APPENDIX 7-7

Diversion Calculations

I hereby certify that the design contained herein was prepared by myself and is true and correct to the best of my knowledge.

Richard B. White

Richard B. White, P.E.

REGISTERED PROFESSIONAL ENGINEER
No. 7102
RICHARD B. WHITE
STATE OF UTAH

4/9/92

DESIGN OF DIVERSIONS AND CULVERTS — CRANDALL CANYON MINE

Design of UD-1

Watersheds draining to UD-1 ⟶ WS-1 and WS-2

WS-1 ⟶ Area = 95.2 ac = 0.149 mi²

$\ell = 3850$ ft

CN = 69 (undisturbed)

$$S = \frac{1000}{69} - 10 = 4.49$$

$$Y = \left[\frac{(55{,}600\text{ ft})(40\text{ ft})}{(95.2\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100)$$

$$= 53.6\%$$

$$L = \frac{(3850)^{0.8}(1+4.49)^{0.7}}{(1900)(53.6)^{0.5}} = 0.17\text{ hr}$$

$$T_c = (1.67)(0.17) = 0.29\text{ hr}$$

WS-2 ⟶ Area = 0.9 ac undisturbed
+ 0.3 ac reclaimed
1.2 ac = 0.002 mi²

$\ell = 650$ ft

CN = 69 for undisturbed area
= 75 for reclaimed area

$$\overline{CN} = \frac{(69)(0.9) + (75)(0.3)}{1.2} = 71$$

$$S = \frac{1000}{71} - 10 = 4.08$$

$$Y = \left[\frac{(1000\text{ ft})(40\text{ ft})}{(1.2\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 76.5\%$$

$$L = \frac{(650)^{0.8}(1+4.08)^{0.7}}{(1900)(76.5)^{0.5}} = 0.03\text{ hr}$$

$$T_c = (1.67)(0.03) = 0.05\text{ hr}$$

Design storm → use 25-yr, 24-hr storm, P = 2.92 in (Miller et al., 1973),

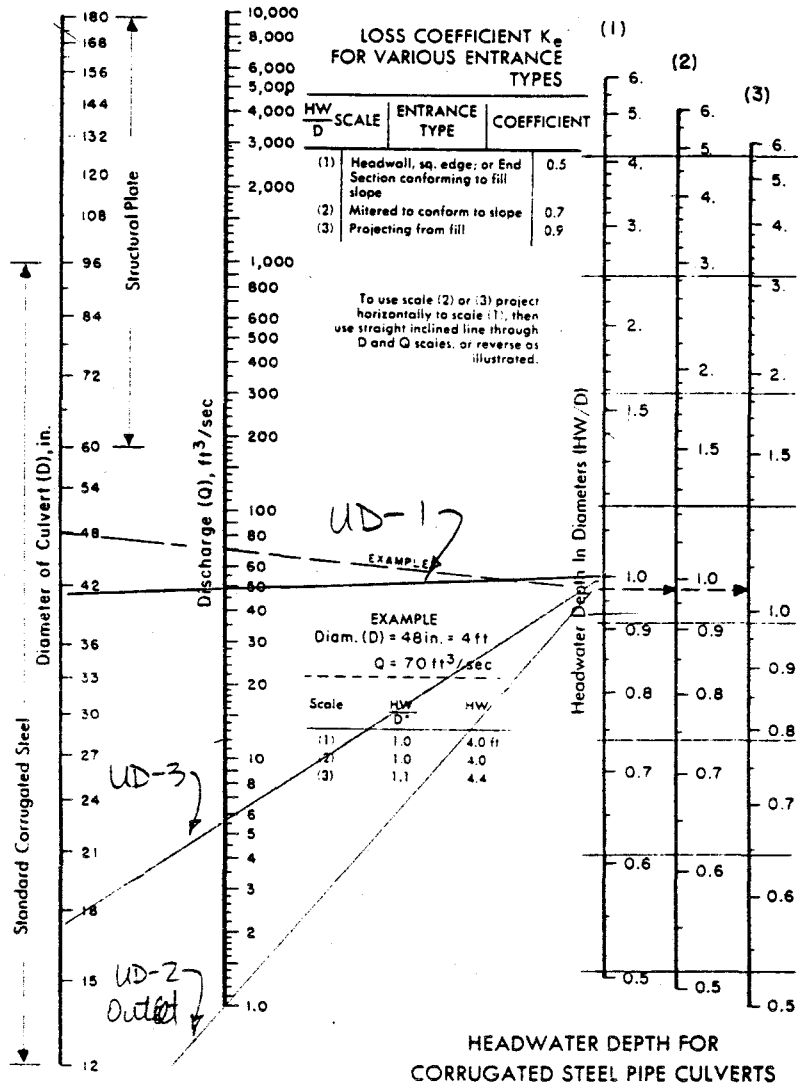
Rainfall distribution → SCS Type II

Hydrograph results (from Hawkins & Marshall model) – see page 3 of this calc.:

WS-1 → q = 46.7 cfs @ 12.08 hr
WS-2 → q = 1.0 cfs @ 12.00 hr

→ q_{Total} = 46.7 + 1.0 = 47.7 cfs

This flow will be diverted into a CMP. Required size:



Use 42" CMP w/ flared end section

HEADWATER DEPTH FOR CORRUGATED STEEL PIPE CULVERTS WITH INLET CONTROL

FHWA HEC 5

```
*****************************
* EARTHFAX ENGINEERING, INC. *
*                           *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER   *
*         METHODOLOGY        *
*****************************
```

IDENTIFICATION: WS-1 - TYPE II

INPUT SUMMARY:

```
*****************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.149 SQ. MI.
        DEPTH =  2.92 IN.            CN = 69.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.29 HR.
*****************************************************************
```

```
*****************************************************************
```

OUTPUT SUMMARY:

```
*****************************************************************
     TOTAL RUNOFF DEPTH =  0.6273 INCHES
     INITIAL ABSTRACTION =  0.8986 INCHES
     PEAK FLOW =     46.72 CFS  ( 0.4856 IN/HR)
     TIME TO PEAK =  12.08 HOURS
     RUNOFF VOLUME CHECK =  0.6285 INCHES
*****************************************************************
```

IDENTIFICATION: WS-2 25-YR 24-HR STORM

INPUT SUMMARY:

```
*****************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.002 SQ. MI.
        DEPTH =  2.92 IN.            CN = 71.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.05 HR.
*****************************************************************
```

```
*****************************************************************
```

OUTPUT SUMMARY:

```
*****************************************************************
     TOTAL RUNOFF DEPTH =  0.7148 INCHES
     INITIAL ABSTRACTION =  0.8169 INCHES
     PEAK FLOW =     0.99 CFS  ( 0.7637 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.7163 INCHES
*****************************************************************
```

Determine critical slope for UD-1 – From nomographs in HEC-5:

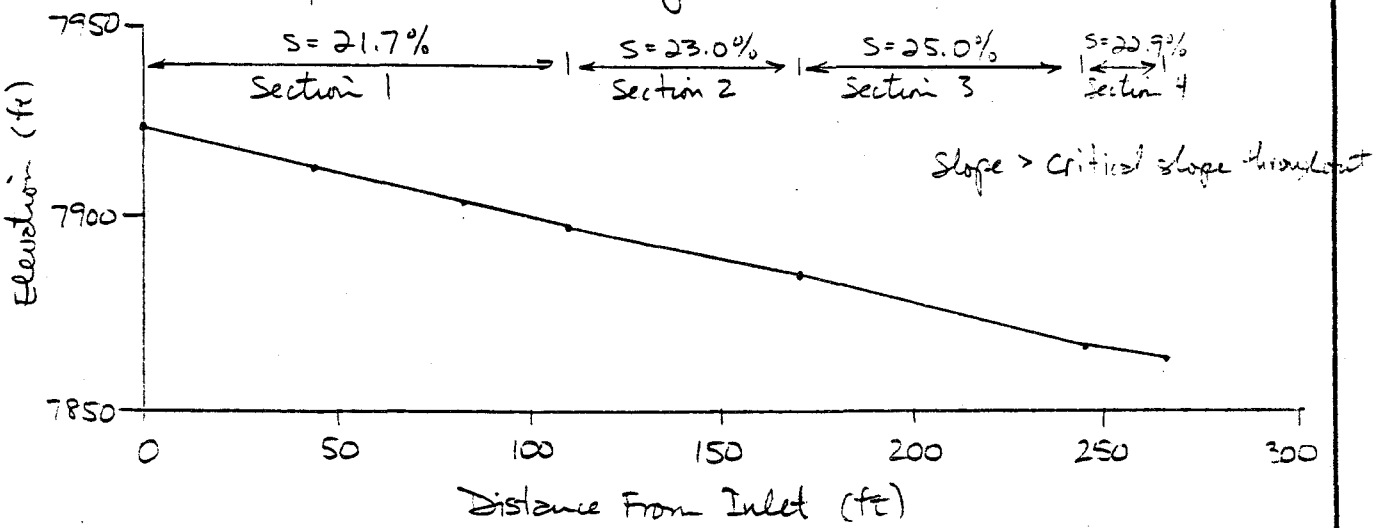
$$\frac{Q}{D^{2.5}} = \frac{47.7 \text{ cfs}}{(3.5)^{2.5}} = 2.081 \Longrightarrow \frac{d_c}{D} = 0.616$$

When $\frac{d_n}{D} = 0.616$, $\frac{nQ}{D^{8/3} S_c^{\frac{1}{2}}} = 0.324$

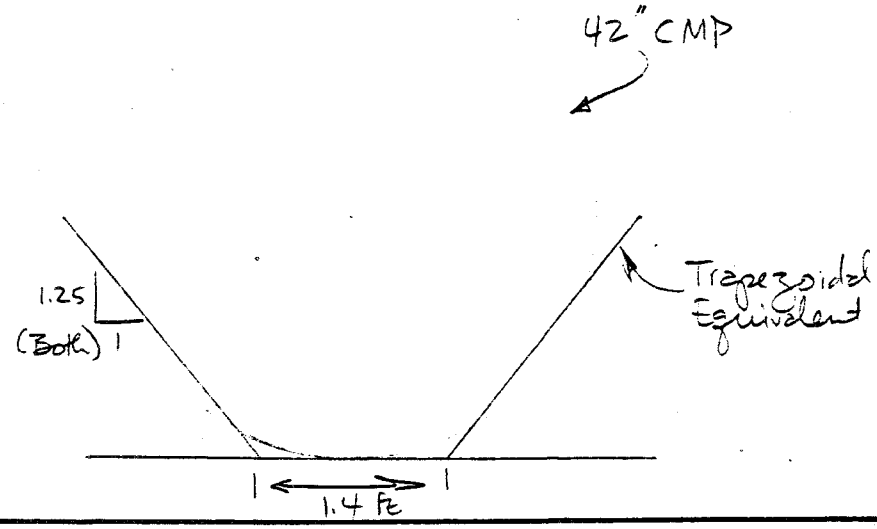
With $n = 0.024$, $Q = 2025$, $D = 2.5$

$$S_c = \left[\frac{(0.024)(47.7)}{(3.5)^{8/3}(0.324)}\right]^2 = 0.016 \text{ ft/ft}$$

Culvert profile (from survey):



Approximate flow depths in each section → treat the culvert as a trapezoidal channel and use TRAP1 from the OSM Hydro. package:



Section 1:

Bed Slope =	.217	
Manning's N =	.024	
Bottom Width =	1.4	feet
Channel Side Slope =	1.25	
Flow Depth =	1.056449	feet
Cross Sectional Area =	2.371896	square feet
Wetted Perimeter =	4.105829	feet
Hydraulic Radius =	.5776898	feet
Discharge =	47.7	cubic feet/sec
Velocity =	20.1105	feet/sec
Froude Number =	3.448027	

Section 2:

Bed Slope =	.23	
Manning's N =	.024	
Bottom Width =	1.4	feet
Channel Side Slope =	1.25	
Flow Depth =	1.040392	feet
Cross Sectional Area =	2.32248	square feet
Wetted Perimeter =	4.064703	feet
Hydraulic Radius =	.5713776	feet
Discharge =	47.7	cubic feet/sec
Velocity =	20.53839	feet/sec
Froude Number =	3.548461	

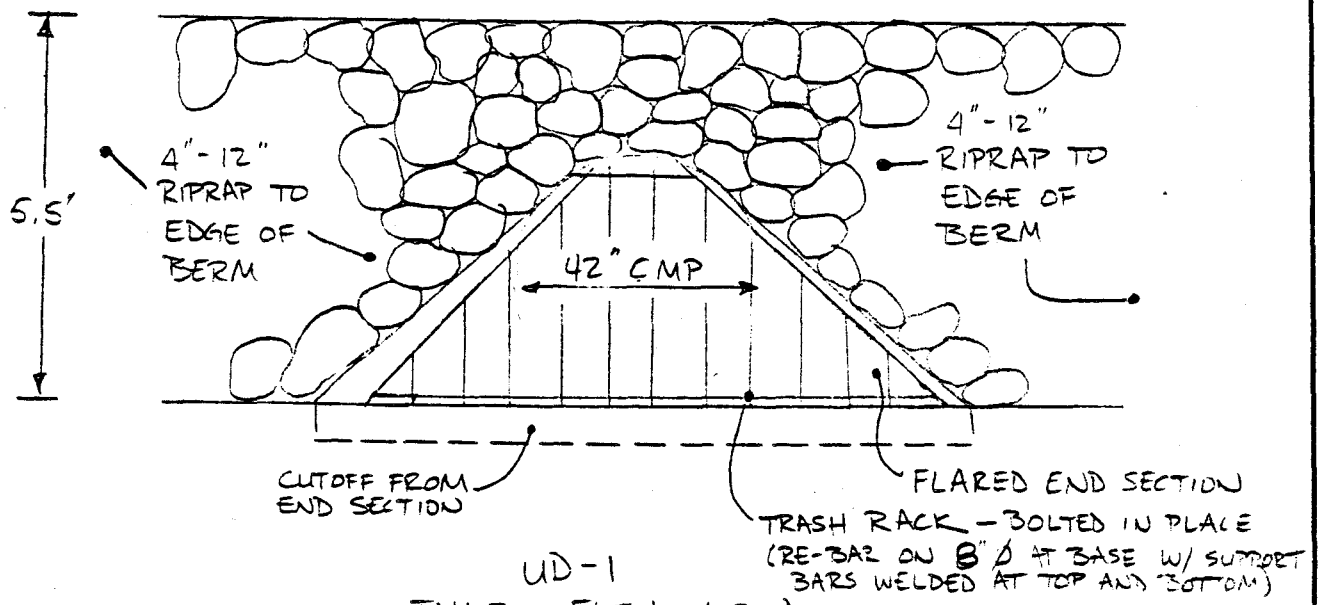
Section 3:

Bed Slope =	.25	
Manning's N =	.024	
Bottom Width =	1.4	feet
Channel Side Slope =	1.25	
Flow Depth =	1.017745	feet
Cross Sectional Area =	2.253487	square feet
Wetted Perimeter =	4.006699	feet
Hydraulic Radius =	.5624298	feet
Discharge =	47.7	cubic feet/sec
Velocity =	21.1672	feet/sec
Froude Number =	3.697566	

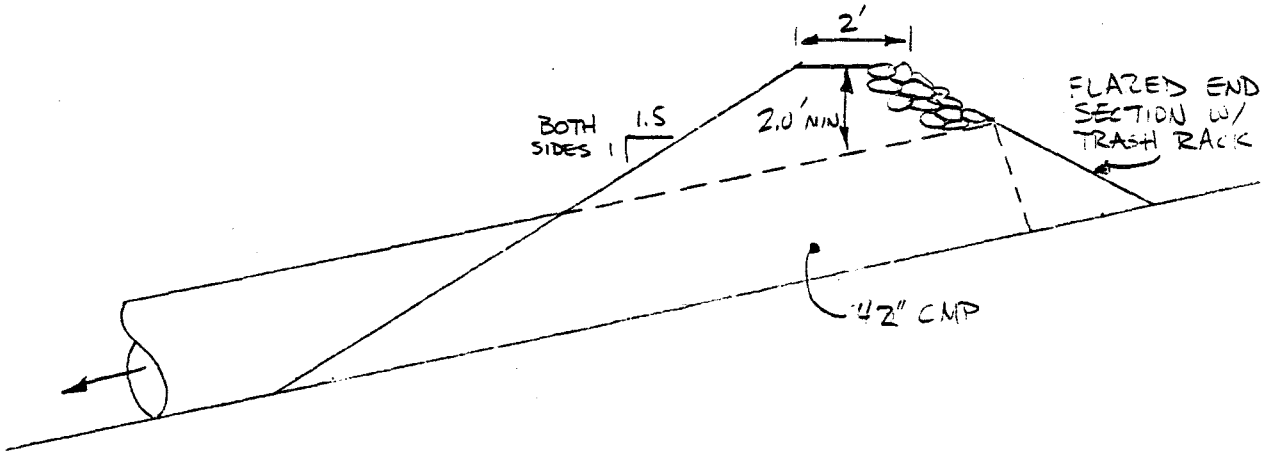
Section 4:

Bed Slope =	.229	
Manning's N =	.024	
Bottom Width =	1.4	feet
Channel Side Slope =	1.25	
Flow Depth =	1.041587	feet
Cross Sectional Area =	2.326144	square feet
Wetted Perimeter =	4.067764	feet
Hydraulic Radius =	.5718483	feet
Discharge =	47.7	cubic feet/sec
Velocity =	20.50604	feet/sec
Froude Number =	3.540839	

Diversion inlet:
(UD-1)



UD-1
INLET ELEV. VIEW



UD-1
INLET SIDE VIEW

UD-1 to remain as a full-round culvert through its entire length. Typical elev. and side views of the culvert at the USFS road crossing are shown on page 8 of this calc.

Exit velocity from UD-1 → use the pipe flow equation:

$$V = \frac{(2gH)^{1/2}}{(1 + K_e + K_b + K_c L)^{1/2}}$$

where H = total head (elevation head + velocity head)

K_e = entrance loss coefficient

K_b = bend loss coefficient

$K_c = \frac{5087\, n^2}{d_i^{4/3}}$

L = length (ft)

Elevation head = 22.5 ft (see page 8 of this calc)

Velocity head $= \frac{V^2}{2g} = \frac{(20.5)^2}{(2)(32.2)}$ → (from page 5 of this calc.)

$= 6.5$ ft

$L = 25$ ft

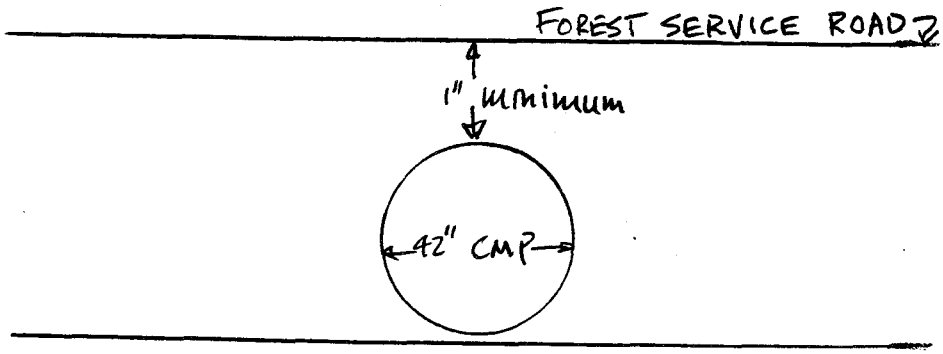
$H = 22.5 + 6.5 = 29.0$ ft

$K_e = 1.0$, $K_b = 0.5$ } Barfield et al. (1981)

$K_c = \frac{5087\, n^2}{d_i^{4/3}}$ (Assume $n = 0.024$)

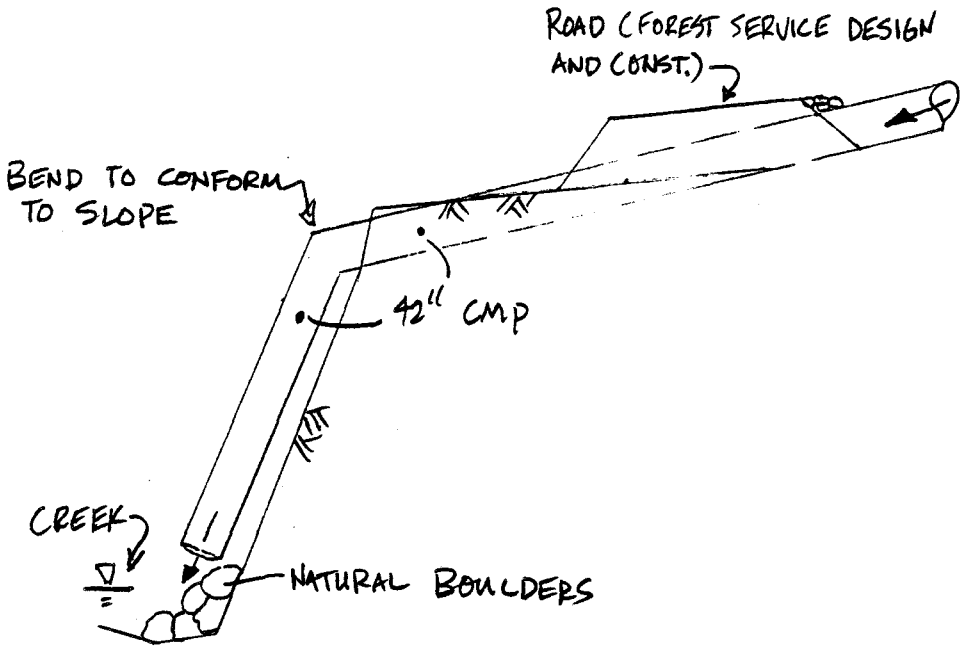
$= \frac{(5087)(0.024)^2}{(42)^{4/3}} = 0.020$

Diversion outlet:



UD-1

DOWNSTREAM INLET ELEVATION VIEW



UD-1

DOWNSPOUT SIDE VIEW

Scale: 1" = 10'

$$V = \frac{[(2)(32.2)(29.0)]^{\frac{1}{2}}}{[1 + 1.0 + 0.5 + (0.020)(25)]^{\frac{1}{2}}} = 25.0 \text{ ft/s}$$

The downspout will discharge onto rock and natural alluvial boulders. Hence, this velocity is acceptable and no additional energy dissipation will be required.

Design of UD-2

Contributing watershed → WS-2

25-yr, 24-hr storm peak flow → $q = 0.99$ cfs (see page 3 of this calc.)

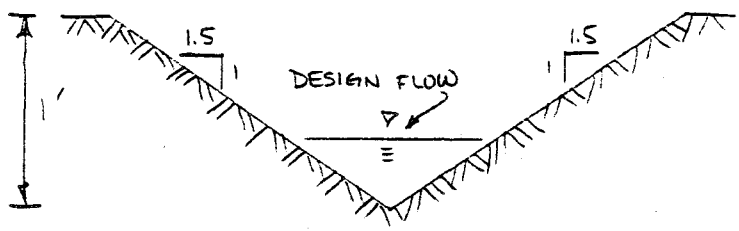
Slope along substation pad = (2.8 ft / 115 ft)(100) = 2.4%

Assume $n = 0.040$ (see Barfield et al. 1981 — Their pg. 159, Table 3.1, design n value for "small drainage ditches".)

Max. permissible velocity = 5.0 ft/s (see Barfield et al. 1981 — Their pg. 162, Table 3.2, value for "graded loam to cobbles when noncolloidal. Compare with gradation curve on pg. 13 of Appendix [illegible]).

DESIGN USING TRAP1:

Bed Slope =	.024	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.6667	
Flow Depth =	.5516454	feet
Cross Sectional Area =	.4564462	square feet
Wetted Perimeter =	1.988917	feet
Hydraulic Radius =	.2294948	feet
Discharge =	.99	cubic feet/sec
Velocity =	2.168931	feet/sec
Froude Number =	.5146213	- Acceptable

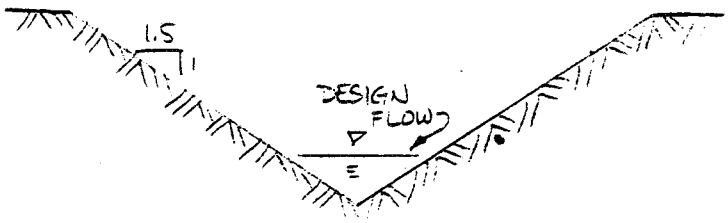


UD-2 AT SUBSTATION PAD - ELEV.

SCALE: 1" = 1'

Along the road leading to the substation pad, the slope of UD-2 will increase. Using this new slope, the following results were obtained from TRAP1:

Bed Slope =	.172	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.6667	
Flow Depth =	.3811063	feet
Cross Sectional Area =	.2178521	square feet
Wetted Perimeter =	1.374051	feet
Hydraulic Radius =	.1585474	feet
Discharge =	.99	cubic feet/sec
Velocity =	4.544368	feet/sec
Froude Number =	1.297246	Acceptable



UD-2 AT SUBSTATION ROAD - ELEV.
SCALE: 1" = 1'

Note → same size used throughout UD-2.

Design of UD-3

Contributing watershed → WS-3

$\ell = 1320$ ft

$S = \frac{1000}{69} - 10 = 4.49$

$Y = \left(\frac{160\text{ ft}}{230\text{ ft}}\right)(100) = 69.6\%$

$L = \frac{(1320)^{0.8}(5.49)^{0.7}}{(1900)(69.6)^{0.5}} = 0.07\text{ hr}$

$T_c = (1.67)(0.07) = 0.12$ hr

Area = 8.8 ac = 0.014 mi^2

Hawkins-Marshall model output → see page 11 of this calc.

```
*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: UD-3

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE B            AREA =  0.014 SQ. MI.
        DEPTH =  1.90 IN.             CN = 69.0
        DURATION = 6.0 HR.            TIME OF CONC. =  0.12 HR.
*************************************************************
```

```
*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.1825 INCHES
     INITIAL ABSTRACTION =  0.8986 INCHES
     PEAK FLOW =     0.78 CFS  ( 0.0861 IN/HR)
     TIME TO PEAK =   2.55 HOURS
     RUNOFF VOLUME CHECK =  0.1829 INCHES
*************************************************************
```

From calculations on pages 13 and 13a of this appendix a 12" pipe is adequate to handle storm runoff from WS-3. An 18" PVC inlet structure (as shown on p. 12) and a reducer (18" to 12") will be used. The 12" pipe will run along the face of the highwall and discharge into an existing channel east of the portal pad. The 12" pipe shall be fastened to the highwall with metal straps, roof bolts, and other braces as required.

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: Genwall UD-3

Comment: 12" CMP - Outlet velocity

Solve For Actual Depth

Given Input Data:

Diameter.....	1.00 ft
Slope.....	0.0800 ft/ft
Manning's n.....	0.024
Discharge.....	0.78 cfs

Computed Results:

Depth.....	0.26 ft
Velocity.....	4.93 fps ← Outlet Velocity OK ✓
Flow Area.....	0.16 sf
Critical Depth....	0.37 ft
Critical Slope....	0.0194 ft/ft
Percent Full.....	25.54 %
Full Capacity.....	5.46 cfs
QMAX @.94D.....	5.87 cfs
Froude Number.....	2.04 (flow is Supercritical)

Open Channel Flow Module, Version 3.2 (c) 1990
Haestad Methods, Inc. * 37 Brookside Rd * Waterbury, Ct 06708

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: Genwall UD-3

Comment: 12" CMP - 24-year, 6-hour storm

Solve For Actual Depth

Given Input Data:

Diameter.....	1.00 ft
Slope.....	0.0100 ft/ft
Manning's n.....	0.024
Discharge.....	0.78 cfs

Computed Results:

Depth.....	0.44 ft ← Maximum Depth OK ✓
Velocity.....	2.33 fps
Flow Area.....	0.34 sf
Critical Depth....	0.37 ft
Critical Slope....	0.0194 ft/ft
Percent Full.....	44.24 %
Full Capacity.....	1.93 cfs
QMAX @.94D.....	2.08 cfs
Froude Number.....	0.71 (flow is Subcritical)

Open Channel Flow Module, Version 3.2 (c) 1990
Haestad Methods, Inc. * 37 Brookside Rd * Waterbury, Ct 06708

Determination of exit velocity from UD-3 → use pipe-flow equation:

$$V = \frac{(2gH)^{\frac{1}{2}}}{(1+K_e+K_b+K_cL)^{\frac{1}{2}}}$$

$H = 57.0$ ft

$K_e = 1.0$, $K_b = 0.5$ } Bafield et al. (1981)

$$K_c = \frac{(5087)(0.013)^2}{(18)^{4/3}} = 0.018 \qquad (n = 0.013, \text{assumed})$$

$L = 430$ ft

$$V = \left[\frac{(64.4)(57)}{(2.5 + [0.018][430])}\right]^{\frac{1}{2}} = 18.9 \text{ ft/s}$$

The receiving channel is cut in competent bedrock. Thus, the calculated exit velocity is not considered excessive and additional erosion protection will not be required.

Design of Stilling Basin at the Downstream End of UD-2

This stilling basin will provide erosion protection during the period that vegetation is being established on the substation pad. Sufficient space exists for as basin with surface dimensions of 15'×10'. The outlet from this basin will consist of a 12" CMP that will stub into UD-1 a sufficient distance downstream from the stilling basin to ensure that the elevation of the top of UD-1 is lower than the invert of the outlet culvert from the stilling basin. See Appendix 7-9 for design details.

Design of DD-1

Total area = 0.24 ac = 0.0004 mi² (use A = 0.001 mi²)
Undisturbed = 0.15 ac
Reclaimed = 0.09 ac

$l = 164$ ft

$$\overline{CN} = \frac{(0.15)(69) + (0.09)(75)}{0.21} = 71$$

$$S = \frac{1000}{74} - 10 = 4.08$$

$$Y = \left[\frac{(473\ ft)(10\ ft)}{(0.24\ ac)(43{,}560\ ft^2/ac)}\right](100) = 45.2\%$$

$$L = \frac{(164)^{0.8}(5.08)^{0.7}}{(1900)(45.2)^{0.5}} = 0.014\ hr$$

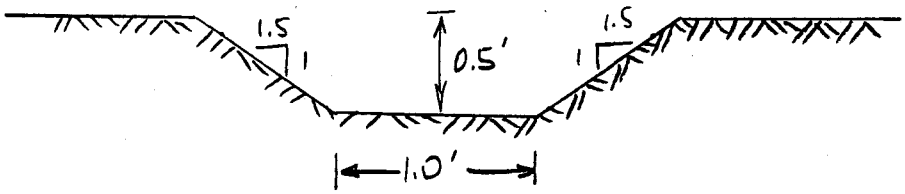
$$T_c = (1.67)(0.014) = 0.02\ hr$$

Design storm → 10-yr, 24-hr P = 2.50 in
Rainfall distribution → SCS Type II

Hawkins-Marshall model results → see page 15 of this calc.
Acceptable channel design → TRAP1 results:

Bed Slope =	.4	
Manning's N =	.04	
Bottom Width =	1	feet
Channel Side Slope =	.6667	
Flow Depth =	4.604699E-02	feet
Cross Sectional Area =	4.922731E-02	square feet
Wetted Perimeter =	1.166019	feet
Hydraulic Radius =	4.221828E-02	feet
Discharge =	.14	cubic feet/sec
Velocity =	2.84395	feet/sec
Froude Number =	2.335573	<5 — Acceptable

```
IDENTIFICATION:  DD-1

INPUT SUMMARY:
*************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.000 SQ. MI.
        DEPTH =  2.50 IN.               CN = 71.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.02 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =  0.4912 INCHES
     INITIAL ABSTRACTION =  0.8169 INCHES
     PEAK FLOW =      0.14 CFS  ( 0.5547 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.4921 INCHES
*************************************************************
```



DD-1
TYPICAL ELEVATION

SCALE: 1" = 1'

DESIGN OF DD-5

Undisturbed area = 3.52 ac (CN = 69)
Reclaimed area = 0.90 ac (CN = 75)
Disturbed area
Paved = 0.77 ac (CN = 95)
Unpaved = 0.18 (CN = 90)
Total area = 5.37 ac = 0.0084 mi²

$$\overline{CN} = \frac{(3.52)(69) + (0.90)(75) + (0.18)(90) + (0.77)(95)}{5.37} = 74$$

(S = 3.51)

$l = 1718$ ft

$$Y_{DDB} = \left[\frac{(2540\ ft)(40\ ft)}{(3.21\ ac)(43{,}560\ ft^2/ac)}\right](100) = 72.7\%$$

$$Y_{other} = \left[\frac{(3523\ (ft)(10\ ft)}{(2.16\ ac)(43{,}560\ ft^2/ac)}\right](100) = 37.4\%$$

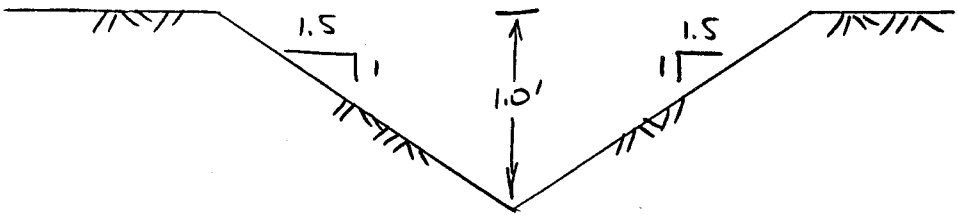
$$y' = \frac{(72.7)(3.21) + (37.4)(2.16)}{5.37} = 58.5\%$$

$$L = \frac{(1718)^{0.8}(4.51)^{0.7}}{(1900)(58.5)^{0.5}} = 0.08\ hr. \Longrightarrow T_c = 1.67L = 0.13\ hr.$$

Hydrograph & TRAP 1 results:

```
IDENTIFICATION:   DD-5

INPUT SUMMARY:
*************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =   0.008 SQ. MI.
        DEPTH =   2.50 IN.              CN = 74.0
        DURATION = 24.0 HR.             TIME OF CONC. =   0.13 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =   0.6082 INCHES
     INITIAL ABSTRACTION =   0.7027 INCHES
     PEAK FLOW =       3.21 CFS   ( 0.5928 IN/HR)
     TIME TO PEAK =   12.01 HOURS
     RUNOFF VOLUME CHECK =   0.6095 INCHES
*************************************************************
```

Bed Slope =	.07	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.6667	
Flow Depth =	.7017343	feet
Cross Sectional Area =	.7386097	square feet
Wetted Perimeter =	2.530051	feet
Hydraulic Radius =	.2919347	feet
Discharge =	3.21	cubic feet/sec
Velocity =	4.346003	feet/sec
Froude Number =	.9142727	<5 - Acceptable



DD-5
TYPICAL ELEVATION
SCALE: 1" = 1'

Design of DD-2 thru DD-4

DD-2 → Drainage area < DD-5
Slope < DD-5

DD-3 → Drainage area < DD-5
Slope < DD-5

DD-4 → Drainage area < DD-5
Slope < DD-5

} Use DD-5 cross section

Note on DD-6

DD-6 formerly existed adjacent to the coal loadout at the mine site. This ditch has since been culverted. Thus, no ditch with the designation DD-6 currently exists.

Design of DD-7 thru DD-9, DD-11

Each channel → Drainage area << DD-5
slope < DD-5 } Use DD-5 cross section

Design of C-2

Peak flow = 3.21 cfs (see DD-5 calcs.)

This culvert currently exists as a 24" CMP with a projecting inlet. From the nomograph on pg. 2 of this calc., the capacity of C-2 is 12 cfs. Hence, this culvert is adequately designed.

Outlet velocity determination → use hydraulic elements graph (see pg. 19 of this calc.),

For slope = 0.08 ft/ft

$$Q_{full} = \left(\frac{1.486}{0.024}\right)(0.50)^{2/3}(0.08)^{1/2}(3.142)$$

$$= 34.66 \text{ cfs}$$

$$V_{full} = \frac{34.66 \text{ cfs}}{3.142 \text{ ft}^2} = 11.03 \text{ ft/s}$$

$$\frac{Q_{design}}{Q_{full}} = \frac{3.21}{34.66} = 0.09 \Rightarrow \text{At this ratio, } \frac{d}{D} = 0.20$$

(see pg 19)

$$\text{At } \frac{d}{D} = 0.20, \quad \frac{V_{design}}{V_{full}} = 0.61$$

$$V_{design} = (0.61)(11.03) = 6.73 \text{ ft/s}$$

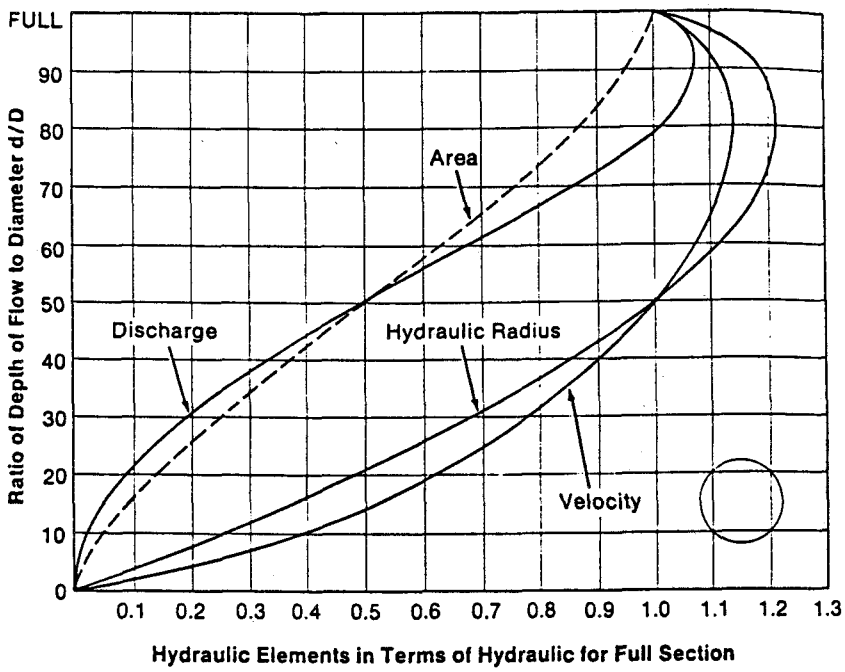


Figure 4-37 Hydraulic elements graph for circular corrugated steel pipe.

Table 4-14 Full Flow Data for Round Pipe

Diameter, in.	Area, ft²	Hydraulic Radius, ft	Diameter, in.	Area, ft²	Hydraulic Radius, ft
12	0.785	0.250	156	132.7	3.25
15	1.227	0.3125	162	143.1	3.375
18	1.767	0.375	168	153.9	3.5
21	2.405	0.437	174	165.1	3.625
24	3.142	0.50	180	176.7	3.75
30	4.909	0.625	186	188.7	3.875
36	7.069	0.75	192	201.1	4.0
42	9.621	0.875	198	213.8	4.125
48	12.566	1.0	204	227.0	4.25
54	15.904	1.125	210	240.5	4.375
60	19.635	1.25	216	254.5	4.5
66	23.758	1.375	222	268.8	4.625
72	28.27	1.5	228	283.5	4.75
78	33.18	1.625	234	298.6	4.875
84	38.49	1.75	240	314.2	5.0
90	44.18	1.875	246	330.1	5.125
96	50.27	2.0	252	346.4	5.25
108	63.62	2.25	258	363.1	5.375
114	70.88	2.375	264	380.1	5.5
120	78.54	2.5	270	397.6	5.625
126	86.59	2.625	276	415.5	5.75
132	95.03	2.75	282	433.7	5.875
138	103.87	2.875	288	452.4	6.0
144	113.10	3.00	294	471.4	6.125
150	122.7	3.125	300	490.9	6.25

Design of C-4 → Disturbed area = 0.93 ac (CN=90) Undisturbed = 2.05 ac (CN=69)
Reclaimed area = 0.22 ac (CN=75)

$$\text{Weighted avg. CN} = \frac{(2.05)(69) + (0.22)(75) + (0.93)(90)}{3.20} = 76$$

Total area = 3.20 ac = 0.005 mi²

$l = 962$ ft

$$Y_{DD11} = \left[\frac{(1480\text{ ft})(40\text{ ft})}{(2.00\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 68.0\%$$

$$Y_{DD10} = \left[\frac{(2821\text{ ft})(10\text{ ft})}{(1.20\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 54.0\%$$

$\bar{Y} = 62.7\%$

$$L = \frac{(962)^{0.8}(4.16)^{0.7}}{(1900)(62.7)^{0.5}} = 0.04\text{ hr}$$

$T_c = 1.67\,L = 0.07$ hr

Hydrograph results:

```
IDENTIFICATION:   C-4

INPUT SUMMARY:
*************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.005 SQ. MI.
        DEPTH =  2.50 IN.               CN = 76.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.07 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =  0.6945 INCHES
     INITIAL ABSTRACTION =  0.6316 INCHES
     PEAK FLOW =      2.33 CFS   ( 0.7227 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.6959 INCHES
*************************************************************
```

C-4 is currently a 24" CMP. Determine exit velocity using hydraulic elements graph. Slope = 8/35 = 0.23 ft/ft

$Q_{full} = \left(\frac{1.486}{0.024}\right)(0.5)^{2/3}(0.23)^{1/2}(3.142) = 58.8$ cfs

$V_{full} = (58.8/3.142) = 18.7$ ft/s

$(Q_{design}/Q_{full}) = 2.33/58.8 = 0.04 \Rightarrow \frac{d}{D} = 0.14$

$V_d/V_f = 0.49$

$V_f = (0.49)(18.7) = 9.2$ ft/s

DESIGN of C-8

Culvert C-8 carries flow from DD-9 to sedimentation pond. From page 18 of this calc. DD-9 flow is less than DD-5 flow. Culvert C-2 carries flow from DD-5 to sedimentation pond. C-2 is a 24" CMP and is shown on page 18 to be adequate. C-8 is thereby designed as a 24" CMP also and is adequate to carry 10-YR, 24-hr storm water.

Note: DD-9 is a rip rapped trapezoidal drainage ditch.

$$Q_{full} = \left(\frac{1.486}{0.024}\right)(0.5)^{2/3}(0.23)^{1/2}(3.142) = 58.8 \text{ cfs}$$

$$V_{full} = (58.8/3.142) = 18.7 \text{ ft/s}$$

$$(Q_{design}/Q_{full}) = 2.33/58.8 = 0.04 \Rightarrow \frac{d}{D} = 0.14$$

$$V_d/V_f = 0.49$$

$$V_f = (0.49)(18.7) = 9.2 \text{ ft/s}$$

Design of DD-10

Undisturbed = 3.57 ac
Disturbed = 1.95 ac
Reclaimed = 1.24 ac

Total = 6.76 ac = 0.0106 mi²
$\overline{CN}$ = 76

$l = 2086$

$Y_{DD8} = 72.7\%$ (see pg. 16 of this calc.)

$$Y_{other} = \left[\frac{(6514 \text{ ft})(10 \text{ ft})}{(3.55 \text{ ac})(43{,}560 \text{ ft}^2/\text{ac})}\right](100) = 42.1\%$$

$\overline{Y} = 56.6\%$

$$L = \frac{(2086)^{0.8}(4.16)^{0.7}}{(1900)(56.6)^{0.5}} = 0.09 \text{ hr} \Rightarrow T_c = 1.67L = 0.15 \text{ hr}$$

Hydrograph results

```
IDENTIFICATION:  DD-10

INPUT SUMMARY:
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II           AREA =  0.011 SQ. MI.
        DEPTH =  2.50 IN.             CN = 76.0
        DURATION = 24.0 HR.           TIME OF CONC. =  0.15 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =  0.6945 INCHES
     INITIAL ABSTRACTION =  0.6316 INCHES
     PEAK FLOW =      4.57 CFS  ( 0.6675 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.6959 INCHES
*************************************************************
```

Channel design → Assume 2:1 side slopes, bed slope = 0.33 (3:1 slope)
n = 0.04
2 ft bottom width

Bed Slope =	.33	
Manning's N =	.04	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	.2493204	feet
Cross Sectional Area =	.6229622	square feet
Wetted Perimeter =	3.114995	feet
Hydraulic Radius =	.1999882	feet
Discharge =	4.57	cubic feet/sec
Velocity =	7.33592	feet/sec
Froude Number =	2.589093	

Will require 6" d_{50} riprap for erosion protection (see U.S. Army Corps of Engineers, 1970).

Riprap gradation – see page 23 of this calc. (from dimensionless curve of Barfield et al., 1981).

Filter blanket sizing (see pg. 23 of this calc.):

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{3.1\text{ in}}{0.62\text{ in}} = 5.0 \qquad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{3.1}{0.078\text{ in}} = 39.7 < 40 \qquad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (bed)}} = \frac{0.078\text{ in}}{0.94\text{ in}} = 0.08 < 5 \qquad \underline{\underline{OK}}$$

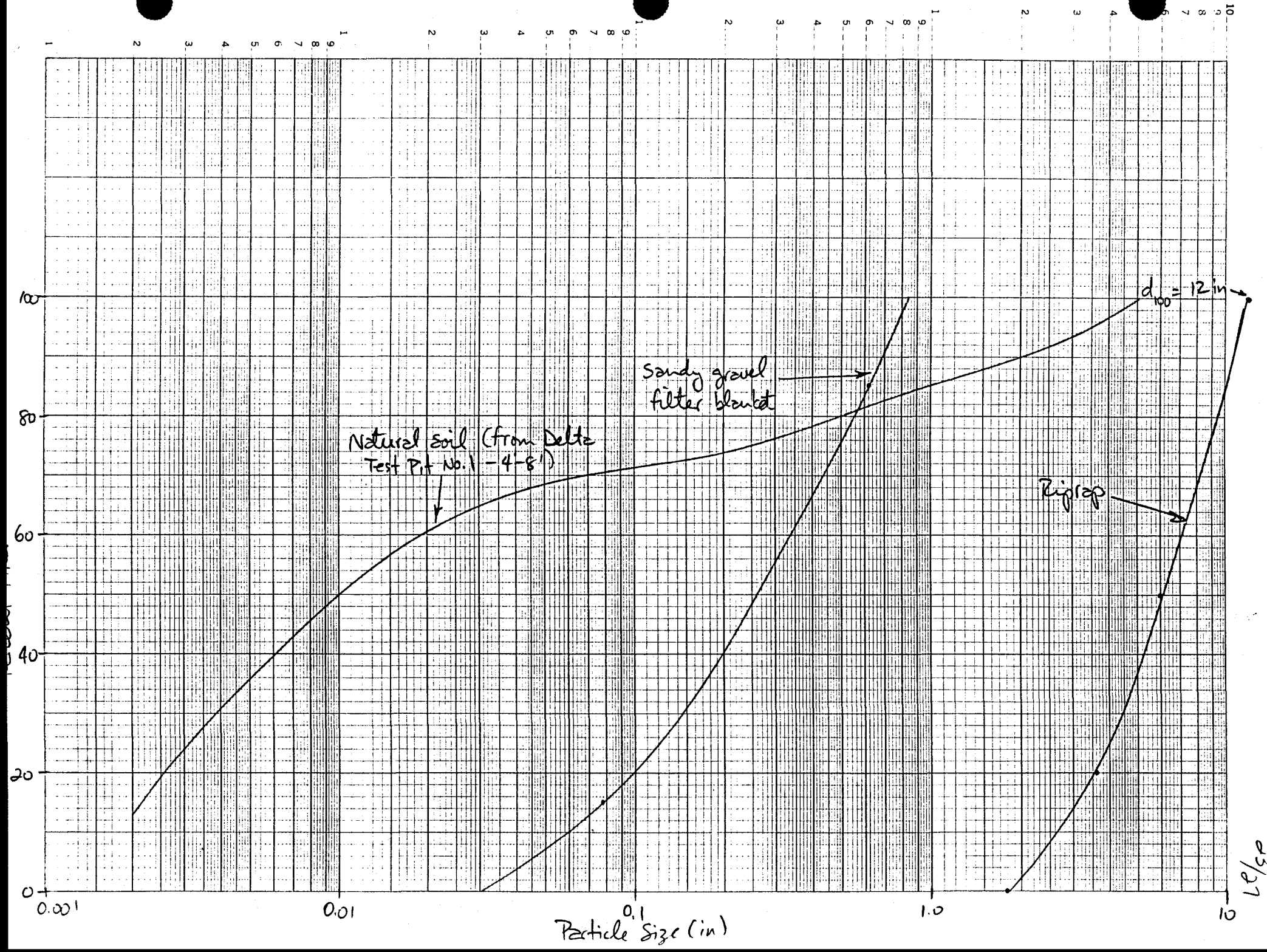
$$\frac{D_{15}\text{ (filter)}}{D_{15}\text{ (bed)}} = \frac{0.078\text{ in}}{0.0021\text{ in}} = 37.1 < 40 \qquad \underline{\underline{OK}}$$

Indicated sandy gravel is sufficient for a filter blanket.

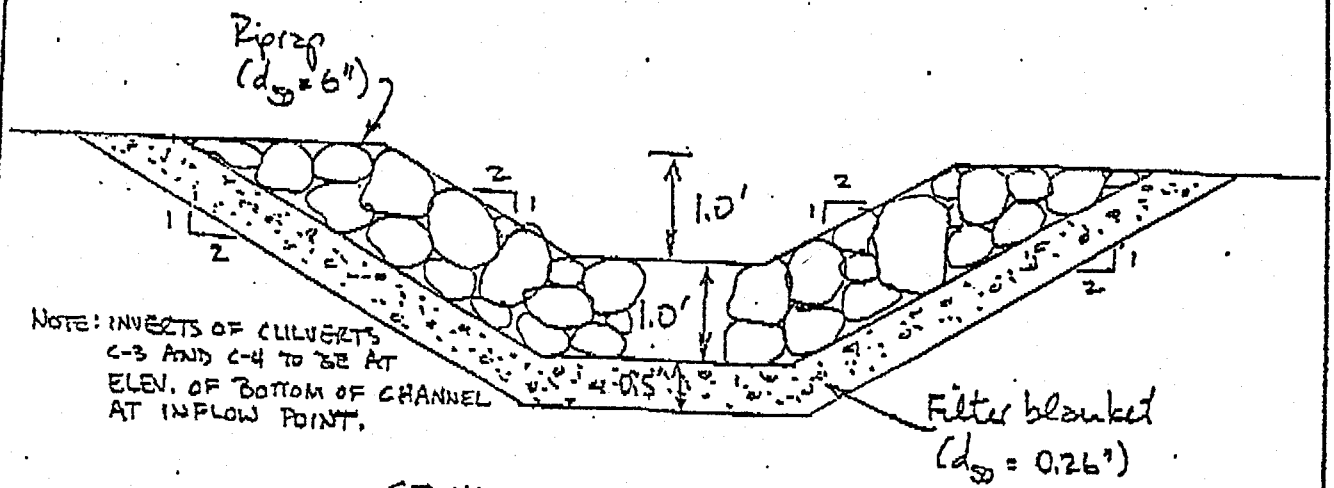
Typical elevation view of channel → see page 24 of this calc.

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6010



25/27



SEDIMENTATION POND INLET CHANNEL
ELEVATION VIEW
SCALE: 1" = 2'

Design of C-3 → Area less than for C-2. According to nomograph on pg. 2 of this calc., a 12" CMP is adequate to handle the flow to C-2 (3.21 cfs), WITH 1.5 FEET OF HEAD WATER. THE HEADWATER DEPTH FOR THE CULVERT IS PRESENTLY 32 INCHES, THEREFORE THE 1.5 FEET IS ADEQUATELY MET.

Design of culvert C-1 → Since this culvert is upstream from C-2, it need not be larger than C-2. According to the nomograph on pg. 2 of this calc., an 18" CMP is adequate to pass the C-2 design flow of 3.21 cfs (as well as smaller upstream flows). An 18" CMP will be used at C-1. Typical plan and elevation views on pg. 25 of this calc.

Design of culvert C-5 →

Undisturbed drainage = 2.13 ac from WS-5 (CN=69)
Reclaimed drainage = 0.10 ac from portal pad (CN=75)
Disturbed drainage = 0.02 ac from highwall (CN=90)

$$\overline{CN} = \frac{(2.13)(69) + (0.10)(75) + (0.02)(90)}{2.25} = 70$$

Total area = 2.25 ac = 0.004 mi²

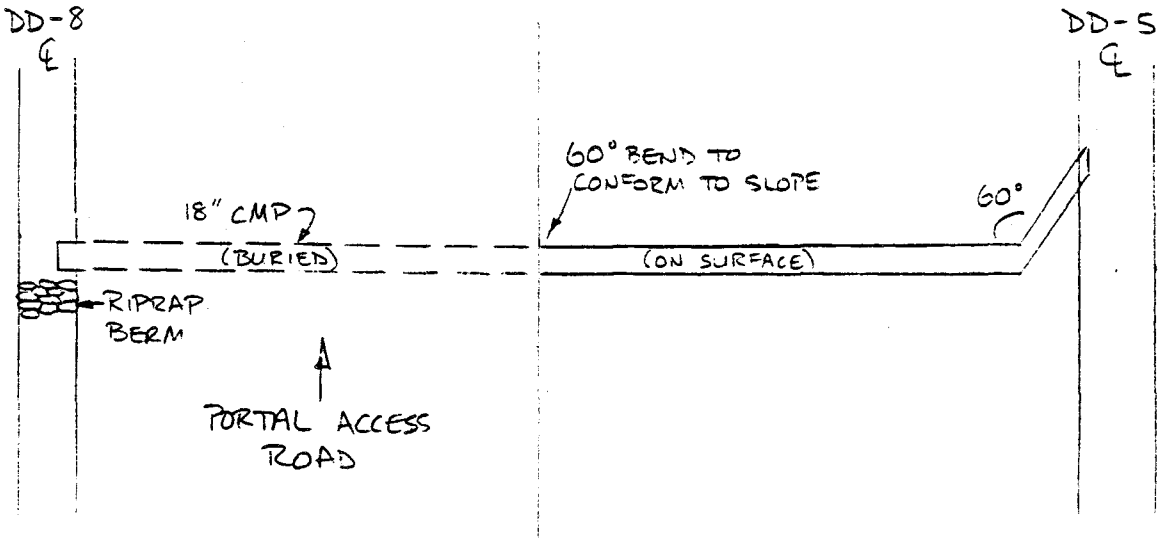
Upland method

$(T_c)_{WS-5}$ → V = 1.4 ft/s, l = 550 ft } $(T_c)_{WS-5}$ = 0.11 hr

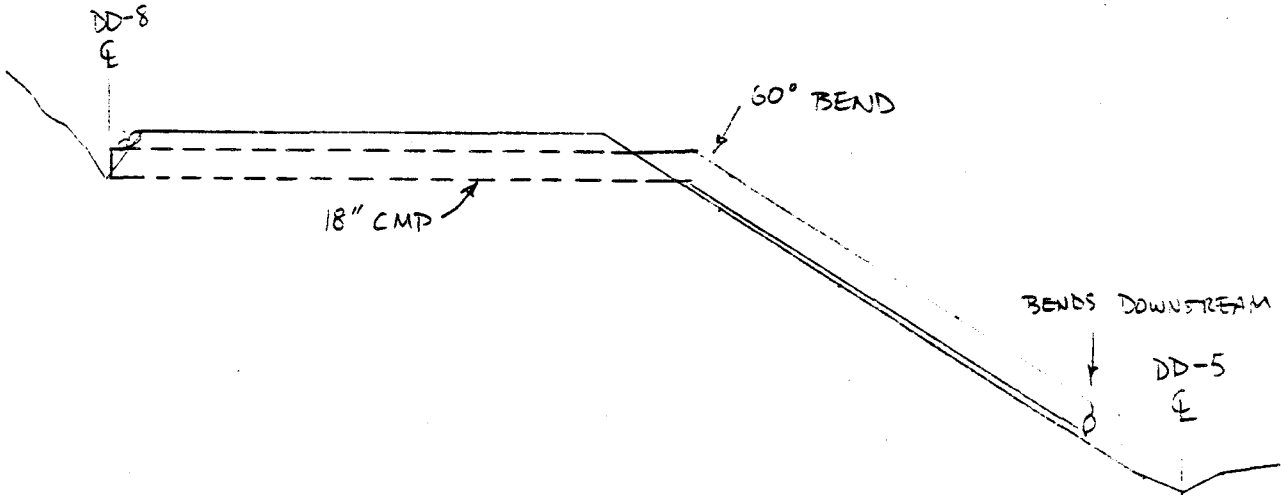
$(T_c)_{pad}$ → V = 0.7 ft/s, l = 80 ft } $(T_c)_{pad}$ = 0.03 hr

$(T_c)_{tot}$ = 0.11 + 0.03 = 0.14 hr

See hydrograph summary on page 26 of this calc.



C-1
PLAN VIEW
SCALE: 1" = 10'



C-1
ELEV. VIEW
SCALE: 1" = 10'

```
*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: C-5 CULVERT

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II           AREA =  0.004 SQ. MI.
        DEPTH =  2.50 IN.             CN = 70.0
        DURATION = 24.0 HR.           TIME OF CONC. =  0.14 HR.
*************************************************************
```

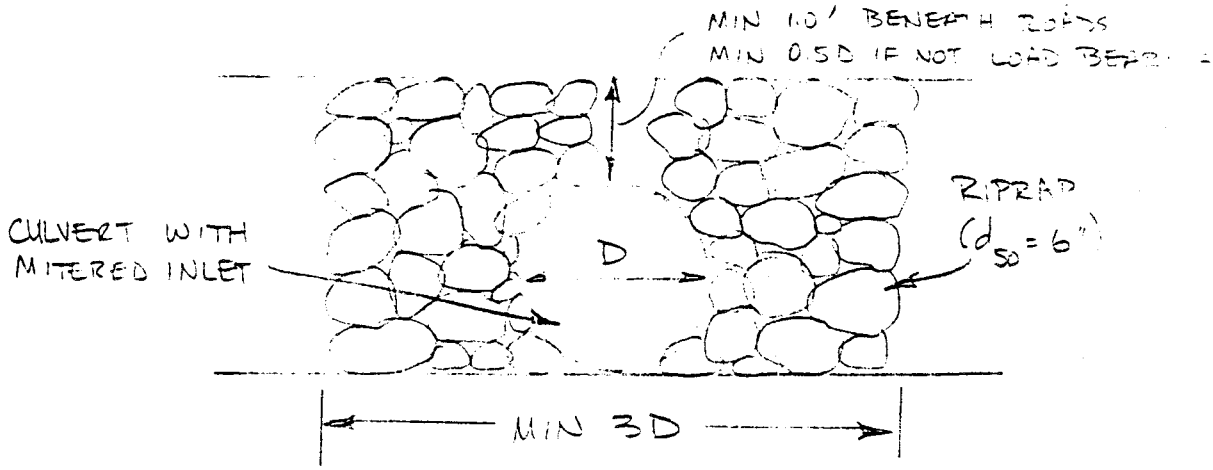
```
*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.4552 INCHES
     INITIAL ABSTRACTION =  0.9571 INCHES
     PEAK FLOW =     1.09 CFS  ( 0.4219 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.4562 INCHES
*************************************************************
```

Required culvert size → 12" (see nomograph on pg. 2 of this calc.). Collect the water in a full-round culvert add 2 60° elbows to bend the pipe down the hill, and convert the culvert to a half-round.

Culvert inlet design → Typical inlet on page 27 of this calc.



TYPICAL CULVERT INLET
(APPLIES TO CULVERTS C-1 THRU C-5)
ELEV. VIEW

NO SCALE

Design of C-6 → Reclaimed area = 0.24 ac (CN = 75)
= 0.0004 mi^2

T_c ⇒ 110 ft @ 84% → V = 6.5 ft/s

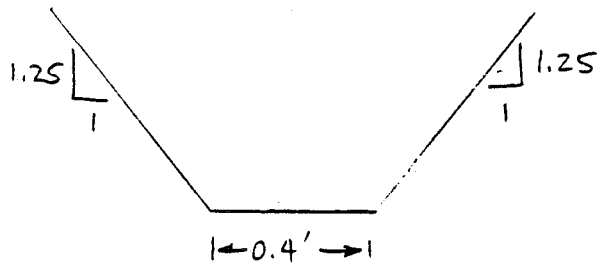
$$T_c = \frac{110\ ft}{6.5\ ft/s} = 16.9\ s = 0.005\ hr$$

SCSHYDRO results:

```
IDENTIFICATION:  CULVERT C-6

INPUT SUMMARY:
*****************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.000 SQ. MI.
        DEPTH =  2.50 IN.               CN = 75.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.01 HR.
*****************************************************************


*****************************************************************


OUTPUT SUMMARY:
*****************************************************************
     TOTAL RUNOFF DEPTH =  0.6505 INCHES
     INITIAL ABSTRACTION =  0.6667 INCHES
     PEAK FLOW =      0.13 CFS   ( 0.5000 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.6513 INCHES
*****************************************************************
```

From the nomograph on pg. 2 of this calc., a 12" CMP is adequate to pass the design flow (0.13 cfs).

Exit velocity — calculate using an equivalent trapezoidal section.



Q = 0.13 cfs
Assume bed slope = 0.1 ft/ft (same as C-4)
n = 0.024 (CMP)

Bed Slope =	.1	
Manning's N =	.024	
Bottom Width =	.4	feet
Channel Side Slope =	1.25	
Flow Depth =	.0870056	feet
Cross Sectional Area =	4.085822E-02	square feet
Wetted Perimeter =	.6228431	feet
Hydraulic Radius =	6.559954E-02	feet
Discharge =	.13	cubic feet sec
Velocity =	3.181734	feet/sec
Froude Number =	1.900913	

This design velocity is sufficiently low to minimize erosion. Discharge directly to pond.

EARTHFAX ENGINEERING, INC.
ENGINEERS / SCIENTISTS

PROJECT C-27 PAGE 26c OF
COMPUTED BKB DATE Revised 3-26-92
CHECKED DATE

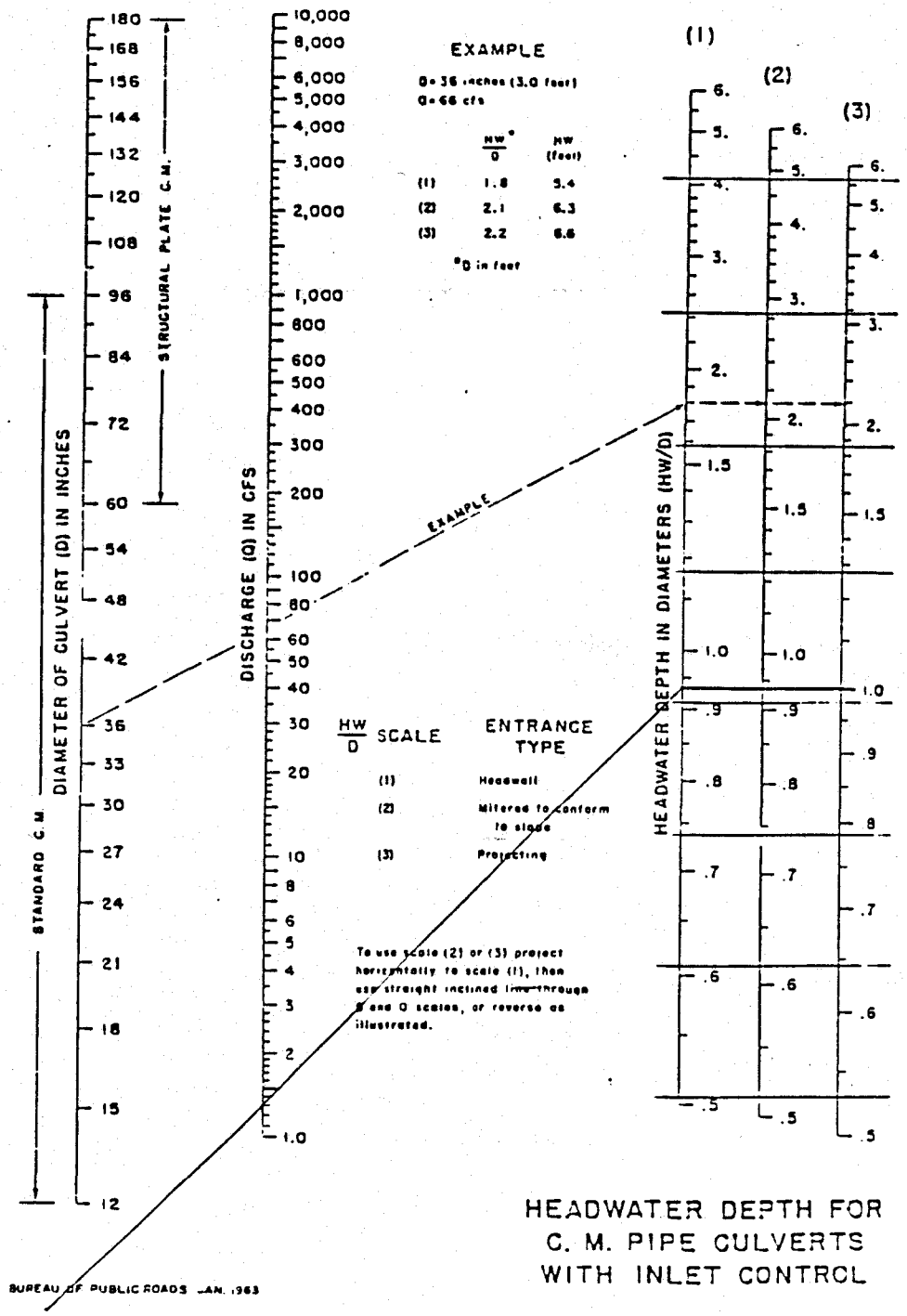
DESIGN OF CULVERT C-7

From the design flow of DD-3 (page 7 of Appendix 7-11) the runoff depth is 0.94 inches and the peak flow is 1.3 cfs.

Using the nomograph on page 26d of this appendix a 12-inch diameter CMP culvert is adequate to handle the design flow (10 yr. 24 hr.).

C-7

CHART 5



HEADWATER DEPTH FOR
C. M. PIPE CULVERTS
WITH INLET CONTROL

Source: Hydraulic Charts for the Selection of Highway Culverts. U.S. Dept. of Transportation. Hydraulic Engineering Circular 5.

— DESIGN OF RECLAMATION CHANNELS —

Design of RD-1

Watershed draining to RD-1 → WS-1 + adjacent undisturbed and reclaimed area

Undisturbed area = 95.2 ac (WS-1) + 0.2 ac (Adjacent) = 95.4 ac

Reclaimed area = 0.3 ac (Adjacent)

Total = 95.7 ac = 0.150 mi²

$l = 4110$ ft

$$\overline{CN} = \frac{(95.4)(69) + (0.3)(75)}{95.7} = 69$$

$$S = \frac{1000}{CN} - 10 = 4.49$$

$$Y = \left[\frac{(55{,}700 \text{ ft})(40 \text{ ft})}{(95.7 \text{ ac})(43{,}560 \text{ ft}^2/\text{ac})}\right](100) = 53.4\%$$

$$L = \frac{(4110)^{0.8}(1 + 4.49)^{0.7}}{(1900)(53.4)^{0.5}} = 0.18 \text{ hr}$$

$$T_c = (1.67)(0.18) = \underline{0.31 \text{ hr}}$$

Design storm → 50-yr, 24-hr. USFS designs culverts for road crossings with 10- to 20-yr return period. Since this channel will empty into such a culvert, a 50-yr return period is a conservative design for the channel.

P = 3.25 in (Miller et al. 1973)

Hydrograph results:

```
*****************************
* EARTHFAX ENGINEERING, INC. *
*                            *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER   *
*         METHODOLOGY        *
*****************************
```

IDENTIFICATION: WATERSHED DRAINING TO RD-1

INPUT SUMMARY:

```
*****************************************************************
    STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.150 SQ. MI.
        DEPTH =  3.25 IN.            CN = 69.0
        DURATION = 24.0 HR.          TIME OF CONC. =  [illegible]
*****************************************************************
```

```
*****************************************************************
```

OUTPUT SUMMARY:

```
*****************************************************************
    TOTAL RUNOFF DEPTH =  0.8079 INCHES
    INITIAL ABSTRACTION =  0.8986 INCHES
    PEAK FLOW =     61.21 CFS  ( 0.6323 IN/HR)
    TIME TO PEAK =  12.09 HOURS
    RUNOFF VOLUME CHECK =  0.8095 INCHES
*****************************************************************
```

Maximum slope of channel = $\frac{10}{24}$ = 0.42 ft/ft

Minimum slope of channel = $\frac{10}{75}$ = 0.13 ft/ft

Use maximum slope for design of riprap, minimum slope for design of cross section.

Run TRAP1 with bottom widths of 3 ft and 5 ft, assuming n=0.04 and sideslopes of 2h:1v. Check required riprap size, adjust roughness coefficient, and re-run TRAP1.

Bed Slope =	.42	
Manning's N =	.04	
Bottom Width =	3	feet
Channel Side Slope =	.5	
Flow Depth =	.8082538	feet
Cross Sectional Area =	3.73131	square feet
Wetted Perimeter =	6.614621	feet
Hydraulic Radius =	.5641003	feet
Discharge =	61.2	cubic feet/sec
Velocity =	16.40175	feet/sec
Froude Number =	3.215054	

Bed Slope =	.42	
Manning's N =	.04	
Bottom Width =	5	feet
Channel Side Slope =	.5	
Flow Depth =	.6358769	feet
Cross Sectional Area =	3.988063	square feet
Wetted Perimeter =	7.843728	feet
Hydraulic Radius =	.5084398	feet
Discharge =	61.2	cubic feet/sec
Velocity =	15.3458	feet/sec
Froude Number =	3.391368	

Determine riprap sizing from the figure on page 27c of this calc. Determine new n value from the equation:

$$n = 0.0395\, d_{50}^{1/6}$$

where d_{50} = median stone diameter (ft)

For b = 3 ft $\longrightarrow$ d_{50} = 2.3 ft (ft 2:1 sideslopes)
n = 0.045

For b = 5 ft $\longrightarrow$ d_{50} = 2.1 ft
n = 0.045

Rerun w/ n = 0.044

27c/

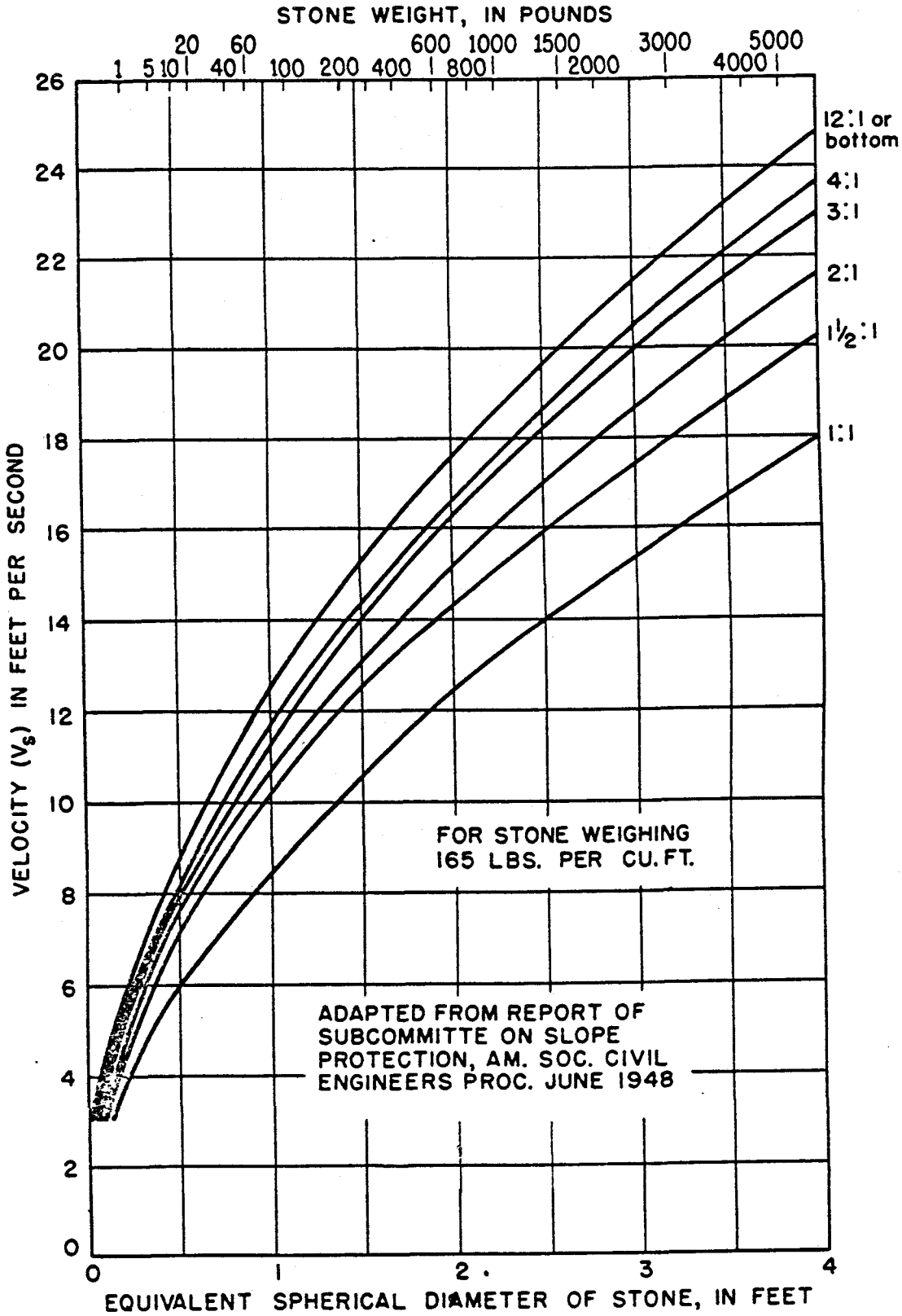


FIG. 2-SIZE OF STONE THAT WILL RESIST DISPLACEMENT FOR VARIOUS VELOCITIES AND SIDE SLOPES

Source: HEC-11

Bed Slope =	.42	
Manning's N =	.044	
Bottom Width =	3	feet
Channel Side Slope =	.5	
Flow Depth =	.8459342	feet
Cross Sectional Area =	3.969013	square feet
Wetted Perimeter =	6.783133	feet
Hydraulic Radius =	.5851297	feet
Discharge =	61.2	cubic feet/sec
Velocity =	15.41945	feet/sec
Froude Number =	2.954423	

Bed Slope =	.42	
Manning's N =	.044	
Bottom Width =	5	feet
Channel Side Slope =	.5	
Flow Depth =	.6708703	feet
Cross Sectional Area =	4.254486	square feet
Wetted Perimeter =	8.000223	feet
Hydraulic Radius =	.5317959	feet
Discharge =	61.2	cubic feet/sec
Velocity =	14.38462	feet/sec
Froude Number =	3.094975	

For $b = 3$ ft $\longrightarrow$ $d_{50} = 2.1$ ft, $n = 0.045$

For $b = 5$ ft $\longrightarrow$ $d_{50} = 1.6$ ft, $n = 0.043$

Design w/ $b = 5$ ft. Rerun w/ $n = 0.043$

Bed Slope =	.42	
Manning's N =	.043	
Bottom Width =	5	feet
Channel Side Slope =	.5	
Flow Depth =	.6622636	feet
Cross Sectional Area =	4.188504	square feet
Wetted Perimeter =	7.961733	feet
Hydraulic Radius =	.5260795	feet
Discharge =	61.2	cubic feet/sec
Velocity =	14.61142	feet/sec
Froude Number =	3.164092	

$d_{50} = 1.8$ ft $\longrightarrow$ $n = 0.044$

Use $d_{50} = \dfrac{1.6 + 1.8}{2} = \underline{\underline{1.7 \text{ ft}}}$

$= \underline{\underline{20 \text{ inches}}}$

$n = 0.043$

Channel cross section → determine from reach with minimum slope:

Red Slope =	.13	
Manning's N =	.045	
Bottom Width =	5	feet
Channel Side Slope =	.5	
Flow Depth =	.9184562	feet
Cross Sectional Area =	6.279405	square feet
Wetted Perimeter =	9.107462	feet
Hydraulic Radius =	.6894792	feet
Discharge =	61.2	cubic feet/sec
Velocity =	9.746146	feet/sec
Froude Number =	1.792196	

Design cross section: Construct with finished depth of 1.5 ft (providing approx. 0.6 ft freeboard – see Barfield et al., 1981). See cross section on page 27f of this calc.

Riprap gradation → see pg. 27g of this calc. (based on dimensionless curve provided by Barfield et al., 1981).

Filter-blanket design:

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{7.5\text{ in}}{2.0\text{ in}} = 3.75 < 5 \qquad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{7.5\text{ in}}{0.2\text{ in}} = 37.5 < 40 \qquad \underline{\underline{OK}}$$

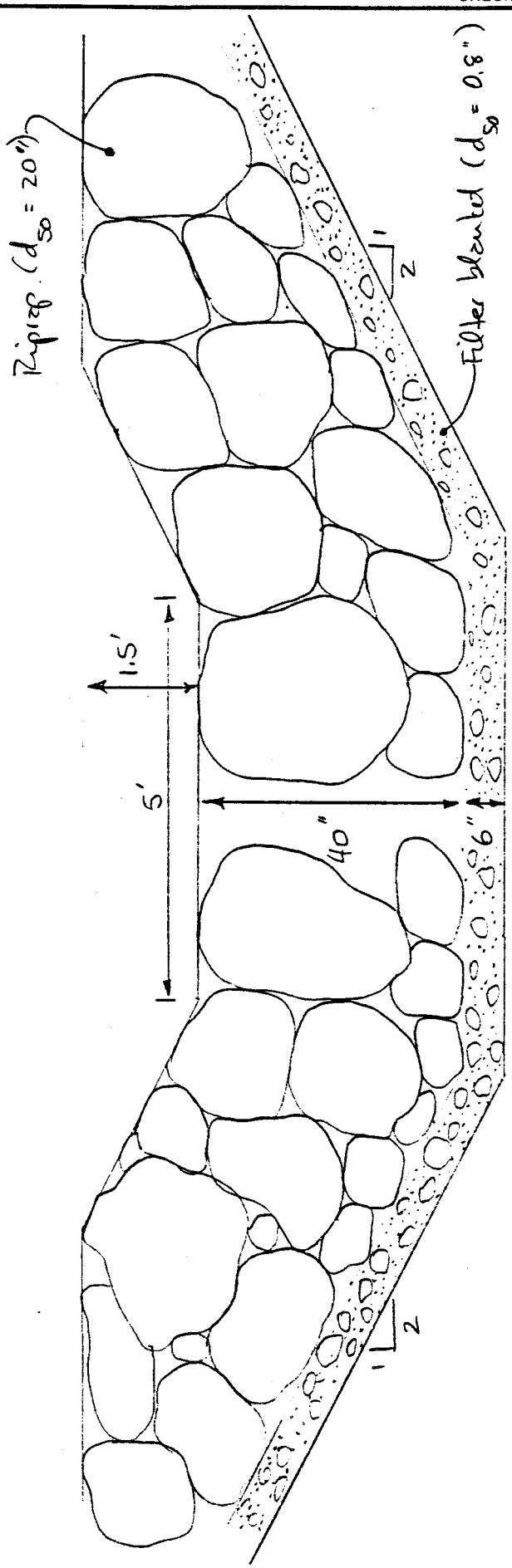
$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (bed)}} = \frac{0.2\text{ in}}{0.94\text{ in}} = 0.2 < 5 \qquad OK$$

$$\frac{D_{15}\text{ (filter)}}{D_{15}\text{ (bed)}} = \frac{0.2\text{ in}}{0.0021\text{ in}} = 95.2 > 40$$

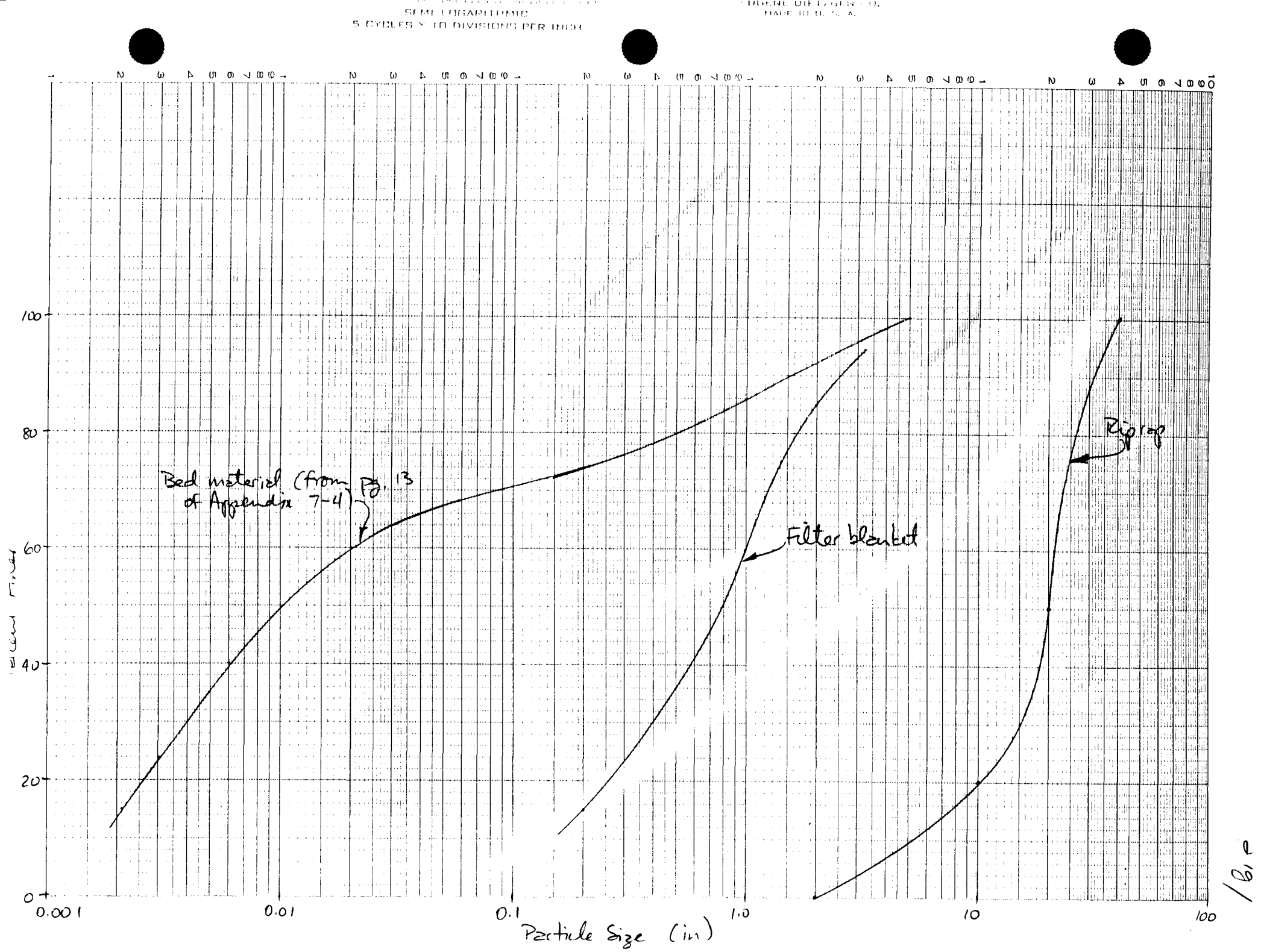
Although this final value is outside of the normal range, this filter blanket will be accepted due to the high factor of safety inherent in the runoff estimate (compare with the discussion in Appendix 7-5).

EARTHFAX ENGINEERING, INC.
ENGINEERS / SCIENTISTS

PROJECT C-27 PAGE 27f OF
COMPUTED TEW DATE 8 Jul 1986
CHECKED DATE



RD-1 ELEVATION VIEW
SCALE: 1" = 2'


SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
Bed material (from pg. 13 of Appendix 7-4)
Filter blanket
Riprap
Percent finer
100
80
60
40
20
0
0.001
0.01
0.1
1.0
10
100
Particle Size (in)

RD-1 will be constructed during Phase I of final reclamation but will divert water from WS-1 only during Phase II. WS-1 will continue to flow through UD-1 during Phase I to allow more time for RD-1 and the surrounding area to stabilize.

During Phase I, RD-1 will discharge into RD-2, thus causing site water to flow to the sedimentation pond. During Phase II, UD-1 will be removed to the USFS road and RD-1 will discharge to this culvert. The culvert will be maintained by the USFS as part of the post-mining land use. RD-1 will be extended to the head of the existing UD-1.

Design of RD-2

Contributing watershed → WS-2 + WS-4 + portion of reclaimed area east of UD-1 and west of RD-4.

Area → Undisturbed = $\underset{(WS-2)}{0.9} + \underset{(WS-4)}{5.5} = 6.4$ ac

Reclaimed = $\underset{(WS-2)}{0.3} + \underset{(WS-4)}{0.3} + \underset{(site)}{1.9}$ ac = 2.5 ac

Total = 6.4 + 2.5 = 8.9 ac
= 0.014 mi^2

$l = 1020$ ft

$$\bar{CN} = \frac{(6.4)(69) + (2.5)(75)}{8.9} = 71$$

$$S = \frac{1000}{71} - 10 = 4.08$$

$$Y = \left[\frac{(3010\text{ ft})(40\text{ ft})}{(8.9\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 31.1\%$$

$$L = \frac{(1020)^{0.8}(1+4.08)^{0.7}}{(1900)(31.1)^{0.5}}$$

$= 0.08$ hr

$T_c = (1.67)(0.08)$
$= \underline{0.13}$ hr

Design storm → 50-yr, 24-hr = 3.25 in.

Hydrograph results → see pg 27i of this calc.

```
*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: WATERSHED DRAINING TO RD-2

INPUT SUMMARY:

```
*************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.014 SQ. MI.
        DEPTH =  3.25 IN.            CN = 71.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.13 HR.
*************************************************************
```

```
*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.9083 INCHES
     INITIAL ABSTRACTION =  0.8169 INCHES
     PEAK FLOW =      8.04 CFS   ( 0.8901 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.9101 INCHES
*************************************************************
```

Maximum channel slope $= \frac{10}{95} = 0.11$ ft/ft (for riprap design)

Minimum slope $= \frac{10}{160} = 0.063$ ft/ft (for cross section design)

Initially assume $n = 0.035$. Run TRAP1 and compare riprap requirements with roughness coefficient.

Bed Slope =	.11	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	.431134	feet
Cross Sectional Area =	1.234021	square feet
Wetted Perimeter =	3.92809	feet
Hydraulic Radius =	.3141529	feet
Discharge =	8.04	cubic feet/sec
Velocity =	6.515287	feet/sec
Froude Number =	1.748636	

Bed Slope =	.11	
Manning's N =	.035	
Bottom Width =	4	feet
Channel Side Slope =	.5	
Flow Depth =	.3024303	feet
Cross Sectional Area =	1.392649	square feet
Wetted Perimeter =	5.35251	feet
Hydraulic Radius =	.2601862	feet
Discharge =	8.04	cubic feet/sec
Velocity =	5.77317	feet/sec
Froude Number =	1.880008	

For $b = 2$ ft $\longrightarrow$ $d_{50} = 0.30$ ft $= 3.6$ in

For $b = 4$ ft $\longrightarrow$ $d_{50} = 0.25$ ft $= 3.0$ in

See pg. 27c of this calc

$n_2 = 0.032$

$n_4 = 0.031$

Rerun w/ $n = 0.033$

Bed Slope =	.11	
Manning's N =	.033	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	.4175808	feet
Cross Sectional Area =	1.183909	square feet
Wetted Perimeter =	3.867479	feet
Hydraulic Radius =	.3061192	feet
Discharge =	8.04	cubic feet/sec
Velocity =	6.791062	feet/sec
Froude Number =	1.851994	

Required $d_{50} = 0.35$ ft
$= 4.2$ in

$n = 0.033 \Rightarrow$ OK

Bed Slope =	.11	
Manning's N =	.033	
Bottom Width =	4	feet
Channel Side Slope =	.5	
Flow Depth =	.2923076	feet
Cross Sectional Area =	1.340118	square feet
Wetted Perimeter =	5.30724	feet
Hydraulic Radius =	.2525076	feet
Discharge =	8.04	cubic feet/sec
Velocity =	5.999472	feet/sec
Froude Number =	1.955532	

Required d_{50} = 0.30 ft
= 3.6 in

$n = 0.032 \Rightarrow$ OK

Determine cross section using $b = 2$ ft, $n = 0.033$

Bed Slope =	.063	
Manning's N =	.033	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	.4840931	feet
Cross Sectional Area =	1.436876	square feet
Wetted Perimeter =	4.16493	feet
Hydraulic Radius =	.3449946	feet
Discharge =	8.04	cubic feet/sec
Velocity =	5.595464	feet/sec
Froude Number =	1.417241	

Riprap gradation → see pg 27l of this calc.

Filter blanket design (see also pg. 27g of this calc.):

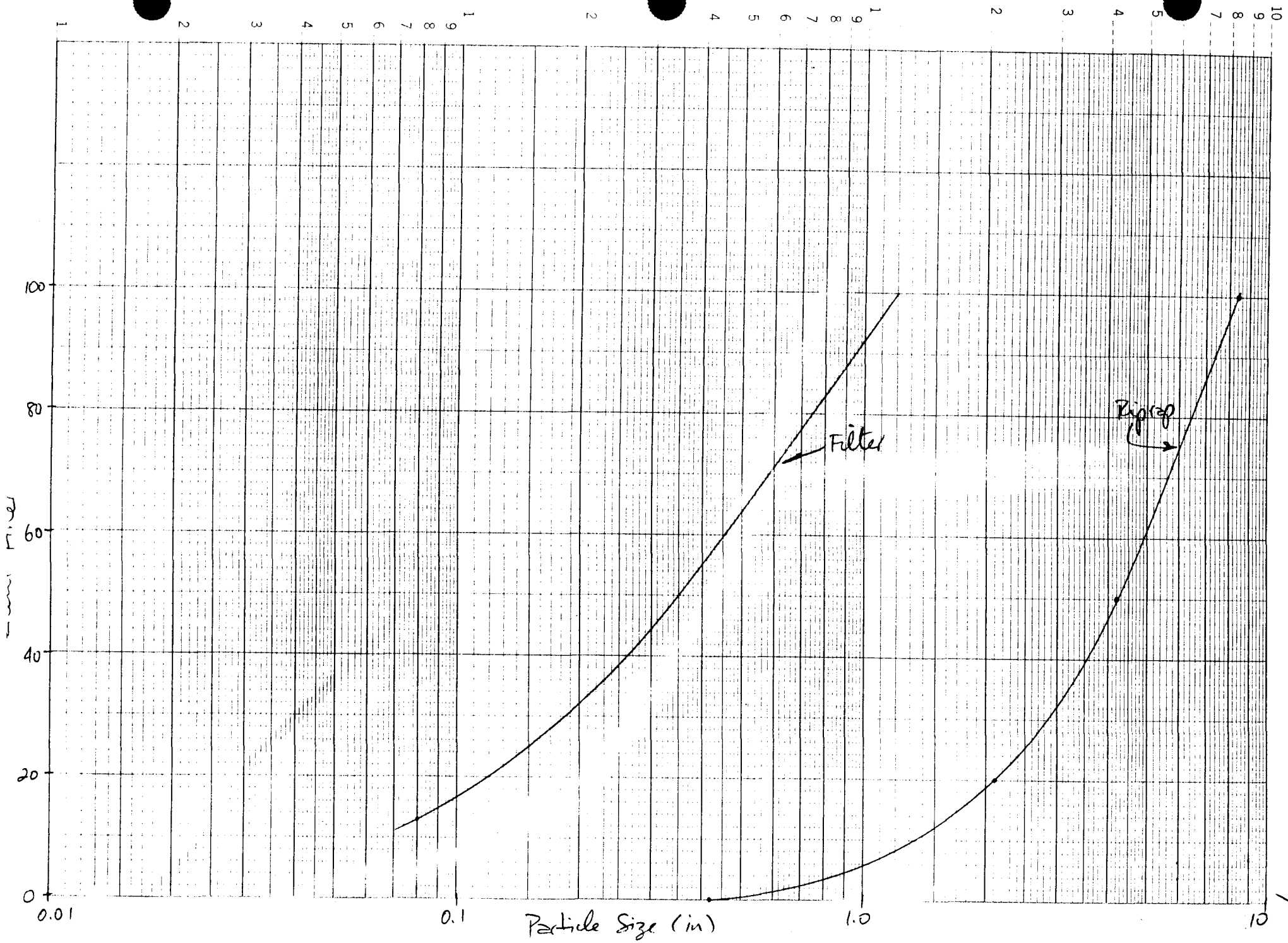
$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{1.7\text{ in}}{0.85\text{ in}} = 2.0 < 5 \quad \underline{\underline{OK}}$$

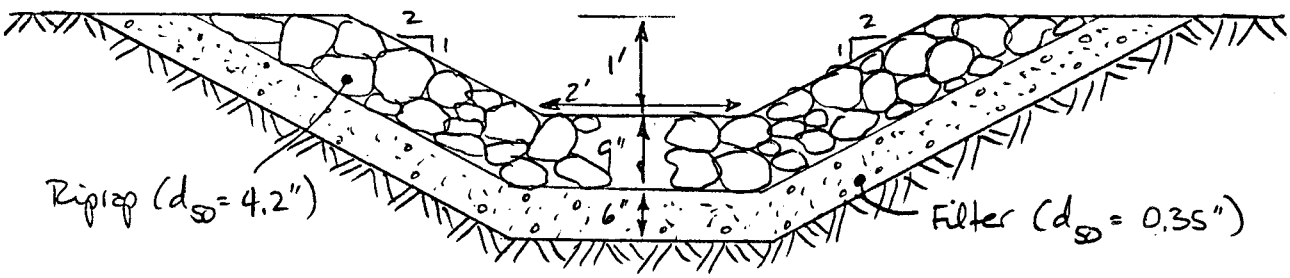
$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{1.7\text{ in}}{0.08\text{ in}} = 21.3 < 40 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (bed)}} = \frac{0.08\text{ in}}{0.94\text{ in}} = 0.09 < 5 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (filter)}}{D_{15}\text{ (bed)}} = \frac{0.08\text{ in}}{0.0021\text{ in}} = 38.1 < 40 \quad \underline{\underline{OK}}$$

K+E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 5492





RD-2 ELEVATION VIEW
SCALE: 1" = 2'

Design of RD-3

Ultimate drainage area = WS-5 + site reclaimed area

Undisturbed area = 2.1 ac (WS-5)
Reclaimed area = 0.6 ac (site)
Total = 2.7 ac = 0.004 mi²

$l = 750$ ft

$\bar{C}_N = \frac{(2.1)(69) + (0.6)(75)}{2.7} = 71$

$S = \frac{1000}{71} - 10 = 4.08$

$Y = \left[\frac{(1990\ ft)(40\ ft)}{(2.7ac)(43{,}560\ ft^2/ac)}\right](100) = 67.7\%$

$L = \frac{(750)^{0.8}(1+4.08)^{0.7}}{(1900)(67.7)^{0.5}}$

$= 0.04$ hr

$T_c = (1.67)(0.04)$

$= \underline{0.07}$ hr

Design storm → 50-yr, 24-hr = 3.25 in

Hydrograph results → see pg. 27n of this calc.

RD-3 no longer to be used.

TRBowlitz
1 Dec 1989

EARTHFAX ENGINEERING, INC.
ENGINEERS / SCIENTISTS

PROJECT C-27 PAGE 27n OF
COMPUTED RBW DATE 1 Dec 1989
CHECKED DATE

```
*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: WATERSHED DRAINING TO RD-3

INPUT SUMMARY:

```
*****************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II              AREA =  0.004 SQ. MI.
        DEPTH =  3.25 IN.                CN = 71.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.07 HR.
*****************************************************************
```

```
*****************************************************************
```

OUTPUT SUMMARY:

```
*****************************************************************
     TOTAL RUNOFF DEPTH =  0.9083 INCHES
     INITIAL ABSTRACTION =  0.8169 INCHES
     PEAK FLOW =      2.45 CFS   ( 0.9473 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.9101 INCHES
*****************************************************************
```

Maximum channel slope = $\frac{10}{30}$ = 0.33 ft/ft

Minimum channel slope = 0.01 ft/ft (design condition along base of cut)

Initially assume n = 0.033. Run w/ b = 2 ft.

Bed Slope =	.33	
Manning s N =	.033	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	.1564641	feet
Cross Sectional Area =	.3618902	square feet
Wetted Perimeter =	2.699729	feet
Hydraulic Radius =	.1340469	feet
Discharge =	2.45	cubic feet/sec
Velocity =	6.77001	feet/sec
Froude Number =	3.016158	

Required d_{50} = 0.35 ft
= 4.2 in
n = 0.033 OK

RD-3 no longer to be use.
RBW 12/1/89

Cross section design:

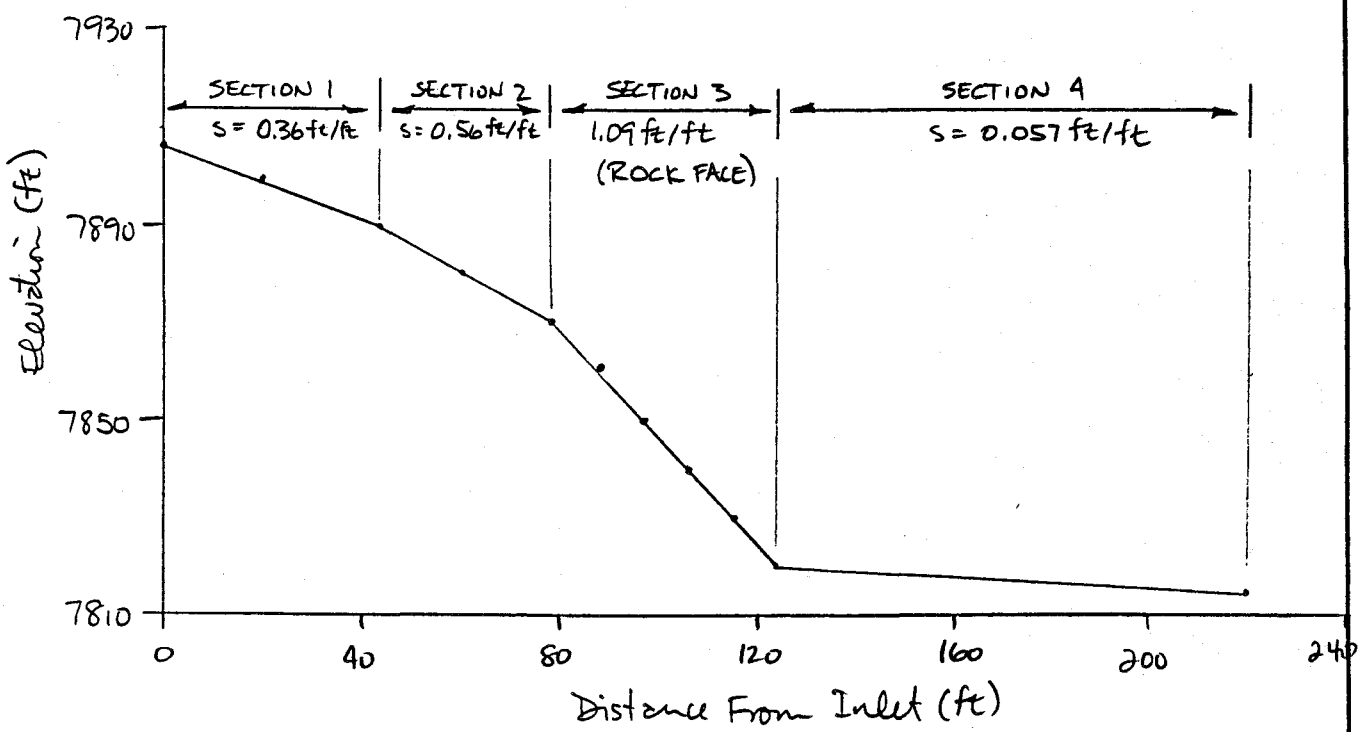
Bed Slope =	.01	
Manning's N =	.033	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	.4199953	feet
Cross Sectional Area =	1.192783	square feet
Wetted Perimeter =	3.878276	feet
Hydraulic Radius =	.3075549	feet
Discharge =	2.45	cubic feet/sec
Velocity =	2.05402	feet/sec
Froude Number =	.5585404	

Use the same cross section designed for RD-2.

RD-3 no longer to be used.
RBW 12/1/89

Design of RD-4

Longitudinal profile:



Determine peak flow and design the channel by section

Watershed draining to RD-4 → WS-3 + portion of reclaimed area

Drainage area = 8.8 ac (WS-3) + 0.2 ac (site) = 9.0 ac
= 0.014 mi²

$l = 1540$ ft

$\bar{CN} = \frac{(8.8)(69) + (0.2)(75)}{9.0} = 70$

$S = \frac{1000}{70} - 10 = 4.29$

$Y = \left[\frac{(1600\text{ ft})(40\text{ ft})}{(9.0\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 16.3\%$

$L = \frac{(1540)^{0.8}(1+4.29)^{0.7}}{(1900)(16.3)^{0.5}}$

$= 0.15$ hr

$T_c = (1.67)(0.15)$

$= \underline{0.25}$ hr

Design storm → 50-yr, 24-hr = 3.25 in

```
*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: WATERSHED DRAINING TO RD-4

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.014 SQ. MI.
        DEPTH =  3.25 IN.              CN = 70.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.25 HR.
*************************************************************
```

```
*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.8573 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      6.62 CFS  ( 0.7323 IN/HR)
     TIME TO PEAK =  12.05 HOURS
     RUNOFF VOLUME CHECK =  0.8590 INCHES
*************************************************************
```

Above the rock face, design riprap size based on section 2 and channel cross section based on section 1.

Section 2 run (assume n = 0.037, b = 4 ft):

Bed Slope =	.56	
Manning's N =	.037	
Bottom Width =	4	feet
Channel Side Slope =	.5	
Flow Depth =	.1736899	feet
Cross Sectional Area =	.7550959	square feet
Wetted Perimeter =	4.776765	feet
Hydraulic Radius =	.1580768	feet
Discharge =	6.62	cubic feet/sec
Velocity =	8.767098	feet/sec
Froude Number =	3.707154	

Required d_{50} (from pg 27c) = 0.70 ft
= 8.4 in

n = 0.037 ⇒ OK

Section 1 run:

Bed Slope =	.36	
Manning's N =	.037	
Bottom Width =	4	feet
Channel Side Slope =	.5	
Flow Depth =	.1975886	feet
Cross Sectional Area =	.8684367	square feet
Wetted Perimeter =	4.883643	feet
Hydraulic Radius =	.1778256	feet
Discharge =	6.62	cubic feet/sec
Velocity =	7.622893	feet/sec
Froude Number =	3.022115	

Riprap gradation → see pg 27r of this calc.

Check filter blanket design using the blanket designed for RD-2:

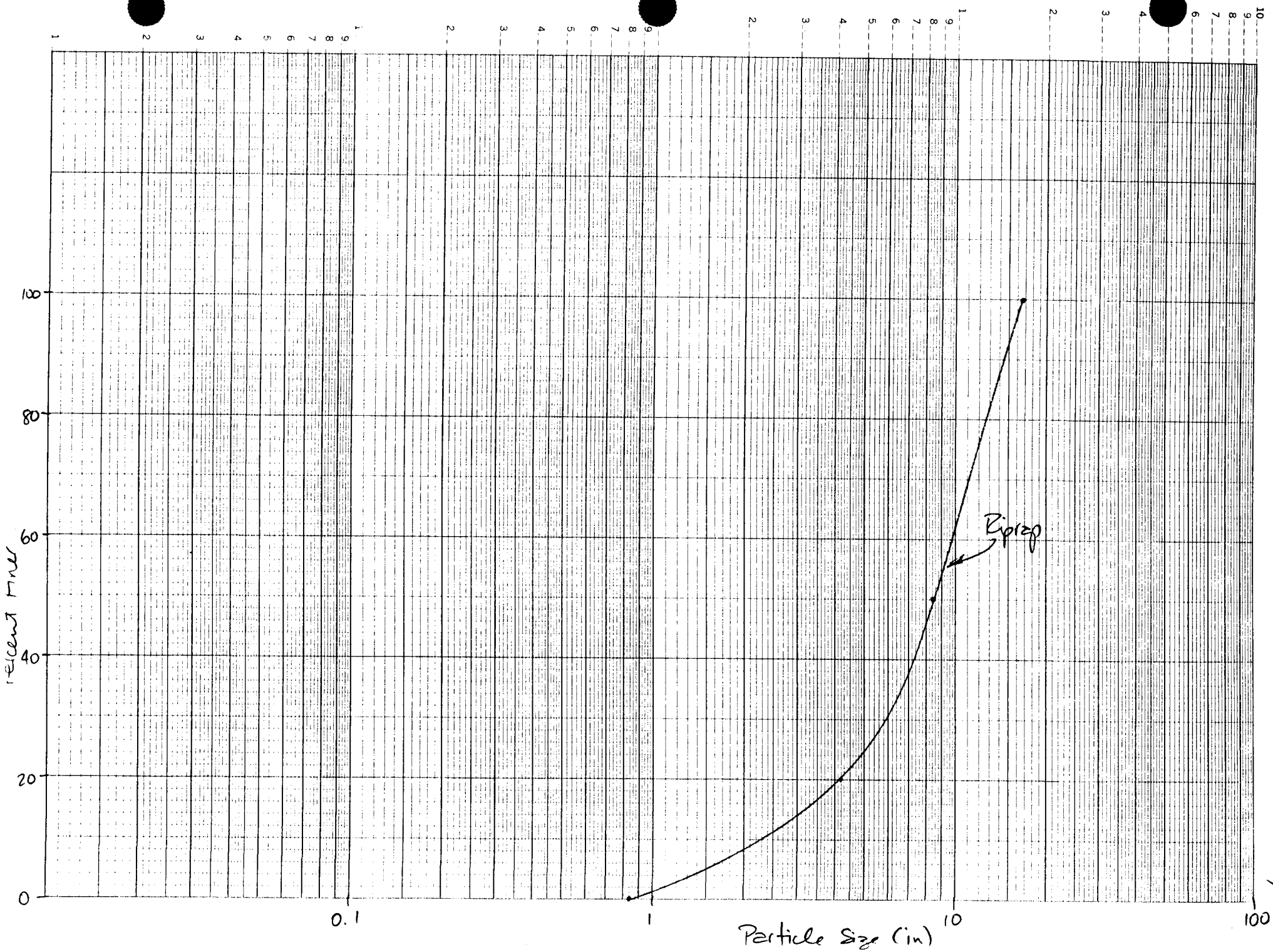
$$\frac{D_{15}\text{(riprap)}}{D_{85}\text{(filter)}} = \frac{3.2\text{ in}}{0.85\text{ in}} = 3.8 < 5 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{(riprap)}}{D_{15}\text{(filter)}} = \frac{3.2\text{ in}}{0.08\text{ in}} = 40 = 40 \quad \underline{\underline{OK}}$$

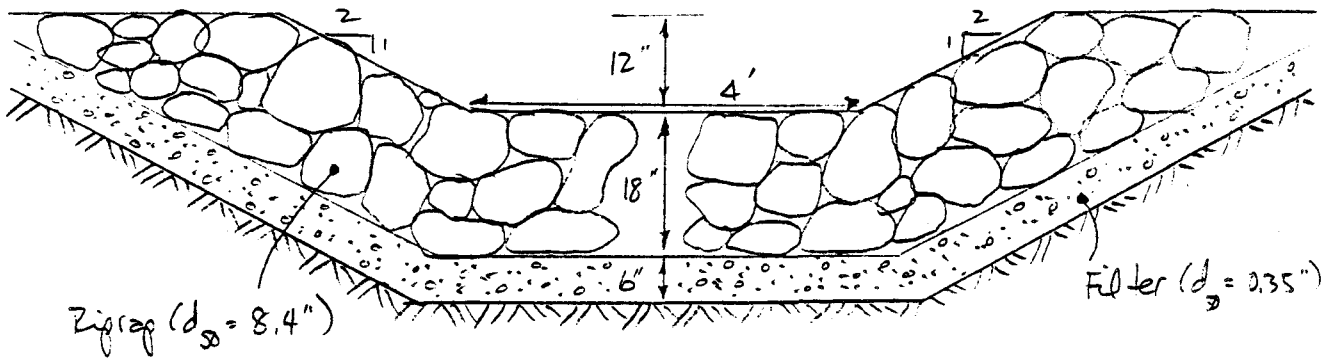
Use this filter blanket.

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 6010



A12

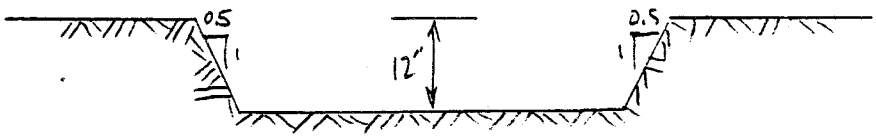


SECTION 1 / SECTION 2
RD-4 ELEV. VIEW
SCALE: 1" = 2'

Section 3 of this channel will be blasted into rock. The U.S. Soil Conservation Service (1956) suggests a range of roughness coefficients for similar channels of 0.035 to 0.045. Assume n = 0.040.

Bed Slope =	1.09	
Manning's N =	.04	
Bottom Width =	4	feet
Channel Side Slope =	2	
Flow Depth =	.1521696	feet
Cross Sectional Area =	.6202561	square feet
Wetted Perimeter =	4.340262	feet
Hydraulic Radius =	.1429075	feet
Discharge =	6.62	cubic feet/sec
Velocity =	10.67301	feet/sec
Froude Number =	4.821644	

This velocity is considered acceptable for rock (see U.S. Army Corps of Engineers, 1970).



SECTION 3
RD-4 ELEV. VIEW
SCALE: 1" = 2'

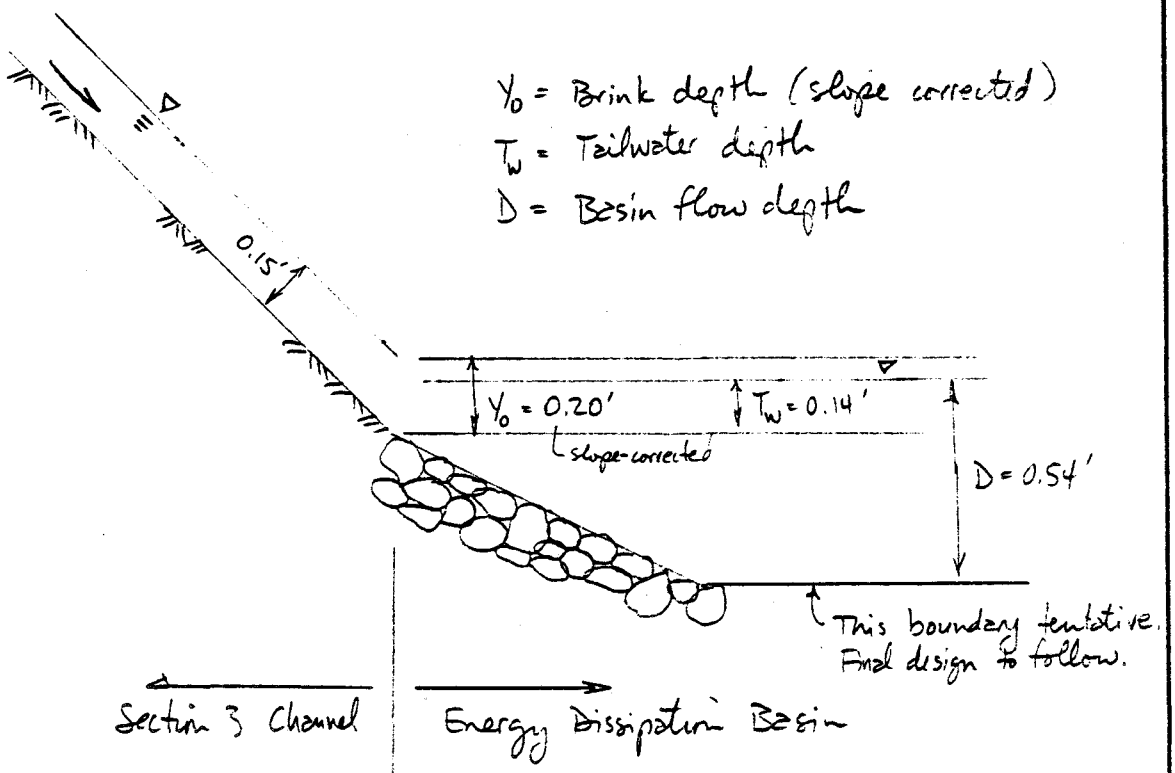
Design of Energy Dissipation Basin at Downstream Edge of Section 3 Channel (where rock face meets pad) – use the design procedure of Corry et al. (1975):
↳ HEC-14

Depth of flow in basin – Assume 1% slope on basin floor
4 ft bottom width
2:1 sideslopes

TRAP1 results:

Bed Slope =	.01	
Manning's N =	.035	
Bottom Width =	4	feet
Channel Side Slope =	.5	
Flow Depth =	.5392388	feet
Cross Sectional Area =	2.738512	square feet
Wetted Perimeter =	6.41155	feet
Hydraulic Radius =	.4271218	feet
Discharge =	6.62	cubic feet/sec
Velocity =	2.417371	feet/sec
Froude Number =	.5801293	

General schematic:



$$\frac{T_W}{Y_0} = \frac{0.14}{0.20} = 0.70 < 0.75 \quad \underline{\underline{OK}}$$

Determine riprap sizing for basin — see pg 27s4 of this calc:

Select d_{50} such that $0.25 < \frac{d_{50}}{Y_e} < 0.45$

AND

$2 < \frac{h_s}{d_{50}} < 4$

Y_e = equivalent depth = $(A/2)^{1/2}$ where A is for Section 3 channel

$= \frac{(2.74/2)^{1/2}}{\sin 47.5°}$

$= 1.59$ ft

To meet the design criteria ($0.25 < d_{50}/Y_e < 0.45$), select $d_{50}/Y_e = 0.35 \Rightarrow d_{50} = (0.35)(1.59') = 0.56$ ft (min)

However, the Division has requested the use of $d_{50} = 1.25$ ft (see pg 27s7). Thus, this size will be used. Filter blanket calculations included on page 27s8 of this calc.

From pg 27s4 $\rightarrow \frac{h_s}{Y_e} = 0.90 \Rightarrow h_s = (0.90)(1.59)$
$= 1.43$ ft (scour hole depth)

$$\frac{h_s}{d_{50}} = \frac{1.43}{0.70} = 2.04 \Rightarrow \underline{\underline{OK}}$$

Basin length = $10 h_s = 14.3$ ft $\Rightarrow$ use 15 ft

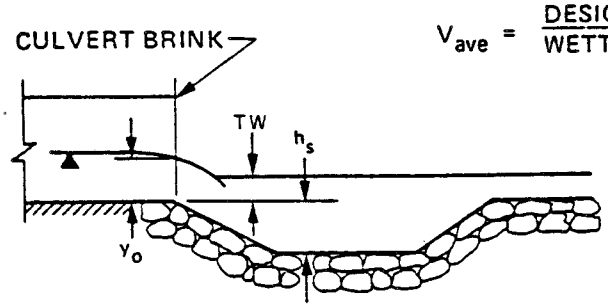
Apron length = $5 h_s = 7.15$ ft $\Rightarrow$ use 7.5 ft

Freeboard = 1.0 ft

Total basin depth = $h_s + Y_o + 1.0$
$= 1.43 + 0.20 + 1.00$
$= 2.63$ ft $\Rightarrow$ Construct with depth = $\underline{\underline{2.75 \text{ ft}}}$

Design sections $\rightarrow$ see pg 27s5 and 27s6 of this calc.

$$V_{ave} = \frac{\text{DESIGN DISCHARGE} - Q}{\text{WETTED AREA AT BRINK OF CULVERT}}$$

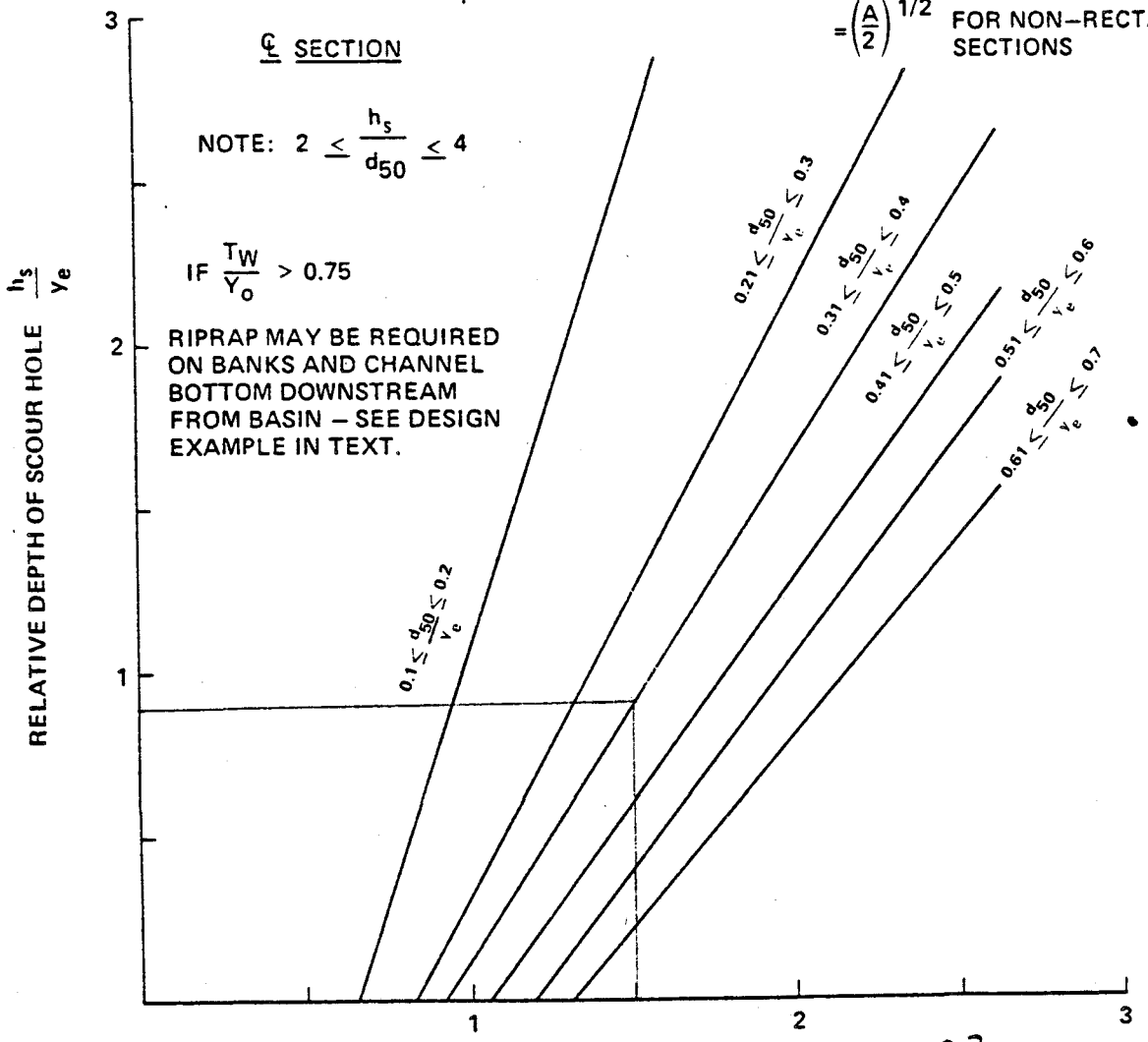


d_{50} = THE MEDIAN SIZE OF ROCK BY WEIGHT. ROUNDED ROCK OR ANGULAR ROCK.

Y_e = EQUIVALENT BRINK DEPTH

= BRINK DEPTH FOR BOX CULVERT

$= \left(\frac{A}{2}\right)^{1/2}$ FOR NON-RECTANGULAR SECTIONS

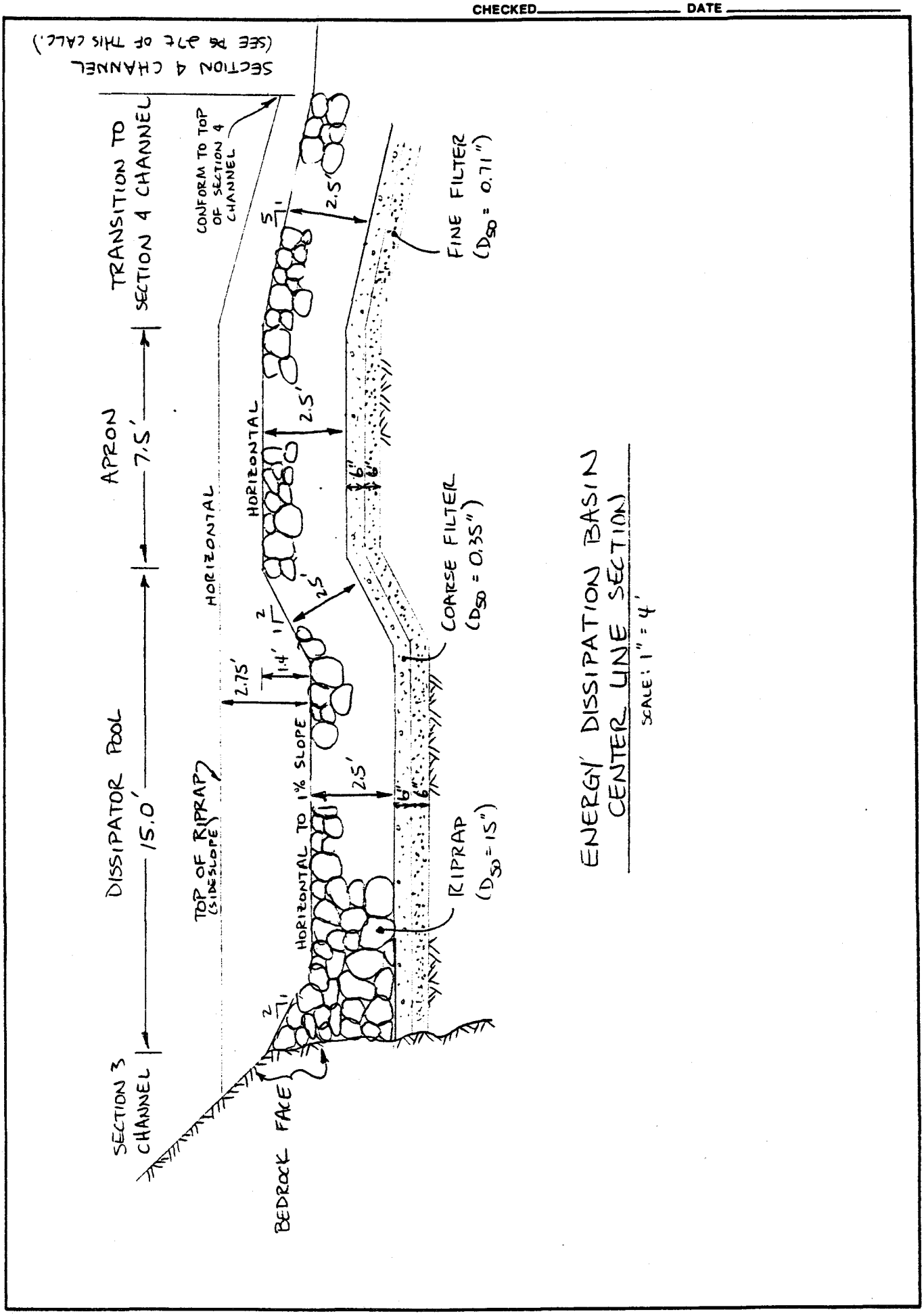


$$\text{FROUDE NUMBER} = \frac{V_{ave}}{\sqrt{(32.2)(Y_e)}} = \frac{10.7}{\sqrt{(32.2)(1.59)}} = 1.50$$ for Section 3 channel

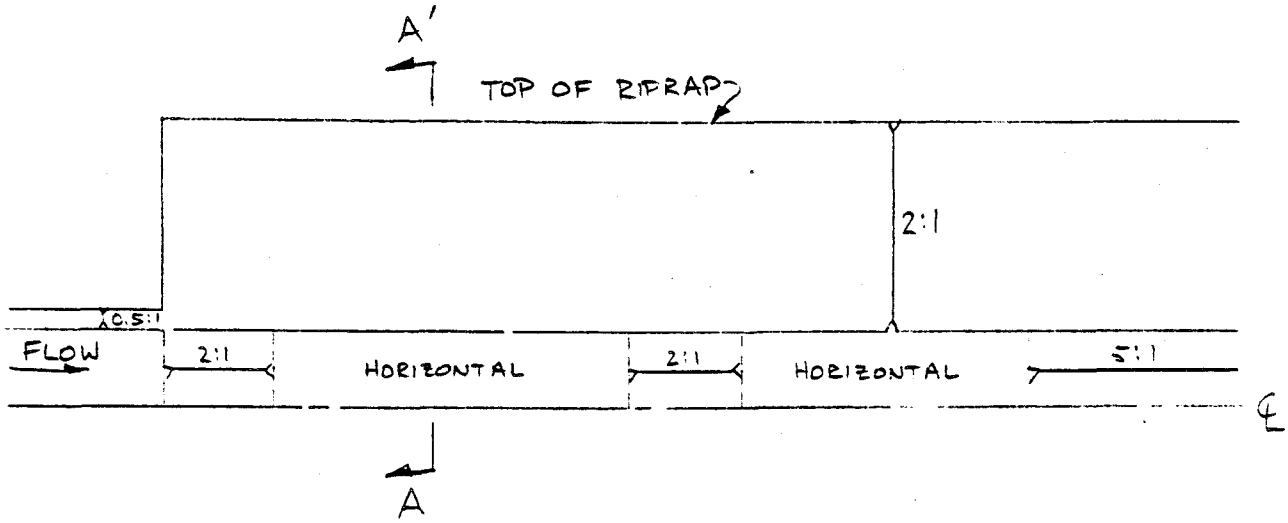
Source: Corry et al. (1975) (HEC-14)

EARTHFAX ENGINEERING, INC.
ENGINEERS / SCIENTISTS

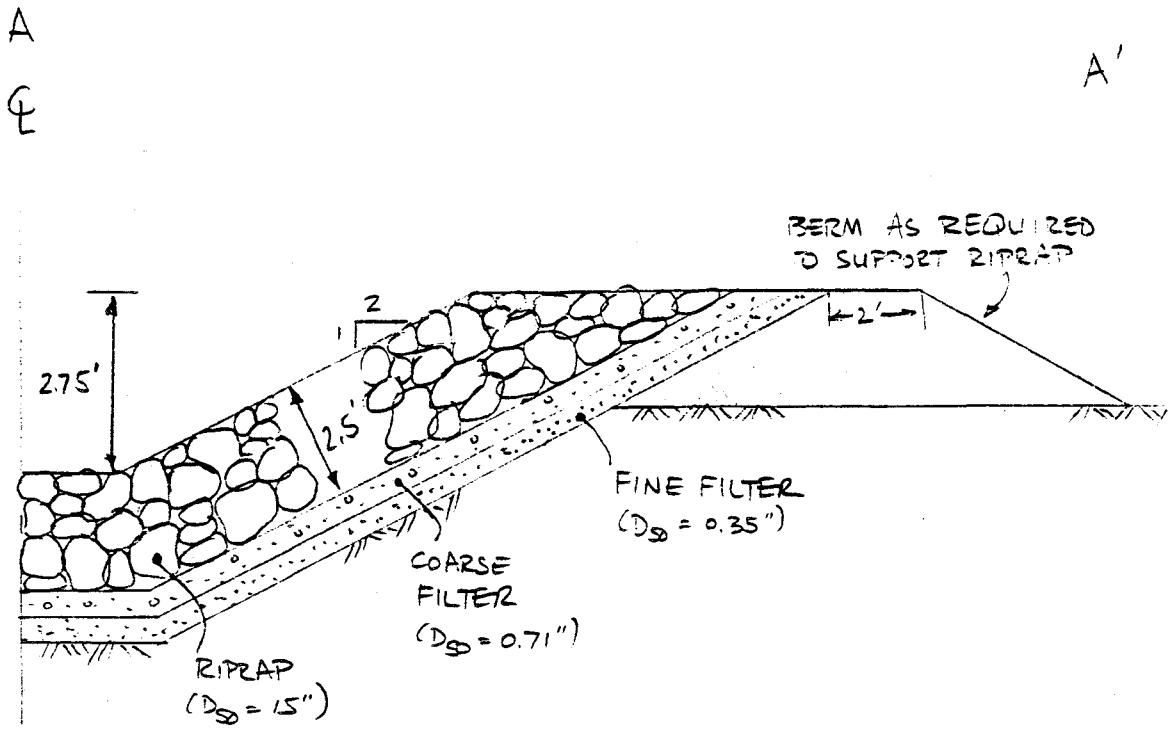
PROJECT C-27 PAGE 27 SS OF
COMPUTED RBW DATE 2 Dec 1987
CHECKED DATE



ENERGY DISSIPATION BASIN
CENTER LINE SECTION
SCALE: 1" = 4'

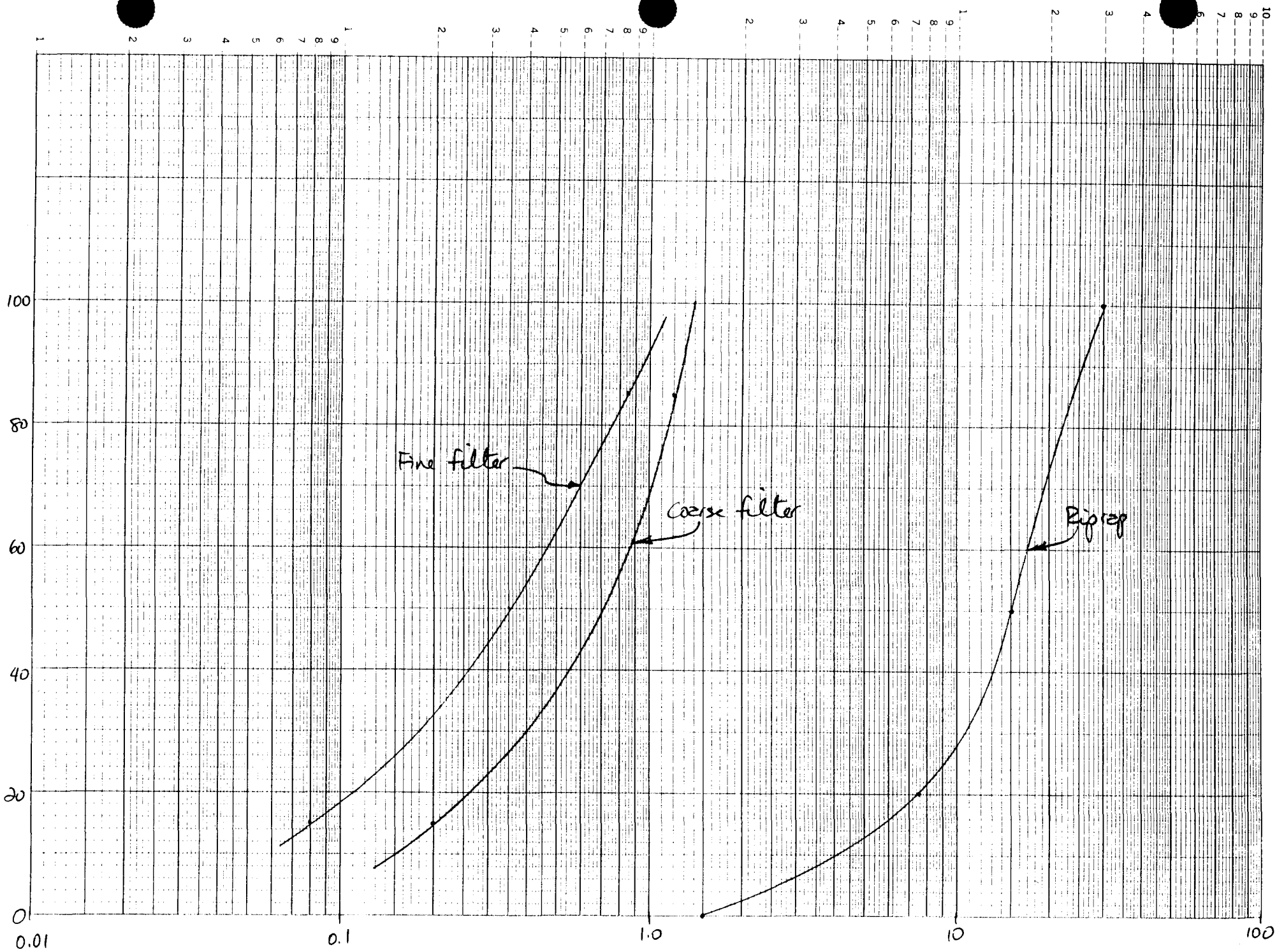


ENERGY DISSIPATION BASIN
HALF PLAN
SCALE: 1" = 50'



ENERGY DISSIPATION BASIN
SECTION A-A'
SCALE: 1" = 4'

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6010



Check filter blanket design using the RD-2 blanket (see pg. 27l of this calc.):

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{5.7\text{ in}}{0.85\text{ in}} = 6.7 > 5.0$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{5.7\text{ in}}{0.08\text{ in}} = 71.2 > 40$$

Unacceptable

New filter blanket design (see pg. 27sr of this calc.):

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{5.7\text{ in}}{1.2\text{ in}} = 4.8 < 5.0 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{5.7\text{ in}}{0.2\text{ in}} = 28.5 < 40 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (bed)}} = \frac{0.2\text{ in}}{0.94\text{ in}} = 0.2 < 5.0 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (filter)}}{D_{15}\text{ (bed)}} = \frac{0.2\text{ in}}{0.0021\text{ in}} = 95.2 > 40 \quad \underline{\underline{\text{Unacceptable}}}$$

Include two filter blankets (the coarse blanket above and the RD-2 blanket). Check design between the two:

$$\frac{D_{15}\text{ (coarse)}}{D_{85}\text{ (fine)}} = \frac{0.2\text{ in}}{0.85\text{ in}} = 0.24 < 5.0 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (coarse)}}{D_{15}\text{ (fine)}} = \frac{0.2\text{ in}}{0.08\text{ in}} = 2.5 < 40 \quad \underline{\underline{OK}}$$

Section 1 → [illegible]

Bed Slope =	.057	
Manning's N =	.031	
Bottom Width =	4	feet
Channel Side Slope =	.5	
Flow Depth =	.3047183	feet
Cross Sectional Area =	1.40458	square feet
Wetted Perimeter =	5.362742	feet
Hydraulic Radius =	.2619145	feet
Discharge =	6.62	cubic feet/sec
Velocity =	4.713154	feet/sec
Froude Number =	1.504646	

Required d_{50} = 0.25 ft
= 3.0 in

n = 0.031 ⇒ OK

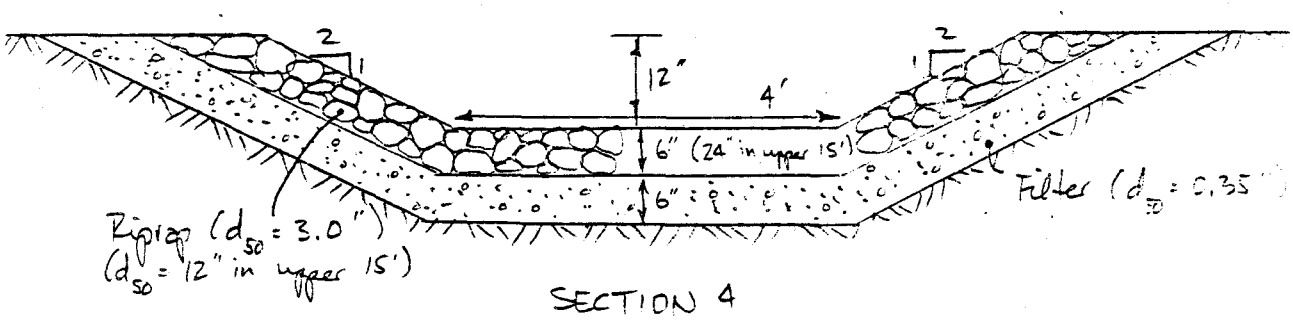
Gradation of Section 4 riprap → see pg. 27u of this calc.

Filter blanket requirement → compare with filter blanket designed for RD-2.

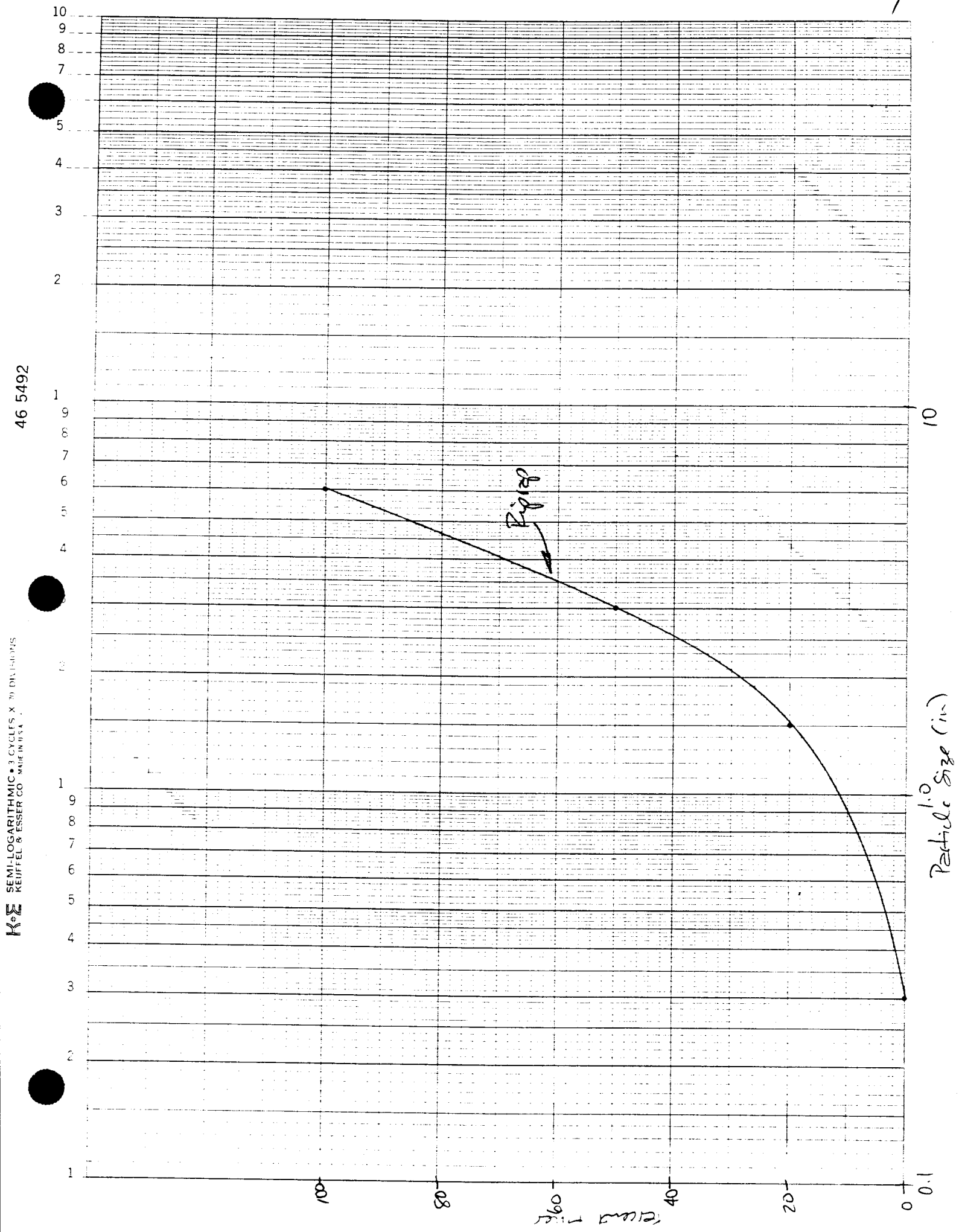
$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{1.25\text{ in}}{0.85\text{ in}} = 1.5 < 5 \qquad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{1.25\text{ in}}{0.08\text{ in}} = 15.6 < 40 \qquad \underline{\underline{OK}}$$

Use the filter blanket designed for RD-2.



SECTION 4
RD-4 ELEV. VIEW
SCALE 1" = 2'


27u/
Riprap
Particle Size (in)
10
1.0
0.1
100
80
60
40
20
0
46 5492
K+E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

Design of RD-5

Contributing area → all areas contributing to RD-2 and RD-4 plus the reclaimed area between RD-3 and RD-5.

Undisturbed area = 6.4 (RD-2) + 8.8 (RD-4) = 15.2 ac

Reclaimed area = 2.5 (RD-2) + 0.2 (RD-4) + 0.3 (site) = 3.0 ac

Total = 18.2 ac = 0.028 mi²

$l = 1730$ ft

$$\overline{CN} = \frac{(15.2)(69) + (3.0)(75)}{18.2} = 70$$

$$S = \frac{1000}{70} - 10 = 4.29$$

$$Y = \left[\frac{(4770\text{ ft})(40\text{ ft})}{(18.2\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 24.1\%$$

$$L = \frac{(1730)^{0.8}(1+4.29)^{0.7}}{(1900)(24.1)^{0.5}} = 0.13\text{ hr}$$

$$T_L = (1.67)(0.13) = 0.22\text{ hr}$$

Design storm → 50-yr, 24-hr = 3.25 in

```
IDENTIFICATION:  WTERSHED DRAINING TO RD-5

INPUT SUMMARY:
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.028 SQ. MI.
        DEPTH =  3.25 IN.              CN = 70.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.22 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =  0.8573 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =     13.69 CFS  ( 0.7576 IN/HR)
     TIME TO PEAK =  12.04 HOURS
     RUNOFF VOLUME CHECK =  0.8590 INCHES
*************************************************************
```

Channel slope = 0.031 ft/ft. Assume n = 0.032

Bed Slope =	.031	
Manning's N =	.032	
Bottom Width =	4	feet
Channel Side Slope =	.5	
Flow Depth =	.561434	feet
Cross Sectional Area =	2.876153	square feet
Wetted Perimeter =	6.51081	feet
Hydraulic Radius =	.4417504	feet
Discharge =	13.69	cubic feet/sec
Velocity =	4.759831	feet/sec
Froude Number =	1.119475	

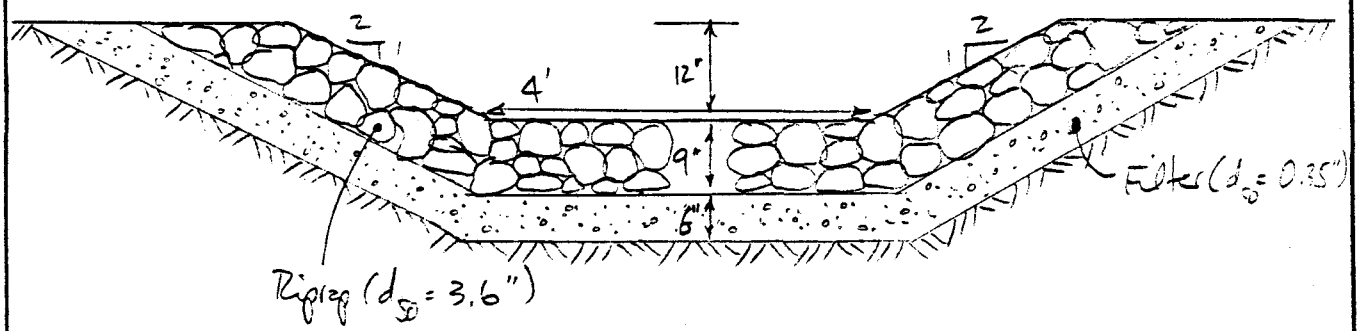
Required d_{50} = 0.30 ft (from pg. 27c)
= 3.6 in

n = 0.032 ⇒ OK See gradation on pg. 27x

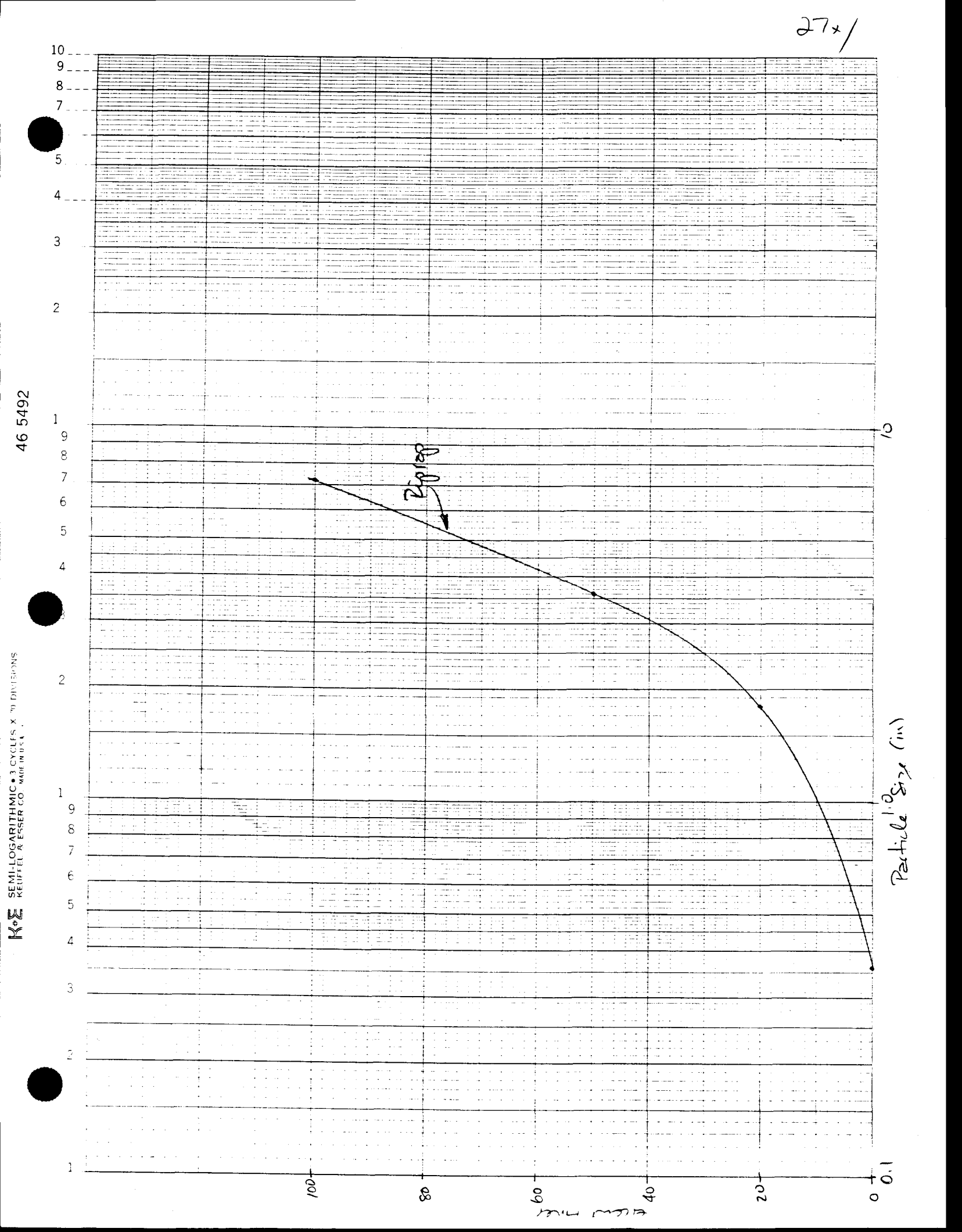
Check RD-2 filter:

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{1.4\text{ in}}{0.85\text{ in}} = 1.6 < 5 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{1.4\text{ in}}{0.08\text{ in}} = 17.5 < 40 \quad \underline{OK}$$



RD-5 ELEV. VIEW
SCALE: 1"=2'


27x/
Riprap
Particle Size (in)
10
1.0
0.1
100
80
60
40
20
0
46 5492
K+E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.