APPENDIX 7-11

As-Built Calculations for
Diversions and Culverts

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

Richard B. White

Richard B. White, P.E.

2/10/88

AS-BUILT REVIEW OF DIVERSIONS AND CULVERTS – CRANDALL CANYON MINE –

Undisturbed Areas

No alteration occurred to watersheds draining to proposed undisturbed-area diversions. Thus, check to determine that correct sizing was used.

Diversion No.	Proposed Size	Actual Size
UD-1	42" CMP	42" CMP
UD-2	V-ditch, 1.5:1 sides, 1' deep	See below
UD-3	18" CMP	18" PVC

Summary:

UD-1 → Constructed as designed OK

UD-2 → See cross sections F-F' and G-G' on Plate 3
In both cases, the actual cross section is larger than the design cross section. Thus, the actual velocity will be lower than the design velocity. OK

UD-3 → PVC has a lower roughness than CMP. Thus, the diversion as installed has a higher capacity than the design condition, making the diversion adequate. OK

Stilling Basin at Downstream End of UD-2

Item	Design	Actual	
Surface area (ft^2)	150	152	OK
Depth (ft)	3.0	4.4	OK
Volume (ft^3)	130	660	OK
Overflow device	12" CMP	12" CMP	OK

Basin is adequately sized.

Disturbed Areas – Diversion Ditches

Model input:

Diversion No.	Watershed Area (ac)				Average Curve Number [a]
	Undisturbed	Disturbed	Reclaimed	Total	
DD-1	0.11	0.00	0.10	0.21	72
DD-2	0.00	0.06	0.11	0.17	80
DD-3 [b]	0.27	0.59	0.34	1.20	81
DD-4	0.00	0.09	0.13	0.22	81
DD-5 [c]	3.70	1.46	1.10	6.26	75
DD-6 [d]	3.70	1.58	1.10	6.38	75
DD-7	0.05	0.09	0.31	0.45	77
DD-8	3.36	0.44	0.23	4.03	72
DD-9	0.00	0.13	0.13	0.26	82
DD-10 [e]	5.74	2.45	1.94	10.13	75
DD-11	1.94	0.02	0.15	2.11	70

(a) Based on CN = 69 → undisturbed
CN = 90 → disturbed
CN = 75 → reclaimed

(b) Includes WSDD-1 thru WSDD-3 (See Plate 7-5c for Watersheds)

(c) Includes drainage to DD-3, DD-4 & DD-8 plus WSDD-5

(d) Includes drainage to DD-5 plus WSDD-6

(e) Includes drainage to DD-6, DD-7, DD-9, and DD-11 plus WSDD-10

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

Time of concentration calculations (use CN and upland methods):

DD-1 → $l = 165$ ft
$\bar{CN} = 72 \Rightarrow S = 3.89$
$Y = 39.9\%$

$$L = \frac{(165)^{0.8}(4.89)^{0.7}}{(1900)(39.9)^{0.5}} = 0.02 \text{ hr}$$

$T_c = (1.67)(0.02) = \underline{0.03 \text{ hr}}$

DD-2 → Travel distance = 140 ft (NNW to SSE)
Velocity = 3.5 ft/s (see attached chart for "short pasture grass", 25% slope)

$$T_c = \frac{140 \text{ ft}}{3.5 \text{ ft/s}} = 40 \text{ s} = \underline{0.01 \text{ hr}}$$

DD-3 → $l = 330$ ft
$\bar{CN} = 81 \Rightarrow S = 2.35$
$Y = 29.8\%$

$L = 0.02$ hr

$T_c = (1.67)(0.02) = \underline{0.04 \text{ hr}}$

DD-4 → Travel distance = 210 ft (down channel)
Velocity = 6.4 ft/s (see attached chart for "small upland gullies", 10% slope)

$$T_c = \frac{210 \text{ ft}}{6.4 \text{ ft/s}} = \underline{0.01 \text{ hr}}$$

DD-5 → To the end of DD-8, $T_c = 0.13$ hr (see DD-8 calcs.)

From DD-8 to end of DD-5, travel distance = 370 ft @ 10% slope
Velocity = 6.4 ft/s

$$(T_c)_2 = \frac{370 \text{ ft}}{6.4 \text{ ft/s}} = 0.02 \text{ hr}$$

$T_c = 0.13 + 0.02 = \underline{0.15 \text{ hr}}$

DD-6 → Travel distance from DD-5 thru DD-6 = 220 ft
Velocity = 4.5 ft/s (see attached chart for "small upland gullies", 5% slope)

$$T_c = 0.15 \text{ hr} + \left(\frac{220 \text{ ft}}{4.5 \text{ ft/s}}\right) / 3600 \text{ s/hr} = \underline{0.16 \text{ hr}}$$

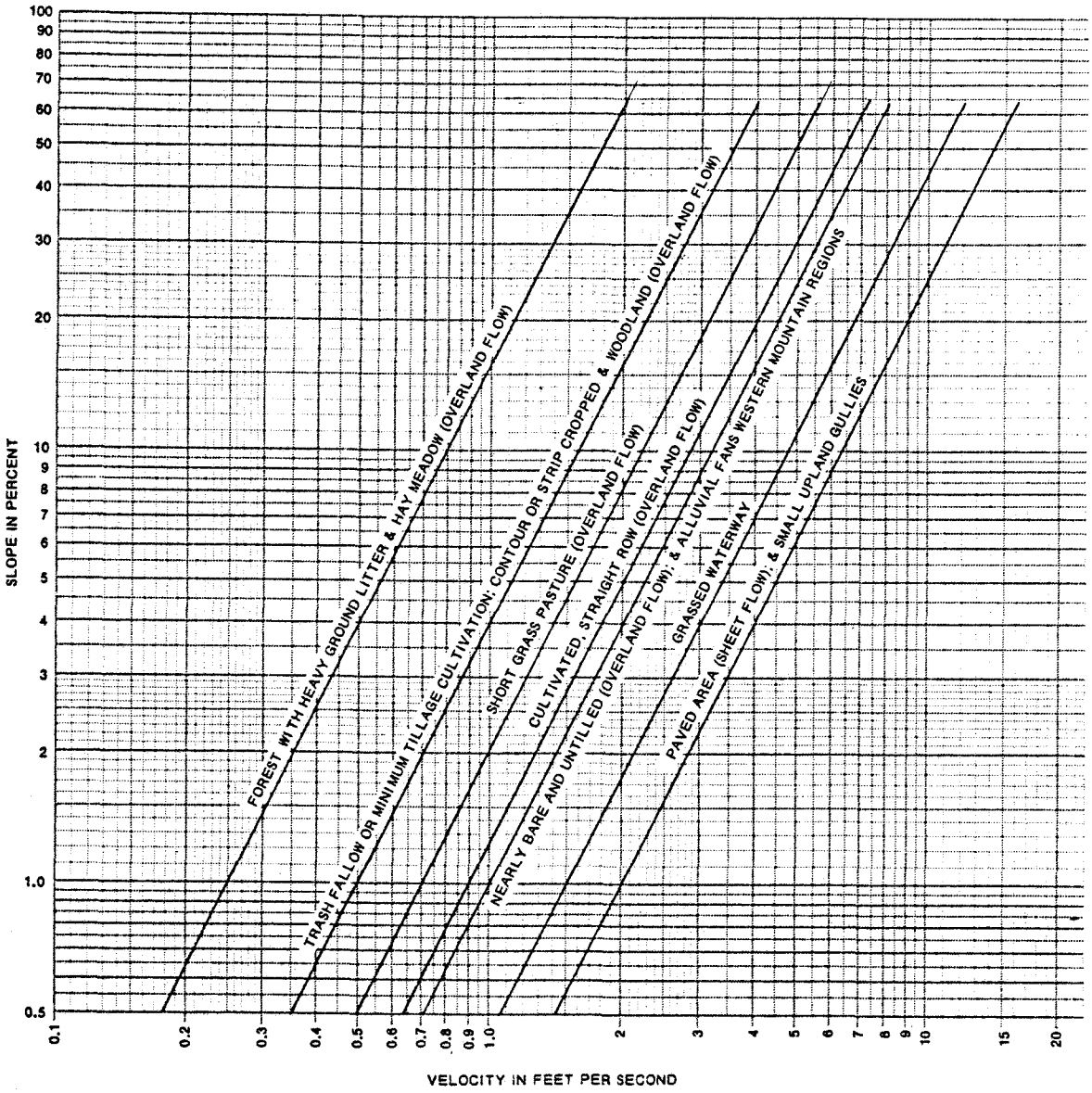

Figure 15.2.--Velocities for upland method of estimating T_c

Source: NEH-4

DD-7 → Travel distance = 110 ft
Velocity = 5.8 ft/s (see attached chart for "short pasture grass", 70% slope)

$$T_c = \frac{110\,ft}{5.8\,ft/s} = \underline{\underline{0.01\ hr}}$$

DD-8 → Undisturbed travel distance = 750 ft @ 66.1% slope
Velocity = 2.1 ft/s ("Forest w/ heavy litter")

$$(T_c)_1 = \frac{750\,ft}{2.1\,ft/s} = 360\ s$$

Disturbed travel distance = 540 ft @ 5.4% slope
Velocity = 4.6 ft/s

$$(T_c)_2 = \frac{540\,ft}{4.6\,ft/s} = 120\ s$$

$$T_c = (360\ s + 120\ s) = 480\ s = \underline{\underline{0.13\ hr}}$$

DD-9 → Travel distance = 310 ft @ 6.7% slope
Velocity = 5.2 ft/s ("small upland gullies")

$$T_c = \frac{310\,ft}{5.2\,ft/s} = \underline{\underline{0.02\ hr}}$$

DD-10 → To the end of DD-6, T_c = 0.16 hr

From DD-6 to end of DD-10, travel distance = 160 ft @ 33.3% slope
Velocity = 12 ft/s ("small upland gullies")

$$(T_c)_2 = \frac{160\,ft}{12\,ft/s} = 0.01\ hr$$

$$T_c = 0.16 + 0.01 = \underline{\underline{0.17\ hr}}$$

DD-11 → Travel distance = 550 ft @ 70% slope
Velocity = 2.1 ft/s ("Forest w/ heavy litter")

$$T_c = \frac{550\,ft}{2.1\,ft/s} = \underline{\underline{0.07\ hr}}$$

Hydrograph results → attached (pg. 6 - 11 of this calc.)

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

IDENTIFICATION: DIVERSION DD-1

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.001 SQ. MI.
        DEPTH =  2.50 IN.              CN = 72.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.03 HR.
*************************************************************
```

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

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.5286 INCHES
     INITIAL ABSTRACTION =  0.7778 INCHES
     PEAK FLOW =      0.37 CFS   ( 0.5781 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.5297 INCHES
*************************************************************
```

IDENTIFICATION: DIVERSION DD-2

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.001 SQ. MI.
        DEPTH =  2.50 IN.              CN = 80.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.01 HR.
*************************************************************
```

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

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.8889 INCHES
     INITIAL ABSTRACTION =  0.5000 INCHES
     PEAK FLOW =      0.58 CFS   ( 0.9063 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.8907 INCHES
*************************************************************
```

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

IDENTIFICATION: DIVERSION DD-3

INPUT SUMMARY:

```
*************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.002 SQ. MI.
        DEPTH =  2.50 IN.            CN = 81.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.04 HR.
*************************************************************
```

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

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.9424 INCHES
     INITIAL ABSTRACTION =  0.4691 INCHES
     PEAK FLOW =     1.28 CFS  ( 0.9883 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.9443 INCHES
*************************************************************
```

IDENTIFICATION: DIVERSION DD-4

INPUT SUMMARY:

```
*************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.001 SQ. MI.
        DEPTH =  2.50 IN.            CN = 81.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.01 HR.
*************************************************************
```

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

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.9424 INCHES
     INITIAL ABSTRACTION =  0.4691 INCHES
     PEAK FLOW =     0.65 CFS  ( 1.0000 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.9443 INCHES
*************************************************************
```

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

IDENTIFICATION: DIVERSION DD-5

INPUT SUMMARY:

```
************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.010 SQ. MI.
        DEPTH =  2.50 IN.            CN = 75.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.15 HR.
************************************************************
```

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

OUTPUT SUMMARY:

```
************************************************************
     TOTAL RUNOFF DEPTH =  0.6505 INCHES
     INITIAL ABSTRACTION =  0.6667 INCHES
     PEAK FLOW =     4.02 CFS  ( 0.6228 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.6518 INCHES
************************************************************
```

IDENTIFICATION: DIVERSION DD-6

INPUT SUMMARY:

```
************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.010 SQ. MI.
        DEPTH =  2.50 IN.            CN = 75.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.16 HR.
************************************************************
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************************************************************
```

OUTPUT SUMMARY:

```
************************************************************
     TOTAL RUNOFF DEPTH =  0.6505 INCHES
     INITIAL ABSTRACTION =  0.6667 INCHES
     PEAK FLOW =     3.96 CFS  ( 0.6140 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.6518 INCHES
************************************************************
```

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

IDENTIFICATION: DIVERSION DD-7

INPUT SUMMARY:

```
************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.001 SQ. MI.
        DEPTH =  2.50 IN.            CN = 77.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.01 HR.
************************************************************
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************************************************************
```

OUTPUT SUMMARY:

```
************************************************************
     TOTAL RUNOFF DEPTH =  0.7403 INCHES
     INITIAL ABSTRACTION =  0.5974 INCHES
     PEAK FLOW =      0.52 CFS  ( 0.8125 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.7418 INCHES
************************************************************
```

IDENTIFICATION: DIVERSION DD-8

INPUT SUMMARY:

```
************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.006 SQ. MI.
        DEPTH =  2.50 IN.            CN = 72.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.13 HR.
************************************************************
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************************************************************
```

OUTPUT SUMMARY:

```
************************************************************
     TOTAL RUNOFF DEPTH =  0.5286 INCHES
     INITIAL ABSTRACTION =  0.7778 INCHES
     PEAK FLOW =      1.97 CFS  ( 0.5078 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.5297 INCHES
************************************************************
```

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

IDENTIFICATION: DIVERSION DD-9

INPUT SUMMARY:

```
*************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.001 SQ. MI.
        DEPTH =  2.50 IN.            CN = 82.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.02 HR.
*************************************************************
```

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

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.9980 INCHES
     INITIAL ABSTRACTION =  0.4390 INCHES
     PEAK FLOW =     0.67 CFS  ( 1.0313 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  1.0000 INCHES
*************************************************************
```

IDENTIFICATION: DIVERSION DD-10

INPUT SUMMARY:

```
*************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.016 SQ. MI.
        DEPTH =  2.50 IN.            CN = 75.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.17 HR.
*************************************************************
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*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.6505 INCHES
     INITIAL ABSTRACTION =  0.6667 INCHES
     PEAK FLOW =     6.27 CFS  ( 0.6069 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.6518 INCHES
*************************************************************
```

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

IDENTIFICATION: DIVERSION DD-11

INPUT SUMMARY:

```
*************************************************************
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.003 SQ. MI.
        DEPTH =  2.50 IN.            CN = 70.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.07 HR.
*************************************************************
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*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.4552 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.91 CFS  ( 0.4688 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.4562 INCHES
*************************************************************
```

Determine adequacy of actual cross sections based on flow rates presented on pg. 6-11 of this calc. See cross sections on Plate 3. For ease of calculation, initially assume equal side slopes on both sides of channel, with both side slopes being equal to the minimum actual slope (thus making the cross section conservatively small). If the velocity as calculated with this condition is acceptable, the channel design will be considered adequate. If the velocity is > 5 ft/s under this conservative condition, calculate velocity using actual non-uniform cross section.

TRAP1 results:

DD-1 (cross section H-H'):

Bed Slope =	.25	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.5	
Flow Depth =	.2172315	feet
Cross Sectional Area =	9.437906E-02	square feet
Wetted Perimeter =	.9714888	feet
Hydraulic Radius =	9.714889E-02	feet
Discharge =	.37	cubic feet/sec
Velocity =	3.920361	feet/sec
Froude Number =	1.482302	< 5.0 ⇒ OK

DD-2 (cross section N-N'):

Bed Slope =	.03	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.5	
Flow Depth =	.3813819	feet
Cross Sectional Area =	.2909044	square feet
Wetted Perimeter =	1.705592	feet
Hydraulic Radius =	.1705592	feet
Discharge =	.58	cubic feet/sec
Velocity =	1.993783	feet/sec
Froude Number =	.5689443	< 5.0 OK

DD-3 (cross section I-I'):

Bed Slope =	.03	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.8333	
Flow Depth =	.6473446	feet
Cross Sectional Area =	.5028862	square feet
Wetted Perimeter =	2.022417	feet
Hydraulic Radius =	.248656	feet
Discharge =	1.28	cubic feet/sec
Velocity =	2.545308	feet/sec
Froude Number =	.5574997	<5.0 ok

DD-4 (cross section C-C'):

Bed Slope =	.095	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.625	
Flow Depth =	.3534331	feet
Cross Sectional Area =	.199864	square feet
Wetted Perimeter =	1.333713	feet
Hydraulic Radius =	.1498554	feet
Discharge =	.65	cubic feet/sec
Velocity =	3.252212	feet/sec
Froude Number =	.964045	<5.0 ok

DD-5 (cross section E-E'):

Bed Slope =	.08	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.7143	
Flow Depth =	.7700968	feet
Cross Sectional Area =	.830252	square feet
Wetted Perimeter =	2.649814	feet
Hydraulic Radius =	.3133246	feet
Discharge =	4.02	cubic feet/sec
Velocity =	4.841903	feet/sec
Froude Number =	.9723341	<5.0 ok

DD-6 (cross section J-J'):

Bed Slope =	.065	
Manning's N =	.04	
Bottom Width =	1.3	feet
Channel Side Slope =	.6667	
Flow Depth =	.4594088	feet
Cross Sectional Area =	.9138001	square feet
Wetted Perimeter =	2.956365	feet
Hydraulic Radius =	.3090959	feet
Discharge =	3.96	cubic feet/sec
Velocity =	4.333552	feet/sec
Froude Number =	1.126721	< 5.0 ok

DD-7 (cross section L-L'):

Bed Slope =	.005	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	1	
Flow Depth =	.7044704	feet
Cross Sectional Area =	.4962785	square feet
Wetted Perimeter =	1.992543	feet
Hydraulic Radius =	.2490679	feet
Discharge =	.52	cubic feet/sec
Velocity =	1.047799	feet/sec
Froude Number =	.2199979	< 5.0 ok

DD-8 (cross section B-B'):

Bed Slope =	.051	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.4167	
Flow Depth =	.5064729	feet
Cross Sectional Area =	.6155863	square feet
Wetted Perimeter =	2.633479	feet
Hydraulic Radius =	.233754	feet
Discharge =	1.97	cubic feet/sec
Velocity =	3.200202	feet/sec
Froude Number =	.7924489	< 5.0 ok

DD-9 (cross section K-K'):

Bed Slope =	.065	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.4762	
Flow Depth =	.3413474	feet
Cross Sectional Area =	.244683	square feet
Wetted Perimeter =	1.587882	feet
Hydraulic Radius =	.154094	feet
Discharge =	.67	cubic feet/sec
Velocity =	2.738237	feet/sec
Froude Number =	.825933	< 5.0 OK

DD-10 (cross section M-M'):

Bed Slope =	.3333	
Manning's N =	.04	
Bottom Width =	8	feet
Channel Side Slope =	.4	
Flow Depth =	.1357868	feet
Cross Sectional Area =	1.132389	square feet
Wetted Perimeter =	8.731234	feet
Hydraulic Radius =	.1296941	feet
Discharge =	6.27	cubic feet/sec
Velocity =	5.536766	feet/sec
Froude Number =	2.647983	> 5.0. However, channel riprapped for V = 8.2 ft/s Thus, channel OK

DD-11 (cross section O-O'):

Bed Slope =	.03	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	1	
Flow Depth =	.6230584	feet
Cross Sectional Area =	.3882018	square feet
Wetted Perimeter =	1.762275	feet
Hydraulic Radius =	.2202844	feet
Discharge =	.91	cubic feet/sec
Velocity =	2.344142	feet/sec
Froude Number =	.5233492	

Disturbed Areas - Culverts

Culvert No.	Type		Inflow (cfs)		Adequacy
	Design	Actual	Design	Actual	
C-1	18" CMP	18" CMP	4.15	3.25 (a)	OK
C-2	24" CMP	24" CMP	4.15	4.02 (b)	OK
C-3	24" CMP	24" CMP	4.15	3.96 (c)	OK
C-4	24" CMP	24" CMP	0.67	1.43 (d)	OK (f)
C-5	12" CMP	12" PVC	1.09	0.91 (e)	OK
C-6	12" CMP	12" CMP	(g)	(g)	OK

(a) DD-3 + DD-8 flows

(b) DD-5 flow

(c) DD-6 flow

(d) DD-7 + DD-11 flows

(e) DD-11 flow

(f) Capacity of 24" CMP (w/ HW/D = 1.0) is 13.0 cfs

(g) Outflow from stilling basin. With larger actual basin than designed, outflow culvert (w/ additional routing) is considered adequate.