Culvert Calculator Report
6'x4' Box Culvert - FINAL

Solve For: Headwater Elevation

EDGE OF SHOULDER

Culvert Summary

Allowable HW Elevation	6,840.22 ft	Headwater Depth/Height	1.08
Computed Headwater Eleva	6,837.45 ft	Discharge	132.00 cfs
Inlet Control HW Elev.	6,837.11 ft	Tailwater Elevation	6,832.96 ft
Outlet Control HW Elev.	6,837.45 ft	Control Type	Entrance Control

ALLOWABLE ≤1.5

MAX INFLOW @ POWERS (BASIN ULT-AC Φ5)

OUTLET + DEPTH

Grades

FUTURE INV.

Upstream Invert	~~6,833.13~~ ft	Downstream Invert	6,830.60 ft
Length	506.19 ft	Constructed Slope	0.004998 ft/ft

FUTURE LENGTH

Hydraulic Profile

Profile	S2	Depth, Downstream	2.29 ft
Slope Type	Steep	Normal Depth	2.29 ft
Flow Regime	Supercritical	Critical Depth	2.47 ft
Velocity Downstream	9.62 ft/s	Critical Slope	0.004057 ft/ft

Section

Section Shape	Box	Mannings Coefficient	0.013
Section Material	Concrete	Span	6.00 ft
Section Size	6 x 4 ft	Rise	4.00 ft
Number Sections	1		

Outlet Control Properties

Outlet Control HW Elev.	6,837.45 ft	Upstream Velocity Head	1.23 ft
Ke	0.50	Entrance Loss	0.62 ft

Inlet Control Properties

Inlet Control HW Elev.	6,837.11 ft	Flow Control	Unsubmerged
Inlet Type	30 to 75° wingwall flares	Area Full	24.0 ft^2
K	0.02600	HDS 5 Chart	8
M	1.00000	HDS 5 Scale	1
C	0.03470	Equation Form	1
Y	0.86000		

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	Discharge Channel from
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.030	
Slope	005000	ft/ft
Left Side Slope	4.00	H : V
Right Side Slope	4.00	H : V
Bottom Width	7.00	ft
Discharge	175.00	cfs

→ MAX DISCHARGE (BASIN ULT-AC15)

Results		
Depth	2.36	ft
Flow Area	38.7	ft²
Wetted Perim	26.44	ft
Top Width	25.86	ft
Critical Depth	1.90	ft
Critical Slope	0.012528	ft/ft
Velocity	4.52	ft/s
Velocity Head	0.32	ft
Specific Energ	2.67	ft
Froude Numb	0.65	
Flow Type	Subcritical	

DRAFT

Appendix E: Hydraulics - Multiple Drop Structure Design For Elkhorn Basin

EXHIBIT 5.3-1
URS Greiner
CALCULATION COVER SHEET

Client: CDOT - REGION 2 Project Name: POWERS / SH83

Project/Calculation Number: 67000042 500.02

Title: POWERS / SH83 WEIR / DROP STRUCTURE NEAR RAMP E

Total number of pages (including cover sheet): ______

Total number of computer runs: ______

Prepared by: E. DANNY ELSNER Date: 9-26-02

Checked by: W. Alspach Date: 27 Sep 02

Description and Purpose: - DESIGN WEIR / DROP STRUCTURE FOR ELKHORN BASIN NEAR RAMP E (NEED TO DROP AROUND 20' TO BRING DRAINAGE UNDER RAMP E.

Design bases/references/assumptions:
- CDOT DRAINAGE CRITERIA MANUAL
- QA'D RATIONAL CALCS
- HEC-15
- TRI-LOCK INFO
- CONCRETE PIPE HANDBOOK
- ASSUMED INV @ 48" FES UNDER RAMP E

Remarks/conclusions:

Calculation Approved by: ______

Project Manager/Date

Revision No.:	Description of Revision:	Approved by:
1	Change max to 22fps X TYPE Change	X W. Alspach 2 Oct 02

Project Manager/Date

URS

		Page ____	of ____
Job: POWERS / SH83	Project No. 69000042500.02	Sheet 1	of ____
Description: WEIR / DROP STRUCTURE	Computed by SDE	Date 9-25-02	
	Checked by W. Alspach	Date 27 Sep 02	
		Reference	

USING THE INV @ THE 48" FES AS A STARTING POINT
INV = 6866.73

ASSUME 20' UP TO INV OUT. OF PIPE

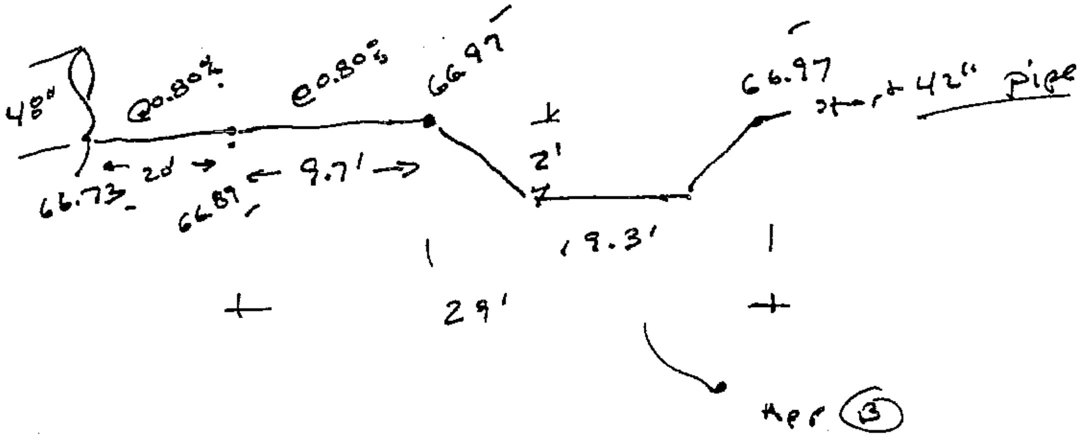
MAX DISCHARGE IN CHANNEL = Q_{100} = 129 cfs
(BASIN ULT-AC04)
USING A 5 fps MAXIMUM GIVES A SLOPE OF
0.80% AND A DEPTH OF 1.82'
APP. (A)

∴ INV OUT OF PIPE = 66.73
+20 (.008)
6866.89 ✓

ASSUMPTION IS USE INTERNAL ENERGY DISSAPATOR TO
LET MAX SLOPE

FORGOT PLUNGE POOL
~~2ND PLUNGE POOL @ 48" RCP~~

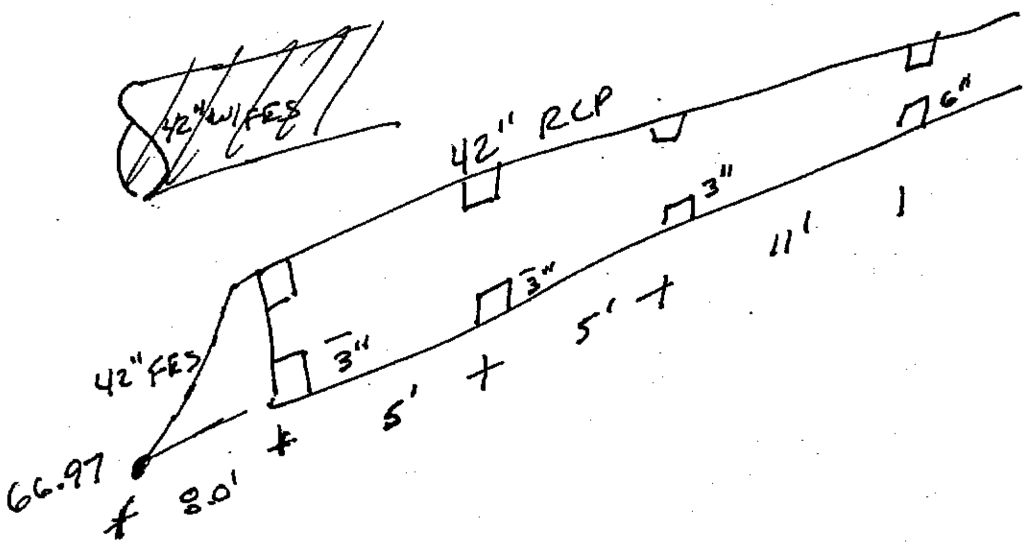
PLUNGE POOL WILL START @ 66.89 (20' AWAY)



* ASSUME ~~MAX SLOPE~~ MIN SIZE PIPE W/ FULL FLOW DISSAPATORS TO MAINTAIN EXIT VELOCITY OF 16 fps.

∴ A 42" PIPE W/ INTERNAL DISSAPTORS

SEE APP. (C)



SLOPE OF 42" RCP WILL BE MAXIMIZED TO GAIN ELEVATION.

TRY 3 DIFF. VELOCITIES

(D)	20 fps ✓	SLOPE = 3.25%
(E)	25 fps ✓	SLOPE = 6.00%
(F)	30 fps ✓	SLOPE = 9.75%

use thickened walls!

NEED TO CHECK THE ADVANTAGE TO WEIGH THE VELOCITY VS. THE GAIN IN ELEVATION.

Note 22 fps is max allowed by CDOT ✓

∴ slope = 4.25% → (K) ✓

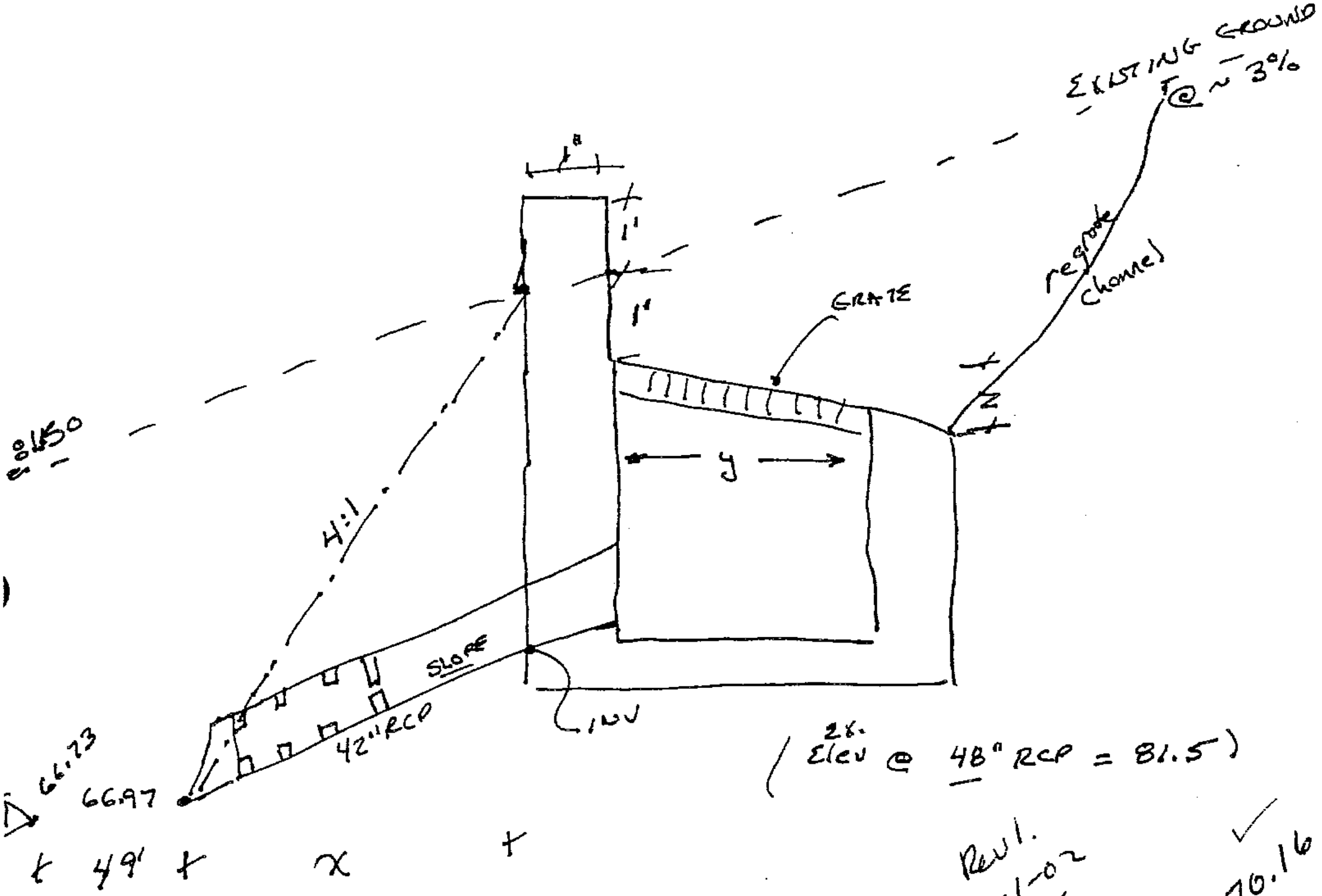
Rev ~~10-1-02~~ 10-1-02 EDE

WA 2 Oct 02

URS

Job POWERS /SH83	Project No. 6900042500.02	Sheet 3 of	Page of
Description WEIR /DROP STRUCTURE	Computed by EDE	Date 9-25-02	
	Checked by W. Alspach	Date 27 Sep 02	

Reference



(Ex. Elev @ 48" RCP = 81.5)

$\therefore 66.97 + x/4 = 81.5 + (49 + x)(.03)$

$.22x = 16$

$x = 72.7 \approx 75'$

Rev 1. 10-1-02 EDE

4.25% ⇒ INV = 70.16

H = 14.84 still ok!

∴ GROUND = 85

3.25% ⇒ INV = 69.41 H = 85 − 69.41 = 15.59'

6.00% ⇒ INV = 71.47 H = 85 − 71.47 = 13.53'

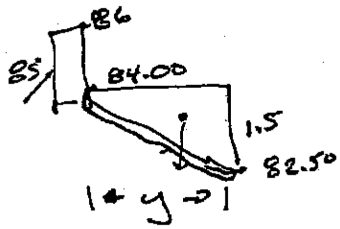
9.75% ⇒ INV = 74.28 H = 85 − 74.28 = 10.72'

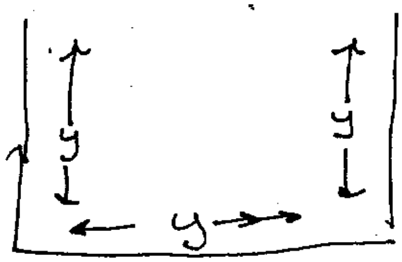
TYPICAL STRUCTURES COME IN 5', 10' & 15' FOR H

USE 6.00% TO MIN. VELOCITY BUT BE IN H = 15'

FOR THE WEIR, ASSUME Z (FROM ORIGINAL DRAWING = 1.5', ALSO ASSUME A ~~BOX~~ SQUARE BOX.

∴ TO CALCULATE y ASSUME MAX DEPTH WILL BE 1.5' above weir @ 82.50' ∴ WS = 82.5+1.5 = ~~83~~ 84.0





∴ weir length = y + 1/3y + 1/3y

(1/3 is using centroid theory)

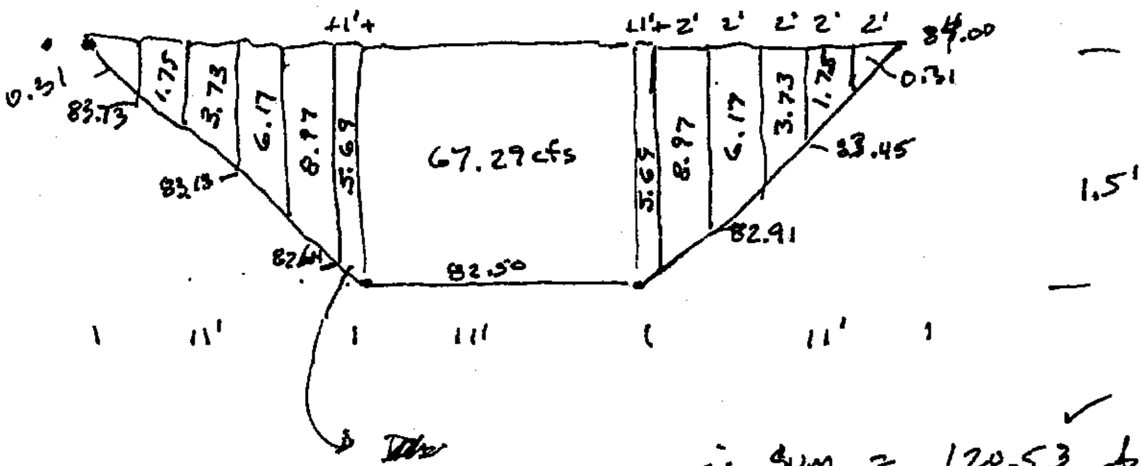
∴ weir length = 5/3y

(G) w = 18.14 = 5/3y   y = 10.8 = 11' ~~≠~~ round

(H) ∴ w = 18.33
gives a depth of 1.49'

QUICK CHECK FOR ASSUMPTION OF CENTROID

*DO IN PIECES

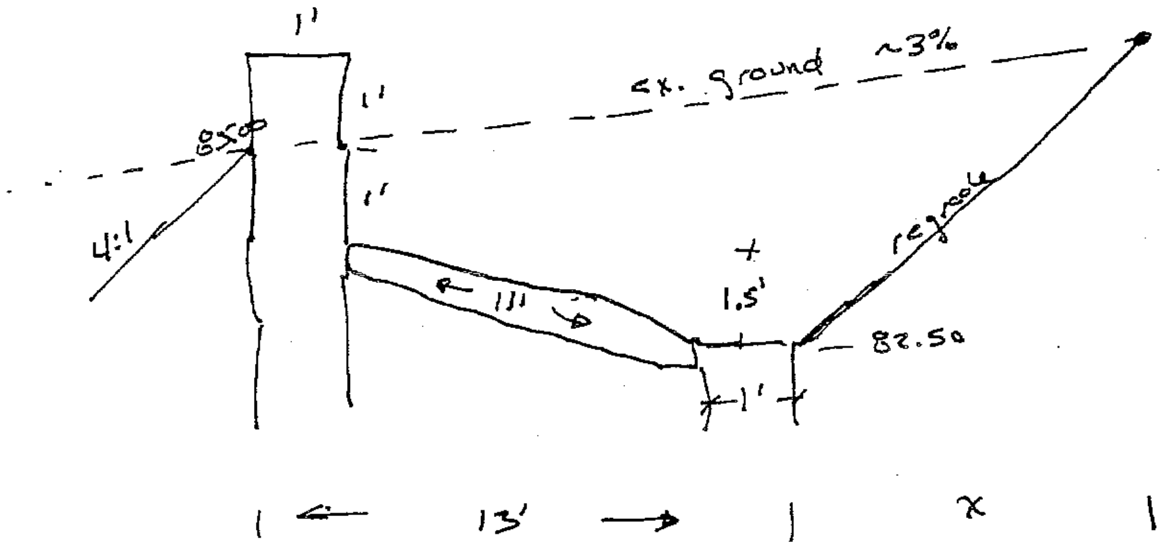


∴ SUM = 120.53 cfs ✓ conservative OK!

URS

Job: POWERS / SH83	Project No. 6700042500.02	Page ___ of ___	Sheet 5 of ___
Description: WEIR / DROP STRUCTURE	Computed by: EDE	Date: 9-25-02	
	Checked by: W. Alspach	Date: 27 Sep 02	

Reference



try some slopes

∴ @ 4%

$85.00 + (13 + x)(.03) = 82.50 + .04x$

$2.89 = .01x$

$x = 289$ ← way too long ✓

try a 10:1 (10% slope)

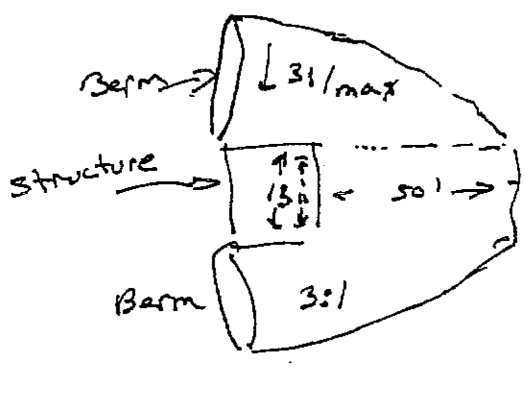
$85.00 + (13 + x)(.03) = 82.50 + .10x$

$2.89 = .07x$

$x = 41.3'$ better

Say = x = 50' at 10:1 ✓

velocities will be high 9. fps (I)
rip rap to be used ✓



TOTAL DISTANCE = 20'
29'
75'
13'
50'
← FROM ...

URS

Job: Powers /5483	Project No. 6700042500.02	Page ___ of ___	
Description: Weir / Drop Structure	Computed by: SDE	Sheet 6 of ___	Date 9-26-01
	Checked by: W. Abpach		Date 27Sep02
		Reference	

TRY CONCRETE BLOCK REVETMENT FOR RIPRAP

CHECK COSTS (ESTIMATED OFF CDOT NUMBERS)

ASSUME 50' × 50' AREA FOR SIMPLICITY = 2500 SF

USING $50 /SQ YD FOR REVETMENT

$$CBR = \frac{2500\ SF}{} \times \frac{1\ SY}{9\ SF} \times \frac{\$50}{SY} = \$13,889$$ ✓

RIPRAP ASSUMING $d_{50} = 12"$ (GUESS)

∴ THICKNESS = 2'

$$2500\ SF \times 2' \times \frac{1\ CY}{27\ SF} \times \frac{\$41}{CY} = \$7,593$$ ✓

TRY $d_{50} = 24"$ (MAX. GUESS)

THICKNESS = 4'

$$2500\ SF \times 4' \times \frac{1\ CY}{27\ CF} \times \frac{\$45}{CY} = \$16,667$$ ✓

QUICK ESTIMATE ON SIZE (FROM CSDCM)

$$\frac{V\ S^{0.17}}{(S_s - 1)^{0.66}} = \frac{(9.07)(.10)^{0.17}}{(2.5-1)^{0.66}} = 4.69$$

TYPE H ($d_{50} = 18"$)

C.B.R. COULD BE COST EQUIV. AS LONG AS IT'S AROUND $50/SQ.YD.

HOWARD WAGNER GAVE AN INST. COST OF $5.00/SF OR $45/SQ.YD. (PURSUE C.B.R.)

URS

				Page ____	of ____
Job	POWERS /SH83	Project No.	6700042 500.02	Sheet 7	of ____
Description	WEIR / DROP STRUCTURE	Computed by	EDE	Date	9-26-02
		Checked by	W. Alspach	Date	27 Sep 02
				Reference	

FROM ~~AE~~ AMERICAN EXCELSIOR COMPANY
PUBLICATION "HYDRAULIC STABILITY OF TRI-LOCK
4010 REVETMENT IN HIGH VELOCITY FLOW"
A MANNINGS N = 0.03 WAS AVERAGED
A VELOCITY OF 10 - 16 fps FOR THE 4" (SMALLEST)
WAS SHOWN TO BE STABLE.

FLOWMASTER SHOWS A VELOCITY OF 10.97 fps.
STABLE. (J)

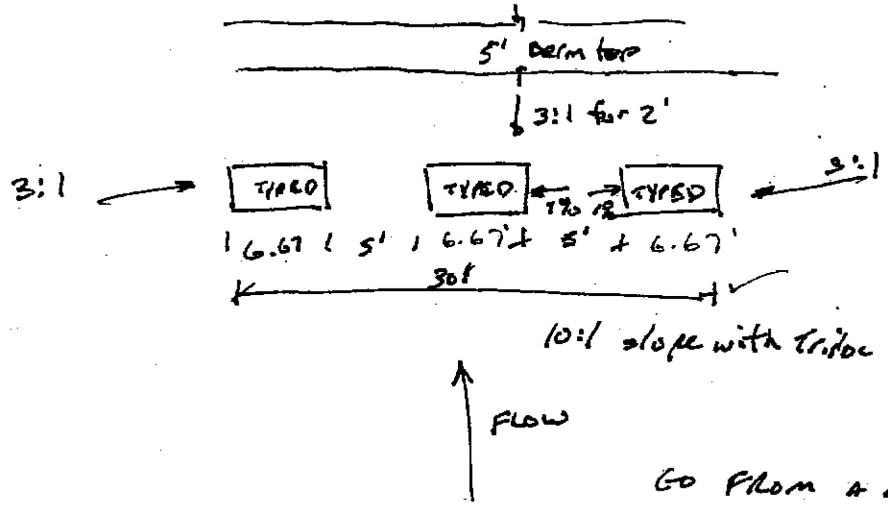
* WILL DESIGN WEIR BOX STRUCTURAL
ON SEPERATE CALCS.

URS

Job: POWERS BOULEVARD	Project No. 6700042500.02	Page ___ of ___	
Description: WEIR DROP STRUCTURE	Computed by EDE	Sheet 8 of ___	Date 10-1-02
	Checked by WHspach		Date 2 OCT 02
REVISION 1			Reference

- TRY TO CHANGE WEIR STRUCTURE TO 3 each TYPE D INLETS

- ASSUMED BASIN ULT-A01 = 111 cfs ✓
- ASSUME MINIMUM THREE TYPE D INLETS
  ∴ 111 / 3 = 37 cfs per INLET ✓
- ASSUME MAX PONDING DEPTH = 1FT

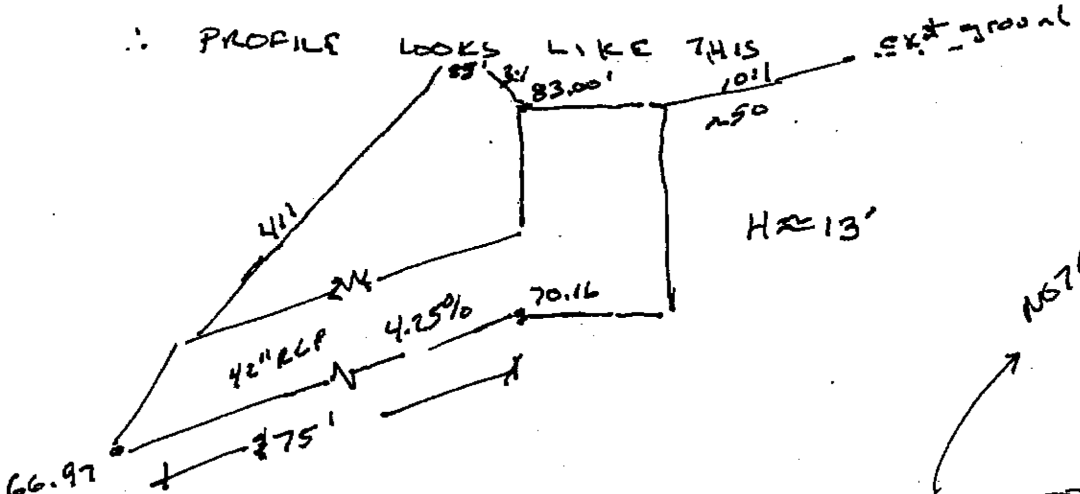


GO FROM A 10' BW TO 30' BW

(ASSUMPTION: 5' SEPERATION WILL GIVE ENOUGH SEPERATION FOR INFLUENCE.

3 TYPE D INLETS WILL GIVE A DEPTH OF 0.84' ✓ OK! (L)

∴ PROFILE LOOKS LIKE THIS



NOTE 10' BW IS WORST CASE SCENARIO.

CHECK TRILOC W/ 10' BW (M)
V=11.64 OK.

Redo with 6:1 due to R.O.W.

URS

Job	POWERS BOULEVARD	Project No. 67000042500.02	Page ___ of ___
Description	WEIR/DROP STRUCTURE	Computed by EDE	Sheet 9 of ___
		Checked by W. Alspach	Date 10-1-02
			Date 2 OCT 02

Reference

PIPES FROM SIDE INLETS WILL HAVE 37 cfs
TRY TO HAVE 18" RCP AT MAX VEL OF 22 fps
TO MINIMIZE CHANGING STRUCTURE.

SLOPE OF 10% GIVES A VELOCITY OF 21.62 fps
OK. (N) ✓

NEED TO SET INV ON SIDE INLETS SO
HEADWATER NEEDED INTO 18" IS BELOW
GRATE SO AS NOT TO INFLUENCE GRATE. ✓

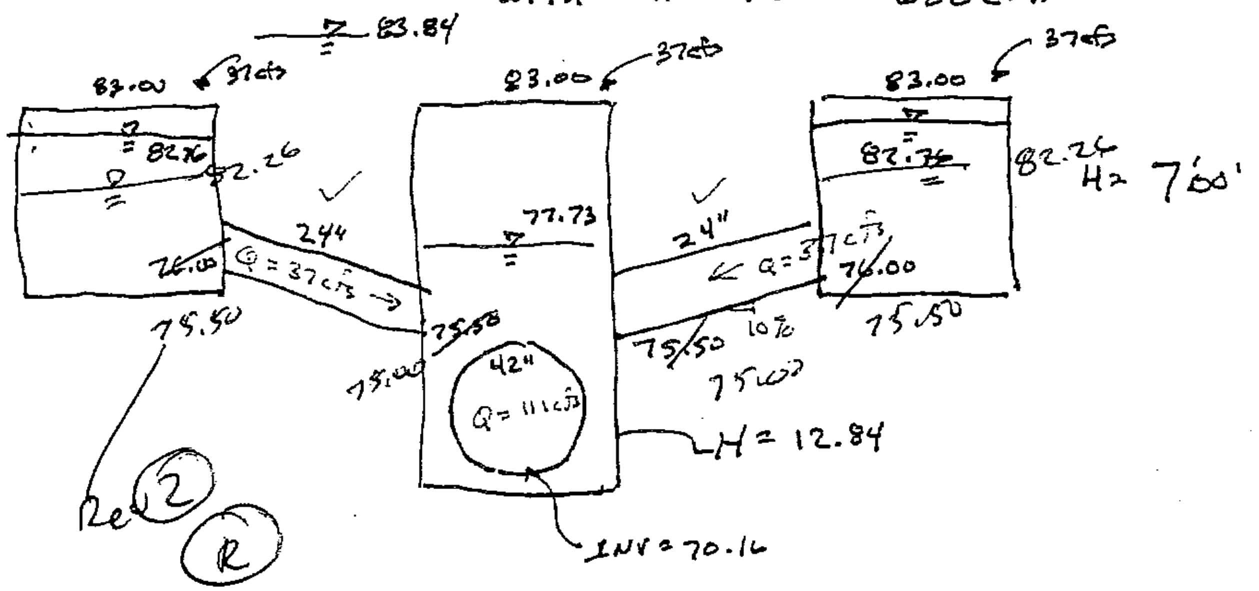
* NOT POSSIBLE (HEADWATER ELEV HIGHER
THAN INLET)! (O)

NEED TO CHECK HEADWATER IN 42" RCP. (P)

HW = 6877.73 ✓

TRY 24" PIPE AS HIGH AS POSSIBLE ✓

GIVES
INV OUT = 6876.00 75.50
INV IN = 6875.50 75.00
WITH A HW = 6882.76 (Q)



(A)

Worksheet
Worksheet for Trapezoidal Channel

Project Description	
Worksheet	Discharge Channel for Weir/Drop
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.030	
Slope	008000	ft/ft
Left Side Slope	4.00	H : V
Right Side Slope	4.00	H : V
Bottom Width	7.00	ft
Discharge	129.00	cfs ✓ ← (BASIN ULT-AC04)

Results		
Depth	1.82	ft ✓
Flow Area	26.0	ft²
Wetted Perim	22.03	ft
Top Width	21.58	ft
Critical Depth	1.62	ft
Critical Slope	0.013076	ft/ft
Velocity	4.95	ft/s ✓ ← LESS THAN 5fps
Velocity Head	0.38	ft
Specific Energ	2.20	ft
Froude Numb	0.79	
Flow Type	Subcritical ✓	

Plunge Pool Design

Weir Drop Plunge Pool — BASIN ULT-A01

111.00 Q (cfs)

21.84 Tailwater (in) — DOWNSTREAM DEPTH

Box Culvert

Height (in)

Width (in)

Circular

42 Diameter (in)

Circular

42.00 Normal Depth (in) — FULL FLOW

4.84	Q/D^(2.5)	Rounded	5.00
0.52	TW/D	Rounded	0.50
0.87	Yo/D		1.00

36.54 Brink Depth (in)

0.60 TW/yo **LOW TAILWATER DEPTH**

1280 Brink Area (sq in)
12.49 Brink Velocity (fps)

25.29 Equivalent Brink Depth (in)
1.52 Froude

Rip Rap Sizing

Type	d50 (in)	dmax (in)	d50/Ye	Hs/Ye	Hs (in)	Hs/d50	2<Hs/d50<4
VL	6	12	0.24	1.24	31.46	5.24	**BAD**
L	9	15	0.36	0.92	23.16	2.57	**OK** ✓
M	12	21	0.47	0.63	15.85	1.32	**BAD**
H	18	30	0.71	N/A	#VALUE!	#VALUE!	**#VALUE!**
VH	24	42	0.95	N/A	#VALUE!	#VALUE!	**#VALUE!**

Rip Rap

Type	d50 (in)	dmax (in)	Hs (in)
L	**9**	**15**	**23.16** — round to ~~2ft~~ 2'

Dissapator Length			**Apron Length**			**Thickness of Approach**			**Thickness of Basin**		
19.30	10*hs (ft)	Max (ft)	9.65	5*hs (ft)	Max (ft)	2.25	3*d50 (ft)	Max (ft)	1.50	2*d50 (ft)	Max (ft)
10.50	3*Wo (ft)	**19.30**	3.50	Wo (ft)	**9.65** (round to 9.7')	2.50	2*dmax (ft)	**2.50**	1.88	1.5*dmax (ft)	**1.88**

(B)

Riprap Quantities

Hs (ft)	1.93	
W (ft)	3.50	
thickness approach (ft)	2.50	
thickness basin (ft)	1.88	
dissapator length (ft)	19.30	
apron length (ft)	9.65	
channel bottom (ft)	7.00	Channel Bottom must be larger than W
tailwater (ft)	1.82	

Areas	(ft^3)	length (ft)	width (ft)	depth (ft)
A	46.19	3.86	4.79	2.50
B	189.22	15.44	6.54	1.88
C	126.65	9.65	7.00	1.88
D	634.56	9.50	13.36	2.50
E	412.50	11.58	9.50	1.88
F	676.78	13.51	13.36	1.88

Total (cy) 77

CONCRETE PIPE HANDBOOK

Published by
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222 West Las Colinas Blvd., Suite 641
Irving, Texas 75039-5423
(972) 506-7216

$31.50 (U.S.)

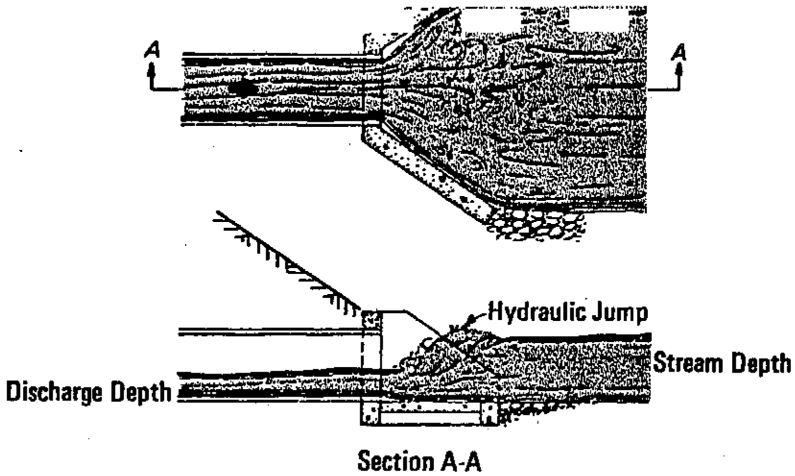


Figure 5.25. Transformation of Kinetic to Potential Energy by Hydraulic Jump and Flow Distribution.

INTERNAL ENERGY DISSIPATORS

Research conducted in the 1960's at Virginia Polytechnic Institute and State University, **VPI**, on the use of roughness elements in open channels established that excess energy in storm water flowing down steep drainage channels could be dissipated by constructing roughness elements within the channel. Since culverts operating under inlet control simulate open channel flow, application of this type of internal energy dissipation to culverts would result in more efficient utilization of the culvert barrel and reduced outlet velocities.

In 1969, the American Concrete Pipe Association contracted with VPI to investigate and determine the feasibility and applicable design procedures for using roughness elements as energy dissipators of **free surface flow** in circular concrete pipe culverts, and the results were published in 1971.

Research was based on free surface flow, therefore, full capacity of the pipe was not realized. This necessitated an increase in pipe size within the length of the culvert in which the roughness elements were placed. Based on the laboratory and field observations during this initial research, subsequent tests were conducted for **full flow** conditions occurring near the outlet end at maximum design discharge. By eliminating the criteria of free surface flow and allowing the culvert to approach full flow, it was found velocity reduction could be effected without an increase in pipe size. The results of this later research and design procedures were published in 1972.

[illegible] high velocities associated with culverts on what are considered steep slopes, the culverts were operating under inlet control. Accordingly, the flow characteristics were observed to be one of critical flow at the entrance of the pipe with the flow accelerating down the length of the pipe until the first ring, or roughness element, was reached. At that point a hydraulic jump was formed, with extreme turbulence. The flow then encountered another roughness element while still in an agitated condition from the first and this pattern of action was repeated until a cyclic condition was reached, where the flow conditions over the roughness elements were uniform. Generally, this cyclic action was attained after the second or third element. An early conclusion was that a maximum of five rings were necessary to achieve consistent results. The agitated flow is called tumbling flow and is characterized by a greater depth over the element than before it, a fall into a valley between the elements, and a form resembling a hydraulic jump shortly before the next element. When one cycle is completed, the flow tumbles into the next cycle until the outlet is reached. Tumbling flow can only be established and maintained under less than full flow conditions, *Figure 5.26*.

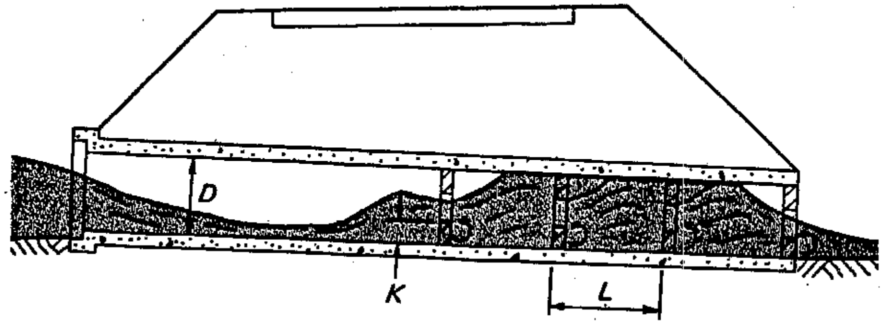


Figure 5.26. Internal Energy Dissipators with Tumbling Flow.

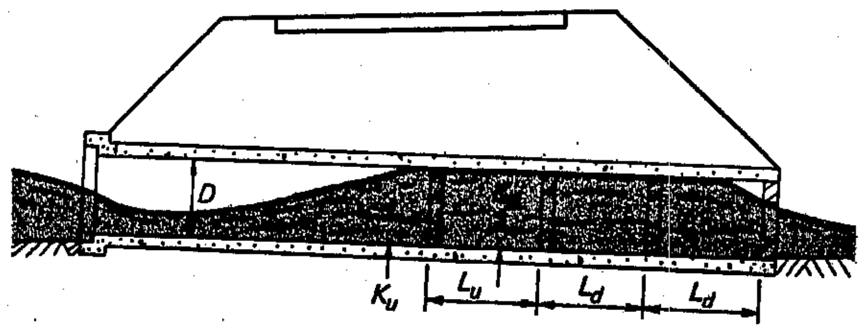


Figure 5.27. Internal Energy Dissipators with Full Flow.

During the VPI research on open channel flow, it was observed that if one large dissipator element was placed upstream a large hydraulic jump was created and maintained by smaller downstream elements. ACPA research validated this observation for pipe flow at maximum design discharges and concluded that three small rings preceded by one large ring at twice the small ring spacing would maintain full flow at slopes greater than 4 percent, *Figure 5.27*.

DESIGN PROCEDURES AND CRITERIA

Based on the test results, the following design procedures and criteria for full flow and free surface flow are presented.

Full Flow

1. Select required pipe size in accordance with the appropriate design procedures presented in *Chapter 3*.
2. Determine outlet velocity per *Chapter 3*.
3. Select a ring height for the three downstream elements within a range determined by:

$$0.06 \leq \frac{K_d}{D} \leq 0.09 \quad (5.21)$$

Where: K_d = ring height of the downstream elements, inches
D = pipe diameter, inches

4. Select a ring height for the single upstream element within the range determined by:

$$0.12 \leq \frac{K_u}{D} \leq 0.18 \quad (5.22)$$

Where: K_u = ring height of the single upstream element, inches

5. Select a spacing for the three downstream elements as determined by:

$$L_d \approx \frac{1.5D}{12} \quad (5.23)$$

Where: L_d = Spacing of the downstream elements, feet

6. Select a spacing for the single upstream element as determined by:

$$L_u \approx \frac{3.0D}{12} \quad (5.24)$$

Where: L_u = spacing of the single upstream element, feet

7. Determine the hydraulic cross-sectional area in square feet at the last downstream element.
8. Determine the outlet velocity by dividing the design discharge by the cross-sectional area of flow determined previously.

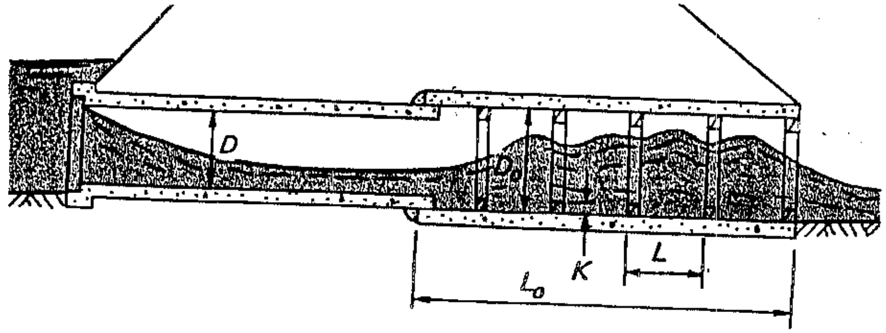


Figure 5.28. Internal Energy Dissipators with Free Surface Flow.

Free Surface Flow

If full flow design reduces outlet velocity to an acceptable level, free surface flow design, *Figure 5.28*, is not required. However, if the outlet velocity is not acceptable, continue with free surface flow design as follows:

1. Select an outlet pipe diameter within the range determined by:

$$\left[\frac{Q^2}{3.22}\right]^{1/5} \leq D_0 \leq \left[\frac{Q^2}{1.42}\right]^{1/5} \quad (5.25)$$

Where: D_0 = outlet pipe diameter, feet
Q = design flow, cubic feet per second

2. Select a ring height for the elements within the range determined by:

$$1.2 \leq \frac{K}{D_0} \leq 1.8 \quad (5.26)$$

Where: K = ring height of the elements, inches

3. Select a ring spacing for the five elements within the range determined by:

$$1.5 \leq \frac{L}{D_0} \leq 2.5 \quad (5.27)$$

Where: L = spacing of the elements, feet

4. Determine the approximate length of the outlet pipe by:

$$L_0 \approx 5L \quad (5.28)$$

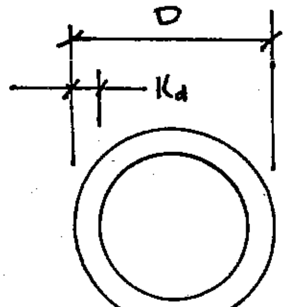
Where: L_0 = length of the outlet pipe, feet

5. Determine hydraulic cross-sectional area at last dissipator ring based upon critical depth as presented in *Chapter 3*.
6. Determine the outlet velocity by dividing the design discharge by the cross-sectional area of flow determined in the previous step.

Internal Energy Dissipators

Weir Drop Structure

Checked WA 27Sep02



Equations taken from the ACPA Concrete Pipe Handbook Chapter 5, 1998.
Note: There is two types of Tumbling Flow (Full Flow and Free Surface Flow)
Full Flow should be checked first, then Free Surface Flow

Q (cfs)	111	Design flow ← BASIN ULT-AQ1	
D (in)	42	Diameter of outlet pipe	

Full Flow

Min Kd (in)	2.52	Minimum ring height of the downstream elements	0.06*D ✓
Max Kd (in)	3.78	Maximum ring height of the downstream elements	0.09*D ✓
Kd (in)	3	Chosen Kd between min and max	0.06<Kd/D<0.09
	OK		
Min Ku (in)	5.04	Minimum ring height of the single upstream element	0.12*D
Max Ku (in)	7.56	Maximum ring height of the single upstream element	0.18*D
Ku (in)	6	Chosen Ku between min and max	0.12<Ku/D<0.18
	OK		
Ld (ft)	5	Spacing of the downstream elements ✓	1.5*D/12 (rounded) ✓
Lu (ft)	11	Spacing of the single upstream element ✓	3.0*D/12 (rounded) ✓
Area (ft^2)	7.07	Hydraulic cross-sectional area at last ring	pi*((D-2*Kd)/12)^2)/4
V (fps)	**15.7**	**Outlet velocity**	Q/A

less than 16 fps

Free Surface Flow (NOT USED)

Min Do (ft)	5.21	Minimum outlet pipe diameter	((Q^2)/3.22)^(1/5)
Max Do (ft)	6.13	Maximum outlet pipe diameter	((Q^2)/1.42)^(1/5)
Do (ft)	5.5	Chosen Do between min and max	((Q^2)/3.22)^(1/5)<Do<((Q^2)/1.42)^(1/5)
	OK		
M:in K (in)	6.6	Minimum ring height of elements	1.2*Do
Max K (in)	9.9	Maximum ring height of elements	1.8*Do
K (in)	8	Chosen K between min and max	1.2<K/Do<1.8
	OK		
Min L (ft)	8.25	Minimum spacing of the elements	1.5*Do
Max L (ft)	13.75	Maximum spacing of the elements	2.5*Do
L (ft)	10	Chosen L between min and max	1.5<L/Do<2.5
	OK		
Lo (ft)	50	Length of the outlet pipe	5*L

Using Flowmaster find critical depth, area at critical depth, and velocity at critical depth

Diameter (in)	50.00	
Q (cfs)	111	
dc (ft)	3.16	Critical Depth from Flowmaster
Area (ft^2)	11.1	Area at Critical Depth from Flowmaster
V (fps)	**10**	**Velocity at Critical Depth from Flowmaster**

Worksheet
Worksheet for Circular Channel

D

Project Description	
Worksheet	42" RCP for Weir
Flow Element	Circular Channel
Method	Manning's Formul
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.013	
Slope	032500	ft/ft
Diameter	42	in
Discharge	111.00	cfs

← BASIN ULT-A01

Results		
Depth	1.98	ft
Flow Area	5.6	ft²
Wetted Perime	5.96	ft
Top Width	3.47	ft
Critical Depth	3.18	ft
Percent Full	56.5	%
Critical Slope	0.010644	ft/ft
Velocity	19.79	ft/s
Velocity Head	6.09	ft
Specific Energ;	8.07	ft
Froude Numbe	2.75	
Maximum Disc	195.10	cfs
Discharge Full	181.37	cfs
Slope Full	0.012173	ft/ft
Flow Type	Supercritical	

← 20 fps max

(51)

Worksheet
Worksheet for Circular Channel

Project Description	
Worksheet	42" RCP for Weir Drop
Flow Element	Circular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.013	
Slope	060000	ft/ft ✓
Diameter	42	in
Discharge	111.00	cfs ← BASIN ULT-A01

Results		
Depth	1.65	ft
Flow Area	4.4	ft²
Wetted Perime	5.29	ft
Top Width	3.49	ft
Critical Depth	3.18	ft
Percent Full	47.1	%
Critical Slope	0.010644	ft/ft
Velocity	24.94	ft/s ✓ ← 25 fps max
Velocity Head	9.67	ft
Specific Energ	11.32	ft
Froude Numbe	3.90	
Maximum Disc	265.09	cfs
Discharge Full	246.43	cfs
Slope Full	0.012173	ft/ft
Flow Type	Supercritical	

Worksheet
Worksheet for Circular Channel

(F)

Project Description	
Worksheet	42" RCP for Weir Drop
Flow Element	Circular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.013	
Slope	097500	ft/ft ✓
Diameter	42	in
Discharge	111.00	cfs ← Basin ULT-AØ1

Results		
Depth	1.44	ft
Flow Area	3.7	ft²
Wetted Perime	4.87	ft
Top Width	3.44	ft
Critical Depth	3.18	ft
Percent Full	41.1	%
Critical Slope	0.010644	ft/ft
Velocity	29.83	ft/s ✓ ← 30 fps max
Velocity Head	13.83	ft
Specific Energ;	15.27	ft
Froude Numbe	5.06	
Maximum Disc	337.92	cfs
Discharge Full	314.14	cfs
Slope Full	0.012173	ft/ft
Flow Type	;upercritical	

Worksheet
Worksheet for Sharp Crested Rectangular Weir

(G)

Project Description	
Worksheet	Weir Drop w/ 1.5' Depth
Type	Sharp Crested Rectangul
Solve For	Crest Length

Input Data			
Discharge	111.00	cfs	← BASIN ULT-A01 ✓
Headwater Elevati	,884.00	ft	✓
Crest Elevation	,882.50	ft	✓ ← 1.5' DEPTH
Tailwater Elevation	,874.97	ft	
Discharge Coeffici	3.33	US	
Number of Contrac	0		

Results			
Crest Length	18.14	ft	← WEIR LENGTH NEEDED ✓
Headwater Height Abov	1.50	ft	
Tailwater Height Above	-7.53	ft	
Flow Area	27.2	ft²	
Velocity	4.08	ft/s	
Wetted Perimeter	21.14	ft	
Top Width	18.14	ft	

Worksheet
Worksheet for Sharp Crested Rectangular Weir

(H)

Project Description	
Worksheet	Weir Drop w/ 1.5' Depth
Type	Sharp Crested Rectangul
Solve For	Headwater Elevation

Input Data			
Discharge	111.00	cfs	← BASIN U27-A01
Crest Elevation	,882.50	ft	
Tailwater Elevation	,874.97	ft	
Discharge Coefficic	3.33	US	
Crest Length	18.33	ft	← 4=11'
Number of Contrac	0		

Results			
Headwater Elevation	,883.99	ft	← 1.49' DEPTH
Headwater Height Abov	1.49	ft	
Tailwater Height Above	-7.53	ft	
Flow Area	27.3	ft²	
Velocity	4.06	ft/s	
Wetted Perimeter	21.31	ft	
Top Width	18.33	ft	

Worksheet
Worksheet for Trapezoidal Channel

(1)

Project Description	
Worksheet	Channel into We
Flow Element	Trapezoidal Cha
Method	Manning's Formι
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.040	← RIPRAP
Slope	100000 ft/ft	← 10:1 DROP
Left Side Slope	3.00 H : V	
Right Side Slope	3.00 H : V	← WEIR OF 11' + 1' WALL ON EITHER SIDE
Bottom Width	13.00 ft	
Discharge	111.00 cfs	← BASIN ULT-A Q1

Results	
Depth	0.80 ft
Flow Area	12.2 ft²
Wetted Perimι	18.03 ft
Top Width	17.77 ft
Critical Depth	1.19 ft
Critical Slope	0.024070 ft/ft
Velocity	9.07 ft/s ✓
Velocity Head	1.28 ft
Specific Energ	2.07 ft
Froude Numbι	1.93
Flow Type	Supercritical

Worksheet
Worksheet for Trapezoidal Channel

(J)

Project Description	
Worksheet	Channel into Weir (tri-lo
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

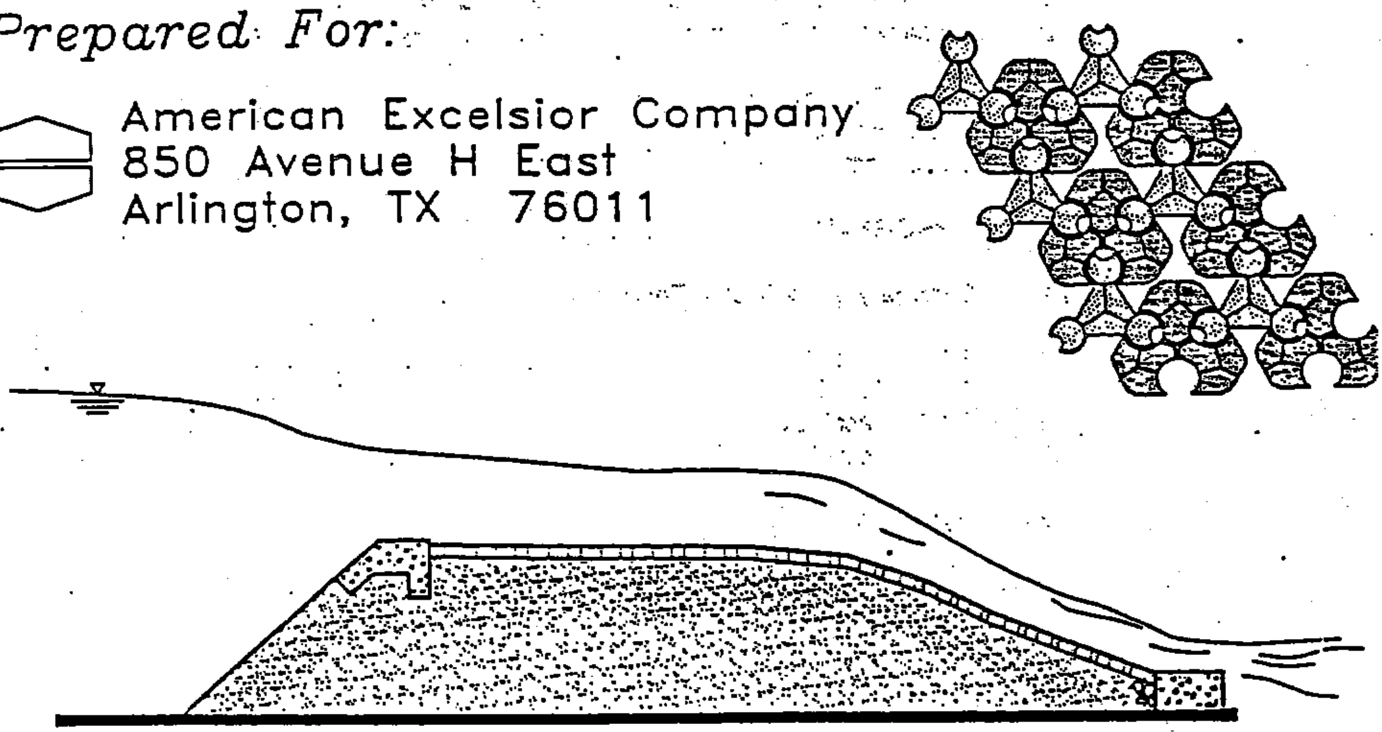
Input Data			
Mannings Coeffic	0.030		← TRI-LOCK ✓
Slope	100000	ft/ft	← 10:1 DROP ✓
Left Side Slope	3.00	H : V	
Right Side Slope	3.00	H : V	
Bottom Width	13.00	ft	← WEIR 11' +1' WALL ON EITHER SIDE ✓
Discharge	111.00	cfs	← BASIN ULT-A01

Results			
Depth	0.67	ft	
Flow Area	10.1	ft²	
Wetted Perim	17.26	ft	
Top Width	17.04	ft	
Critical Depth	1.19	ft	
Critical Slope	0.013540	ft/ft	
Velocity	10.97	ft/s	← BETWEEN 10 fps AND 16 fps (4" TRI-LOCK OK) ✓
Velocity Head	1.87	ft	
Specific Energ	2.54	ft	
Froude Numb	2.51		
Flow Type	Supercritical		

HYDRAULIC STABILITY OF TRI-LOCK 4010 REVETMENT IN HIGH VELOCITY FLOW

Prepared For:

American Excelsior Company
850 Avenue H East
Arlington, TX 76011



Prepared By:

Resource Consultants & Engineers, Inc.
3665 JFK Parkway
Bldg. 2, Suite 300
Fort Collins, CO 80525

Project Number 92-857
February 1993

RCE RESOURCE CONSULTANTS & ENGINEERS, INC
A KLH Engineering Group Company

Table 3.2. Summary of Key Hydraulic Parameters.

Test Number	Embankment Slope (ft/ft)	Typical Depth (ft)	Maximum Velocity (ft/s)	Maximum Energy Slope S_f (ft/ft)	Maximum Shear Stress τ_o (lb/ft^2)	Manning's n Values		Comments
						Crest	Slope	
TL-1A	0.20	0.35	9.7	0.20	4.8	0.026	0.035	Stable
TL-2A	0.20	0.61	15.0	0.20	7.6	0.026	0.035	At stability threshold
TL-3A	0.20	1.01	15.8	0.115	7.4	0.028	0.032	At stability threshold
TL-1B	0.50	0.26	11.6	0.50	8.1	0.026	0.038	Failed

4. SELECTION OF TRI-LOCK BLOCK

The selection of the proper Tri-Lock System, 4", 6", or 8" is affected by site or project conditions such as soil permeability, flow or wave intensity, soil compaction and slope or grade conditions.

Generally acceptable guidelines are:

4010 (Nominal 4" Tri-Lock)
Flow - 10-16 fps
Wave - 4' Height

4015 (Nominal 6" Tri-Lock)
Flow - 16-20 fps
Wave - 7' Height

4020 (Nominal 8" Tri-Lock)
Contact American Excelsior Specialist

Worksheet
Worksheet for Circular Channel

(K)

Project Description	
Worksheet	42" RCP for Weir Drop
Flow Element	Circular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.013	
Slope	042500	ft/ft
Diameter	42	in
Discharge	111.00	cfs

Results		
Depth	1.82	ft
Flow Area	5.1	ft²
Wetted Perime	5.64	ft
Top Width	3.50	ft
Critical Depth	3.18	ft
Percent Full	52.1	%
Critical Slope	0.010644	ft/ft
Velocity	21.92	ft/s
Velocity Head	7.47	ft
Specific Energ;	9.29	ft
Froude Numbe	3.21	
Maximum Disc	223.10	cfs
Discharge Full	207.40	cfs
Slope Full	0.012173	ft/ft
Flow Type	Supercritical	

Worksheet
Worksheet for Ditch Inlet In Sag

(L)

Project Description	
Worksheet	Type D Inlets at W
Type	Ditch Inlet In Sag
Solve For	Spread

Input Data		
Discharge	37.00	cfs
Left Side Slope	3.00	H : V
Right Side Slope	1,000.00	H : V
Bottom Width	4.00	ft
Grate Width	3.42	ft
Grate Length	5.67	ft
Local Depression	0.0	in
Local Depression \	0.00	ft
Grate Type	ɔ mm (P-1-7/8")	
Clogging	30.0	%

← 111 cfs / 3 inlets (BASIN ULT-AP1 ✓

← ESTIMATE FOR FLAT BOTTOM ON ONE SIDE ✓

"flat" 1' / 1000'

Results		
Spread	142.75	ft
Depth	0.84	ft
Wetted Perimeter	142.89	ft
Top Width	142.75	ft
Open Grate Area	12.2	ft²
Active Grate Weir Le	16.13	ft

← PONDING DEPTH

Worksheet
Worksheet for Trapezoidal Channel

(M)

Project Description	
Worksheet	Channel into Weir (tri-lo
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data			
Mannings Coeffic	0.030		
Slope	100000	ft/ft	← 10%
Left Side Slope	3.00	H : V	
Right Side Slope	3.00	H : V	
Bottom Width	10.00	ft	← 10' B.W.
Discharge	111.00	cfs	← BASIN ULT-A01

Results			
Depth	0.77	ft	
Flow Area	9.5	ft²	
Wetted Perim	14.90	ft	
Top Width	14.64	ft	
Critical Depth	1.36	ft	
Critical Slope	0.013314	ft/ft	
Velocity	11.64	ft/s	← LESS THAN 16 fps
Velocity Head	2.10	ft	
Specific Energ	2.88	ft	
Froude Numb	2.54		
Flow Type	Supercritical		

Worksheet
Worksheet for Circular Channel

(N)

Project Description	
Worksheet	Side Pipes for Type D Inlets a ✓
Flow Element	Circular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data			
Mannings Coeffic	0.013		✓
Slope	100000	ft/ft	← 10% ✓
Diameter	18	in	← MIN SIZE ✓
Discharge	37.00	cfs	← 111 cfs / 3 ✓

Results			
Depth	1.34	ft	
Flow Area	1.7	ft²	
Wetted Perime	3.70	ft	
Top Width	1.02	ft	
Critical Depth	1.53	ft	
Percent Full	87.2	%	
Critical Slope	0.105437	ft/ft	
Velocity	21.62	ft/s	← LESS THAN 22fps ✓
Velocity Head	7.26	ft	
Specific Energ	8.60	ft	
Froude Numbe	2.95		
Maximum Disc	37.95	cfs	
Discharge Full	35.28	cfs	
Slope Full	0.110000	ft/ft	
Flow Type	Supercritical		

(6)

Culvert Calculator Report
18" RCP between Type D inlets at weir

Solve For: Headwater Elevation

INLET RIM

Culvert Summary

Allowable HW Elevation	83.00 ft	Headwater Depth/Height	12.25
Computed Headwater Eleva	89.38 ft	Discharge	37.00 cfs
Inlet Control HW Elev.	89.38 ft	Tailwater Elevation	75.00 ft
Outlet Control HW Elev.	85.84 ft	Control Type	Inlet Control

111 cfs/3 ✓

I GUESS

OUTSIDE INLET! ✓

LOWEST POSSIBLE

Grades

Upstream Invert	71.00 ft	Downstream Invert	70.50 ft
Length	5.00 ft	Constructed Slope	0.100000 ft/ft

Hydraulic Profile

Profile	PressureProfile	Depth, Downstream	4.50 ft
Slope Type	N/A	Normal Depth	N/A ft
Flow Regime	N/A	Critical Depth	1.50 ft
Velocity Downstream	20.94 ft/s	Critical Slope	0.119703 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.50 ft
Section Size	18 inch	Rise	1.50 ft
Number Sections	1		

Outlet Control Properties

Outlet Control HW Elev.	85.84 ft	Upstream Velocity Head	6.81 ft
Ke	0.50	Entrance Loss	3.41 ft

Inlet Control Properties

Inlet Control HW Elev.	89.38 ft	Flow Control	Submerged
Inlet Type	Square edge w/headwall	Area Full	1.8 ft²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

P

Culvert Calculator Report
42" RCP for weir

Solve For: Headwater Elevation

Culvert Summary

INLET RIM

Allowable HW Elevation	6,883.00 ft	Headwater Depth/Height	2.16
Computed Headwater Eleva	6,877.73 ft	Discharge	111.00 cfs ← BASIN ULT-A01
Inlet Control HW Elev.	6,877.73 ft	Tailwater Elevation	6,868.79 ft
Outlet Control HW Elev.	6,876.75 ft	Control Type	Inlet Control

CALC HEADWATER

Grades

Upstream Invert	6,870.16 ft (ACTUAL)	Downstream Invert	6,866.97 ft (ACTUAL)
Length	75.00 ft	Constructed Slope	0.042533 ft/ft

Hydraulic Profile

Profile	S2	Depth, Downstream	2.14 ft
Slope Type	Steep	Normal Depth	1.82 ft
Flow Regime	Supercritical	Critical Depth	3.18 ft
Velocity Downstream	18.05 ft/s	Critical Slope	0.010644 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	3.50 ft
Section Size	42 inch	Rise	3.50 ft
Number Sections	1		

Outlet Control Properties

Outlet Control HW Elev.	6,876.75 ft	Upstream Velocity Head	2.27 ft
Ke	0.50	Entrance Loss	1.14 ft

Inlet Control Properties

Inlet Control HW Elev.	6,877.73 ft	Flow Control	Submerged
Inlet Type	Square edge w/headwall	Area Full	9.6 ft²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
24" RCP between Type D inlets at weir - trial

Solve For: Headwater Elevation

RIM ELEV

Culvert Summary

Allowable HW Elevation	6,883.00 ft	Headwater Depth/Height	3.38
Computed Headwater Eleva	6,882.76 ft	Discharge	37.00 cfs
Inlet Control HW Elev.	6,882.76 ft	Tailwater Elevation	6,877.73 ft
Outlet Control HW Elev.	6,881.23 ft	Control Type	Inlet Control

= 111 cfs / 3 inlets

COMP. HW OF MAIN INLET

BELOW RIM ELEV.

Grades

Upstream Invert	6,876.00 ft ✓	Downstream Invert	6,875.50 ft ✓
Length	5.00 ft	Constructed Slope	0.100000 ft/ft

Hydraulic Profile

Profile	CompositePressureProfileS1S2	Depth, Downstream	1.61 ft
Slope Type	N/A	Normal Depth	1.02 ft
Flow Regime	N/A	Critical Depth	1.94 ft
Velocity Downstream	13.66 ft/s	Critical Slope	0.023483 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 ft
Section Size	24 inch	Rise	2.00 ft
Number Sections	1		

Outlet Control Properties

Outlet Control HW Elev.	6,881.23 ft	Upstream Velocity Head	2.20 ft
Ke	0.50	Entrance Loss	1.10 ft

Inlet Control Properties

Inlet Control HW Elev.	6,882.76 ft	Flow Control	Submerged
Inlet Type	Square edge w/headwall	Area Full	3.1 ft²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
24" RCP between Type D inlets at weir - FINAL

R

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	6,883.00 ft	Headwater Depth/Height	3.38
Computed Headwater Eleva	6,882.26 ft	Discharge	37.00 cfs
Inlet Control HW Elev.	6,882.26 ft	Tailwater Elevation	6,877.73 ft
Outlet Control HW Elev.	6,881.10 ft	Control Type	Inlet Control

Grades

Upstream Invert	6,875.50 ft	Downstream Invert	6,875.00 ft
Length	5.00 ft	Constructed Slope	0.100000 ft/ft

Hydraulic Profile

Profile	PressureProfile	Depth, Downstream	1.61 ft
Slope Type	N/A	Normal Depth	1.02 ft
Flow Regime	N/A	Critical Depth	1.94 ft
Velocity Downstream	13.66 ft/s	Critical Slope	0.023483 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 ft
Section Size	24 inch	Rise	2.00 ft
Number Sections	1		

Outlet Control Properties

Outlet Control HW Elev.	6,881.10 ft	Upstream Velocity Head	2.20 ft
Ke	0.50	Entrance Loss	1.08 ft

Inlet Control Properties

Inlet Control HW Elev.	6,882.26 ft	Flow Control	Submerged
Inlet Type	Square edge w/headwall	Area Full	3.1 ft²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Worksheet
Worksheet for Trapezoidal Channel

(5)

Project Description	
Worksheet	Channel into Weir (tri-lo
Flow Element	Trapezoidal Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.030	
Slope	166667	ft/ft
Left Side Slope	3.00	H : V
Right Side Slope	3.00	H : V
Bottom Width	10.00	ft
Discharge	111.00	cfs

Results		
Depth	0.67	ft
Flow Area	8.0	ft²
Wetted Perim	14.23	ft
Top Width	14.02	ft
Critical Depth	1.36	ft
Critical Slope	0.013314	ft/ft
Velocity	13.81	ft/s
Velocity Head	2.97	ft
Specific Energ	3.63	ft
Froude Numb	3.22	
Flow Type	Supercritical	

EXHIBIT 5.3-1
URS Greiner
CALCULATION COVER SHEET

Client: CDOT REGION 2 Project Name: 67000042500.02

Project/Calculation Number: POWERS /SH83 INTERCHANGE

Title: WATERFALL AREA DESIGN

Total number of pages (including cover sheet): ______

Total number of computer runs: ______

Prepared by: E. DANNY ELSNER Date: 9-23-02

Checked by: W. ALSPACH Date: 25 SEP 02

Description and Purpose: TO DESIGN WATERFALL AREA WITH PROVEN DROP STRUCTURES.

Design bases/references/assumptions: · CDOT DESIGN MANUAL
- QA'D FLOWS
- QA'D DROP STRUCTURE SPREADSHEET
- QA'D GROUTED BOULDER DROP.
- ASSUMPTION: ROCK DROPS INSTEAD OF CONCRETE.

Remarks/conclusions:

Calculation Approved by: ______

Project Manager/Date

Revision No.:	Description of Revision:	Approved by:

Project Manager/Date

URS

Job: Powers / SH83	Project No. 67000425??.02	Page ___ of ___	Sheet 1 of ___
Description: Waterfall Area Design	Computed by: EDZ	Date: 9-20-02	
	Checked by: WA	Date: 25 Sep 02	

Reference

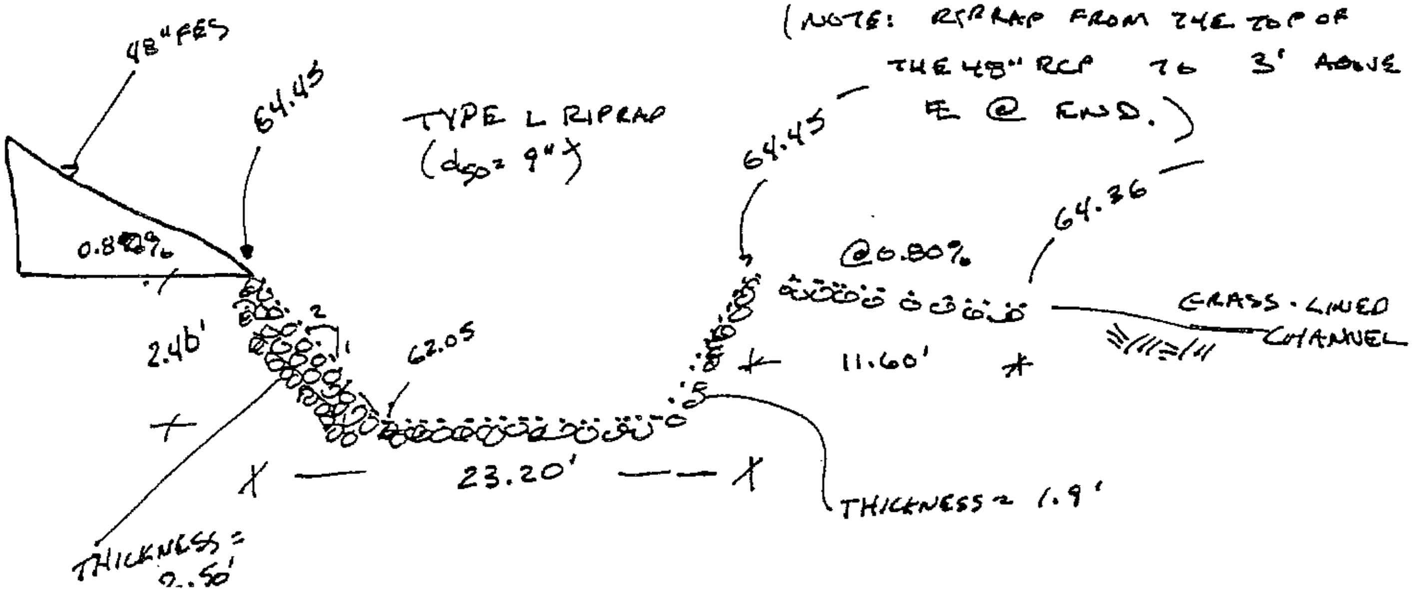
31.19'

ASSUMPTIONS:
- THE UPPER END OF THE WATERFALL AREA IS SET BY THE 48" RCP UNDER RAMP E (INV OUT = 6864.45' (PREV. CALCS))
- THE LOWER END OF THE WATERFALL AREA IS SET BY THE FUTURE 6'x4' RCBC UNDER POWERS (INV IN @ WINGWALL = 6833.31' (PREV. CALCS))
- THE WATERFALL WILL CONSIST OF 2 DIFFERENT AREAS, THE UPPER AREA WILL HAVE VERTICAL DROPS, THE LOWER AREA WILL HAVE A SLOPED DROP. THE CHANGE WILL BE ROUGHLY AT THE ELEV OF POWERS (I.E. ~~NOT A~~ LOWER PART IS NOT HIGHLY VISIBLE TO POWERS).
- THE DESIGN FLOW WILL BE A Q_{100} (ULTIMATE) = 132 cfs (FROM PREVIOUS CALCS).

STARTING FROM THE TOP, A PLUNGEPOOL WILL BE NEEDED OUT OF THE 48" RCP. THE WIDTH OF A 48" FES IS 7' AT THE ~~BOTTOM~~ ∴ A 7' BOTTOM WIDTH WILL BE USED. (129 cfs is the Q @ EXIT)

USING APPENDIX (A). A PLUNGE POOL @ THE 48" WILL BE

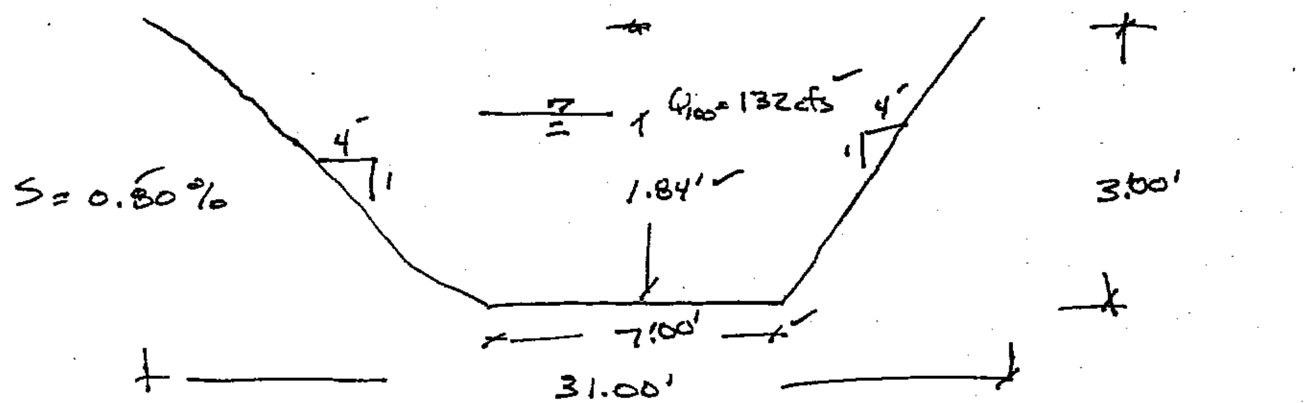
(NOTE: RIPRAP FROM THE TOP OF THE 48" RCP TO 3' ABOVE E @ END.)



URS

		Page ____ of ____
Job POWERS / SH 83	Project No. 67000042500.02	Sheet 2 of ____
Description WATERFALL AREA	Computed by EDE	Date 9-20-02
DESIGN	Checked by W. Alspach	Date 25 Sep 02
		Reference

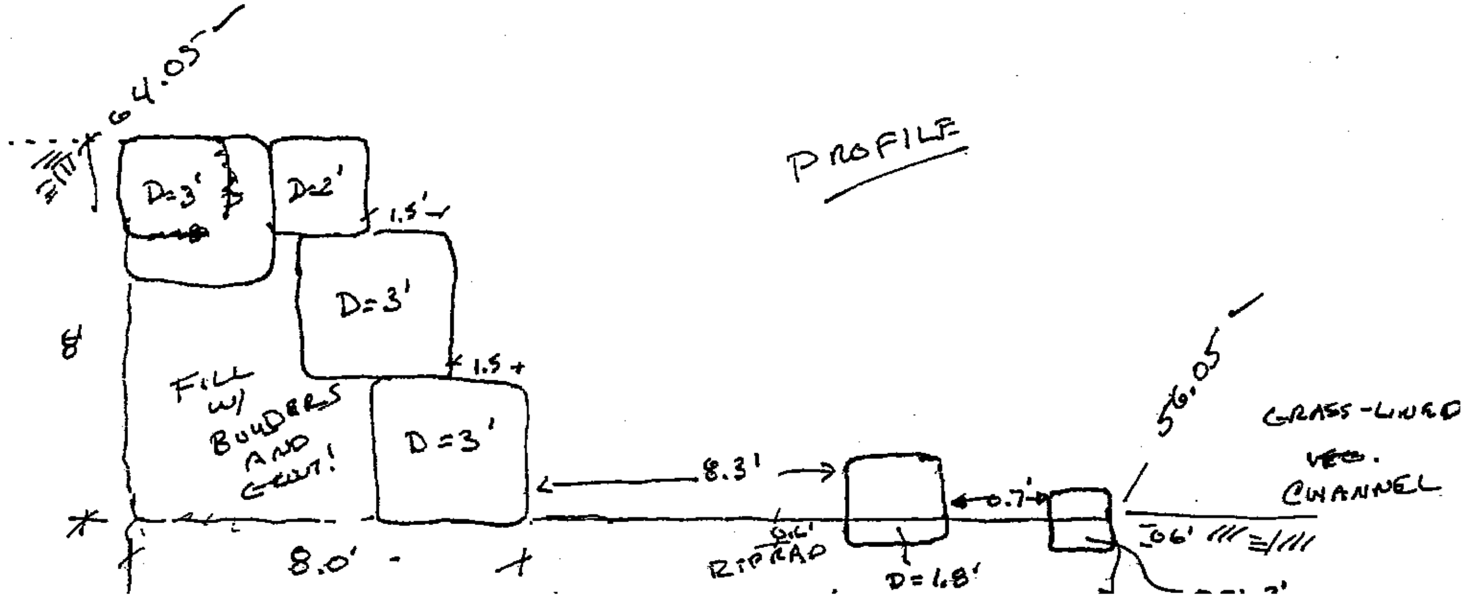
USING A 7' BOTTOM WIDTH WITH 4:1 SIDE SLOPES A CHANEL X-SECTION FOR THE GRASS LINED CHANNEL LOOKS LIKE THE FOLLOWING:



FROM FLOW MASTER, APPENDIX (B)
THE V_{100} = 4.98 ft/s AND F_r = 0.80.
BOTH ACCEPTABLE FOR GRASS-LINED CHANNELS.

(THIS X-SECTION WILL BE USED AS A DEFAULT THRU THE WATER FALL AREA.)

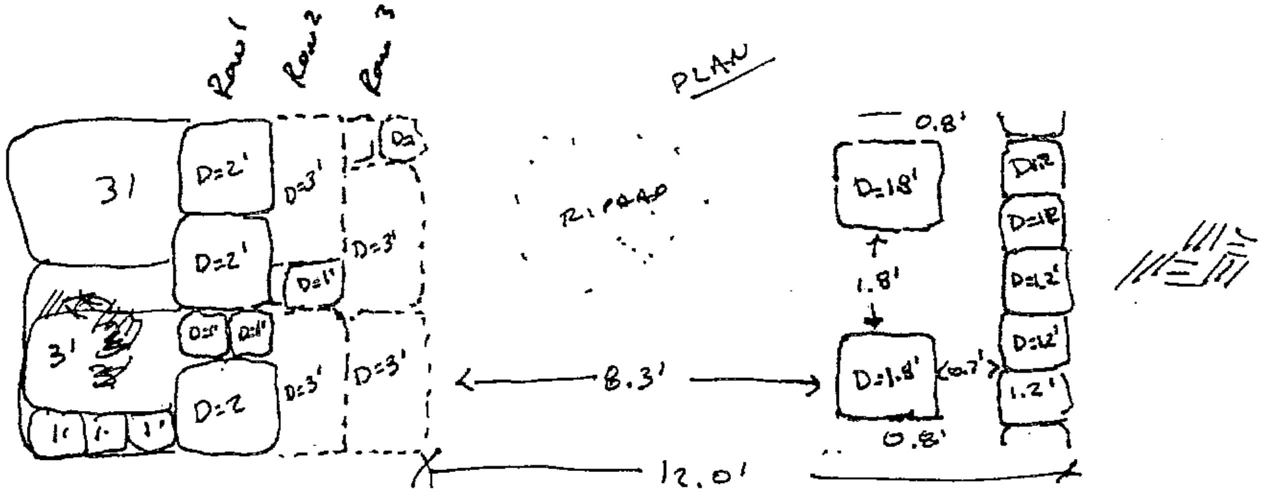
FROM THE END OF THE PLUNGE POOL THIS GRASS-LINED CHANNEL WILL GO 38.54' @ 0.80% TO INV OF 6864.05 AND START THE BEGINNING OF THE FIRST DROP OF 8' APPENDIX (C)

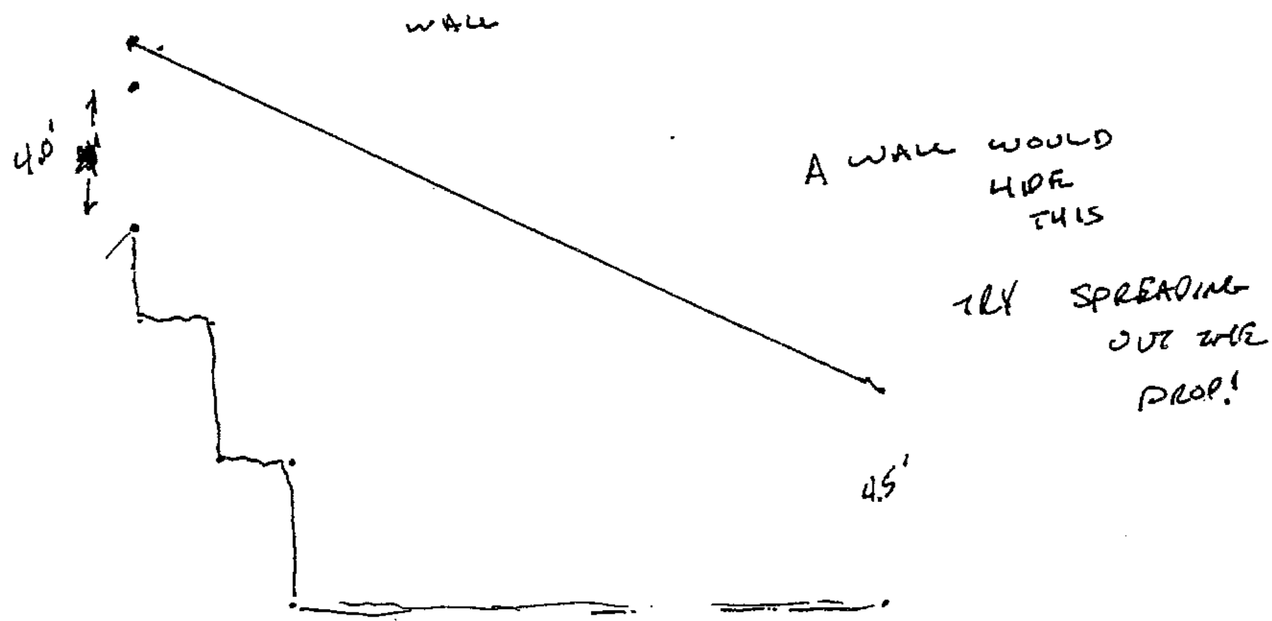


URS

Job: POWERS / SH83	Project No. 67000 42500.02	Page ___ of ___	Sheet 3 of ___
Description: WATERFALL AREA DESIGN	Computed by: EDE	Date: 9-20-02	
	Checked by: W. Alspach	Date: 25 Sep 02	

Reference





URS

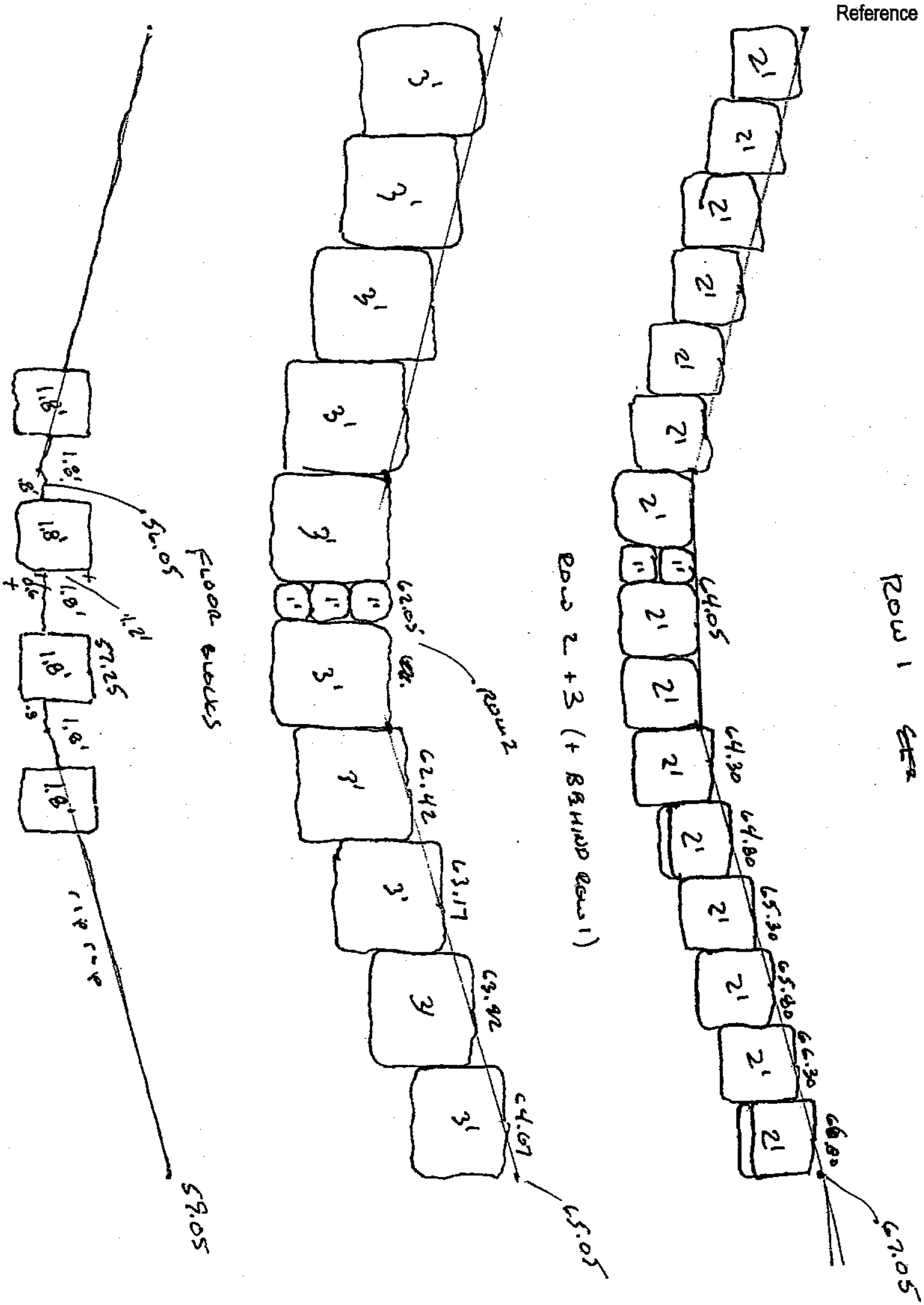
Job: POWERS / SH83
Project No. 67000 42500.02
Page ____ of ____
Sheet 4 of ____

Description: WATER FALL AREA DESIGN

Computed by: SDE
Date: 9-20-02

Checked by: W. Alspach
Date: 25 Sep 02

Reference



URS

Job POWER / SH83	Project No. 6700042500.02	Sheet 5 of	Page of
Description WATERFALL AREA DESIGN	Computed by EDE	Date 9-20-02	
	Checked by W. Alspach	Date 25 Sep 02	

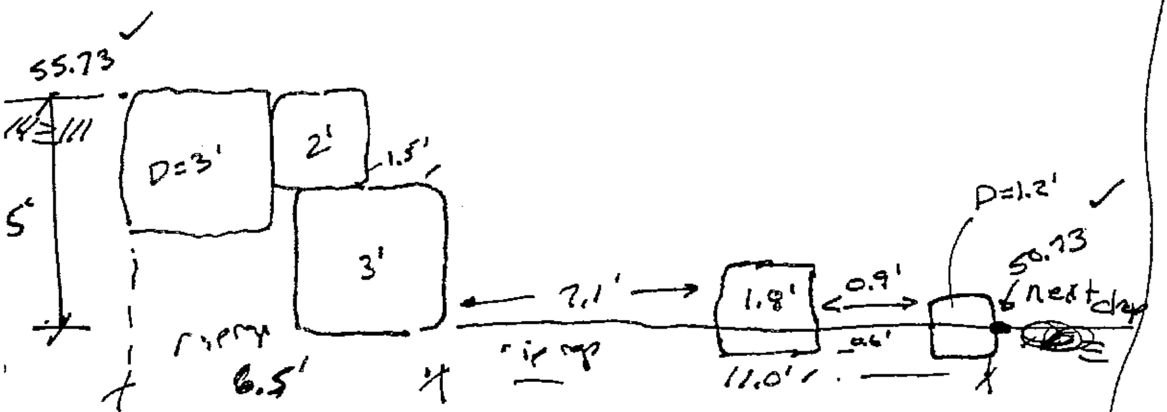
Reference

THE GRASS-LINED CHANNEL WILL CONTINUE FOR 40' FROM END OF 8' DROP STRUCTURE

$\therefore$ 56.05 − 40(.008) = 55.73' ✓

5' DROP APPENDIX (D)

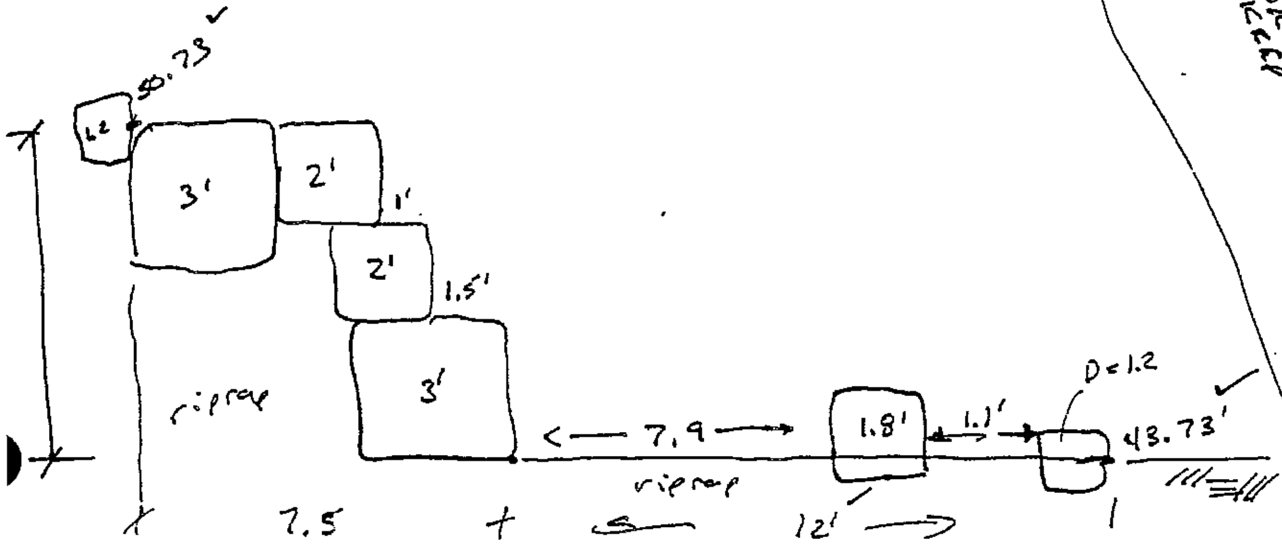
PROFILE

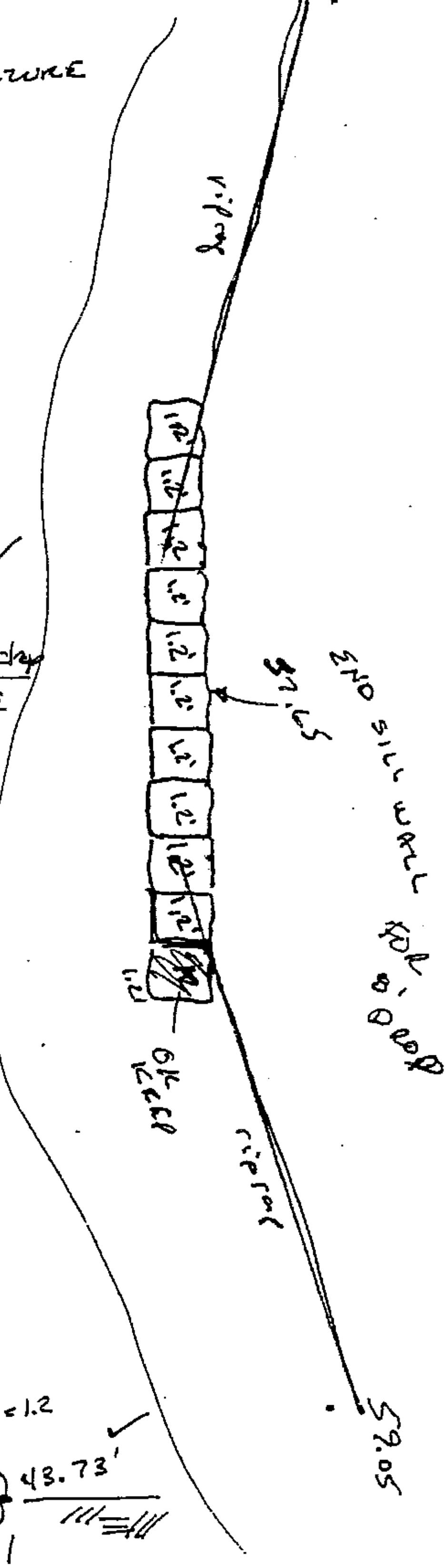


Use same layout

7' DROP APPENDIX (E)

THE 7' DROP WILL FOLLOW RIGHT BEHIND THE 5' DROP.





URS

			Page ___ of ___
Job	POWERS /SH83	Project No. 6100042500.02	Sheet 6 of ___
Description	WATERFALL AREA	Computed by EDE	Date 9-20-02
	DESIGN	Checked by W. Alspach	Date 25 Sep 02
			Reference

FROM THE END OF THE 7' DROP USE A NATURAL CHANNEL @ 0.80% FOR 15'

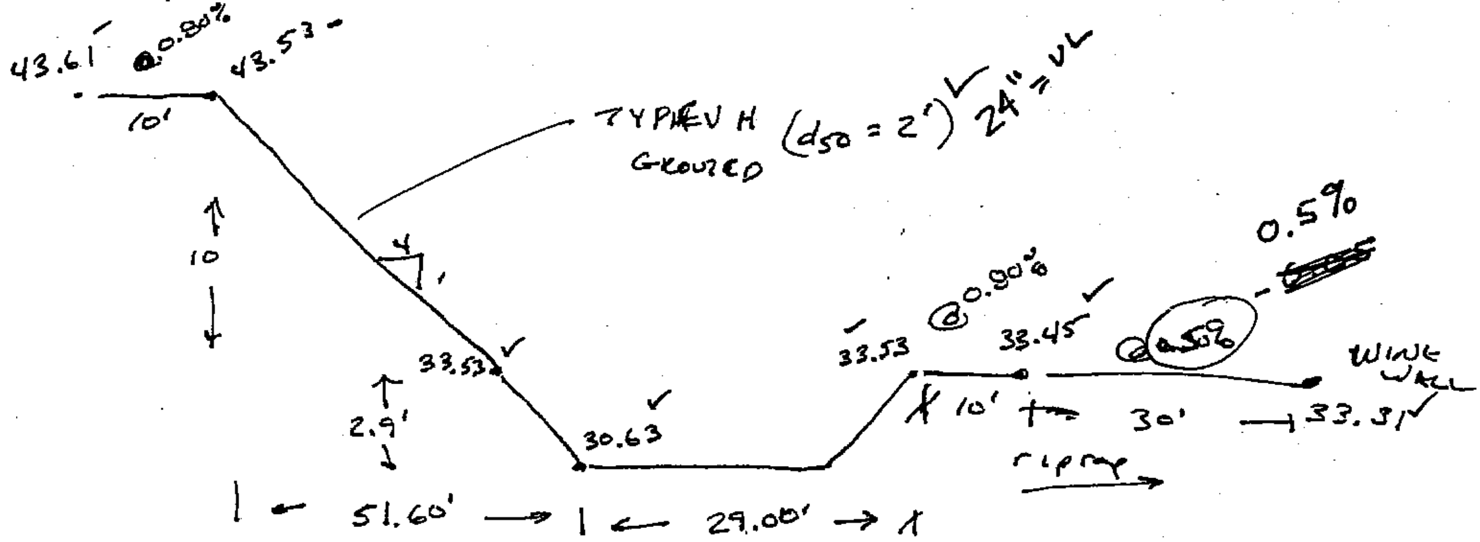
∴ 43.73 − 15 × (.008) = 43.61 ✓

THE ℄ OF POWERS @ BOXCULVERT = 43.59

∴ A GROUTED RIPRAP BOULDER DROP WILL BE USED FROM HERE.

APPENDIX (F)

A 10' DROP @ 4:1 W/ PLUNGE POOL



FROM AUTOCAD, THE DISTANCE BETWEEN 48" FES TO WING WALL IS 315.94'

QUICK CHECK.

23.20'	(PLUNGE POOL)
11.60'	(APRON)
38.54'	(GRASS CHANNEL)
8.00'	(ROCK DROP)
12.00'	(DROP POOL)
40.00'	(GRASS CHANNEL)
6.50'	(ROCK DROP)
11.00'	(DROP POOL)

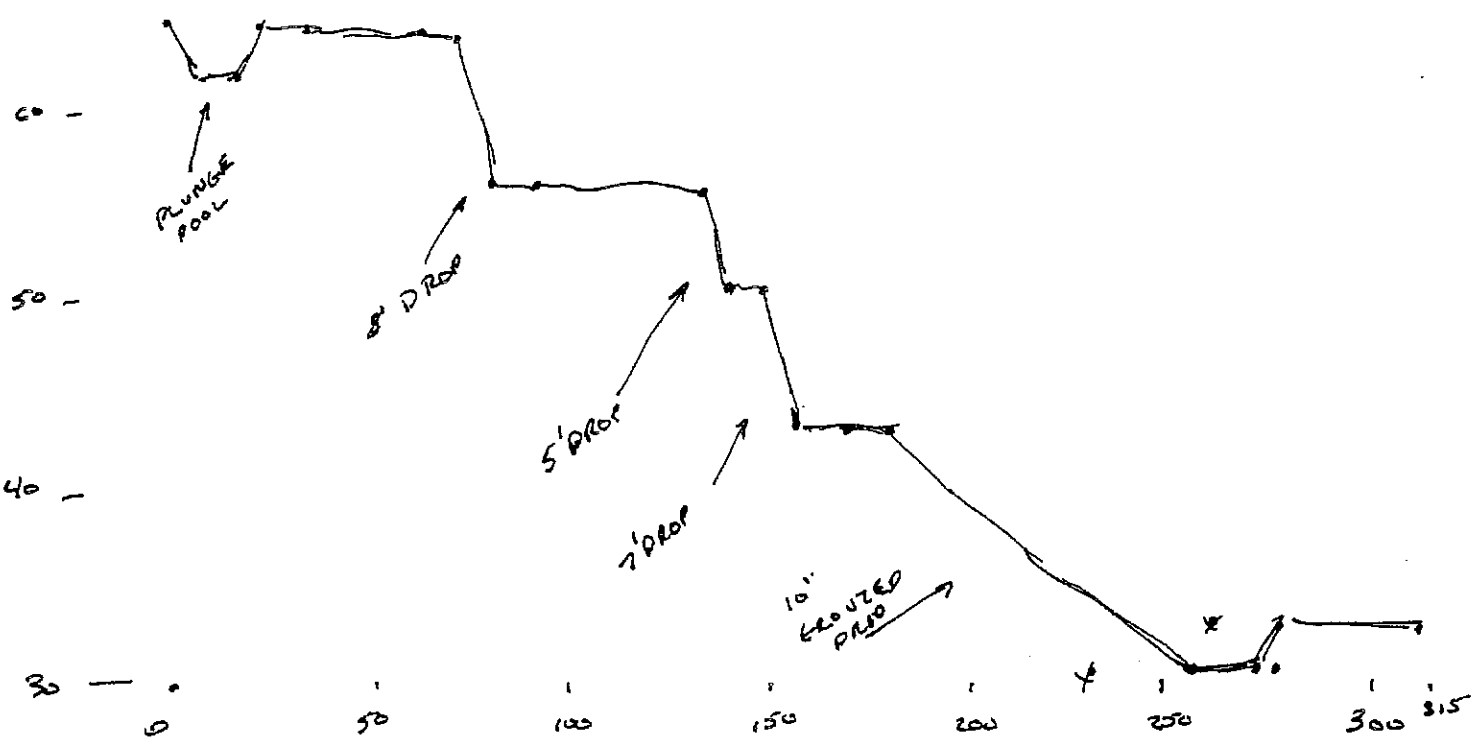
(CONT.) →

URS

Job POWERS /SH83 Project No. 67000425OO.02 Page ___ of ___
Sheet 7 of ___
Description WATERFALL AREA DESIGN Computed by EDE Date 9-23-02
Checked by ___ Date ___
Reference

(CONT.)

7.50'	(ROCK DROP)
12.00'	(DROP POOL)
15.00'	(GRASS CHANEL)
10.00'	(APPROACH)
51.60'	(GROUTED SLOP DROP)
27.00'	(PLUNGE POOL AREA)
10.60'	(APRON)
30.00'	(APPROACH TO WINGWALL)
315.94'	(OK!)



Plunge Pool Design

Ramp E 48" RCP exit

129.00	Q (cfs)	**Box Culvert**		**Circular**	
			Height (in)	48	Diameter (in)
22.08	Tailwater (in)		Width (in)		
				Circular	
		29.28	Normal Depth (in)		

4.03	Q/D^(2.5)	Rounded	4.00
0.46	TW/D	Rounded	0.50
0.71	Yo/D		0.50

34.08 Brink Depth (in)

0.65 TW/yo **LOW TAILWATER DEPTH**

1374 Brink Area (sq in)
13.52 Brink Velocity (fps)

26.21 Equivalent Brink Depth (in)
1.61 Froude

Rip Rap Sizing

Type	d50 (in)	dmax (in)	d50/Ye	Hs/Ye	Hs (in)	Hs/d50	2<Hs/d50<4
VL	~~6~~	12	0.23	1.42	37.28	6.21	BAD
L	9	15	0.34	1.06	27.73	3.08	OK
M	12	21	0.46	0.76	19.79	1.65	BAD
H	18	30	0.69	0.36	9.39	0.52	BAD
VH	24	42	0.92	N/A	#VALUE!	#VALUE!	#VALUE!

Rip Rap

Type	d50 (in)	dmax (in)	Hs (in)
L	9	15	**27.73**

Dissapator Length		**Apron Length**		**Thickness of Approach**		**Thickness of Basin**	
23.11 10*hs (ft)	Max (ft)	11.55 5*hs (ft)	Max (ft)	2.25 3*d50 (ft)	Max (ft)	1.50 2*d50 (ft)	Max (ft)
12.00 3*Wo (ft)	**23.11**	4.00 Wo (ft)	**11.55**	2.50 2*dmax (ft)	**2.50**	1.88 1.5*dmax (ft)	**1.88**

Riprap Quantities

Hs (ft)	2.31	
W (ft)	4.00	
thickness approach (ft)	2.50	
thickness basin (ft)	1.88	
dissapator length (ft)	23.11	
apron length (ft)	11.55	
channel bottom (ft)	7.00	Channel Bottom must be larger than W
tailwater (ft)	1.84	

Areas	(ft^3)	length (ft)	width (ft)	depth (ft)
A	63.54	4.62	5.50	2.50
B	242.60	18.48	7.00	1.88
C	151.63	11.55	7.00	1.88
D	768.56	10.30	14.92	2.50
E	535.51	13.86	10.30	1.88
F	905.03	16.17	14.92	1.88

Total (cy) 99

Worksheet
Worksheet for Trapezoidal Channel

(B)

Project Description	
Worksheet	Trapezoidal Chann(
Flow Element	Trapezoidal Chann(
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Mannings Coeffic	0.030	
Slope	008000	ft/ft
Left Side Slope	4.00	H : V
Right Side Slope	4.00	H : V
Bottom Width	7.00	ft
Discharge	132.00	cfs

Results		
Depth	1.84	ft
Flow Area	26.5	ft²
Wetted Perim(	22.20	ft
Top Width	21.74	ft
Critical Depth	1.64	ft
Critical Slope	0.013033	ft/ft
Velocity	4.98	ft/s
Velocity Head	0.39	ft
Specific Energ	2.23	ft
Froude Numb(	0.80	
Flow Type	Subcritical	

c

Drop Structure with Floor Blocks

Bennett Ranch Channel 6' Drop ?

Q (cfs)	132	
Normal depth (ft)	1.84	Yo
Normal Velocity (fps)	5.00	Vo
Drop height (ft)	8.00	Hd
Slope of Channel (ft/ft)	0.008	Ss
	1.68	ft^1/2/sec
Specific Head (ft)	2.23	
Critical depth (ft)	1.49	Yc
Min height tailwater (ft)	3.19	Y3
Vert. Dist (Crest-Tailwater) (ft)	-6.16	H2
Vert. Dist (Crest-Floor) (ft)	-9.35	Ho
	7.63	Lf
	6.25	Lt
	7.78	Ls
Horz. Dist (Wall-striking pt.) (ft)	7.71	L1
Horz. Dist (striking pt.-block) (ft)	1.19	L2
Horz. Dist (block-end of basin) (ft)	3.11	L3
Total length of basin (ft)	12.00	Lb
Floor Blocks height (ft)	1.19	
Width Blocks (ft)	0.59	
Spacing between Blocks (ft)	0.59	
End Sill Height (ft)	0.59	
Sidewall Height (ft)	4.46	

Check to see if Drop Size within parameters

Min Drop	(Hd/Yc)	1.49	**OK**
Max Drop	15*(Hd/Yc) or 15'	15.00	**OK**

NOTE

Line upstream channel with riprap 5.00 feet with VL Type Riprap from headwall.

Bottom width of basin should be equal to the spillway notch .

Crest of spillway should be at same elevation as approach channel.

D

Drop Structure with Floor Blocks

Bennett Ranch Channel 6' Drop

Q (cfs)	132	
Normal depth (ft)	1.84	Yo
Normal Velocity (fps)	5.00	Vo
Drop height (ft)	5.00	Hd
Slope of Channel (ft/ft)	0.008	Ss
	1.68	ft^1/2/sec
Specific Head (ft)	2.23	
Critical depth (ft)	1.49	Yc
Min height tailwater (ft)	3.19	Y3
Vert. Dist (Crest-Tailwater) (ft)	-3.16	H2
Vert. Dist (Crest-Floor) (ft)	-6.35	Ho
	6.35	Lf
	4.65	Lt
	6.64	Ls
Horz. Dist (Wall-striking pt.) (ft)	6.49	L1
Horz. Dist (striking pt.-block) (ft)	1.19	L2
Horz. Dist (block-end of basin) (ft)	3.32	L3
Total length of basin (ft)	11.00	Lb
Floor Blocks height (ft)	1.19	
Width Blocks (ft)	0.59	
Spacing between Blocks (ft)	0.59	
End Sill Height (ft)	0.59	
Sidewall Height (ft)	4.46	

Check to see if Drop Size within parameters

Min Drop	(Hd/Yc)	1.49	**OK**
Max Drop	15*(Hd/Yc) or 15'	15.00	**OK**

NOTE

Line upstream channel with riprap 5.00 feet with VL Type Riprap from headwall.

Bottom width of basin should be equal to the spillway notch .

Crest of spillway should be at same elevation as approach channel.