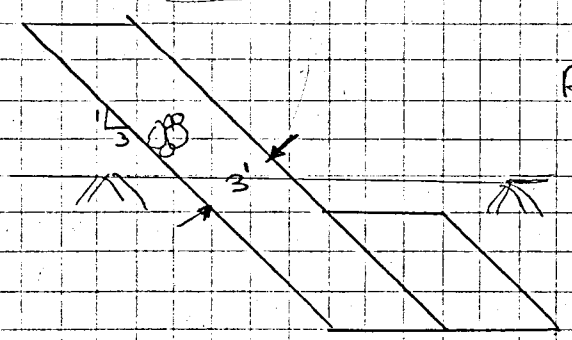
CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: 1
PROJECT: SPF Design | DATE CHECKED: | DATE: 2/8/84
DETAIL: ISPR to Confluence Bank Protection | CHECKED BY: | COMPUTED BY: MJB



Soil Cement West Bank

$V_{SC} = (32.5')(2000')(5.67')$

$V_{SC} = 368{,}550\ ft^3$ or $\underline{13{,}650\ yd^3}$



Rip Rap West Bank

$V_{RR} = \left(\frac{22.5' + 23.5'}{2}\right)(3)(3')(2000') +$

$(15')(3')(2000')$

$V_{RR} = 504{,}000\ ft^3$ or $\underline{18{,}660\ yd^3}$

Filter Fabric

$A_{FF} = 3(23')(2000') = 138{,}000\ ft^2$

$\underline{5110\ yd^2}$

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CLIENT FCD of MC
PROJECT SPF Design
DETAIL ISRB to Camelback West Levee 2:1 side slopes

JOB NO. AZ-MC-05
DATE CHECKED 2/2/84
CHECKED BY MJB

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DATE 2/2/84
COMPUTED BY MM

Section	Dist.	WEST LEVEE	VOLUME ~~yd~~ yd^3
	0		
427.35		0	
	900		4,617.
433+50		277	
	545		4,935
439+45		212	
	525		2926
444+75		89	
	730		3569
452+60		175	
			Total 16,047 yd^3

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CLIENT FCD of MC
PROJECT SPF Design
DETAIL Channelization UPSTREAM OF ISRB without siphon

JOB NO. AZ-MC-05 PAGE 2/9
DATE CHECKED 2/2/84 DATE 2/2/84
CHECKED BY MJB COMPUTED BY MM

Section	Dist.	Cut Area	Fill Area	Cut Vol Yd³	Fill Vol
	0				
427+35		7587	0		0
	900			237,783	
433+50		6680	0		0
	545			126,944	
439+45		5898	0		0
	525			113,127	
444+75		5738	0		0
				477,854	

Cut and fill Vols. Indian School Road north

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CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: UPSTREAM OF ISRB
JOB NO.: AZ-MC-05
DATE CHECKED:
CHECKED BY:
PAGE: 3/9
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COMPUTED BY: MM

West levee 1:1 side slopes

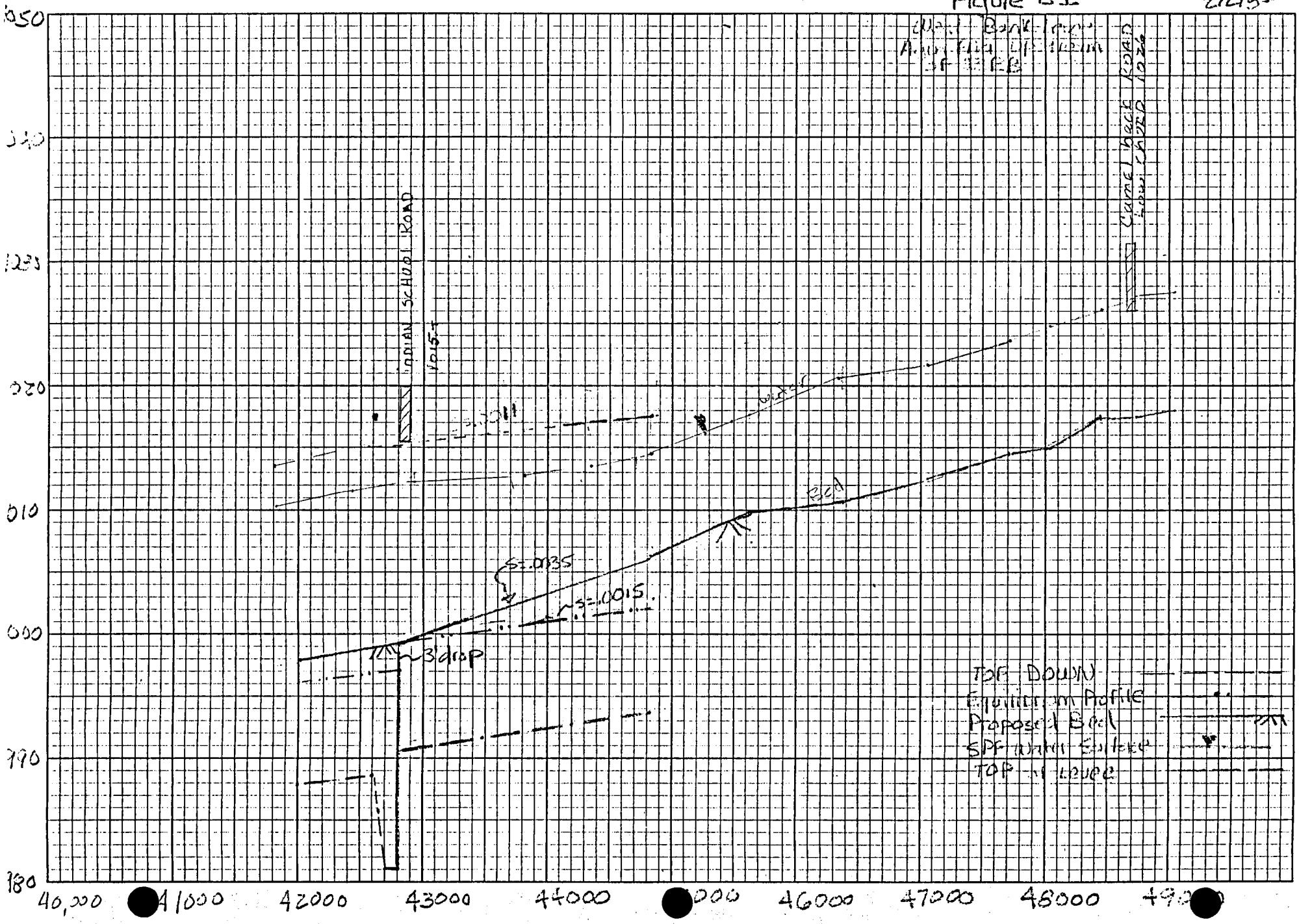
Section	Dist	AREA	Vol yd³
426+95		0	
	900		2700
433+50		162	
	545		3340
439+45		169	
	525		2391
444+75		77	
			8123

AREA Figured at 1-3 slope between Indian School Road and Sect. 444+75 west Levee only

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 0780

4/9
MM
2/22/34

Figure B1



K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
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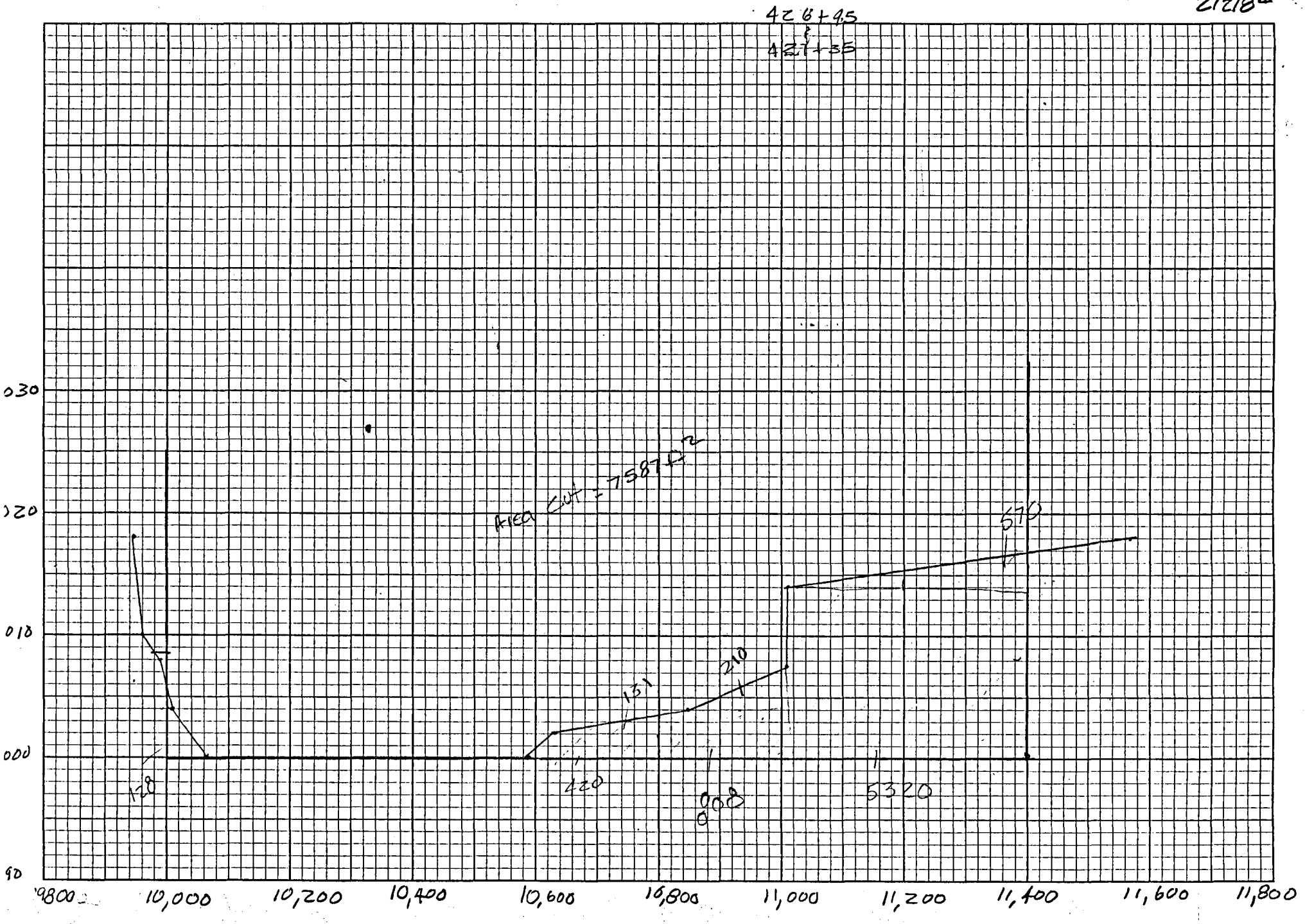
2/2/84



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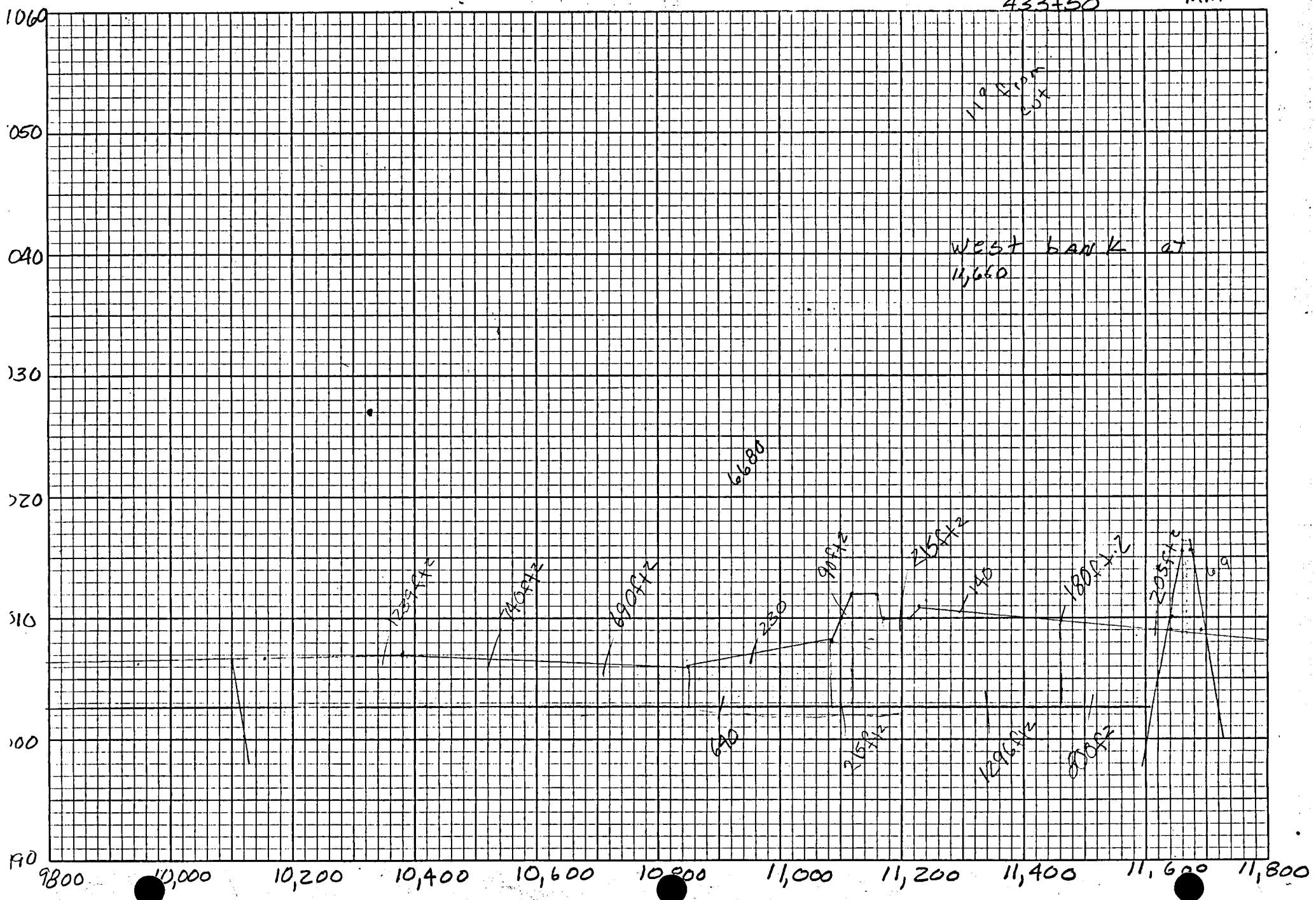
2/12/84
MM



K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
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MM
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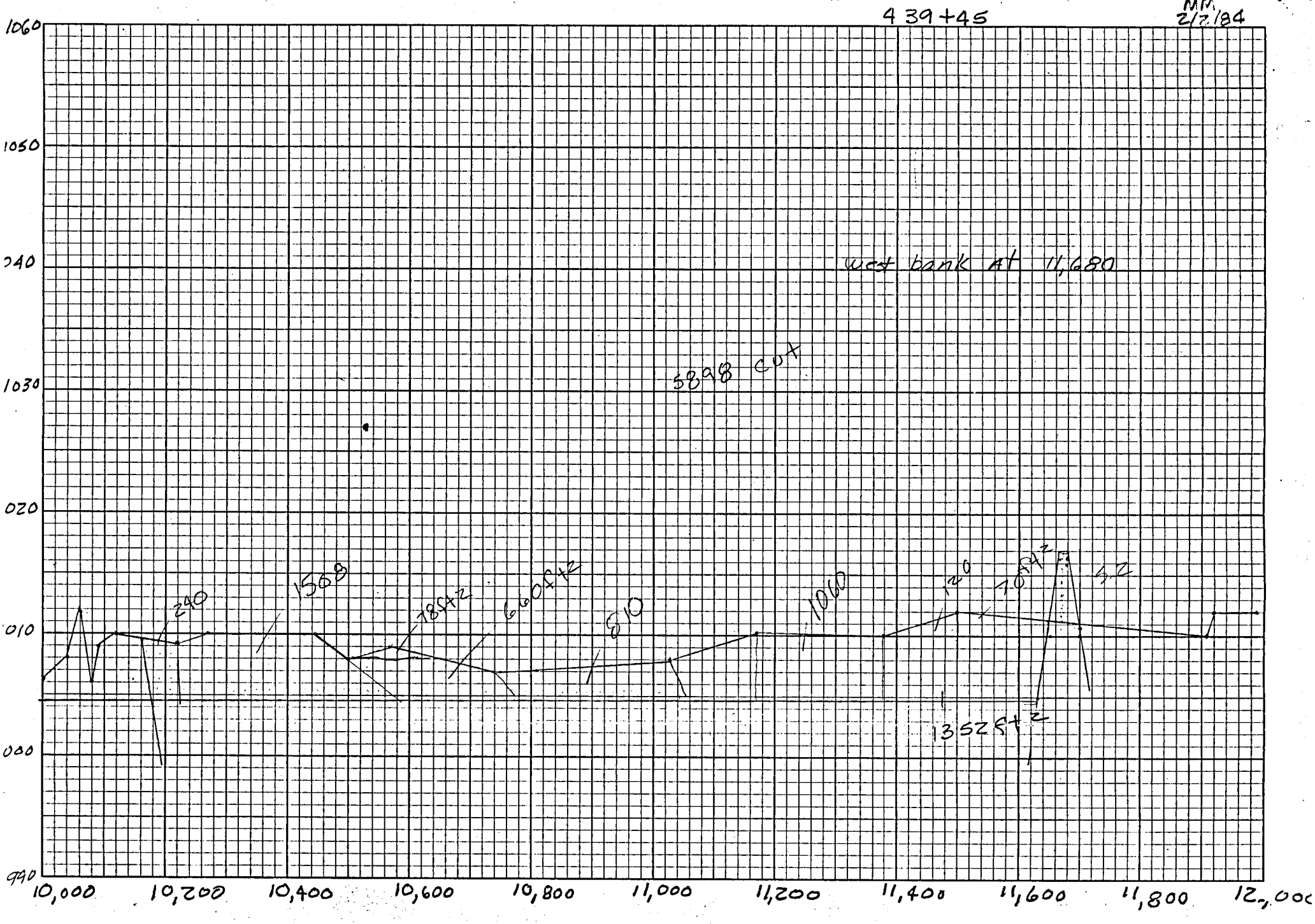
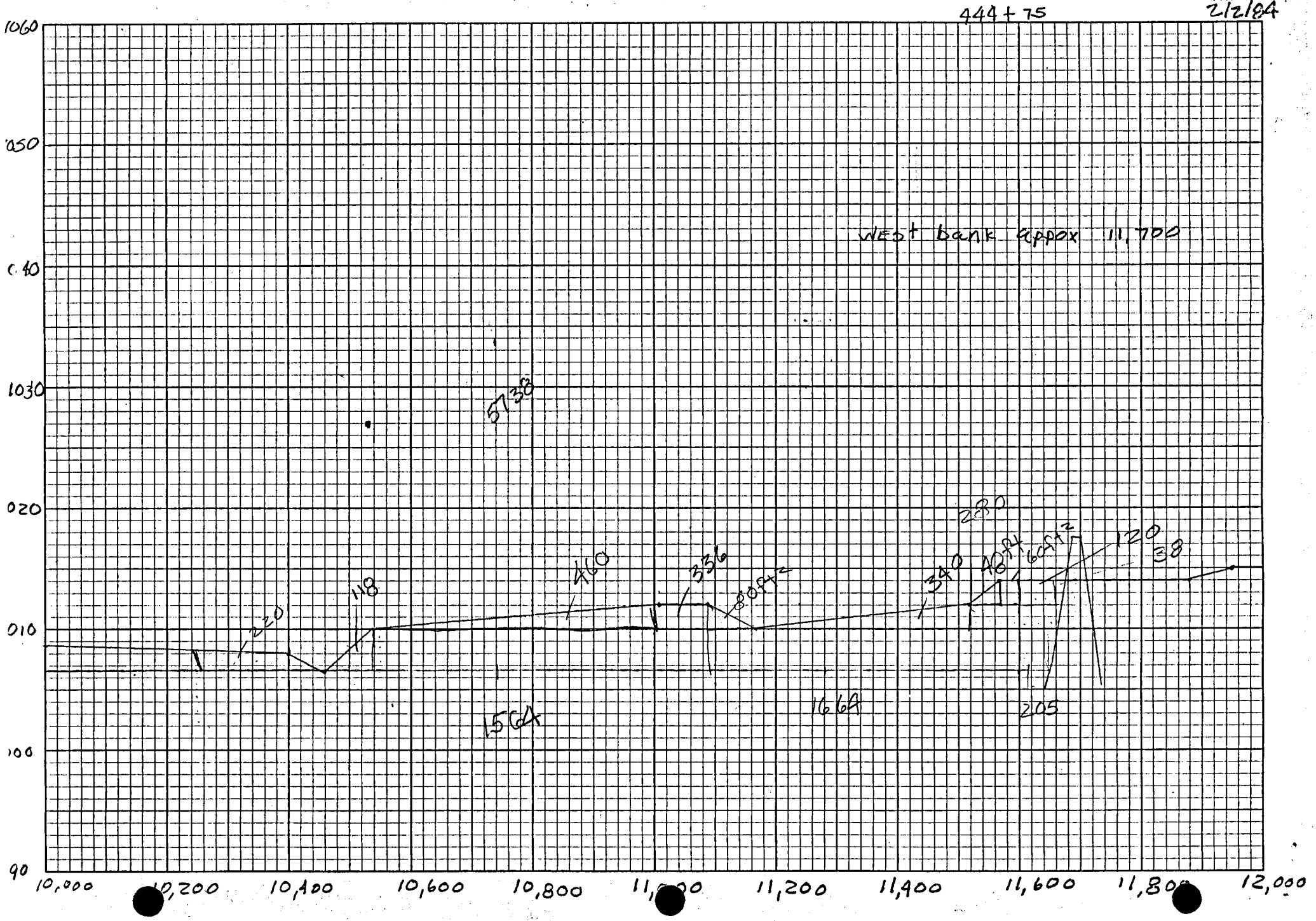


K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

8/9
MM
2/2/84

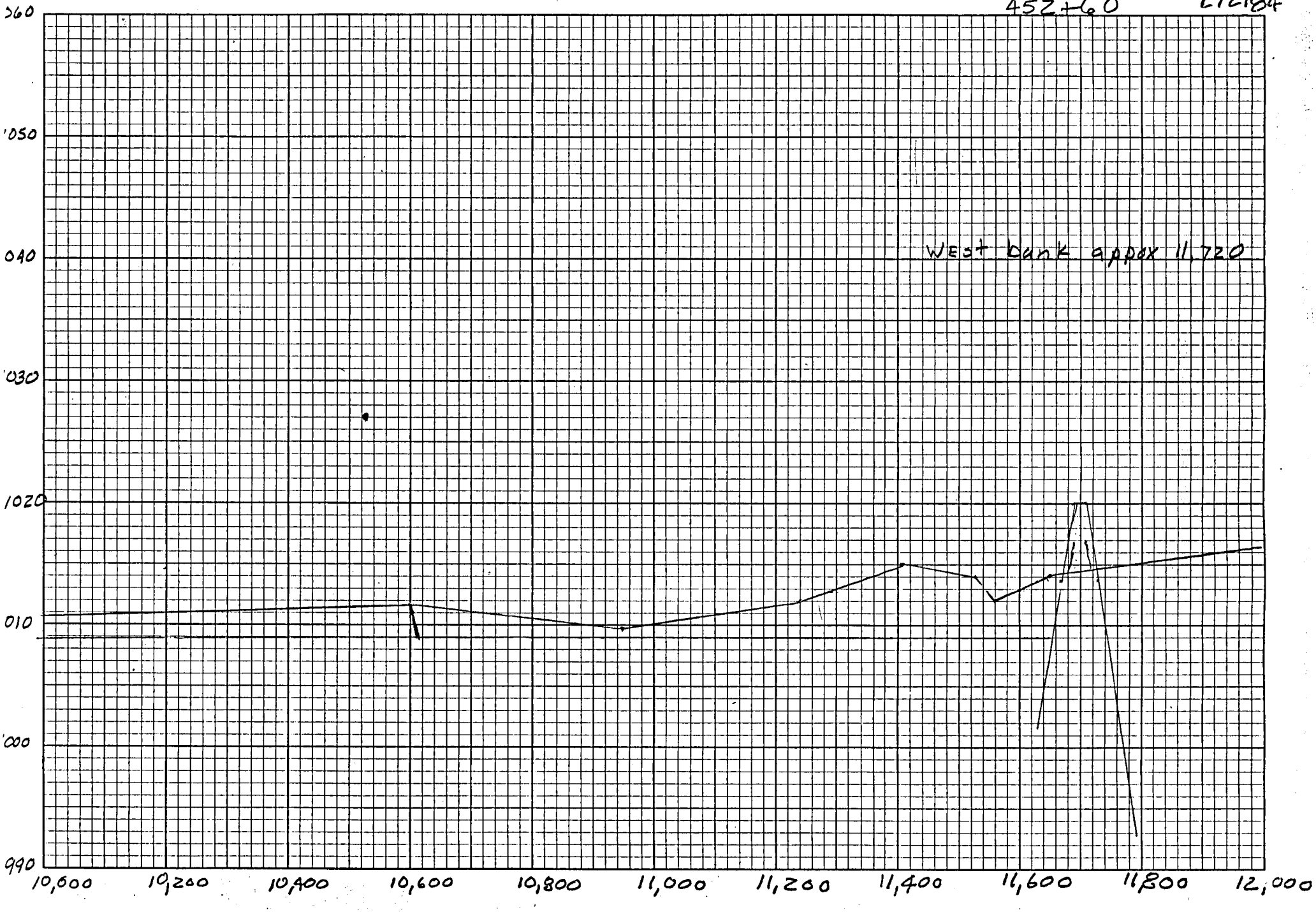


K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

a/a
MM
2/12/84

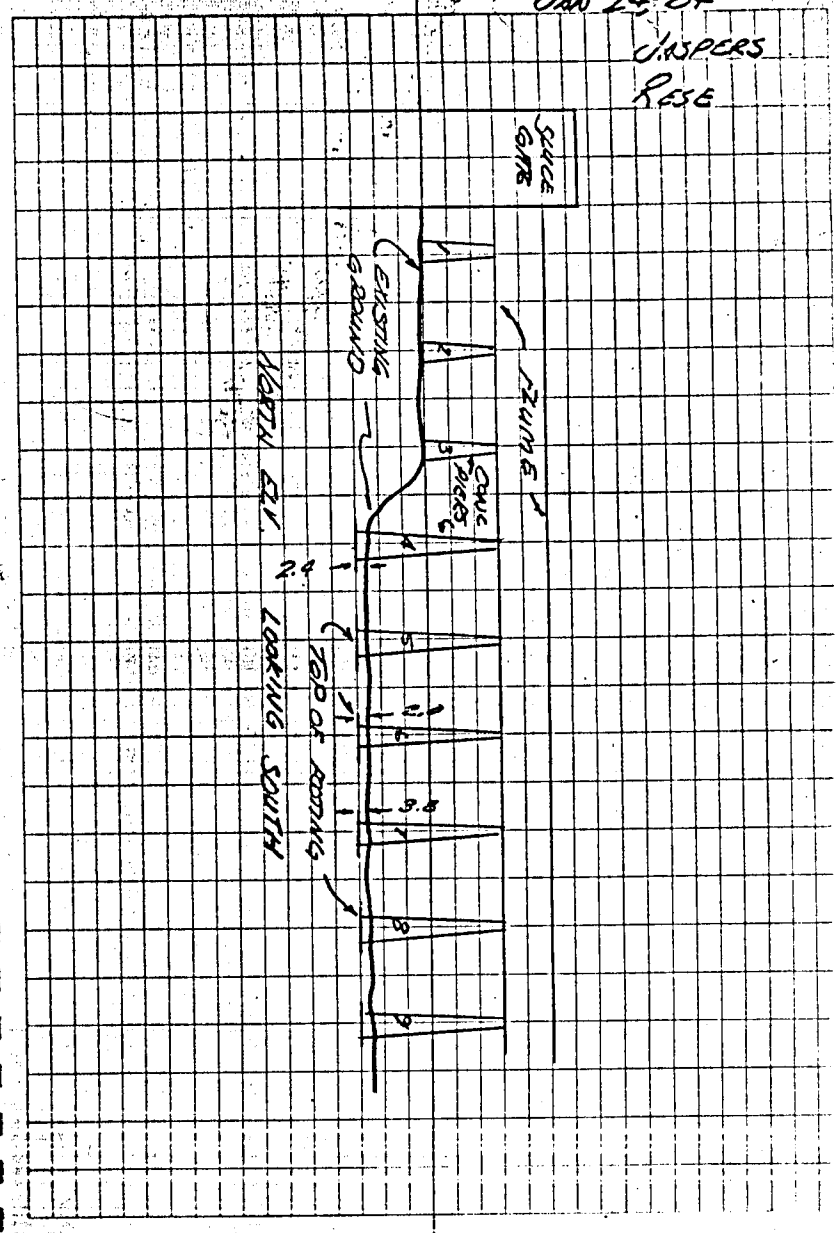
452+60



TOP OF FOOTING ELEVATIONS
FOR FLUME PIERS

Sta	BS	HI	F.S.	ELV.
BM H #6	23	ADJ ELV =		1005.37
	8.66	1014.03		
TP 1			8.33	1005.70
	2.56	1008.26		
TP 2			11.57	996.69
	3.30	999.90		
T.O.F. PIER #4			7.20	992.70
T.O.F. PIER #6			7.16	992.74
T.O.F. PIER #7			7.01	992.89
T.O.F. PIER #8			7.00	992.90
T.O.F. PIER #9			7.08	992.82
TP 3			3.94	996.05
	10.29	1006.34		
TP 4			2.44	1003.90
	9.96	1013.86		
BMH			8.48	1005.38

JAN 24 84
JASPERS
RESE



cc: RML

SAMER, LAHLUM AND ASSOCIATES, INC.

CONSULTING SERVICES
CIVIL & STRUCTURAL ENGINEERING SURVEYING

4250 NORTH NINETEENTH AVE.
PHOENIX, ARIZONA 85015
602-263-8551

JAMES M. SAMER, P.E.
ARNE LAHLUM, P.E.
RONALD G. OLMSTEAD, R.L.S.

February 2, 1984

Simons, Li and Associates, Inc.
3555 Stanford Road
P.O. Box 1816
Fort Collins, Colorado 80522

FEB 0 6 1984

Attn; Mike Ballantine

Dear Mr. Ballantine:

Enclosed is a copy of Filed Notes for elevations of top footing of Piers for the Roosevelt Irrigation District Flume across the Agua Fria River. The numbers for the Piers were written on by the Flood Control District Rep. at the site. The datum for this bench circuit is a brass cap 1/16 cor 476.67 East of Indian School Road Bridge Elevation=1019.63. If there are any questions please contact our office.

Sincerely,

Byron W. Jaspers

Byron W. Jaspers
Samer & Associates
4250 North 19th Avenue
Phoenix, Arizona 85015

Floodwall on east approach to ISRB

Length of headwall required 3410 ft
Distance determined from Road Profile + OBANK1.OUT HEC II Profile. see Page 2 Profile.

Use Jersey barrier for Floodwall max. height 3.5'

Precast median 3.5' height ≈ $23/LF MEANS cost guid
use $30/LF with preparation.

Cost of Floodwall ≈ $102,300.00
Distance along 113th Ave. = 200 ft cost $6000.0

Raise Road 113th Avenue. (profile shown on page 3)

Quantities		Unit Cost installed	Cost
Road Fill	1120 yd³	$ 5.15 yd³	$ 5750
Shoulder Fill	970 yd³	$ 5.15 yd³	$ 5000
base coarse	105 yd³	$ 3.50 / yd³	$ 360
gravel	105 yd³	$ 5.00 / yd³	$ 525
			$ 11,635

Riprap protection of embankment along ISRB

Max velocity ≈ 7 ft/sec
steepest side slope ≈ 2:1

use shield's criteria for sizing

$$d_s = \frac{1/8\,\rho f V^2}{.047(\gamma_s - \gamma)} = \frac{(1/8)(1.936)(.04)(7\,ft/sec)^2}{(.047)(165.4 - 62.4)}$$

.77 for banks $d_s = \frac{.098\ ft}{.77} = .127\ ft.$

1.5 FS = .2 ft
D50 = 4 inches
toe down riprap 1 ft. below embankment.

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.
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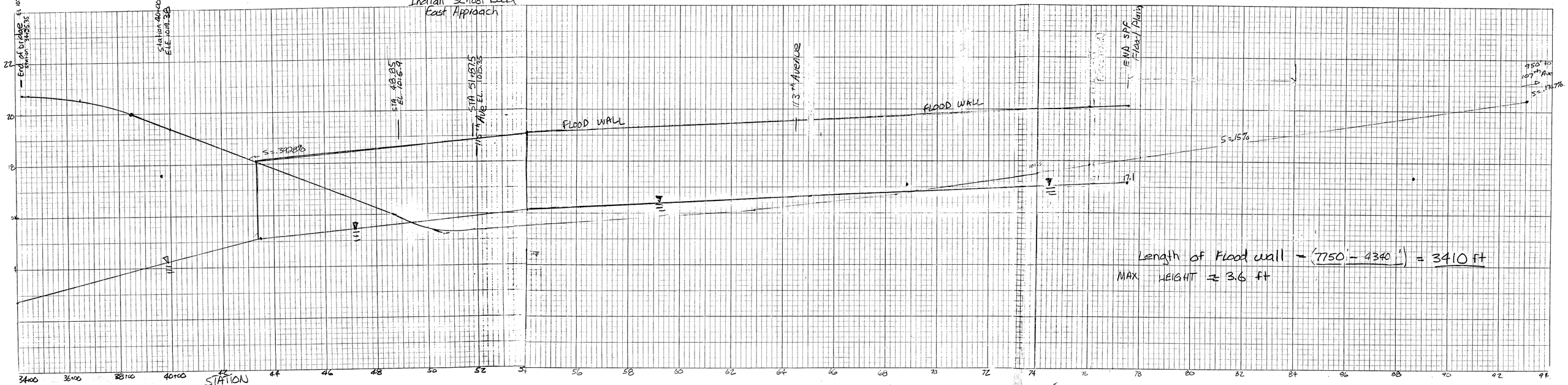
2/4
MJB
2/25/04

Indian School Road
East Approach



Length of Flood wall = (7750' - 4340') = 3410 ft

MAX HEIGHT ≅ 3.6 ft

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

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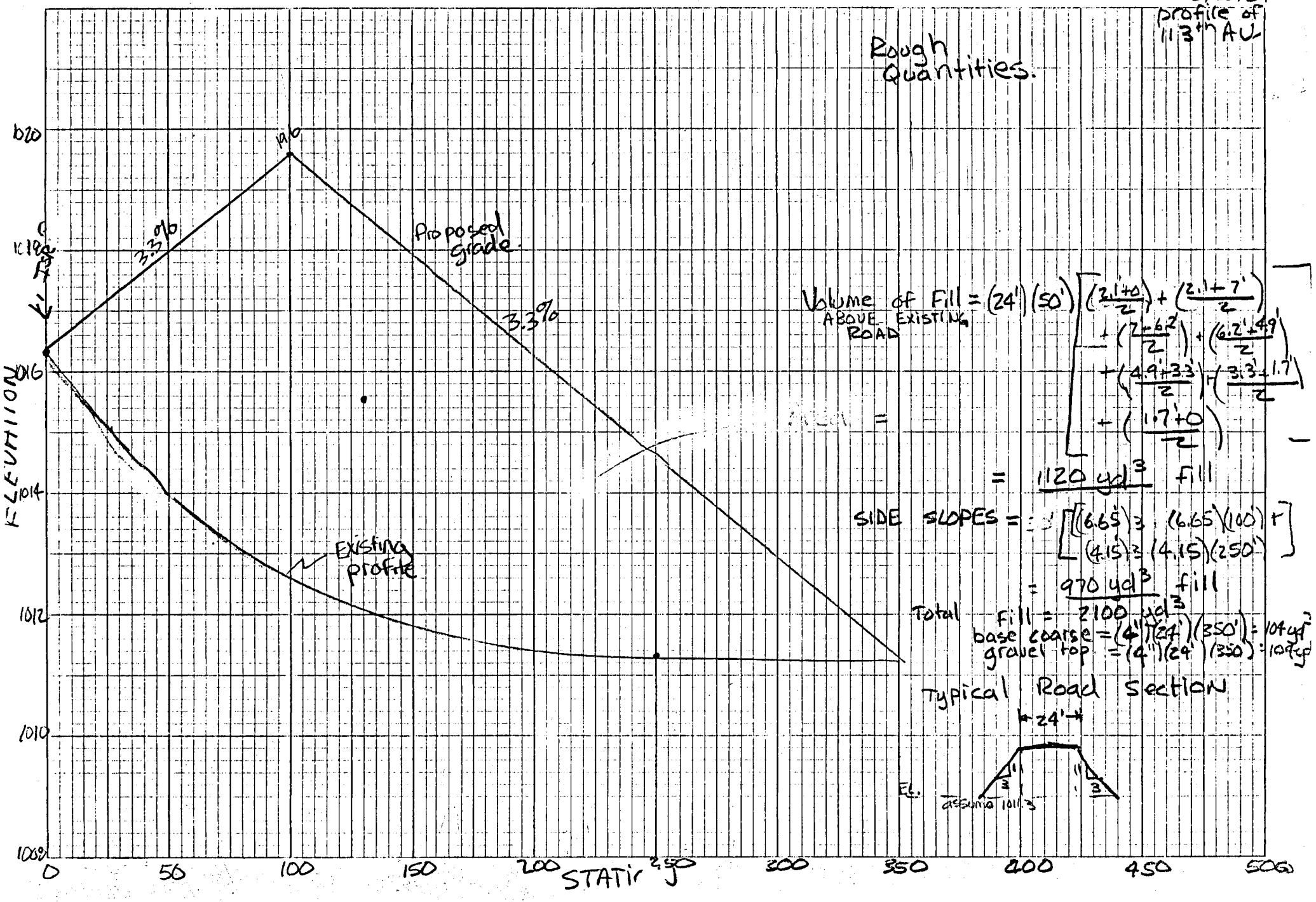
3/K
NJB
2/26/84
profile of
113th AV.



Place riprap along embankment for 2/3 the height of embankment where velocities are larger from Station 34+25.35 to Station 64+00 (113th Ave.)

Approximate ground elevation 1011.0
Approximate embankment height 1018.0

Height of riprap = (7 ft) 2/3 + (1 ft) toe down = 5.67 ft.

thickness = 8"
length = 2975 ft
height = 18'

Volume = 35,700 ft³ or 1325 yd³

Area Filter Fabric = (2975 ft)(18 ft) = 53,550 ft² or 5950 yd²

Item	Quantity	Unit Cost	Cost
Riprap	1325 yd³	$22/yd³	$29,150
Filter fabric	5950 yd²	$1.50/yd²	$8,925
			$38,075

ISRB Embankment protection + Floodwalls.

Jersey Barrier	$108,300
Raise 113th Avenue	$11,635
Embankment protection	$38,075
	$158,010

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Embankment protection	$38,075
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COST ESTIMATE FOR INVERTED SIPHON, WITH APPROACH CANALS

1. CONSTRUCT CANAL BERM (2:1 SIDE SLOPES)

Upstream of siphon 174,463 yd^3 @ \$2.50/yd^3 = \$436,160

Downstream of Siphon 120,762 yd^3 @ \$2.50/yd^3 \$301,905

2. EXCAVATE TRAPEZOIDAL CROSS SECTION

40,000 yd^3 @ \$3.50/yd^3 = \$140,000

3. Gunite - Canal Lining

22,500 yd^2 @ \$20/yd^2 = \$450,000

4. Dismantle Existing Flume 300,000

Canal Subtotal 1,628,065

~~4.~~ 5. Two Transitions 2 @ \$50,000/ea \$100,000

6. 1500 lin. feet 108" RCP \$1500 ft × \$400/ft \$600,000

~~5.~~ 7. Canal Drainage/Overflow structure \$40,000

Siphon Subtotal \$740,000

~~4. Dismantle Existing Flume~~

Siphon plus Canal \$2,368,065

10% Contingencies and Construction Supervision \$236,805

GRAND TOTAL \$2,604,870

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SIMONS, LI & ASSOCIATES
ENGINEERING CONSULTANTS
FORT COLLINS, COLORADO

CLIENT FCD of MC — JOB NO. AZ-MC-05 — PAGE 1/
PROJECT SPF Design — DATE CHECKED — DATE 1/29/84
DETAIL Quantities between Thomas Road + ISRB with siphon — CHECKED BY — COMPUTED BY MJB

1) Channelization Quantities

Backfilling of gravel pits (10,000 yd³ have been filled by PS+E)	880,000 yd³
East LEVEE (fill)	82,980 yd³
West Levee (fill)	94,690 yd³
channel Excavation	541,800 yd³

2) Drop Structure Below ISRB

Soil Cement	24,440 yd³
Structural Excavation	58,280 yd³
Special Backfill	16,920 yd³
Common Fill	16,920 yd³
Riprap	3,130 yd³
Gravel Filter	1,565 yd³

3) Land Acquisition

154 acres (already acquired)	154 acres

4) Transmission Tower Protection

2 towers	2 towers

5) Sludge Removal

20,000 yd³	20,000 yd³

6) Trash Removal

170,000 yd³	170,000 yd³

7) Levee Protection

Riprap East Levee	54,520 yd³
" West Levee	54,520 yd³
Filter fabric East Levee	45,530 yd²
Filter fabric West Levee	45,530 yd²

8) ISRB Pier Protection

Drainage Excavation	1440 yd³
Riprap	9610 yd³
Gravel Filter	4300 yd³

Siphon Cost Separated from above.

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CLIENT: FCD of MC. JOB NO. AZ-MC-05 PAGE 21
PROJECT: SPF Design DATE CHECKED: DATE 1/31/84
DETAIL: Cost Estimates CHECKED BY: COMPUTED BY MJB
Thomas Road to ISRB

1) Channelization

Backfilling of Gravel Pits	870000 yd³ @ $1.25/yd³		$1,087,500
Levee Common Fill	177,670 @ $1.25/yd³		$220,090
Channel Excavation	541,000 yd³ @ $.90/yd³		$486,900
			$1,794,490

2) Drop Structure Below ISRB

Soil Cement	24400 yd³ @	22.50/yd³	$549,000
Structural Excavation	58,280 yd³ @	2.00/yd³	116,560
Special Backfill	16,920 yd³ @	2.00/yd³	33,840
Common Fill	16,920 yd³ @	1.25/yd³	21,150
Riprap	3130 yd³ @	22.0/yd³	68,860
Gravel Filter	1,565 yd³ @	15.0/yd³	23,475
		subtotal	$812,885

3) Land Acquisition
154 acres (already complete) —

4) Transmission Tower Protection
2 towers @ $100,000/tower $200000

5) Sludge Removal
20000 yd³ @ $2.00/yd³ $40,000

6) Trash Removal
170,000 yd³ @ $.50/yd³ $85,000

7) Levee Protection

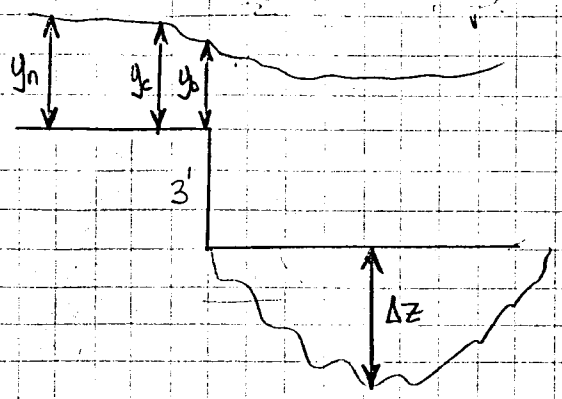
Riprap	109,040 yd³ @	$22.00/yd³	$2,398,880
Filter Fabric	91,060 yd² @	$1.50/yd²	136,590
		$2860,470	$2,535,470.0

8) ISRB Pier Protection

Drainage Excavation	12410 yd³ @	.90/yd³	$12,970.0
Riprap	9610 yd³ @	22.0/yd³	211,420.0
Gravel Filter	4800 yd³ @	15.0/yd³	72,000.0
		subtotal	296,390.00

Total Cost Thomas to ISRB
$ 5,764,235
10% cont. + S+I 576,425
6,340,660

Drop Structure Below ISRB for Alternative with siphon



Local Scour computation

$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

$$q = \frac{1.486}{n} Y^{5/3} S^{1/2}$$

Slope = .0017

Q = 142000 cfs
W = 1410 ft

$$q = 100.7 \text{ cfs/ft}$$

$$Y_n = \left(\frac{(100.7 \text{ cfs/ft})(.03)}{1.486 \quad (.0017)^{1/2}} \right)^{3/5} = 10.4 \text{ ft}$$

$$Y_c = \sqrt[3]{\frac{q^2}{g}} \doteq 6.8 \text{ ft.}$$

$$V_c = 100.7/6.8 = 14.8 \text{ ft/sec}$$

Compute the Chow Drop Number to determine the distance the water will travel horizontally over the drop structure

$$D = q^2/g h^3 = (100.7 \text{ cfs/ft})^2 / (32.2 \text{ ft/sec}^2)(3 \text{ ft})^3$$

$$D = 11.66$$

$$L_D = 4.3 h D^{.27} = 4.3 (3') (11.66)^{.27} = 25.0 \text{ ft.}$$

Local Scour Depth using the Veronese Equation.

$$\Delta z = 1.32 H_T^{.225} q^{.54} - y_c$$

$$\Delta z = 1.32 (3)^{.225} (100.7)^{.54} - 6.8' = \underline{13.6 \text{ ft}}$$

Local Scour Depth using the Scholitsch Equation

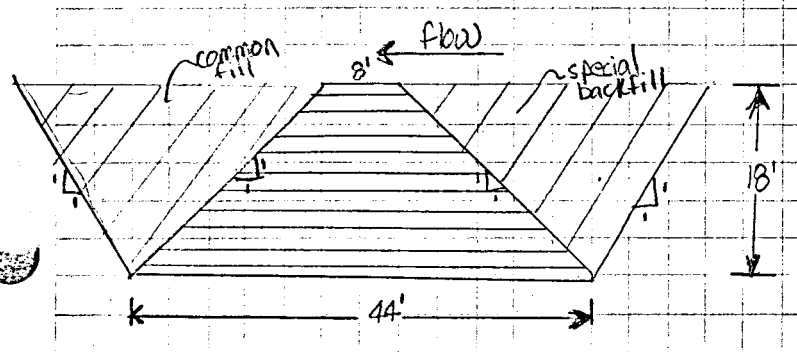
$$\Delta Z = 4.75 \frac{H_T^{.2} q^{.5}}{D_{90}} - y_c$$

$$\Delta Z = 4.75 \left(\frac{(.144)^{.2} (9.355)^{.5}}{(10\,mm)^{.32}} \right) - 2.07\,m = 4.76 \text{ meters.}$$

$$\Delta Z = 15.6 \text{ ft}$$

Adopt local scour ≈ 14.6'

Soil Cement Drop Structure Quantities



Volume of Soil Cement in Drop Structure

$$V_{SC} = \left(\frac{8' + 44'}{2} \right) (18') (1410')$$

$$V_{SC} = 659{,}880\ ft^3 \text{ or } \underline{24{,}440\ yd^3}$$

Structural Excavation for Drop Structure

$$V_{SE} = \left(\frac{44' + 80'}{2} \right) (18') (1410') = 1{,}573{,}560\ ft^3$$

$$V_{SE} = 58{,}280\ yd^3$$

Special Backfill

$$V_{SB} = (36')(18')(1/2)(1410') = 456{,}840\ ft^3 \text{ or } 16{,}920\ yd^3$$

Common Fill

$$V_{CF} = (36')(18')(1/2)(1410') = 456{,}840\ ft^3 \text{ or } 16{,}920\ yd^3$$

Riprap upstream of Drop Structure.

$V_{RR} = (3')(20')(1410') = 84{,}600\ ft^3$ or $3{,}130\ yd^3$

Gravel Filter upstream of Drop structure

$V_{GF} = (1.5')(20')(1410') = 42{,}300\ ft^3$ or $156.5\ yd^3$

✓

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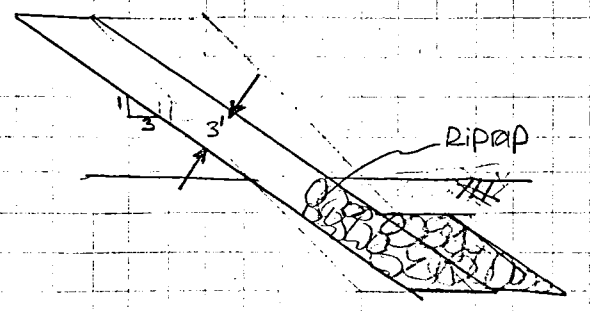
CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: 1/1
PROJECT: SPF Design | DATE CHECKED: | DATE: 1/29/84
DETAIL: Bank Protection Thomas Road to ISRB | CHECKED BY: | COMPUTED BY: MJB



Rip Rap Bank Protection Recommended Because of settlement due to gravel pits

East Bank

$$V_{RR} = (5190')(3')(3)\left(\frac{23.2'+26.9'}{2}\right) + (100')(3')(3)\left(\frac{26.9'+35'}{2}\right)$$

$$+ (100')(3')(3)(35') + (5390')(3')(15')$$

$$V_{RR} \approx 1{,}471{,}990\ ft^3 \text{ or } 54{,}520\ yd^3$$

Volume both banks

$$V_{RR} = (2)(54{,}520\ yd^3) = \underline{109{,}040\ yd^3}$$

Filter Fabric Area

$$A_{FF} = (5190')\left(\frac{23.2'+26.9'}{2}\right)(3) + (100')\left(\frac{26.9'+35'}{2}\right)(3)$$

$$+ (100')(35')(3)$$

$$A_{FF} = 409{,}815\ ft^2 \text{ or } 45{,}530\ yd^2$$

Area filter fabric both banks.

$$A_{FF} = (2)(45{,}530\ yd^2) = \underline{91{,}060\ yd^2}$$

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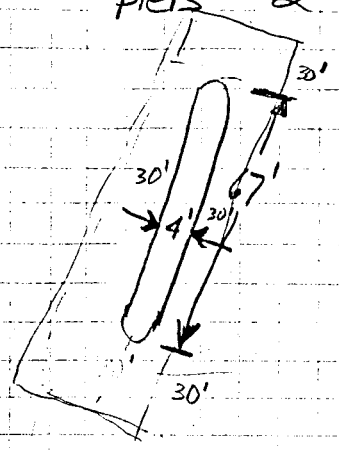
CLIENT FCD of MC | JOB NO. AZ-MC-05 | PAGE 1/1
PROJECT SPF Design | DATE CHECKED | DATE 1/30/84
DETAIL ISRB Pier Protection | CHECKED BY | COMPUTED BY MSB

Piers 2-12 protection



$$V_{RR} = \underset{\text{No of piers}}{(11)} \times \underset{\text{width}}{(64')} \times \underset{\text{Length}}{(127')} \times \underset{\text{thickness}}{(3')} - \underset{\text{pier volume}}{(11)(4')(67')(3')}$$

$$V_{RR} = 259{,}380\ ft^3 \text{ or } \underline{9{,}610\ yd^3}$$

$$V_{GF} = \underset{\text{No of piers}}{(11)}\underset{\text{width}}{(64')} \times (127')(1.5') - (11)(4')(67')(1.5')$$

$$V_{GF} = 129{,}690\ ft^3 \text{ or } \underline{4800\ yd^3}$$

Drainage Excavation

$$V_{DE} = 9610\ yd^3 + 4800\ yd^3$$

$$= \underline{14{,}410\ yd^3}$$

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FORT COLLINS, COLORADO

CLIENT FCD of MC | JOB NO. AZ-MC-05 | PAGE 1/12
PROJECT SPF Design | DATE CHECKED 2/3/84 | DATE 1/31/84
DETAIL Thomas Road + ISRB | CHECKED BY MPB | COMPUTED BY MM

3:1

Section Number	Distance (ft.)	Area East Levee (ft²)	Area West Levee (ft²)	Volume East Levee (yd³)	Volume West Levee (yd³)
370+50		299	629		
	1000			8,390	16,315
381+40		154	252		
	320			2,830	2,820
385+50		324	224		
	650			8,040	6,840
392+10		344	344		
	630			9,260	9,260
398+00		450	450		
	500			6,540	7,455
403+75		192	282		
403+90		192	282		
	570			8780	9,730
409+45		640	640		
	850			23,780	22,780
417+75		807	807		
	720			16,360	19,490
426+95		420	655		
			Subtotal	82,980 yd³	94,690 yd³

SIMONS, LI & ASSOCIATES
ENGINEERING CONSULTANTS
FORT COLLINS, COLORADO

CLIENT: FED of MC
PROJECT: SH Design
DETAIL: Channelization Quantities
Thomas Road to ISRB

JOB NO.: A2-MC-05
DATE CHECKED:
CHECKED BY:

PAGE: 2/12
DATE: 1/31/84
COMPUTED BY: MM

X-section	Dist	Area(Fill)	Area(Cut)	Vol(Fill)	Vol(Cut)
370+50		0	4050 Ft²		
	1000			0	4,101,500
381+40		0	4153 Ft²		
	320			8320	1,286,400
385+50		52 Ft²	3887 Ft²		
	650			1690	1,910,675
392+16		0	1992		
	630			88,200	1,756,755
398+00		280	3585		
	550			168,850	1,109,350
403+90		334	449		
	570			95 190	1,294,185
409+45		0	4092		
	850			0	2,297,975
417+75		0	1315		
	720			0	871,200
426+95		0	1105		
				13,417 cu/yds	541,779 cu/yd

Area, Vol., Cut, Fill

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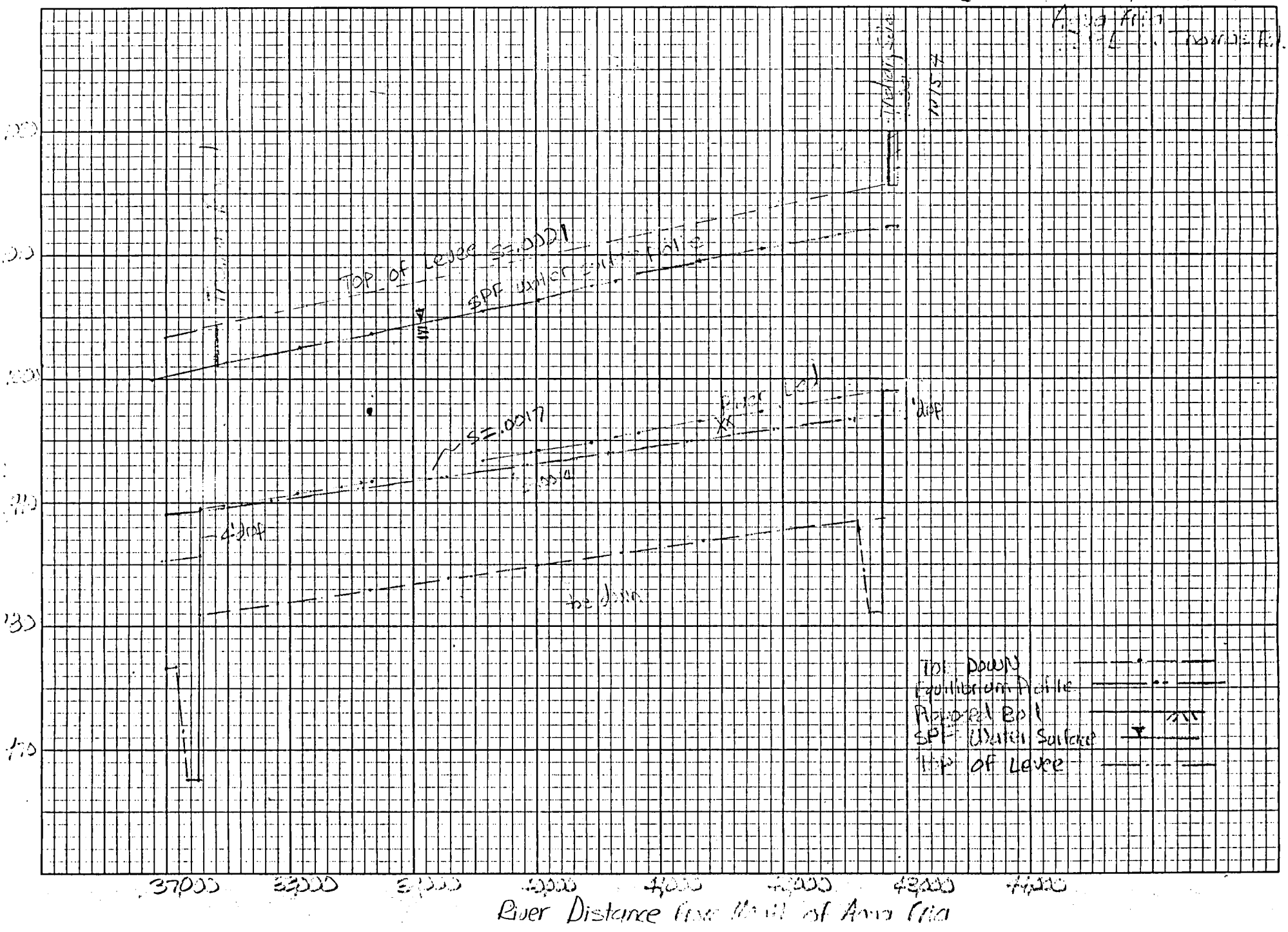
2/12
1/29/84
11 JB

Figure B.2 East and West Bank



K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
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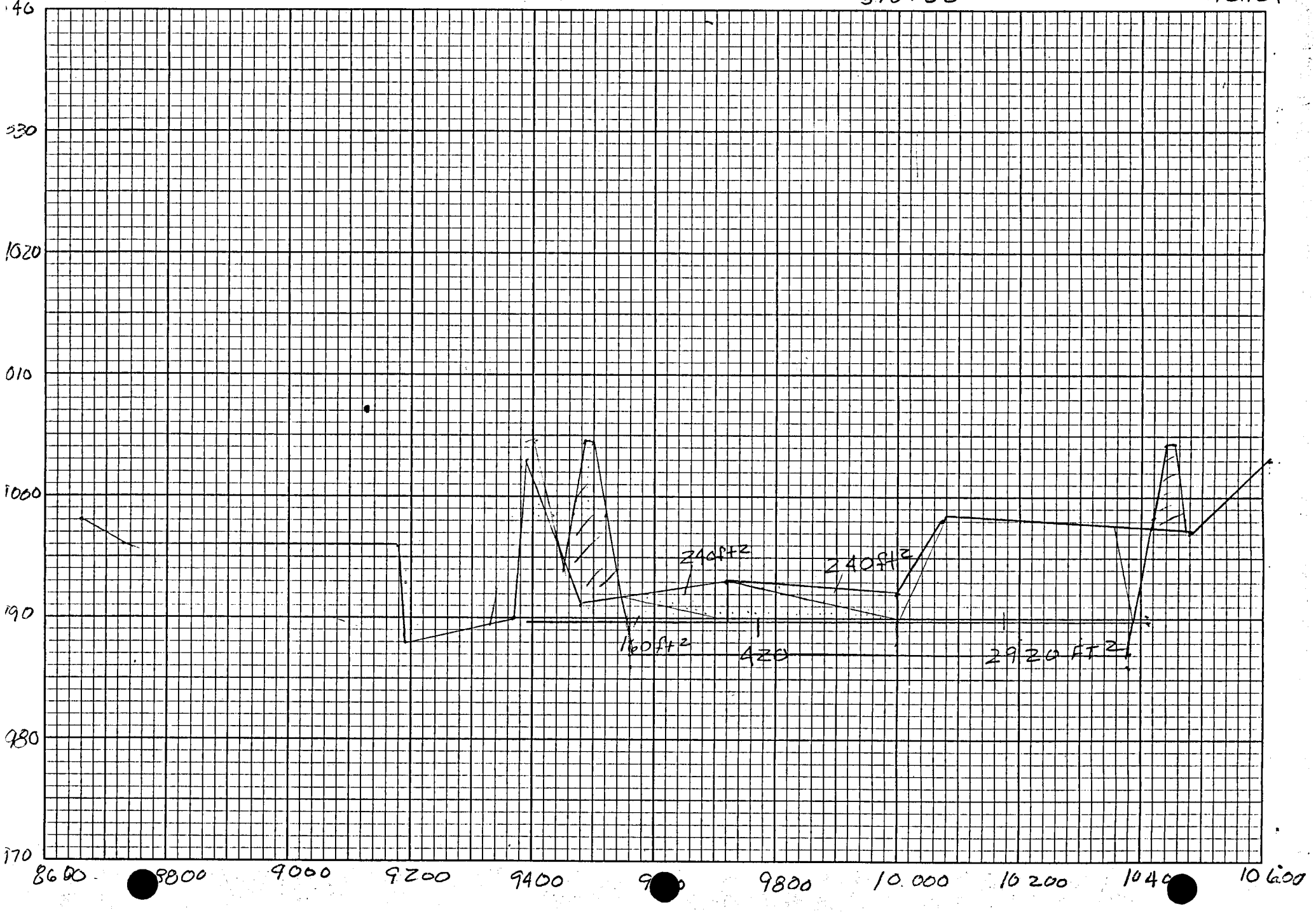
4/2
MM
1/31/84

370+50



K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
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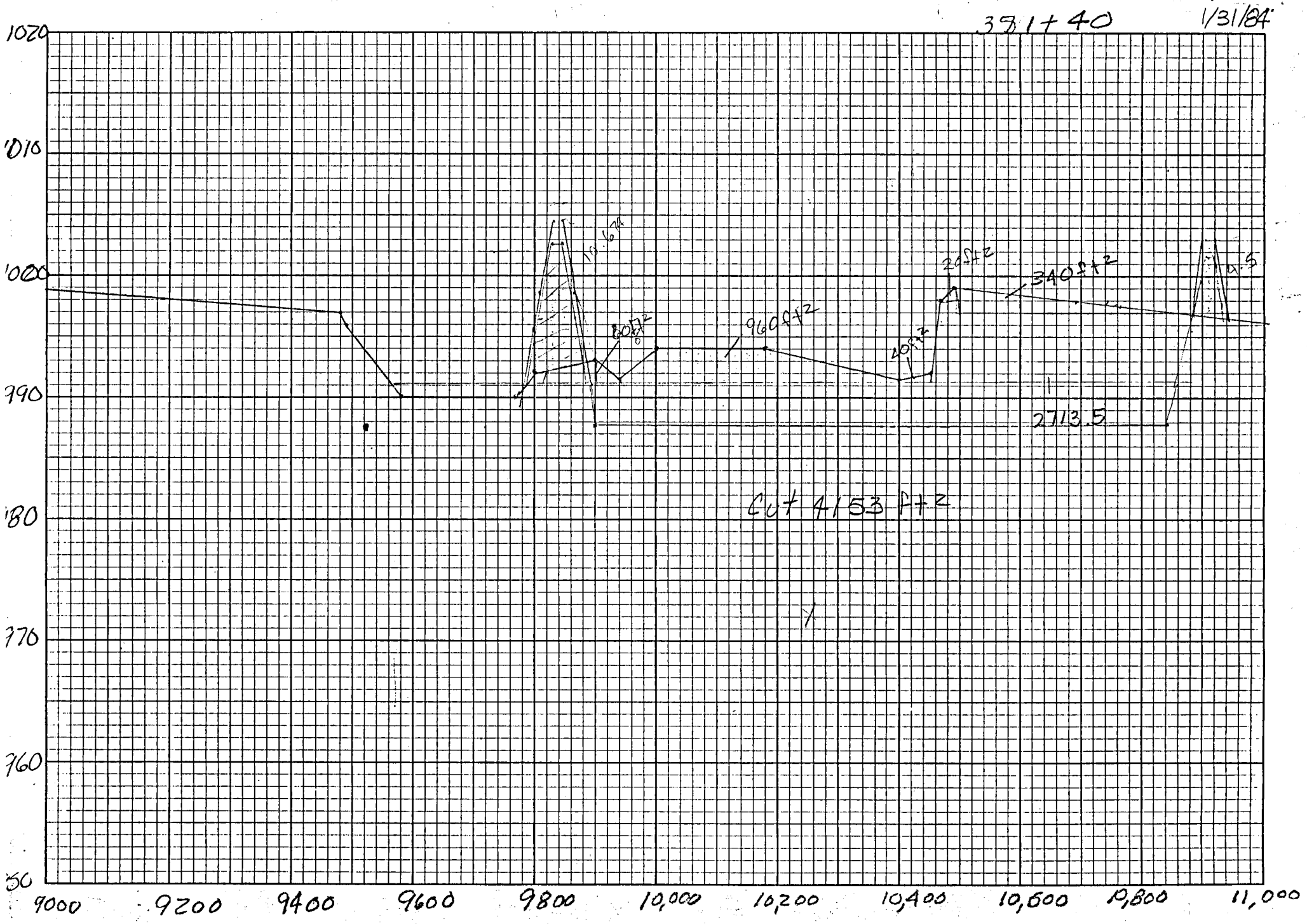
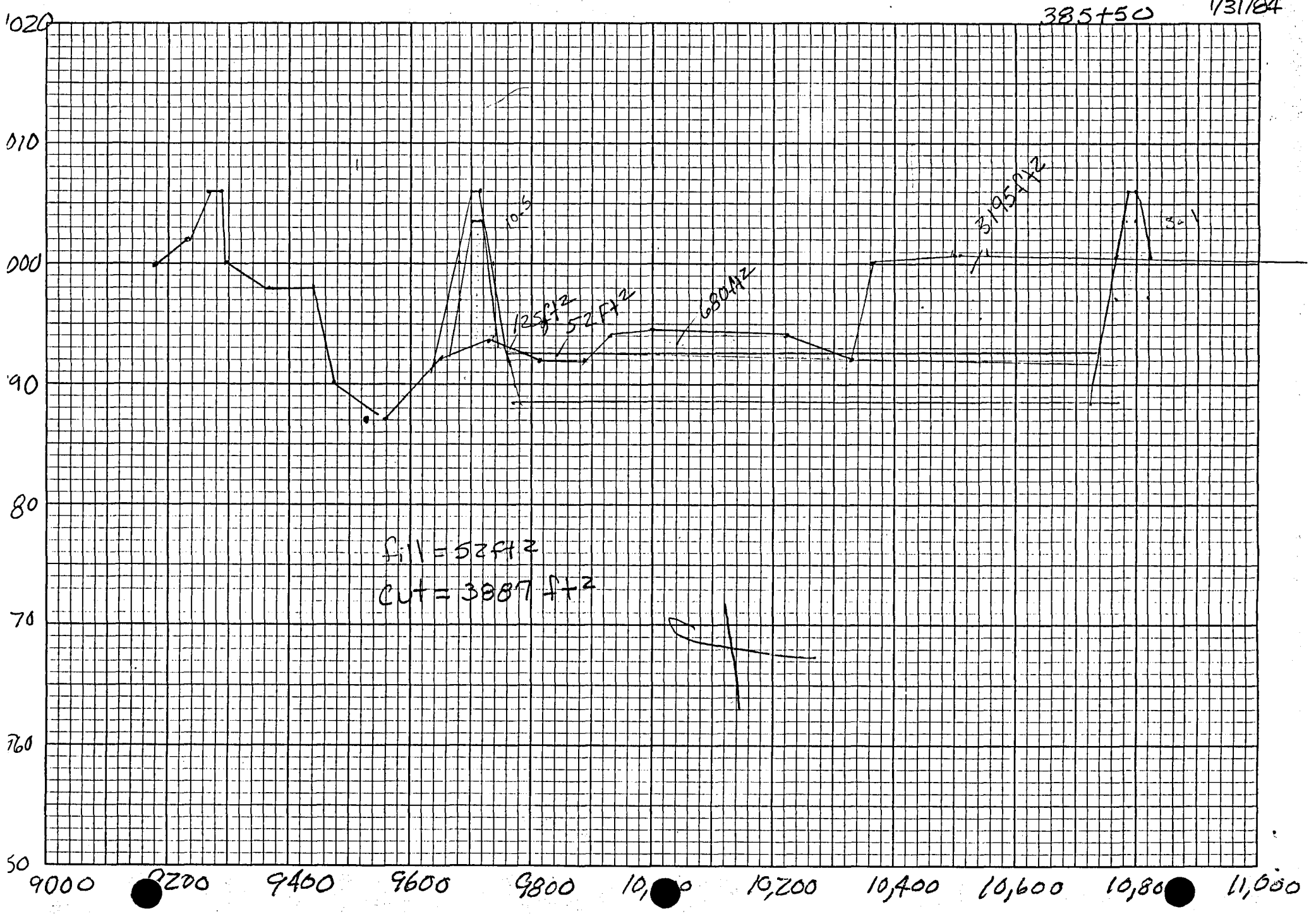
5/12
PMM
1/31/84



K•E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

6½
MM
1/31/84

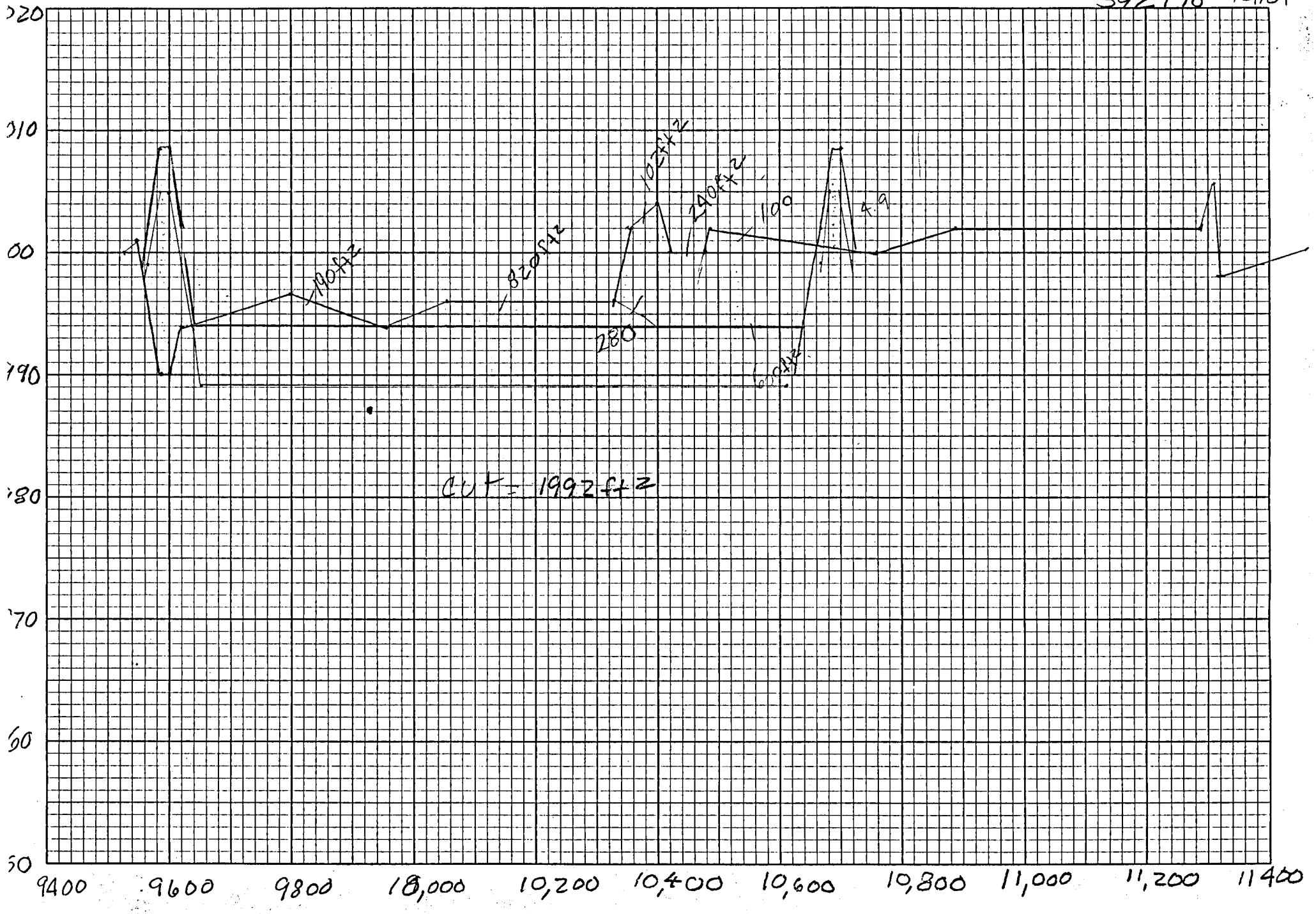


K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

7/12
MM
1/31/84

392+10

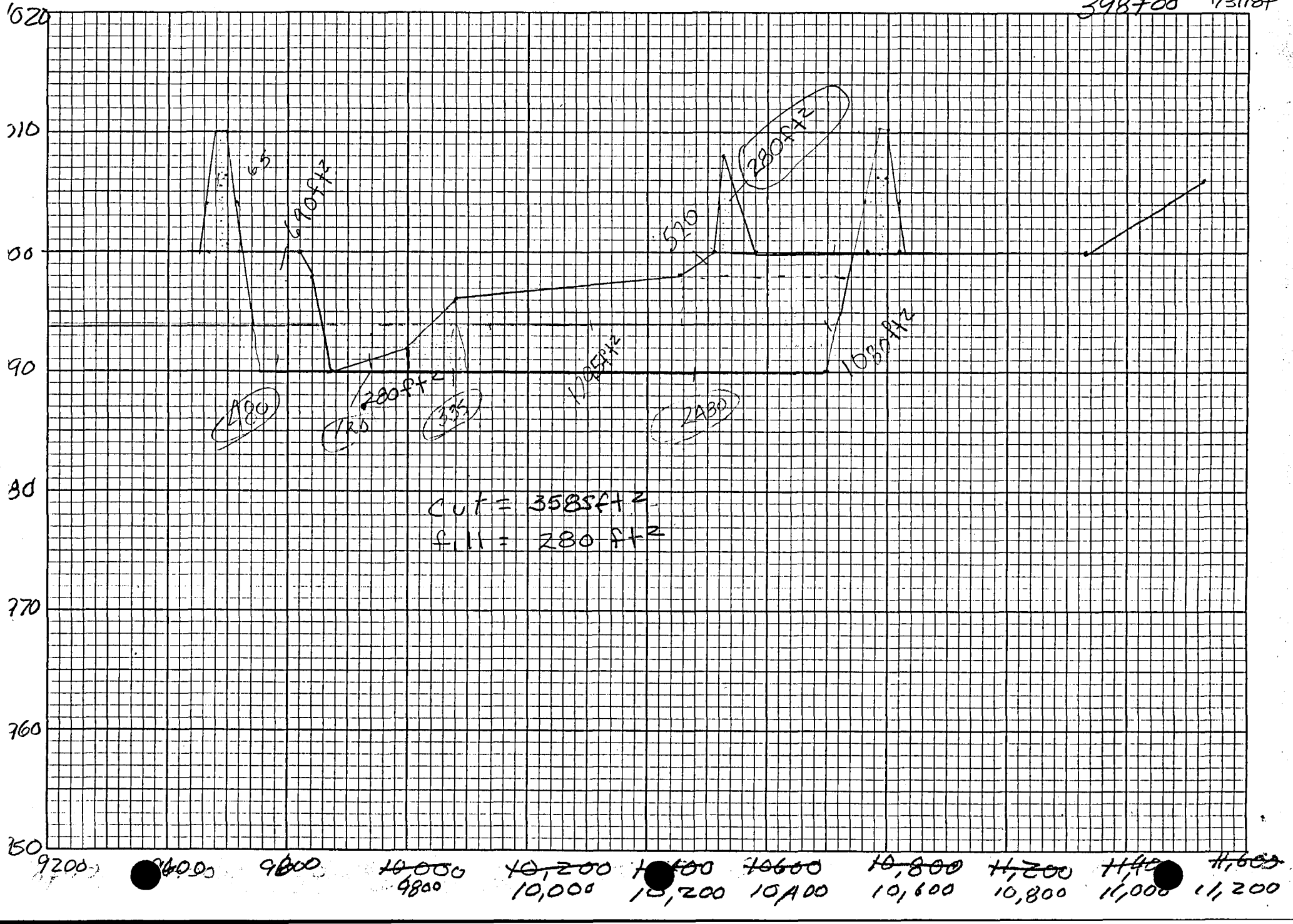


K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

8/12
MM
1/31/84

398+00

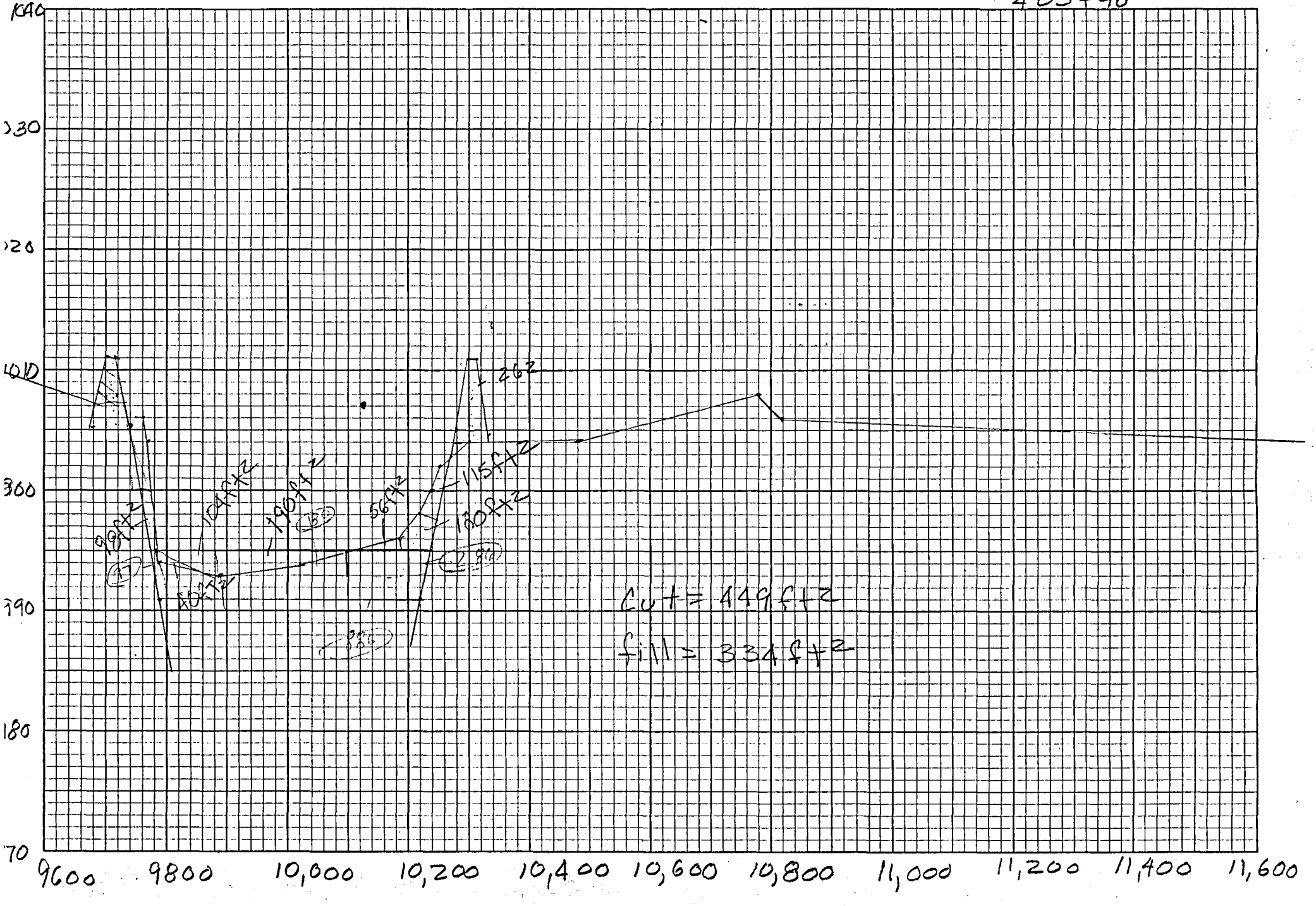


K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

9/12
MM
1/31/84

403+90



K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
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46 0780

T.L. = 1010
T.B. =

409+45

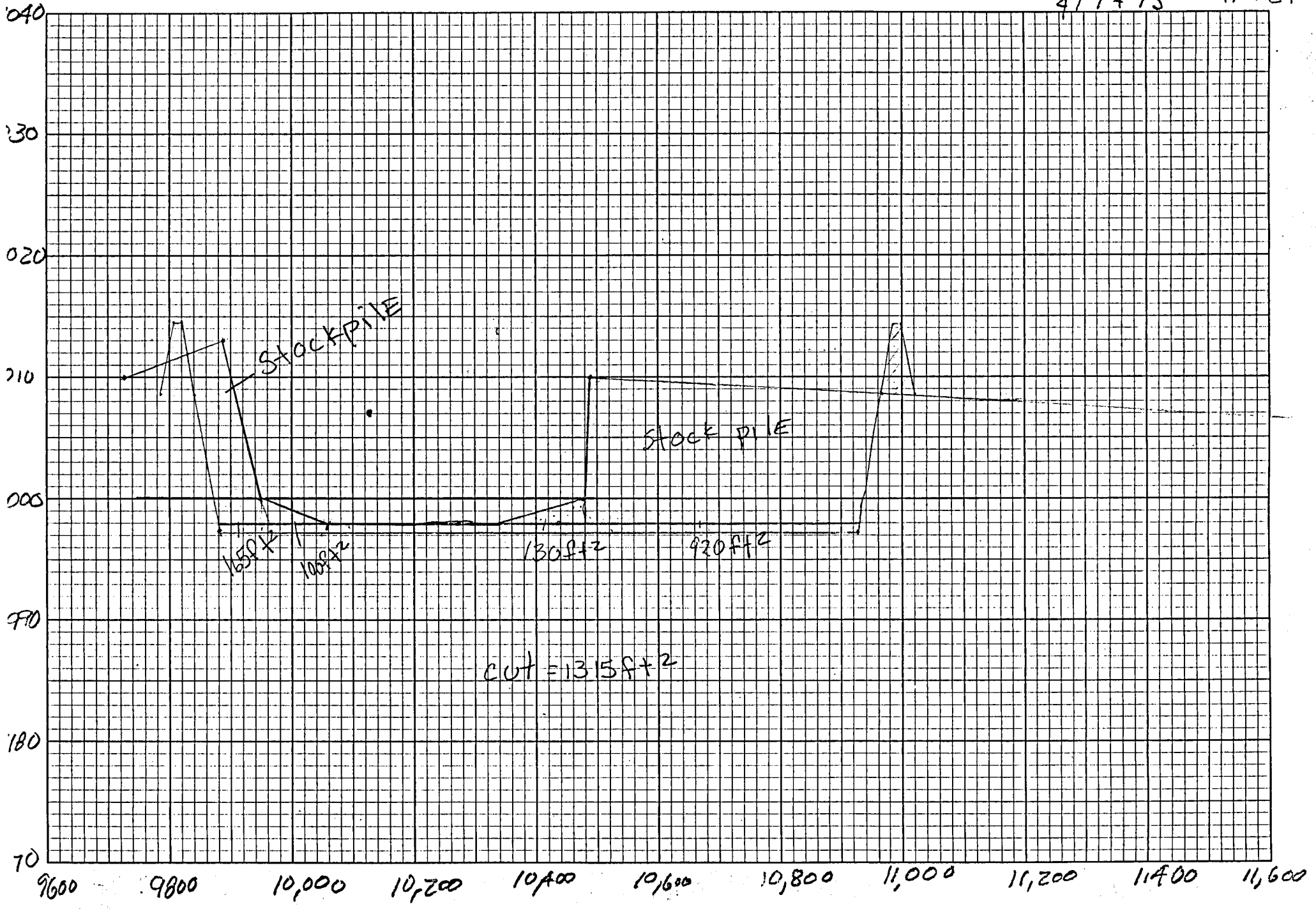
10/12
MM.
1/31/84

K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

11/12
MM
1/31/84

417+75

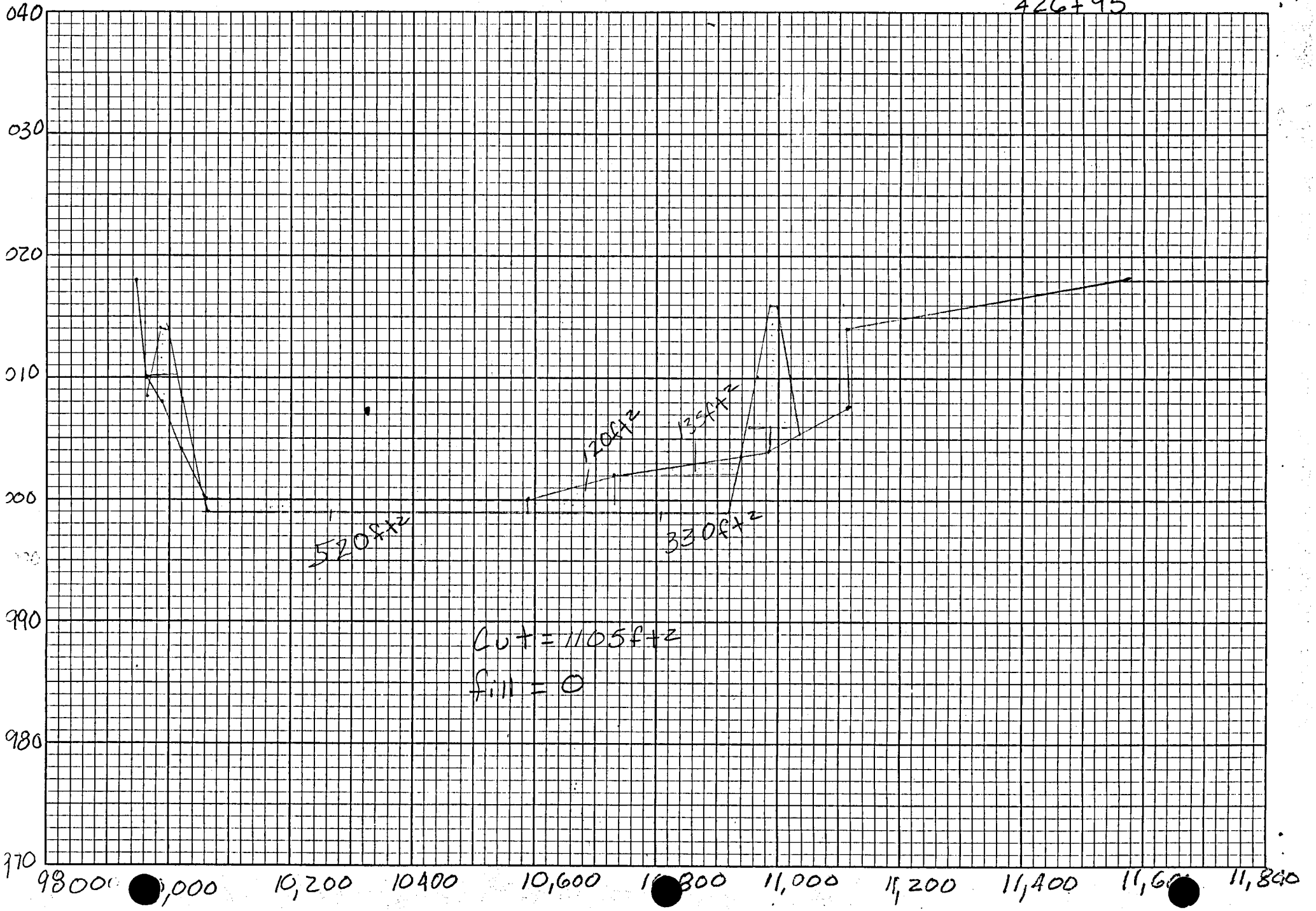


K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 0780

12/12
MM
1/31/84

150

426+95



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FORT COLLINS, COLORADO

CLIENT FCD of MC
PROJECT SIF Design
DETAIL ROW between McDowell + I-10.

JOB NO. AZ-MC-05
DATE CHECKED
CHECKED BY

PAGE 1/1
DATE 2/1/84
COMPUTED BY MM

Section	Owned By	Acreage in Reach	
	AREA below BRIDGE		
6	Resident Vacant	11.9	Public st. of Az
7	imp. Agric.	13.3	17.26
8	Public Agency st. of Az	17.26	Public Maricopa County
9	imp. Agric.	9.8	
10	Public Agency	7.7	0
		Total 59.96 Acres	
	AREA ABOVE BRIDGE		
4	Resident Vacant	3.8	Public st. of Az
6	Resident Vacant	14.2	
7	imp. Agric.	.41	0
		Total 18.41 Acres	Public Maricopa County
			0
		Total Acres 78.37 Total State Acres 17.26 Total Maricopa 0	
		Total other Acres 61.11	

AREA of study REACH between I-10 and McDowell ROAD

SIMONS, LI & ASSOCIATES
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FORT COLLINS, COLORADO

CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Quantities + Cost Estimate
I-10 to Thomas Road with siphon

JOB NO. AZ-MC-05
DATE CHECKED
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PAGE 1/-
DATE 1/27/84
COMPUTED BY MJB

1) Channelization quantities

Drainage Excavation	1,867,000 yd^3
I-10 Excavation	−850,000 yd^3
	1,017,000 yd^3 *
Levee fill	
3:1 SS West Bank	143,500 yd^3
3:1 SS East Bank	110,820 yd^3
1:1 SS West Bank	93,400 yd^3
1:1 SS East Bank	91,160 yd^3

2) ② Drop structure Quantities

Soil Cement	53,780 yd^3
Structural Excavation	132,650 yd^3
Special Backfill	39,440 yd^3
Common fill	39,440 yd^3
Rip rap upstream of drop	4,880 yd^3
gravel filter	2,440 yd^3

3) Transmission Tower Protection

8 towers	8 towers.

4) Land Acquisition

(purchased) 280 acres for Channelization	280 acres
2.53 acres for I-10 collector Channel	2.53 acres

5) Bank Protection Measures

Soil Cement	
East Bank	65,315 yd^3
West Bank	69,340 yd^3
Riprap	
West Bank	102,360 yd^3
East Bank	88,240 yd^3
Filter fabric West Bank	77,990 yd^2
Filter fabric East Bank	73,050 yd^2

6) I-10 Siltation Basin

Drainage Excavation (use for basin + area)	440,000 yd^3
Soil Cement Bank Protection	6,420 yd^3
50 ft. rc. culvert	51 ft

7) Relocated flap gate [illegible] at Thomas Road 1 unit

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CLIENT FCD of MC | JOB NO. AZ-MC-05 | PAGE 21
PROJECT SPF Design | DATE CHECKED | DATE 1/27/84
DETAIL Quantities + Cost Between I-10 and Thomas Road | CHECKED BY | COMPUTED BY MJB

1) Channelization

1:1 ss Common Fill levee	184,560 yd³ @ 1.25/yd³		$ 230,700.0
3:1 ss Common Fill levee	254,320 yd³ @ 1.25/yd³		$ 317,900.0
Drainage Excavation	1,017,000 yd³ @ .90/yd³		$ 915,300.0

2) 2 Drop Structures

Soil Cement	53,780 yd³ @ 22.50/yd³	$ 1,210,050
Structural Excavation	132,650 yd³ @ 2.00/yd³	$ 265,300
Special Backfill	39,440 yd³ @ 2.00/yd³	$ 78,880
Common Fill	39,440 yd³ @ 1.25/yd³	$ 49,300
Riprap	4,880 yd³ @ 22.00/yd³	$ 107,360
Gravel Filter	2,440 yd³ @ 15.0/yd³	$ 36,600
	subtotal	$1,747,490

3) Transmission Tower Protection

8 towers @ $100,000/tower $ 800,000

4) Land Acquisition

2.53 acres @ $5000/acre $ 12,650
43 acres non-state owned @ $5000/acre $ 215,000

5) Bank Protection

Soil Cement	134,655 yd³ @ 22.50/yd³	$3,029,740
Rip Rap	190,600 yd³ @ 22.0/yd³	$ 4,193,200
Filter Fabric	151,040 yd² @ 1.50/yd²	226,560

6) I-10 Siltation Basin

Drainage Excavation	440,000 yd³ @ .90/yd³	$396,000
Soil Cement	6420 yd³ @ $22.5/yd³	$ 144,450
3' RCP Pipe	50 ft @ $50/ft	$ 2,500
Flap Gate	1 Gate @ $2000.0	$ 2,000
		$544,950

Cost Excluding Utility Relocation using soil cement Protection $ 7,270,670
10% Contingency + Supervision $ 727,060
total cost $ 7,997,680
Land Acquisition 227,650

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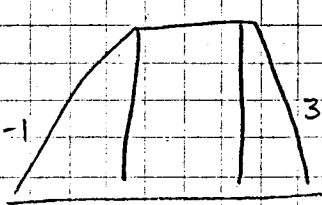
CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Levee Volume 3:1 side slopes I-10 to Thomas Road
JOB NO.: AZ-MC-05
DATE CHECKED:
CHECKED BY:
PAGE: 1/4
DATE: 1/31/84
COMPUTED BY: MM

AREA LEVEE EAST BANK

283+50		0	
X	1255		
294+00		414.25	259,941.87
X	1500		
308+30		773.55	890,850.00
X	900		
316+20		711.76	668,389.5
X	720		
323+20		657.73	493,016.40
	1090		
334+20		832.5	812,175.35
	1040		
344+20		930.00	916,500.00
	440		
348+60		804.72	381,638.40
	925		
358+30		665.2	679,838.
	1220		
370+50		780.78	882,047.8

~~Cu~~ 5,984,394 ... 1
Cu yds 221,644/= 110,822



Area levee West bank

283+5		0 (ft²)	ft³
	1255		640,677
294+00		1021	
	1500		1,589,250
308+30		1098	
	900		861,750
316+20		817	
	720		585,720
323+20		810	
	1090		919,071.65
334+20		876.37	
	1040		990,272.40
344+20		1028	
	440		400,752.00
348+60		793.6	
	925		730,380.0
358+30		785.6	
	1220		1,030,961
370+50		904.5	

7748,834 ft³
~~Cu yds~~ ~~2,582,944.68~~
286,993.85 yd³/2
143,500 yd³
Cu yd

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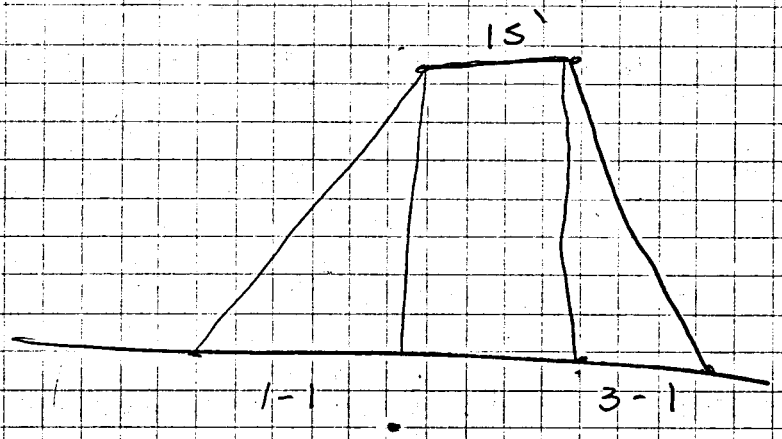
FORT COLLINS, COLORADO

CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: levee Volumes 1:1 side slopes I-10 to Thomas Road

JOB NO.: AZ-MC-05
DATE CHECKED:
CHECKED BY:

PAGE: 1A14
DATE: 1/31/84
COMPUTED BY: MM

	D	Levee V = East		Levee V = West	
283 + 50		0 (?)		0 (?)	
	1255		186,367		255,392
294 + 00		297		407	
	1500		445,500		547,500
308 + 30		297		323	
	900		298,350		256,950
316 + 20		366		248	
	720		210,960		215,280
323 + 20		220		350	
	1090		295,935		381,500
334 + 20		323		350	
	1040		382,200		336,440
344 + 20		412		297	
	440		151,360		142,340
348 + 60		276		350	
	925		221,537		261,775
358 + 30		203		216	
	1220		269,010		424,560
370 + 50		238		480	
		Cu ft	2,461,219		Cu ft 2,521,797
		Cu yds	91,156		Cu yds 93,398



K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
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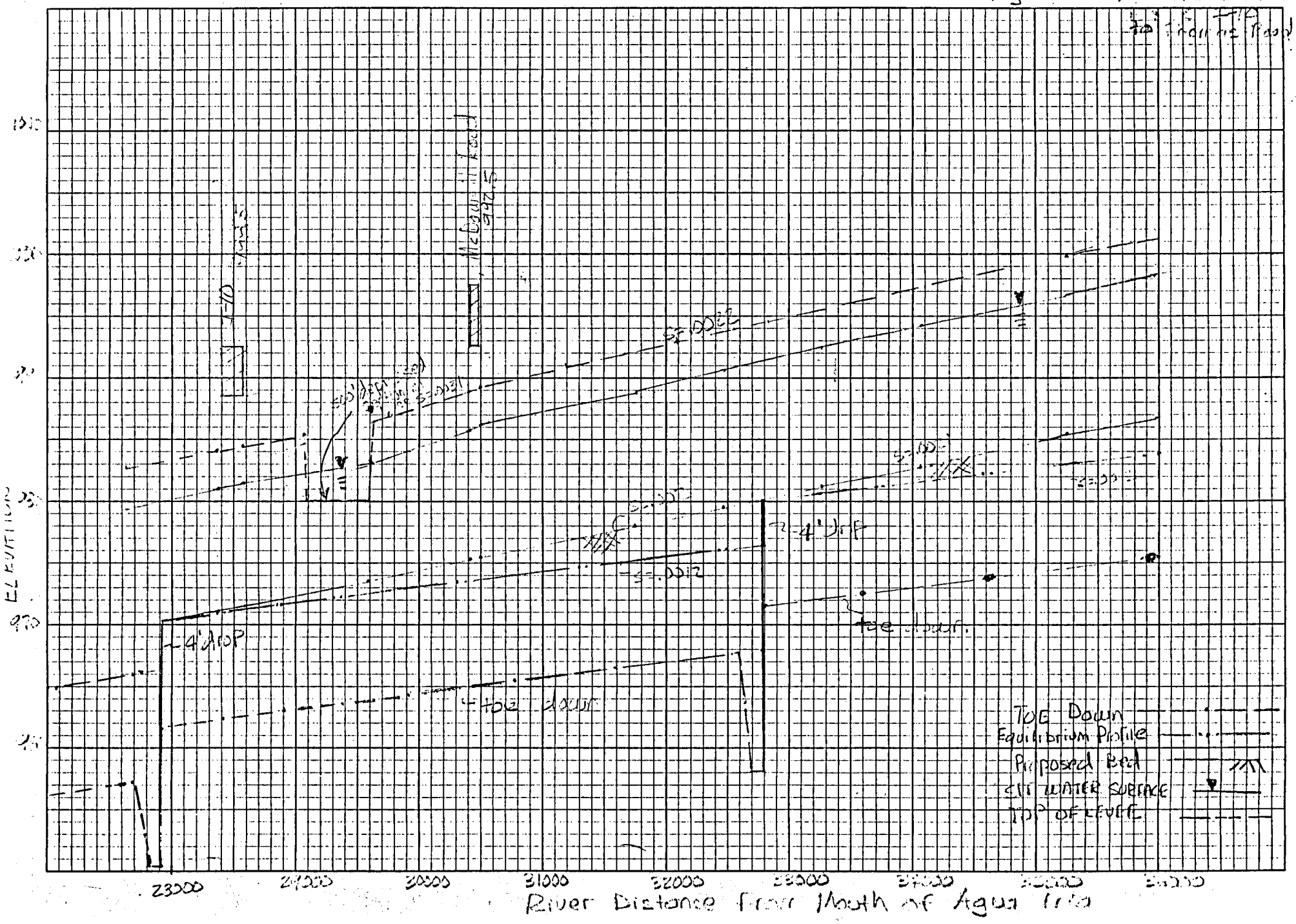
1/25/84
NSB
2/4

Figure B.3



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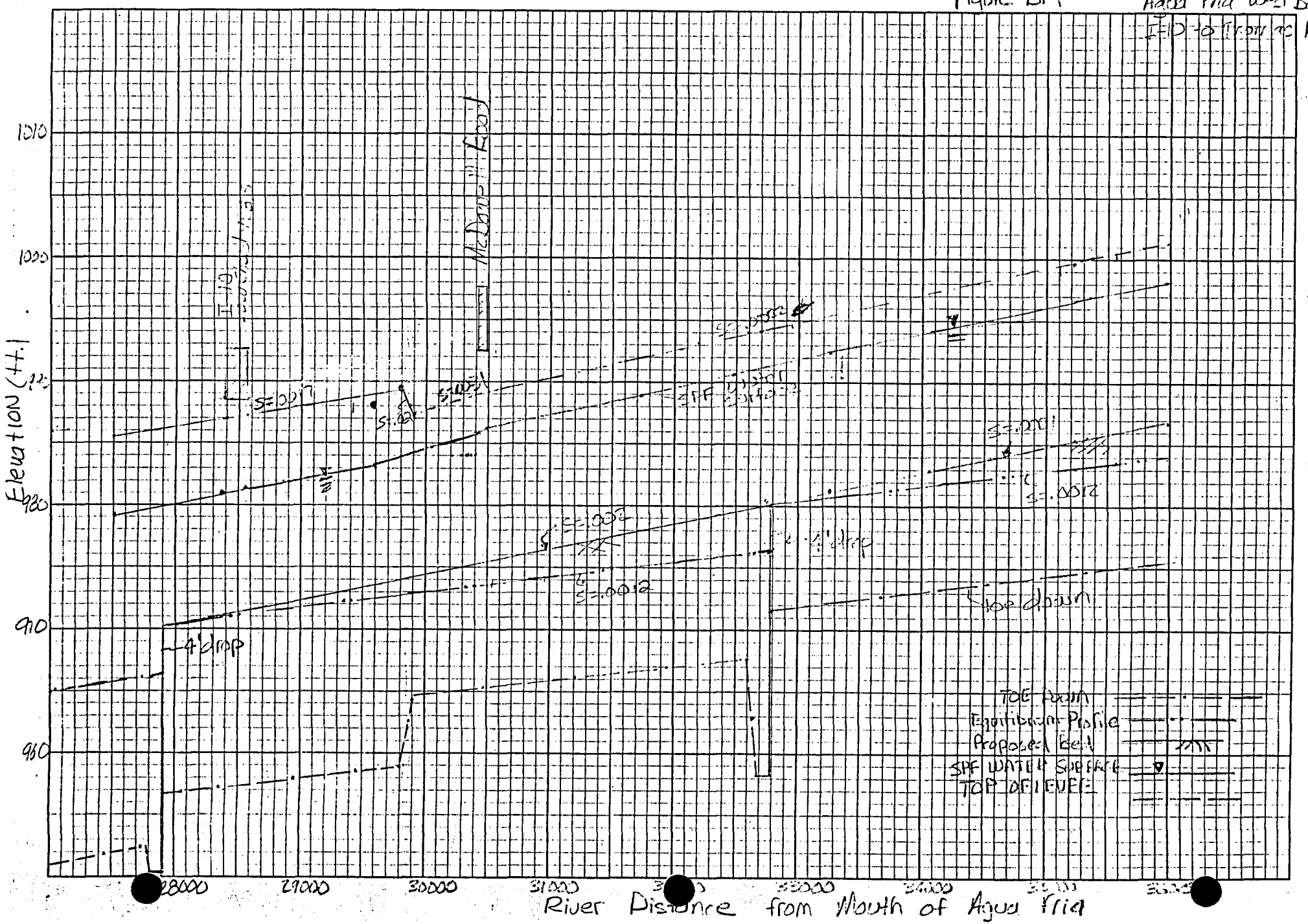
11JB
3/4

Figure B.4

Agua Fria West Bank
FID to Trom to Pa



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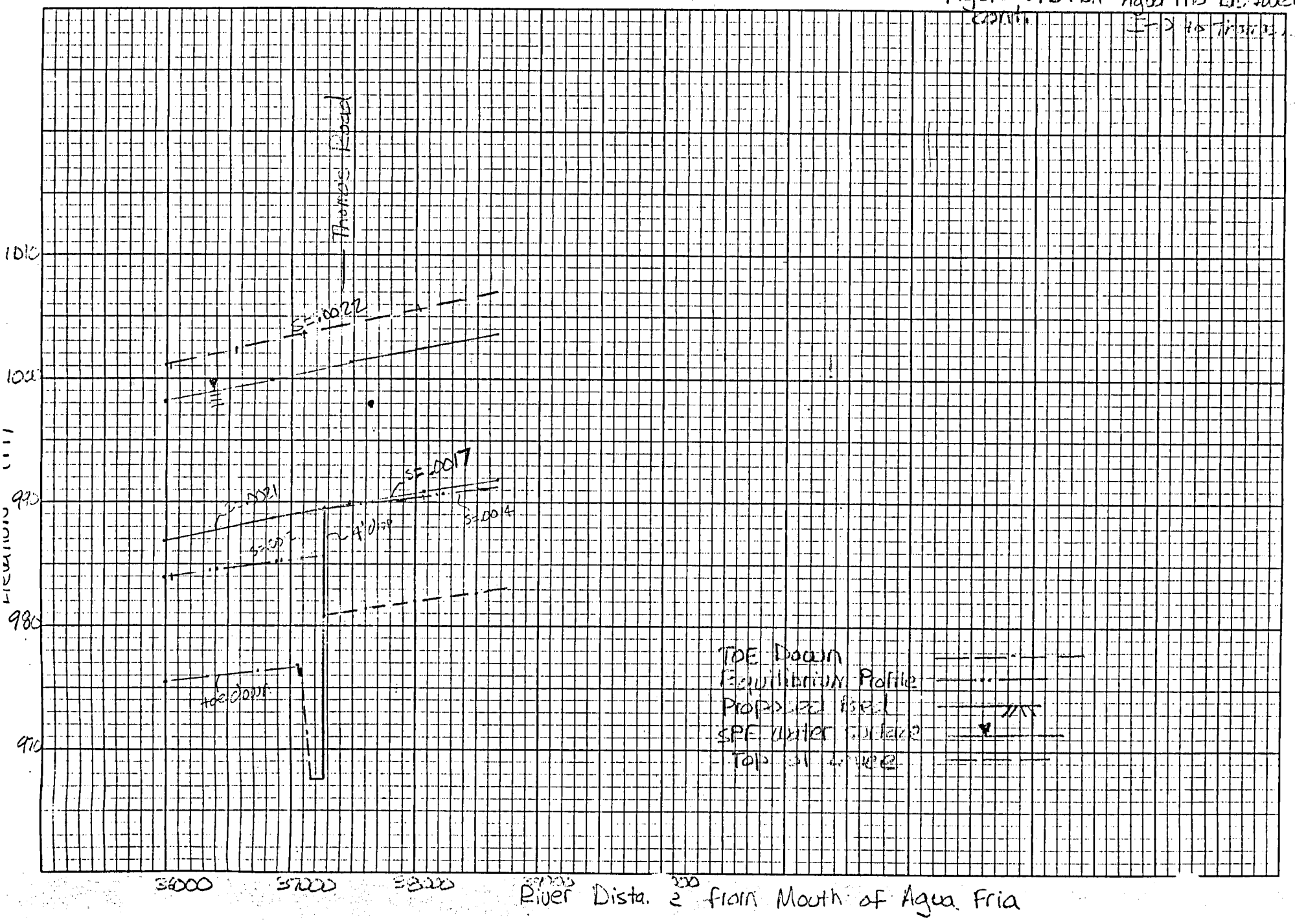
1/25/8
NJB
4/4

Figure B.3 + B.4 Agua Fria East + West B
cont.



River Dista. 2 from Mouth of Agua Fria

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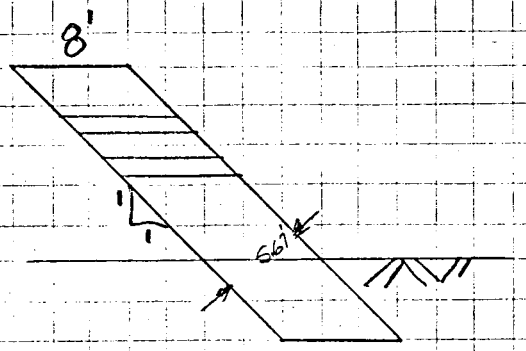
FORT COLLINS, COLORADO

CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Bank Protection
I-10 - Thomas without siphon

JOB NO.: AZ-MC-05
DATE CHECKED:
CHECKED BY:

PAGE: 1/5
DATE: 2/7/84
COMPUTED BY: MJB



Soil Cement Bank Protection

West Bank

$$V_{sc} = (1450')(5.67')(43.3') + (100')(5.67')(38.3')$$
$$+ (2640')(5.67')(34.9') + (100')(5.67')(41.9')$$
$$+ (100')(5.67')(46.9') + (34.9')(5.67')(3250')$$
$$+ (1100')(5.67')(36.8') + (100')(5.67')(43.0')$$
$$+ (100')(5.67')(48.6')$$

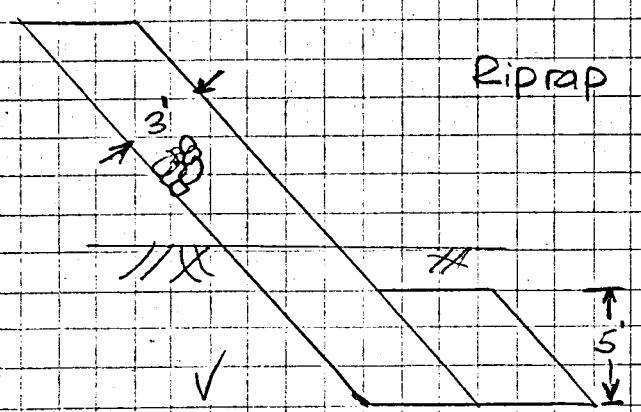
$V_{sc} = 1,875,050\ ft^3$ or $\underline{69,450\ yd^3}$

East Bank

$$V_{sc} = (750')(5.67')(31.2') + (500')(5.67')(24.5')$$
$$+ (34.5')(5.67')(2950') + (100')(5.67')(41.9')$$
$$+ (100')(5.67')(46.9') + (34.9')(5.67')(3250')$$
$$+ (1100')(5.67')(36.8') + (100')(5.67')(43.0')$$
$$+ (100')(5.67')(48.6')$$

$V_{sc} = 1,754,130\ ft^3$ or $\underline{64,970\ yd^3}$

Riprap



$V_{RR} = 2,817,000\ ft^3$ or $\underline{104,330\ yd^3}$

West Bank

$$V_{RR} = (1450')(3')(3)\left(\frac{30.4' + 30.8'}{2}\right) + (100')(3')(3)\left(\frac{30.8' + 2[illegible]}{2}\right)$$
$$+ (2640')(3')(3)\left(\frac{23.3' + 26.3'}{2}\right) + (100')(3')(3)\left(\frac{26.3' + 33.2'}{2}\right)$$
$$+ (100')(3')(3)\left(\frac{33.2' + 33.4'}{2}\right) + (3250')(3')(3)\left(\frac{23.7' + 25.5'}{2}\right)$$
$$+ (1100')(3')(3)\left(\frac{25.5' + 26.5'}{2}\right) + (100')(3')(3)\left(\frac{26.5' + 34.3'}{2}\right)$$
$$+ (100')(3')(3)\left(\frac{34.3' + 34.5'}{2}\right) + (1450')(15')(5') + (7490')(15')(3')$$

Riprap Protection

East Bank

$$V_{RR} = (750')(3')(3)\left(\frac{21.9'+22.2'}{2}\right) + (500')(3')(3)\left(\frac{17.6'+17'}{2}\right)$$

$$+ (2950')(3')(3)\left(\frac{22.4'+26.3'}{2}\right) + (100')(3')(3')\left(\frac{26.3'+33.2'}{2}\right)$$

$$+ (100')(3')(3)(33.3') + (3250')(3')(3)(24.6') + (1100')(3')(3)(26.0')$$

$$+ (100')(3')(3)(30.4') + (100')(3')(3)(34.4') + (8940')(15')(3')$$

✓ $V_{RR} = 2{,}366{,}200\ ft^3$ or $\underline{87{,}640\ yd^3}$

Filter Fabric

West Bank

$$A_{FF} = (1450')(3)(30.6') + (100')(3)(27.0') + (2640')(3)(24.8')$$
$$+ (100')(3)(29.8') + (100')(3)(33.3') + (3250')(3)(24.6')$$
$$+ (1100')(3)(26.0') + (100')(3)(30.4') + (100')(3)(34.4')$$

✓ $A_{FF} = 701{,}650\ ft^2$ or $\underline{77{,}960\ yd^2}$

East Bank

$$A_{FF} = (750')(3)(22.1') + (500')(3)(17.3') + (2950')(3)(24.4')$$
$$+ (100')(3)(29.8') + (100')(3)(33.3') + (3250')(3)(24.6')$$
$$+ (1100')(3)(26.0') + (100')(3)(30.4') + (100')(3)(34.4')$$

✓

$A_{FF} = 655{,}635\ ft^2$ or $\underline{72{,}850\ yd^2}$

SIMONS, LI & ASSOCIATES
ENGINEERING CONSULTANTS
FORT COLLINS, COLORADO

CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: 7-0 to Thomas Road 3:1 ss levees

JOB NO. AZ-MC-05
DATE CHECKED
CHECKED BY

PAGE 2A/5
DATE 2/7/84
COMPUTED BY MM

section	Dist	AREA EAST LEVEE ft²	AREA WEST LEVEE ft²	VOL EAST LEVEE Yd³	VOL WEST LEVEE Yd³
283+50		0	0		
	1255			4810	11 852
294+00		1207	510		
	1500			16,500	29416
308+30		387	549		
	900			13,950	15450
316+20		450	378		
	720			10,667	8,946
323+20		350	293		
	1090			12 857	12 979
334+20		287	350		
	1040			8955	11,594
344+20		178	252		
	440			3 145	3748
348+60		208	208		
	925			10,889	7776
358+30		427.7	246		
	1225			20,251	9754
370+50		465	184		
				102,024 Yd³	104,515 Yd³

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FORT COLLINS, COLORADO

CLIENT: FED of MC
PROJECT: SPF Design
DETAIL: I-10 to Thomas Levee Fill
JOB NO.: AZ-MC-05
DATE CHECKED:
CHECKED BY:
PAGE: 2B/5
DATE: 2/8/84
COMPUTED BY: DMM

Section	Dist. (1:1)	AREA EAST LEVEE	AREA WEST LEVEE	Vol EAST LEVEE	Vol WEST LEVEE
	0				
283+50		0	101		
	1255			3881	9450
294+00		187	407		
	1500			12,888	19,861
308+30		297	308		
	900			11,050	9266
316+20		366	248		
	720			8560	6426
323+20		276	234		
	1090			10,193	10,294
334+20		229	276		
	1040			7222	9225
344+20		146	203		
	440			2566	2998
348+60		169	165		
	925			8616	6218
358+30		334	198		
	1220			15701	8012
370+50		361	158		
				80,677 yd³	81,780 yd³

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3/5
11:E
2/7/04

Figure 7.5 East bank Agua
Fria I-0
Thomas Road
Detroit Siphon

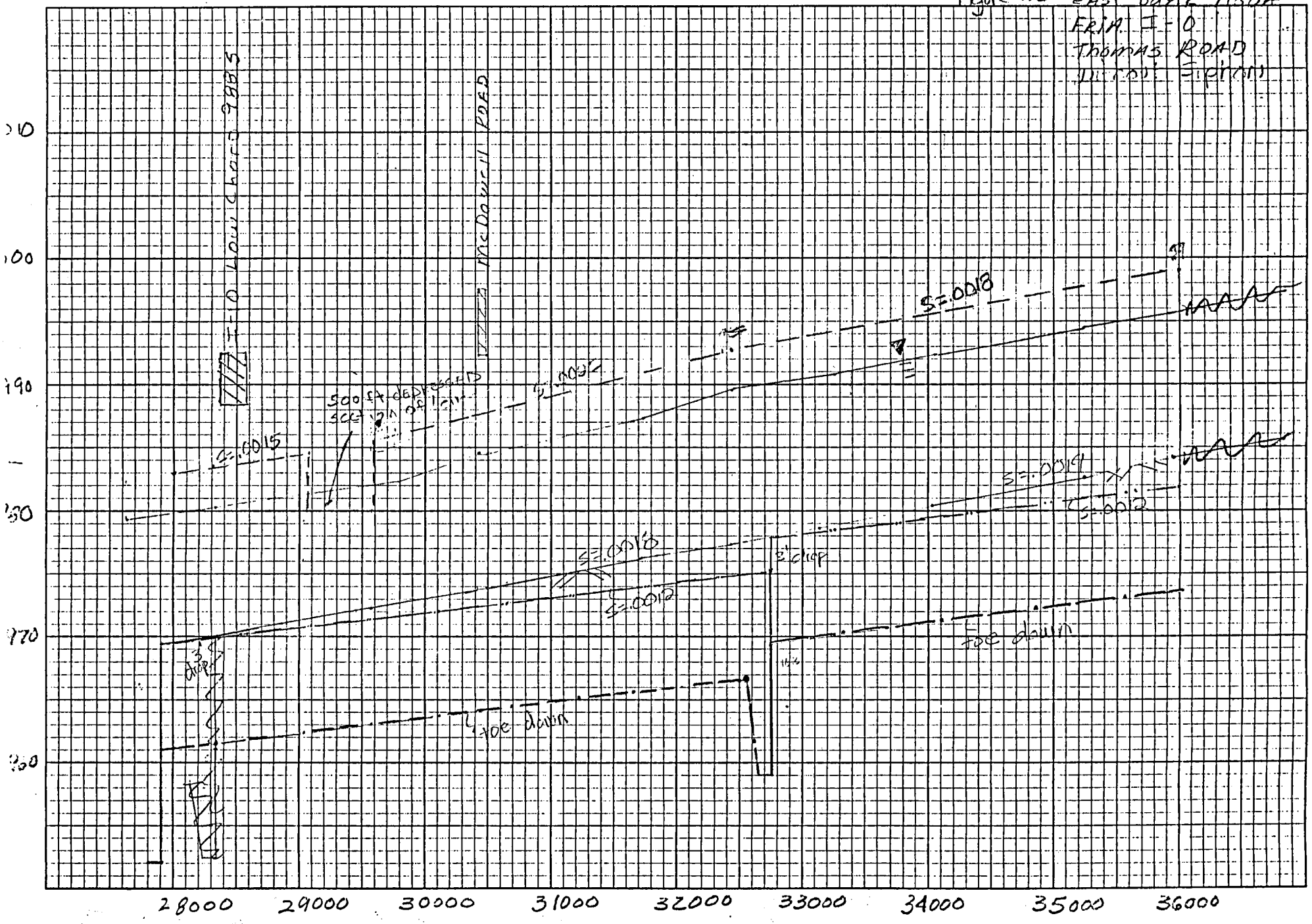

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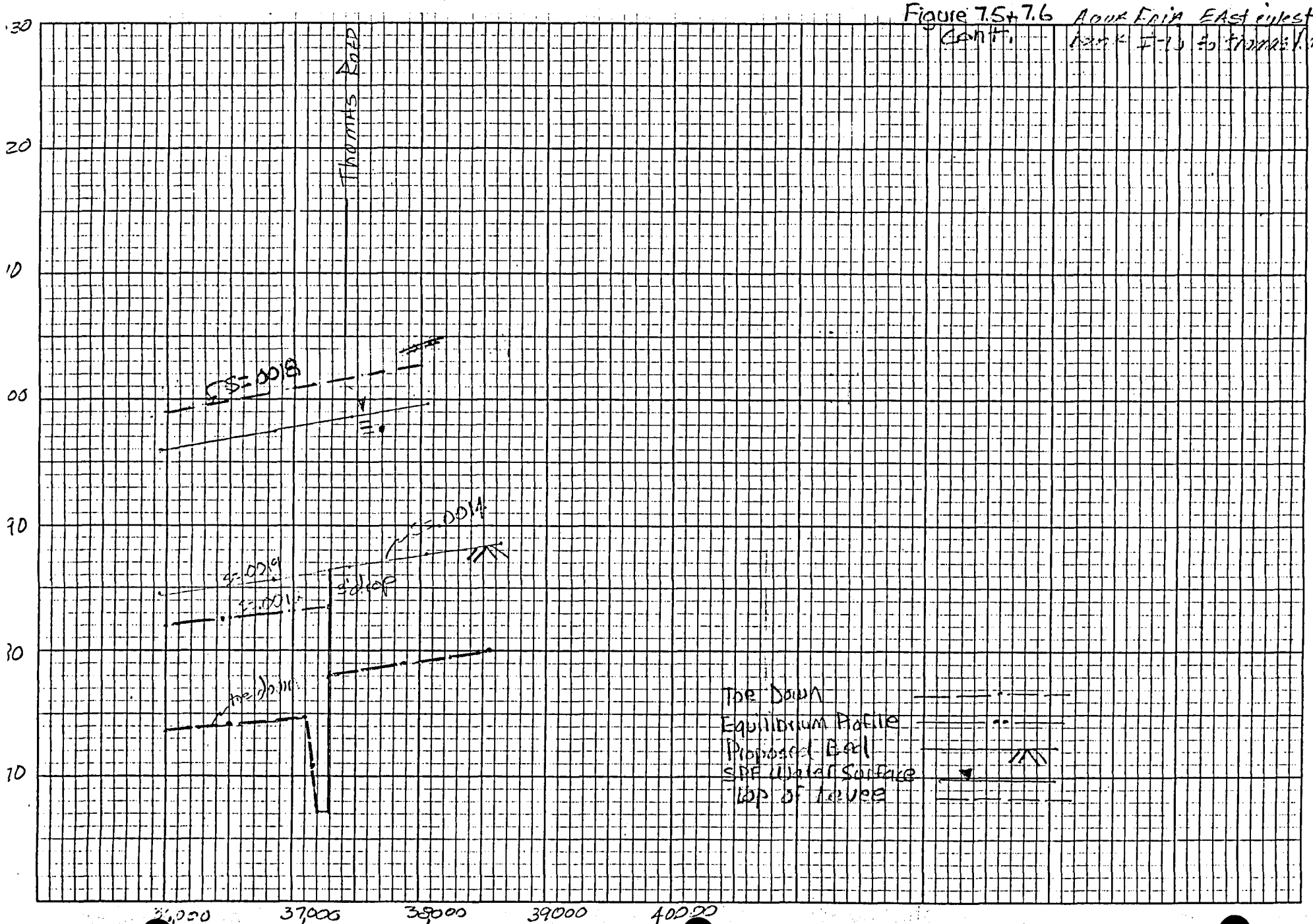
Figure 7.5+7.6 Aqua Fria East Levee
Cont. Bank I-10 to Thomas Road



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KEUFFEL & ESSER CO. MADE IN U.S.A.

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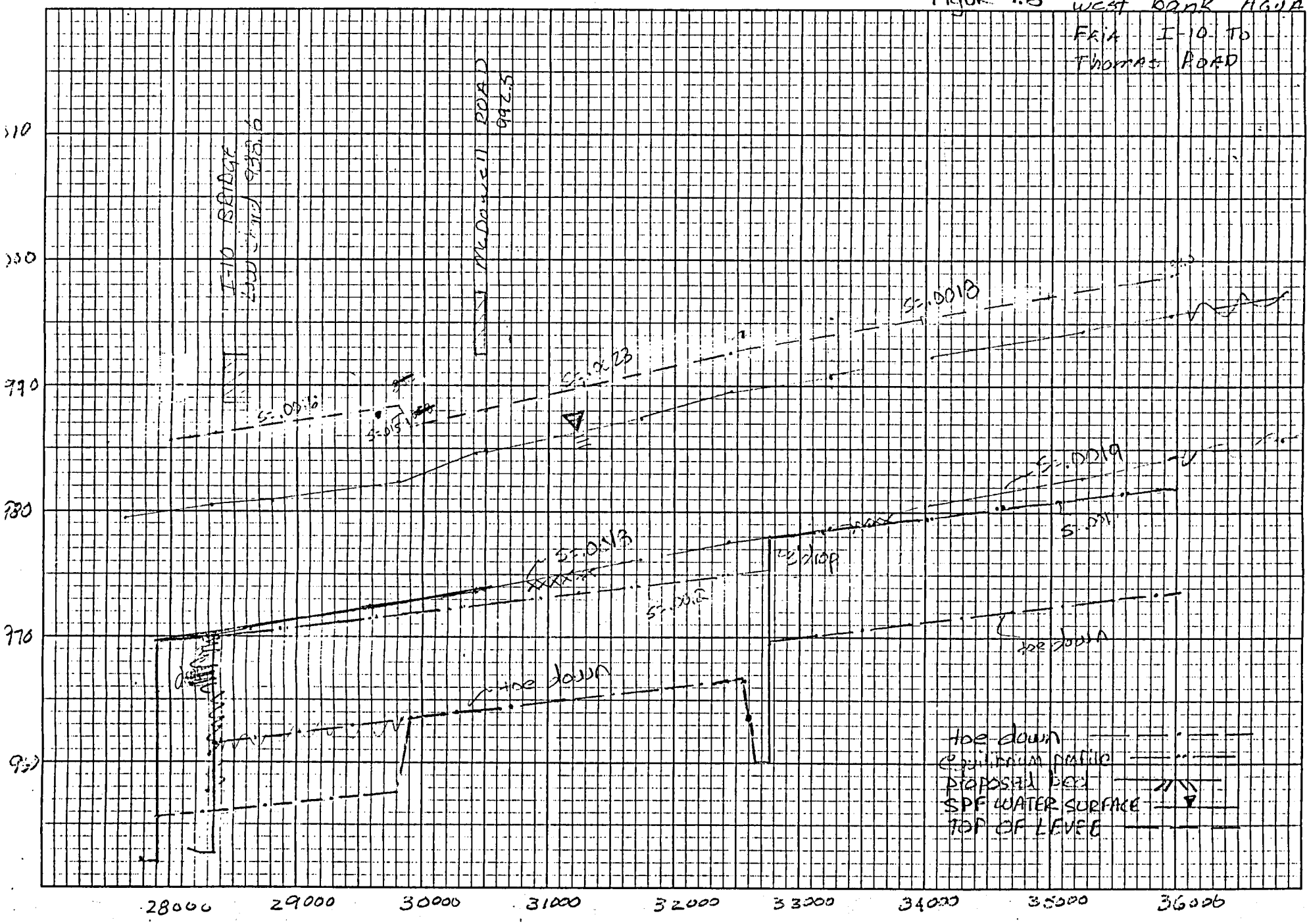
Figure 7.6 west bank Agua Fria I-10 To Thomas Road



SIMONS, LI & ASSOCIATES
ENGINEERING CONSULTANTS
FORT COLLINS, COLORADO

CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: ROW Acquisition U/S of ISRB.
JOB NO.: AZ-MC-05
DATE CHECKED:
CHECKED BY:
PAGE: 1/1
DATE: 2/26/04
COMPUTED BY: MJB

Area upstream of ISRB for ROW.

Area.

62.83 acres. Parcel 48 $(1170 \times 570) + (1200')(1300') + (1/2)(1200')(950')$

18.24 acres Parcel 50 $\left(\frac{630+780}{2}\right) 220 + \left(\frac{730+670}{2}\right) 350 + 650'\left(\frac{530+700}{2}\right)$

24.42 acres Parcel 47 $(350 \times 550) + \left(\frac{700+550}{2}\right)(220)$

$\left(\frac{700+1050}{2}\right)(530) + (1350')(200')$

11.19 acres Parcel 45 $(650 \times 750')$

1.40 acres PARCEL 58 $(70' \times 870')$

18.42 acres Parcel 46 $(1360' \times 590')$

5.45 acres Parcel 26 $(250' \times 950')$

15.56 acres Parcel 49. $\left(\frac{950'+360'}{2}\right)(650') + \left(\frac{360'+540'}{2}\right)(560')$

total 157.51 acres.

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ENGINEERING CONSULTANTS
FORT COLLINS, COLORADO

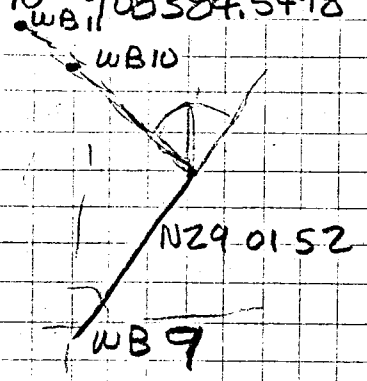
CLIENT FCD of MC — JOB NO. AZMC-05 — PAGE 1/1
PROJECT SPF Design — DATE CHECKED — DATE 2/27
DETAIL West transverse Dike Alignment U/S OF ISRB — CHECKED BY — COMPUTED BY MJB

Coordinates of West Bank Transverse Dike.

WB 11 E 377,730.0 N 909,730.0 — Tangent N 55°41'59" W

Coordinates of West Bank

WB 9 E 378,287.7065 N 908384.5498 — Tangent N 29°01'52" E



$$\Delta = \begin{array}{r} 55^\circ 41' 59'' \\ 29\ 01\ 52 \\ \hline 84^\circ 43' 51'' \end{array}$$

$\Delta = 84^\circ 43' 51''$

INTERSECTION OF TWO LINES.

Bearing 1 = N 29° 01' 52" E
Dist 1 = 800.5691 ft.
Bearing 2 S 55.41 59 E
Dist 2 = 1145.40
PI { N3 = 909,084.53
E3 = 378,676.2102

T = 800.5691 ft.

$$R = \frac{T}{\tan \frac{1}{2}\Delta} = \frac{800.5691}{\tan(1/2)(84^\circ 43' 51'')} = 877.7985'$$

$$D = \frac{5729.58}{877.7985} = 6^\circ 31' 38''$$

$L = 100 \frac{\Delta}{D} = 1298.11'$

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FORT COLLINS, COLORADO

CLIENT: FCD of MC | JOB NO. AZ-MC-05 | PAGE 1/4
PROJECT: | DATE CHECKED: | DATE 1/24/84
DETAIL: Quantities between Buckeye ← I-10 Water Siphon | CHECKED BY: | COMPUTED BY MTB

1) Channelization quantities

Backfilling of gravel pits	70,000 yd³
3:1 ss. Levee volume East Bank	89,015 yd³
3:1 ss. Levee volume West Bank	94,525 yd³
1:1 ss Levee Volume East Bank	73,375 yd³
1:1 ss Levee Volume West Bank	79,100 yd³
Excavation Volume	741,960 yd³

2) Drop structure quantities

Soil Cement	29,250 yd³
Structural Excavation	71,020 yd³
Special backfill	20,900 yd³
Common fill	20,900 yd³
Rip rap upstream of drop	3,130 yd³
gravel filter	1,570 yd³

3) Transmission tower

7 towers — 7 towers

4) Land Acquisition

300 acres — 300 acres
≈(150 acres owned by County + State)

5) Bank Protection

Soil Cement

East Bank	62,080 yd³
West Bank	68,525 yd³

Rip rap

East Bank	83,510 yd³
West Bank	105,555 yd³
filter fabric East Bank	69,680 yd²
filter fabric West Bank	73,415 yd²

6) I-10 Bridge pier protection

rip rap	17,930 yd³
gravel filter	8,900 yd³
drainage excavation	26,890 yd³

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FORT COLLINS, COLORADO

CLIENT FCD of MC
PROJECT SPF Design
DETAIL Cost + Quantities

JOB NO. AZ-MC-05
DATE CHECKED
CHECKED BY

PAGE 2/4
DATE 2/8/84
COMPUTED BY MJB

7) SPRR Bridge Pier Protection

Riprap	7465 yd^3
Gravel Filter	3730 yd^3
Drainage Excavation	11,195 yd^3

8) Buckeye Road Bridge Pier Protection.

Riprap	7,790 yd^3
Gravel Filter	3,900 yd^3
Drainage Excavation	11,690 yd^3

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CLIENT: FCD of MC | JOB NO. AZ-MC-05 | PAGE 3/4
PROJECT: | DATE CHECKED: | DATE 1/24/84
DETAIL: Quantities + Cost between Buckeye Road + I-10 | CHECKED BY: | COMPUTED BY MJB

1) Channelization

1:1 SS	Common Fill levee + pits	322,475 yd^3 @	1.25/yd^3	= $ 403,015.0
3:1 SS	Common Fill levee + pits	353,540 yd^3 @	1.25/yd^3	= $ 441,925.0
	Excavation Volume	741,960 yd^3 @	.90/yd^3	= $ 667,765.0
	Channel Fill	291,150 yd^3		

2) Drop Structure

Soil Cement	29,250 yd^3 @	22.50/yd^3	= $ 658,125.0
Structural Excavation	71,020 yd^3 @	2.00/yd^3	= $ 142,040.0
Special Backfill	20,900 yd^3 @	2.00/yd^3	= $ 41,800.0
Common Fill	20,900 yd^3 @	1.25/yd^3	= $ 26,125.0
Riprap	3,130 yd^3 @	22.0/yd^3	= $ 68,860.0
gravel filter	1,570 yd^3 @	15.0/yd^3	= $ 23,550.0

✓ subtotal $960,500.0

3) Transmission Tower Protection

7 towers @ $100,000/tower ✓ $700,000.0

4) Land Acquisition

300 acres @ $5000/acre ✓ $1,500,000

5) Bank Protections

Soil Cement	130,605 yd^3 @	22.50/yd^3	✓ $2,938,610
Riprap	189,065 yd^3 @	22.00/yd^3	✓ = $ 4,159,430
filter fabric	143,095 yd^2 @	1.50/yd^2	✓ = $ 214,640

6) I-10 Pier protection

riprap	17,930 yd^3 @	22.00/yd^3	= $ 394,460
gravel filter	8,960 yd^3 @	15.00/yd^3	= $ 134,400
drainage excavation	26,890 yd^3 @	.90/yd^3	= $ 24,200

subtotal $553,060.0

7) Buckeye Road Bridge Pier Protection

Riprap	7740 yd^3 @	$22.0/$yd^3$	✓ $171,380
Gravel filter	3900 yd^3 @	$15.0/$yd^3$	✓ $58,500
Drainage Excavation	11,690 yd^3 @	$.90/$yd^3$	✓ $10,520

$240,400

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CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Cost and Quantities
Buckeye Road + I-10

JOB NO.: A7-MC-05
DATE CHECKED:
CHECKED BY:

PAGE: 4/4
DATE: 2/8/84
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8) SPRR Bridge Pier Protection

Riprap	7465 yd³ @ $22.0/yd³	$164,230
Gravel Filter	3730 yd³ @ $15/yd³	$55,950
Drainage Excavation	11,195 yd³ @ $.90/yd³	$10,075
	subtotal	$230,255

Cost of Protection Measures with Soil Cement $6,693,685
10% contingencies and construction super $669,370
$7,363,055
land acquisition $750,000
$8,113,055

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CLIENT FCD of MC — JOB NO. AZ-MC-05 — PAGE 1/
PROJECT SPF — DATE CHECKED — DATE 2/8/84
DETAIL Above ISRB — CHECKED BY — COMPUTED BY MJB

QUANTITY + COSTS without siphon

1) Channelization

Levees
Common Fill

Soil cement 1:1 SS	West Levee	8,575 yd^3
Riprap 3:1 SS	West Levee	14,410 yd^3
Channel Excavation		477,850 yd^3

2) TRANSVERSE Dike #2

Riprap	20,780 yd^3
Filter Fabric	23,800 yd^2
Common Fill	33,250 yd^3
Soil Cement	21,205 yd^3
Common Fill	6,925 yd^3

3) TRANSVERSE DIKE #1

Riprap	8,170 yd^3
Filter fabric	9,330 yd^2
Common Fill	12,[illegible] yd^3
Soil Cement	8320 yd^3
Common Fill	2,540 yd^3

4) West Bank Transverse Dike

Riprap	3170 yd^3
Filter Fabric	3160 yd^2
Common Fill	4650 yd^3
Soil Cement	2820 yd^3
Common Fill	3840 yd^3

5) SPUR Dike

Riprap	4870 yd^3
Filter Fabric	4870 yd^2
Common Fill	8000 yd^3
Soil Cement	4340 yd^3
Common Fill	2240 yd

6) Land Acquisition — ~~[illegible]~~ acres 157.5

7) Floodwall on Indian School Road —

8) BANK Protection

Soil Cement West Levee	13,860 yd^3
Riprap West Levee	18,930 yd^3
Filter Fabric West Levee	15,510 yd^2

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CLIENT: FCD of MC | JOB NO. A2-MC-05 | PAGE 2/3
PROJECT: SPF Design | DATE CHECKED: | DATE 2/8/84
DETAIL: ISRB to Camelback Rd | CHECKED BY: | COMPUTED BY MJB

Cost and Quantities without Siphon.

1) Channelization

3:1 ss	Common Fill	14410 yd³ @ $1.25/yd³	$18,000
1:1 ss	Common Fill	8575 yd³ @ $1.25/yd³	$10,720
	Drainage Excavation	477,850 yd³ @ $.90/yd³	$430,065
			$440,785

2) Tranverse Dike #2

Soil Cement	21,205 yd³ @ $22.50/yd³	$477,110
Common Fill	6,925 yd³ @ $1.25/yd³	$ 8,660
	Subtotal	485,770
Riprap	20,780 yd³ @ $22.00/yd³	$457,160
Filter Fabric	23,800 yd² @ $1.50/yd²	$ 35,700
Common Fill	33,250 yd³ @ $1.25/yd²	$ 41,560
	Subtotal	$534,420

3) Transverse Dike #1

Soil Cement	8320 yd³ @ $22.50/yd³	$187200
Common Fill	2590 yd³ @ $1.25/yd³	$ 3,240
	subtotal	$190,440
Riprap	8170 yd³ @ $22.0/yd³	$179,740
Filter Fabric	9330 yd² @ $1.50/yd²	$ 13,995
Common Fill	12445 yd³ @ $1.25/yd³	$ 15,560
	subtotal	$209,295

4) West Bank Transverse Dike

Soil Cement	2820 yd³ @ $22.50/yd³	$63450
Common Fill	3840 yd³ @ $1.25/yd³	$ 4800
		$68,250
Riprap	3170 yd³ @ $22.0/yd³	$69,740
Filter fabric	3160 yd² @ $1.50/yd²	$ 4,740
Common Fill	4650 yd³ @ $1.25/yd³	$ 5,810
		$80,290

5) SPur Dike

Soil Cement	4340 yd³ @ $22.50/yd³	$97,650
Common Fill	2240 yd³ @ $1.25/yd³	$ 2800
		$100,450

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CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: ISRB to Camelback
Cost + Quantity Estimate w/o siphon

JOB NO. AZ-MC-05
DATE CHECKED:
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DATE 2/8/84
COMPUTED BY MJB

5) cont. Spur Dike

Riprap	4870 yd³ @	$22.00/yd³	$107,140
Filter Fabric	4870 yd² @	$1.50/yd²	$7,305
Common Fill	8000 yd³ @	$1.25/yd³	$10,000
		subtotal	$124,445

6) Land Acquisition

157.51 acres at $5000/acre ✓ $787,500

7) Bank Protection

Soil Cement	13,860 yd³ @	$22.50/yd³	✓ $311,850
Riprap	18,930 yd³ @	22.00/yd³	✓ $416,460
Filter Fabric	15,510 yd² @	1.50/yd²	✓ $23,265
		subtotal	$439,725

8) Floodwall Protection on Indian School Road 155,360

Total cost for Soil Cement Protection $1,752,905
10% contingencies + construction super. 175,290
$1,928,195

land acquisition 787,500

$2,715,695

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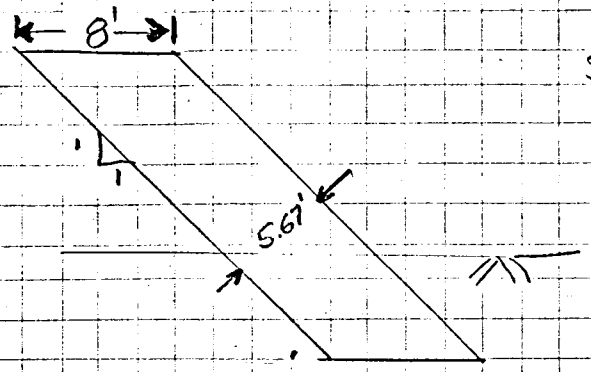
CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: V7
PROJECT: SFF Design | DATE CHECKED: | DATE: 2/7/84
DETAIL: Bank Protection | CHECKED BY: | COMPUTED BY: MJB

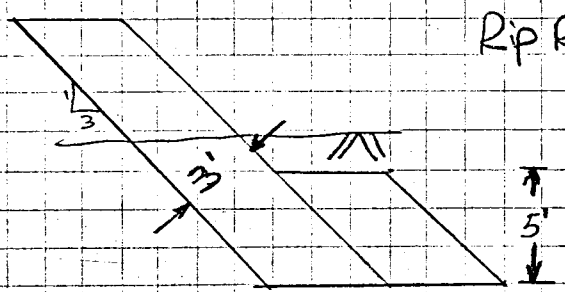
Upstream of ICRB without siphon.



Soil Cement

West Bank

$V_{SC} = (2050')(5.67')(32.2') = 374{,}280\ ft^3$ or $\underline{13{,}860\ yd^3}$



Rip Rap

West Bank

$V_{RR} = (2050')(3')(3)\left(\frac{22.5' + 22.9}{2}\right) + (15')(3')(2050')$

$V_{RR} = 511{,}065\ ft^3$ or $\underline{18{,}930\ yd^3}$ ✓

Filter Fabric

$A_{FF} = (2050')(3)(22.7') = 139{,}605\ ft^2$ or $\underline{15{,}510\ yd^2}$ ✓

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CLIENT FCD of MC
PROJECT SPF Design
DETAIL TSRB to Camelback Rd. Levee Fill without siphon

JOB NO. AZ-MC-05
DATE CHECKED
CHECKED BY

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DATE 2/8/84
COMPUTED BY DMM

3:1

Section	Distance	AREA Levee ft²	Vol Levee yd³
4[illegible]			
	0		
427+35		0	
	900		4,016
433+50		241	
	545		4228
439+45		178	
	525		2595
444+75		89	
	730		3569
452+60		175	
			14,408 yd³

Section	Distance	AREA Cut	AREA Fill	Vol Cut	Vol Fill
	0				
427+35		7587	0		0
	900			237,783	
433+50		6680	0		0
	545			126,944	
439+45		5898	0		0
	525			113,127	
444+75		5738	0		0
	730				
[illegible]				477,854 yd³	

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CLIENT FCD of MC JOB NO. AZ-MC-05 PAGE 3/4
PROJECT SPF Design DATE CHECKED DATE 2/8/84
DETAIL FSRB to Camelback Rd CHECKED BY COMPUTED BY DMM

1:1 side slopes

Section	Dist	West Levee ft²	vol yd³
	0		
427+35		0	
	900		3300
433+50		198	
	545		3330
439+45		132	
	525		1944
444+75		68	
	730		
			8,575 yd³

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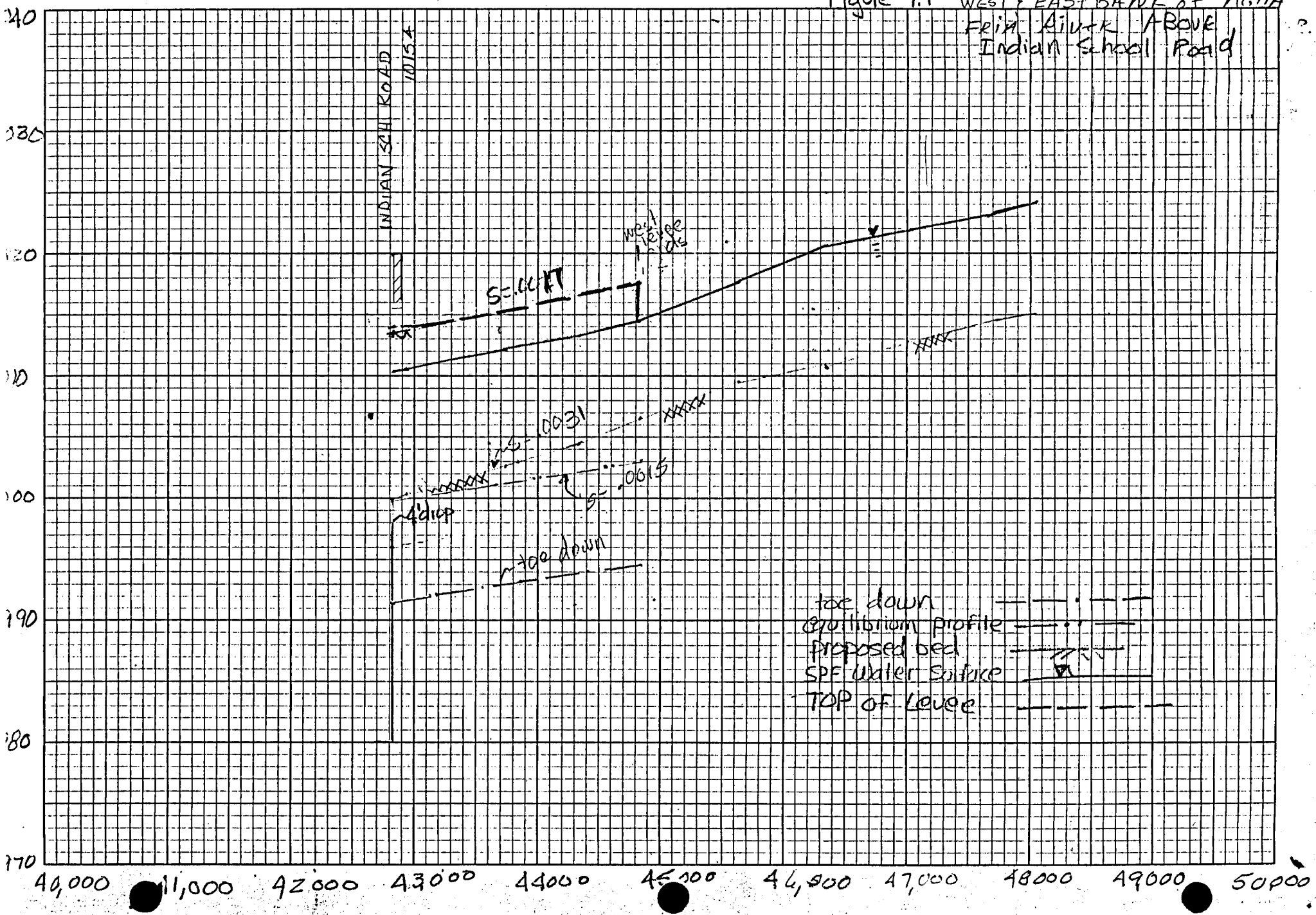
Figure 7.1 West & East bank of Agua Fria River Above Indian School Road



East Bank

$$V_{RR} = (3')(3340')(3)\left(\frac{22.9'+25.8'}{2}\right) + (3')(4560')(3)\left(\frac{25.8+25.5'}{2}\right)$$

$$+ (3')(100')(3)\left(\frac{25.5'+32.9}{2}\right) + (3')(100')(3)\left(\frac{32.9+33.6}{2}\right)$$

$$+ (3')(200')(3)\left(\frac{22.4'+22.9}{2}\right) + (8300')(3')(15')$$

$V_{RR} = 2{,}254{,}840\ ft^3$ or $\underline{83{,}510\ yd^3}$

Filter fabric East Bank Protection

$$\text{Area} = (3340')(3)\left(\frac{22.9+25.8}{2}\right) + (4560')(3)\left(\frac{25.8+25.5}{2}\right)$$

$$+ (100')(3)\left(\frac{25.5+32.9}{2}\right) + (100')(3)\left(\frac{32.9+33}{2}\right)$$

$$+ (200')(3)\left(\frac{22.4+22.9}{2}\right)$$

Area $= 627{,}115\ ft^2$ or $\underline{69{,}680\ yd^2}$

Filter Fabric West Bank

$$\text{Area} = (3340')(3)\left(\frac{22.9+25.8}{2}\right) + (2760')(3)\left(\frac{25.8+25.6}{2}\right)$$

$$(100')(3)\left(\frac{25.6+33.5}{2}\right) + (1700')(3)\left(\frac{33.5+33.6}{2}\right)$$

$$+ (100')(3)\left(\frac{33.6+32.7}{2}\right) + (200')\left(\frac{22.4'+22.9'}{2}\right)(3)$$

Area $= 660{,}740\ ft^2$ or $73{,}415\ yd^2$

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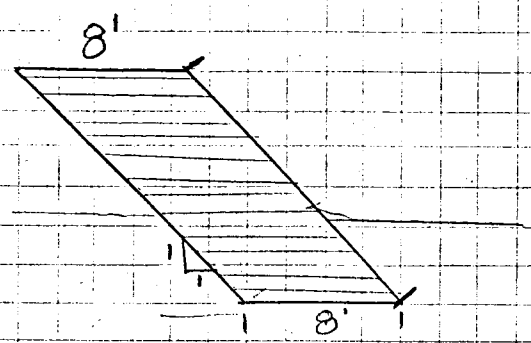
CLIENT FCD of MC | JOB NO. AZ-MC-05 | PAGE 1/2
PROJECT SPF Design | DATE CHECKED | DATE 1/24/84
DETAIL Bank Protection: Soil Cement + Riprap I-10 to Buckeye Rd. | CHECKED BY | COMPUTED BY MJB

1) Soil Cement Bank Protection



West bank

$$V_{sc} = (5.67')(34.4')(3340') + (5.67')(39.9')(2760') + (5.67')(100')(41.7') + (5.67')(47.5)(1700') + (5.67')(100')(49.1') + (5.67')(100')(50.6') + (5.67')(200')(32.0)$$

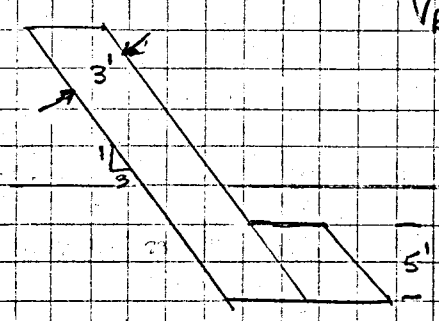
$V_{sc} = 1{,}850{,}180\ ft^3$ or $68{,}525\ yd^3$

EAST Bank

$$V_{sc} = (5.67')(34.4')(3340') + (5.67')(36.3')(4560') + (5.67')(100')(41.2') + (100')(5.67')(46.70) + (200')(5.67')(32.0)$$

$V_{sc} = 1{,}676{,}130\ ft^3$ or $62{,}080\ yd^3$

2) Rip rap Bank Protection West bank



$$V_{RR} = (3')(3340')\left(\frac{22.9'+25.8'}{2}\right)(3) + (3')(2760')(3)\left(\frac{25.8'+25.6'}{2}\right) + (5')(100')(3)\left(\frac{25.6+33.5}{2}\right) + (5')(1700')(3)\left(\frac{33.5+33.6}{2}\right) + (5')(3)(100')\left(\frac{33.6'+35.7}{2}\right) + (3')(200')(3)\left(\frac{22.4'+22.9}{2}\right) + (3')(63\ldots) + (2000')(5')(15') + (5')(3)(100')(35.7')$$

$V_{RR} = 2{,}849{,}995\ ft^3$ or $105{,}555\ yd^3$

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CLIENT: FCD of MC.
PROJECT: SPF design
DETAIL: Net Volume of Excavation I-10 to Buckeye Road.
JOB NO.: AZ-MC-05 (28)
DATE CHECKED:
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DATE: 1/26/84
COMPUTED BY: MJB

Channelization volume

1) $\left(\frac{944' + 3030'}{2}\right)(1040') = \checkmark 76,540 \text{ yd}^3$

2) $\left(\frac{3030' + 470'}{2}\right)(1500') = \checkmark 97,220 \text{ yd}^3$

3) $\left(\frac{470' + 625'}{2}\right)(1225') = \checkmark 24,840 \text{ yd}^3$

4) $\left(\frac{625' + 1215'}{2}\right)(1425') = \checkmark 48,560 \text{ yd}^3$

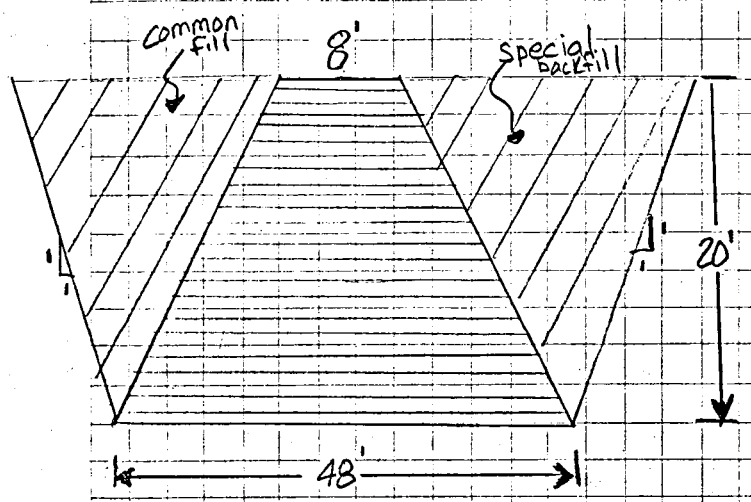
5) $\left(\frac{1215' + 3610'}{2}\right)(1165') = \checkmark 104,100 \text{ yd}^3$

6) $\left(\frac{3610' + 913'}{2}\right)(830') = \checkmark 69,520 \text{ yd}^3$

7) $\left(\frac{913' + 1720'}{2}\right)(780') = \checkmark 38,030 \text{ yd}^3$

$458,810 \text{ yd}^3$

Drop structure Downstream of I-10



Volume of Soil Cement

$$V_{SC} = \left(\frac{48' + 8'}{2}\right)(20')(1410') = \checkmark 789{,}600\ ft^3$$

$$V_{SC} = \checkmark 29{,}250\ yd^3$$

Volume of Structural Excavation

$$V_{SE} = \left(\frac{48' + 88'}{2}\right)(20')(1410') = \checkmark 1{,}917{,}600\ ft^3$$

$$V_{SE} = \checkmark 71{,}020\ yd^3$$

Volume of special backfill

$$V_{SB} = \tfrac{1}{2}(40')(20')(1410') = \checkmark 564{,}000\ ft^3$$

$$V_{SB} = \checkmark 20{,}900\ yd^3$$

Volume of Common fill

$$V_{CF} = \tfrac{1}{2}(40')(20')(1410') = \checkmark 564{,}000\ ft^3$$

$$V_{CF} = 20{,}900\ yd^3$$

Rip rap blanket protection upstream of drop structure

$$V_{RR} = \underset{\text{thick}}{(3')}\underset{\text{length}}{(20')}\underset{\text{width}}{(1410')} = \checkmark 84{,}600 \text{ ft}^3$$

$$V_{RR} = \checkmark 3{,}130 \text{ yd}^3$$

Gravel filter beneath riprap

$$V_{GF} = (1.5')(20')(1410') = \checkmark 42{,}300 \text{ ft}^3$$

$$V_{GF} = \checkmark 1570 \text{ yd}^3$$

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CLIENT: FCD of MC
PROJECT: (SPF) (I-10 to Buckeye Rd)
DETAIL: Channel Cut
JOB NO.: AZ-MC-05
DATE CHECKED:
CHECKED BY:
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DATE: 1/27/84
COMPUTED BY: MJB

	Distance	Channel (Area)	Vol. (yd^3)
202.3		944 sqft	
	1040		✓ 84,182
212.85		3427 sqft	
	1500		✓ 125,938
227.95		1106.75 sqft	
	1225		✓ 62,794
240.20		1661.3 sqft	
	1425		✓ 125,513
254.30		3095 sqft	
	1165		✓ 163,078
266+80		4464 sqft	
	830		✓ 105,136
275+15		2376.15	
	780		✓ 75,318
281+50		2838.2	

total cut = 741,959 yd^3

Channel Fill

	Distance	channel Area	Vol (yd^3)
202+3		0	
	1040		✓ 9,244
212+85		480.	
	1500		✓ 33,785
227+95		736.25	
	1225		✓ 34,600
240+20		789.0	
	1425		✓ 68849
254.30		1820	
	1165		✓ 63,406
266+80		1119	
	830		✓ 41,108
275+15		1555.5	
	780		✓ 41,156
281+50		1293.75	

total Fill = ✓ 292,148 yd^3

Difference = ✓ 449,811

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CLIENT FCD of MC
PROJECT SPF Design
DETAIL Buckeye to I-10, 1:1 side slopes levees

JOB NO. AZ-MC-05
DATE CHECKED
CHECKED BY

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COMPUTED BY MM

Study Reach	Dist	East Levee	Vol Cu Yd	Dist	West Levee	Vol Cu Yd
202+3		0			0	
	1040		2,977	1040		5238
212+85		154.6			272	
	1500		14,794	1500		17,270
227+9		378			350	
	1225		15,811	1225		16,514
240+20		319.2			378	
	1425		17,654	1425		13,405
254+30		350			130	
	1165		12,901	1165		11,585
266+80		248			407	
	830		6,609	830		10,805
275+15		182			296	
	780		2628	780		4,275
281+50		0			0	
			73,374			79,099

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CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: levee Common fill and Channel Excavation I-10 to Buckeye. 3:1 side slopes.

JOB NO.: AZ-MC-05
DATE CHECKED:
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DATE: 1/27/84
COMPUTED BY: MJB

Section No.	EAST Distance (ft.)	Levee (Area)	Vol (yd³)	West Levee. (area)	Vol. yd³
202.3		0			
	1040		3,470		6,355
212.85		180		330	
	1500		17,000		20,280
227.95		432		400	
	1225		18,875		18,940
240.20		400		435	
	1425		20,925		16,200
254.30		393		179	
	1165		14,950		15,125
266+80		300 ft²		522	
	830		9,345		12,975
275+15		308 ft²		322	
	780		4,450		4,650
281+50		0		0	
		subtotal	89,015 yd³		subtotal 94,525 yd³

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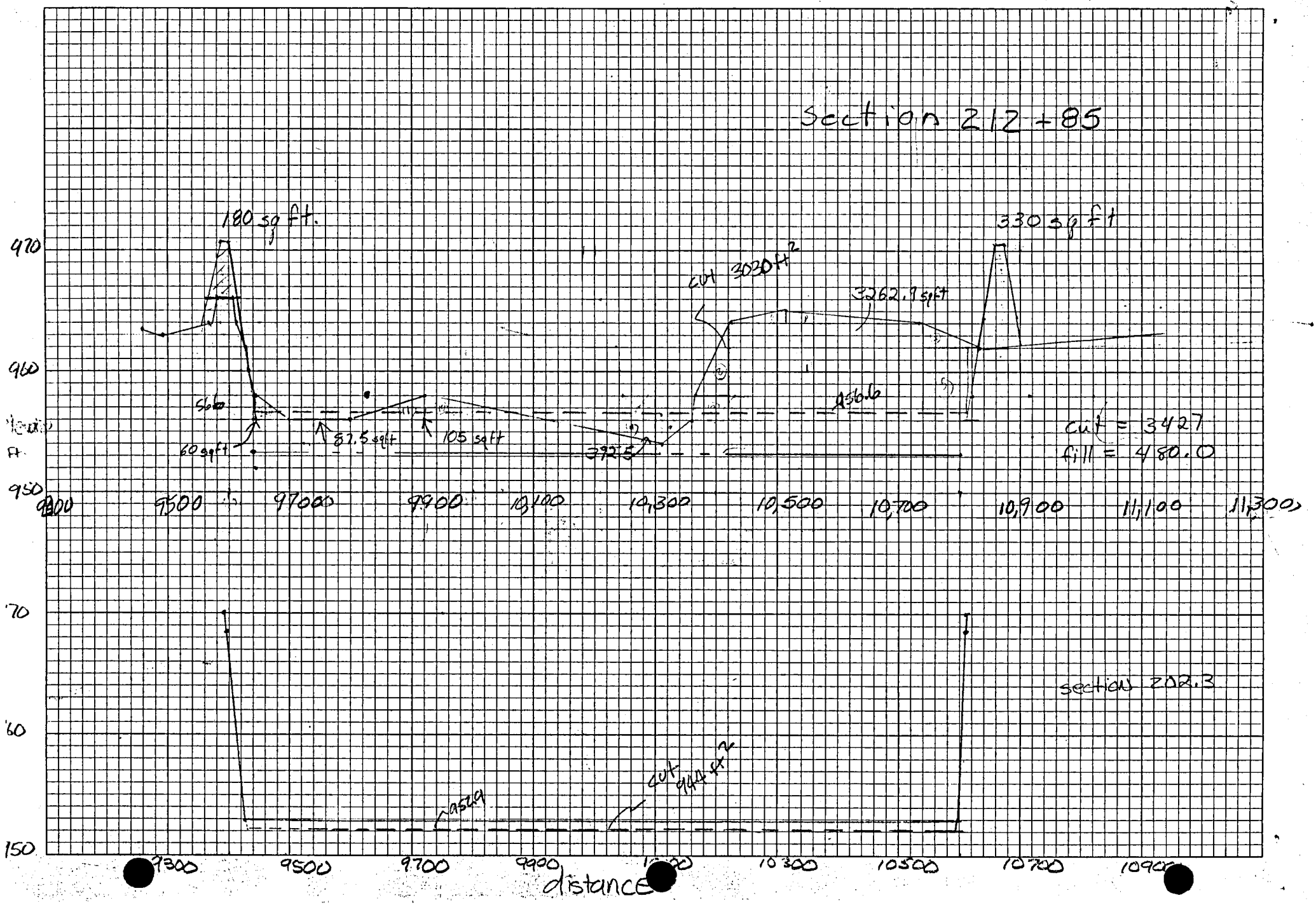

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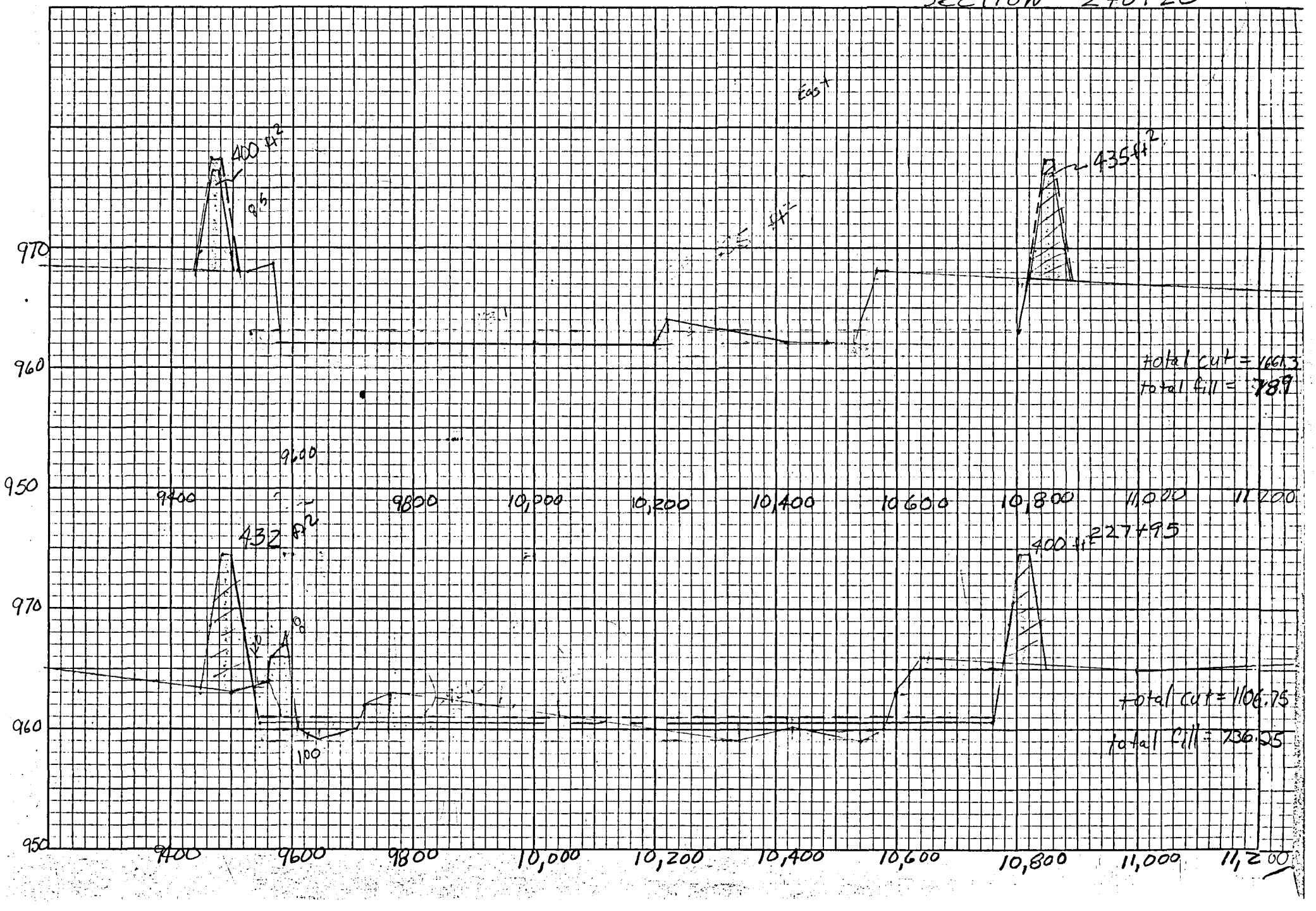
1/27/84

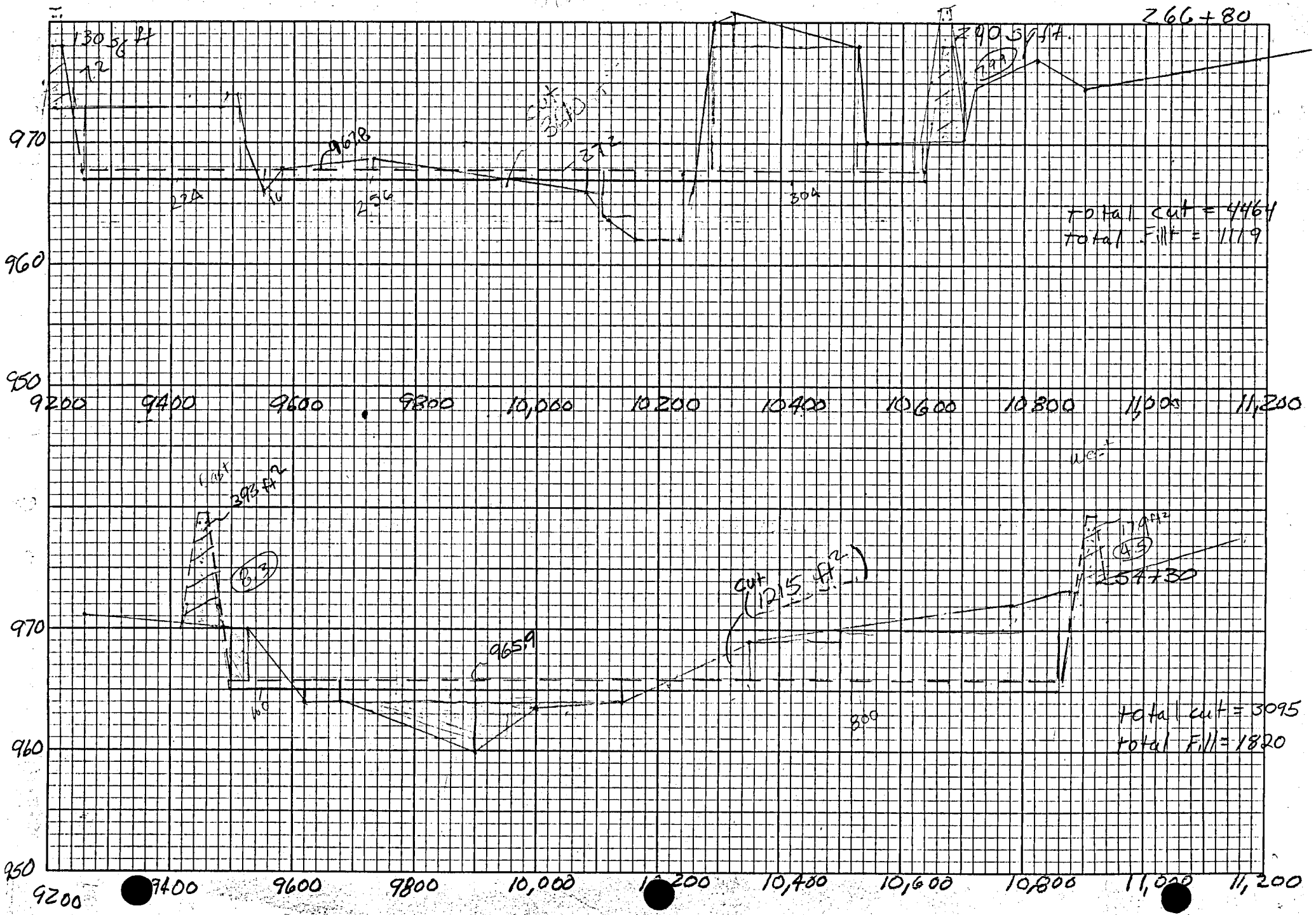
Section 240+20



K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

MM
5/7
1/27/84

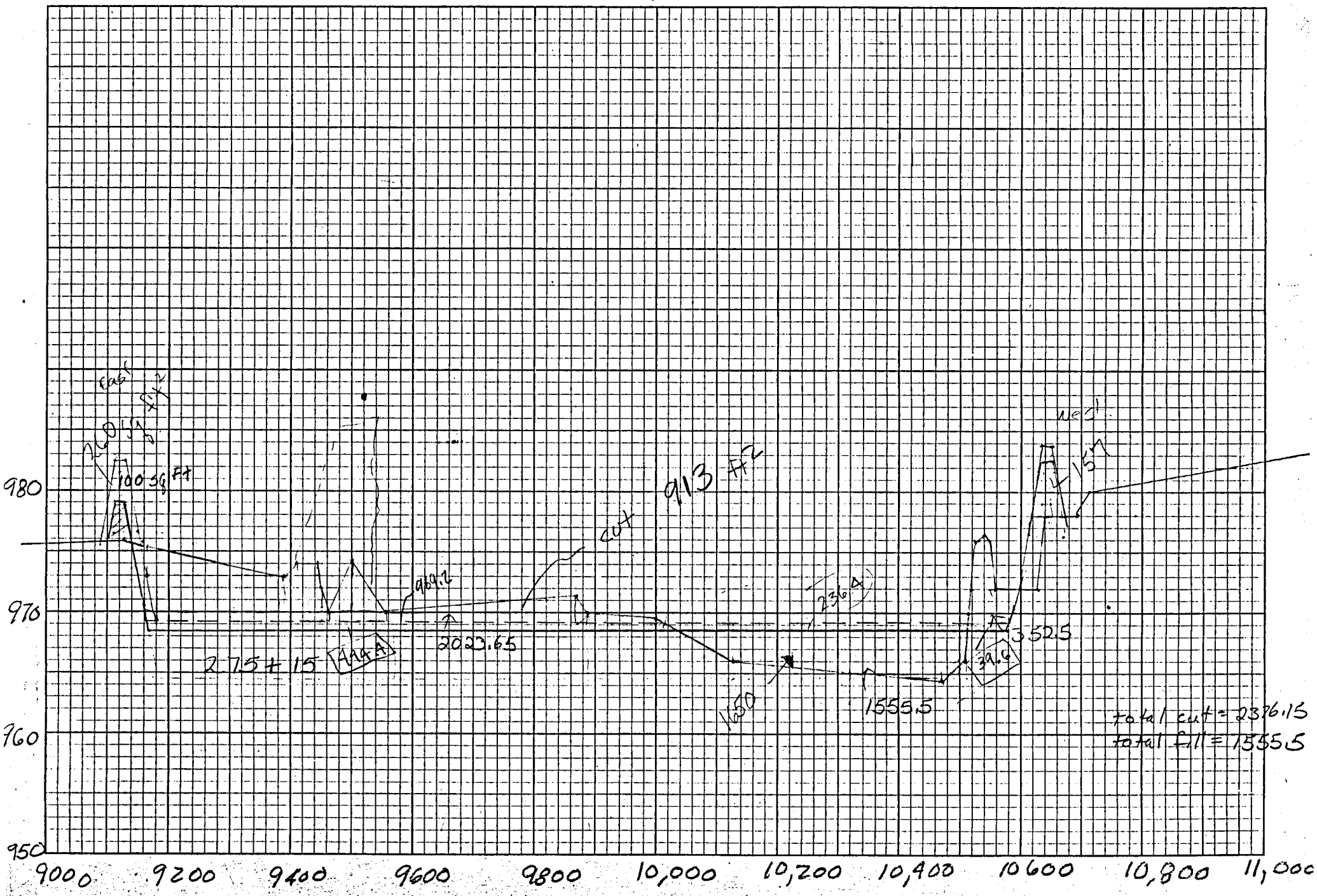


K+E 10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

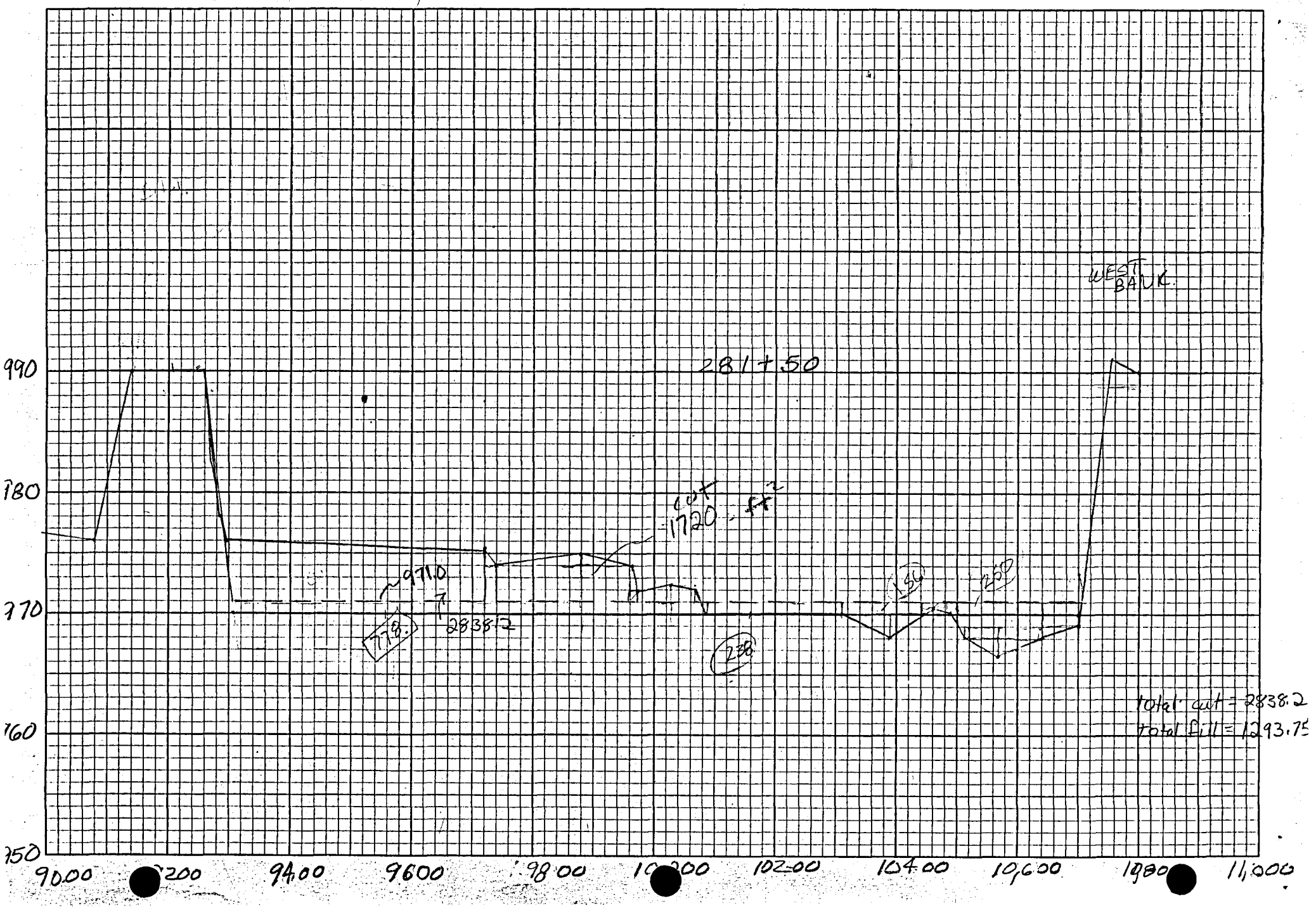
18.8

MM
6/7-
1/27/84



K+E 10 X 10 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 0780

MM 7/7 1/27/84



SIMONS, LI & ASSOCIATES
ENGINEERING CONSULTANTS
FORT COLLINS, COLORADO

CLIENT FCD of MC JOB NO. AZ-MC-05 PAGE 1
PROJECT SPF Design DATE CHECKED DATE 1/26/84
DETAIL Right of Way Acquisition CHECKED BY COMPUTED BY MJB

County Cost Estimates McDowell to Buckeye Road

Flowage easements

Reach	Floodway Tillible (acres)	Floodway Non Tillible (acres)	Fringeway Tillible (acres)	Fringeway Nontillible (acres)	Cost
Buckeye to Van Buren	218	225	150	74	$5,911,000
Van Buren to McDowell	251	257	98	111	$6,028,000
				subtotal	$11,939,000

Tillible ≈ 12,000/acre
Non Tillible ≈ 5,000/acre

STATE of ARIZONA, ADOT + State Highway land owned between McDowell + Buckeye Road Reduces flowage easement cost to $7.1 million

Flood Control District of Maricopa County was given $5.0 million to provide flood control Measures Downstream of I-10.

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CLIENT FCD of MC
PROJECT SPF Design
DETAIL LAND OWNERSHIP I-10 to Buckeye Road

JOB NO. AZ-MC-05
DATE CHECKED 2/1/84
CHECKED BY MJB

PAGE 1/1
DATE 2/1/84
COMPUTED BY MM

Section	Owned By	Acreage in Reach
8	Public Agency State of Az	22.7
10	Public Agency State of Az	1.84
11	Imp. Agric	2.02
32	Public Utility	4.78
33	Imp Agric.	22.25
34	Commercial	49.13
50	Imp Agric	54.15
51	Public Utility	2.16
52	Imp. Agric.	13.40
53	Resident (Vacant) State of Az	12.38
54	Public Agency State of Az	15.65
55	Imp Agric.	4.21
56	Imp Agric	2.89
57	Public Utility	1.15
65	Imp Agric	3.2
69	Imp Agric	28.70
70	Public Agency Maricopa County	16.21
80	Imp Agric	.52
101	Public Agency Maricopa County	14.92
		Total 272.32 Acres

Public Agency State of Az
52.57 Acres

Public Agency Maricopa County
31.13 Acres

Private or Other
188.62

Study Reach between Buckeye Road and I-10

Approximately 30.7% owned by State + County. or 92.2 acres out of 300 acres.

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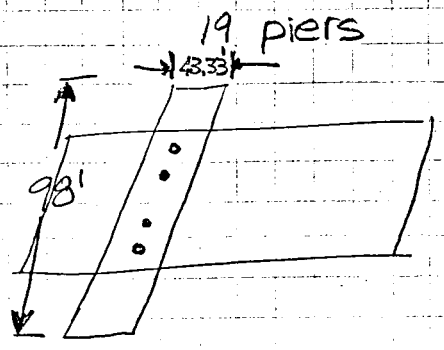
CLIENT: KCDOT MC | JOB NO. A2-MC-05 | PAGE 1/1
PROJECT: SPF Design | DATE CHECKED | DATE 1/24/81
DETAIL: I-10 bridge pier protection | CHECKED BY | COMPUTED BY MTB

I-10 bridge pier protection



diameter of piers 3.33 ft.

161,360 m²

Protection Area

No. of lanes

$(43.33')(98')(19 \text{ piers})(2) = 161{,}360 \text{ ft}^2$

161,249

thickness of riprap 3 ft.

$V_{RR} = (3 \text{ ft})(161{,}360 \text{ ft}^2) = 484{,}080 \text{ ft}^3$ or $\underline{17930 \text{ yd}^3}$

Volume of gravel filter

$V_{GF} = (1.5 \text{ ft})(161{,}360 \text{ ft}^2) = 242{,}040 \text{ ft}^3$ or $\underline{8960 \text{ yd}^3}$

Drainage Excavation Volume

$17930 \text{ yd}^3 + 8960 \text{ yd}^3 = \underline{26{,}890 \text{ yd}^3}$

Riprap sizing around bend at I-10

Data
$Q = 142000$ cfs
$n = .025$
maximum velocity ≈ 19.2 ft/sec
side slope 3 horizontal : 1 vertical $\theta = 18.43°$
flow across rocks $\lambda = 0°$
angular material $f = .066$
angle of repose of material $41°$

D_{50} (ft.)	ϕ	$\tan\phi$	η	$\tan\beta$	β	η'	SF	
2.0	41	.8693	.6005	.8256	39.54	.491	1.23	
2.5	41	.8693	.4804	.6605	33.94	.373	1.41	✓OK

Use D_{50} material 2.5 ft in diameter
may want to consider soil cement

Gradation of Material

D_{100}	5 ft
D_{50-70}	2.5 ft
D_{15-30}	1.25 ft
D_{0-5}	.75 ft

Use filter fabric underneath riprap.

D_{85} of natural material

$$\frac{P_{85}}{D_{85}} \leq 1$$

$P_{85} = .16$ mm

$D_{85} > .16$ mm therefore

Typar 3401 by Dupont will work.

place 6" of natural material above filter fabric before dumping riprap on banks to prevent puncturing of the fabric.

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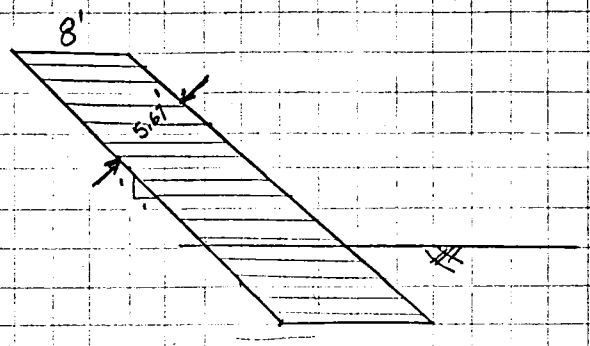
CLIENT: FCD of Maricopa County | JOB NO. AZ-NC-05 | PAGE 1/2
PROJECT: SPF Design | DATE CHECKED: | DATE 1/27/84
DETAIL: Levee Bank Protection I-10 to Thomas Road | CHECKED BY: | COMPUTED BY MJB

Soil Cement Bank Protection



West Bank

$$V_{SC} = (180')(5.67')(42.1') + (1220')(5.67')(42.4')$$
$$+ (100')(5.67')(37.4') + (2700')(5.67')(34.7')$$
$$+ (100')(5.67')(44.0') + (100')(5.67')(51.0')$$
$$+ (3200')(5.67')(34.2') + (1075')(5.67')(37.2')$$
$$+ (100')(5.67')(44.7') + (100')(5.67')(51.5')$$
$$+ (150')(5.67')(32.8')$$

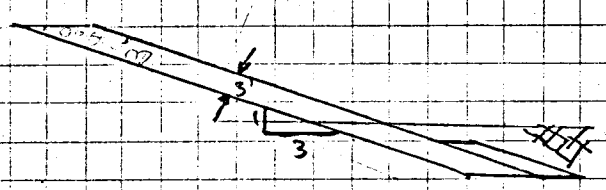
$V_{SC} = 1{,}872{,}270\ ft^3$ or $\approx$ <u>69,340 yd³</u>

East Bank

$$V_{SC} = (180')(5.67')(30.4') + (500')(5.67')(30.8')$$
$$+ (500')(5.67')(23.1') + (900')(5.67')(33.0')$$
$$+ (2100')(5.67')(35.6') + (100')(5.67')(44.1')$$
$$+ (100')(5.67')(51.3') + (3200')(5.67')(34.4)$$
$$+ (1075')(5.67')(37.2') + (100')(5.67')(44.7')$$
$$+ (100')(5.67')(51.5') + (150')(5.67')(32.8')$$

$V_{SC} = 1{,}763{,}550\ ft^3$ or <u>65,315 yd³</u>

Rip Rap Bank Protection



West Bank

$$V_{RR} = (180')(5')\left(\frac{29.8+29.8'}{2}\right)(3) + (1220')(5')\left(\frac{29.8+30.2'}{2}\right)3$$
$$+ (100')(3')\left(\frac{30.2'+23'}{2}\right)(3) + (2700')(3')\left(\frac{23'+26.5'}{2}\right)3$$
$$+ (100')(3')\left(\frac{26.5'+36.2'}{2}\right)3 + (100')(3')\left(\frac{26.2'+36.4'}{2}\right)3$$
$$+ (3200')(3')\left(\frac{22.8'+25.6'}{2}\right)3 + (1075')(3')\left(\frac{25.6'+26.6'}{2}\right)3$$
$$+ (100')(3')\left(\frac{26.6+36.3'}{2}\right)3 + (100')(3')\left(\frac{36.3'+36.5'}{2}\right)3$$
$$+ (150')(3')\left(\frac{23.2+23.3}{2}\right)3 + (\ )(15')(90.25')$$

$V_{RR} = 2{,}763{,}700\ ft^3$ or $102{,}360\ yd^3$

Rip rap Bank Protection

East Bank

$$V_{RR} = (180')(3')\left(\frac{21.5'+21.5'}{2}\right)3 + (500')(3')\left(\frac{21.5'+22'}{2}\right)3 + (500')(3')\left(\frac{16.7'+16.0'}{2}\right)3$$
$$+ (900')(3')\left(\frac{22.3'+24.2'}{2}\right)3 + (2100')(3')\left(\frac{24.2'+28.5'}{2}\right)3 + (100')(3')\left(\frac{26.5'+36.2'}{2}\right)3$$
$$+ (100')(3')\left(\frac{36.2'+36.4'}{2}\right)3 + (3200')(3')\left(\frac{29.8'+25.6'}{2}\right)3 + (1075')(3')\left(\frac{25.6'+26.6'}{2}\right)3$$
$$+ (100')(3')\left(\frac{26.6'+36.3'}{2}\right)3 + (100')(3')\left(\frac{36.3'+36.5'}{2}\right)3 + (150')(3')\left(\frac{23.2'+23.3'}{2}\right) =$$
$$+ (3')(15')(9025')$$

$V_{RR} = 2{,}382{,}500\ ft^3$ or $88240\ yd^3$

Filter fabric Beneath Rip Rap

East Bank

$$A_{FF} = (180')(21.5')(3) + (500')(21.75')(3) + (500')(16.35')(3)$$
$$+ (900')(22.75')(3) + (2100')(25.35')(3) + (100')(31.35')(3)$$
$$+ (100')(36.3')(3) + (3200')(24.2')(3) + (1075')(26.1')(3)$$
$$+ (100')(31.45')(3) + (100')(36.4')(3) + (150)(23.2)(3)$$

Area $= 657{,}470\ ft^2$ or $73{,}050\ yd^2$

West Bank

$$A_{FF} = (180')(29.8')(3) + (220)(30.0')(3) + (100')(26.6')(3)$$
$$+ (2700')(24.15')(3) + (100)(31.35)(3) + (100')(36.3)(3)$$
$$+ (3200')(24.2)(3) + (1075)(26.1)(3) + (100)(31.45)(3)$$
$$+ (100)(36.4)(3) + (150)(23.2)(3)$$

$A_{FF} = 701{,}930\ ft^2$ or $77{,}990\ yd^2$

SIMONS, LI & ASSOCIATES
ENGINEERING CONSULTANTS
FORT COLLINS, COLORADO

CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Cost + Quantities
Buckeye Rd. to I-10 w/o siphon

JOB NO. AZ-MC-05
DATE CHECKED
CHECKED BY

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DATE 2/7/84
COMPUTED BY MJB

1) Channelization

Backfilling of gravel pits	170,000 yd^3
3:1 SS Volume of East Levee	77,550 yd^3
3:1 SS Volume of West Levee	77,980 yd^3
1:1 SS Volume of East Levee	66,135 yd^3
1:1 SS Volume of West Levee	70,730 yd^3
Excavation Volume	875,535 yd^3

(231,510 yd^3 can be filled in channel)

2) Drop Structure below I-10

Soil Cement	23,530 yd^3
Structural Excavation	55,880 yd^3
Special Backfill	16,180 yd^3
Common Fill	16,180 yd^3
Rip Rap	3,130 yd^3
Gravel Filter	1,570 yd^3

3) Transmission Towers — 7 towers

4) Land Acquisition — 300 acres
(2150 acres, state + County owned land)
Willdan report

5) Bank Protection

Soil Cement East Bank	61,550 yd^3
Soil Cement West Bank	66,040 yd^3
Riprap East Bank	83,120 yd^3
Riprap West Bank	103,980 yd^3
Filter Fabric East Bank	69,280 yd^2
Filter Fabric West Bank	74,250 yd^2

6) I-10 bridge pier protection

riprap	17,930 yd^3
gravel filter	8,960 yd^3
drainage excavation	26,890 yd^3

7) Buckeye Road Bridge Pier Protection

Riprap	7790 yd^3
Gravel Filter	3900 yd^3
Drainage Excavation	11,690 yd^3

SIMONS, LI & ASSOCIATES
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FORT COLLINS, COLORADO

CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Cost + Quantities
Bluegee Rd to I-10

JOB NO. AZ-MC-05
DATE CHECKED:
CHECKED BY:

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DATE 2/8/94
COMPUTED BY MJB

8) SPRR Bridge Pier Protection

Riprap	7465 yd^3
Gravel Filter	3730 yd^3
Drainage Excavation	11,195 yd^3

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FORT COLLINS, COLORADO

CLIENT: FCD of MC | JOB NO. A-7-MC-05 | PAGE 2/4
PROJECT: SPF Design | DATE CHECKED: | DATE 2/8/99
DETAIL: Cost & Quantities | CHECKED BY: | COMPUTED BY MJB
Buckeye Rd to I-10 w/o Siphon

1) Channelization

3:1 ss Common Fill (levees)	155,520 yd³ @ $1.25/yd³	$194,410
Common Fill (gravel pits)	170,000 yd³ @ $1.25/yd³	$212,500
1:1 ss Common Fill (levees)	136,865 yd³ @ $1.25/yd³	$171,080
Drainage Excavation	875,535 yd³ @ $.90/yd³	$787,980
		$1,171,560

2) Drop Structure Below I-10

Soil Cement	23,520 yd³ @ 22.50/yd³	$529,425
Structural Excavation	55,880 yd³ @ 2.00/yd³	$111,760
Special Backfill	16,180 yd³ @ 2.00/yd³	$32,360
Common Fill	16,180 yd³ @ 1.25/yd³	$20,225
Riprap	3,130 yd³ @ 22.0/yd³	$68,860
Gravel Filter	1,570 yd³ @ 15.0/yd³	$23,550
		$786,180

3) Transmission Tower — 7 towers @ $100,000/tower — $700,000

4) Land Acquisition — 300 acres @ $5000/acre — $1,500,000

5) Bank Protection

Soil Cement	127,590 yd³ @ $22.50/yd³	$2,870,775
Riprap	187,100 yd³ @ $22.0/yd³	$4,116,200
Filter Fabric	143,530 yd² @ $1.50/yd²	$215,295
		$4,331,495

6) I-10 Bridge Pier Protection

Riprap	17,920 yd³ @ $22.0/yd³	$394,240
Gravel Filter	8960 yd³ @ $15.0/yd³	$134,400
Drainage Excavation	26,890 yd³ @ .90/yd³	$24,200
	subtotal	$553,060

7) Buckeye Road Bridge Pier Protection

Riprap	7790 yd³ @ $22.00/yd³	$171,380
Gravel Filter	3900 yd³ @ $15.00/yd³	$58,500
Drainage Excavation	11,690 yd³ @ $1.90/yd³	$19,520
	subtotal	$249,400

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FORT COLLINS, COLORADO

CLIENT FCD of MC
PROJECT SPF Design
DETAIL Cost and Quantities
JOB NO. AB-MC-05
DATE CHECKED
CHECKED BY
PAGE 4/4
DATE 2/8/94
COMPUTED BY MJB

Buckeye Road to I-10 w/o siphon

8) SPRR Bridge Pier Protection

Riprap	7465 yd^3 @	$22.0/$yd^3$	✓ $ 164,230
Gravel Filter	3,730 yd^3 @	$ 15.0/yd^3	✓ $ 55,950
Drainage Excavation	11,195 yd^3 @	$ .90/yd^3	✓ $ 10,075
		subtotal	$ 230,255

Total Cost Using Soil Cement Protection	$ 6,552,230
10% contingencies + const. super.	$ ✓ 655,220
	$ 7,207,450
land acquisition	1,500,000
	$ 8,707,450

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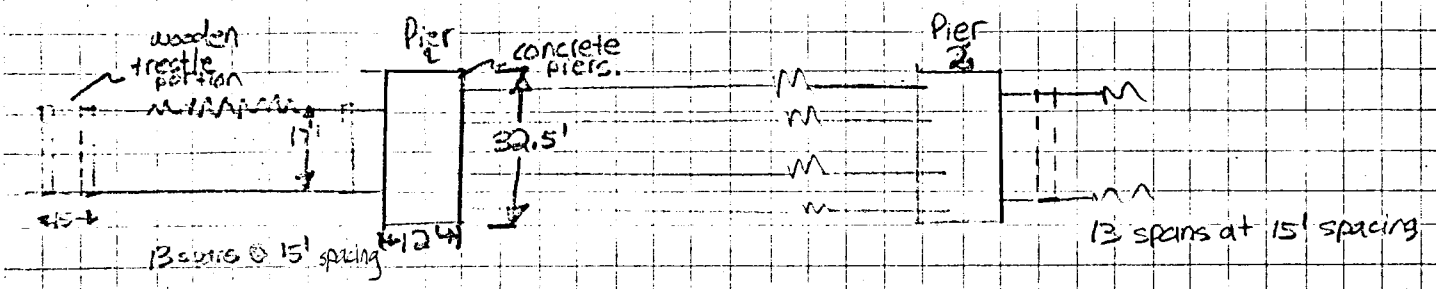
FORT COLLINS, COLORADO

CLIENT: FCD of MC | JOB NO. A2-MC-05 | PAGE 1/2
PROJECT: SPF Design | DATE CHECKED: | DATE 2/8/04
DETAIL: Bridge Pier Protection | CHECKED BY: | COMPUTED BY MJB
SPR2



1) Complete riprap blanket for wooden trestle portion of the bridge extending 20' upstream and downstream of crossing

$V_{RR} = 2(57')(3')(450') - (30)(3')(2')(17') = 150,840\ ft^3$ or $5592\ yd^3$

$V_{GF} = (2)(57')(1.5')(450') - (30)(1.5)(2')(17') = 75,420\ ft^3$ or $2790\ yd^3$

2) Riprap 20' in all directions around piers 2-5

$V_{RR} = 4(72.5')(52')(3') - 4(32.5')(12')(3') = 40,560\ ft^3$ or $1500\ yd^3$

$V_{GF} = 4(72.5')(52')(1.5') - 4(32.5')(12')(1.5') = 20,280\ ft^3$ or $750\ yd^3$

3) Riprap volume half around piers 1+6 vs 2-5 because wooden trestle blanket extends to the edges of these piers

$V_{RR} = 2(1/2)\left[(72.5')(52')(3') - (32.5')(12')(3')\right] = 10,140\ ft^3$ or $375\ yd^3$

$V_{GF} = (2)(1/2)\left[(72.5')(52')(1.5') - (32.5')(12')(1.5')\right] = 5070\ ft^3$ or $190\ yd^3$

Total $V_{RR} = 7465\ yd^3$

$V_{GF} = 3730\ yd^3$

DE = Drainage Excavation

$V_{DE} = 11,195\ yd^3$

SIMONS, LI & ASSOCIATES
ENGINEERING CONSULTANTS
FORT COLLINS, COLORADO

CLIENT: ACE of NC
PROJECT: SH Design
DETAIL: Bridge Pier Protection
Buckeye Road Bridge

JOB NO.: AZ-M665
DATE CHECKED:
CHECKED BY:

PAGE: 2/2
DATE: 2/9/84
COMPUTED BY: MJB

Buckeye Road Pier Protection

14 piers. 4' diameter piers
width of SR 80 = 75'

$$V_{RR} = (3')(115')(44')(14) - \overset{\text{no. piers}}{(4)(14)}(3')\left(\frac{\pi 4'^2}{4}\right) = 210{,}410\ ft^3$$

$$\underline{7790\ yd^3}$$

$$V_{GF} = (1.5')(115')(44')(14) - (4)(14)(1.5')\left(\frac{\pi 4'^2}{4}\right) = 105{,}205\ ft^3$$

$$\underline{3900\ yd^3}$$

$V_{RR} = 7790\ yd^3$
$V_{GF} = 3900\ yd^3$
$V_{DE} = 11{,}690\ yd^3$

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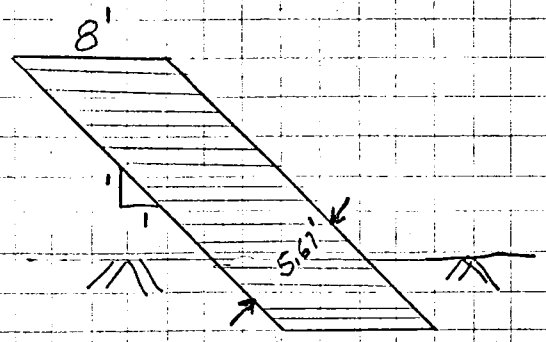
FORT COLLINS, COLORADO

CLIENT: FCD of MC | JOB NO. AZ-MC-05 | PAGE 1/2
PROJECT: SPF Design | DATE CHECKED | DATE 2/7/94
DETAIL: Bank Protection | CHECKED BY | COMPUTED BY MJB
Buckeye Rd to I-10
without siphon.



Soil Cement Bank Protection

East Bank

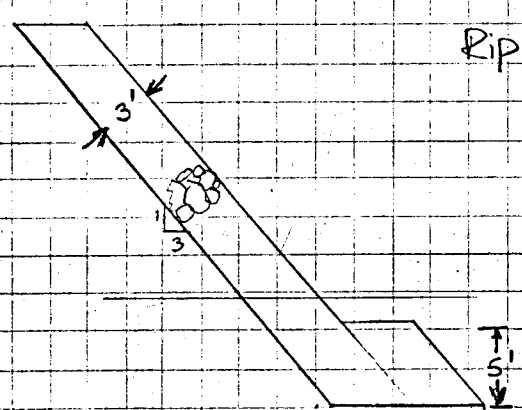
$V_{SC} = (200')(5.67')(31.3') + (3250')(5.67')(34.5')$
$+ (4630')(5.67')(35.9') + (100')(5.67')(39.5')$
$+ (100')(5.67')(45.4')$

$V_{SC} = 1,661,830\ ft^3$ or $\underline{61550\ yd^3}$

West Bank

$V_{SC} = (200')(5.67')(31.3') + (3250')(5.67')(34.5')$
$+ (2850')(5.67')(36.5') + (100')(5.67')(41.6')$
$+ (1680')(5.67')(46.7') + (100')(5.67')(47.0)$
$+ (100')(5.67')(47.5')$

$V_{SC} = 1,783,080\ ft^3$ or ✓ $\underline{66,040\ yd^3}$



Riprap Bank Protection

East Bank

$V_{RR} = (200')(3')(22.8')3 + (3250')(3')(3)\left(\frac{23+25.8}{2}\right)$
$+ (4650')(3')\left(\frac{25'+25.8'}{2}\right)3 + (100')(3')\left(\frac{25.0'+30.8'}{2}\right)3$
$+ (100')(3')\left(\frac{30.8'+31.0'}{2}\right)3 + (8300')(15')(3')$

$V_{RR} = 2,244,150\ ft^3$ or ✓ $\underline{83120\ yd^3}$

Riprap Bank Protection
West Bank

$$V_{RR} = (200')(3')(22.8')(3) + (3250')(3')\left(\frac{23'+25.8'}{2}\right)3$$
$$+ (2850')(3')(3)\left(\frac{25.8'+26'}{2}\right) + (100')(3')(3)\left(\frac{26'+33'}{2}\right)$$
$$+ (1680')(3')(3)\left(\frac{33'+33'}{2}\right) + (100')(3')(3)\left(\frac{33'+33.5'}{2}\right)$$
$$+ (100')(3')(3)\left(\frac{33.5'+33.7'}{2}\right) + (6420')(15')(3') +$$
$$+ (1880')(15')(5')$$

$V_{RR} = 2{,}807{,}400\ ft^3$ OR ✓ $\underline{103{,}980\ yd^3}$

Filter Fabric Area

East Bank

$$A_{FF} = (200')(22.8')(3) + (3250')(3)(24.4') + (4650')(3)(25.4')$$
$$+ (100')(3)(27.9') + (100')(3)(30.9')$$

$A_{FF} = 623{,}550\ ft^2$ or ✓ $\underline{69{,}280\ yd^2}$

West Bank

$$A_{FF} = (200')(3)(22.8') + (3250')(3)(24.4') + (2850')(3)(25.9')$$
$$+ (100')(3)(29.5') + (1680')(3)(33') + (100')(3)(33.25')$$
$$+ (100')(3)(33.6')$$

$A_{FF} = 668{,}250\ ft^2$ or ✓ $\underline{74{,}250\ yd^2}$

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CLIENT: [illegible] JOB NO. [illegible] PAGE [illegible]
PROJECT: [illegible] DATE CHECKED: [illegible] DATE: [illegible]
DETAIL: [illegible] CHECKED BY: [illegible] COMPUTED BY: [illegible]

section	Dist	AREA EAST LEVEE	AREA WEST LEVEE	VOL EAST LEVEE Yd³	VOL WEST LEVEE Yd³
				0	
202+30		0	0		
	1040			3470	6355
212+85		180	330		
	1500			17000	20 280
227+95		432	400		
	1225			17,013	17 331
240+20		318	364		
	1425			16,968	13,458
254+30		325	146		
	1165			12 275	12 771
266+80		244	446.		
	830			7,703	10,328
275+15		216	223		
	780			3120	3221
281+50		0	0		
				77,549 yd³	83,744 yd³

section	Dist	AREA Cut	AREA Fill	Vol Cut Yd³	Vol. Fill Yd³
202+30		944	0		
	1040			84182 yd³	9244 yd³
212+85		3427	480		
	1500			145,916	28,333
227+95		1826	540		
	1225			79110	30,143
240+20		1661.3	789		
	1425			149,263	55786
254+30		3995	1325		
	1165			199,409	46,513
266+80		5248	831		
	830			125,391	33046
275+15		2910	1319		
	780			92,264	28,436
281+50		3616	649.8		
				875,[illegible] yd³	[illegible] yd³

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CLIENT _____ JOB NO. _____ PAGE 12
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1:1 SIDE SLOPE

section	Dist	AREA EAST	AREA WEST	Vol East	Vol WEST
202+30		0	0		
	1040			2977	5238
212+85		154.6	272		
	1500			14749	17278
227+95		378	350		
	1225			14754	15267
240+20		272	323		
	1425			14,091	11,373
254+30		262	108		
	1165			10,399	10,118
266+60		220	361		
	850			6,363	8592
275+15		194	198		
	780			2802	2860
281+50		0	0		
				66,135 yd³	70,726 yd³

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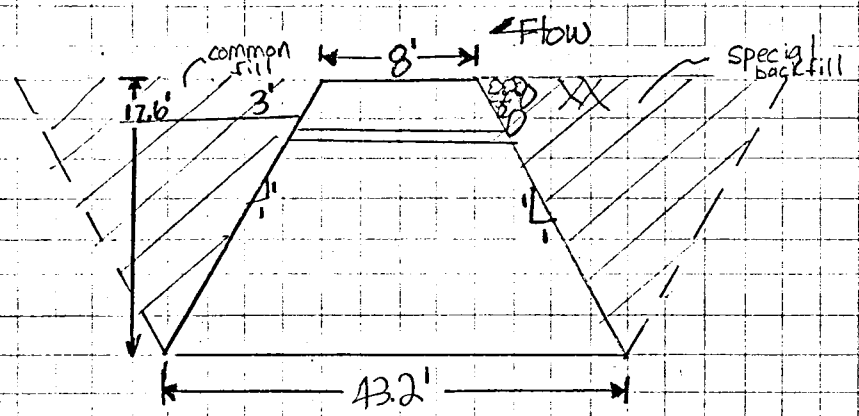
CLIENT FCD of MC | JOB NO. AZ-MC-05 | PAGE 1/1
PROJECT SPF DESIGN | DATE CHECKED | DATE 2/7/84
DETAIL Quantities for I-10 Drop. | CHECKED BY | COMPUTED BY MJB

Soil Cement Drop structure. without siphon.



Soil Cement

$$V_{SC} = \left(\frac{8' + 43.2'}{2}\right)(17.6')(1410') = 635{,}290\ ft^3$$

$$V_{SC} = 23{,}530\ yd^3$$

Structural Excavation

$$V_{SE} = \left(\frac{43.2' + 78.4'}{2}\right)(17.6')(1410') = 1{,}508{,}810\ ft^3$$

$$V_{SE} = 55{,}880\ yd^3$$

Special Backfill

$$V_{SB} = \tfrac{1}{2}(35.2')(17.6')(1410') = 436{,}760\ ft^3$$

$$V_{SB} = 16{,}180\ yd^3$$

Common Fill

$$V_{CF} = \tfrac{1}{2}(35.2')(17.6')(1410') = 436{,}760\ ft^3$$

$$V_{CF} = 16{,}180\ yd^3$$

Rip rap

$$V_{RR} = (20')(3')(1410') = 84{,}600\ ft^3 \text{ or } 3130\ yd^3$$

$$V_{GF} = (20')(1.5')(1410') = 42{,}300\ ft^3 \text{ or } 1565\ yd^3$$

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CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: 1/2
PROJECT: SPF Design | DATE CHECKED: | DATE: 2/7/84
DETAIL: Quantities + Cost Estimate I-10 to Thomas Road without siphon | CHECKED BY: | COMPUTED BY: MJB

1) Channelization

Drainage Excavation	2,597,250 yd³
I-10 Excavation	850,000 yd³
Levee Fill	
rip rap 3:1 SS West Bank	104,515 yd³
3:1 SS East Bank	102,025 yd³
1:1 SS West Bank	81,780 yd³
1:1 SS East Bank	80,680 yd³

2) 2 Drop Structures

Soil Cement	42,930 yd³
Structural Excavation	103,640 yd³
Special Backfill	30,350 yd³
Common Fill	30,350 yd³
Riprap upstream of drop	4,890 yd³
Gravel Filter	2,490 yd³

3) Transmission Towers — 8 towers

4) Land Acquistion

Channelization	~~280~~ 43 acres
I-10 Siltation Basin	2.53 acres

5) Bank Protection

Soil Cement	
East Bank	64,970 yd³
West Bank	69,450 yd³
Riprap	
West Bank	104,330 yd³
East Bank	87,640 yd³
Filter Fabric West Bank	77,960 yd²
Filter Fabric East Bank	72,850 yd²

6) I-10 Siltation Basin

Drainage Excavation	440,000 yd³
Soil Cement Protection	6420 yd³
linear feet Reinforced Concrete Pipe	51 feet
Flap Gate	1

7) Relocate Water + Gas Line at Thomas Rd.

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CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: 2/2
PROJECT: SPF Design | DATE CHECKED: | DATE: 2/8/84
DETAIL: Quantities + Cost Estimate | CHECKED BY: | COMPUTED BY: MJB

I-10 to Thomas Road without Siphon

1) Channelization

Drainage Excavation	1,747,250 yd³ @ $.90/yd³	= $1,572,525
Common Fill 3:1 SS Levee	206,540 yd³ @ $1.25/yd³	$ 258,175
Common Fill 1:1 SS Levee	162,460 yd³ @ $1.25/yd³	$ 203,075

2) 2 Drop structures

Soil Cement	42,430 yd³ @ $22.50/yd³	$ 965,925
Structural Excavation	103,640 yd³ @ $2.00/yd³	$ 207,280
Special Backfill	30,350 yd³ @ $2.00/yd³	$ 60,700
Common Fill	30,350 yd³ @ $1.25/yd³	$ 37,940
Riprap	4,880 yd³ @ $22.0/yd³	$ 107,360
Gravel Filter	2440 yd³ @ $15.0/yd³	$ 36,600
	subtotal	$1,415,805

3) Transmission Towers

8 towers @ $100,000/tower $800,000

4) Land Acquisition

43.0 acres	non-state @ $5000/acre	$ 215,000
2.53 acres	@ $5000/acre	$ 12,650

5) Bank Protection

Soil Cement	134,420 yd³ @ $22.50/yd³	$ 3,024,450
Riprap	191,970 yd³ @ $22.0/yd³	$ 4,223,340
Filter Fabric	150,810 yd³ @ $1.50/yd³	$ 226,215

6) I-10 Siltation Basin

Drainage Excavation	440,000 yd³ @ $.90/yd³	$ 396,000
Soil Cement Protection	6420 yd³ @ $22.50/yd³	$ 144,450
Reinforced Concrete Pipe	50 linear feet @ $50/ft	$ 2500
Flap Gate	1 @ $2000/gate	$ 2000
	subtotal	$ 542,450

7) Relocate Water + Sewer Line at Thomas Road

	Soil cement Cost of protection	$ 7,560,805
10%	contingencies + const. super	$ 756080
		8,316,885
		777,650

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CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: 1/1
PROJECT: SPF Design | DATE CHECKED: | DATE: 2/8/84
DETAIL: Channelization | CHECKED BY: | COMPUTED BY: MJB

I-10 to Thomas Road

Excavation with 100 year channel

1,867,000 yd³

from I-10 to first drop S=.0018
from 1st drop to Thomas Road S=.0019

SPF	Elevation	at	I-10	970.0	
Channel	"	"	1st drop	978.0	station 32+75
with siphon	"	at	Thomas Rd	986.6	

SPF	Elevation	at	I-10	971.0 ft.		
channel	Elevation	at	1st drop	980.0 ft.	station 32+75	S=.002
without siphon	Elevation	at	Thomas Rd.	989.5 ft	station 37+28	S=.0021

from station

28330 to 30410 Channel width varies from 1410' to 1100'

Extra Excavation volume

I-10 to McDowell $V = (2080')\left(\frac{1410'+1100'}{2}\right)\left(\frac{1'+1.4'}{2}\right) = 3,132,480\ ft^3$ or $116,020\ yd^3$

McDowell to 1st drop $V = (2340')(1100')\left(\frac{1.4'+2}{2}\right) = 4,375,800\ ft^3$ or $162,070\ yd^3$

1st drop to Thomas $V = (4530')(1100')\left(\frac{2'+2.9'}{2}\right) = 12,208,350\ ft^3$ or $452,160\ yd^3$

total volume increase = 730,250 yd³

Total Excavation = 2,597,250 yd³

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CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Quantities associated with Drops I-10 Thomas without Siphon.

JOB NO. AZ-MC-05
DATE CHECKED:
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PAGE 1/1
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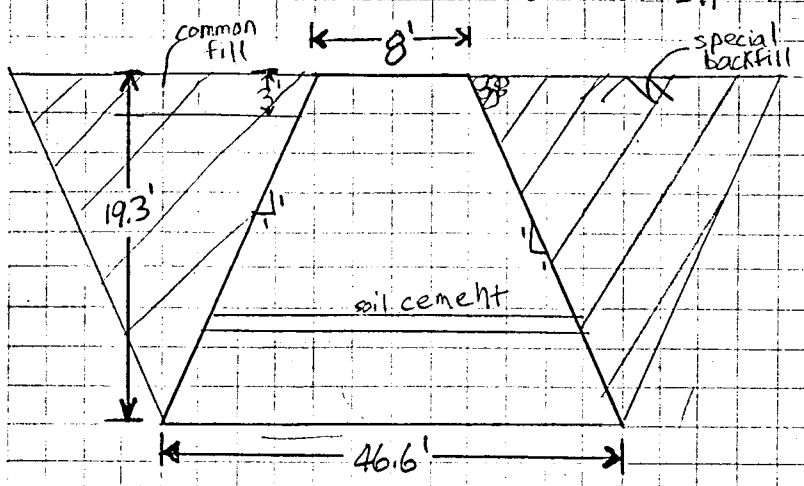
COMPUTED BY MJB



Volume of Soil Cement

$$V_{SC} = \left(\frac{46.6' + 8'}{2}\right)(19.3')(1100') = 579{,}580\ ft^3$$

✓ $V_{SC} = \underline{21{,}465\ yd^3}$

Structural Excavation

$$V_{SE} = \left(\frac{46.6' + 85.2'}{2}\right)(19.3')(1100') = 1{,}399{,}050\ ft^3$$

✓ $V_{SE} = \underline{51{,}820\ yd^3}$

Special Backfill

$$V_{SB} = \tfrac{1}{2}(38.6')(19.3')(1100') = 409{,}740\ ft^3$$ ✓

$V_{SB} = \underline{15{,}175\ yd^3}$ ✓

Common Fill

$$V_{CF} = \tfrac{1}{2}(38.6')(19.3')(1100') = 409{,}740\ ft^3$$

$V_{CF} = \underline{15{,}175\ yd^3}$

Riprap

$$V_{RR} = (1100')(3')(20') = 66000\ ft^3$$

$V_{RR} = \underline{2440\ yd^3}$

Gravel Filter

$$V_{GF} = (1100')(20')(1.5') = 33000\ ft^3$$

$V_{GF} = \underline{1220\ yd^3}$

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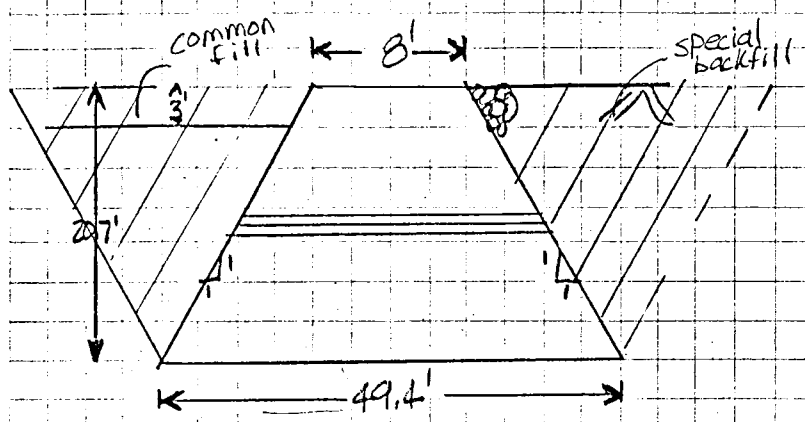
CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: 1/2
PROJECT: SFF Design | DATE CHECKED: | DATE: 2/7/94
DETAIL: Drop Structure Quantity Thomas to ISKE | CHECKED BY: | COMPUTED BY: MJB

Without Siphon Below RID Flume



Volume of Soil Cement

$V_{SC} = \left(\frac{8' + 49.4'}{2}\right)(920')(20.7') = 546,560\ ft^3$ or $\underline{20,240\ yd^3}$

Volume of Structural Excavation

$V_{SE} = \left(\frac{49.4' + 90.8'}{2}\right)(20.7')(920') = 1,334,980\ ft^3$ or $\underline{49,440\ yd^3}$

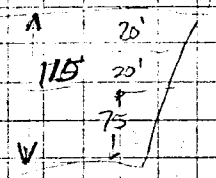
Volume of Special Fill

$V_{SF} = (41.4')(1/2)(20.7')(920') = 394,210\ ft^3$ or $\underline{14,600\ yd^3}$

Volume of Common Fill

$V_{CF} = 1/2(41.4')(20.7')(920') = 394,210\ ft^3$ or $\underline{14,600\ yd^3}$

Riprap blanket through flume



$V_{RB} = (3')(115')(920') = 317,400\ ft^3$ or $\underline{11,755\ yd^3}$

Gravel Filter

$V_{GF} = (1.5')(115')(920') = 158,700\ ft^3$ or $\underline{5880\ yd^3}$

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CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Drop Structure Quantity ISRB without siphon

JOB NO.: AZ-MC-05
DATE CHECKED:
CHECKED BY:

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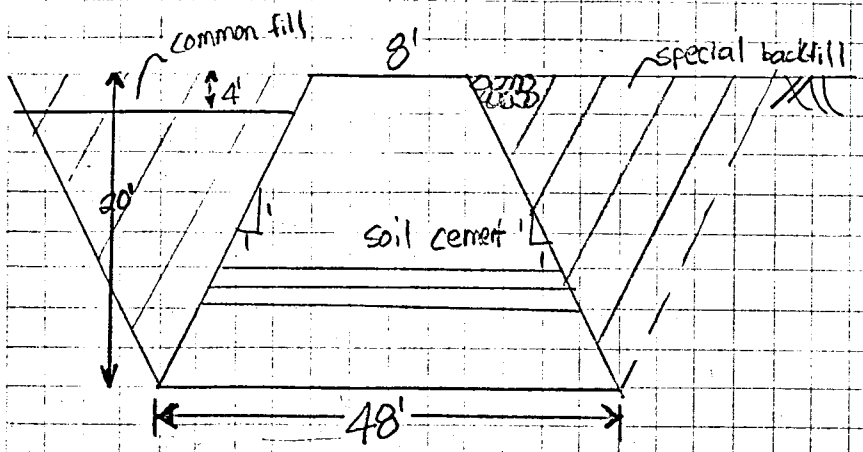
COMPUTED BY: MJB



Volume of Soil Cement

$$V_{SC} = (1440')\left(\frac{8'+48'}{2}\right)(20') = 806{,}400\ ft^3 \text{ or } \underline{29{,}870\ yd^3}$$

Volume of Structural Excavation

$$V_{SE} = (1440')\left(\frac{48'+88'}{2}\right)(20') = 1{,}958{,}400\ ft^3 \text{ or } \underline{72{,}530\ yd^3}$$

Volume of Special Backfill

$$V_{SB} = (1440')(40')(1/2)(20') = 576{,}000\ ft^3 \text{ or } \underline{21{,}330\ yd^3}$$

Volume of Common Fill

$$V_{CF} = (1440')(40')(1/2)(20') = 576{,}000\ ft^3 \text{ or } \underline{21{,}330\ yd^3}$$

Riprap

$$V_{RR} = (1440')(3')(20') = 86{,}400\ ft^3 \qquad \underline{3200\ yd^3}$$

Gravel Filter

$$V_{GF} = (1440')(1.5')(20') = \underline{43200\ ft^3} \qquad \underline{1600\ yd^3}$$

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CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Levee + Channel Excavation Thomas Road to ISRB without siphon. 3:1 S.S.

JOB NO.: FZ-MC-05
DATE CHECKED:
CHECKED BY:

PAGE: 19 1
DATE: 2/7/84
COMPUTED BY: MM

Section	Dist	AREA EAST LEVEE ft²	AREA WEST LEVEE ft²	Vol. EAST LEVEE yd³	Vol WEST LEVEE yd³
370+50		465	184		
	1000			17,777	7,537
381+40		495	223		
	320			6,186	1949
385+50		456	106		
	650			12097	2793
392+10		549	126		
	630			9088	4153
398+00		230	230		
	550			3381	4522
403+75		102	214		
403+90		102	214		
	570			6618	7425
409+45		525	525		
	850			20,226	20226
417+75		760	760		
	720			16,653	14746
426+95		489	346		
				92026 yd³	63,351 yd³

Section	Dist	AREA cut	AREA Fill	Vol cut	Vol Fill
370+50		6428	0		
	1000			262,092	0
381+40		7725	0		
	320			87,034	
385+50		6962	0		
	650			166,749	
392+10		6891	0		
	630			162,061	
398+00		7000	0		
	550			90,627	
403+75		1898	0		
403+90		1898	0		
	570			75440	
409+45		5249	0		
	850			109933	
417+75		1735	0		
	720			37866	0
426+95		1105			
				991,802 yd³	

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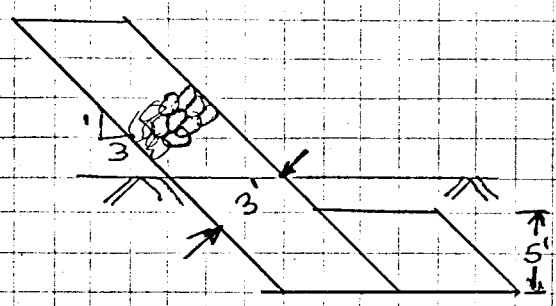
CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: V2
PROJECT: SPF Design | DATE CHECKED: | DATE: 2/7/84
DETAIL: Bank Protection | CHECKED BY: | COMPUTED BY: MJB

Thomas Rd to ISRB without siphon.



Riprap Bank Protection

East + West Bank

$$V_{RR} = (3)\left(\frac{23.3' + 23.5'}{2}\right)(3')(720') + (2450')\left(\frac{23.5' + 25.5'}{2}\right)(3)(3')$$

$$+ (100')(3')(3)\left(\frac{25.5' + 34.7'}{2}\right) + (100')(3')(3)\left(\frac{34.7' + 35.0'}{2}\right)$$

$$+ (1950')(3')(3)\left(\frac{24.0' + 26.2'}{2}\right) + (100')(3')(3)\left(\frac{26.2' + 33.8'}{2}\right)$$

$$+ (100')(3')(3)\left(\frac{33.8' + 34.0'}{2}\right) + (15')(3')(5520')$$

$V_{RR} =$ 1,496,730 ft^3 or 55,430 yd^3

both banks $V_{RR} =$ 110,860 yd^3

Filter Fabric

$$A_{FF} = (3)(23.4')(720') + (3)(24.5')(2450') + (100')(3)(30.1')$$

$$+ (100')(3)(34.85') + (1950')(3)(25.1') + (100')(3)(30')$$

$$+ (100')(3)(33.9')$$

$A_{FF} =$ 416,110 ft^2 or 46,230 yd^2

both banks $A_{FF} =$ 92,460 yd^2

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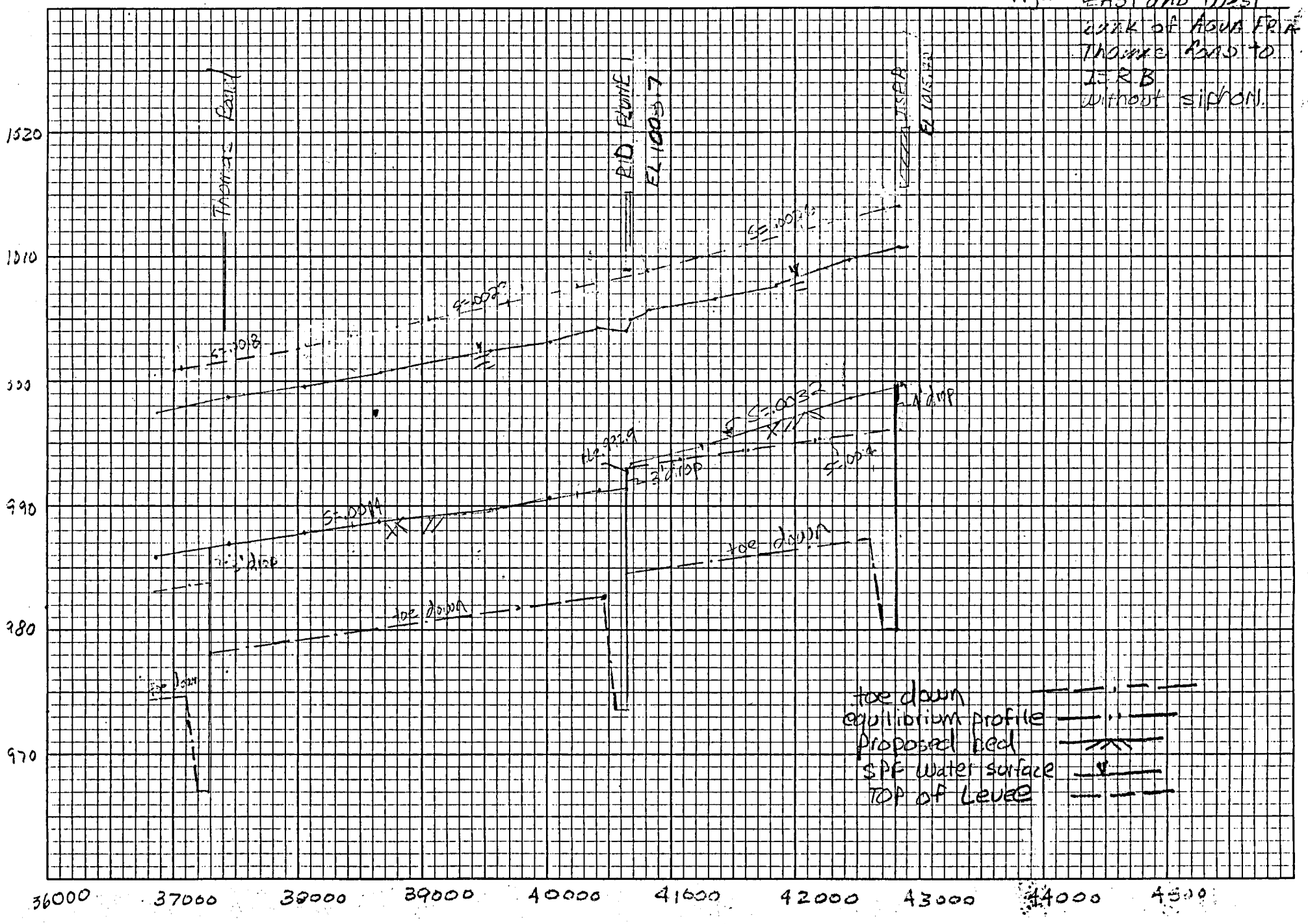
2/8/84

Figure 7.4 East and West bank of Agua Fria Thomas Road to IERB without siphon.



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CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: 1/3
PROJECT: SPF Design | DATE CHECKED: | DATE: 2-18-94
DETAIL: Cost + Quantity Estimate | CHECKED BY: | COMPUTED BY: MJB
Tromas to ISRB without Siphon

1) Channelization

Backfilling of gravel pits (10,000 yd³ completed by PS+R)	870,000 yd³
East Levee 3:1 SS.	92,030 yd³
West Levee 3:1 SS.	63,350 yd³
channel Excavation	991,800 yd³

(Common fill)

2) Drop Structure Below RID flume.

Soil Cement	20,240 yd³
Structural Excavation	49,440 yd³
Special Fill	14,600 yd³
Common Fill	14,600 yd³
Rip Rap (blanket protects piers)	11,755 yd³
Gravel Filter (protects piers)	5,880 yd³

930
35

Drop Structure Below ISRB

Soil Cement	29,870 yd³
structural Excavation	72,530 yd³
Special Backfill	21,330 yd³
Common Fill	21,330 yd³
Riprap	3200 yd³
Gravel Filter	1600 yd³

3) Land Acquisition (already acquired) 154 acres

4) Transmission Tower Protection 2 towers

5) Sludge Removal 20,000 yd³

6) Trash Removal 170,000 yd³

7) Bank Protection

Levees

Riprap	
East Levee	55,430 yd³
West Levee	55,430 yd³
Filter fabric East Levee	46,230 yd²
Filter fabric West Levee	46,230 yd²

8) ISRB Pier Protection

Drainage Excavation	14,410 yd³
Riprap	9610 yd³
Gravel Filter	4800 yd³

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CLIENT: FCD of MC | JOB NO. 02-MC-05 | PAGE 2/3
PROJECT: SPF Design | DATE CHECKED: | DATE 2/9/04
DETAIL: Cost + Quantity Estimate | CHECKED BY: | COMPUTED BY MJB

Thomas to ISRB w/o siphon

1) Channelization

Common Fill gravel pits	870,000 yd³ @ $1.25/yd³	$ 1,087,500
Common Fill Levees	155,380 yd³ @ $1.25/yd³	$ 194,225
Channel Excavation	991,800 yd³ @ $.90/yd³	$ 892,620
	subtotal ✓	$2,174,345

2) Drop Structure Below RID flume

Soil Cement	20,240 yd³ @ $22.50/yd³	$455,400
structural Excavation	49,440 yd³ @ $ 2.00/yd³	$ 98,880
Special Fill	14,600 yd³ @ $2.00/yd³	$ 29,200
Common Fill	14,600 yd³ @ $ 1.25/yd³	$ 18,250
Riprap (Pier protection)	11,755 yd³ @ $ 22.00/yd³	$ 258,610
Gravel Filter (pier protection)	5,880 yd³ @ $ 15.00/yd³	$ 88,200
	subtotal ✓	$ 948,540

3) Drop Structure Below ISRB

Soil Cement	29,870 yd³ @ $22.50/yd³	$ 672,075
Structural Excavation	72,530 yd³ @ $ 2.00/yd³	$ 145,060
Special Backfill	21,330 yd³ @ $ 2.00/yd³	$ 42,660
Common Fill	21,330 yd³ @ $ 1.25/yd³	$ 26,660
Riprap	3,200 yd³ @ $ 22.0/yd³ ✓	$ 70,400
Gravel Filter	1,600 yd³ @ $15.0/yd³	$ 24,000
	subtotal	$980,855

4) Transmission Tower

2 towers	@ $100,000/tower	$200,000

5) Sludge Removal	20,000 yd³ @ $2.00/yd³	$40,000
6) Trash Removal	170,000 yd³ @ $.50/yd³	$85,000

7) Levee Protection

Riprap	110,860 yd³ @ $22.0/yd³	$2,438,92[illegible]
Filter Fabric	92,460 yd² @ $1.50/yd²	$ 138,690
	subtotal ✓	$ 2,577,610

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CLIENT: RCD of MC
PROJECT: SPF Design
DETAIL: Cost and Quantities
Thomas Rd to ISRB w/o siphon.

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8) ISRB pier protection.

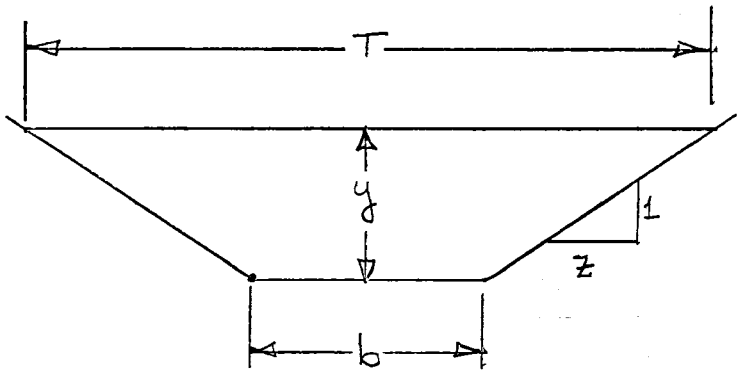
Drainage Excavation	14410 yd^3 @ $1.90/$yd^3$		$ 2970.0
Riprap	9610 yd^3 @ $22.00/$yd^3$		$ 211,420.0
Gravel Filter	4800 yd^3 @ $15.00/$yd^3$		$ 72,000
	✓	Subtotal	$ 296,390

Cost of Reach	$ 7,307,545
10% contingencies + const. super	$ 730,755
✓	$ 8,038,300

4805

296390

1. Check Capacity of Trapezoidal Canal upstream of semi-circular flume



$$\frac{A}{P} = \frac{y(b+zy)}{b+2y\sqrt{1+z^2}}$$

In RID canal $b = 8.0'$ on the average

$z = 1.5$ on the average

$A = y(8+1.5y)$ $\quad P = 8 + 3.606y$

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

$$\frac{Qn}{S^{1/2}} = 1.49 A R^{2/3}$$

HP15-C Program

0 y	STO 0 1.5 × 8 + RO × STO 1
1 A	RO R4 × 8 + STO 2 Y× R1 ×
2 P	.6667 y^x R1 × 1.49 × RTN
3 R	RS
4 3.606	
5 .6667	

y	$\frac{Qn}{S^{1/2}}$	Y	$\frac{Qn}{S^{1/2}}$
1	12.386	7	477.72
2	41.92	10	1031.26
3	88.48	12	1549.5
4	153.59	15	2581.2
5	238.99	18	3952.79
		20	5074.36

$$\frac{Qn}{S^{1/2}} = 7.1677\, y^{2.1763}$$

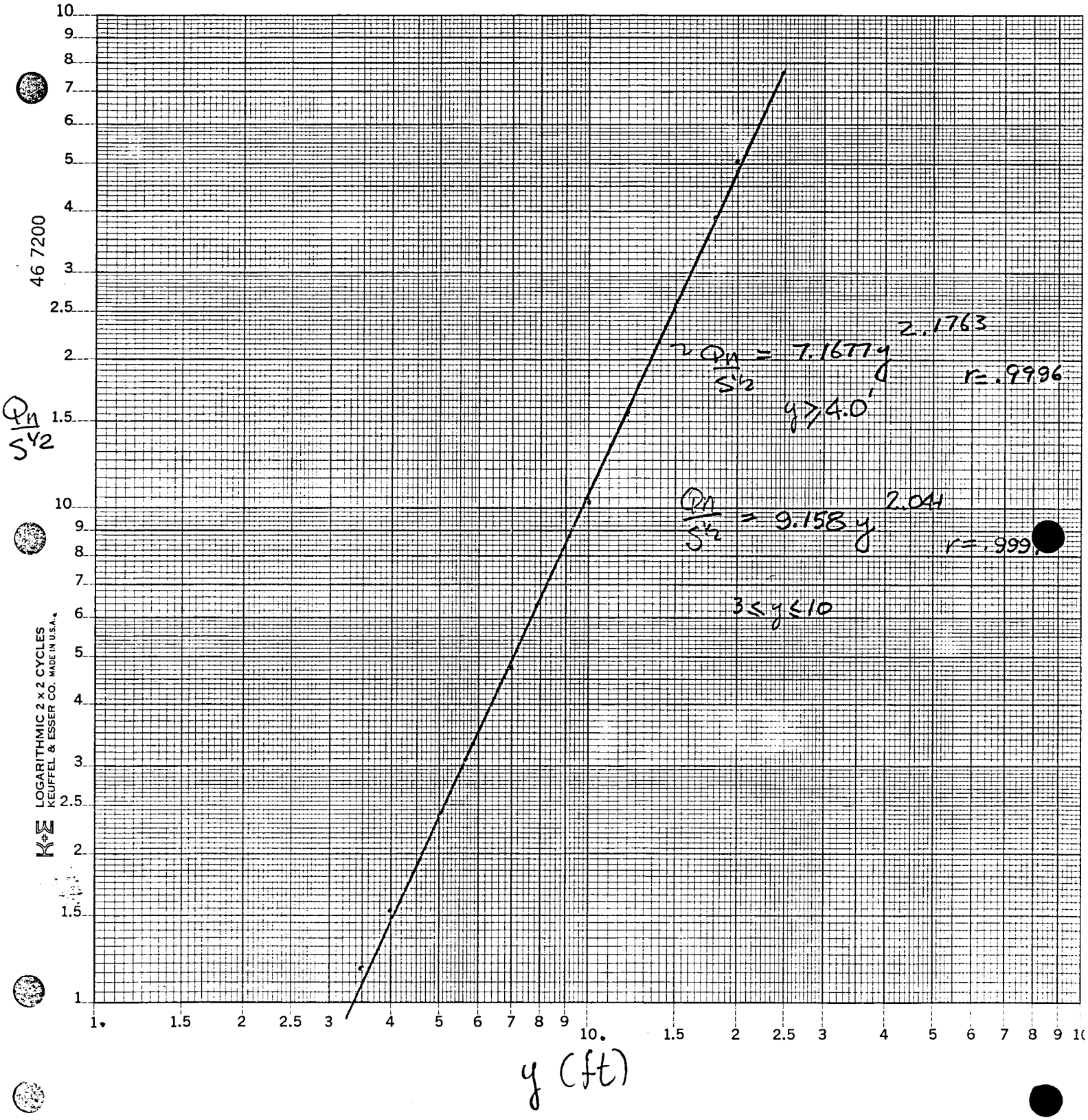
~~r = .9996~~

$$9.158\, y^{2.041}$$

r = .9997

$$\left(\frac{Qn}{9.158\, y^{2.041}}\right)^2 = S$$

1-2



RID

Trap. Channel

z = 1.5

n = 8

Say $S = .000152$

$n = .017$

$Q = 390$ cfs

$$y = \left(\frac{Qn}{7.1677\, S^{1/2}}\right)^{\frac{1}{2.1763}} = 7.27'$$

Check sensitivity to n

Say $n = .022$, $y = 8.19'$

$n = .020$ $y = 7.80'$

Check

$$Q = \frac{1.49}{.022} \frac{8.187(8+(8.187\times 1.5))^{5/3}}{[8+(3.606)(8.187)]^{2/3}} (.000152)^{1/2} = 374$$

11.2080

$A = 166.0365$

$P = 37.521$

Flume diameter $= 13' + \frac{43/8''}{12''/'} = 13.365'$ $R = 6.682'$

Determine $h_f = \frac{fL}{D}\frac{V^2}{2g}$ for Round Concrete Conduit

use $\epsilon = .0006$ feet (USBR Monograph No.7)

use $T°F = 50°F$ $\nu = 1(10)^{-5}\ \frac{ft^2}{sec}$

$R = \frac{VD}{\nu}$

$\frac{\epsilon}{D_{8'}} = .000075$ $\frac{\epsilon}{D_{10'}} = .00006$

$A_{8'} = \pi r^2$ $\pi 16 = 50.27\ ft^2$ $V_{390} = 7.76\ ft/sec$ $R_8 = 6.2(10)^6$

$A_{10'} = 25\pi$ $= 78.54\ ft^2$ $V_{390} = 4.97$ $R_{10} = 4.97(10)^6$

$f_{8'} \cong .012$ $\frac{V^2}{2g}_8 = .935'$ $\frac{V^2}{2g}_{10} = .384'$

$f_{10'} \cong .012$

$\frac{h_f}{L} = \frac{f}{D}\frac{V^2}{2g}$ $S_8 = \frac{(.012)(.935)}{8} = .001403$

$S_{10} = \frac{(.012)(.384)}{10} = .000461$

In General $\frac{h_f}{L} = \frac{f}{D}\frac{Q^2}{A^2 2g} = \frac{f}{D2g}\frac{Q^2}{\left(\pi\frac{D^2}{4}\right)^2} = \frac{fQ^2}{\cancel{2}gD\pi^2\frac{D^4}{\cancel{16}8}}$

$\frac{h_f}{L} = \frac{8fQ^2}{g\pi^2 D^5}$ $D = \left(\frac{8fQ^2}{g\pi^2\left(\frac{h_f}{L}\right)}\right)^{.2}$

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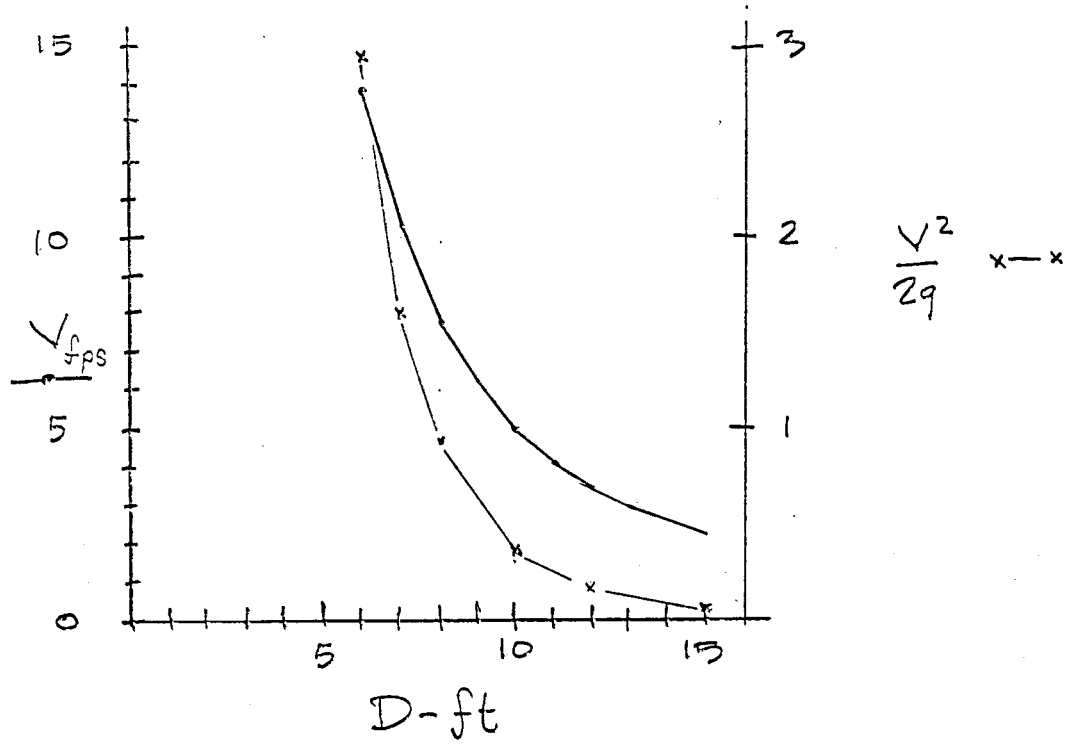
DETAIL Siphon Alt. CHECKED BY _____ COMPUTED BY LSS

Q=390 ○ | Q=390 ◡ n=.015

D	A	V	$\frac{V^2}{2g}$	y	V	$\frac{V^2}{2g}$	S
6	28.27	13.79	2.954	6.4	3.46	.186	.000209
7	38.48	10.13	1.595	6.6	3.301	.169	.000184
8	50.26	7.76	.935	6.8	3.15	.154	.000163
9	63.62	6.13	.584	7.0	3.01	.141	.000145
10	78.54	4.97	.383	7.2	2.88	.129	.000129
11	95.03	4.10	.262	7.4	2.76	.118	.0001155
12	113.097	3.448	.1846	7.6	2.645	.109	.0001036
13	132.7	2.94	.134	7.8	2.54	.100	.000093
15	176.7	2.21	.0756	9	2.02	.063	.0000515
				6.92	3.066	.146	.000152



Check potential total head difference between u/s and d/s end of siphon:

$$U/S = 1009.4 + 9 = 1018.4$$
$$D/S = 1007.5 + 7 = \underline{-1014.5}$$
$$3.9$$

$$S_f = \frac{3.9}{1315} = .002966$$

$$D = \left[\frac{(8)(.012)\,390^2}{32.2\,\pi^2\,(.002966)}\right]^{.2} = 6.89'$$

What is S_f for $D = 8.0$ feet diameter

$$\frac{h_f}{L} = \frac{(8)(.012)(390^2)}{(32.2)(\pi^2)(8.0^5)} = .001402$$

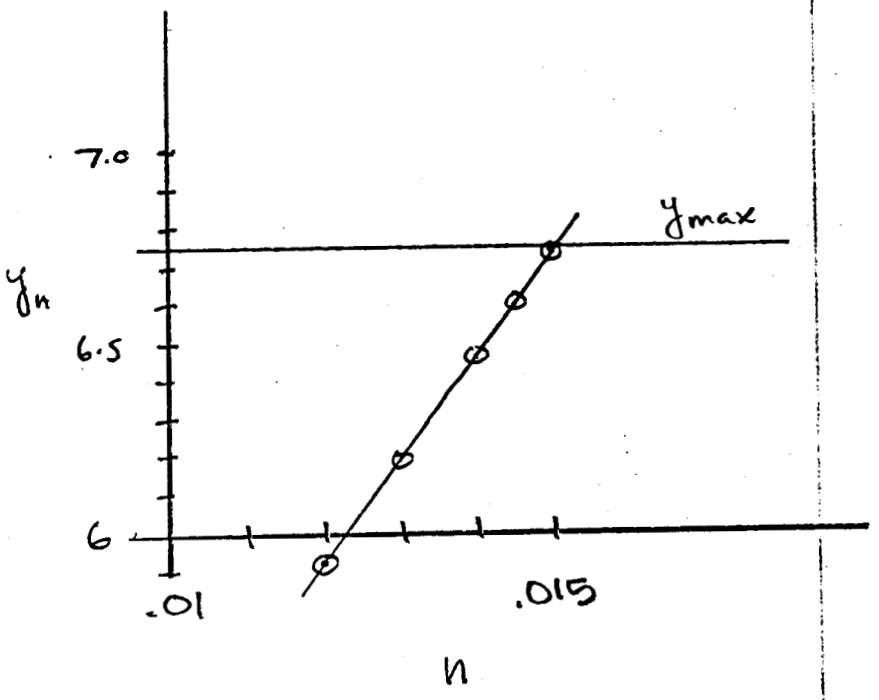
SEMI-CIRCLE NORMAL DEPTH

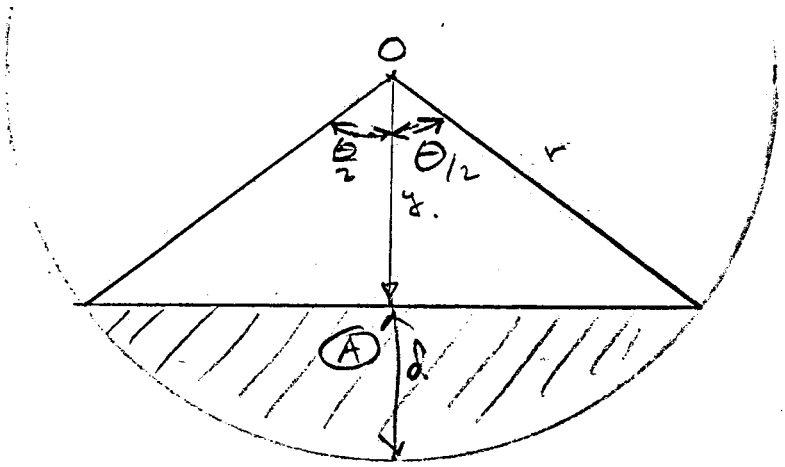
$Q = 390$

$R = (13.5')/2 = 6.75'$

$S = .0006$

n	θ	y_n
.012	165.9	5.922
.014	175.25	6.47
.015	179.6	6.726
.0145	177.45	6.60
.013	170.51	6.192





$y = r\cos\frac{\theta}{2}$

$d = r - y$

$s = r\theta$

$A = \frac{r^2}{2}(\theta - \sin\theta)$

$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$

$R = \frac{A}{P}$ $\quad P = r\theta$

$$\frac{A}{P} = \frac{\frac{1}{2}r^2(\theta - \sin\theta)}{r\,\theta}$$

0	r
1	θ
2	A
3	P
4	R
→ 5	Q
6	d
→ 7	n
→ 8	S

STO ~~0~~ 1 Enter sin − 2 ÷ RO x^2 × STO 2
RO RI × STO 3 1/x R2 × STO 04
.6667 y^x R2 × 1.49 × R7 ÷ R8 √x ~~t~~ ×
+/− RC 5 + ~~=~~ ~~RST~~

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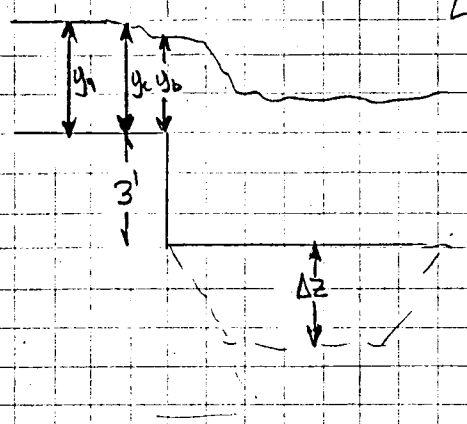
CLIENT: FCD of MC | JOB NO.: AZ-MC-05 | PAGE: 1/2
PROJECT: SPF Design | DATE CHECKED: | DATE: 2/6/84
DETAIL: Local Scour D/s of RID drop Thomas to ISRB without siphon | CHECKED BY: | COMPUTED BY: MJB

Local Scour over drop below RID flume



$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

$S = .0032$

$$q = \frac{1.486}{n} Y^{5/3} S^{1/2}$$

$q = 142000 \text{ cfs}/920 \text{ ft} = 154 \text{ cfs/ft}$

$$y_n = \left(\frac{(154 \text{ cfs/ft})(.025)}{(1.486)(.0032)^{1/2}}\right)^{.6} = 9.9 \text{ ft}$$

$$y_c = \sqrt[3]{q^2/g} = \sqrt[3]{(154)^2/(32.2)} = 9.0 \text{ ft.}$$

$V_c = q/y_c = 154/9.0 = 17.1 \text{ ft/sec.}$

Compute Drop Number to determine length of protection

$$D_n = q^2/gh^3 = (154)^2/(32.2)(3)^3 = 27.3$$

$$L_D = 4.3\, H D^{.27} = 4.3(3)(27.3)^{.27} = 31.5 \text{ ft.}$$

Protection Length

$$L_{PL} = L_D + 4 Y_c = 31.5 \text{ ft} + (4)(9) = \underline{67.5 \text{ ft}}$$

Local Scour using Veronese Eqn.

$$\Delta z = 1.32\, H_T^{.225}\, q^{.54} - y_c$$

$$\Delta z = 1.32\,(3)^{.225}(154)^{.54} - (9) \checkmark = \underline{16.7 \text{ ft.}}$$

Local Scour using Scholitsch

$$\Delta z = 4.75 \frac{H_T^{.2}\, q^{.5}}{d_{90}^{.32}} - y_c$$

$$\Delta z = 4.75 \frac{(.9144)^{.2}(14.3)^{.5}}{(10)^{.32}} - 2.74 = 5.7 \text{m or } 18.7 \text{ ft.}$$

Adopt Scour $\underline{17.7 \text{ ft}}$

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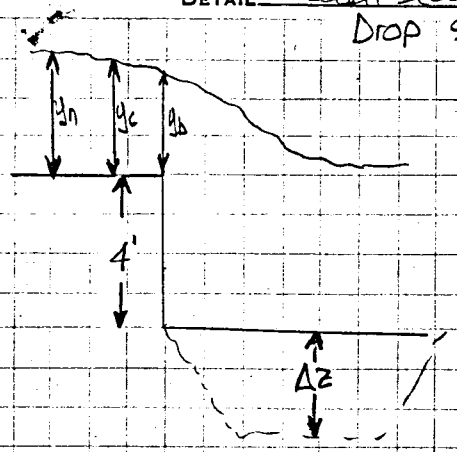
DETAIL: Local Scour D/S of ISRB | CHECKED BY | COMPUTED BY MJB

Drop structure without siphon



$q = Q/w$

$q = 142{,}000\,cfs/1440\,ft = 100\,cfs/ft$

$y_n = \left(\frac{q\,n}{1.486\,s^{1/2}}\right)^{.6}$

$y_n = \left(\frac{(100\,cfs/ft)(.025)}{(1.486)(.0031)^{1/2}}\right)^{.6} = 7.8\,ft.$ ✓

$y_c = \sqrt[3]{q^2/g} = 6.8\,ft.$

Length protection extends can be computed using the Chow Drop Number

$D_n = q^2/g h^3 = 100^2/(32.2)(3)^3 = 11.5$

$L_D = 4.3\,H\,D^{.27} = 4.3(4')(11.5)^{.27} = 33.3\,ft.$

Protection Length $= L_D + 4y_c = 33.3' + 4(6.8) = 60.5'$

Local Scour Using Veronese Eqn.

$\Delta Z = 1.32\,H_T^{.225}\,q^{.54} - y_c$

$\Delta Z = 1.32\,(4)^{.225}(100)^{.54} - 6.8 = 14.9\,ft.$ ✓

Local Scour Using Scholitsch Eqn.

$\Delta Z = 4.75\,\frac{H^{.2}\,q^{.5}}{D_{90}^{.32}} - y_c$

$\Delta Z = 4.75\,\frac{(1.22)^{.2}(9.29)^{.5}}{(1.0)^{.32}} - 2.07 = 5.14\,m$ or $16.9\,ft$ ✓

Adopt local scour or 16 ft.

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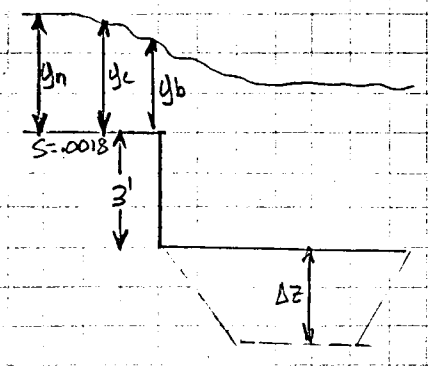
DETAIL Local Scour over Drop I-10 to Thomas Rd without siphon | CHECKED BY | COMPUTED BY MJB

Local scour over Drop Structures between I-10 + Thomas.



$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

$$q = \frac{1.486}{n} y^{5/3} S^{1/2}$$

$$q = 142000 \text{ cfs}/1100 \text{ ft} = 129 \text{ cfs/ft.}$$

$$y_n = \left[\frac{(129 \text{ cfs/ft})(.025)}{(1.486)(.0018)^{1/2}}\right]^{3/5} = 10.6 \text{ ft}$$

$$y_c = \sqrt[3]{q^2/g} = 8.0 \text{ ft.}$$

$$V_c = q/y_c = 129/8 = 16.1 \text{ ft/sec.}$$

Compute the Drop Number to determine Extend of scour hole.

$$D_1 = q^2/gh^3 = (129)^2/(32.2)(3)^3 = 19.14$$

$$L_D = 4.3 h D^{.27} = (4.3)(3)(19.14)^{.27} = 28.6 \text{ ft.}$$

Extent of scour hole

$$L_{sc} = L_D + 4Y_c = 28.6 \text{ ft} + (4)(8 \text{ ft}) = \underline{60 \text{ ft}}$$

Local Scour using Veronese Eqn

$$\Delta Z = 1.32 H_T^{.225} q^{.54} - Y_c$$

$$\Delta Z = 1.32 (3)^{.225} (129)^{.54} - 8.0 = \underline{15.3 \text{ ft}}$$

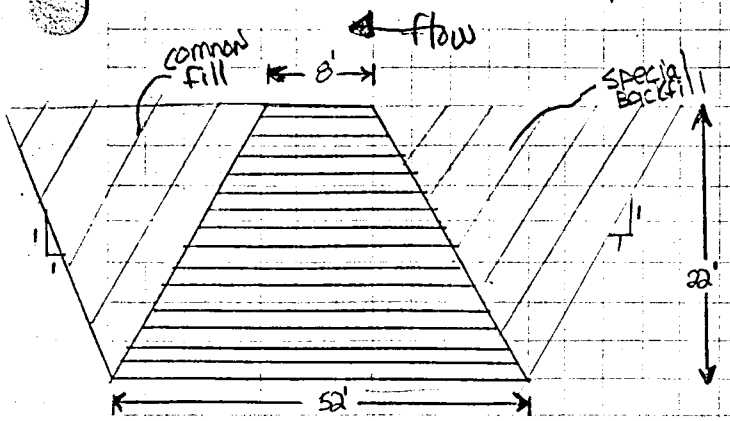
Local scour using Scholitsch Eqn.

$$\Delta Z = 4.75 \frac{H^{.2} q^{.5}}{d_{90}^{.32}} - y_c$$

$$\Delta Z = 4.75 \frac{(.9144)^{.2} (11.98)^{.5}}{(10)^{.32}} - 2.43 = 5.3 \text{ meters or } \underline{17.4 \text{ ft.}}$$

Adopt local scour = 16.3 ft

Drop structures Between I-10 & Thomas Rd.



Volume of Soil Cement

$V_{SC} = \left(\frac{52' + 8'}{2}\right)(22')(1100')$

$V_{SC} = 726{,}000\ ft^3$ or $\underline{26{,}890\ yd^3}$

Volume of Structural Excavation

$V_{SE} = \left(\frac{52' + 96'}{2}\right)(22')(1100')$

$V_{SE} = 1{,}790{,}800\ ft^3$ or $\underline{66{,}325\ yd^3}$

Volume of Special Backfill

$V_{SB} = (44')(1/2)(22')(1100')$

$V_{SB} = 532{,}400\ ft^3$ or $\underline{19{,}720\ yd^3}$

Volume of Common Fill

$V_{CF} = (44')(1/2)(22')(1100')$

$V_{CF} = 532{,}400\ ft^3$ or $\underline{19{,}720\ yd^3}$

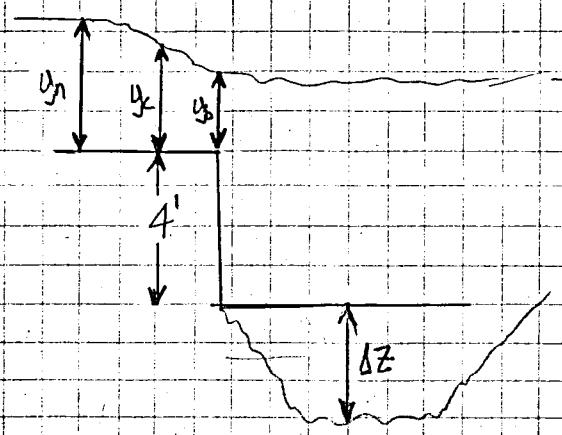
Riprap blanket Protection upstream of drop

$V_{RR} = (3')(20')(1100') = 66{,}000\ ft^3$ or $2440\ yd^3$

Gravel filter

$V_{GF} = (1.5')(20')(1100') = 33000\ ft^3$ or $1220\ yd^3$

Local Scour over 4ft drop ≈ 2300 ft upstream of McDowell Road Bridge



$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

$$q = \frac{1.486}{n} Y^{5/3} S^{1/2}$$

Slope ≈ .002

Q = 142,000 cfs
WIDTH = 1100 ft.

$$q = 142000 \text{ cfs/ft} / 1100 \text{ ft} = 129.1 \text{ cfs/ft.}$$

$$Y_n = \left(\frac{q\,n}{1.486\, S^{1/2}}\right)^{3/5} = \left(\frac{(129.1 \text{ cfs/ft})(.03)}{(1.486)(.002)^{1/2}}\right)^{3/5} = 11.46 \text{ ft.}$$

$$Y_c = \sqrt[3]{q^2/g} = \sqrt[3]{(129.1)^2/32.2} = 8.03 \text{ ft.}$$

$$V_c = q_c/Y_c = 129.1/8.03 = 16.08 \text{ ft/sec.}$$

Compute the Chow Drop Number

$$D = q^2/gh^3 = (129.1)^2/(32.2)(4)^3 = 8.09$$

$$L_D = 4.3\,h\,D^{.27} = 4.3(4)(8.09)^{.27} = 30.2 \text{ ft.}$$

Local Scour using Veronese Eqn.

$$\Delta z = 1.32\, H_T^{.225}\, q^{.54} - y_c$$

$$\Delta z = 1.32(4)^{.225}(129.1)^{.54} - 8.03 \text{ ft} = \underline{16.9 \text{ ft}}$$

Using Scholitsch Eqn.

$$\Delta z = 4.75 \frac{H_T^{.2}\, q^{.5}}{D_{90}^{.32}} - y_c$$

$$\Delta z = 4.75 \frac{(1.22)^{.2}(11.99)^{.5}}{(10)^{.32}} - 2.45 = 5.74 \text{ meters}$$

or 18.9 ft.

Adopt 18ft

Local Scour for SPF for existing conditions

Shen's Method.

$$\text{Local Scour Depth} = .00073\, R^{.619}$$

$$R = \frac{(12.85\ ft/sec)(7\ ft)}{(1.0 \times 10^{-5}\ ft^2/sec)} = 8.995 \times 10^6$$

Hydraulics from HEC II
$n = .035$

$$S = .00073\,(8.995 \times 10^6)^{.619}$$

$$S = 14.7\ ft.$$

Velocity = 12.85 ft/sec
Discharge = 131,000 cfs
pier diameter = 3'
add 4' for debris
depth = 9.4 ft.

Neil's Method.

$$S = (dw)(2.0)\left(\frac{a}{dw}\right)^{.65} F^{.43}$$

$$S = (9.4')(2.0)\left(\frac{7'}{9.4'}\right)^{.65}\left(\frac{12.85\ ft/sec}{\sqrt{(32.2\ ft/sec^2)(9.4')}}\right)^{.43}$$

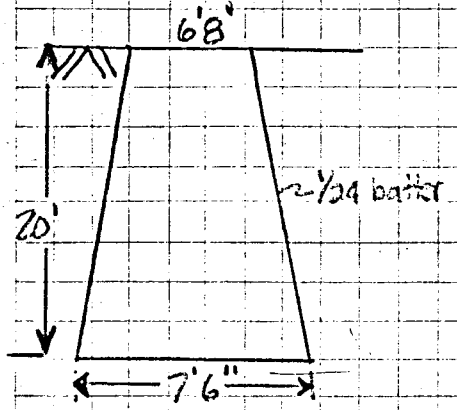
$$S = 13.6\ ft$$

Velocity = 12.85 ft/sec
pier diameter = 3'
add 4' for debris
depth = 9.4 ft.
Q = 131,000 cfs

Adopted scour value

$$S = \frac{14.7\ ft + 13.6\ ft}{2} = \underline{14.2\ ft}$$

Local Scour for 100 year Flood with proposed channelization.



Shen's Method

$$\text{Local Scour Depth} = .00073\, R^{.619}$$

Pier Reynold's Number

$$R = \frac{(9.65\ \text{ft/sec})(11.5\ \text{ft})}{1\times10^{-5}\ \text{ft}^2}$$

$$R = 11.1\times10^{6}$$

Hydraulics from HEC-II
n = .025
Velocity = 9.65 ft/sec
Discharge = 1420.00
pier diameter = 7.5'
add 4' for debris

$$\text{Local Scour} = .00073\,(11.1\times10^{6})^{.619}$$

$$= \underline{16.8\ \text{ft.}}$$

Neil's Method.

$d_w = 9.13$ ft.
$a = 11.5$ ft.
Velocity = 9.65 ft/sec

$$\text{Local Scour} = d_w\,(2.2)\left(\frac{a}{d_w}\right)^{.65} F^{.43}$$

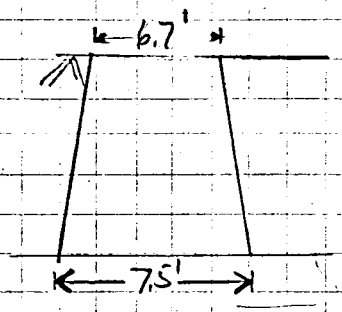
$$\text{Local Scour} = (9.13\ \text{ft})(2.2)\left(\frac{11.5\ \text{ft}}{9.1\ \text{ft}}\right)^{.65}\left(\frac{9.65}{\sqrt{(32.2)(9.13)}}\right)^{.43}$$

$$\text{Local Scour} = \underline{18.3\ \text{ft}}$$

Adopt local Scour

$$\text{Scour} = \frac{18.3' + 16.8'}{2} = \underline{\underline{17.6\ \text{ft}}}$$

Local Scour for Standard Project Flood As-Is Condition



Shen's Method

$$S = .00073\, R^{.619}$$

$$R = \frac{Vd}{\nu}$$

$$R = \frac{(12.85\ ft/sec)(11.5')}{1\times10^{-5}\ ft^2/sec}$$

$$R = 14.78 \times 10^6$$

$$S = .00073\,(14.78\times10^6)^{.619}$$

$$S = \underline{20.0\ ft}$$

Hydraulics from HEC II
$n = .035$

Velocity = 12.85 ft/sec
pier width = 7.5'
Q = 131,000 cfs
add 4' for debris

Neil's Method

$$S = d_w(2)\left(\frac{a}{d_w}\right)^{.65} F^{.43}$$

$$S = (9.8\,ft)(2)\left(\frac{11.5\,ft}{9.8\,ft}\right)^{.65}\left(\frac{12.85\ ft/sec}{\sqrt{(32.2\ ft/sec^2)(9.8')}}\right)^{.43}$$

$$S = \underline{18.9\ ft}$$

Velocity = 12.85 ft/sec
Depth = 9.8 ft
Q = 131,000 cfs
a = 7.5'
add 4' for debris accumulation.

Adopted Scour Value

$$S = \frac{20.0\,ft + 18.9\,ft}{2} = \underline{19.5\ ft}$$

Local Scour at Southern Pacific Railroad Bridge Considering "skewed" flow at the Bridge.

The Flow angle for natural conditions can approach 20 to 30 degrees from the normal. This can be seen from the aerial photo taken during the February 20, 1980 flood on the Agua Fria.

The skew of the flow can accelerate the local scour process by reducing the effective flow area, which consequently increases the flow velocity near the piers, and increases the sediment transport rates.

Simons and Sentürk (1977) proposed the following Multiplying factors for Depth of Scour for skewed piers.

TABLE 9.6

MULTIPLYING FACTORS FOR DEPTH OF SCOUR S FOR SKEWED PIERS

Horizontal Angle of Attack β	Length to Width Ratio of Pier in Flow			
	4	8	12	16
0	1.0	1.0	1.0	1.0
15	1.5	2.0	2.5	3.0
30	2.0	2.5	3.5	4.5
45	2.5	3.5	4.5	5.0
60	2.5	3.5	4.5	6.0

The length of SPRR wall piers is 32'
width of piers considering debris 11.5'

$L/w = 2.8$

Assume Horizontal Angle of attack $\approx 15°$ during the 100-year & standard Project Flood.

Multiplying factor becomes 1.5 for scour depts.

100 year Local Scour Depth
$S = (17.2\text{ ft})(1.5) = \underline{26\text{ ft}}$

Standard Project Flood Local Scour Depth
$S = (19.5\text{ ft})(1.5) = \underline{29.3\text{ ft}}$

910 12.47

SHEN → $S = 0.00073 \left(\frac{V \times W}{TAT \times 10^{-3}}\right)^{0.619}$ LOCAL SCOUR AROUND TOWERS - TUSCON GAS & ELECTIRIC CO.
STANDARD PROJECT FLOOD

NEIL → $\frac{S}{d} = 2.21 \left(\frac{W}{D}\right)^{0.65} \left(\frac{V}{\sqrt{32.2 \times d}}\right)^{.43}$

TOWER	WIDTH (D)	VELOC. (1)	Depth (2)	TOC	Bottom FOUD.	SHEN	NEIL	SCOUR	ELMIN	expected scour elev.
87	5'	11.08	11.15	1001'	977	11.3	11.6	11.5	990	978.5
88	10'	11.13	10.93			17.4	21.7	19.6	984.8	965.2
89	10'	11.11	10.94	997		17.4	21.7	19.6	983.5	963.9
94	5'	11.32	10.5	986.75	961.75	11.5	13.8	12.7	994.1	961.4
95(R)	5'	11.1	10.5	985	953.5	11.3	13.7	12.5	973.6	961.1
96	10'	12.25	9.44	982.75		18.5	22.2	20.4	972.1	951.7
97	5'	9.76	9.89			10.5	12.9	11.7	967.0	955.3
98	5'	9.80	9.85			10.5	12.9	11.7	964.6	952.9
99(R)	10'	9.0	10.65			15.3	19.7	17.5	962.6	945.1
100(R)	10'	9.6	10.5	973.25		15.9	20.2	18.0	960.4	942.4
101(R)	10'	10.04	10.35	970.00		16.4	20.7	18.6	958.3	939.7
102(R)	10'	12.40	9.2	966.75		18.7	22.2	20.5	956.1	935.6
103(R)	10'	9.76	12.5			16.1	20.9	18.5	953.7	935.2

(1) VELOCITY WAS INCREASED BY 50% in LOCAL SCOUR Computation
(2) Both VELOCITY AND FLOW Depth WERE TAKEN from HEC-II Run at 142,000 cfs for Siphon Alternative.

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STANDARD PROJECT FLOOD.

TOWER	WIDTH	VEL.	Depth	T.O.C.	Bot. Foun.	SHEN	NEIL	SCOUT	ELmin	Expected Scour
58	3'	11.21	11.22		987'	8.3	10.0	9.2	990.5	981.3
59	3'	11.06	11.0		987	8.2	9.9	9.1	985.5	976.4
60	3'	11.1	10.95		987	8.3	9.9	9.1	984.0	974.9
61	3'	11.1	10.95		987	8.3	9.9	9.1	982	972.9

(1) velocity was increased by 50% in Local scour computation

SHEN: $s = .00073 \left(\frac{V \times w}{1.41 \times 10^{-5}}\right)^{.169}$

NIEL: $\frac{s}{d} = 2.2 \left(\frac{w}{d}\right)^{0.65} \left(\frac{V}{\sqrt{32.2 \times D}}\right)^{.43}$

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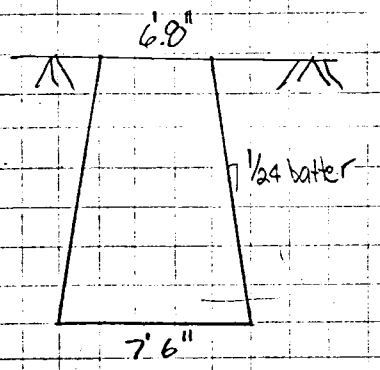
SPRR

Local Scour for 100-year Flood As-is Condition



Shen's Method

$$S = .00073\, R^{.619}$$

$$R = \frac{Vd}{\nu} = \frac{(10.3'/sec)(11.5')}{1.0 \times 10^{-5} ft^2/sec}$$

$$R = 11.85 \times 10^6$$

$$S = .00073\,(11.85 \times 10^6)^{.619}$$

$$S = \underline{17.5\ ft}$$

Hydraulics from HEC-II
n = .035
Velocity = 10.3 ft/sec
Pier width = 7.5'
Q = 90,000 cfs

Neil's Method

$$S = d_w\,(2)\left(\frac{a}{d_w}\right)^{.65} F^{.43}$$

$$S = (8.4')(2)\left(\frac{11.5'}{8.4'}\right)^{.65}\left(\frac{10.3}{\sqrt{(32.2)(8.4')}}\right)^{.43}$$

$$S = 16.8\ ft.$$

Hydraulics from HEC-II
n = .035
Velocity = 10.3 ft/sec
d_w = 8.4 ft
a = 7.5 ft
add 4' for debris

Adopt Local Scour

$$\text{Scour} = \frac{16.8' + 17.5'}{2} = \underline{17.2\ ft}$$

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CLIENT: ICD of MC
PROJECT: SPF Design
DETAIL: Local Scour
SPRR without Spheres.

JOB NO.: AE-MC-05
DATE CHECKED:
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PAGE: 2/6
DATE: 2/5/84
COMPUTED BY: MJB

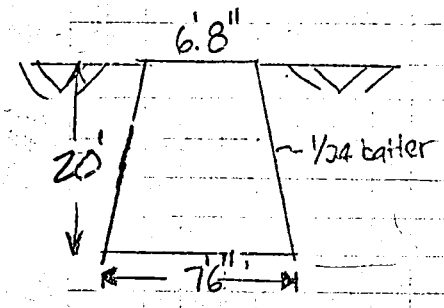
SPRR Local Scour for SPF with proposed channelization

Hydraulics from HEC II
n=.025

Shen Method

$S = .00073\, R^{.619}$

Velocity = 12.1 ft/sec
Pier diameter = 7.5 ft.
add 4' for debris accumulation



$R = \frac{Vd}{\nu} = \frac{(12.1\,ft/sec)(11.5\,ft)}{1 \times 10^{-5}\,ft^2/sec}$

$R = 13.915 \times 10^6$

$S = .00073\,(13.915 \times 10^6)^{.619}$

Local S_{cour} = 19.3 ft.

Neil Method

$d_s = d_w (2) \left(\frac{a}{d_w}\right)^{.65} F^{.43}$

Velocity = 12.1 ft/sec
Depth = 10.9 ft.
a = 7.5 ft
add 4' for debris

F = .65

$d_s = (10.9\,ft)(2)\left(\frac{11.5\,ft}{10.9\,ft}\right)^{.65}\left(\frac{12.1\,ft/sec}{\sqrt{(32.2)(10.9)}}\right)^{.43}$

d_s = 18.7 ft

Adopt Scour = $\frac{19.3' + 18.7'}{2}$ = 19.0 ft.

Needs protection

11/23/84
MJB
1/11

Flow around bend at I-10 for S.P.F.

superelevation around bend

$$\Delta y = \frac{C\, V^2 W}{g\, r}$$

Average HEC II velocity around bend ≈ 12 ft/sec with $n = .025$

$C = 1$ for trapazoid on a simple curve

$$\Delta y = \frac{V^2 (1300\text{ ft})}{(32.2\text{ ft/sec}^2)(3600\text{ ft})} = V^2 (.0112)$$

$$\Delta y = (12)^2 (.0112) = 1.6\text{ ft.}$$

using flow around bend in the shear stress equation the velocity increases 1.4 times or the square root of the increase in the shear stress (1.88). See SCS curve on following page where $R_c/b = 2.75$

Antidune height

$$h = .14\, \frac{2\pi V^2}{g} = \frac{.14(\pi)2(16.44\text{ ft/sec})^2}{(32.2\text{ ft/sec}^2)} = 7.4\text{ ft}$$

½ antidune height = 3.7 ft

total height around bend 5.5 ft.
above SPF Elevation.

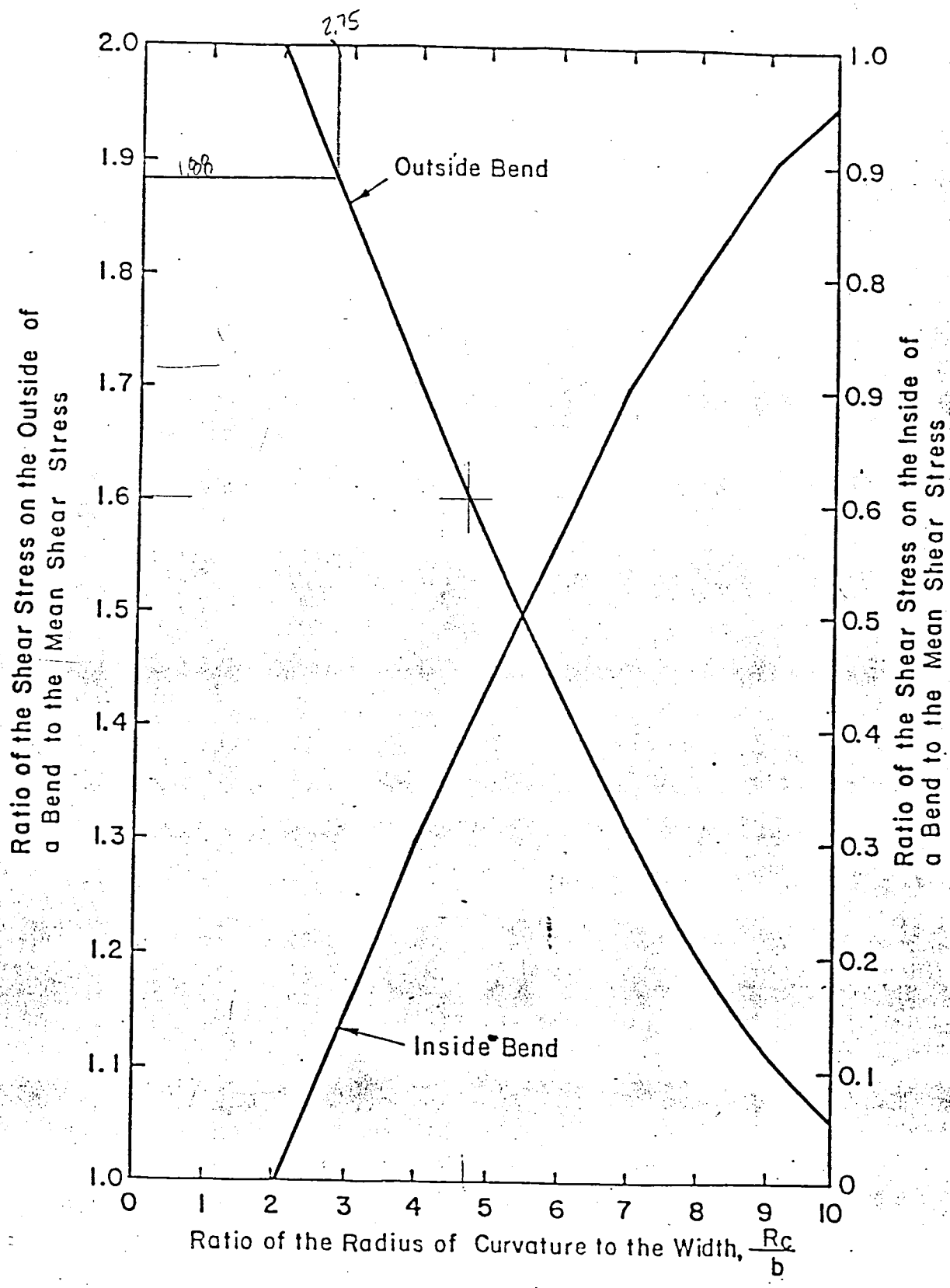


Figure 9
Effect of bend on boundary shear stress

1/23/84
3/11

Toe Down depths standard Project flood.
Manning "n" value = .025 in channel

Method 1 (½ antidune height) + (low flow thalweg) + (30% FS) below the general scour potential.

maximum velocity ≈ 14.6 ft/sec

$$\frac{1}{2}\text{ antidune height} = \frac{.14\ \pi\ 2V^2}{2g} = \frac{(.14)(\pi)(14.6\ ft/sec)^2}{(32.2\ ft/sec^2)}$$

$$y = 2.91\ ft \approx 3\ ft.$$

Low flow thalweg ≈ 3.5 ft maximum.

toe down = 6.5ft + 30% FS
= 6.5' + 2'
= 8.5 ft

Method 2 low flow thalweg depth plus impingement scour.

Impingement scour is defined as scour that occurs at low flows when the low flow thalweg meanders within channel banks and attacks the banks. Low flow considered is ≈ the 2-year return flow or 10,000 cfs. Lui's embankment scour is used to determine scour depths slightly modified to reflect 3:1 sideslope

$$S = d_1 (.75) \left(\frac{q}{d_1}\right)^{.4} F_r^{.33}$$

unit $q \approx 10$ cfs/ft if uniformily distributed across the x-section

assume $q \approx 25$ cfs/ft for concentrated flows.

$$q = \frac{1.486}{n} y^{5/3} S^{1/2}$$

$S = .003$
$S = .0015$
$n = .03$

For $S = .003$ $y = 3.8$ ft. $V = 6.6$ ft/sec

for $S = .0015$ $y = 4.67$ ft. $V = 5.36$ ft/sec.

for $S = .003$ Scour $= 3.72$ ft

" $S = .0015$ Scour $= 3.95$ ft.

impingement scour ≈ 4.0 ft
low flow thalweg ≈ 3.5 ft
$\sqrt{7.5}$ ft.

conclusion

toe down should be extended 8.5 ft below the general scour potential in the channel bed throughout, except at severe bends where the velocity & subsequently the shear stress increases.

1/23/84
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5/11

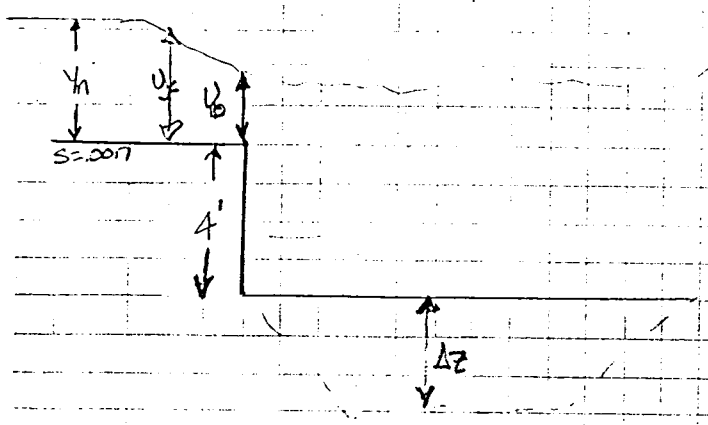
Toe down depth increase around I-10 bend.

As shown previously the shear stress around the west bend at I-10 increased 1.88 times and the velocity increased 1.37 times. To maintain similar velocities around the corner the depth will have to increase ≈ the same as the velocity increases. (Continity) The approximate depth in this bend before superelevation is 10 ft. Therefore the bend increases scour ≈ 3.7 ft.

total scour	3.7 ft.	around bend
	3.7 ft	½ antidune height.
	3.5 ft	thalweg depth
	10.9 ft	total scour
	30% FS 3.3 ft	

depth of burial 14 ft

Local scour on the downstream side of drop structure below I-10. Drop height is 4 ft.



$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

$$q = \frac{1.486}{n} Y^{5/3} S^{1/2}$$

Slope ≈ .0017

Q = 142,000 cfs
Width ≈ 1400 ft

$$q = 142{,}000 \text{ cfs} / 140 \text{ ft} = 101.4 \text{ cfs/ft.}$$

$$Y_n = \left(\frac{qn}{1.486 (S^{1/2})}\right)^{3/5} = \left(\frac{(101.4 \text{ cfs/ft})(.03)}{(1.486)(.0017)^{1/2}}\right)^{3/5} = 10.4 \text{ ft}$$

$Y_n = 10.4$ ft.

$$Y_c = \sqrt[3]{q^2/g} = \sqrt[3]{(101.4)^2/(32.2)} = 6.84 \text{ ft}$$

$$V_c = q/y_c = 101.4/6.84 = 14.82 \text{ ft/sec}$$

Compute the Chow Drop Number

$$D = q^2/gh^3 = (101.4)^2/(32.2)(4)^3 = 4.99$$

$$L_d = 4.3\, h\, D^{.27} = (4.3)(4')(4.99)^{.27} = 26.5 \text{ ft} \approx 27'$$

Local Scour Depth using Veronese Eqn.

$$\Delta Z = 1.32\, H_T^{.225}\, q^{.54} - y_c$$

$$\Delta Z = 1.32\,(4)^{.225}\,(101.4)^{.54} - 6.84 = \underline{15.00 \text{ ft.}}$$

Using Scholitsch eqn.

$$\Delta Z = 4.75 \frac{H_T^{.2}\, q^{.5}}{D_{90}^{.32}} - y_c \qquad \text{metric units.}$$

$$\Delta Z = 4.75 \frac{(1.22m)^{.2} (9.42)^{.5}}{(10mm)^{.32}} - 2.085$$

ΔZ = 5.18 meters or ≈ 17 ft

Adopt local scour depth of 16 ft.

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Figure 8.6 West Bank Aqua

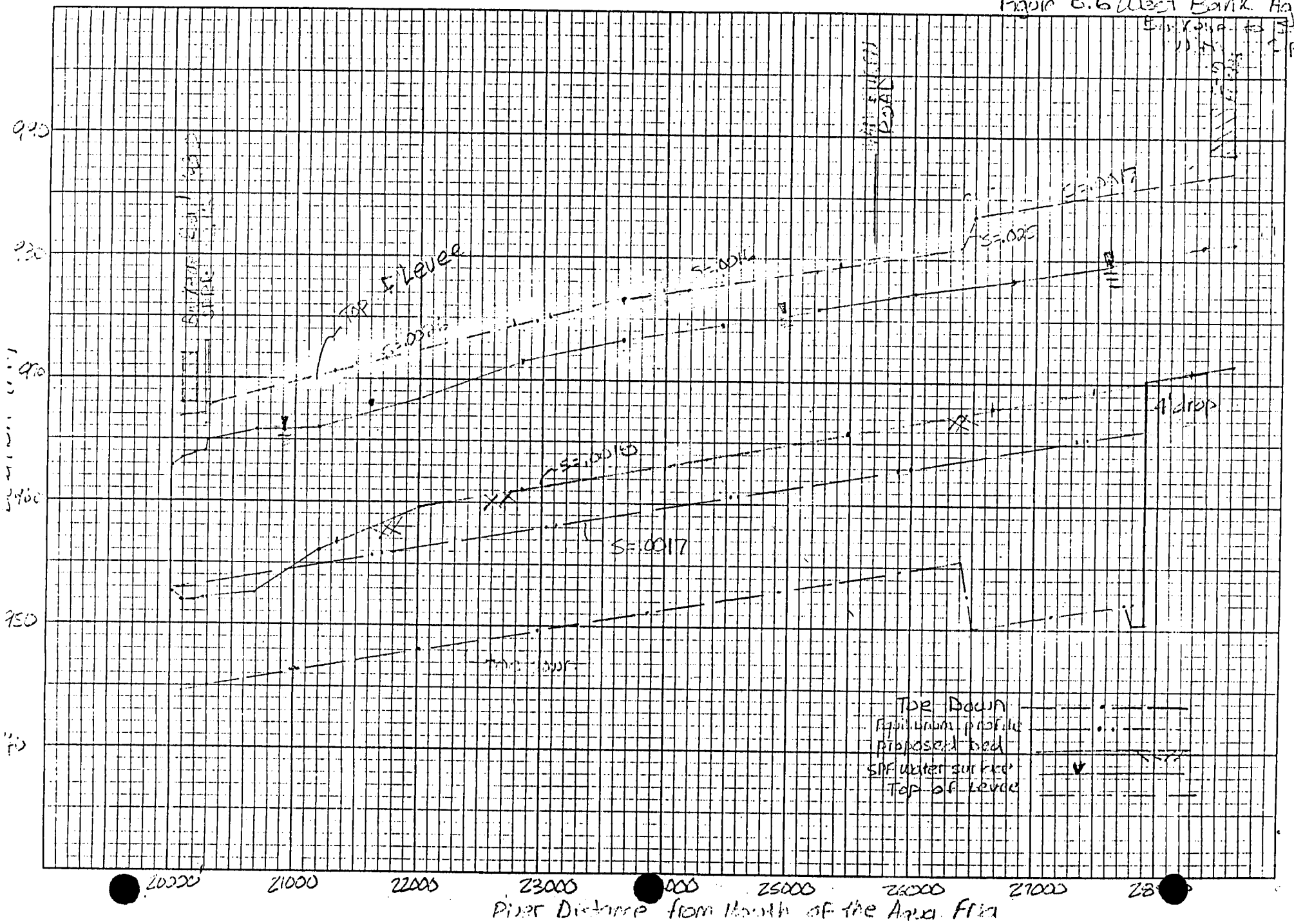

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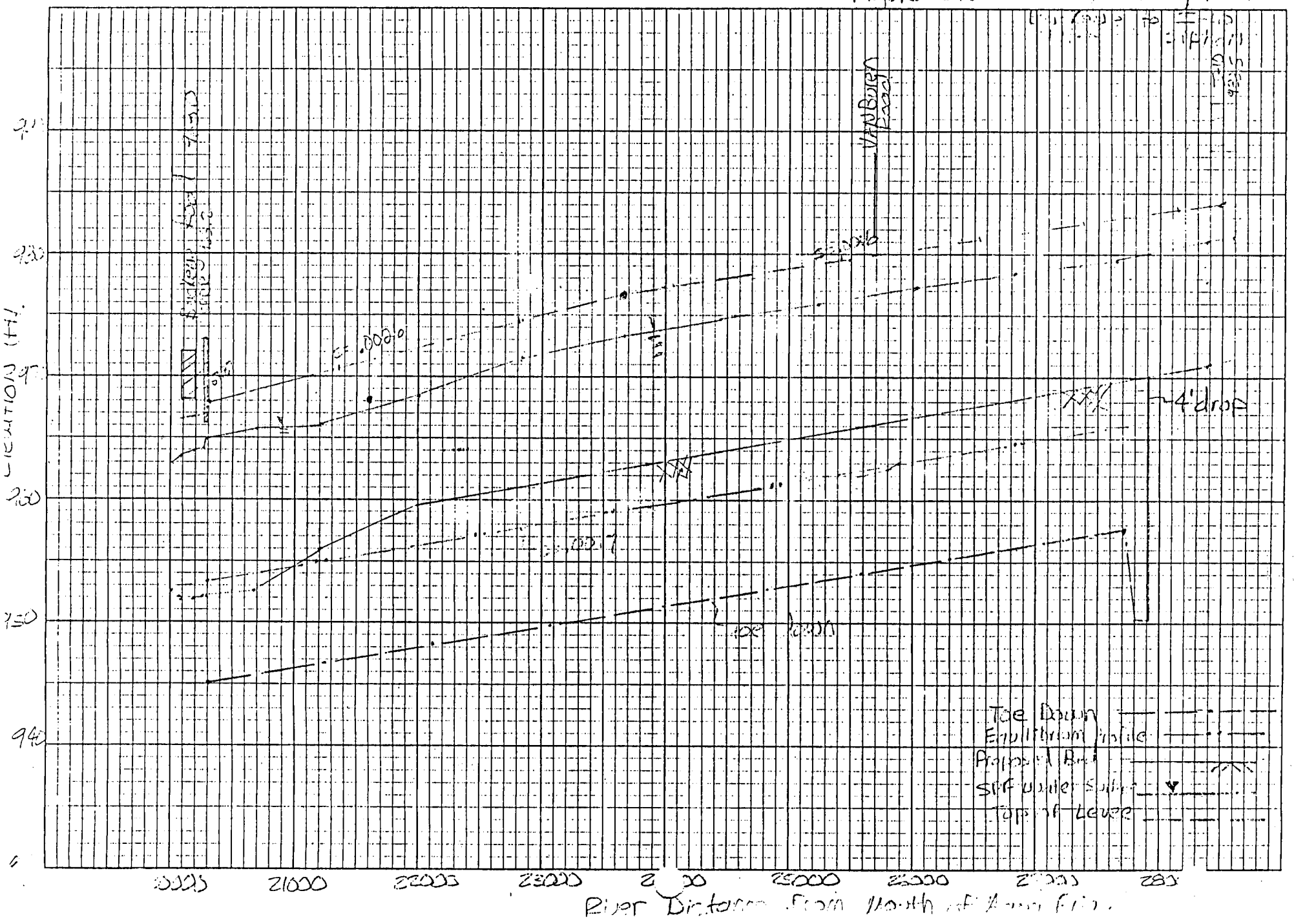
Figure B.5



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CLIENT FCDMC
PROJECT
DETAIL BANK PROTECTION. Details

JOB NO. AZ-MC-05
DATE CHECKED
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PAGE 10/11
DATE 1/24/84
COMPUTED BY MJB

Rip Rap sizing of banks. not considering bends

Data $Q = 142000$ cfs
$n = .025$
Maximum velocity ≈ 15 ft/sec
side slope = 3 horizontal : 1 vertical $\theta = 18.43°$
Flow across rocks = 0° $\lambda = 0$
assume material is angular $f = .066$

angle of repose of material 41°

D_{50} (ft.)	ϕ	$\tan\phi$	η	$\tan\beta$	β	η'	SF	
1.5	41°	.8693	.489	.6723	33.91	.3809	1.4	OK ✓
Velocity 17.0 ft/sec 1.5	41°	.8693	.628	.8634	40.80	.519	1.2	OK

USE material $D_{50} = 18''$
$D_{100} = 3'$

Gradation

D_{100}	3'
D_{50-70}	1.5'
D_{15-30}	.75'
D_{0-5}	.3'

$\tau_s = 1/8 \rho f V^2$ $\tau_s = 3.5937$

$\tau_c = .047(\gamma_s - \gamma) d_s$

$\eta = \dfrac{21 \tau_s}{(S_s - 1)\gamma D_{50}}$ Stability no. for plane bed.

$\tan\beta = \dfrac{\cos\lambda}{\dfrac{2\sin\theta}{\eta\tan\phi} + \sin\lambda}$ direction of particle motion

$\eta' = \left[\dfrac{1 + \sin(\lambda + \beta)}{2}\right]\eta$

$SF = \dfrac{\cos\theta \tan\phi}{\eta' \tan\phi + \sin\theta \cos\beta}$

Flow Around Bend at I-10

Hydraulics from HEC-II
$n = .025$
Average Velocity = 11.5 ft/sec

Superelevation Around Bend

$$\Delta y = \frac{C V^2 W}{g r}$$

$C = 1$ for trapezoidal Channel

$$\Delta y = \frac{(11.5\ ft/sec)^2 (1300\ ft)}{(32.2\ ft/sec^2)(3600\ ft)} = 1.5\ ft.$$

The increased shear stress artina upon the bank due to the flow around the bend is 1.88 using the SCS procedure

Velocity increase is the square root of the increase in shear stress ≈ 1.37

Antidune height $V = (12\ ft/sec)(1.4) = 16.44\ ft/sec.$

$$h = .14\ \frac{2\pi V^2}{g} = 7.4\ ft.$$

½ antidune height = 3.7 ft.

total height around bend **5.5 ft.**

Toe down around bend at I-10

n=.025 for computations

Method 1

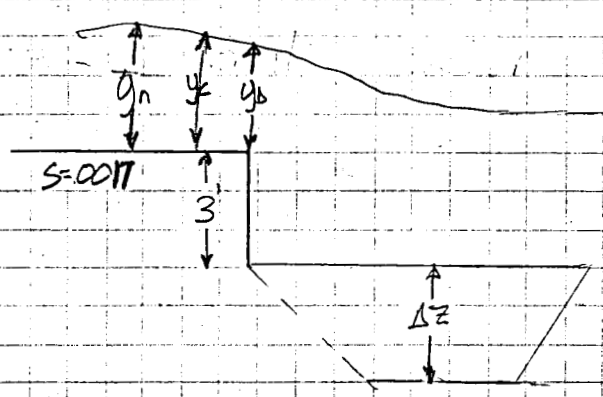
bend scour + (½ antidune height) + (low flow thalweg) + (30% F.S.)

Maximum velocity	16.44 ft/sec.
	3.7 ft
½ antidune height	3.7 ft
low flow thalweg	3.5 ft
30% F.S.	3.3 ft.

toe down ≈ 14.2 ft.

use 14.0 ft toe down.

Local scour downstream of 3' drop structure.



$$Q = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

$$q = \frac{1.486}{n} V^{5/3} S^{1/2}$$

S=.0017

$$q = 142000 \text{ cfs/ft} / 1400 \text{ ft} = 101.4 \text{ cfs/ft.}$$

$$y_n = \left(\frac{qn}{1.486\, S^{1/2}}\right) = \left(\frac{(101.4 \text{ cfs/ft})(.025)}{(1.486)(.0017)^{1/2}}\right) = 10.4 \text{ ft.}$$

$y_n = 10.4$ ft.

$$y_c = \sqrt[3]{q^2/g} = \sqrt[3]{(101.4^2/32.2)} = 6.94 \text{ ft.}$$

$V_c = q_c / y_c = 101.4 / 6.84 = 14.82$ ft/sec

Compute the Chow Drop Number

$D = q^2 / g h^3 = (101.4)^2 / (32.2)(3')^3 = 11.83$ ✓

$L_d = 4.3 h D^{.27} = (4.3)(3')(11.83)^{.27} = \underline{25.1 \text{ ft}}$

Extend protection

$L_P = (4 * \text{Depth}) + L_D$

$L_P = (4)(6.84 \text{ ft}) + 25.1 \text{ ft}$

$L_P = 52.5$ ft. or $\underline{55 \text{ ft.}}$

Local Scour Depth using Veronese Eqn.

$\Delta z = 1.32 H_T^{.225} q^{.54} - y_c$

$\Delta z = 1.32 (3)^{.225} (101.4)^{.54} - (6.84)$

$\Delta z = \underline{13.6 \text{ ft}}$ ✓

Local Scour Depth using Scholitsch eqn.

$\Delta z = 4.75 \dfrac{H_T^{.2} q^{.5}}{D_{90}^{.32}} - y_c$

$\Delta z = 4.75 \dfrac{(.9144)^{.2} (9.42 \text{ m}^2/\text{sec})^{.5}}{(10)^{.32}} - 2.085 \text{ m}$

$\Delta z = 4.769$ meters or $\underline{15.6 \text{ ft}}$ ✓

Local Scour $\underline{14.6 \text{ ft}}$ or $\underline{14.5 \text{ ft}}$

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11.1E 1/5
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Figure 7.8

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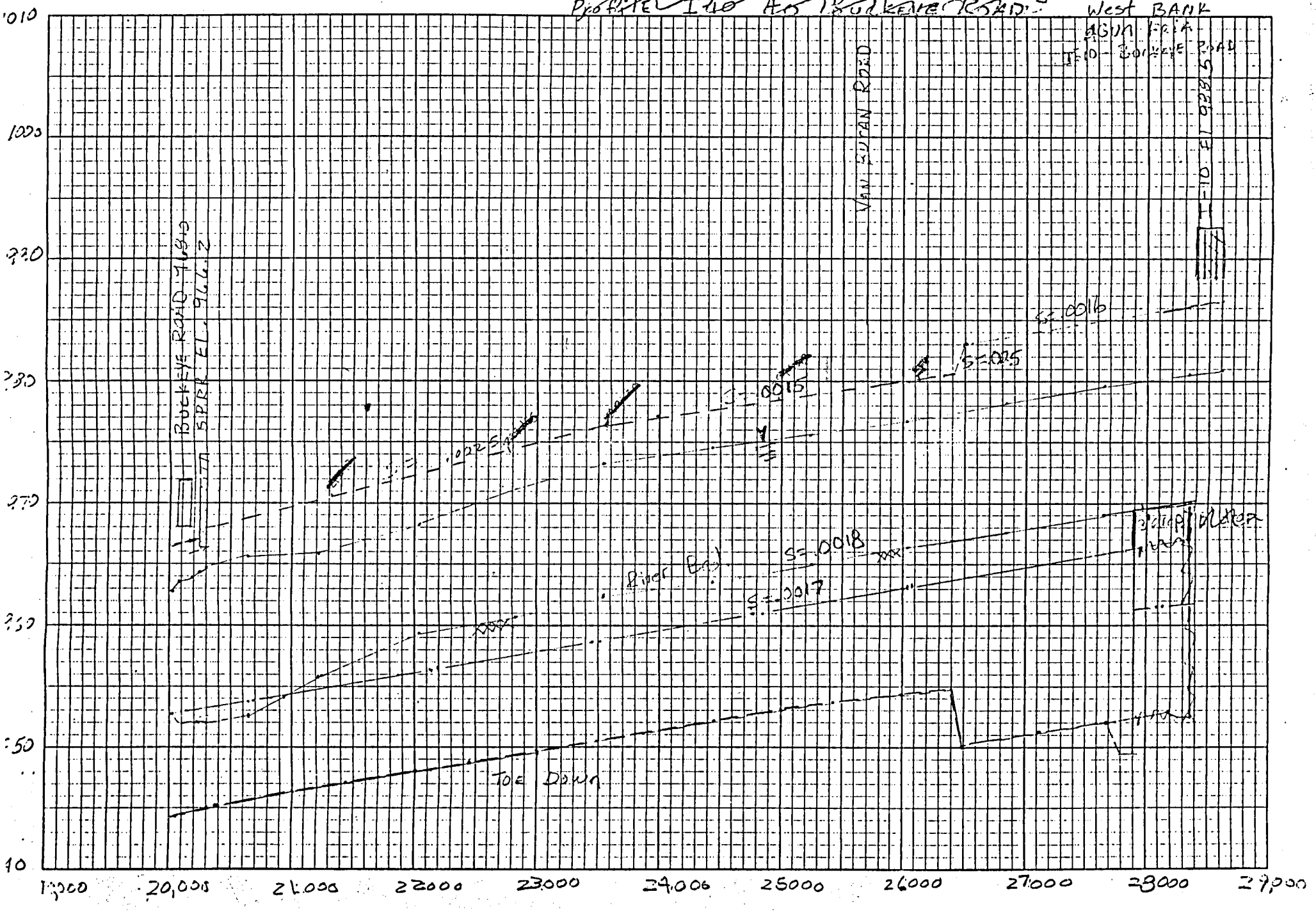
Figure 7.9

Profile I-10 to Buckeye Road



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FORT COLLINS, COLORADO

CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Local Scour Around Bridge Piers

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Bridge	With Siphon: Shen (ft.)	Neil (ft.)	Adopted (ft.)	Without Siphon: Shen (ft.)	Neil (ft.)	Adopted (ft.)
Camelback	13.7	13.2	13.5	13.6	13.1	13.4
ISRB *	25.8	22.1	24.0	25.8	22.1	24.0
McDowell	18.0	16.4	17.2	17.5	16.2	17.0
I-10 *	16.5	14.2	15.4	16.5	14.2	15.4
SPRR	19.3	18.7	19.0	19.3	18.8	19.0
Buckeye elevation 451.8	14.5	13.7	14.1	14.5	13.7	14.1
RID flume *	—	—	—	19.0	16.4	17.7

* Assuming critical velocity exist

SPRR spread footings buried 30+ feet below present bed. Would appear as if the foundations are OK for SPF.

Buckeye Rd: piers buried to elevation 449.3 ft. piles buried 25' below pile caps.

Call ADOT about minimum cover requirements for SR 85 Buckeye Rd.

Buckeye Road

Local Scour using Shen's Equation

$$S = .00073\ R^{.619}$$

$$R = \frac{Vd}{\nu}$$

Hydraulics from HEC II
$n = .025$

Velocity 12.5 ft/sec.
pier diameter 3.0 ft (add 4' for debris accumulation)
$\nu = 1 \times 10^{-5}\ ft^2/sec$

$$R = \frac{(12.5\ ft/sec)(7ft)}{1 \times 10^{-5}\ ft^2/sec} = 8{,}743{,}000$$

$$S = .00073\ (8.743 \times 10^6)^{.619}$$

$$S = \underline{\underline{14.5\ ft.}}$$

Neil's Method

$$d_s = d_w\ (2) \left(\frac{a}{d_w}\right)^{.65} F^{.43}$$

$$F = \frac{V}{\sqrt{g d_w}}$$

$a = 3ft$ (add 4' for debris)
Velocity = 12.5 ft/sec.
Depth = 10.5 ft.

$$F = \frac{12.5\ ft/sec}{\sqrt{(32.2\ ft/sec^2)(10.5ft)}} = .68$$

$$d_s = (10.5ft)(2)\left(\frac{7\ ft}{10.5ft}\right)^{.65}(.68)^{.43}$$

$$d_s = \underline{\underline{13.7\ ft.}}$$

Adopt $\left(\frac{14.5 + 13.7}{2}\right) = \underline{14.1\ ft}$

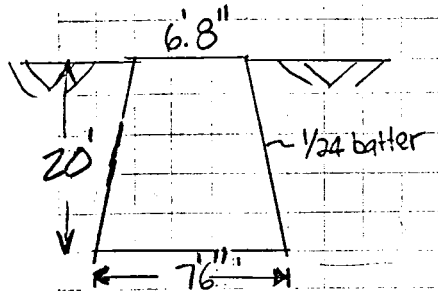
SPRR without Siphon.

SPRR

Shen Method

$S = .00073\ R^{.619}$

Hydraulics from HEC II
n=.025
Velocity = 12.1 ft/sec
Pier diameter = 7.5 ft.
add 4' for debris accumulation



$R = \frac{Vd}{\nu} = \frac{(12.1\ ft/sec)(11.5\ ft)}{1 \times 10^{-5}\ ft^2/sec}$

$R = 13.915 \times 10^6$

$S = .00073\ (13.915 \times 10^6)^{.619}$

Local S_{scour} = 19.3 ft.

Neil Method

$d_s = d_w (2) \left(\frac{a}{d_w}\right)^{.65} F^{.43}$

Velocity = 12.1 ft/sec
Depth = 10.9 ft.
a = 7.5 ft
add 4' for debris

F = .65

$d_s = (10.9\ ft)(2)\left(\frac{11.5\ ft}{10.9\ ft}\right)^{.65}\left(\frac{12.1\ ft/sec}{\sqrt{(32.2)(10.9)}}\right)^{.43}$

d_s = 18.7 ft

Adopt Scour = $\frac{19.3' + 18.7'}{2}$ = 19.0 ft

Needs protection

Shen's Method

Critical Velocity Assumed

$$d_s = .00073\, R^{.619}$$

Velocity = 14.8 ft/sec
pier diameter = 3.3 ft.
$\nu = 1.0 \times 10^{-5}$ ft²/sec
add 4' for debris

$$R = \frac{(14.8 \text{ ft/sec})(7.3 \text{ ft})}{1.0 \times 10^{-5}}$$

$$R = 10.80 \times 10^{6}$$

$$d_s = .00073\,(10.80 \times 10^{6})^{.619}$$

$$d_s = \underline{16.5 \text{ ft.}}$$

Neil's Method

$$d_s = d_w\,(2)\left(\frac{a}{d_w}\right)^{.65} F^{.43}$$

$d_w = 6.8$
Velocity = 14.8 ft/sec
$a = 3.3$ ft.
add 4 ft for debris

$$d_s = (6.8)\,(2)\left(\frac{7.3}{6.8}\right)^{.65}(1.0)^{.43}$$

$$d_s = \underline{14.2 \text{ ft}}$$

Adopted scour $= \left(\frac{16.5 + 14.2}{2}\right) = 15.4$ ft.

McDowell Road

Hydraulics from HEC II
$n = .025$
Velocity = 13.84 ft/sec
Pier Diameter = 5'
add 4' for debris
$\nu = 1 \times 10^{-5}$ ft²/sec

Shen's Method

$$d_s = .00073 R^{.619}$$

$$R = \frac{Vd}{\nu} = \frac{(13.84 \text{ ft/sec})(9 \text{ ft})}{1.0 \times 10^{-5} \text{ ft}^2/\text{sec}} = 12.456 \times 10^6$$

$$d_s = .00073 (12.456 \times 10^6)^{.619}$$

$$d_s = 18.0 \text{ ft.}$$

Neil's Method

$$d_s = d_w (2) \left(\frac{a}{d_w}\right)^{.65} F^{.43}$$

$d_w = 9$ ft.
Vel = 13.84 ft/sec
$a = 5'$
add 4' for debris

$$F = \frac{V}{\sqrt{gd}} = \frac{13.84}{\sqrt{(32.2)(9)}} = .81$$

$$d_s = (9 \text{ ft})(2)\left(\frac{9 \text{ ft}}{9 \text{ ft}}\right)^{.65} (.81)^{.43}$$

$$d_s = 16.4 \text{ ft.}$$

$$\text{Adopted Scour} = \frac{18.0 \text{ ft} + 16.4 \text{ ft}}{2} = \underline{17.2 \text{ ft}}$$

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Indian School Road Bridge

Shens Method

$S = .00073\, R^{.619}$

Critical Depth Assumed underneath bridge

Velocity = 14.7 ft/sec
pier diameter = 1.67 ft
add 4' for debris

$R = \frac{(14.7\ ft/sec)(5.67\ ft)}{(1.0 \times 10^{-5}\ ft^2/sec)}$

$R = 8.33 \times 10^6$

$d_s = .00073\,(8.33 \times 10^6)^{.619}$

$d_s = 14.0\ ft$

10° skew due to uncertainty of transverse dikes totally aligning flow

Multiplying factor Table 9.6 page 693 Simons + Sentürk

Length to Width Ratio 60/5.67 ≈ 10

Factor = 1.83

$d_s = (14.0)(1.83) = \underline{25.8\ ft}$

Neil's Method

$d_s = d_w (2) \left(\frac{a}{d_w}\right)^{.65} F^{.43}$

$d_w = 6.8\ ft$
Velocity = 14.7 ft/sec
a = 1.67 ft
add 4' for debris

$d_s = (6.8\ ft)(2)\left(\frac{5.67'}{6.8'}\right)^{.65}(10)^{.43}$

$d_s = 12.1\ ft.$

$d_s = (12.1\ ft)(1.83) = \underline{22.1\ ft}$

Adopt local scour of $\underline{24.0\ ft}$

Camelback Road Bridge

Shen's Method

Hydraulics from HEC II
n=.025

Velocity = 10 ft/sec
Pier diameter = 4 ft.
add 4' for debris

$$S = .00073\,R^{.619}$$

$$R = \frac{(10\text{ ft/sec})(8\text{ ft})}{1\times10^{-5}} = 8\times10^{6}$$

$$S = .00073\,(8\times10^{6})^{.619}$$

$$S = \underline{13.7\text{ ft.}}$$

Neil's Method

$$d_s = d_w(2)\left(\frac{a}{d_w}\right)^{.65} F^{.43}$$

$d_w = 8.5$ ft.
$V = 10$ ft/sec
$a = 4$ ft
add 4' for debris

$$d_s = (8.5\text{ ft})(2)\left(\frac{8'}{8.5'}\right)^{.65}(.6)^{.43}$$

$$F = \frac{V}{\sqrt{gd}} = \frac{10}{\sqrt{(32.2)(8.5)}}$$

$$F = .60$$

$$d_s = 13.2\text{ ft.}$$

Adopt local scour of <u>13.5 ft</u>

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Shen's Method

Hydraulics from HEC II
n=.025

Bridge	Flow Velocity (ft/sec)	Pier diameter (ft)	Debris width (ft)	Pier Reynolds No.	Skew Factor	Local Scour (ft.)
Buckeye Road	12.5	3	7	8.75×10^6	1	14.5
SPRR	12.1	7.5	11.5	13.92×10^6	1	19.3
I-10 *	14.8	3.3	7.3	10.8×10^6	1	16.5
McDowell	13.2	5	9	11.88×10^6	1	17.5
ISRB *	14.7	1.67	5.67	8.37×10^6	1.33	25.8
Camelback	9.9	4	8	7.92×10^6	1	13.6
RID flume *	17.0	4	8	13.6×10^6	1	19.8

* critical velocity assumed because of downstream Drop Structure

$$R = \frac{Vd}{\nu}$$

$$S = .00073\, R^{.619}$$

Neil's Method

Hydraulics from HEC II
n=.025

Bridge	Flow Velocity (ft/sec)	Water Depth (ft.)	Pier Diameter (ft.)	Debris Width (ft.)	Froude No.	Skew factor	Local scour (ft.)
Buckeye Road	12.5	10.5	3	7	.68	1	13.7
SPRR	12.1	11.1	7.5	11.5	.64	1	18.8
I-10 *	14.8	6.8	3.3	7.3	1.0	1	14.2
McDowell Road	13.2	9.4	5	9	.76	1	16.2
ISRB *	14.7	6.8	1.67	5.67	1.0	1.83	22.1
Camelback Road	9.9	8.5	4	8	.60	1	13.1
RID flume *	17.0	7.6	4	8	1.0	1	16.4

* Critical Velocity Assumed because of downstream Drop.

$$S = dw(2)\left(\frac{a}{dw}\right)^{.65} F^{.43}$$

RID flume problem with critical flow

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1) The equilibrium slopes were computed for the 10-year return event, which is 31000 cfs, for all the channelized reaches between Camelback Rd and Buckeye Road.

2) The channelized reach between Indian School Road and Camelback Road was broken down into two reaches for the analysis. Reach 1 is from Camelback Rd to 4000 ft downstream of Camelback. Reach 2 is from 4000 ft downstream of Camelback Rd to Indian School Road. Reach 2 is very steep while Reach 1 flattens considerably. Realizing the necessity for fill material, the two reaches were combined into 1 reach, and the hump was taken out of the steep reach #2. The equilibrium slope for the two combined reaches was .0015. This considers both banks have levees that are protected. The other option would be to protect the east bank and leave the west bank open. The analysis for this option has not been completed.

3) Soil samples were assumed homogeneous throughout the channelized reaches based on available soil reports of surface material.

4) The equilibrium slope profiles along with the existing bed profiles (August, 1981 topographic map) are compared in Table 1. The average hydraulics are also summarized in Table 1.

5) A grade control structure approximately 100' downstream of the RID flume should be constructed at an elevation of 994.8' at the top. The gradient between the RID flume and ISRB will go to .0014 from its existing slope of .0024. The design grade might be a little steeper than .0014.

6) Computations of the 10 yr equilibrium slope (or dynamic equilibrium slope, as stated by RML) follow for each of the channelized reaches between Camelback Road and Buckeye Rd.

7) A blueprint of suggested grade control locations and equilibrium slope profiles is attached with this set of material.

Equilibrium Slope Computations for the 10 YEAR Return Discharge of 31,000 cfs. New slopes were computed to be consistent with the As-is supply study as determined by Lan-Yin Li. These slopes are slightly flatter than the ones previously computed and should be used as the controlling grade.

Using the 10 YR discharge of 31,000 cfs, and using the Pima County unit width regressions for sediment transport capacity with a D_{50} of 1 mm; and a gradation coefficient of 4. the following sediment transport equation is used.

$$q_s = 8.61 \times 10^{-5}\ V^{3.7}\ Y^{.324}$$

where q_s is the unit transport rate per unit width
V is the flow velocity
Y is the flow depth

The following equilibrium slope equation is used to determine the eventual gradient in the Channelized reaches.

$$S_{eq} = S_{ex} \left(\frac{Q_{sup}}{Q_{rea}}\right)^{\frac{2}{b - 3/5\left(\frac{2b}{3} + C\right)}}$$

where S_{eq} — is the equilibrium slope of the reach
S_{ex} — is the existing slope of the reach
Q_{sup} — is the sediment from the supply reach
Q_{rea} — is the sediment transport capacity of the reach
b — is the velocity exponent
C — is the depth exponent.

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TABLE 1

Summary of Equilibrium Slope Analysis 10 Year Return Flood.

Reach	Description of Reach	TW (ft)	Q (cfs)	V (ft/sec)	HY (ft)	Q_s (cfs)	conc (ppm wgt)	S*	Seq.
Supply	upstream of Camelback Rd 1	1673	31000	5.36	3.26	105.5	9000	.0017	.001+
1	Camelback Rd to 4000' below Camelback	1626	31000	6.04	3.16	157.7	13,480	.0021	.001
2	4000' below Camelback to ISRB	1567	31000	7.55	2.62	326.6	27920	.0048	.001
3	ISRB to EID flume	1151	31000	6.70	4.02	177.1	15140	.0024	.001
4	EID flume to Thomas Rd.	965	31000	6.90	4.66	173.7	14850	.0023	.001
5	Thomas Rd to I-10	1129	31000	6.82	4.03	185.7	15880	.0021	.001
6	I-10 to Van Buren	1455	31000	5.96	3.57	139.7	11940	.0023	.001
7	Van Buren to Buckeye Rd.	1310	31000	5.54	4.27	102	8720	.0016	.001

1 Average hydraulics of main channel braid.

* Profile determined from thalweg of August 31, 1981 topographic map.

TW – Top width
Q – Water Discharge
V – Flow Velocity
HY – hydraulic depth
Q_s – sediment transport rate
S – existing thalweg slope
Seq – equilibrium slope.

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Supply Reach

(Agua Fria upstream of confluence with New River to ½ mile below Glendale Avenue)

Q = 31000 cfs

main channel				left overbank				right overbank			
Vel. (ft/sec)	HV (ft)	TW (ft)	Q_s (cfs)	Vel. (ft/sec)	HV (ft)	TW (ft)	Q_s (cfs)	Vel (ft/sec)	HV (ft)	TW (ft)	Q_s (cfs)
5.36	3.26	1673	105.3	.43	.18	528	.001	.91	1.0	2492	.15

Q_s = 105.49 cfs

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Equiliprium slope REACH 1

10YR DISCHARGE 31000 SECTIONS (450.2-4755
from Camelback to 3700 downstream of Camelback

$$\text{Velocity} = 4.55\left(\frac{1138}{3746}\right) + 8.04\left(\frac{1050}{3746}\right) + 4.27\left(\frac{1003}{3746}\right) + 8.48\left(\frac{55}{374}\right.$$

Velocity = 6.04 ft/sec
TOP WIDTH = 1626'
HY = 31000 / (6.04) (1626) = 3.16 ft
Slope = .0021

$$Q_s = 8.61 \times 10^{-6} (6.04)^{3.7} (1626) (3.16)^{.324}$$

$$Q_s = 157.7 \text{ cfs}$$

$$S_{eq} = .0021 \left(\frac{105.5}{157.7}\right)^{.9874} \approx .0014$$

Degrades ≈ (.0021 - .0014) (3746') = 2.6'

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Equilibrium Slope REACH 2.

10 YR DISCHARGE Q = 31000 cfs
Sections (427.35 - 438.80)
from ISRB to 2200 upstream of brid

$$\text{Velocity} = 5.11\left(\frac{360}{2256}\right) + 8.60\left(\frac{823}{2256}\right) + 7.57\left(\frac{1073}{2256}\right)$$

slope = .0048
Velocity = 7.55 ft/sec
TW = 1567 ft

HY = 31000 cfs / (7.55)(1567) = 2.62 ft.

$$Q_s = 8.61 \times 10^{-5} (1567)(7.55)^{3.7}(2.62)^{.324}$$

$$Q_s = 326.59$$

$$S_{eq} = .0048\left(\frac{1055}{326.59}\right)^{.9874} = .0016$$

$$D_{eq} = (.0048 - .0016)\ 2256' = 7.2'$$

REACH 1 + 2 combined
between ISRB + Camelback Road.

10 YR Discharge = 31,000 cfs.
slope existing = .003
slope equilibrium = .0015.

$V = 1/6\,(6.39 + 6.82 + 6.50 + 6.69 + 6.56 + 6.46)$

$V = 6.57$ ft/sec.

$TW = 1607$ ft.

$HY = 31000 / (6.57)(1607) = 2.94$ ft.

$Q_s = 8.61 \times 10^{-5}\,(6.57)^{3.7}(1607)(2.94)^{.324}$

$Q_s = 207.85$ cfs

$S_{eq} = .003\left(\frac{105}{207.85}\right)^{.9874}$

$S_{eq} = .0015$

Distance ≈ 5850 ft.

Deg $\approx (.003 - .0015)(5850) \approx 8.78$ ft.

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Design Parameters RID FLUME to ISRB
REACH 3

Cross Sections. (403.70 – 426.95)

10 YEAR FLOOD PEAK Q = 31000 cfs.

Distance weighted Velocity = $7.18\left(\frac{105}{2325}\right) + 7.48\left(\frac{86}{2325}\right) + 6.64\left(\frac{328}{2325}\right) + 9.89\left(\frac{500}{2325}\right) + 5.91\left(\frac{573}{2325}\right) + 4.97\left(\frac{508}{2325}\right) + 5.14\left(\frac{225}{2325}\right)$

Slope existing = .0024

Velocity = 6.70 ft/sec

TOP WIDTH = 1151 ft.

HY = 31000/(6.7)(1151) = 4.02 ft.

$Q_s = 8.61 \times 10^{-5}\ V^{3.7}\ HY^{.324}\ TW$

$Q_s = 8.61 \times 10^{-5}\ 6.7^{3.7}\ 4.02^{.324}\ 1151 = 177.14$ cfs

$d_{50} = 1$ mm

$G = 4.0$

10 YR. Equilibrium slope

$S_{eq} = .0024\left(\frac{105.5 \text{ cfs}}{177.14 \text{ cfs}}\right)^{.9874} = .0014$

$D_{eq} \approx (.0024 - .0014)(2325') = 2.3'$

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Equilibrium Slope REACH 4
Thomas Rd. to RID flume.
Sections (363.60 to 403.70)
10 YEAR FLOOD PEAK 31000 cfs.

$$\text{Velocity} = 6.47\left(\frac{141}{4238}\right) + 10.20\left(\frac{600}{4238}\right) + 6.83\left(\frac{600}{4238}\right) + 6.90\left(\frac{750}{4238}\right)$$
$$+ 5.35\left(\frac{675}{4238}\right) + 5.89\left(\frac{448}{4238}\right) + 6.44\left(\frac{319}{4238}\right) + 7.18\left(\frac{105}{4238}\right)$$

Slope = .0023
Velocity = 6.90 ft/sec
TOP WIDTH = 965 ft
HY = 31000 / (6.90)(965) = 4.66 ft.

$$Q_s = 5.61 \times 10^{-5} (6.9)^{3.7} (4.66)^{.324} 965$$
$$Q_s = 173.7 \text{ cfs.}$$

$$S_{eq} = .0023\left(\frac{105.5 \text{ cfs}}{173.7 \text{ cfs}}\right)^{.9874}$$

$S_{eq} = \underline{.0014}$

Degrades = (.0023 - .0014) 4238' = $\underline{3.8'}$

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Equilibrium slope I-10 through Thomas Rd
X-SECTIONS (281.5-354.80) REACH 5

$$\text{Velocity} = \overset{1425.25}{\overset{8.6}{7.92}}\left(\frac{470}{8437}\right) + \overset{1447.06}{\overset{3.51}{3.48}}\left(\frac{625}{8437}\right) + \overset{1186.95}{\overset{9.47}{9.52}}\left(\frac{915}{8437}\right)$$

$$\overset{1177.59}{\overset{9.06}{9.71}}\left(\frac{460}{8437}\right) + \overset{1180.97}{\overset{7.58}{8.15}}\left(\frac{670}{8437}\right) + \overset{1128.91}{\overset{6.25}{6.14}}\left(\frac{980}{8437}\right)$$

$$\overset{1127.40}{\overset{6.14}{6.22}}\left(\frac{755}{8437}\right) + \overset{1128.131}{\overset{5.96}{6.23}}\left(\frac{798}{8437}\right) + \overset{1128.25}{\overset{5.91}{6.20}}\left(\frac{995}{8437}\right)$$

$$\overset{1126.47}{\overset{6.58}{6.31}}\left(\frac{963}{8437}\right) + \overset{1127.43}{\overset{6.13}{6.30}}\left(\frac{806}{8437}\right)$$

with 1100 ft bottom width

$S_{exist} = .0021$
$V = 6.82$ ft/sec
$TW = 1129$ ft.

$V = 6.71$ ft/sec with $n = .025$
$TW = 1181.13$ ft
$HV = 3.91$

$HV = 31000 / (6.82)(1129) = 4.03$ ft

$Q_s = 8.61 \times 10^{-5} (6.82)^{3.7} (4.03)^{.324} (1129)$

$Q_s = 185.7$ cfs

$Q_s = 8.61 \times 10^{-5} v^{3.7} d^{.324} TW$
$Q_s = 181.15$

$S_{eq} = S_{ex} \left(\frac{105.5}{181.15}\right)^{.9874}$

$S_{eq} = .0021 \left(\frac{105.5}{181.15}\right)^{.9874}$

$S_{eq} = .0012$

$$S_{eq} = S_{exist} \left(\frac{129.7 \text{ cfs}}{185.7 \text{ cfs}}\right)^{.9874}$$

$$S_{eq} = .0021 \left(\frac{105.5}{185.7}\right)^{.9874} = .0012$$

$$D_{eq} \approx (.0021 - .0012)\, 8437 = 7.6 \text{ ft}$$

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Equilibrium slope Van Buren to I-10
10YR PEAK. X-SECTIONS (2623 + 281.50) REACH 5

Velocity = 1/4(3.81 + 4.77 + 7.37 + 7.92)

Velocity = 5.96

T.W = 1455 ft.

HV = (31000 cfs)/(5.96)(1455) = 3.57 ft.

Slope = .0023

$Q_s = 8.61 \times 10^{-5} (1455 ft)(5.96)^{3.7} (3.57 ft)^{.324}$

$Q_s = 139.7$ cfs

$S_{eq} = .0023 \left(\frac{1055}{139.7}\right)^{.9874} \approx .0017$

$D_{eq} \approx (.0023 - .0017)\, 2355 = 1.4'$

Sections (201.45 – 254.30) Equilibrium slope.

10 YR FLOOD PEAK (31,000 cfs) REACH 7

$$\text{Velocity} = 4.79\left(\frac{188}{5710}\right) + 4.74\left(\frac{95}{5710}\right) + \overset{4.79}{5.0}\left(\frac{60}{5710}\right) + \overset{4.71}{4.9}\left(\frac{205}{5710}\right)$$

$$+ 4.82\left(\frac{453}{5710}\right) + 9.47\left(\frac{663}{5710}\right) + \overset{7.85}{7.33}\left(\frac{813}{5710}\right) + \overset{4.12}{4.37}\left(\frac{823}{5710}\right)$$

$$+ 4.64\left(\frac{815}{5710}\right) + \overset{4.12}{4.87}\left(\frac{800}{5710}\right) + \overset{4.07}{4.13}\left(\frac{745}{5710}\right)$$

Velocity = 5.54 ft/sec

TOP WIDTH = 1310. Ft.

$HY = (31{,}000\ cfs)/(5.54)(1310) = 4.27$ ft

$Q_s = 8.61 \times 10^{-5}\,(1310)(4.27)^{.324}(5.54)^{3.7}$

$Q_s = 102$ cfs

$S_{exist} = .0016$

$$S_{eq} = .0016\left(\frac{105.5\ cfs}{102\ cfs}\right)^{.9874} = .0017$$

Aggrades $\approx (.0017 - .0016)\ 5710 = .6$ ft.

virtually in equilibrium

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short-term bed response: Option 1

HEC-II Run Without siphon n=.03 HECMOD.OUT.

Reach No.	Cross Sections	Velocity (ft/sec)	% increase or decrease	Top Width (ft)	% increase or decrease Res.
Supply Reach	(486.0 – 510.3)	7.6		1902	
1	(483.3 – 452.6)	8.6	+ 64%	1912	+.5% degrade
2	(444.8 – 427.35)	10.1	+ 90%	1530	-20% degrade
3	(426.95 – 403.9)	11.1	+ 46%	1140	-25% degrade
4	(403.7 – 363.6)	11.3	+ 7%	1041	-9% degrade
5	(354.8 – 283.5)	10.8	-17%	1175	+13% slight aggrade
6	(283.5 – 254.3)	9.3	-45%	1441	+23% aggrade
7	(244.1 – 200.2)	10.7	+75%	1203	-17% degrade

Velocity increase is raised to the fourth power.

Reach 1 Camelback to 2200' u/s of ISRB
Reach 2 2200' u/s of ISRB to ISRB
Reach 3 ISRB to RID flume
Reach 4 RID flume to Thomas Road
Reach 5 Thomas Road to I-10
Reach 6 I-10 to Van Buren
Reach 7 Van Buren to Buckeye Road.

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Long-term response option 1

HEC-II run without siphon n=.03 HECMOD.OUT

Reach No.	Cross Sections	Velocity (Ft/sec)	% increase or decrease	Top Width (Ft)	% increase or decrease	Response
Supply	(510.3-488.0)	7.6		1902		
1	(483.3-452.6)	8.6	+64%	1912	+.5%	degrades
2	(444.8-427.35)	10.1	+212%	1530	-20%	degrades
3	(426.95-403.9)	11.1	+355%	1140	-40%	degrades
4	(403.7-363.6)	11.3	+389%	1041	-45%	degrades
5	(354.8-283.5)	10.8	+308%	1175	-38%	degrades
6	(281.5-254.3)	9.3	+124%	1441	-25%	degrades
7	(244.1-200.2)	10.7	+293%	1203	-37%	degrades

Velocity increase is raised to the fourth power

Reach 1 Camelback Road to 2200' u/s of ISRB
Reach 2 2200' u/s of ISRB to ISRB
Reach 3 ISRB to RID flume
Reach 4 RID flume to Thomas Road
Reach 5 Thomas Road to I-10
Reach 6 I-10 to Van Buren
Reach 7 Van Buren to Buckeye Road

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CLIENT FCD of Maricopa County JOB NO. AZ-MC-05 PAGE 3/4
PROJECT SPF Design DATE CHECKED _____ DATE 2/18/84
DETAIL Qualitative Analysis CHECKED BY _____ COMPUTED BY MJB
Short-term response with siphon

HEC-II Run With Siphon n=.03 HECEQWS.OUT

Reach No.	Cross Sections	Velocity (ft/sec)	% increase or decrease	Top Width (ft.)	% increase or decrease	Response
Supply Reach	(510.3-486.0)	7.1		2254		
1	(483.3-452.6)	8.7	+125%	1908	-16%	degrade
2	(444.8-427.35)	9.3	+31%	1533	-20%	degrade
3	(426.95-403.9)	9.4	+4%	1183	-23%	aggrade
4	(403.7-363.6)	11.5	+124%	1041	-12%	degrade
5	(354.8-283.5)	11.2	-10%	1182	+13%	equilibrium
6	(281.5-254.3)	9.5	-48%	1440	+22%	aggrade
7	(244.1-200.2)	10.7	+61%	1223	-15%	degrade

Velocity increase is raised to the fourth power

Reach 1 Camelback to 2200' u/s of ISRB
Reach 2 2200' u/s of ISRB to ISRB
Reach 3 ISRB to RID flume
Reach 4 RID flume to Thomas Road
Reach 5 Thomas Road to I-10
Reach 6 I-10 to Van Buren
Reach 7 Van Buren to Buckeye

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CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Qualitative Analysis
Long-term response for Option 2

JOB NO. AZ-MC-05
DATE CHECKED
CHECKED BY

PAGE 4/4
DATE 2/18/84
COMPUTED BY MJB

HEC-II Run With Siphon n=.03 HECEQWS1.OUT

Reach No.	Cross Sections	Velocity	% increase or decrease	Top Width	% increase or decrease	Response
supply	(510.3-486.0)	7.1		2254		
1	(483.3-452.6)	8.7	+125%	1908	-16%	degrade
2	(444.8-427.35)	9.3	+194%	1533	-32%	degrade
3	(426.95-403.9)	9.4	+207%	1183	-48%	degrade
4	(403.7-363.9)	11.5	+538%	1041	-54%	degrade
5	(354.8-283.3)	11.2	+519%	1182	-48%	degrade
6	(281.5-254.3)	9.5	+220%	1440	-36%	degrade
7	(244.1-200.2)	10.7	+416%	1223	-46%	degrade

Velocity increased raised to the fourth power

Reach 1 Camelback Road to 2200' u/s of ISRB
Reach 2 2200' u/s of ISRB to ISRB
Reach 3 ISRB to RID flume
Reach 4 RID flume to Thomas Road
Reach 5 Thomas Road to I-10
Reach 6 I-10 to Van Buren
Reach 7 Van Buren to Buckeye Rd.

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CLIENT FCD of MC | JOB NO. AZ-MC-05 | PAGE 1/1
PROJECT SPF Design | DATE CHECKED | DATE 2/20/84
DETAIL Armor Control Method | CHECKED BY | COMPUTED BY MTB

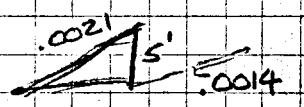
1) Static Equilibrium Slope Analysis.

Reach	ds	V (ft/sec)	TW (ft.)	Q (cfs/ft)	Sexist	Sequil.	Distance (ft)	Potential Scour.
1	2"	9.13	1912	74.3	.0021	.0014	3746	6.0
2	2"	9.13	1530	92.8	.0048	.0011	2256	9.5
3	2"	9.13	1140	124.6	.0024	.0007	2325	5.4
4	2"	9.13	1041	136.4	.0023	.0006	4238	8.5
5	2"	9.13	1175	120.9	.0021	.0008	8437	12.9
6	2"	9.13	1441	98.5	.0023	.0010	2355	5.2
7	2"	9.13	1203	118.0	.0016	.0008	5710	7.0

$$S_{equil} = \left(\frac{V^{5/3}\, n}{1.486\, q^{2/3}}\right)^2$$

$n = .025$

potential Scour = $(S_{ex} - S_{eq})$ (distance)



$\tau_c = (\gamma_s - \gamma)\, .047\, d_s$

$\tau = \frac{1}{8} \rho f V^2$

$f = .04$
$\rho = 1.936$
$\gamma_s = 165.4$
$\gamma = 62.4$
$d_s = 2/12$

2) Particle Size Armoring Method.

$D_s = \frac{2 d_s}{P_c}$ assume 2" armor size

$D_s = \frac{(2)\,(2''/12)}{.05} = 6.67'$ subsurface material

$\frac{5'}{11.5'}$ of surface material / of scour potential

at Camelback + ISRB for SPF with siphon

Camelback Road General Regional Scour

$Q = 142{,}000$ cfs.

Hydraulics upstream of Camelback Road.
$n = .025$

use sections no. 490.9, 496.7, 501.45 + 510.3

effective width $W_1 = \frac{3181 + 2535 + 1163 + 1637}{4} = 2130$ ft.

$V_1 = 7.6$ ft/sec.

$q_1 = 142{,}000$ cfs/2130 ft $= 66.7$ cfs/ft

$HV_1 = 8.8$ ft.

Downstream Cross Sections 483.3, 483.0, 476.9

effective width $W_2 = \frac{1890 + 1658 + 1658}{3} = 1735$ ft.

$V_2 = 8.7$ ft/sec

$q_2 = 142000$ cfs/1735 ft $= 81.9$ cfs/ft

$q_{s1} = 8.61 \times 10^{-5} V^{3.7} Y^{.324}$

2) $q_{s1} = 8.61 \times 10^{-5} (7.6)^{3.7} (8.8)^{.324} = .3162$ cfs/ft.

3) $q_{s2} = \frac{2130}{1735} (.3162) = .3882$ cfs/ft

4) $Y_2 = \left[\frac{q_{s2}}{a\, q_2^{b}} \right]^{\frac{1}{c-b}} = \left(\frac{.3882 \text{ cfs/ft}}{8.61 \times 10^{-5} (81.9 \text{ cfs/ft})^{3.7}} \right)^{\frac{1}{.324 - 3.7}}$

$Y_2 = 10.34$ ft.

$Y_s = 10.34$ ft $- 8.8$ ft $= \underline{1.5 \text{ ft}}$

ISRB for SPF

upstream sections 452.6, 459.9, 466.6, 473.3

Q = 142,000 cfs

Velocity = 7.9 ft/sec

Effective Top Width = $\frac{2023' + 2222' + 2180' + 1910'}{4}$ = 2084'

Hydraulic Depth = 8.6'

q = 142000 cfs / 2084 = 68.1 cfs/ft.

downstream sections 444.8, 439.5, 433.5, 427.35 + 426.95

Effective Top Width = $\frac{1479 + 1479 + 1540 + 1527 + 1585}{5}$ = 1522'

Velocity = 8.9 ft/sec

2) $q_2 = \frac{2084'}{1522'}(68.1 \text{ cfs/ft}) = 93.2 \text{ cfs/ft.}$

3) $q_{s1} = 8.61 \times 10^{-5} V^{3.7} D^{.324} = 8.61 \times 10^{-5} (7.9 \text{ ft/sec})^{3.7} (8.6)^{.324} = .3622 \text{ cfs}$

4) $q_{s2} = \frac{2084'}{1522'}(.3622 \text{ cfs}) = .496 \text{ cfs}$

5) $Y_2 = \left(\frac{q_{s2}}{a\, q_2^{\,b}}\right)^{\frac{1}{c-b}} = \left(\frac{.496}{8.6 \times 10^{-5} (93.2)^{3.7}}\right)^{\frac{1}{.324 - 3.7}}$

$Y_2 = 11.1$ ft.

general regional scour = 11.1 ft − 8.6 ft = **2.5 ft**

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CLIENT: FCD of MC
PROJECT: SPF Design
DETAIL: Antidune Heights
JOB NO.: AZ-MC-05
DATE CHECKED:
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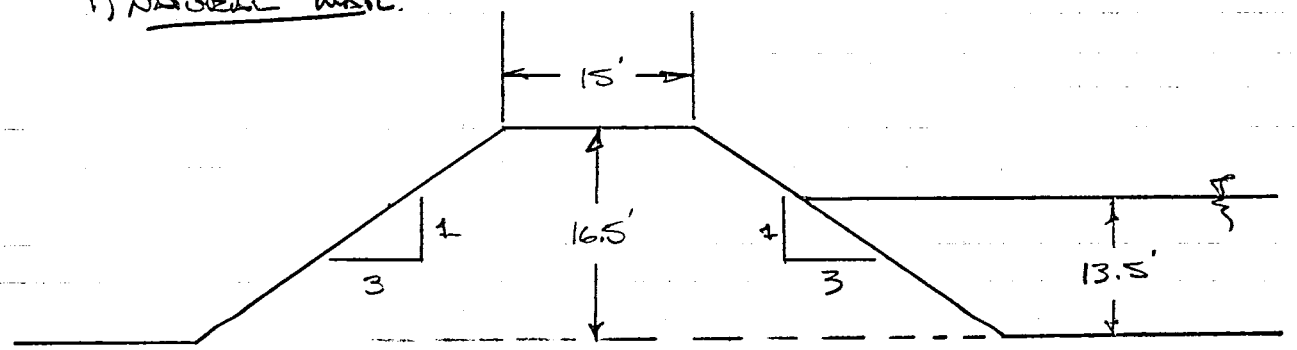
COMPUTED BY: MJB

Bridge	HEC II Velocity w/o (ft/sec)	w (ft/sec)	Antidune Height w/o	w	½ Antidune Height w/o	w
Camelback Road	10.5	10.6	3.0	3.1	1.5	1.5
Indian School Road	10.3	8.2	2.9	1.8	1.5	.9
RID Flume	17.0	—	7.9	—	4.0	—
McDowell Road	13.2	13.8	4.8	5.2	2.4	2.6
I-10	12.2	13.2	4.1	4.8	2.0	2.4
SPRR	12.10	12.1	4.0	4.0	2.0	2.0
Buckeye Rd.	12.5	12.5	4.3	4.3	2.2	2.2

$$A_H = (.14)(2)\frac{\pi V^2}{32.2}$$

CHECK TWO (2) CASES

1) NATURAL MATL.

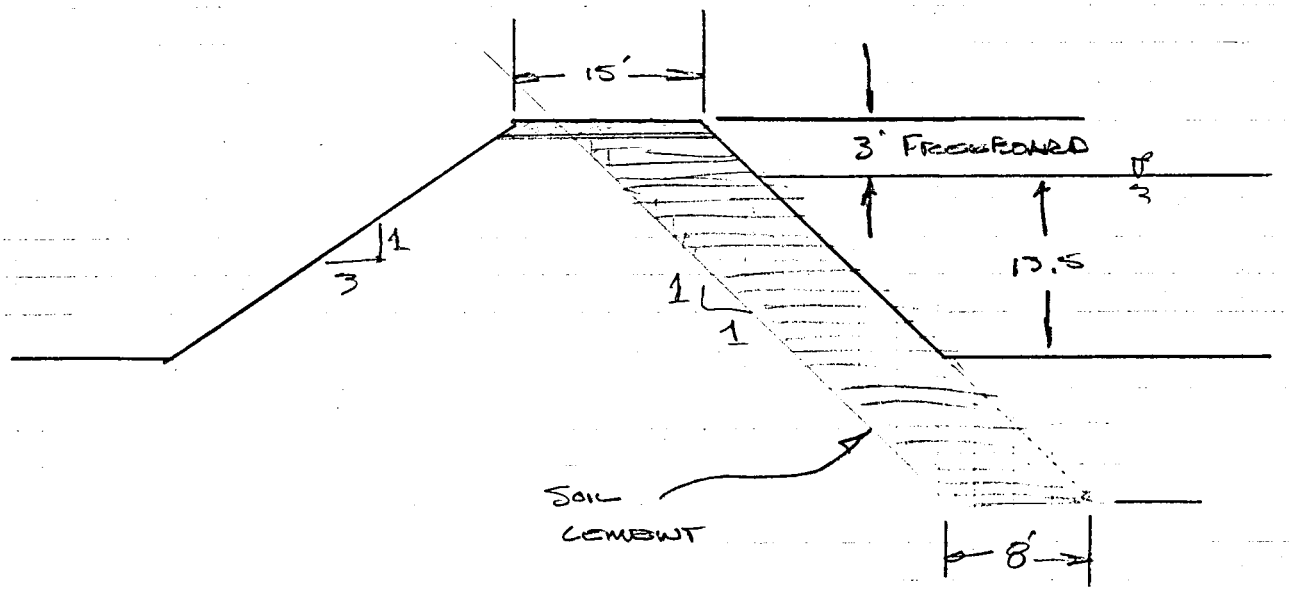


$\gamma_{MOIST} = 113$ pcf
$\gamma_{SAT} = 132$ pcf
$C = 0.0$
HOMOGENEOUS SAND & GRAVEL

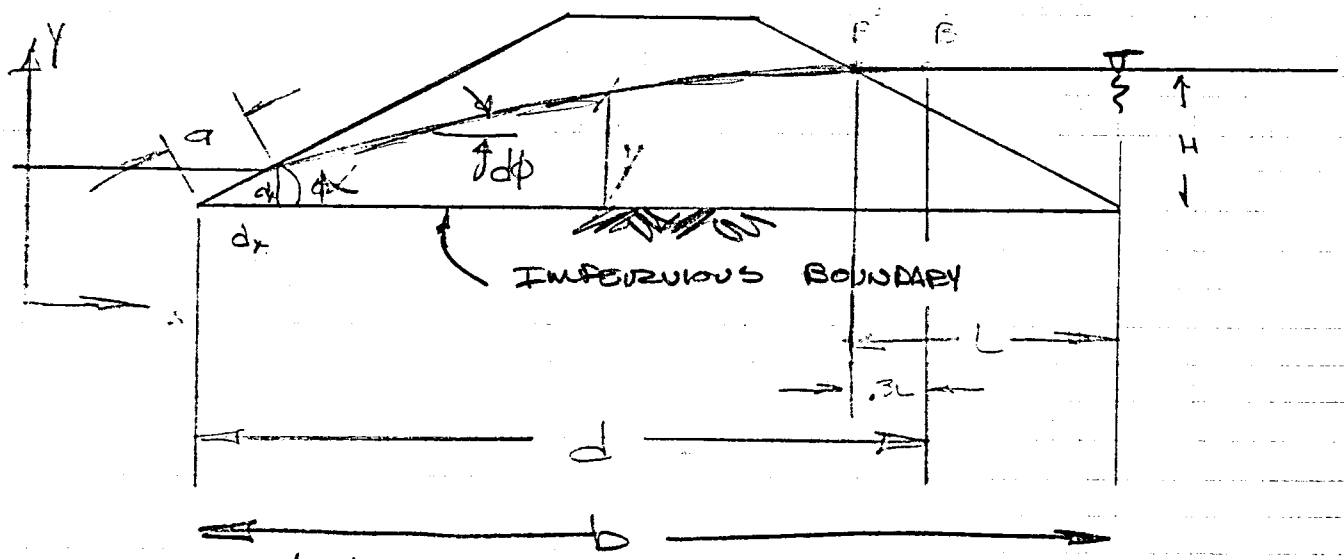
$\gamma_{DRY} = 108$ pcf
POROSITY $= 0.35$
$32 \le \phi \le 36.0$
PORE PRESS. PARAM $= 0.0$
PRES. CONST $= 0.0$

SAND & FINE GRAVEL
N = 30-50 BLOWS/FT
@ 8'-20'

2) SOIL CEMENT



DETERMINE PHEATIC SURFACE USING CASAGRANDES METHOD



$$Q = k\frac{dy}{dx}A$$

$$q = k\frac{dy}{dx}y$$

$$y\,dy = \frac{q}{k}dx$$

$$\frac{y^2}{2} = \frac{q}{k}x + C_1$$

ASSUMPTIONS

1) HOMOGENEOUS, ISOTROPIC
2) IMPERVIOUS BOUNDARY BELOW EMBANKMENT
3) DUPUIT-FORCHEIMER ASSUMPTION – AT EVERY POINT IN A VERTICAL LINE, THE HYDRAULIC GRADIENT IS EQUAL TO THE SLOPE OF THE PHEATIC SURFACE AT. REASONABLE IF $d\phi \leq 30°$

$y = H$ @ $x = d$

$$\frac{H^2}{2} = \frac{q}{k}d + C_1 \longrightarrow C_1 = \frac{H^2}{2} - \frac{Q}{k}d$$

$$\frac{y^2}{2} = \frac{q}{k}x + \frac{H^2}{2} - \frac{Q}{k}d$$

$$\frac{y^2}{2} = \frac{q}{k}(x-1) + \frac{H^2}{2}$$

Evaluate a $\longrightarrow y = a\sin\phi,\ x = a\sin\alpha \therefore \frac{dy}{dx} = \tan\alpha$

$$Q = ka\sin\alpha\tan\alpha$$

$$a = \frac{d}{\cos\alpha} - \sqrt{\frac{d^2}{\cos^2\alpha} - \frac{H^2}{\sin^2\alpha}}$$

PHEATIC SURFACE CONT

$L = z H$ where z = side slope

$= 3(13.5)$

$= 40.5$

$.3L = 12.15$

$d = b - L + .3L = b - [1 - .3]L =$

$= 114.0 - [1 - .3]\,40.5$

$= 85.65$ ft

$$a = \frac{d}{\cos\alpha} - \left[\frac{d^2}{\cos^2\alpha} - \frac{H^2}{\sin^2\alpha}\right]^{1/2}$$

where $\alpha = \tan^{-1}\frac{1}{3} = 18.43°$

$= .323$ radians

$\cos^2\alpha = .90$

$\sin^2\alpha = .10$

$\cos\alpha = 0.95$

$$a = \frac{85.65}{.95} - \left[\frac{85.65^2}{.90} - \frac{13.5^2}{.10}\right]^{1/2}$$

$a = 90.16 - 79.55 = \underline{\underline{10.61}}$

$a_y = a \sin\alpha = 3.35$

$a_x = a \cos\alpha = 10.06$

PHREATIC SURFACE CONT

DETERMINE $\frac{q}{k}$

$$\frac{y^2}{2} = \frac{q}{k}(x-d) + \frac{H^2}{2}$$

BOUNDARY CONDITIONS

@ $y = 3.35$, $x = 10.06$

$$\frac{q}{k} = \left[\frac{y^2}{2} - \frac{H^2}{2}\right] \Big/ (x-d)$$

$$= \left[\frac{3.35^2}{2} - \frac{13.5^2}{2}\right] \Big/ (10.06 - 85.65)$$

$$\frac{q}{k} = \frac{-85.51}{-75.59} = 1.13$$

$$\frac{y^2}{2} = \frac{q}{k}(x-d) + \frac{H^2}{2}$$

$$= 1.13\,(x - 85.65) + \frac{13.5^2}{2}$$

$$y = \left[\left[1.13\,(x-85.65) + \underbrace{\frac{13.5^2}{2}}_{91.13}\right]2\right]^{1/2}$$

x	y
0	0
10.06	3.38
20	5.82
30	7.52
40	8.89
50	10.08
60	11.15
70	12.12
80	13.02
90	13.5

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CLIENT MARICOPA COUNTY
PROJECT AGUA FRIA
DETAIL LEVEE STABILITY

JOB NO. AZ-M6-05
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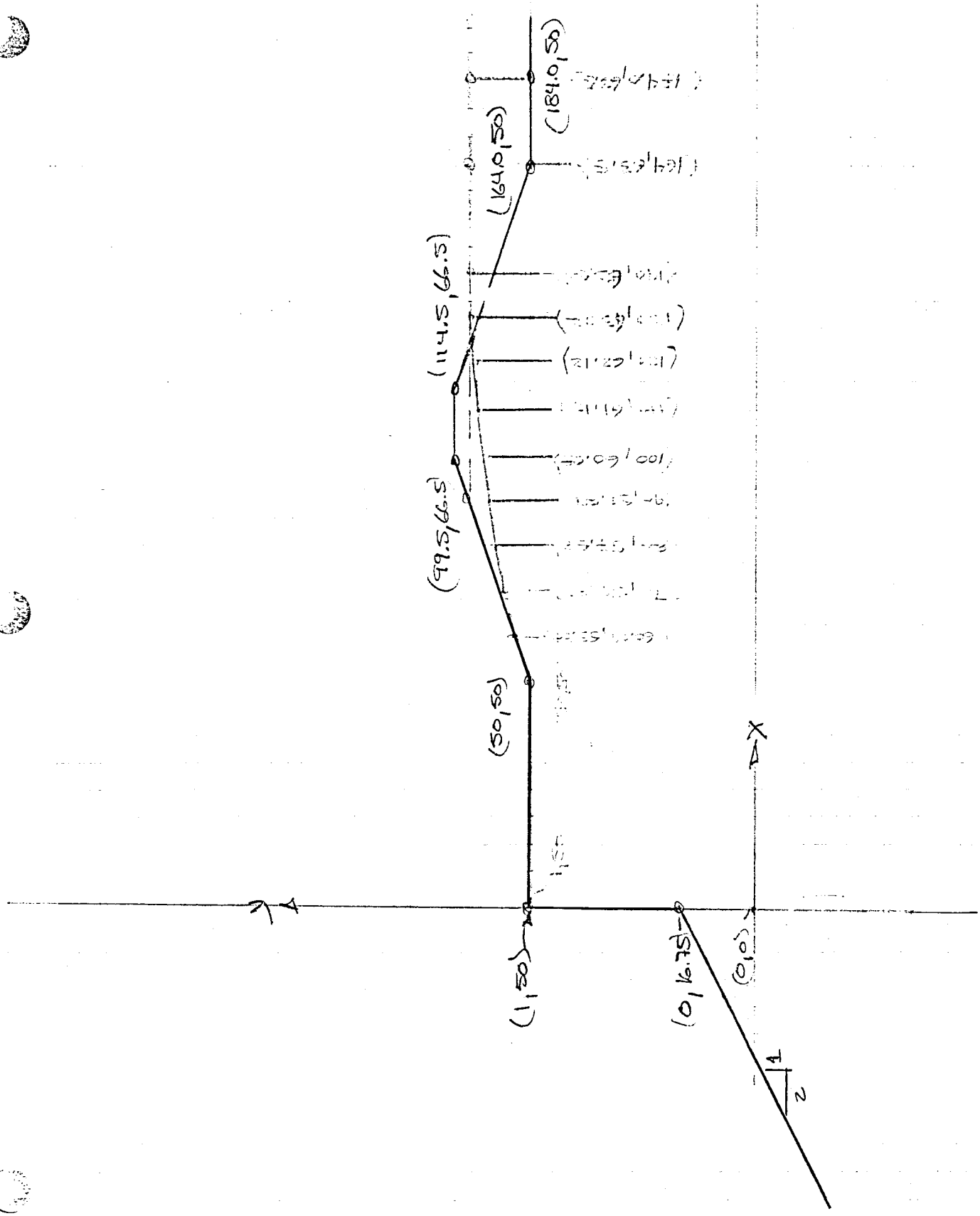


INPUT FILE CONT

WATER

```
1  62.4
14
0.0  16.8
1.0  50.0
50.0  50.0
60.1  53.4
70.0  55.8
80.0  57.5
90.0  58.9
100.0  60.1
110.0  61.2
120.0  62.1
130.0  63.0
140.0  63.5
164.0  63.5
184.0  63.5
```

WATER [RAPID DRAWDOWN WITH SPF W.S. BEHIND LEVEE]

```
1  62.4
4
0.0  50.0
50.0  50.0
90.5  63.5
184.0  63.5
```

SOIL

VARIES 32.0 -> 36.0

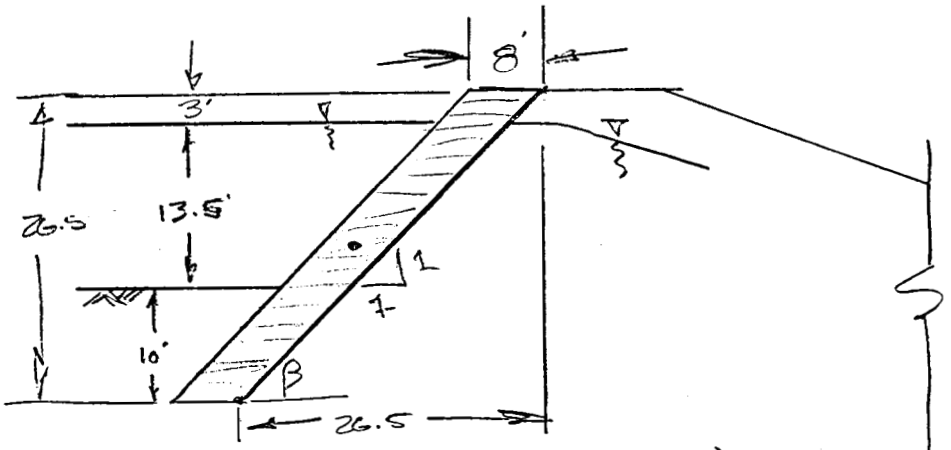
```
1
113.  132.  0.0  32.0  0.0  0.0  1
```

CIRCLE

```
4  25

1.  80.  80.  120.

0.0  10.  0.0  0.0
```



INITIAL SITUATION

ASSUMPTIONS

$\gamma_{S.L.} = 125$ pcf

$\gamma_w = 62.4$ pcf

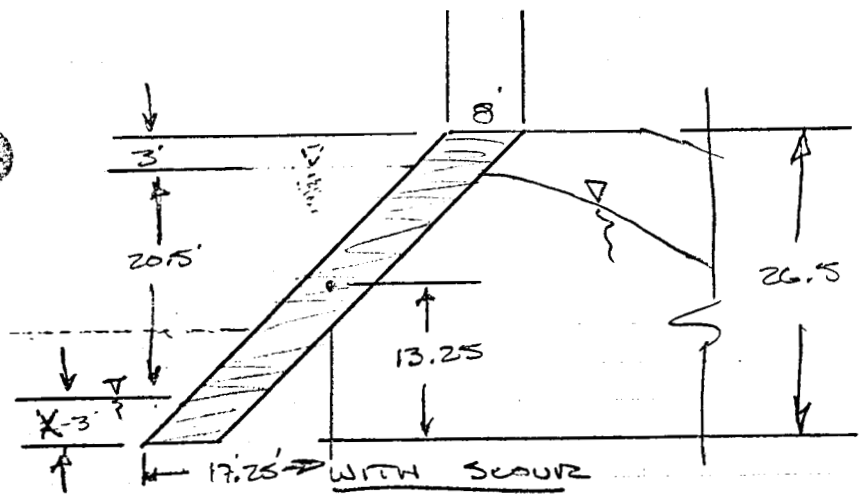
$\gamma_s =$

$\phi = 32°$

$\phi_w = 0°$

$\beta = 45°$

TOE BURIAL AFTER SCOUR = 3 ft.

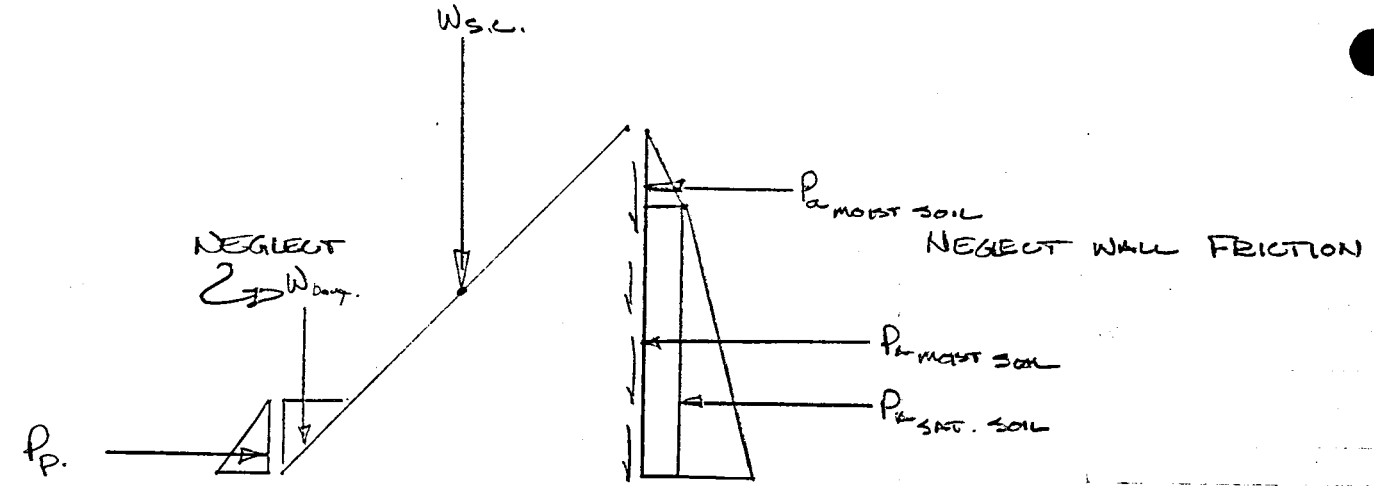


WITH SCOUR

ANALYSIS:

BASED ON WORST CASE

1) TOE BURIAL - 3'
2) NO WATER IN THE CHANNEL
3) EMBANKMENT SATURATED TO FLOOD STAGE LEVEL
4) TOE MATL IS SATURATED



FORCES / FT

1) WEIGHT OF SOIL CEMENT MASS

$W_{s.c.} = 0.135\ kcf \times 26.5 \times 8 = 28.62\ k/ft$

MOMENT ARM $= 26.5/2 + 4 = 17.25\ ft$

2) ACTIVE SOIL PRESSURES

ASSUME RANKINE CONDITIONS & USE COULOMB EQUATION

$$P_a = \frac{1}{2}\gamma H^2 \left\{ \frac{\csc B \sin(B-\phi)}{\sqrt{\sin(B+\phi_w)} + \sqrt{\frac{\sin(\phi+\phi_w)\sin\phi}{\sin B}}} \right\}^2$$

a) FOR THREE FEET OF MOIST SOIL ABOVE PHEATIC SURFACE

$$P_a = \frac{1}{2}(113)\,3^2 \left\{ \frac{\csc(45)\sin(45-32)}{\sqrt{\sin 45} + \sqrt{\frac{\sin^2 32}{\sin 45}}} \right\}^2 = .047$$

$= 23.9\ lb/ft$ [MOMENT ARM $= \left[26.5 - \frac{2}{3}3\right] = 24.5\ ft$]

b) FOR SATURATED FILL

$$P_a = \frac{1}{2}(132-62.4)\,pcf\ (26.5-3)^2 \left\{ .047 \right\}$$

$= 903.26\ lb/ft$

MOMENT ARM $= \frac{23.5}{3} = 7.83$

c) SURCHARGE LOAD OF MOIST FREEBOARD SOIL

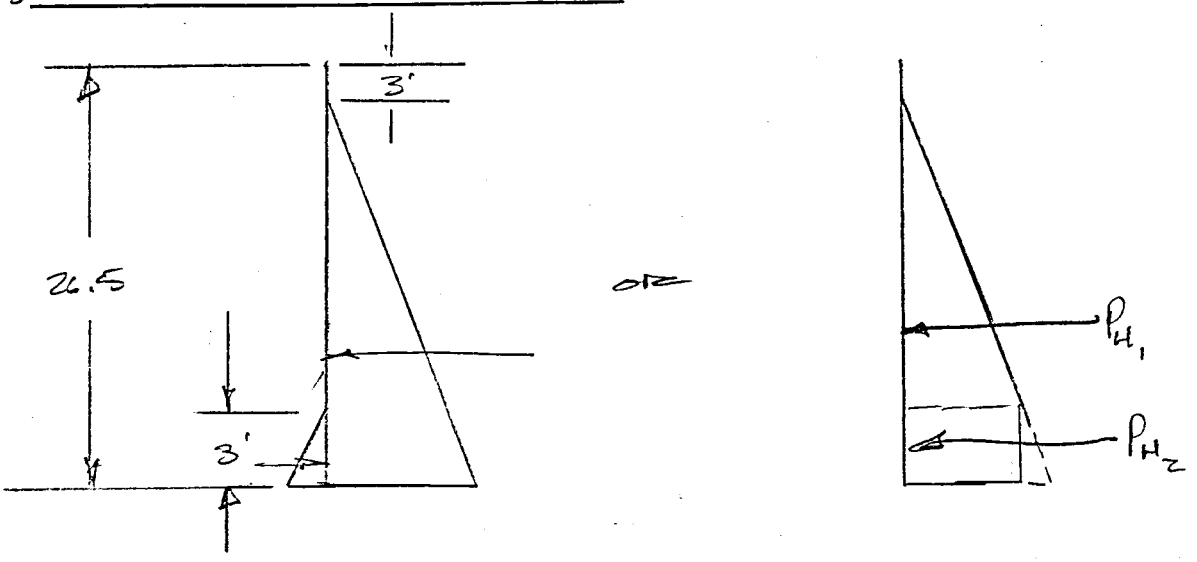
$$P_a = (113)(3)\,.047\,(23.5) = 374.4 \text{ lb/ft}$$

MOMENT ARM $= 23.5/2 = 11.75$ ft

TOTAL ACTIVE THRUST DUE TO SOIL

$$= 374.4 + 903.26 + 23.9 = 1301.6 \text{ lb/ft}$$

3) HYDROSTATIC LOADS



a) $P_{H_1} = \frac{1}{2}(62.4)\,[26.5-3-3]^2 = 13{,}111.8$ lb/ft

$M_A = 20.3/3 + 3 = 9.8$ ft

$P_{H_2} = (62.4)\,[26.5-3-3]\,[3] = 3{,}837.6$ lb/ft

$M_A = 3/2 = 1.5$ ft

4) PASSIVE SOIL PRESSURE AGAINST TOE

$P_p = \frac{1}{2} K_p \gamma_b H^2$ where $K_p = \tan^2(45 + \frac{\phi}{2}) =$

$$= \frac{1}{2}(3.25)(132-62.4)(3)^2 = 1{,}017.90 \text{ lb/ft}$$

$M_A = 3/3 = 1$ ft

CHECK OVERTURNING ABOUT THE TOE

$$\sum M_{CCW} = 23.9\,lb[24.5'] + 903.3[7.83'] + 374.4\,lb[11.75]$$

$$+ 13{,}111.8\,lb[9.8\,ft] + 3{,}837.6\,lb[1.5']$$

$$= 146{,}309.63\,lb\text{-}ft = 146.3\,kip\text{-}ft$$

$$\sum M_{CW} = 28{,}620.1\,lb[17.25]$$

$$= 493{,}695.0\,lb\text{-}ft = 493.7\,kip\text{-}ft/ft$$

$$F.S._{O.T.} = \frac{493.7}{146.3} = 3.37 \text{ — O.K.}$$

CALCULATE FRICTIONAL FORCE

$F_f = (\tan\phi)N$ where $N = \sum$ VERTICAL FORCES

$\therefore F_f = (\tan\phi)W_{SL}$ neglects overburden on toe and wall friction

$= (\tan 32°)(28{,}620\,lb)$

$= 17{,}883.8\,lb/ft$

CHECK SLIDING

$$\sum F_{CAUSING} = 23.9\,lb + 903.3\,lb + 374.4\,lb$$

$$+ 13{,}111.8\,lb + 3837.6\,lb$$

$$= 18{,}251.0\,lb$$

$$\Sigma F_{RESISTING} = 17,883.8 + 1017.9$$

$$= 18,901.7 \text{ lb}$$

$$F.S. = \frac{18,901.7}{18,251.0} = 1.04$$

A.1 Design of Streambank Stabilization Using Soil-Cement

The stabilization of streambanks may be accomplished through the use of soil-cement protection. Although soil-cement is commonly applied as a thin layer of protection over an existing embankment, it may also be applied in wide swaths, and built up in layers. When constructed in this manner, the soil-cement bank protection functions as a retaining wall.

A defining sketch for bank protection analysis is given in Figure A.1. The stability of the structure is determined by computing the overturning moment caused by the active thrust behind the bank and the hydrostatic load produced by water behind the bank, and comparing it to the resisting moment resulting from the weight of the structure. The moments are taken around the toe of the structure.

The active pressure behind the bank protection may be computed by assuming active Rankine conditions and using the Coulomb equation, as follows:

$$P_a = \frac{1}{2} \gamma_b H^2 \left\{ \frac{\csc \beta \sin (\beta - \phi)}{\sqrt{\sin(\beta + \phi_w)} + \sqrt{\frac{\sin(\phi + \phi_w)\sin \phi}{\sin \beta}}} \right\}^2$$

P_a = active thrust on bank protection

γ_b = buoyant specific weight of soil = $\gamma_t - \gamma_w$

γ_t = saturated specific weight of soil

γ_w = specific weight of water

H = total vertical height of bank protection

β = angle of bank protection with horizontal

ϕ = angle of internal friction for soil

ϕ_w = angle of wall friction

With P_a known, the weight of the structure and the overturning and resisting moments calculated, the factor of safety against overturning may be determined. If this factor of safety is acceptable, the resistance to sliding should be checked. An initial step in this computation is summing up all the vertical forces to obtain the normal force. The maximum frictional force which can be mobilized will be

$$F = (\tan \phi) N$$

where F is the frictional resistance force and N is the normal force.

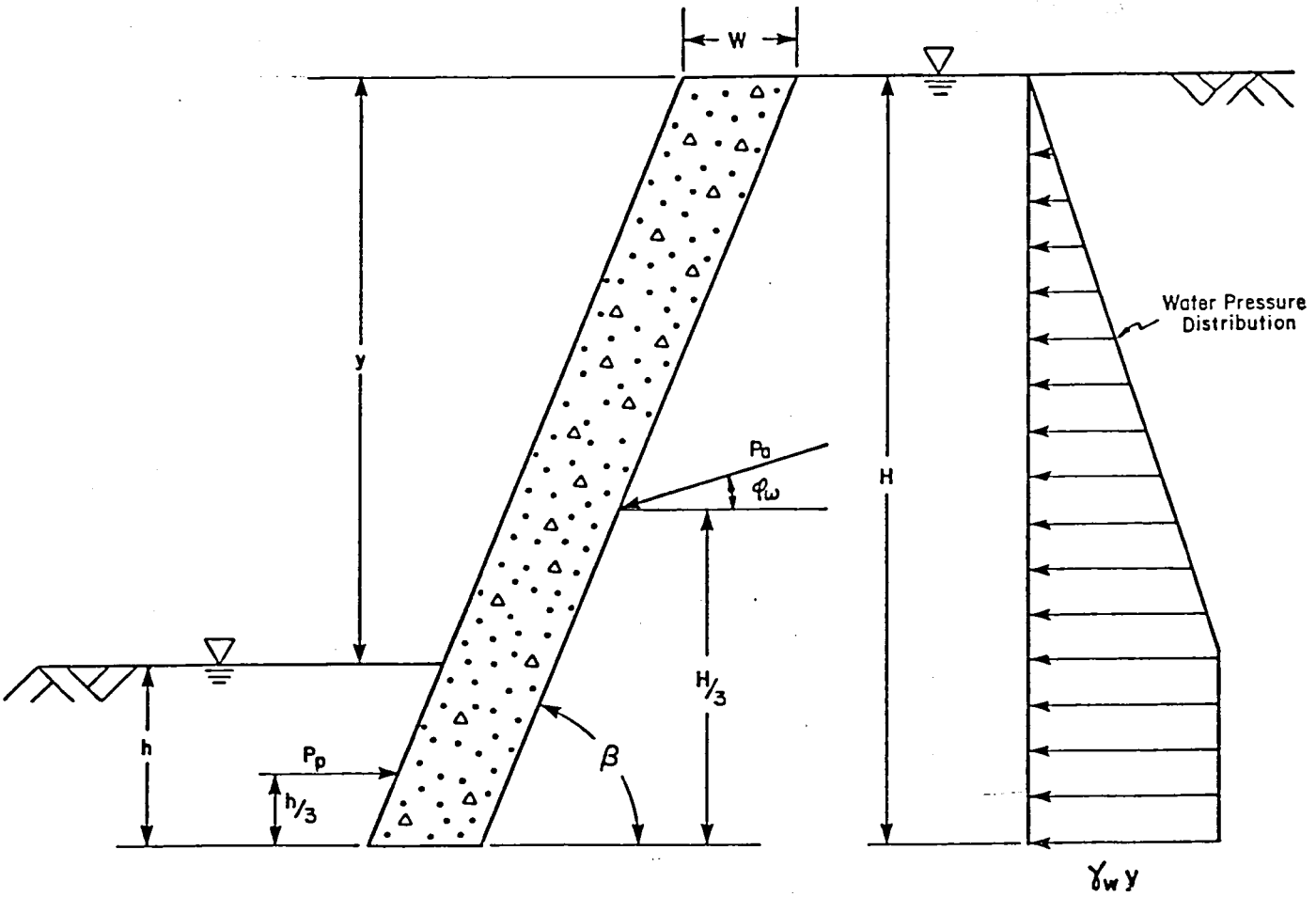


Figure A.1. Definition sketch for soil cement bank protection.

Also resisting sliding will be the passive soil pressure, P_p, defined as

$$P_p = 1/2\ K_p\ \gamma_b h^2$$

where

P_p is the passive soil resistance

K_p is the coefficient of passive pressure

h is the vertical depth of the buried protection, after scour

The force acting to cause sliding will be that portion of the active thrust in the horizontal direction as well as the hydrostatic pressure force.

Example: Assume a bank protection structure is 30 feet high. After scour, 25 feet of the structure is exposed on the stream-side of the structure. The bank has a one to one slope, the width of the structure is eight feet.

Find: The stability of the structure.

Given: $\gamma_t = 125$ pcf $\quad \phi = 30°$ $\quad H = 30$ ft $\quad \beta = 45°$

$\gamma_w = 62.4$ pcf $\quad \phi_w = 0°$ $\quad h = 5$ ft $\quad W = 8$ ft

(1) Compute Active Thrust

$$P_a = 1/2\ (125 - 62.4)\text{pcf}(30\ \text{ft})^2 \left\{ \frac{\csc(45)\sin(45-30)}{\sqrt{\sin(45)} + \sqrt{\frac{\sin(30)\sin(30)}{\sin 45}}} \right\}^2$$

$$P_a = 1{,}832\ \#/\text{ft}$$

Since the angle of wall friction is zero, P_a will act horizontally, 1/3 above the base of the structure, or ten feet above the base.

(2) Compute the Hydrostatic Loads

The hydrostatic loads may be considered in two portions, a triangular distribution over the distance y (see Figure 1) and a rectangular distribution over distance h. The first force will be

$$R_1 = (1/2)(62.4\ \text{pcf})(25\ \text{ft})^2 = 19{,}500\ \#/\text{ft}$$

and will act 13.3 feet above the base. The second force will be

$$R_2 = (62.4\ \text{pcf})(25\ \text{ft})(5\ \text{ft}) = 7{,}800\ \#/\text{ft}$$

and will act 2.5 feet above the base.

(3) Compute the Structure Weight

The weight of the structure can be computed assuming a specific weight of the soil-cement mixture of 135 pound per cubic foot. The weight will then be

$$W = (135 \text{ pcf})(8 \text{ ft})\left(\frac{30\text{ft}}{\text{Sin } 45}\right) \qquad W = 45{,}821 \text{ \#/ft}$$

Since the structure is 30 feet high, on a one to one slope and 8 feet wide, the weight will act a horizontal distance of 19 feet from the toe of the slope.

(4) Compute the overturning moment (counter clockwise) around the toe of the structure:

$$\Sigma M_{ccw} = (1{,}832 \text{ \#/ft})(10\text{ft}) + (19{,}500 \text{ \#/ft})(13.3 \text{ ft}) +$$

$$(7800 \text{ \#/ft})(2.5 \text{ ft}) \qquad \Sigma M_{ccw} = 297 \frac{\text{Kip-ft}}{\text{ft}}$$

(5) Compute the resisting moments (clockwise)

$$\Sigma M_{cw} = (45{,}821 \text{ \#/ft})(15 \text{ ft} + 4 \text{ ft}) \qquad \Sigma M_{cw} = 871 \frac{\text{Kip-ft}}{\text{ft}}$$

(6) Compute the factor of safety against overturning

$$F.S = \frac{871}{297}$$ Factor of safety against overturning = 2.9 O.K.

(7) Compute the normal force (with zero wall friction, the normal force equals the structure weight)

$$N = W \qquad N = 45{,}821 \text{ \#/ft}$$

(8) Compute the maximum frictional force which may be mobilized

$$F = N \tan \phi = (45{,}821 \text{ \#/ft}) \tan 30 \qquad F_{max} = 26{,}455 \text{ \#/ft}$$

(9) Compute the coefficient of passive resistance

$$K_p = \tan^2 (45 + \frac{\phi}{2}) = \tan^2 (60) \qquad K_p = 3.0$$

(10) Compute the Passive Resistance Force

$$P_p = (1/2)(3)(125-62.4) \text{ pcf } (5 \text{ ft})^2 \qquad P_p = 2{,}348 \text{ \#/ft}$$

(11) Compute the Factor of Safety Against Sliding

$$F.S. = \frac{\Sigma \text{ Resisting Forces}}{\Sigma \text{ Sliding Forces}}$$

$$F.S. = \frac{26,455 + 2,348}{1,832 + 19,500 + 7,800}$$

Factor of safety against sliding = 1.0

Discussion of Results

The foregoing computations indicate that the bank protection structure is safe from overturning failure, though only marginally safe from sliding. Assuming zero wall friction is conservative, however, as the soil-cement/sand interface probably has a wall friction angle close to the angle of internal friction for the sand. By considering wall friction, both the normal force and the force resisting sliding could increase by a substantial amount. In actuality, therefore, the factor of safety against sliding is probably well above one. Furthermore, the rapid-drawdown case considered in the analysis is probably extreme. Since soil-cement bank protection is generally used only where sandy material is present, the material behind the bank protection is likely to be well-drained. It is quite unlikely that a rapid drawdown could occur which could simulate the example considered here. Since the hydrostatic loading is the largest force acting on the structure, the rapid-drawdown case produces over-conservative results. Hydrostatic pressures against the back of the wall could be relieved by the installation of drains and weepholes, although this may not be required where well drained materials are present. The factor of safety could be recalculated assuming some value for the wall friction, ϕ_w. If the factor of safety against sliding is still unsatisfactory, the dimensions of the bank protection should be resized and the calculations done again. As a final note, the conditions assumed in this example were extreme and over-conservative. However, even with such extreme conditions, the worst factor of safety was still close to 1.0. This indicates that the bank protection, over the range of expected operating conditions, will always be stable.

A.2 Design of Drop Structures Using Soil-Cement

Drop structures are often required in stream channels and canals to convey water from a higher to a lower elevation while preventing channel degradation and head cutting. A single drop structure with a large vertical differential can be quite expensive, since the structure is usually constructed of reinforced concrete. An alternative to the single, large drop

structure is a series of smaller drops. Since the smaller drop structures are exposed to forces of lesser magnitude than the large drop structure, weaker, less expensive construction materials may be utilized.

One material which offers several advantages in the construction of small drop structures is soil-cement. This type of construction utilizes the on-site soil-sand in a mix with Portland Cement to form a high quality, erosion resistant mixture. Construction using soil-cement involves forming rectangularly shaped vertical drop structures.

The nature of the soil-cement material limits the total height of a drop constructed of such a soil-cement mixture. Preliminary investigations indicate that three feet may be a practical upper limit for the drop height. Downstream of any drop structure, local scour should be expected to occur. A successful design of a soil-cement drop structure will ensure that the structure will remain stable and in working order after the maximum amount of local scour occurs.

The analysis of the stability of a soil-cement drop structure is similar to the analysis of a common retaining wall. A stable drop structure implies that the structure is stable both from overturning and sliding. A defining sketch is given in Figure A.2, with a list of symbols on the following page.

As shown in the figure, acting on the structure will be water pressure due to the drop in head as flow passes over the structure, the active soil pressure on the upstream face of the structure, the passive resistance on the downstream face of the structure and the weight of the structure.

Analysis of the structure will proceed assuming active Rankine conditions exist. This assumption amounts to allowing the structure to yield slightly in the downstream direction, ignoring any passive resistance. Such a situation would exist if the streambed scoured to the downstream toe of the structure. Rotational equilibrium may then be determined by taking moments around the downstream toe of the structure. Acting to cause overturning will be the active soil pressure and the water pressure. These moments act in the counter-clockwise direction (see Figure 4) and may be stated as:

$$\Sigma M_{ccm} = \frac{K_a \gamma_b H^3}{6} + \frac{\Delta Y \gamma_w H^2}{2}$$

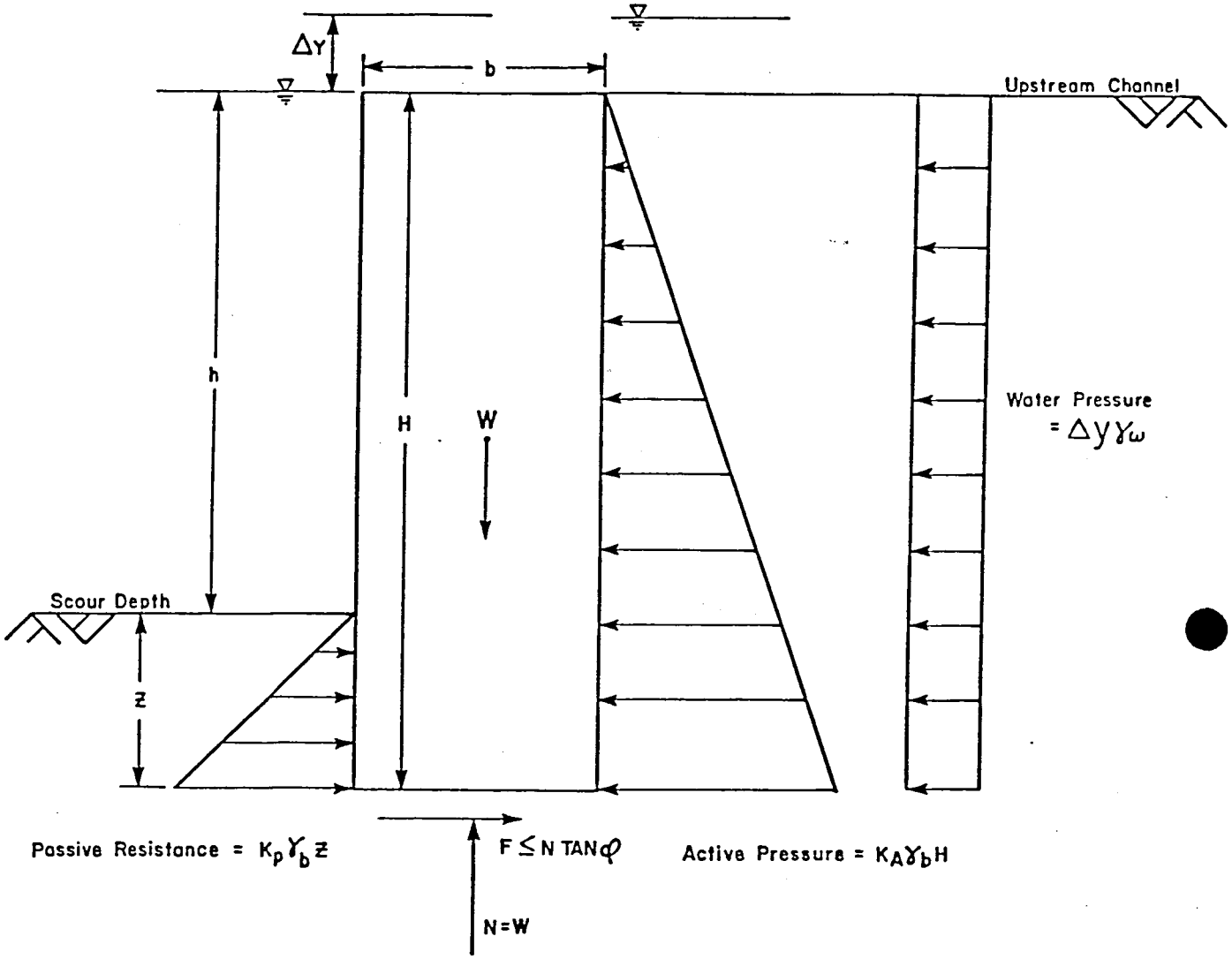


Figure A.2. Defining sketch for soil-cement drop structures.

Table A.1. Definition of Terms

h	-	depth of local scour downstream of drop
b	-	width of drop structure
H	-	overall height of drop structure
Z	-	buried depth of drop structure after scour
Δy	-	drop in water surface as flow passes over structure
γ_y	-	specific weight of water
γ_t	-	specific weight of saturated soil
γ_b	-	buoyant specific weight of soil
γ_{sc}	-	specific weight of soil-cement mixture
K_a	-	coefficient of active pressure = $\tan^2 (45 - \phi/2)$
K_p	-	coefficient of passive pressure = $\tan^2 (45 + \phi/2)$
ϕ	-	angle of internal friction of the soil
N	-	normal force on the structure
F	-	friction force between the structure and the soil

Resisting the overturning will be the clockwise moment produced by the weight of the structure, or

$$\Sigma M_{cw} = \frac{\gamma_{sc} H b^2}{2}$$

The factor of safety against overturning may then be determined by

$$F.S. = \frac{\Sigma M_{cw}}{\Sigma M_{ccw}} \cdot \qquad \text{(rotation)}$$

The resistance against sliding may also be determined neglecting any passive resistance in the downstream soil. The normal force must first be determined which is, assuming no wall friction, equal to the weight of the structure. A check should be performed to see that the normal force acts on the base of the structure. This may be done by

$$X = \frac{\Sigma M_{cw} - \Sigma M_{ccw}}{N}$$

If X is positive and less than w, the normal force acts on the base of the structure and the calculations may proceed. The maximum frictional resistance to sliding which may be mobilized will then be

$$F = N \tan \phi$$

The forces acting to produce sliding will be the active soil pressure and the water pressure. The factor of safety against sliding will then be

$$F.S. = \frac{N \tan \phi}{\frac{K_a \gamma_b H^2}{2} + \Delta Y \gamma_w H} \qquad \text{(sliding)}$$

In designing soil-cement drop structures, the dimensions of the structure will usually be assumed. The factors of safety against overturning and sliding may then be calculated. If the factors of safety seem too small or too large, the structure may be resized and the calculations redone until acceptable results are attained. An example follows.

Numerical Example: Soil-Cement Drop Structure

Given: 3 foot drop, 20 feet high, 8 feet wide

$\Delta y = 2.75$ ft $\quad H = 20$ ft $\quad b = 8$ ft

Soil properties: $\gamma_t = 120$ pcf

$\gamma_b = \gamma_t - \gamma_w = 120 - 62.4 = 57.6$ pcf

$\phi = 30°$

$K_a = \tan^2 (45 - \phi/2) = 1/3$

$K_p = \tan^2 (45 + \phi/2) = 3$

$\gamma_{sc} = 135$ pcf

Find: Factor of safety against overturning and sliding

(1) Overturning Moments

$$\Sigma M_{ccw} = \frac{(1/3)(57.6 \text{ pcf})(20 \text{ ft})^3}{6} + \frac{(2.75 \text{ ft})(62.4 \text{ pcf})(20 \text{ ft})^2}{2}$$

$$\Sigma M_{ccw} = \frac{59.9 \text{ kip-ft}}{\text{ft}}$$

(2) Resisting Moment

$$\Sigma M_{cw} = \frac{(135 \text{ pcf})(20 \text{ ft})(8 \text{ ft})^2}{2} \qquad \Sigma M_{ccw} = 86.4 \frac{\text{kip-ft}}{\text{ft}}$$

(3) Factor of Safety Against Overturning

$$\text{F.S.} = \frac{86.4}{59.9} \qquad \text{F.S.} = 1.4 \text{ (overturning) O.K.}$$

(4) Normal Force

$$N = W = (135 \text{ pcf})(20 \text{ ft})(8 \text{ ft}) \qquad N = 21.6 \text{ kips/ft}$$

(5) Location of Normal Force

$$X = \frac{86.4 \frac{\text{kip/ft}}{\text{ft}} - 59.9 \frac{\text{kip/ft}}{\text{ft}}}{21.6 \text{ kip ft}} \qquad X = 1.2 \text{ ft O.K.}$$

(6) Maximum Frictional Force Mobilized

$$F = (21.6 \text{ kip/ft})(\tan 30) \qquad F = 12.5 \text{ kip/ft}$$

(7) Factor of Safety Against Sliding

$$\text{F.S.} = \frac{12{,}500 \text{ lb/ft}}{\frac{(1/3)(57.6 \text{ pcf})(20 \text{ ft})^2}{2} + (2.75 \text{ ft})(624 \text{ pcf})(20 \text{ ft})}$$

F.S. = 1.7 (sliding) O.K.

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Soil properties: $\gamma_t = 120$ pcf

$\gamma_b = \gamma_t - \gamma_w = 120 - 62.4 = 57.6$ pcf

$\phi = 30°$

$K_a = \tan^2 (45 - \phi/2) = 1.3$

$K_p = \tan^2 (45 + \phi/2) = 3$

$\gamma_{sc} = 135$ pcf

Find: Factor of safety against overturning and sliding

(1) Overturning Moments

$$\Sigma M_{ccw} = \frac{(1/3)(57.6 \text{ pcf})(20 \text{ ft})^3}{6} + \frac{(2.75 \text{ ft})(62.4 \text{ pcf})(20 \text{ ft})^2}{2}$$

$$\Sigma M_{ccw} = \frac{59.9 \text{ kip-ft}}{\text{ft}}$$

(2) Resisting Moment

$$\Sigma M_{cw} = \frac{(135 \text{ pcf})(20 \text{ ft})(8 \text{ ft})^2}{2} \qquad \Sigma M_{ccw} = 86.4 \frac{\text{kip-ft}}{\text{ft}}$$

(3) Factor of Safety Against Overturning

$$F.S. = \frac{86.4}{59.9} \qquad F.S. = 1.4 \text{ (overturning) O.K.}$$

(4) Normal Force

$$N = W = (135 \text{ pcf})(20 \text{ ft})(8 \text{ ft}) \qquad N = 21.6 \text{ kips/ft}$$

(5) Location of Normal Force

$$X = \frac{86.4 \frac{\text{kip/ft}}{\text{ft}} - 59.9 \frac{\text{kip/ft}}{\text{ft}}}{21.6 \text{ kip ft}} \qquad X = 1.2 \text{ ft O.K.}$$

(6) Maximum Frictional Force Mobilized

$$F = (21.6 \text{ kip/ft})(\tan 30) \qquad F = 12.5 \text{ kip/ft}$$

(7) Factor of Safety Against Sliding

$$F.S. = \frac{12{,}500 \text{ lb/ft}}{\frac{(1/3)(57.6 \text{ pcf})(20 \text{ ft})^2}{2} + (2.75 \text{ ft})(624 \text{ pcf})(20 \text{ ft})}$$

$$F.S. = 1.7 \text{ (sliding) O.K.}$$

Comments on Soil-Cement Drop Structure

Soil-cement drop structures will behave as retaining walls as long as the point of rotation remains at or above the toe of the downstream face. This condition will be satisfied as long as the local scour which occurs on the downstream side of the structure does not undermine the toe of the structure. Should scour begin to undermine the structure, the point of rotation will begin to move back under the structure. At some point the stabilizing moment produced by the weight of the structure will be reduced to the point that the overturning moments will threaten the stability of the structure.

To prevent such a situation from occurring, an additional block of soil-cement may be placed at the foot of the soil-cement drop structure. This additional block, illustrated in Figure A.3, will help insure that scour below the toe of the structure does not occur, providing an additional factor of safety in the event that local scour calculations were in error.

A.3 Use of Soil-Cement as a Protection Agent

Successfully employing soil-cement to protect from erosion requires the proper use of the material. Detailed information concerning the use of soil-cement as an erosion control agent is available from the Portland Cement Association. There are, however, several points concerning its use worth mentioning in this report.

First of all, a much better quality soil-cement may be obtained by removing the soil and mixing in a plant than can be obtained by in place mixing. When using soil-cement (mixed in plant) as a thin covering to protect a bank, the maximum bank slope should not exceed two to one, with three to one slopes being more preferable. If the soil-cement was mixed in place, the maximum slope should not exceed four to one.

It may be advisable to include weep holes at intervals along the protected bank. These would provide subsurface drainage thereby reducing the back pressure on the soil-cement shell.

If the soil-cement mixture is to be exposed to the abrasion usually associated with sediment transport, the mixture should contain a minimum of 20 percent gravel sizes, or those sizes retained in a number 4 (4.75 mm) sieve. The mixture should also have a two percent increase (by weight) in the amount of cement, over that required if no abrasion were to occur. The cement content by weight typically ranges from 7 to 15 percent, with a moisture content

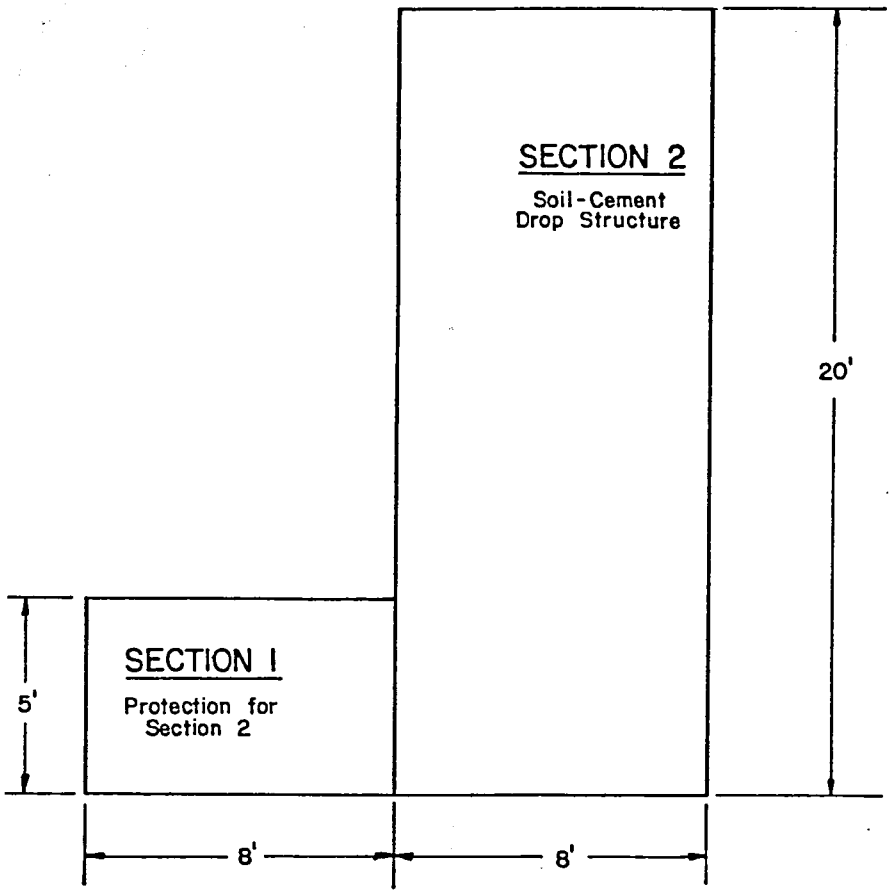

Figure A.3. Toe protection for soil-cement drop structures.

ranging from 8 to 14 percent.

Finally, special attention should be given to the bonding of successive layers of soil-cement. Since soil-cement protection is usually done in lifts from 6 to 9 inches in depth, precautions must be taken to insure that a tight bond is achieved between lifts. One possible technique is to lay down the succeeding layers before the soil-cement of the lower layer has time to set up. A second method, if rapid placement is not possible, is spreading dry cement over the hardened lower layer to bond the adjacent layers. Another popular method is scarification of the lower layer before the mixture hardens. By developing a rough surface an interlocking mechanism is created when the overlying layer is placed.