Bonneville Adult Collection & Monitoring Facility (AFF)
Hydraulic Design Calculations

CENWP-EC-HD

Comp by	SJS	12/21/12
Checked by		

Hydraulic Data Collection Oct 31, 2012

Elevations (NGVD): Ref: BDF-2 -18/9 and BDF-2--18/24

Lower Exit Channel Invert (grating) =	**39**	ft, NGVD
Upper Exit Channel Invert (concr.) =	**42**	ft, NGVD
Floor supporting Valve 15, 14	**32**	ft, NGVD
Work Platform Floor =	**45**	ft, NGVD
Grating Platform (about 1.5" higher) =	45.1	ft, NGVD

Valve Pipe OD (field checked)

Valve 14	**36**	in =	3.0 feet
Valve 15	**30**	in =	2.5 feet

CL Valve Elevations

Valve 14	33.5 ft, NGVD
Valve 15 (Z-15)	33.25 ft, NGVD

Main Exit Channel at Trashrack

Flow depth =	**4.9** ft	WS Elev =	43.9 ft
Width =	**8** ft		

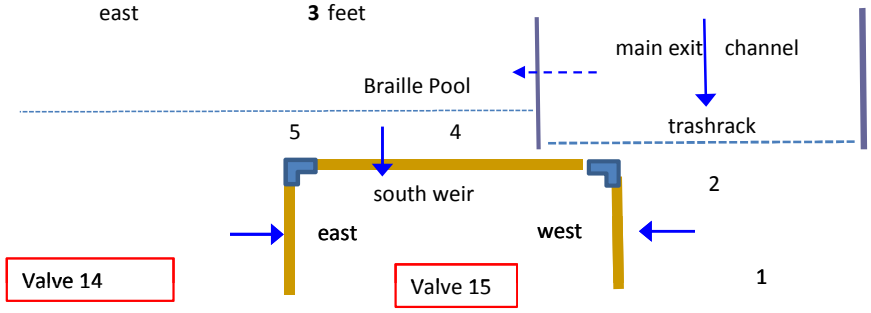
Current Valve Settings:		
Valve No.	14	15
% Open	0	75%

Weir Data

Distance from Top of Grating =	**24.5**	inches =	2.04	feet	Weir Elev = 43.04 ft

Weir Lengths (open length between guides)

west	**3** feet
south	**6.5** feet
east	**3** feet



Velocities Measured using Price Metter (single count setting)

Depth below WS (ft)	Lateral Location (looking U/s) in feet (Bi) 1	2.5	4	5.5	7	Integrated Average	Straight Average
0.5	**2.85**	**3.31**	**3.44**	**2.60**	**2.06**	2.81	2.85
1.5	**3.15**	**3.12**	**2.20**	**1.81**	**1.89**	2.44	2.44
2.5	**2.00**	**2.04**	**1.01**	**1.32**	**1.41**	1.57	1.56
3.5	**1.37**	**0.76**	**0.68**	**0.60**	**0.96**	0.91	0.87
4.3	**0.64**	**0.51**	**0.62**	**0.49**	**0.90**	0.65	0.63

	Integrated	Straight
Average Velocity (feet/sec) =	1.69	1.67
Computed Flow Rate (cfs) =	66.1	65.4

Integrated row average $V_j = \Sigma (B_{i+1} - B_i) * (V_i + V_{i+1})/2$ for i = 0 to n

$Vo = V_1 + (V_2 - V_1)/(B_2 - B_1) * (B_1 - B_0) *$ Edge coef

$Vn = V_{n-1} + (V_{n-2} - V_{n-1})/(B_{n-2} - B_{n-1}) * (B_n - B_{n-1}) *$ Edge coef

Edge coeff = 0.5

B_n = total width

Total Integrated average $V = \Sigma (Y_{j+1} - Y_j) * (V_j + V_{j+1})/2$ for j = 0 to n

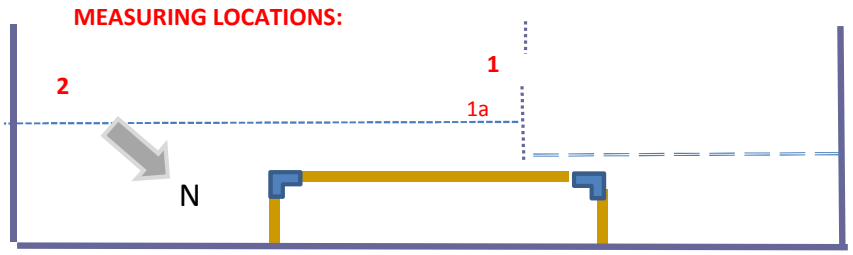
$Vo = V_1$ *Surface same as 0.5 ft down*

$Vn = V_{n-1} + (V_{n-2} - V_{n-1})/(Y_{n-2} - Y_{n-1}) * (Y_n - Y_{n-1}) *$ Edge coef

Y_n =m total depth

Braille Pools Data

Depth of Pool at North end = 4 feet



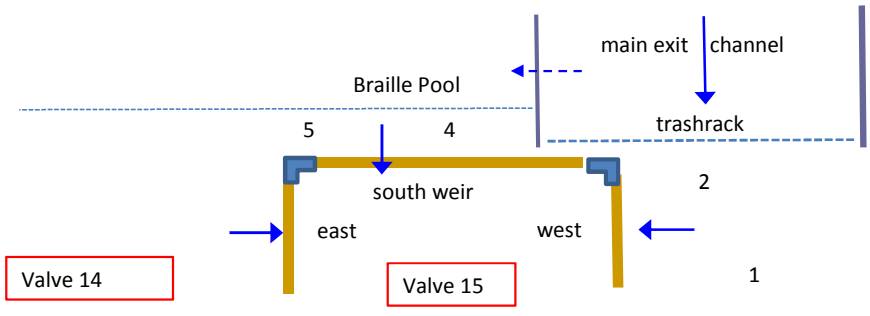
CURRENT Operation	Valve 15		75%
	Valve 14		0%
Depth Below Water (ft)	VELOCITIES (ft/s) MEASURING LOCATION 1	1a	2
0.5	0.29	0.46	0.10
1.5	0.27	0.56	0.10
2.5	0.10		0.20
3.2	0.21		0.20
Average V	0.22	0.51	0.15
Average direction	↓	←	↙

Modified Operation	Valve 15		70%
	Valve 14		30%
Depth Below Water (ft)	VELOCITIES (ft/s) MEASURING LOCATION 1	1a	2
0.5	0.29		0.00
1.5	0.23		0.19
2.5	0.19		0.22
3.2	0.17		0.29
Average V	0.22		0.18
Average direction	↓	←	↗

Centerline Velocities in Main Channel under Modified Operations

Depth Below Water (ft)		Current OP Valve 15 75% Valve 14 0%		Valve 15 70% Valve 14 40%		Valve 15 60% Valve 14 50%
0.5		3.44		4.12		3.99
1.5		2.20		2.63		2.60
2.5		1.01		1.33		1.34
3.5		0.68		0.67		1.01
4.3		0.62		0.70		0.51
Average Velocity (ft/s)		1.59		1.89		1.89
Percent Above Normal		0.00		19%		19%

Water Level Data upstream of Stop Log weirs



Location	Distance from top of grating (ft)	(H) Depth above weir (ft)	surface cond.	(q) Unit discharge rate (cfs/ft)	Surface Velocity (ft/s)	Ws Elevations
1	1.04	1.00	no flow	3.31	3.31	44.0
2	1.08	0.96	fast	3.11	3.24	44.0
4	1.25	0.79	moderate	2.33	2.95	43.8
5	1.33	0.71	slow	1.97	2.79	43.8
	Average head =	0.83	Total Q =	30.8	cfs	

Table 5-3 of King & Brater, "Handbook of Hydraulics"

Broad crested weir coefficient = 3.31 3

Edge contraction = 0.1 x H 13.9

35.2 2.534552

		Weirs West	South	East	Total	
ave H =	feet	0.98	0.82	0.71		
L =	feet	3	6.5	3	12.5	
L' =	feet	2.90	6.42	2.93	12.25	ave DH =(Qwr/L'/Cw)^0.67
Q weir =	cfs	9.3	15.8	5.8	30.8	ave DH = 0.83 feet

Weir Coeff. Factoring in Leakage = CWl = Qmeas/ Qcomp * 3.31 = 7.09 very high

Weir coefficient using max head = 5.39

Estimated Bypass Flume Diameter

Pipe = 14 Inch Sch 40 steel pipe

OD = **14.0** inches

Th = **0.437** inches

ID = 13.13 inches = 1.09 feet 66 4.3

38 2.5

Measured distances from walkway over exit channel to:

Bottom of channel raise **13.53** feet

distance to top of flume pipe at exit = **7.93** feet

depth in channel upstream of sill = **4.9** feet

depth in d/s elevated channel = **1.9** feet

distance to water surface elev = 11.63 feet

distance to flume invert = 9.0 feet

Height of flume invert above water = 2.6 feet

Elevation Difference in Pool Crest (DZ) = **1** foot

Orifice sqr Dim = **18** inch

Orifice Area (Ao) = 2.25 ft^2

Orifice coeff (Cdo) = **0.67** Qo = Ao * Cdo * sqrt(2g * (DZ)

Weir Crest Length (Lw) = **5** ft

Ladder Flow

Normal Case		**Shad flow**	
Ladder head (DH) =	**1.0** feet	Ladder hd (DHs) =	**1.3** feet
Weir coeff (CW) =	**5.07**	Weir coeff (CWs) =	**5.25**
Qw = L *CW *(DH)^1.5		Qw(shad) = L *CWs *(DsH)^1.5 * {1 - (DHs-1)/DHs)^1.5}^0.385	
Qo = Orifice flow =	12.1 cfs	Qo (shad)=	12.1 cfs
Qw = Weir Flow =	25.4 cfs	Qw (shad) =	37.2 cfs
Qt = Total Exit Ladder flow =	37.4 cfs	QT (shad) =	49.3 cfs
		Vp	
measured =	66.1 cfs	14.16	
ladder =	37.4 cfs		
difference =	28.6 cfs		

Valve 15

Butterfly Valve CD (ref: Figure 4.3, "Hydraulics of Pipelines", Tullis (1989))

Valve Loss Coeff = (Kv) Kv = 1/CD^ 2 - 1

Operation case	Valve Opening	CD	Kv
Original Operation	**55%**	0.34	7.7
Current Operation	**75%**	0.50	3.0
Full open	**100%**	0.80	0.6
Intake loss coeff (Ki) =			**0.15**

Butterfly Discharge Coefficients

Valve Opening	CD
0%	**0.00**
10%	**0.02**
20%	**0.07**
30%	**0.14**
40%	**0.22**
50%	**0.30**
60%	**0.38**
70%	**0.46**
80%	**0.54**
90%	**0.64**
100%	**0.80**

OD-15 = Valve 15 Pipe diameter = 30 in = 2.5 ft

Wall thickness = **3/8** in = typical pipe wall thickness assumed

ID - 15 = inside pipe Dia (vale 15) = 29.25 in = 2.44 ft

A15 = Valve 15 Pipe area = 4.67 ft^2

HL = Estimated Headloss through Valve = (Q/A) ^2/2g (Kv+ Ki)

HGL = HL + Z-15		Valve OP	Q	Vp	VH	HL	HGL	Measured	10/31/12
Z-15 =	33.25	75% open	65	13.9	3.01	9.5	42.7	43.0	ft
		55% open	**41**	8.8	1.20	9.4	42.6		
		100% open	**100**	21.4	7.13	5.1	38.3		

Measured D/s of weir below bottom of grating

10/24/12 19 inches >> HGL = 43.4 Air bulking is factor

10/31/12 24 inches >> HGL = 43.0

Assume Valve HL is same Q1 = Av CD1 * sqrt(2gDH)

Q2 = Av CD2 * sqrt(2gDH)

Q1/Q2 = CD1/CD2 = 0.68

		Vp (ft/s)
Q2 =	66.1 cfs	14.2
Q1 = Q2 * CD1/CD2 =	44.9 cfs	9.6
% Q reduction =	32%	

Size Porosity Plates for Design Flow

Design Flow = 38.0 cfs, or Design Ladder Flow

	Open Length of Porosity Plates South	west	sum	
	1.5	3	4.5	ft
Perf. height	4	5		

Remaining open length of Stop Log weirs Prev sum	Remainder sum
12.5	7.5

CW with leakage estimated = 7.09

Assume with reduce leakage CWr = **4**

Ave DH = 0.83 ft

Raise weirs **4** inches

Revised DH = 0.50 ft

Sum eff length L' = L -0.1 *DH *2 = 7.40 feet

Qwr = New Weir Flow Rate = CWr * L' * Ave DH^1.5

Qwr = 10.5 cfs

Qs = Total Target Exit Discharge = 38.0 cfs

Qpp = Net discharge through Porosity Plates = Qs - Qwr

Qpp = Qs - Qwr 27.5 cfs

Average Channel Velocity 1.0 ft/s

Valve (Tullis) data reversed

CD	Valve Opening
0.00	0%
0.02	10%
0.07	20%
0.14	30%
0.22	40%
0.30	50%
0.38	60%
0.46	70%
0.54	80%
0.64	90%
0.80	100%

Flow depth = 4.9 ft
Assume differential = **2.5** ft
level d/s of weirs = 2.4 ft

Valve can be adjusted to attain this differential
HGL = 41.4 ft
Valve Head loss = 8.15 feet

Required KV = 7.76 >> CD = 0.34 >>> Valve Opening = 55% open

Hole diameter (Do) = **3** inches Hole area(Ao) = 7.07 in^2 = 0.049 ft^2
Discharge coeff (CDo) = **0.63**
Head diff = minimum(Flow depth - WS d/s of weir, flow depth - hole elev)

Assume square grid spacing Set Spacing at **6** inches Porosity = 20%
Number of rows = 9
Number of holes per row N **Discharge =** 27.4
Height (ft) 4 9 check diff from target % diff = 0%
Height (ft) 5 6

Row Discharge = Qr = CD * ΣAo * sqrt(2g * DH)
Σ Ao = N * Ao

		Elev above floor (ft)	Area of Holes (ft^2)	Head diff (ft)	Row Discharge Rate (cfs)	Sum Q (cfs)
1	Row 1	0.25	0.442	2.50	3.53	3.53
2	Row 2	0.75	0.442	2.50	3.53	7.06
3	Row 3	1.25	0.442	2.50	3.53	10.59
4	Row 4	1.75	0.442	2.50	3.53	14.13
5	Row 5	2.25	0.442	2.50	3.53	17.66
6	Row 6	2.75	0.442	2.15	3.28	20.93
7	Row 7	3.25	0.442	1.65	2.87	23.80
8	Row 8	3.75	0.442	1.15	2.40	26.20
9	Row 9	4.25	0.295	0.65	1.20	27.40
10	Row 10					
11	Row 11					
12	Row 12					

Check Shad Condition (Weir Head = 1.3 feet)

Increased head = 0.3
Flow depth = 5.2 ft
Assume differential = **2.2** ft
level d/s of weirs = 3 ft

Weirs
Ave DH with normal Flow = 0.50 ft
Revised DH with increase head 0.80
Sum eff length L' = L -0.1 *DH *2 = 7.34 feet

Qwr = New Weir Flow Rate = CWr * L' * Ave DH^1.5
Qwr = 21.2 cfs

Qs = Total Target Exit Discharge = 49.3 cfs
Average Channel Velocity 1.3 ft/s

Qpp = Qs - Qwr 28.1 cfs

Valve can be adjusted to attain this differential
HGL = 42 ft
Valve Head loss = 8.75 feet
Required KV = 4.90 >> CD = 0.41 >>> Valve Opening = 64% open

Same square grid spacing *(Shad Condition continued)* **6** inches Porosity = 20%

Number of rows = 10

Number of holes per row N **Discharge =** 28.14 % diff = 0%

Height 4 9

Height 5 6

		Elev above floor (ft)	Area of Holes (ft^2)	Head diff (ft)	Row Discharge Rate (cfs)	Sum Q (cfs)
1	Row 1	0.25	0.442	2.20	3.31	3.31
2	Row 2	0.75	0.442	2.20	3.31	6.63
3	Row 3	1.25	0.442	2.20	3.31	9.94
4	Row 4	1.75	0.442	2.20	3.31	13.25
5	Row 5	2.25	0.442	2.20	3.31	16.56
6	Row 6	2.75	0.442	2.20	3.31	19.88
7	Row 7	3.25	0.442	1.95	3.12	23.00
8	Row 8	3.75	0.442	1.45	2.69	25.69
9	Row 9	4.25	0.295	0.95	1.45	27.14
10	Row 10	4.75	0.295	0.45	1.00	28.14
11	Row 11					
12	Row 12					

Check: No Flow Change Scenario

Increased head = 0.1 ft

Flow depth = 5 ft

Assume PP differential = **4.7** ft

level d/s of weirs = 0.3 ft

Weirs

Remove 4" raise

Ave DH with normal Flow = 0.83 ft

Revised DH with increase head 0.93

Sum eff length L' = L -0.1 *DH *2 = 7.31 feet

Qwr = New Weir Flow Rate = CWr * L' * Ave DH^1.5

Qwr = 26.7 cfs

Qs = Total Target Exit Discharge = 68.0 cfs Average Channel Velocity 1.7 ft/s

Qpp = Qs - Qwr 41.3 cfs

Valve can be adjusted to attain this differential

HGL = 39.3 ft

Valve Head loss = 6.05 feet

Required KV = 1.68 >> CD = 0.61 >>> Valve Opening = 87% open

Same square grid spacing *(no Flow Change continued)* **6** inches Porosity = 20%
Number of rows = 10
Number of holes per row **Discharge =** 41.97 % diff = -2%
Height 4 9
Height 5 6

		Elev above floor (ft)	Area of Holes (ft^2)	Head diff (ft)	Row Discharge Rate (cfs)	Sum Q (cfs)
1	Row 1	0.25	0.442	4.70	4.84	4.84
2	Row 2	0.75	0.442	4.70	4.84	9.68
3	Row 3	1.25	0.442	4.70	4.84	14.53
4	Row 4	1.75	0.442	4.70	4.84	19.37
5	Row 5	2.25	0.442	4.70	4.84	24.21
6	Row 6	2.75	0.442	4.70	4.84	29.05
7	Row 7	3.25	0.442	4.70	4.84	33.90
8	Row 8	3.75	0.442	4.70	4.84	38.74
9	Row 9	4.25	0.295	4.70	3.23	41.97
10	Row 10	4.75	0.295			41.97
11	Row 11					
12	Row 12					

Flood Scenario

Assume current discharge rounded up to nearest 10 cfs
Assume all perforation are plugged
All flow over top of weirs and Perf plates

Q = 70.0 cfs WS = **5.87** ft

Weir Length L (ft)	CW	Weir Ht Zwr (ft)	DH (ft)	eff length L' (ft)	Q (cfs)
4.5	3.3	5	0.87	4.3	11.6
8	4.0	4.33	1.54	7.7	58.6
				sum	70.1 cfs
				diff =	0.1

Required Flow for recovery boxes

1 gpm per **15** lbs of fish
5% increase for every degree above 50 degrees

maximum water temp = **72** deg Base temp = **50** deg
Average fish weight = **37** lbs
number of fish/box = **1**
Nb =number of boxes = **4** *= number of inflow pipes*

Total water supply = 1 gpm/15 lbs * 4 boxes * 37 lbs * (1 + (72 - 50) * 5%)
Total water supply = 20.72 gpm = 0.04616435 cfs

V = outlet velocity = Qt/Np/(pi()*D^2/4)

Pipe Diameter (inches) Nominal	OD	ID	Thick-ness	Velocity (ft/s)
1	1.32	1.05	0.133	1.9
1.25	1.66	1.38	0.140	1.1
1.5	1.90	1.61	0.145	0.8
2	2.38	2.07	0.154	0.5
2.5	2.88	2.47	0.203	0.3
3	3.50	3.07	0.216	0.2

Elevation Difference in Pool Crest (DZ) =		1	
Orifice sqr Dim =	18	inch	
Orifice Area (Ao) =	2.25	ft^2	
Orifice coeff (Cdo) =	0.67		Qo = Ao * Cdo * sqrt(2g * (DZ)
Weir Crest Length (Lw) =	5	ft	

Ladder Flow

Normal Case

Ladder head (DH) =	**1.0**	feet	0.8	5.05	0.1
Weir coeff (CW) =	5.07		1	5.07	0.6
Qw = L *CW *(DH)^1.5			1.3	5.25	3.8
Qo = Orifice flow =	12.1	cfs	1.5	6.01	4.0
Qw = Weir Flow =	25.4	cfs	1.7	6.80	
Qt = Total Exit Ladder flow =	37.4	cfs			

Backwater Profile for Exit Ladder to Pool 49 assuming Current Conditions

Q = 66.1 cfs

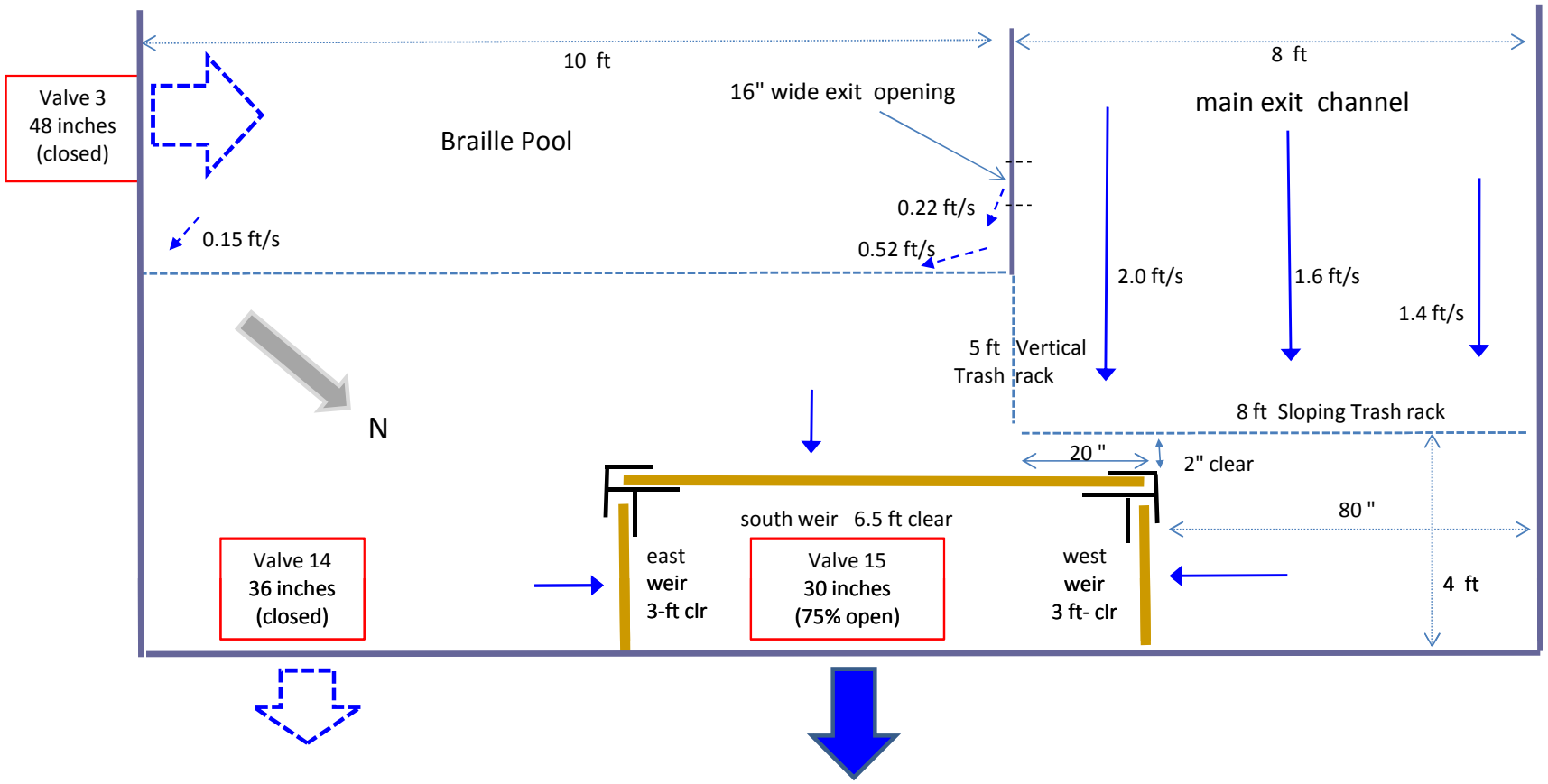
D/s Depth = 4.9 ft WS EL = 43.9 ft

Weir	D/S WS EL	DH	U/S WS	Hu	DH	Qo	Hu	Cw	Qw
44	43.90	1.55	45.45		1	12.1	0.90	5.06	21.6
45	45.45	1.07	46.52		1.55	15.1	2.00	8.00	108.7
46	46.52	1.01	47.54		1.07	12.5	1.59	6.38	59.2
47	47.54	1.00	48.54		1.01	12.2	1.55	6.21	55.0
48	48.54	1.00	49.54		1.00	12.1	1.54	6.18	54.2
49	49.54	1.00	50.54	1.5	1.00	12.1	1.54	6.17	54.0

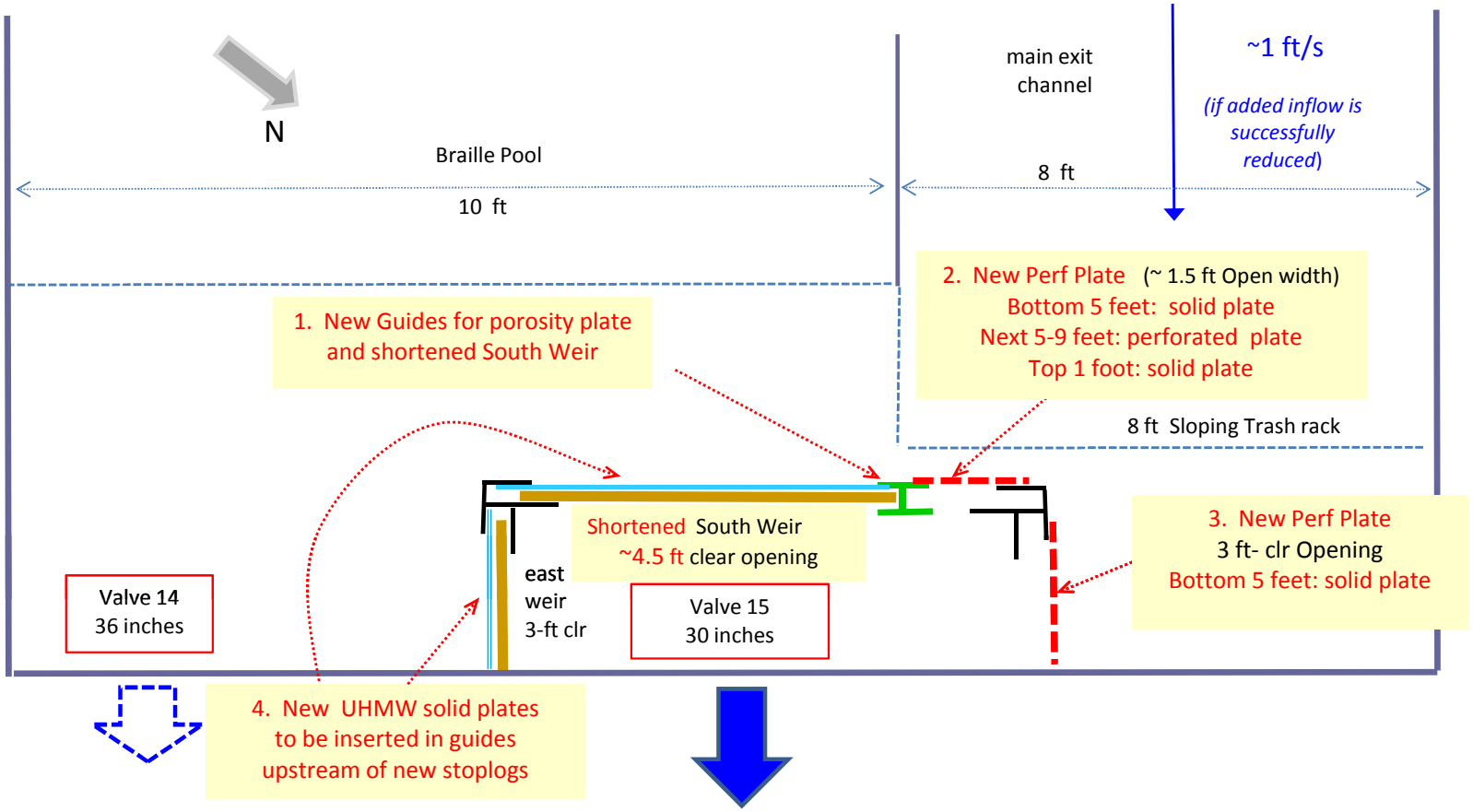
Average Exit Channel Velocities

Case	Flow Rate (cfs)	Channel Velocities (ft/s) Deep Section	Shallow Section
Current OP	66	1.7	4.3
Design	38	1.0	2.5

EXISTING OPERATION WITH DIMENSIONS AND DEPTH AVERAGED VELOCITIES



PROPOPSED REVISIONS



Bonneville AFF : Flume Calcs *INNER FLUME*

Assumptions

Pipe thickness **0.437** inch **g =** **32.2** ft/s^2
Pipe O.D. = **14** inches SDR 40 PVC
Mannings n = **0.010** (PVC)

drop in pipe = 2.00 feet

Diameter = 13.13 inches = 1.1 ft
Flow rate **110** gpm = 0.25 cfs

Nominal Flow Rate **Total L** **39.0** feet

	Z(elevation)		Location			Slope
U/s Flume IE. Elev	49.0 ft	X 1	**0** feet	interval 1		**0.11**
DS end bend 1	46.6 ft	X 2	**21.5** feet	interval 2		**0.12**
US end Bend 2	**44.5** ft	X 3	**39.0** feet			

	DEPTH (ft)	(in)	Velocity (ft/s)	Normal Depth
End of 1st Slope :	0.086	1.04	7.11	0.086 ft
End of 2nd Slope:	0.084	1.01	7.36	0.084 ft

minimum water depth:
0.084 ft = 1.0 inches
min. WS elevation = **43.90** ft Min FROUDE No. = 3.5 (d/s of 1rst 5 feet)

Jet Impact Velocity
Beta = atan (slope) 0.120 radians = 6.9 degrees
Total velocity (Vt) at end of flume = 7.36 ft/s
vertical component (Vzi) = Vt * sin(beta 0.88 ft/s
horizontal comp (Vx) = Vt cos (beta) 7.30 ft/s

Vertical velocity (Vzi) at impact = sqrt(2g*(Z2-z3+y2/2) * Vz' 9.6 ft/s
Total Impact Velocity (Vti) at Impact = sqrt(Vzi^2 + Vx^2) = 12.1 ft/s
βi = Angle of Impact with Respect to horixontal = 0.92 rads = 52.7 degrees

Vti = 12.1 ft/s OK, Vti is less than 25 ft/s

Normal Depth Yn (in)	Locaton	X (feet)	Z elevation (feet)	Depth (in)	Velocity (ft)	FR
1.0	X 1	0	49.0	1.71	3.4	1.9
1.0	X 2	21.5	46.6	1.04	7.1	5.2
	X 3	39.0	44.5	1.01	7.4	5.43

RESULTS OF DIFFERENT FLOW CONDITIONS

Depth of Flow (in)	Discharge		Velocity (ft/s)		Impact Angle (deg)
	gpm	cfs	Exit	Impact	
0.5	25	0.06	4.7	9.1	59
1.0	110	0.25	7.4	12.1	53
1.5	240	0.53	9.3	14.4	50
2.0	450	1.00	11.0	16.7	49

EQUATIONS FOR FLUME CALCULATIONS

Equation for Water Depth

Reference: Henderson (1966), *Open Channel Flow*, Eq 7-52

$$\frac{dy}{dx} = \frac{So - Sf}{1 - Fr^2}$$

in which;

$\frac{dy}{dx}$	=	change in water depth with respect to channel length,			
So	=	channel slope,			
Sf	=	friction slope			
	=	$\frac{Q^2 n^2}{C^2 A^2 Rh^{1.33}}$			
Q	=	flow rate (cfs) in channel at location x,			
g	=	gravity = 32.2 ft/s^2			
A	=	cross-sectional flow area at location x (ft^2)			
	=	$D^2 \cdot \frac{(\beta - \cos\beta \cdot \sin\beta)}{4}$			
Fr^2	=	Froude number squared			
	=	TQ^2 / gA^3			

and:

y	=	flow depth (ft)
D	=	Inside Diameter of Pipe Flume (ft)
n	=	Manning roughness factor,
C	=	coefficient (1.486 for English units, 1 for metric units).
β	=	$\cos^{-1}\left(1 - \frac{2 \cdot y}{D}\right)$ (radians)
Rh	=	hydraulic radius (ft) = area/wetted perimeter,
	=	A/P
P	=	wetted perimeter (ft) = D * β
T	=	Top width of flow (ft)
	=	D * sin (β)

Computation Procedure Using 4th Order Runge-Kutta Methods

Assume initial depth Y1 = (Yc + Yn)/2 due to energy of false weir at u/s end

Yn = normal depth (ft) = depth at which SF = So

Yc = critcical depth (ft) = depth at which $FR^2 = 1$

Given: D, Q, Z, X, Dx, So, g, n, C

From Y1, Compute β, A, V, P, Rh, 1-FR^2, SF and Dy/Dx based on above equations

X + DX = next X location for depth computation (ft)

Fourth Order Runge- Kutta Calculation for Y at X + DX:

DY_1 =	1rst estimate of change in Y over DX;	$DY_1 = DX * (Dy/DX)_1$	DY/DX_1 based on Y_i at X
DY_2 =	2nd estimate of change in Y over DX ;	$DY_2 = DX * (Dy/DX)_2$	DY/DX_2 based on $Y_i + DY_1 i/2$ at X + DX/2
DY_3 =	3rd estimate of change in Y over DX;	$DY_3 = DX * (Dy/DX)_3$	DY/DX_3 based on $Y_i + DY_2/2$ at X + DX/2
DY_4 =	4th estimate of change in Y over DX;	$DY_4 = DX * (Dy/DX)_4$	DY/DX_4 based on $Y_i + DY_3$ at X + DX

$DY = (DY_1 + 2 * DY_2 + 2* DY_3 + DY_4) / 6$

$Y_{i+1} = Y_i + DY$

LEG 1 SUPERCRITICAL FLOW COMPUTATIONS

Existing Pipe

X1 =	**0.0** ft	**D =**	**1.094** ft				
X2 =	**21.5** ft	**Q =**	**0.245** cfs	**z1 =**	**49.0** ft		
Length =	21.5 ft			**Z2=**	**46.6** ft		
		Yc =	0.1984	So =	0.1100		
Y1 =	**0.14**	Yn =	0.0860				
Dx =	0.22 ft						
n =	**0.01**	**g =**	**32.2**	ρ =	1.94		
C =	**1.486**	**2g =**	**64.4**	γ =	62.40		

Critical depth for Circular channels

g = 32.2 ft/sec^2 Tolerence

D = 1.094 ft 1E-08

	Q	Yc	Critical flow area	Critical velocity	Top width	error
Critical Depth supercrit	0.245	0.198	0.116	2.11	0.84	0

	Q	Yn	Dia	slope	n
Normal Depth supercrit	0.245	0.086	1.094	11%	0.01

	end:	0.0863	0.245		7.11

1

x (ft)	Z (ft)	y (ft)	Q (cfs)	beta (rads)	area (ft^2)	V (ft/s)	WS EL (ft)	EGL (ft)	T	FR	1-FR^2	P (ft)	Rh (ft)	SF	dY1/dx	DY (ft)
0.00	48.97	0.142	0.245	0.738	0.0718	3.41	49.11	49.29	0.736	1.93	-2.712	0.807	0.089	0.013	-0.036	0.000
0.22	48.94	0.136	0.245	0.721	0.0674	3.64	49.08	49.28	0.722	2.10	-3.408	0.789	0.085	0.016	-0.028	-0.006
0.43	48.92	0.131	0.245	0.706	0.0636	3.86	49.05	49.28	0.710	2.27	-4.154	0.773	0.082	0.019	-0.022	-0.005
0.65	48.90	0.127	0.245	0.694	0.0606	4.05	49.02	49.28	0.700	2.42	-4.879	0.759	0.080	0.022	-0.018	-0.004
0.86	48.87	0.123	0.245	0.684	0.0581	4.22	48.99	49.27	0.691	2.57	-5.585	0.748	0.078	0.024	-0.015	-0.003
1.08	48.85	0.120	0.245	0.675	0.0560	4.38	48.97	49.27	0.683	2.70	-6.275	0.738	0.076	0.027	-0.013	-0.003
1.29	48.82	0.117	0.245	0.667	0.0542	4.53	48.94	49.26	0.677	2.82	-6.949	0.730	0.074	0.030	-0.012	-0.002
1.51	48.80	0.115	0.245	0.660	0.0526	4.66	48.92	49.25	0.671	2.93	-7.607	0.722	0.073	0.032	-0.010	-0.002
1.72	48.78	0.113	0.245	0.654	0.0512	4.79	48.89	49.25	0.665	3.04	-8.250	0.715	0.072	0.035	-0.009	-0.002
1.94	48.75	0.111	0.245	0.648	0.0500	4.90	48.86	49.24	0.661	3.14	-8.877	0.709	0.070	0.037	-0.008	-0.002
2.15	48.73	0.109	0.245	0.643	0.0489	5.02	48.84	49.23	0.656	3.24	-9.488	0.704	0.069	0.040	-0.007	-0.002
2.37	48.71	0.108	0.245	0.639	0.0479	5.12	48.81	49.22	0.652	3.33	-10.083	0.699	0.069	0.042	-0.007	-0.001
2.58	48.68	0.106	0.245	0.634	0.0470	5.22	48.79	49.21	0.648	3.42	-10.663	0.694	0.068	0.045	-0.006	-0.001
2.80	48.66	0.105	0.245	0.631	0.0462	5.31	48.76	49.20	0.645	3.50	-11.227	0.690	0.067	0.047	-0.006	-0.001
3.01	48.64	0.104	0.245	0.627	0.0454	5.40	48.74	49.19	0.642	3.57	-11.775	0.686	0.066	0.049	-0.005	-0.001
3.23	48.61	0.103	0.245	0.624	0.0447	5.48	48.71	49.18	0.639	3.65	-12.307	0.682	0.066	0.051	-0.005	-0.001
3.44	48.59	0.102	0.245	0.621	0.0441	5.56	48.69	49.17	0.636	3.72	-12.823	0.679	0.065	0.054	-0.004	-0.001
3.66	48.56	0.101	0.245	0.618	0.0435	5.63	48.67	49.16	0.633	3.78	-13.324	0.676	0.064	0.056	-0.004	-0.001
3.87	48.54	0.100	0.245	0.615	0.0430	5.70	48.64	49.15	0.631	3.85	-13.810	0.673	0.064	0.058	-0.004	-0.001
4.09	48.52	0.099	0.245	0.612	0.0425	5.77	48.62	49.13	0.629	3.91	-14.280	0.670	0.063	0.060	-0.004	-0.001
4.30	48.49	0.099	0.245	0.610	0.0420	5.83	48.59	49.12	0.627	3.97	-14.736	0.667	0.063	0.061	-0.003	-0.001
4.52	48.47	0.098	0.245	0.608	0.0416	5.89	48.57	49.11	0.625	4.02	-15.177	0.665	0.063	0.063	-0.003	-0.001
4.73	48.45	0.097	0.245	0.606	0.0412	5.95	48.54	49.09	0.623	4.07	-15.603	0.663	0.062	0.065	-0.003	-0.001
4.95	48.42	0.097	0.245	0.604	0.0408	6.00	48.52	49.08	0.621	4.12	-16.015	0.661	0.062	0.067	-0.003	-0.001
Internal row calculations not shown for brevity																
20.00	46.77	0.086	0.245	0.570	0.0345	7.09	46.85	47.63	0.590	5.17	-25.697	0.623	0.055	0.108	0.000	0.000
20.21	46.74	0.086	0.245	0.570	0.0345	7.10	46.83	47.61	0.590	5.17	-25.719	0.623	0.055	0.108	0.000	0.000
20.43	46.72	0.086	0.245	0.570	0.0345	7.10	46.81	47.59	0.590	5.17	-25.740	0.623	0.055	0.108	0.000	0.000
20.64	46.70	0.086	0.245	0.569	0.0345	7.10	46.78	47.57	0.590	5.17	-25.760	0.623	0.055	0.108	0.000	0.000
20.86	46.67	0.086	0.245	0.569	0.0345	7.10	46.76	47.54	0.590	5.17	-25.779	0.623	0.055	0.108	0.000	0.000
21.07	46.65	0.086	0.245	0.569	0.0345	7.10	46.74	47.52	0.590	5.18	-25.797	0.623	0.055	0.108	0.000	0.000
21.29	46.63	0.086	0.245	0.569	0.0345	7.11	46.71	47.50	0.590	5.18	-25.814	0.623	0.055	0.108	0.000	0.000
21.50	46.60	0.086	0.245	0.569	0.0345	7.11	46.69	47.47	0.590	5.18	-25.831	0.623	0.055	0.108	0.000	

LEG 2 SUPERCRITICAL FLOW COMPUTATIONS

New Pipe Extension

X2 =	21.5 ft	**D =**	**1.094** ft				
X3 =	**39.0** ft	**Q =**	**0.245** cfs	**Z2=**	46.6 ft		
Length =	17.5 ft			**Z3=**	**44.5** ft		
	20	Yc =	0.1984	So =	0.1200		
Y1 =	0.09	Yn =	0.0842				
Dx =	0.88 ft						
n =	**0.01**	**g =**	**32.2**	ρ =	1.94		
C =	**1.486**	**2g =**	**64.4**	γ =	62.40		

Critical depth for Circular channels

g = 32.2 ft/sec^2 Tolerence

D = 1.094 ft 1E-08

	Q	Yc	Critical flow area	Critical velocity	Top width	error
Critical Depth supercrit	0.245	0.198	0.116	2.11	0.84	0

	Q	Yn	Dia	slope	n
Normal Depth supercrit	0.245	0.084	1.094	12%	0.01

End:	0.0843	0.245		7.36	

x	Z	y (ft)	Q	beta (rads)	area	V	ws	EGL	T	FR	1-FR^2	P	Rh	SF	dY1/dx	DY
21.50	46.60	0.086	0.245	0.569	0.0345	7.11	46.69	47.47	0.590	5.18	-25.831	0.623	0.055	0.108	0.000	0.000
21.50	46.60	0.086	0.245	0.569	0.0345	7.11	46.69	47.47	0.590	5.18	-25.834	0.623	0.055	0.108	0.000	0.000
21.51	46.60	0.086	0.245	0.569	0.0345	7.11	46.69	47.47	0.590	5.18	-25.837	0.623	0.055	0.108	0.000	0.000
21.51	46.60	0.086	0.245	0.569	0.0345	7.11	46.69	47.47	0.590	5.18	-25.839	0.623	0.055	0.108	0.000	0.000
21.52	46.60	0.086	0.245	0.569	0.0345	7.11	46.68	47.47	0.590	5.18	-25.842	0.623	0.055	0.108	0.000	0.000
21.52	46.60	0.086	0.245	0.569	0.0345	7.11	46.68	47.47	0.590	5.18	-25.845	0.623	0.055	0.108	0.000	0.000
21.61	46.59	0.086	0.245	0.569	0.0345	7.11	46.67	47.46	0.590	5.18	-25.845	0.623	0.055	0.108	0.000	0.000
21.70	46.58	0.086	0.245	0.569	0.0345	7.11	46.66	47.45	0.589	5.19	-25.892	0.623	0.055	0.109	0.000	0.000
21.79	46.57	0.086	0.245	0.569	0.0344	7.12	46.65	47.44	0.589	5.19	-25.939	0.622	0.055	0.109	0.000	0.000
21.87	46.56	0.086	0.245	0.569	0.0344	7.12	46.64	47.43	0.589	5.19	-25.985	0.622	0.055	0.109	0.000	0.000
21.96	46.55	0.086	0.245	0.569	0.0344	7.13	46.63	47.42	0.589	5.20	-26.031	0.622	0.055	0.109	0.000	0.000
22.05	46.54	0.086	0.245	0.569	0.0344	7.13	46.62	47.41	0.589	5.20	-26.075	0.622	0.055	0.109	0.000	0.000
22.14	46.53	0.086	0.245	0.569	0.0343	7.14	46.61	47.40	0.589	5.21	-26.119	0.622	0.055	0.110	0.000	0.000
22.22	46.51	0.086	0.245	0.568	0.0343	7.14	46.60	47.39	0.589	5.21	-26.162	0.622	0.055	0.110	0.000	0.000
22.31	46.50	0.086	0.245	0.568	0.0343	7.14	46.59	47.38	0.589	5.22	-26.204	0.622	0.055	0.110	0.000	0.000
23.19	46.40	0.086	0.245	0.567	0.0341	7.18	46.48	47.29	0.588	5.25	-26.588	0.620	0.055	0.112	0.000	0.000
24.06	46.29	0.085	0.245	0.566	0.0340	7.21	46.38	47.19	0.587	5.28	-26.908	0.620	0.055	0.113	0.000	0.000
24.94	46.19	0.085	0.245	0.566	0.0339	7.24	46.27	47.09	0.586	5.31	-27.176	0.619	0.055	0.114	0.000	0.000
25.81	46.08	0.085	0.245	0.565	0.0338	7.26	46.17	46.99	0.586	5.33	-27.400	0.618	0.055	0.115	0.000	0.000
26.69	45.98	0.085	0.245	0.565	0.0337	7.28	46.06	46.89	0.585	5.35	-27.586	0.618	0.055	0.116	0.000	0.000
27.56	45.87	0.085	0.245	0.564	0.0336	7.29	45.96	46.78	0.585	5.36	-27.741	0.617	0.054	0.117	0.000	0.000
28.44	45.77	0.085	0.245	0.564	0.0336	7.30	45.85	46.68	0.585	5.37	-27.871	0.617	0.054	0.117	0.000	0.000
29.32	45.66	0.085	0.245	0.564	0.0335	7.31	45.75	46.58	0.584	5.38	-27.979	0.617	0.054	0.118	0.000	0.000
30.19	45.56	0.085	0.245	0.563	0.0335	7.32	45.64	46.48	0.584	5.39	-28.068	0.616	0.054	0.118	0.000	0.000
31.07	45.45	0.084	0.245	0.563	0.0334	7.33	45.54	46.37	0.584	5.40	-28.143	0.616	0.054	0.118	0.000	0.000
31.94	45.35	0.084	0.245	0.563	0.0334	7.34	45.43	46.27	0.584	5.40	-28.205	0.616	0.054	0.119	0.000	0.000
32.82	45.24	0.084	0.245	0.563	0.0334	7.34	45.33	46.16	0.584	5.41	-28.257	0.616	0.054	0.119	0.000	0.000
33.69	45.14	0.084	0.245	0.563	0.0334	7.34	45.22	46.06	0.584	5.41	-28.300	0.616	0.054	0.119	0.000	0.000
34.57	45.03	0.084	0.245	0.563	0.0334	7.35	45.12	45.96	0.584	5.42	-28.335	0.616	0.054	0.119	0.000	0.000
35.44	44.93	0.084	0.245	0.563	0.0333	7.35	45.01	45.85	0.584	5.42	-28.365	0.615	0.054	0.119	0.000	0.000
36.32	44.82	0.084	0.245	0.563	0.0333	7.35	44.91	45.75	0.583	5.42	-28.390	0.615	0.054	0.119	0.000	0.000
37.19	44.72	0.084	0.245	0.563	0.0333	7.35	44.80	45.64	0.583	5.42	-28.410	0.615	0.054	0.120	0.000	0.000
38.07	44.61	0.084	0.245	0.563	0.0333	7.36	44.70	45.54	0.583	5.42	-28.427	0.615	0.054	0.120	0.000	0.000
38.94	44.51	0.084	0.245	0.562	0.0333	7.36	44.59	45.43	0.583	5.43	-28.441	0.615	0.054	0.120	0.000	

Bonneville AFF : Flume Calcs *OUTER FLUME*

Assumptions

Pipe thickness **0.437** inch **g =** **32.2** ft/s^2

Pipe O.D. = **14** inches SDR 40 PVC

Mannings n = **0.010** (PVC)

drop in pipe = 2.00 feet

Diameter = 13.13 inches = 1.1 ft

Flow rate **20** gpm = 0.04 cfs

Nominal Flow Rate **Total L** **51.8** feet

	Z(elevation)		**Location**			**Slope**
U/s Flume IE. Elev	49.4 ft	X 1	**0** feet	interval 1		**0.11**
DS end bend 1	46.6 ft	X 2	**25.4** feet	interval 2		**0.08**
US end Bend 2	**44.5** ft	X 3	**51.8** feet			

	DEPTH (ft)	(in)	**Velocity** (ft/s)	**Normal Depth**
End of 1st Slope :	0.039	0.46	4.25	0.039 ft
End of 2nd Slope:	0.042	0.50	3.80	0.042 ft

minimum water depth:

0.039 ft = 0.5 inches

min. WS elevation **43.90** ft Min FROUDE No. = 4.0 (d/s of 1rst 5 feet)

Jet Impact Velocity

Beta = atan (slope) 0.080 radians = 4.6 degrees

Total velocity (Vt) at end of flume = 3.80 ft/s

vertical component (Vzi) = Vt * sin(beta 0.30 ft/s

horizontal comp (Vx) = Vt cos (beta) 3.79 ft/s

Vertical velocity (Vzi) at impact = sqrt(2g*(Z2-z3+y2/2) * Vz' 7.3 ft/s

Total Impact Velocity (Vti) at Impact = sqrt(Vzi^2 + Vx^2) = 8.2 ft/s

βi = Angle of Impact with Respect to horixontal = 1.09 rads = 62.5 degrees

Vti = 8.2 ft/s **OK, Vti is less than 25 ft/s**

Normal Depth Yn (in)	Locaton	X (feet)	Z elevation (feet)	Depth (in)	Velocity (ft)	FR
0.5	X 1	0	49.4	0.73	2.1	1.9
0.5	X 2	25.4	46.6	0.46	4.3	4.7
	X 3	51.8	44.5	0.50	3.8	4.00

RESULTS OF DIFFERENT FLOW CONDITIONS

Depth of Flow (in)	Discharge		Velocity (ft/s)		Impact Angle (deg)
	gpm	cfs	Exit	Impact	
0.5	20	0.04	3.8	8.2	62
1.0	100	0.22	6.2	10.7	55
1.5	210	0.47	7.8	12.6	52
2.0	400	0.89	9.5	14.7	50

EQUATIONS FOR FLUME CALCULATIONS

Equation for Water Depth

Reference: Henderson (1966), *Open Channel Flow*, Eq 7-52

$$\frac{dy}{dx} = \frac{So - Sf}{1 - Fr^2}$$

in which;

$\frac{dy}{dx}$	=	change in water depth with respect to channel length,			
So	=	channel slope,			
Sf	=	friction slope			
	=	$\frac{Q^2 n^2}{C^2 A^2 Rh^{1.33}}$			
Q	=	flow rate (cfs) in channel at location x,			
g	=	gravity = 32.2 ft/s^2			
A	=	cross-sectional flow area at location x (ft^2)			
	=	$D^2 \cdot \frac{(\beta - \cos\beta \cdot \sin\beta)}{4}$			
Fr^2	=	Froude number squared			
	=	TQ^2 / gA^3			

and:

y	=	flow depth (ft)
D	=	Inside Diameter of Pipe Flume (ft)
n	=	Manning roughness factor,
C	=	coefficient (1.486 for English units, 1 for metric units).
β	=	$\cos^{-1}\left(1 - \frac{2 \cdot y}{D}\right)$ (radians)
Rh	=	hydraulic radius (ft) = area/wetted perimeter,
	=	A/P
P	=	wetted perimeter (ft) = D * β
T	=	Top width of flow (ft)
	=	D * sin (β)

Computation Procedure Using 4th Order Runge-Kutta Methods

Assume initial depth Y1 = (Yc + Yn)/2 due to energy of false weir at u/s end

Yn = normal depth (ft) = depth at which SF = So

Yc = critcical depth (ft) = depth at which $FR^2 = 1$

Given: D, Q, Z, X, Dx, So, g, n, C

From Y1, Compute β, A, V, P, Rh, 1-FR^2, SF and Dy/Dx based on above equations

X + DX = next X location for depth computation (ft)

Fourth Order Runge- Kutta Calculation for Y at X + DX:

DY_1 =	1rst estimate of change in Y over DX;	$DY_1 = DX * (Dy/DX)_1$	DY/DX_1 based on Y_i at X
DY_2 =	2nd estimate of change in Y over DX ;	$DY_2 = DX * (Dy/DX)_2$	DY/DX_2 based on $Y_i + DY_1 i/2$ at X + DX/2
DY_3 =	3rd estimate of change in Y over DX;	$DY_3 = DX * (Dy/DX)_3$	DY/DX_3 based on $Y_i + DY_2/2$ at X + DX/2
DY_4 =	4th estimate of change in Y over DX;	$DY_4 = DX * (Dy/DX)_4$	DY/DX_4 based on $Y_i + DY_3$ at X + DX

$DY = (DY_1 + 2 * DY_2 + 2* DY_3 + DY_4) / 6$

$Y_{i+1} = Y_i + DY$

LEG 1 SUPERCRITICAL FLOW COMPUTATIONS

Existing Pipe

X1 =	**0.0** ft	**D =**	**1.094** ft				
X2 =	**25.4** ft	**Q =**	**0.045** cfs	**z1 =**	**49.4** ft		
Length =	25.4 ft			**Z2=**	**46.6** ft		
		Yc =	0.0837	So =	0.1100		
Y1 =	**0.06**	Yn =	0.0387				
Dx =	0.25 ft						
n =	**0.01**	**g =**	**32.2**	ρ =	1.94		
C =	**1.486**	**2g =**	**64.4**	γ =	62.40		

Critical depth for Circular channels

g = 32.2 ft/sec^2 Tolerence

D = 1.094 ft 1E-08

	Q	Yc	Critical flow area	Critical velocity	Top width	error
Critical Depth supercrit	0.045	0.084	0.033	1.35	0.58	-2.22E-15

	Q	Yn	Dia	slope	n
Normal Depth supercrit	0.045	0.039	1.094	11%	0.01

end:	0.0386	0.045		4.25

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x (ft)	Z (ft)	y (ft)	Q (cfs)	beta (rads)	area (ft^2)	V (ft/s)	WS EL (ft)	EGL (ft)	T	FR	1-FR^2	P (ft)	Rh (ft)	SF	dY1/dx	DY (ft)
0.00	49.39	0.061	0.045	0.478	0.0207	2.15	49.46	49.53	0.503	1.86	-2.473	0.522	0.040	0.015	-0.038	0.000
0.25	49.37	0.055	0.045	0.452	0.0177	2.52	49.42	49.52	0.478	2.31	-4.318	0.495	0.036	0.024	-0.020	-0.005
0.51	49.34	0.051	0.045	0.435	0.0158	2.81	49.39	49.51	0.461	2.68	-6.166	0.476	0.033	0.034	-0.012	-0.003
0.76	49.31	0.048	0.045	0.424	0.0146	3.04	49.36	49.50	0.450	2.97	-7.847	0.463	0.032	0.042	-0.009	-0.002
1.02	49.28	0.046	0.045	0.415	0.0138	3.23	49.33	49.49	0.441	3.22	-9.371	0.454	0.030	0.050	-0.006	-0.002
1.27	49.26	0.045	0.045	0.409	0.0132	3.38	49.30	49.48	0.435	3.43	-10.745	0.447	0.029	0.057	-0.005	-0.001
1.52	49.23	0.044	0.045	0.404	0.0127	3.51	49.27	49.46	0.430	3.60	-11.975	0.441	0.029	0.063	-0.004	-0.001
1.78	49.20	0.043	0.045	0.399	0.0123	3.62	49.24	49.45	0.425	3.75	-13.070	0.437	0.028	0.069	-0.003	-0.001
2.03	49.17	0.042	0.045	0.396	0.0120	3.71	49.21	49.43	0.422	3.88	-14.040	0.433	0.028	0.074	-0.003	-0.001
2.29	49.14	0.042	0.045	0.393	0.0118	3.79	49.19	49.41	0.419	3.99	-14.897	0.430	0.027	0.079	-0.002	-0.001
2.54	49.12	0.041	0.045	0.391	0.0116	3.86	49.16	49.39	0.417	4.08	-15.649	0.428	0.027	0.083	-0.002	0.000
2.79	49.09	0.041	0.045	0.389	0.0114	3.91	49.13	49.37	0.415	4.16	-16.309	0.426	0.027	0.087	-0.001	0.000
3.05	49.06	0.041	0.045	0.387	0.0113	3.96	49.10	49.34	0.413	4.23	-16.886	0.424	0.027	0.090	-0.001	0.000
3.30	49.03	0.040	0.045	0.386	0.0111	4.00	49.07	49.32	0.412	4.29	-17.389	0.422	0.026	0.092	-0.001	0.000
3.56	49.00	0.040	0.045	0.385	0.0110	4.04	49.04	49.30	0.411	4.34	-17.827	0.421	0.026	0.095	-0.001	0.000
3.81	48.98	0.040	0.045	0.384	0.0110	4.07	49.02	49.27	0.410	4.38	-18.207	0.420	0.026	0.097	-0.001	0.000
4.06	48.95	0.040	0.045	0.383	0.0109	4.09	48.99	49.25	0.409	4.42	-18.537	0.419	0.026	0.099	-0.001	0.000
4.32	48.92	0.040	0.045	0.382	0.0108	4.12	48.96	49.22	0.408	4.45	-18.823	0.418	0.026	0.100	-0.001	0.000
4.57	48.89	0.039	0.045	0.382	0.0108	4.13	48.93	49.20	0.408	4.48	-19.071	0.418	0.026	0.101	0.000	0.000
4.83	48.86	0.039	0.045	0.381	0.0107	4.15	48.90	49.17	0.407	4.50	-19.286	0.417	0.026	0.103	0.000	0.000
5.08	48.84	0.039	0.045	0.381	0.0107	4.16	48.88	49.15	0.407	4.52	-19.471	0.417	0.026	0.104	0.000	0.000
5.33	48.81	0.039	0.045	0.380	0.0107	4.18	48.85	49.12	0.406	4.54	-19.631	0.416	0.026	0.105	0.000	0.000
5.59	48.78	0.039	0.045	0.380	0.0106	4.19	48.82	49.09	0.406	4.56	-19.769	0.416	0.026	0.105	0.000	0.000
5.84	48.75	0.039	0.045	0.380	0.0106	4.20	48.79	49.07	0.406	4.57	-19.889	0.415	0.026	0.106	0.000	0.000
Internal row calculations not shown for brevity																
23.62	46.80	0.039	0.045	0.378	0.0105	4.25	46.84	47.12	0.404	4.65	-20.632	0.414	0.025	0.110	0.000	0.000
23.88	46.77	0.039	0.045	0.378	0.0105	4.25	46.81	47.09	0.404	4.65	-20.632	0.414	0.025	0.110	0.000	0.000
24.13	46.74	0.039	0.045	0.378	0.0105	4.25	46.78	47.06	0.404	4.65	-20.632	0.414	0.025	0.110	0.000	0.000
24.38	46.71	0.039	0.045	0.378	0.0105	4.25	46.75	47.03	0.404	4.65	-20.632	0.414	0.025	0.110	0.000	0.000
24.64	46.69	0.039	0.045	0.378	0.0105	4.25	46.72	47.00	0.404	4.65	-20.632	0.414	0.025	0.110	0.000	0.000
24.89	46.66	0.039	0.045	0.378	0.0105	4.25	46.70	46.98	0.404	4.65	-20.632	0.414	0.025	0.110	0.000	0.000
25.15	46.63	0.039	0.045	0.378	0.0105	4.25	46.67	46.95	0.404	4.65	-20.632	0.414	0.025	0.110	0.000	0.000
25.40	46.60	0.039	0.045	0.378	0.0105	4.25	46.64	46.92	0.404	4.65	-20.632	0.414	0.025	0.110	0.000	

LEG 2 SUPERCRITICAL FLOW COMPUTATIONS

New Pipe Extension

X2 =	25.4 ft	**D =**	**1.094** ft				
X3 =	**51.8** ft	**Q =**	**0.045** cfs	**Z2=**	46.6 ft		
Length =	26.4 ft			**Z3=**	**44.5** ft		
	20	Yc =	0.0837	So =	0.0797		
Y1 =	0.04	Yn =	0.0417				
Dx =	1.32 ft						
n =	**0.01**	**g =**	**32.2**	ρ =	1.94		
C =	**1.486**	**2g =**	**64.4**	γ =	62.40		

Critical depth for Circular channels

g = 32.2 ft/sec^2 Tolerence

D = 1.094 ft 1E-08

	Q	Yc	Critical flow area	Critical velocity	Top width	error
Critical Depth supercrit	0.045	0.084	0.033	1.35	0.58	-2.22E-15

	Q	Yn	Dia	slope	n
Normal Depth supercrit	0.045	0.042	1.094	8%	0.01

End:	0.0417	0.045		3.80	

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x	Z	y (ft)	Q	beta (rads)	area	V	ws	EGL	T	FR	1-FR^2	P	Rh	SF	dY1/dx	DY
25.40	46.60	0.039	0.045	0.378	0.0105	4.25	46.64	46.92	0.404	4.65	-20.632	0.414	0.025	0.110	0.001	0.000
25.41	46.60	0.039	0.045	0.378	0.0105	4.25	46.64	46.92	0.404	4.65	-20.608	0.414	0.025	0.110	0.001	0.000
25.41	46.60	0.039	0.045	0.378	0.0105	4.25	46.64	46.92	0.404	4.65	-20.584	0.414	0.025	0.110	0.001	0.000
25.42	46.60	0.039	0.045	0.378	0.0105	4.25	46.64	46.92	0.404	4.64	-20.560	0.414	0.025	0.110	0.001	0.000
25.43	46.60	0.039	0.045	0.378	0.0105	4.24	46.64	46.92	0.404	4.64	-20.537	0.414	0.025	0.109	0.001	0.000
25.44	46.60	0.039	0.045	0.378	0.0105	4.24	46.64	46.92	0.404	4.64	-20.513	0.414	0.025	0.109	0.001	0.000
25.57	46.59	0.039	0.045	0.378	0.0105	4.24	46.63	46.91	0.404	4.64	-20.513	0.414	0.025	0.109	0.001	0.000
25.70	46.58	0.039	0.045	0.379	0.0106	4.21	46.62	46.89	0.405	4.59	-20.108	0.415	0.025	0.107	0.001	0.000
25.83	46.57	0.039	0.045	0.380	0.0106	4.18	46.61	46.88	0.406	4.55	-19.735	0.416	0.026	0.105	0.001	0.000
25.96	46.56	0.039	0.045	0.381	0.0107	4.16	46.60	46.86	0.407	4.52	-19.391	0.417	0.026	0.103	0.001	0.000
26.10	46.55	0.039	0.045	0.382	0.0108	4.13	46.59	46.85	0.408	4.48	-19.073	0.418	0.026	0.101	0.001	0.000
26.23	46.54	0.040	0.045	0.382	0.0108	4.11	46.58	46.84	0.408	4.45	-18.779	0.418	0.026	0.100	0.001	0.000
26.36	46.53	0.040	0.045	0.383	0.0109	4.09	46.56	46.82	0.409	4.42	-18.508	0.419	0.026	0.098	0.001	0.000
26.49	46.51	0.040	0.045	0.384	0.0109	4.07	46.55	46.81	0.410	4.39	-18.257	0.420	0.026	0.097	0.001	0.000
26.62	46.50	0.040	0.045	0.384	0.0110	4.05	46.54	46.80	0.410	4.36	-18.025	0.420	0.026	0.096	0.001	0.001
27.94	46.40	0.041	0.045	0.389	0.0114	3.93	46.44	46.68	0.414	4.18	-16.467	0.425	0.027	0.087	0.000	0.001
29.26	46.29	0.041	0.045	0.391	0.0115	3.86	46.34	46.57	0.417	4.09	-15.730	0.427	0.027	0.083	0.000	0.000
30.58	46.19	0.041	0.045	0.392	0.0116	3.83	46.23	46.46	0.418	4.05	-15.375	0.429	0.027	0.082	0.000	0.000
31.89	46.08	0.042	0.045	0.392	0.0117	3.82	46.13	46.35	0.418	4.03	-15.202	0.429	0.027	0.081	0.000	0.000
33.21	45.98	0.042	0.045	0.393	0.0117	3.81	46.02	46.25	0.418	4.01	-15.118	0.429	0.027	0.080	0.000	0.000
34.53	45.87	0.042	0.045	0.393	0.0117	3.81	45.92	46.14	0.419	4.01	-15.077	0.430	0.027	0.080	0.000	0.000
35.85	45.77	0.042	0.045	0.393	0.0117	3.80	45.81	46.04	0.419	4.01	-15.057	0.430	0.027	0.080	0.000	0.000
37.16	45.66	0.042	0.045	0.393	0.0117	3.80	45.71	45.93	0.419	4.01	-15.048	0.430	0.027	0.080	0.000	0.000
38.48	45.56	0.042	0.045	0.393	0.0117	3.80	45.60	45.82	0.419	4.01	-15.043	0.430	0.027	0.080	0.000	0.000
39.80	45.45	0.042	0.045	0.393	0.0117	3.80	45.50	45.72	0.419	4.01	-15.041	0.430	0.027	0.080	0.000	0.000
41.12	45.35	0.042	0.045	0.393	0.0117	3.80	45.39	45.61	0.419	4.00	-15.039	0.430	0.027	0.080	0.000	0.000
42.43	45.24	0.042	0.045	0.393	0.0117	3.80	45.29	45.51	0.419	4.00	-15.039	0.430	0.027	0.080	0.000	0.000
43.75	45.14	0.042	0.045	0.393	0.0117	3.80	45.18	45.40	0.419	4.00	-15.039	0.430	0.027	0.080	0.000	0.000
45.07	45.03	0.042	0.045	0.393	0.0117	3.80	45.08	45.30	0.419	4.00	-15.038	0.430	0.027	0.080	0.000	0.000
46.39	44.93	0.042	0.045	0.393	0.0117	3.80	44.97	45.19	0.419	4.00	-15.038	0.430	0.027	0.080	0.000	0.000
47.70	44.82	0.042	0.045	0.393	0.0117	3.80	44.86	45.09	0.419	4.00	-15.038	0.430	0.027	0.080	0.000	0.000
49.02	44.72	0.042	0.045	0.393	0.0117	3.80	44.76	44.98	0.419	4.00	-15.038	0.430	0.027	0.080	0.000	0.000
50.34	44.61	0.042	0.045	0.393	0.0117	3.80	44.65	44.88	0.419	4.00	-15.038	0.430	0.027	0.080	0.000	0.000
51.66	44.51	0.042	0.045	0.393	0.0117	3.80	44.55	44.77	0.419	4.00	-15.038	0.430	0.027	0.080	0.000	