APPENDIX C

CULVERT ANALYSIS CALCULATIONS

PIPE CULVERT ANALYSIS
COMPUTATION OF CULVERT PERFORMANCE CURVE

December 2, 2002

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Culvert Diameter (ft)	1.5
FHWA Chart Number	2
FHWA Scale Number (Type of Culvert Entrance)	3
Manning's Roughness Coefficient (n-value)	0.024
Entrance Loss Coefficient of Culvert Opening	0.8
Culvert Length (ft)	49.9
Invert Elevation at Downstream end of Culvert (ft)	0.0
Invert Elevation at Upstream end of Culvert (ft)	0.2
Culvert Slope (ft/ft)	0.005
Starting Flow Rate (cfs)	1.0
Incremental Flow Rate (cfs)	1.0
Ending Flow Rate (cfs)	16.0
Starting Tailwater Depth (ft)	0.0
Incremental Tailwater Depth (ft)	0.0
Ending Tailwater Depth (ft)	0.0

COMPUTATION RESULTS

Flow Rate (cfs)	Tailwater Depth (ft)	Headwater (ft) Inlet Control	Headwater (ft) Outlet Control	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
1.0	0.0	0.52	0.61	0.51	0.37	0.37	2.92
2.0	0.0	0.77	0.88	0.75	0.53	0.53	3.55
3.0	0.0	0.99	1.11	0.97	0.66	0.66	4.02
4.0	0.0	1.19	1.32	1.22	0.77	0.77	4.41
5.0	0.0	1.39	1.52	1.5	0.86	0.86	4.77
6.0	0.0	1.58	1.75	1.5	0.95	0.95	5.11
7.0	0.0	1.78	1.82	1.5	1.02	1.02	5.44
8.0	0.0	2.02	2.12	1.5	1.1	1.1	5.78
9.0	0.0	2.24	2.45	1.5	1.16	1.16	6.13
10.0	0.0	2.58	2.8	1.5	1.22	1.22	6.5
11.0	0.0	2.95	3.18	1.5	1.27	1.27	6.89
12.0	0.0	3.36	3.58	1.5	1.31	1.31	7.31
13.0	0.0	3.8	4.01	1.5	1.35	1.35	7.76
14.0	0.0	4.28	4.46	1.5	1.38	1.38	8.23
15.0	0.0	4.79	4.94	1.5	1.41	1.41	8.72
16.0	0.0	5.34	5.46	1.5	1.42	1.42	9.23

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18" CSP

PIPE CULVERT ANALYSIS
COMPUTATION OF CULVERT PERFORMANCE CURVE

December 2, 2002

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Culvert Diameter (ft)	2.0
FHWA Chart Number	2
FHWA Scale Number (Type of Culvert Entrance)	3
Manning's Roughness Coefficient (n-value)	0.024
Entrance Loss Coefficient of Culvert Opening	0.8
Culvert Length (ft)	40.0
Invert Elevation at Downstream end of Culvert (ft)	0.0
Invert Elevation at Upstream end of Culvert (ft)	0.2
Culvert Slope (ft/ft)	0.005
Starting Flow Rate (cfs)	1.0
Incremental Flow Rate (cfs)	1.0
Ending Flow Rate (cfs)	31.0
Starting Tailwater Depth (ft)	0.0
Incremental Tailwater Depth (ft)	0.0
Ending Tailwater Depth (ft)	0.0

COMPUTATION RESULTS

Flow Rate (cfs)	Tailwater Depth (ft)	Headwater (ft) Inlet Control	Headwater (ft) Outlet Control	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
1.0	0.0	0.47	0.55	0.46	0.34	0.34	2.77
2.0	0.0	0.68	0.79	0.65	0.49	0.49	3.34
3.0	0.0	0.86	0.98	0.81	0.6	0.6	3.75
4.0	0.0	1.01	1.14	0.96	0.7	0.7	4.07
5.0	0.0	1.16	1.29	1.09	0.79	0.79	4.35
6.0	0.0	1.3	1.44	1.22	0.87	0.87	4.6
7.0	0.0	1.43	1.57	1.36	0.94	0.94	4.83
8.0	0.0	1.56	1.7	1.52	1.01	1.01	5.05
9.0	0.0	1.69	1.83	1.72	1.07	1.07	5.26
10.0	0.0	1.82	1.95	2.0	1.13	1.13	5.45
11.0	0.0	1.95	2.08	2.0	1.19	1.19	5.65
12.0	0.0	2.07	2.21	2.0	1.24	1.24	5.84
13.0	0.0	2.2	2.35	2.0	1.3	1.3	6.03
14.0	0.0	2.32	2.5	2.0	1.35	1.35	6.22
15.0	0.0	2.45	2.34	2.0	1.4	2.0	4.77
16.0	0.0	2.62	2.5	2.0	1.44	2.0	5.09
17.0	0.0	2.77	2.66	2.0	1.49	2.0	5.41
18.0	0.0	2.89	2.82	2.0	1.53	2.0	5.73
19.0	0.0	3.1	2.99	2.0	1.57	2.0	6.05
20.0	0.0	3.32	3.17	2.0	1.61	2.0	6.37
21.0	0.0	3.55	3.36	2.0	1.64	2.0	6.68
22.0	0.0	3.79	3.55	2.0	1.68	2.0	7.0
23.0	0.0	4.04	3.74	2.0	1.71	2.0	7.32
24.0	0.0	4.3	3.95	2.0	1.74	2.0	7.64
25.0	0.0	4.58	4.16	2.0	1.76	2.0	7.96
26.0	0.0	4.86	4.36	2.0	1.79	2.0	8.28
27.0	0.0	5.16	4.58	2.0	1.81	2.0	8.59
28.0	0.0	5.47	4.81	2.0	1.83	2.0	8.91
29.0	0.0	5.79	5.04	2.0	1.85	2.0	9.23
30.0	0.0	6.12	5.28	2.0	1.86	2.0	9.55
31.0	0.0	6.46	5.53	2.0	1.88	2.0	9.87

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24" CSP

BOX CULVERT ANALYSIS
COMPUTATION OF CULVERT PERFORMANCE CURVE

December 2, 2002

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Culvert Span (ft)	10.0
Culvert Rise (ft)	4.0
FHWA Chart Number	10
FHWA Scale Number (Type of Culvert Entrance)	1
Manning's Roughness Coefficient (n-value)	0.013
Entrance Loss Coefficient of Culvert Opening	0.5
Culvert Length (ft)	40.0
Invert Elevation at Downstream end of Culvert (ft)	0.0
Invert Elevation at Upstream end of Culvert (ft)	0.2
Culvert Slope (ft/ft)	0.005
Starting Flow Rate (cfs)	200.0
Incremental Flow Rate (cfs)	5.0
Ending Flow Rate (cfs)	450.0
Starting Tailwater Depth (ft)	0.0
Incremental Tailwater Depth (ft)	0.0
Ending Tailwater Depth (ft)	0.0

COMPUTATION RESULTS

Flow Rate (cfs)	Tailwater Depth (ft)	Headwater (ft) Inlet Control	Headwater (ft) Outlet Control	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
200.0	0.0	3.8	0.0	1.97	2.32	1.97	10.17
205.0	0.0	3.86	0.0	2.0	2.36	2.0	10.25
210.0	0.0	3.92	0.0	2.03	2.39	2.03	10.33
215.0	0.0	3.98	0.0	2.07	2.43	2.07	10.41
220.0	0.0	4.04	0.0	2.1	2.47	2.1	10.49
225.0	0.0	4.11	0.0	2.13	2.51	2.13	10.56
230.0	0.0	4.17	0.0	2.16	2.54	2.16	10.63
235.0	0.0	4.23	0.0	2.19	2.58	2.19	10.71
240.0	0.0	4.29	0.0	2.23	2.62	2.23	10.78
245.0	0.0	4.35	0.0	2.26	2.65	2.26	10.85
250.0	0.0	4.4	0.0	2.29	2.69	2.29	10.92
255.0	0.0	4.46	0.0	2.32	2.72	2.32	10.99
260.0	0.0	4.52	0.0	2.35	2.76	2.35	11.05
265.0	0.0	4.58	0.0	2.38	2.79	2.38	11.12
270.0	0.0	4.64	0.0	2.41	2.83	2.41	11.18
275.0	0.0	4.69	0.0	2.45	2.86	2.45	11.25
280.0	0.0	4.75	0.0	2.48	2.9	2.48	11.31
285.0	0.0	4.85	0.0	2.51	2.93	2.51	11.37
290.0	0.0	4.95	0.0	2.54	2.97	2.54	11.43
295.0	0.0	5.05	0.0	2.57	3.0	2.57	11.49
300.0	0.0	5.15	0.0	2.6	3.04	2.6	11.55
305.0	0.0	5.25	0.0	2.63	3.07	2.63	11.61
310.0	0.0	5.35	0.0	2.66	3.1	2.66	11.67
315.0	0.0	5.45	0.0	2.69	3.14	2.69	11.72
320.0	0.0	5.55	0.0	2.72	3.17	2.72	11.78
325.0	0.0	5.63	0.0	2.75	3.2	2.75	11.84
330.0	0.0	5.7	0.0	2.78	3.23	2.78	11.89
335.0	0.0	5.78	0.0	2.8	3.27	2.8	11.94
340.0	0.0	5.86	0.0	2.83	3.3	2.83	12.0
345.0	0.0	5.94	0.0	2.86	3.33	2.86	12.05
350.0	0.0	6.02	0.0	2.89	3.36	2.89	12.1
355.0	0.0	6.1	0.0	2.92	3.4	2.92	12.15
360.0	0.0	6.19	0.0	2.95	3.43	2.95	12.2
365.0	0.0	6.27	0.0	2.98	3.46	2.98	12.25
370.0	0.0	6.36	0.0	3.01	3.49	3.01	12.3
375.0	0.0	6.45	0.0	3.04	3.52	3.04	12.35

10' x 4'
Box Culvert

[illegible]	0.0	6.53	0.0	3.07	3.55	3.07	12.4
385.0	0.0	6.62	0.0	3.09	3.58	3.09	12.45
390.0	0.0	6.71	0.0	3.12	3.62	3.12	12.49
395.0	0.0	6.81	0.0	3.15	3.65	3.15	12.54
400.0	0.0	6.9	0.0	3.18	3.68	3.18	12.58
405.0	0.0	6.99	0.0	3.21	3.71	3.21	12.63
410.0	0.0	7.09	0.0	3.23	3.74	3.23	12.67
415.0	0.0	7.19	0.0	3.26	3.77	3.26	12.72
420.0	0.0	7.28	0.0	3.29	3.8	3.29	12.76
425.0	0.0	7.38	0.0	3.32	3.83	3.32	12.81
430.0	0.0	7.48	0.0	3.35	3.86	3.35	12.85
435.0	0.0	7.58	0.0	3.37	3.89	3.37	12.89
440.0	0.0	7.69	0.0	3.4	3.92	3.4	12.93
445.0	0.0	7.79	0.0	3.43	3.95	3.43	12.97
450.0	0.0	7.9	0.0	3.46	3.98	3.46	13.01

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PIPE CULVERT ANALYSIS
COMPUTATION OF CULVERT PERFORMANCE CURVE

December 2, 2002

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Culvert Diameter (ft)	4.0
FHWA Chart Number	1
FHWA Scale Number (Type of Culvert Entrance)	3
Manning's Roughness Coefficient (n-value)	0.013
Entrance Loss Coefficient of Culvert Opening	0.5
Culvert Length (ft)	40.0
Invert Elevation at Downstream end of Culvert (ft)	0.0
Invert Elevation at Upstream end of Culvert (ft)	0.2
Culvert Slope (ft/ft)	0.005
Starting Flow Rate (cfs)	100.0
Incremental Flow Rate (cfs)	2.0
Ending Flow Rate (cfs)	150.0
Starting Tailwater Depth (ft)	0.0
Incremental Tailwater Depth (ft)	0.0
Ending Tailwater Depth (ft)	0.0

COMPUTATION RESULTS

Flow Rate (cfs)	Tailwater Depth (ft)	Headwater (ft) Inlet Control	Headwater (ft) Outlet Control	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
100.0	0.0	4.78	5.21	3.22	3.03	3.03	9.79
102.0	0.0	4.84	5.28	3.29	3.06	3.06	9.89
104.0	0.0	4.92	5.36	3.37	3.09	3.09	9.99
106.0	0.0	5.01	5.43	3.46	3.12	3.12	10.09
108.0	0.0	5.09	5.5	3.58	3.14	3.14	10.19
110.0	0.0	5.18	5.58	4.0	3.17	3.17	10.3
112.0	0.0	5.27	5.65	4.0	3.2	3.2	10.4
114.0	0.0	5.36	5.73	4.0	3.22	3.22	10.5
116.0	0.0	5.45	5.81	4.0	3.25	3.25	10.61
118.0	0.0	5.55	5.89	4.0	3.27	3.27	10.72
120.0	0.0	5.64	5.97	4.0	3.3	3.3	10.83
122.0	0.0	5.74	6.05	4.0	3.32	3.32	10.94
124.0	0.0	5.84	6.13	4.0	3.35	3.35	11.05
126.0	0.0	5.94	6.21	4.0	3.37	3.37	11.16
128.0	0.0	6.04	6.3	4.0	3.39	3.39	11.27
130.0	0.0	6.14	6.38	4.0	3.41	3.41	11.39
132.0	0.0	6.25	6.47	4.0	3.43	3.43	11.5
134.0	0.0	6.35	6.56	4.0	3.45	3.45	11.62
136.0	0.0	6.46	6.65	4.0	3.47	3.47	11.74
138.0	0.0	6.57	6.75	4.0	3.49	3.49	11.86
140.0	0.0	6.68	6.84	4.0	3.51	3.51	11.98
142.0	0.0	6.8	6.94	4.0	3.53	3.53	12.1
144.0	0.0	6.91	7.05	4.0	3.55	3.55	12.22
146.0	0.0	7.03	5.06	4.0	3.56	4.0	11.62
148.0	0.0	7.15	5.11	4.0	3.58	4.0	11.78
150.0	0.0	7.27	5.16	4.0	3.6	4.0	11.94

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48" CONCRETE PIPE

PIPE CULVERT ANALYSIS
COMPUTATION OF CULVERT PERFORMANCE CURVE

December 2, 2002

PROGRAM INPUT DATA

DESCRIPTION	VALUE
Culvert Diameter (ft)	8.0
FHWA Chart Number	2
FHWA Scale Number (Type of Culvert Entrance)	3
Manning's Roughness Coefficient (n-value)	0.024
Entrance Loss Coefficient of Culvert Opening	0.8
Culvert Length (ft)	40.0
Invert Elevation at Downstream end of Culvert (ft)	0.0
Invert Elevation at Upstream end of Culvert (ft)	0.2
Culvert Slope (ft/ft)	0.005
Starting Flow Rate (cfs)	1.0
Incremental Flow Rate (cfs)	10.0
Ending Flow Rate (cfs)	601.0
Starting Tailwater Depth (ft)	0.0
Incremental Tailwater Depth (ft)	0.0
Ending Tailwater Depth (ft)	0.0

COMPUTATION RESULTS

Flow Rate (cfs)	Tailwater Depth (ft)	Headwater (ft) Inlet Control	Headwater (ft) Outlet Control	Normal Depth (ft)	Critical Depth (ft)	Depth at Outlet (ft)	Outlet Velocity (fps)
1.0	0.0	0.3	0.38	0.31	0.24	0.24	2.28
11.0	0.0	1.06	1.25	0.97	0.8	0.8	4.19
21.0	0.0	1.49	1.74	1.33	1.11	1.11	4.96
31.0	0.0	1.83	2.12	1.61	1.36	1.36	5.5
41.0	0.0	2.13	2.46	1.85	1.56	1.56	5.92
51.0	0.0	2.4	2.75	2.07	1.75	1.75	6.28
61.0	0.0	2.65	3.03	2.26	1.92	1.92	6.6
71.0	0.0	2.88	3.28	2.45	2.07	2.07	6.88
81.0	0.0	3.1	3.52	2.62	2.22	2.22	7.14
91.0	0.0	3.32	3.74	2.79	2.35	2.35	7.38
101.0	0.0	3.52	3.96	2.94	2.48	2.48	7.6
111.0	0.0	3.72	4.17	3.1	2.61	2.61	7.81
121.0	0.0	3.92	4.37	3.25	2.73	2.73	8.01
131.0	0.0	4.1	4.56	3.39	2.84	2.84	8.2
141.0	0.0	4.29	4.75	3.54	2.95	2.95	8.38
151.0	0.0	4.47	4.93	3.68	3.06	3.06	8.55
161.0	0.0	4.65	5.11	3.82	3.16	3.16	8.72
171.0	0.0	4.83	5.28	3.95	3.26	3.26	8.88
181.0	0.0	5.0	5.46	4.08	3.36	3.36	9.03
191.0	0.0	5.17	5.62	4.22	3.46	3.46	9.19
201.0	0.0	5.34	5.79	4.35	3.55	3.55	9.34
211.0	0.0	5.51	5.95	4.49	3.64	3.64	9.48
221.0	0.0	5.68	6.11	4.62	3.73	3.73	9.62
231.0	0.0	5.84	6.27	4.75	3.82	3.82	9.76
241.0	0.0	6.0	6.42	4.89	3.9	3.9	9.9
251.0	0.0	6.17	6.58	5.02	3.99	3.99	10.03
261.0	0.0	6.33	6.73	5.16	4.07	4.07	10.16
271.0	0.0	6.49	6.88	5.29	4.15	4.15	10.29
281.0	0.0	6.65	7.03	5.43	4.23	4.23	10.42
291.0	0.0	6.81	7.17	5.58	4.31	4.31	10.55
301.0	0.0	6.97	7.32	5.73	4.38	4.38	10.67
311.0	0.0	7.13	7.47	5.88	4.46	4.46	10.8
321.0	0.0	7.29	7.61	6.04	4.53	4.53	10.92
331.0	0.0	7.45	7.76	6.21	4.61	4.61	11.04
341.0	0.0	7.61	7.9	6.39	4.68	4.68	11.16
351.0	0.0	7.76	8.04	6.59	4.75	4.75	11.29
361.0	0.0	7.92	8.18	6.83	4.82	4.82	11.4

8' CSP.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
381.0	0.0	8.24	8.47	8.0	4.96	4.96	11.64
391.0	0.0	8.4	8.61	8.0	5.03	5.03	11.76
401.0	0.0	8.55	8.75	8.0	5.09	5.09	11.88
411.0	0.0	8.71	8.89	8.0	5.16	5.16	12.0
421.0	0.0	8.87	9.03	8.0	5.22	5.22	12.11
431.0	0.0	9.03	9.17	8.0	5.29	5.29	12.23
441.0	0.0	9.18	9.31	8.0	5.35	5.35	12.35
451.0	0.0	9.34	9.46	8.0	5.41	5.41	12.47
461.0	0.0	9.5	9.6	8.0	5.47	5.47	12.59
471.0	0.0	9.66	9.74	8.0	5.53	5.53	12.7
481.0	0.0	9.82	9.88	8.0	5.59	5.59	12.82
491.0	0.0	9.98	10.03	8.0	5.65	5.65	12.94
501.0	0.0	10.18	10.17	8.0	5.71	8.0	9.97
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
521.0	0.0	10.67	10.46	8.0	5.82	8.0	10.36
531.0	0.0	10.88	10.61	8.0	5.87	8.0	10.56
541.0	0.0	11.05	10.76	8.0	5.93	8.0	10.76
551.0	0.0	11.2	10.9	8.0	5.98	8.0	10.96
561.0	0.0	11.31	11.06	8.0	6.04	8.0	11.16
571.0	0.0	11.44	11.21	8.0	6.09	8.0	11.36
581.0	0.0	11.69	11.36	8.0	6.14	8.0	11.56
591.0	0.0	11.94	11.52	8.0	6.19	8.0	11.76
601.0	0.0	12.21	11.68	8.0	6.24	8.0	11.96

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