HARZA-EBASCO
Susitna Joint Venture
Document Number
80
Please Return To
DOCUMENT CONTROL

ACRES TASK 6
WATANA & DEVIL CANYON
TUNNEL RATING CALCULATIONS

HARZA-EBASCO
Susitna Joint Venture
Document Number
80
Please Return To
DOCUMENT CONTROL

2

nt Transmittal

Task 6

Please

To: Wayne Coleman
Harza Engineering Company

Date: March 9, 1983

Acres Job No.: P5701.70

Attention:

Project: Susitna Hydroelectric Project

Subject: Engineering Ca

The following are enclosed:

Description		Revision Number	Number of Each	Code*
Devil Canyon Diversion			1	
Watana Diversion: Tunnel Ratir			1	

*A — For Approval or Comments
B — For Construction
C — See Explanatory Letter
[✓ D] — For Information
E — For Purchasing
F — Drawings Approved
G — Drawings Approved Except as Noted
H —

Copies to: (First copy)

ACRES AMERICAN INCORPORATED
00 LIBERTY BANK BUILDING
MAIN AT COURT
BUFFALO, NEW YORK 14202
Telephone: 716-853-7525
Telex: 91-6423

Please Sign and Return Acknowledgement Copy.

Received by [illegible] on 3/11

Yours very truly,

David Crawford

ACRES AMERICAN INCORPORATED

David Crawford
Head Hydraulic Engineer

ACRES

Calculations

SUBJECT:

JOB NUMBER P5700.06.21
FILE NUMBER
SHEET 1 OF 4
BY DC DATE 18.5.81
APP DATE

To: TW GWOZDEK
FROM: D. Crawford

Subject: Susitna HEP
DEVIL CANYON – COFFERDAM/DIVERSION TUNNEL DESIGN.

As per your request we have determined rating curves for pressure tunnel diversions of given diameters. The following assumptions were made:

tunnel length = 2000 ft.
Manning's 'n' = 0.014
Coeff. of Discharge = 0.97
Constant TWEL = 880 ft.

The discharge coefficient assumes a rounded entrance with r/D of 0.10. Constant tailwater was assumed as the rating curve at D.C. tailrace indicates a variation of ten feet (878' to 888') for a discharge range of 9000 to 60,000 cfs; (Based on rating curve extrapolated to D.C. tailrace)

Diversion Flood Flows

Two possible scenarios exist for flood flows. The first assumes a 50-yr return period and the second a 20-yr return period. Both scenarios assumes flood control operation (surcharging) at Watana. To date no decision as to which flood period will be used is known to us.

The capacity, however, under the two scenarios

ACRES

Calculations

SUBJECT:

JOB NUMBER P5700.06.21
FILE NUMBER
SHEET 2 OF 4
BY DC DATE 19 Sep 81
APP DATE

can be determined from Figure 1., and are summarised in Table 1. The 50-yr flood peak is 53,000 cfs, and the 20-yr flood peak is 51,000. These values assume a capacity of

Table 1. Devil Canyon Diversion
HWEL and Tunnel Diameter

Diversion	WSEL upstream 50 YR	20 YR
1 x 40'	925	920
1 x 35'	960	955
2 x 30'	925	915
2 x 25'	970	960

45,000 cfs at Watana, with surcharging of approximately two feet.

A suggestion that has been proposed is to operate Watana during D.C. construction in a manner to reduce flood flows to DC. This would entail utilising the 100-yr flood storage allowance of 4 feet for smaller floods. This would reduce flood flows out of Watana Reservoir from 45000 to 38000 and 28000 for the 50 and 20 YR floods. This would then result in a D.C. inflow peak of

ACRES

Calculations

SUBJECT:

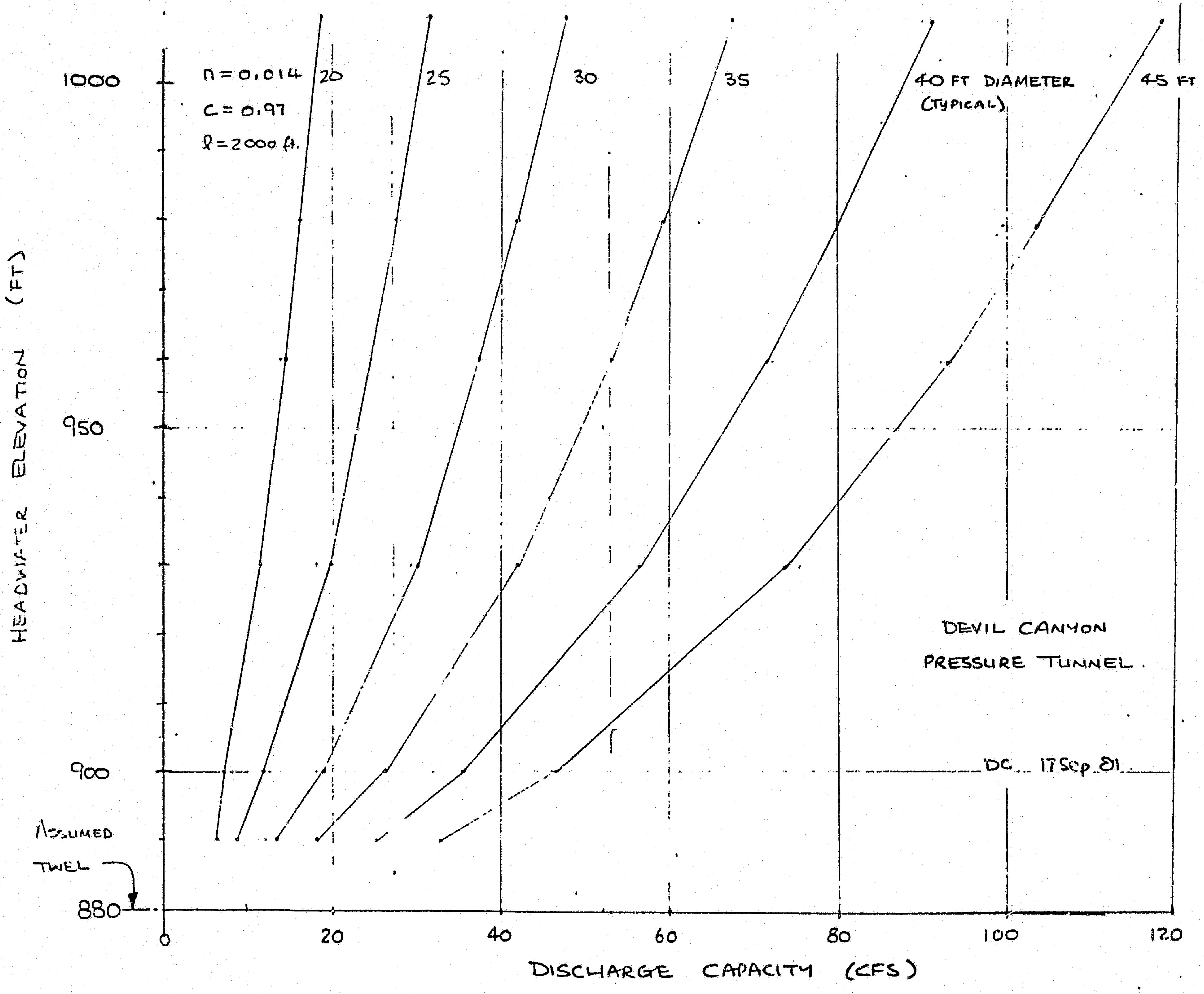
JOB NUMBER
FILE NUMBER
SHEET 3 OF 4
BY DATE
APP DATE

46,000 and 34000 cfs for 50 yr and 20yr return period respectively. The revised water surface elevations would be as in Table 2.

Table 2. Devil Canyon Diversion
HWEL and Tunnel Diameter
With flood operation at Watana

Diversion	WSEL upstream	
	50 YR	20YR
1x40	915	900 ±5
1x35	940	915
2x30	910	900 ±5
2x25	950	920
2x20	--	990

FORM NO. 152 REV. 1



DEVIL CANYON
PRESSURE TUNNEL.

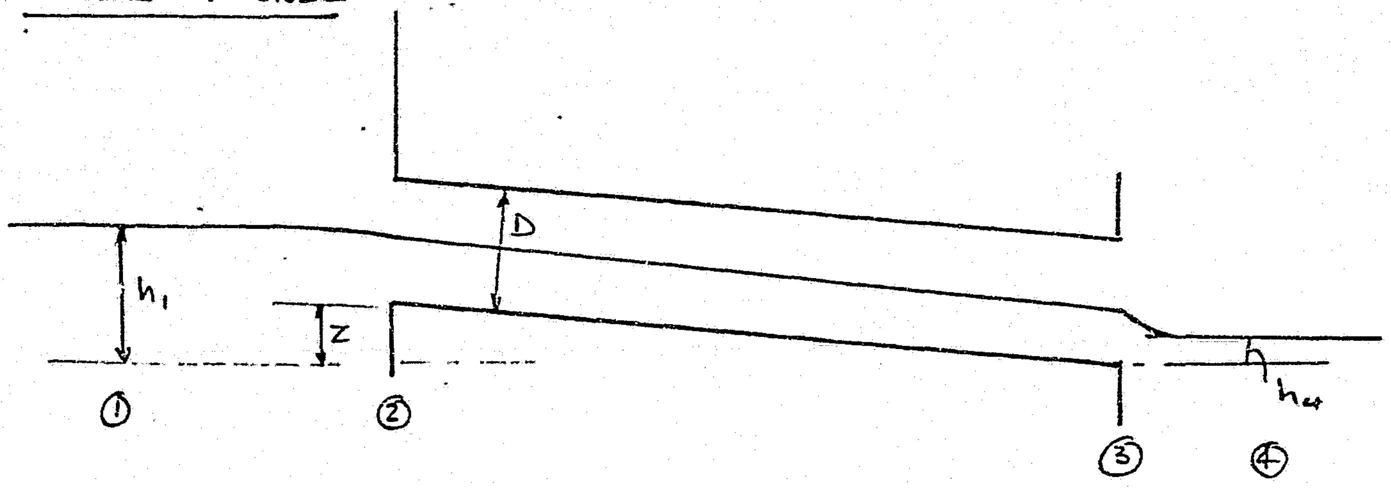
DC 17 Sep 81

Calculations

SUBJECT:

JOB NUMBER FS100.06.21
FILE NUMBER
SHEET 4 OF 4
BY PC DATE 17Sep81
~~APP~~ CHK'D RTS DATE 17 - 81

UPPER TUNNEL



Two stage flow.

(i) Tranquil flow throughout. (Type 3)

$$Q = CA_3\left[2g\left(h_1 + \frac{\alpha_1 v_1^2}{2g} - h_3 - h_{f_{1-2}} - h_{f_{2-3}}\right)\right]^{1/2}$$

(ii) Rapid flow at inlet: (type 5)

$$Q = C A_0 \sqrt{2g\,(h_1 - z)}$$

LOWER TUNNEL

Submerged outlet. (Type 4)

$$Q = C A_0 \left[\frac{2g\,(h_1 - h_4)}{1 + \frac{2g\,C^2 n^2 l}{R_0^{4/3}}}\right]^{1/2}$$

ACRES

Calculations

SUBJECT:

JOB NUMBER P5700.06.21.800
FILE NUMBER
SHEET OF
BY DC DATE 17Sep81
APP [illegible] DATE 17 . 81

$$Q = CA_0\left[\frac{2g(H_1-H_4)}{1+\frac{2gC^2n^2\ell}{R_0^{4/3}}}\right]^{1/2}$$

LOWER TUNNEL Type 4 PRESSURE TUNNEL

$C = .97$ with $r/D = .10$ (Tables, page 42 USGS).

$A_0 = \frac{\pi D^2}{4}$

$(h_1 - h_4) = \text{WSEL} - \text{TWEL} = \text{WSEL} - 880.$

$n = 0.014.$

$\ell = 2000'.$

$R_0^{4/3} = \left(\frac{D}{4}\right)^{4/3}$

$g = 32.2.$

$$\therefore \quad Q = .7618\,D^2\left[\frac{(\text{WSEL}-880)\times 64.4}{1+\frac{10.6962}{(D/4)^{4/3}}}\right]^{1/2}$$

$=$

WSEL	DISCHARGE DIAMETER 30	35	40	45		
890	13,234	18763	25287	32804	STO7	RCL3
900	18,716	26535	35761	46392	g x²	x⇄y
910					RCL2	÷
920					×	RCL4
930	29593	41955	56543	73552	STO0	×
940					RCL7	f √x
950					4	RCL0
960	37432	53070	71521	92784	÷	×
970					RCL6	GTO 00
980	41851	59334	79963	103735	f yˣ	
990					RCL1	
1000					x⇄y	
1010	47,717	67651	91172	118276	÷	
1020					1	
					+	

FORM NO. 152 REV. 1

Calculations

SUBJECT:

JOB NUMBER P5700.0621
FILE NUMBER
SHEET OF
BY RJS DATE 17Sep85
APP DATE

	WSEL	DISCHARGE (FT^3/SEC)	
		20'	25'
	890	5140	8697
	900	7259	12,271
	910		
	920		
–	930	11,493	19,447
	940		
	950		
–	960	14,537	24,599
	970		
–	930	16,253	27,502
	990		
	1000		
–	1010	18,531	31,357
	1020		

one	40'	925
1x	35	960
2 x	30	925
2 x	25	975

INFLOW OF 53,000 cfs.

ACRES

Calculations

SUBJECT:

JOB NUMBER

FILE NUMBER

SHEET OF

BY DATE

APP DATE

UPPER TUNNEL

Type 3

(i) $C =$ Figure 20. variable on $\left(\frac{h_1 - z}{D}\right)$ vs C.

$A_3 =$

$h_1 = (WSEL - \overset{\text{OUTLET}}{\text{INVERT}})$

$h_3 = Q / A_3$

$k = 1$

(ii) $Q = C A_0 \sqrt{2g (h_1 - z)}$

ACRES

Calculations

SUBJECT: SUSITNA HEP
FLOOD ROUTING

JOB NUMBER P570D.
FILE NUMBER
SHEET OF
BY RJS DATE 14 DEC 81
APP DATE

FROM D.C. CALCS.

WATANA DIVERSION

W.S. ELEVATION	PRESSURE TUNNEL 1)	FREE-FLOW TUNNEL	TOTAL
1520	40,560	14,440	55,000
1525	42,200	19,110	61,310
1530	43,850	27,310	71,160
1535	45,450	33,100	78,550
1540	46,930	41,990	88,920
1460	–	10,000	10,000
1470	–	17,570	17,570
1480	–	23,600	23,600
1490	–	28,640	28,640
1500	–	33,000	33,000
1510	–	36,930	36,930

1) OPENS AT 1520'

PEAK FLOWS - WATANA - ANNUAL

50 YR.	81,800
25 YR.	72,500

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT: WATANA DIVERSION

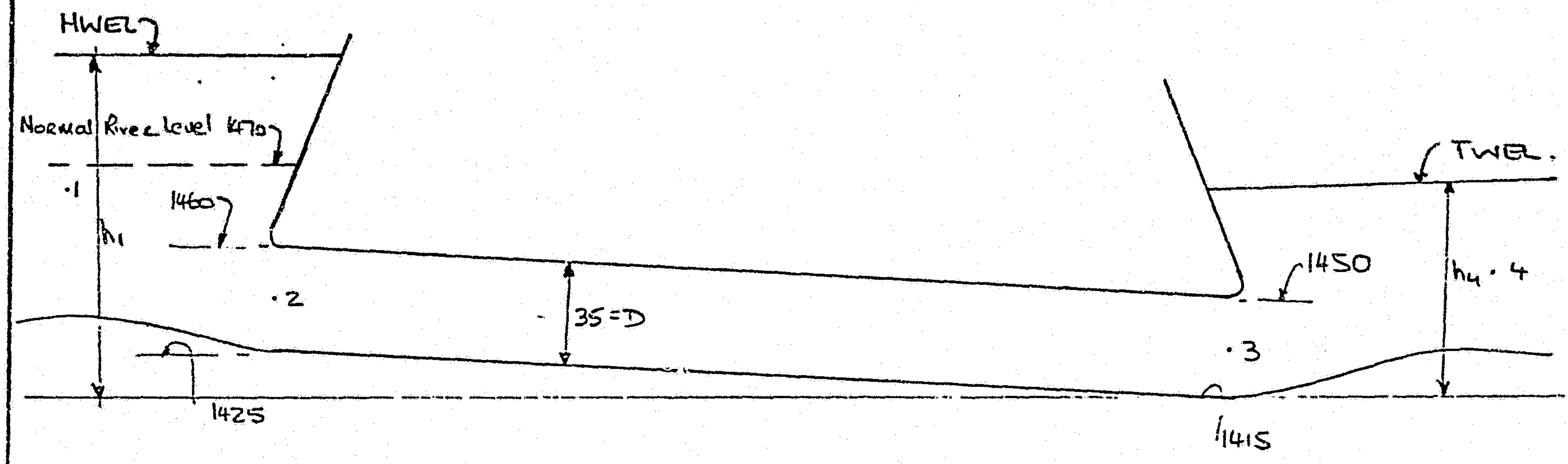
JOB NUMBER
FILE NUMBER
SHEET 1 OF
BY DC DATE 28 Oct 81
APP DATE

Diversion scheme consists of two tunnels -

(1) Pressure tunnel 35' diameter 

(2) "Free" flow 35' diameter.

(1)



Rating

Energy balance between ① and ④

$$\frac{V_1^2}{2g} + h_1 = h_4 + \frac{V_4^2}{2g} + h_{1-2} + h_{ent} + h_{2-3} + h_{ext} + h_{3-4}$$

Assume $\frac{V_1^2}{2g}$, $\frac{V_4^2}{2g}$, h_{1-2}, h_{3-4} negligible and = 0.

$$\therefore \quad h_1 = h_4 + h_{2-3} + (K_{ent} + K_{ext}) \frac{V_o^2}{2g}$$

where $V_o = Q/A_o = \frac{4Q}{\pi D^2}$

ACRES

Calculations

SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 2 OF
BY DC DATE 28Oct 81
APP DATE

$$h_1 = h_4 + \frac{V_0^2 n^2 l}{2.22 R^{4/3}} \cdot \frac{2g}{2g} + (K_{ent} + K_{ext}) \frac{V_0^2}{2g}$$

Assume :

$K_{ent} = 0.16$

$K_{ext} = 1.00$

$n = 0.014$

$l = 4700$ FT

$g = 32.2$ ft/s²

$$\therefore \quad (h_1 - h_4) = \left[\frac{(0.014)^2 \cdot 4700}{2.22 \, (8.75)^{4/3}} \times 64.4 + 0.16 + 1.00 \right] \frac{V_0^2}{2g}$$

$$= 0.041026 \cdot V_0^2$$

$$= 0.041026 \frac{Q^2}{A^2} = \frac{0.041026}{1093.56^2} \cdot Q^2$$

(Area using
(modified
horseshoe

$$\underline{h_1 - h_4 = 3.43065 \times 10^{-8} \, Q^2}$$

From TWL rating of Watana.

$h_4 = 1460 \Rightarrow Q = 26,500$

$h_4 = 1455 \Rightarrow Q = 7,500$

$h_4 = 1465 \Rightarrow Q = 55,000$

$$\Rightarrow \quad \ln h_4 = 0.0034377 \ln Q + 7.252088$$

Calculations

SUBJECT:

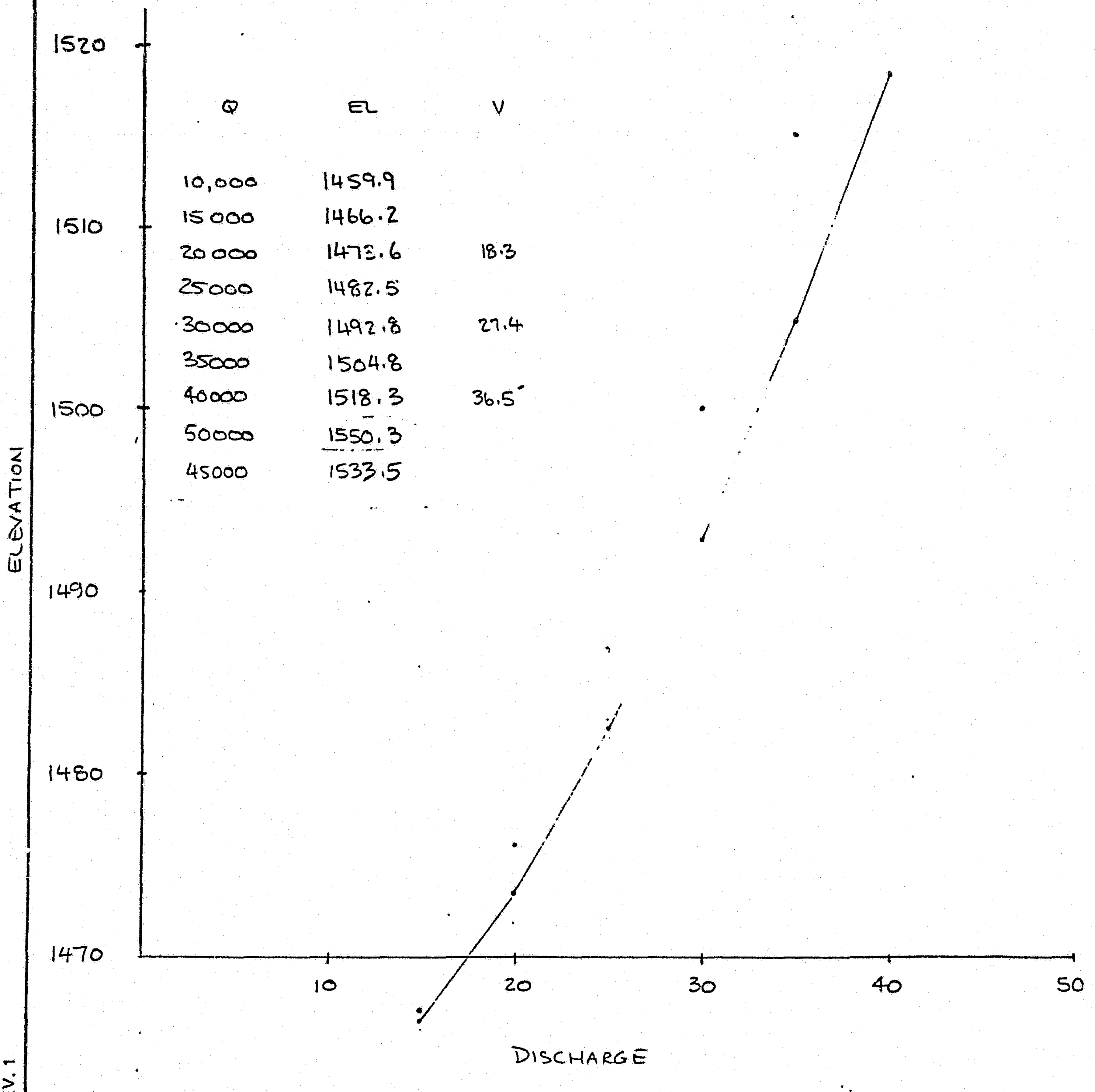
JOB NUMBER

FILE NUMBER

SHEET 3 OF

BY DC DATE 28 OCT 81

APP DATE



Q	EL	V
10,000	1459.9	
15000	1466.2	
20000	1473.6	18.3
25000	1482.5	
30000	1492.8	27.4
35000	1504.8	
40000	1518.3	36.5
50000	1550.3	
45000	1533.5	

$$EL = e^{0.0034377 \ln Q + 7.252088} + 3.43065 \times 10^{-8} Q^2$$

FORM NO. 152 REV. 1

ACRES

Calculations

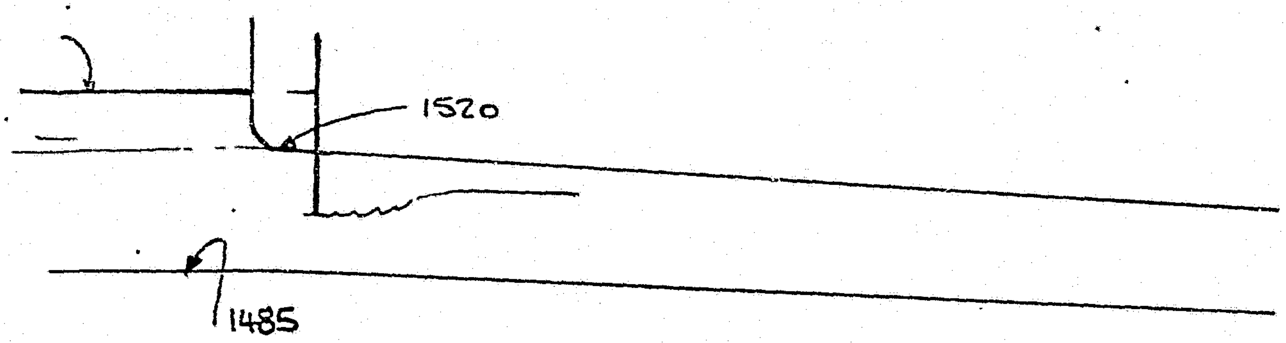
SUBJECT:

JOB NUMBER
FILE NUMBER
SHEET 4 OF
BY DC DATE 29 oct 81
APP DATE

(2) 'FREE' FLOW TUNNEL

ASSUME

GATE CONTROL TO HOLD BACK ICE.



GATE CONTROL SUCH THAT GATE FULL OPEN WHEN $\frac{\text{HWEL} - \text{SILL}}{D} \geq 1.4.$

ie. at HWEL $(1.4 \times 35 + 1485) = 1534.$

FOR PARTIAL GATE OPENINGS. DISCHARGE IS GIVEN BY

$$Q = C\, G_o\, B \sqrt{2gH}$$

REF:

Use hydraulic design criteria, sheet 320-1

Recommended

GATE OPENING %	C
10	·73
20	·73
30	·74
40	·74
50	·75
60	·77
70	·78
80	·80

FORM NO. 152 REV. 1

ACRES

Calculations

SUBJECT:

JOB NUMBER

FILE NUMBER

SHEET 5 OF

BY DC DATE 29 OCT

APP DATE

For rating curve

$$Q = C\,G_o\,B\sqrt{2gH'}$$

$H' = HWEL - (INVERT + C\,G_o)$ FT.

G_o = Gate opening above invert in FT.

B = width of gate opening FT.

C = discharge coeff.

WATANA

$B = 35'$ .. (Q)

G_o = PERCENT × 35 ..(Q).

$H' = HWEL - 1485 - C\,G_o$.

HWEL	DISCHARGE					
	GATE OPENING % (FT)					
	80 (28)	70 (24.5)	60 (21)	50 (17.5)	40 (14)	100 (35) C = ·85
1520	22,300	21,400	19,710	17240	14,440 *	–
1525	26,400	24,530	22,170	19,110 *	15,840	–
1530	29,900	27,310 *	24,390	20,810	17,130	–
1535	33,100 *	29,830	26,420	22,390	18,320	~~37,600~~ 40,000
1540.	35,900	32,160	28,300	23,860	19,440	41,990. *

$Q_{FULL} = 705.5\sqrt{2gH'}$

PROGRAM OVER

[illegible]

FORM NO. 152 REV. 1