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ENERGY WATER INFORMATION GOVERNMENT

Calculation Record

Client Name: FLorida Municipal Power Agency Page 1 of 67

Project Name: Cane Island Power Park Unit 4 Project No.: 147651

Calculation Title: Trench Drain and Culvert Design and Time of Concentration

Calculation No./File No.: 52.5406.1101.01

Calculation Is: (check all that apply) ☐ Preliminary ☒ Final ☐ Nuclear Safety-Related

Objective To design trench drains and culverts to safely pass both the 25-year, 72 hour and 100-year, 72 hour stom events. To calculate the time of concentrations and determine the longest time of concetration for use in the pond design.

Unverified Assumptions Requiring Subsequent Verification

No.	Assumption	Verified By	Date

See Page _____ of this calculation for additional assumptions.

This Section Used for Computer Generated Calculations

Program Name/Number: ______________ Version: ______________

Evidence of or reference to computer program verification, if applicable:

Bases or reference thereto supporting application of the computer program to the physical problem:

Review and Approval

Rev	Prepared By	Date	Verified By	Date	Approved By	Date
0	A.L. Morgan A.L. Morgan	03/07/08	J. M. Stanek JMStanek	3/12/08	[signature]	3/26/08

1.0 PURPOSE

The purpose of this calculation is to:
1.1) To design the trench drains and culverts to safely pass the 25 year, 72-hour and 100 year, 72-hour storm events.
1.2) To calculate the time of concentration for each trench drain and culvert and determine the longest time of concentration for the pond design.

2.0 REFERENCES

2.1) Technical Paper No. 40, Rainfall Frequency Atlas of the United States, United States Department of Commerce, May 1961
2.2) Technical Release 55 (TR55), Urban Hydrology for Small Watersheds, USDA Soil Conservation Service, Conservation Engineering Division, June 1986.
2.3) State of Florida Department of Transportation Drainage Manual, January 2006
2.4) Modern Sewer Design, American Iron and Steel Institute, Third Edition, 1995
2.5) Black & Veatch Drawings 147651-4STF-S3000 through 147651-4STF-S3002
2.6) Black & Veatch Drawing 147651-4STF-S3050, Grading and Drainage Details.

3.0 ASSUMPTIONS

No assumptions.

4.0 DEFINITION OF UNITS AND CONSTANTS

Due to the high number of units and constants, they are defined within Section 7.0 Analysis.

5.0 PROCEDURE/METHODOLOGY OF DESIGN

5.1) Determine lengths and slopes of travel from AutoCAD drawings of Reference 2.5 (See Appendix A for sketches).
5.2) Calculate times of travel for sheet flow using TR-55, Reference 2.2.
5.3) Calculate times of travel for shallow concentrated flow using TR-55, Reference 2.2.
5.4) Calculate times of travel for open channel flow using TR-55, Reference 2.2.
5.5) Determine rainfall intensity from Reference 2.3 (Zone 7, See Appendix D for IDF Curve).
5.6) Calculate weighted runoff coefficient.
5.7) Determine sub-basin area from AutoCAD drawings of Reference 2.5 (See Appendix A for sketches of each sub-basin area).
5.8) Calculate storm water runoff using Rational Method.
5.9) Calculate wetted perimeter and flow area of open channel flow using FlowMaster and CulvertMaster (See Appendix B for Haestad FlowMaster 2005 and Appendix C for CulvertMaster Output.)
5.10) Calculate time of travel for open channel flow using TR-55, Reference 2.2.
5.11) Calculate sub-basin time of concentration using TR-55, Reference 2.2.

6.0 CONCLUSIONS

6.1) See Reference 2.6 for trench drain and culvert sizes.
6.2) The longest time of concentration to the pond is 0.127 hour.

7.0 ANALYSIS

7.1) Trench Drain T-1
7.2) Trench Drain T-2
7.3) Trench Drain T-3
7.4) Trench Drain T-4
7.5) Trench Drain T-5
7.6) Trench Drain T-6
7.7) Culvert C-1
7.8) Culvert C-2

8.0 APPENDICES

8.1) Appendix A - TOC Figures
8.2) Appendix B - FlowMaster Output
8.3) Appendix C - CulvertMaster Output
8.4) Appendix D - Reference Figures

7.1 Trench Drain T-1

7.1.1 Time of Concentration (No Other Contributing Areas)

Sheet Flow Inputs: $i := 1 .. 3$
(Total length of all segments must be less than or equal to 300 ft.)

Flow Segment One

$L_{sheet_1} := 12.00$ ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_1} := 0.011$	Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_1} := 4.75$ in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_1} := 0.0200$ ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Flow Segment Two

$L_{sheet_2} := 5.25$ ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_2} := 0.011$	Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_2} := 4.75$ in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_2} := 0.0110$ ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Flow Segment Three

$L_{sheet_3} := 68.0$ ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_3} := 0.011$	Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_3} := 4.75$ in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_3} := .0029$ ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Sheet Flow Calculation: (Ref. 2.2, eq. 3-3)

$$T_1 := \sum_i \left[0.007 \cdot \frac{\left(n_{sheet_i} \cdot L_{sheet_i}\right)^{0.8}}{\left(P_{2yr24hr_i}\right)^{0.5} \cdot \left(s_{sheet_i}\right)^{0.4}} \right]$$

$T_1 = 0.031$ hr

$T_1 \cdot 60 = 1.883$ min

Shallow Concentrated Flow Inputs:

No inputs.

Open Channel Flow Inputs: $i := 1..2$

*Flow Segment One - **T-1 Part A***

$L_{ocf_1} := 391.10$	ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_1} := 0.005$	ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_1} := 0.033$		Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_1} := 8.10$	ft	Wetted perimeter of open channel cross section	(Appendix B)
$fa_{ocf_1} := 3.18$	ft^2	Flow area of open channel cross section	(Appendix B)

*Flow Segment Two - **T-1 Part B***

$L_{ocf_2} := 23.768$	ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_2} := 0.0025$	ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_2} := 0.033$		Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_2} := 8.76$	ft	Wetted perimeter of open channel cross section	(Appendix B)
$fa_{ocf_2} := 4.03$	ft^2	Flow area of open channel cross section	(Appendix B)

Open Channel Flow Calculation: (Ref. 2.2, eqs. 3-4 & 3-1)

$$V_{ocf_i} := 1.49 \cdot \left(\frac{fa_{ocf_i}}{wp_{ocf_i}}\right)^{\frac{2}{3}} \cdot \left(s_{ocf_i}\right)^{0.5} \cdot \frac{1}{n_{ocf_i}}$$

$$V_{ocf} = \begin{pmatrix} 1.712 \\ 1.345 \end{pmatrix} \quad \begin{matrix} \text{Segment One} \\ \text{Segment Two} \end{matrix} \quad \frac{ft}{sec}$$

$$T_2 := \sum_i \frac{L_{ocf_i}}{3600 \cdot V_{ocf_i}}$$

$T_2 = 0.068$ hr

$T_2 \cdot 60 = 4.102$ min

Total Time of Concentration: (Ref. 2.2, eq. 3-2)

$$T_c := T_1 + T_2$$

$T_c = 0.1$ hr

$T_c \cdot 60 = 5.986$ min

7.1.2 Storm Water Runoff (Rational Method)

Composite Runoff Coefficient

Area (A)	***c***	***A*c***

Area T1a: Impervious Areas (paved streets & roads, paved parking lots & driveways, roofs, etc.)

$A_{T1a} := 7187.22 \cdot ft^2$ $\quad c_{areaT1a} := 0.95$ $\quad Ac_{areaT1a} := A_{T1a} \cdot c_{areaT1a}$

$A_{T1a} = 2.578 \times 10^{-4}\, mi^2$ $\quad Ac_{areaT1a} = 6827.9\, ft^2$

Area T1b: Aggregate Areas

$A_{T1b} := 20882.88 \cdot ft^2$ $\quad c_{areaT1b} := 0.75$ $\quad Ac_{areaT1b} := A_{T1b} \cdot c_{areaT1b}$

$A_{T1b} = 7.491 \times 10^{-4}\, mi^2$ $\quad Ac_{areaT1b} = 15662.2\, ft^2$

Total:

$A_{T1.T} := A_{T1a} + A_{T1b}$ $\quad Ac_{areaT1.T} := Ac_{areaT1a} + Ac_{areaT1b}$

$A_{T1.T} = 0.001\, mi^2$ $\quad Ac_{areaT1.T} = 22490\, ft^2$

Composite c Value:

$$c_{areaT1.T} := \frac{Ac_{areaT1.T}}{A_{T1.T}} \qquad c_{areaT1.T} = 0.801$$

Time of Concentration

Time of Concentration, t_c (hr):

$t_{c.areaT1} := T_c$ $\quad t_{c.areaT1} = 0.1$ hr (This calculation - See above)

Intensity

(An 8 minute intensity will be used since that's the shortest duration shown on the chart)

$i_{areaT1.25} := 9.0 \cdot \frac{in}{hr}$ $\quad i_{areaT1.100} := 10.4 \cdot \frac{in}{hr}$ (Ref. 2.3, Appendix D)

Runoff

$Q_{areaT1.25} := c_{areaT1.T} \cdot i_{areaT1.25} \cdot A_{T1.T}$ $\quad Q_{areaT1.100} := c_{areaT1.T} \cdot i_{areaT1.100} \cdot A_{T1.T}$

$Q_{areaT1.25} = 4.685 \frac{ft^3}{sec}$ $\quad Q_{areaT1.100} = 5.414 \frac{ft^3}{sec}$

7.1.3 Trench Drain T-1

The runoff from the contributory area of Trench Drain T-1 was used to design Trench Drain T-1. The FlowMaster program was used for the design with the following inputs:

Manning's Roughness Coefficient (Concrete Trench) = 0.013 (Ref. 2.4, Appendix D)
Trench Slope = 0.005 ft/ft
Bottom Width of the Trench = 1.5 ft
Design Discharge Flow in the Trench (Q_{25}) = 4.685 cfs
Check Discharge Flow in the Trench (Q_{100}) = 5.414 cfs
Road (Paved) Centerline Elevation = 81.50
Road (Paved) Edge Elevation = 81.25
Maximum Allowable Headwater Elevation = 81.25
Trench Drain Inlet Invert Elevation = 79.88
Trench Drain Outlet Invert Elevation = 79.66
Trench Drain Length =43.12 ft

The FlowMaster design report for Trench Drain T-1 is shown in Appendix B of this calculation. A 1.5 ft wide Trench is sufficient to keep the design headwater and check headwater below the maximum allowable headwater elevation.

Trench Drain T-1 = 1.5' wide concrete trench

7.2 Trench Drain T-2

7.2.1 Time of Concentration (No Other Contributing Areas)

Sheet Flow Inputs: $i := 1..2$

Flow Segment One

$L_{sheet_1} := 25.77$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_1} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_1} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_1} := 0.0100$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Flow Segment Two

$L_{sheet_2} := 102.29$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_2} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_2} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_2} := 0.0033$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Sheet Flow Calculation: (Ref. 2.2, eq. 3-3)

$$T_1 := \sum_i \left[0.007 \cdot \frac{\left(n_{sheet_i} \cdot L_{sheet_i}\right)^{0.8}}{\left(P_{2yr24hr_i}\right)^{0.5} \cdot \left(s_{sheet_i}\right)^{0.4}} \right]$$

$T_1 = 0.042$ hr

$T_1 \cdot 60 = 2.525$ min

Shallow Concentrated Flow Inputs:

No inputs.

Open Channel Flow Inputs: $i := 1 .. 2$

*Flow Segment One - **T-2 Part A***

$L_{ocf_1} := 372.48$	ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_1} := 0.0033$	ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_1} := 0.013$		Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_1} := 6.02$	ft	Wetted perimeter of open channel cross section	(Appendix B)
$fa_{ocf_1} := 2.72$	ft^2	Flow area of open channel cross section	(Appendix B)

*Flow Segment Two - **T-2 Part B***

$L_{ocf_2} := 73.90$	ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_2} := 0.0033$	ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_2} := 0.013$		Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_2} := 6.53$	ft	Wetted perimeter of open channel cross section	(Appendix B)
$fa_{ocf_2} := 2.81$	ft^2	Flow area of open channel cross section	(Appendix B)

Open Channel Flow Calculation: (Ref. 2.2, eqs. 3-4 & 3-1)

$$V_{ocf_i} := 1.49 \cdot \left(\frac{fa_{ocf_i}}{wp_{ocf_i}}\right)^{\frac{2}{3}} \cdot \left(s_{ocf_i}\right)^{0.5} \cdot \frac{1}{n_{ocf_i}}$$

$$V_{ocf} = \begin{pmatrix} 3.877 \\ 3.753 \end{pmatrix} \begin{matrix} \text{Segment One} \\ \text{Segment Two} \end{matrix} \quad \frac{ft}{sec}$$

$$T_2 := \sum_i \frac{L_{ocf_i}}{3600 \cdot V_{ocf_i}}$$

$T_2 = 0.032$ hr

$T_2 \cdot 60 = 1.929$ min

Total Time of Concentration: (Ref. 2.2, eq. 3-2)

$T_c := T_1 + T_2$

$T_c = 0.074$ hr

$T_c \cdot 60 = 4.455$ min

7.2.2 Storm Water Runoff (Rational Method)

Composite Runoff Coefficient

Area (A) ***c*** ***A*c***

Area T2a: Impervious Areas (paved streets & roads, paved parking lots & driveways, roofs, etc.)

$A_{T2a} := 47429.37 \cdot ft^2$ $c_{areaT2a} := 0.95$ $Ac_{areaT2a} := A_{T2a} \cdot c_{areaT2a}$

$A_{T2a} = 1.701 \times 10^{-3} \, mi^2$ $Ac_{areaT2a} = 45057.9 \, ft^2$

Area T2b:Self-Contained Areas

$A_{T2b} := 1392.00 \cdot ft^2$ $c_{areaT2b} := 0$ $Ac_{areaT2b} := A_{T2b} \cdot c_{areaT2b}$

$A_{T2b} = 4.993 \times 10^{-5} \, mi^2$ $Ac_{areaT2b} = 0 \, ft^2$

Total:

$A_{T2.T} := A_{T2a} - A_{T2b}$ $Ac_{areaT2.T} := Ac_{areaT2a}$

$A_{T2.T} = 0.0017 \, mi^2$ $Ac_{areaT2.T} = 45057.9 \, ft^2$

Composite c Value:

$c_{areaT2.T} := \dfrac{Ac_{areaT2.T}}{A_{T2a}}$ $c_{areaT2.T} = 0.95$

Time of Concentration

Time of Concentration, t_c (hr):

$t_{c.areaT2} := T_c$ $t_{c.areaT2} = 0.074$ hr (This calculation - See above)

Intensity (An 8 minute intensity will be used since that's the shortest duration shown on the chart)

$i_{areaT2.25} := 9.0 \cdot \dfrac{in}{hr}$ $i_{areaT2.100} := 10.4 \cdot \dfrac{in}{hr}$ (Ref. 2.3, Appendix D)

Runoff

$Q_{areaT2.25} := c_{areaT2.T} \cdot i_{areaT2.25} \cdot A_{T2.T}$ $\qquad Q_{areaT2.25} = 9.112 \frac{ft^3}{sec}$

$Q_{areaT2.100} := c_{areaT2.T} \cdot i_{areaT2.100} \cdot A_{T2.T}$ $\qquad Q_{areaT2.100} = 10.529 \frac{ft^3}{sec}$

7.2.3 Trench Drain T-2

The runoff from the contributory area of Trench Drain T-2 was used to design Trench Drain T-2. The FlowMaster program was used for the design with the following inputs:

Manning's Roughness Coefficient (Concrete Trench) = 0.013 (Ref. 2.4, Appendix D)
Trench Slope = 0.00549 ft/ft
Bottom Width of the Trench = 2 ft
Design Discharge Flow in the Trench (Q_{25}) = 9.112 cfs
Check Discharge Flow in the Trench (Q_{100}) = 10.529 cfs
Road (Paved) Centerline Elevation = 81.05
Road (Paved) Edge Elevation = 80.80
Maximum Allowable Headwater Elevation = 80.80
Trench Drain Inlet Invert Elevation = 79.60
Trench Drain Outlet Invert Elevation = 79.42
Trench Drain Length = 33.4 ft

The FlowMaster design report for Trench Drain T-2 is shown in Appendix B of this calculation. A 2 ft wide Trench is sufficient to keep the design headwater and check headwater below the maximum allowable headwater elevation.

Trench Drain T-2 = 2' wide concrete trench

7.3 Trench Drain T-3

7.3.1 Time of Concentration (No Other Contributing Areas)

Sheet Flow Inputs: $i := 1 .. 2$

Flow Segment One

$L_{sheet_1} := 54.99$	ft	Flow length		(Ref. 2.5, Appendix A)
$n_{sheet_1} := 0.011$		Manning's Roughness Coef. for sheet flow		(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_1} := 4.75$	in	2-yr, 24-hr rainfall depth		(Ref. 2.1, Appendix D)
$s_{sheet_1} := .002$	ft/ft	Slope of watershed for sheet flow		(Ref. 2.5, Appendix A)

Flow Segment Two

$L_{sheet_2} := 97.39$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_2} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_2} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_2} := 0.0028$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Sheet Flow Calculation:

$$T_1 := \sum_i \left[0.007 \cdot \frac{\left(n_{sheet_i} \cdot L_{sheet_i}\right)^{0.8}}{\left(P_{2yr24hr_i}\right)^{0.5} \cdot \left(s_{sheet_i}\right)^{0.4}} \right]$$

$T_1 = 0.061$ hr

$T_1 \cdot 60 = 3.686$ min

Shallow Concentrated Flow Inputs:

No inputs.

Open Channel Flow Inputs:

No inputs.

Total Time of Concentration: (Ref. 2.2, eq. 3-2)

$T_c := T_1$ $\quad T_c = 0.061$ hr $\quad T_c \cdot 60 = 3.686$ min

7.3.2 Storm Water Runoff (Rational Method)

Composite Runoff Coefficient

Area (A)	***c***	***A*c***

Area T3a: Impervious Areas (paved streets & roads, paved parking lots & driveways, roofs, etc.)

$A_{T3a} := 20225.53 \cdot ft^2$ $\quad c_{areaT3a} := 0.95$ $\quad Ac_{areaT3a} := A_{T3a} \cdot c_{areaT3a}$

$A_{T3a} = 7.255 \times 10^{-4}\, mi^2$ $\quad Ac_{areaT3a} = 19214.3\, ft^2$

Total:

$A_{T3.T} := A_{T3a}$ $\quad Ac_{areaT3.T} := Ac_{areaT3a}$

$A_{T3.T} = 0.0007\, mi^2$ $\quad Ac_{areaT3.T} = 19214.3\, ft^2$

Composite c Value:

$$c_{areaT3.T} := \frac{Ac_{areaT3.T}}{A_{T3.T}} \qquad c_{areaT3.T} = 0.95$$

Time of Concentration

Time of Concentration, t_c (hr):

$$t_{c.areaT3} := T_c \qquad t_{c.areaT3} = 0.061 \text{ hr}$$ (This calculation - See above)

Intensity (An 8 minute intensity will be used since that's the shortest duration shown on the chart)

$$i_{areaT3.25} := 9.0 \cdot \frac{in}{hr} \qquad i_{areaT3.100} := 10.4 \cdot \frac{in}{hr}$$ (Ref. 2.3, Appendix D)

Runoff

$$Q_{areaT3.25} := c_{areaT3.T} \cdot i_{areaT3.25} \cdot A_{T3.T} \qquad Q_{areaT3.100} := c_{areaT3.T} \cdot i_{areaT3.100} \cdot A_{T3.T}$$

$$Q_{areaT3.25} = 4.003 \frac{ft^3}{sec} \qquad Q_{areaT3.100} = 4.626 \frac{ft^3}{sec}$$

7.3.3 Trench Drain T-3

The runoff from the contributory area of Trench Drain T-3 was used to design Trench Drain T-3. The FlowMaster program was used for the design with the following inputs:

Manning's Roughness Coefficient (Concrete Trench) = 0.013 (Ref. 2.4, Appendix D)
Trench Slope = 0.00495 ft/ft
Bottom Width of the Trench = 2 ft
Design Discharge Flow in the Trench (Q_{25}) = 4.003 cfs
Check Discharge Flow in the Trench (Q_{100}) = 4.626 cfs
Road (Paved) Centerline Elevation = 81.32
Road (Paved) Edge Elevation = 81.25
Maximum Allowable Headwater Elevation = 81.13
Trench Drain Inlet Invert Elevation = 80.50
Trench Drain Outlet Invert Elevation = 80.00
Trench Drain Length = 100.95 ft

The FlowMaster design report for Trench Drain T-3 is shown in Appendix B of this calculation. A 2 ft wide Trench is sufficient to keep the design headwater and check headwater below the maximum allowable headwater elevation.

Trench Drain T-3 = 2' wide concrete trench

7.4 Trench Drain T-4

7.4.1 Time of Concentration (No Other Contributing Areas)

Sheet Flow Inputs: $i := 1 .. 2$

Flow Segment One

$L_{sheet_1} := 14.34$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_1} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_1} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_1} := 0.0070$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Flow Segment Two

$L_{sheet_2} := 225.94$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_2} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_2} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_2} := 0.0050$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Sheet Flow Calculation:

$$T_1 := \sum_i \left[0.007 \cdot \frac{\left(n_{sheet_i} \cdot L_{sheet_i}\right)^{0.8}}{\left(P_{2yr24hr_i}\right)^{0.5} \cdot \left(s_{sheet_i}\right)^{0.4}} \right]$$

$T_1 = 0.061$ hr

$T_1 \cdot 60 = 3.644$ min

Shallow Concentrated Flow Inputs:

No inputs.

Open Channel Flow Inputs:

No inputs.

Total Time of Concentration: (Ref. 2, eq. 3-2)

$T_c := T_1$ $\quad T_c = 0.061$ hr $\quad T_c \cdot 60 = 3.686$ min

7.4.2 Storm Water Runoff

(Rational Method)

Composite Runoff Coefficient

Area (A) ***c*** ***A*c***

Area T4a: Impervious Areas (paved streets & roads, paved parking lots & driveways, roofs, etc.)

$A_{T4a} := 18638.70 \cdot ft^2$ $c_{areaT4a} := 0.95$ $Ac_{areaT4a} := A_{T4a} \cdot c_{areaT4a}$

$A_{T4a} = 6.686 \times 10^{-4}\, mi^2$ $Ac_{areaT4a} = 17706.8\, ft^2$

Total:

$A_{T4.T} := A_{T4a}$ $Ac_{areaT4.T} := Ac_{areaT4a}$

$A_{T4.T} = 0.0007\, mi^2$ $Ac_{areaT4.T} = 17706.8\, ft^2$

Composite c Value:

$c_{areaT4.T} := \dfrac{Ac_{areaT4.T}}{A_{T4.T}}$ $c_{areaT4.T} = 0.95$

Time of Concentration

Time of Concentration, t_c (hr):

$t_{c.areaT4} := T_c$ $t_{c.areaT4} = 0.061$ hr (This calculation - See above)

Intensity (An 8 minute intensity will be used since that's the shortest duration shown on the chart)

$i_{areaT4.25} := 9.0 \cdot \dfrac{in}{hr}$ $i_{areaT4.100} := 10.4 \cdot \dfrac{in}{hr}$ (Ref. 2.3, Appendix D)

Runoff

$Q_{areaT4.25} := c_{areaT4.T} \cdot i_{areaT4.25} \cdot A_{T4.T}$ $Q_{areaT4.25} = 3.689 \dfrac{ft^3}{sec}$

$Q_{areaT4.100} := c_{areaT4.T} \cdot i_{areaT4.100} \cdot A_{T4.T}$ $Q_{areaT4.100} = 4.263 \dfrac{ft^3}{sec}$

7.4.3 Trench Drain T-4

The runoff from the contributory area of Trench Drain T-4 was used to design Trench Drain T-4. The FlowMaster program was used for the design with the following inputs:

Manning's Roughness Coefficient (Concrete Trench) = 0.013
Trench Slope = 0.00545 ft/ft
Bottom Width of the Trench = 2 ft
Design Discharge Flow in the Trench (Q_{25}) = 3.689 cfs
Check Discharge Flow in the Trench (Q_{100}) = 4.263 cfs
Road (Paved) Centerline Elevation = 81.50
Road (Paved) Edge Elevation = 81.25
Maximum Allowable Headwater Elevation = 81.25
Trench Drain Inlet Invert Elevation = 80.27
Trench Drain Outlet Invert Elevation = 80.10
Trench Drain Length = 31.19 ft

The FlowMaster design report for Trench Drain T-4 is shown in Appendix B of this calculation. A 2 ft wide Trench is sufficient to keep the design headwater and check headwater below the maximum allowable headwater elevation.

Trench Drain T-4 = 2' wide concrete trench

7.5 Trench Drain T-5

7.5.1 Time of Concentration (No Other Contributing Areas)

Sheet Flow Inputs: $i := 1..3$

Flow Segment One

$L_{sheet_1} := 4.84$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_1} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_1} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_1} := 0.0207$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Flow Segment Two

$L_{sheet_2} := 79.45$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_2} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_2} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_2} := 0.005$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Flow Segment Three

$L_{sheet_3} := 9.83$ ft — Flow length (Ref. 2.5, Appendix A)

$n_{sheet_3} := 0.011$ — Manning's Roughness Coef. for sheet flow (Ref. 2.2, pg. 3-3, Smooth surfaces)

$P_{2yr24hr_3} := 4.75$ in — 2-yr, 24-hr rainfall depth (Ref. 2.1, Appendix D)

$s_{sheet_3} := 0.015$ ft/ft — Slope of watershed for sheet flow (Ref. 2.5, Appendix A)

Sheet Flow Calculation:

$$T_1 := \sum_i \left[0.007 \cdot \frac{\left(n_{sheet_i} \cdot L_{sheet_i}\right)^{0.8}}{\left(P_{2yr24hr_i}\right)^{0.5} \cdot \left(s_{sheet_i}\right)^{0.4}} \right]$$

$T_1 = 0.028$ hr

$T_1 \cdot 60 = 1.702$ min

Shallow Concentrated Flow Inputs:

No inputs.

Open Channel Flow Inputs:

No inputs.

Total Time of Concentration: (Ref. 2, eq. 3-2)

$T_c := T_1$ $\quad T_c = 0.028$ hr $\quad T_c \cdot 60 = 1.702$ min

7.5.2 Storm Water Runoff (Rational Method)

Composite Runoff Coefficient

Area (A)	***c***	***A*c***

Area T5a: Impervious Areas (paved streets & roads, paved parking lots & driveways, roofs, etc.)

$A_{T5a} := 11746.1618 \cdot ft^2$ $\quad c_{areaT5a} := 0.95$ $\quad Ac_{areaT5a} := A_{T5a} \cdot c_{areaT5a}$

$A_{T5a} = 4.213 \times 10^{-4}\ mi^2$ $\quad Ac_{areaT5a} = 11158.9\ ft^2$

Area T5b: Self-Contained Areas

$A_{T5b} := 150.7500 \cdot ft^2$ $\quad c_{areaT5b} := 0$ $\quad Ac_{areaT5b} := A_{T5b} \cdot c_{areaT5b}$

$A_{T5b} = 5.407 \times 10^{-6}\ mi^2$ $\quad Ac_{areaT5b} = 0\ ft^2$

Total:

$A_{T5.T} := A_{T5a} - A_{T5b}$ $\quad$ $Ac_{areaT5.T} := Ac_{areaT5a}$

$A_{T5.T} = 0.0004\,mi^2$ $\quad$ $Ac_{areaT5.T} = 11158.9\,ft^2$

Composite c Value:

$$c_{areaT5.T} := \frac{Ac_{areaT5.T}}{A_{T5a}} \qquad c_{areaT5.T} = 0.95$$

Time of Concentration

Time of Concentration, t_c (hr):

$t_{c.areaT5} := T_c$ $\quad$ $t_{c.areaT5} = 0.028$ hr $\quad$ (This calculation - See above)

Intensity (An 8 minute intensity will be used since that's the shortest duration shown on the chart)

$i_{areaT5.25} := 9.0 \cdot \frac{in}{hr}$ $\quad$ $i_{areaT5.100} := 10.4 \cdot \frac{in}{hr}$ $\quad$ (Ref. 2.3, Appendix D)

Runoff

$Q_{areaT5.25} := c_{areaT5.T} \cdot i_{areaT5.25} \cdot A_{T5.T}$ $\quad$ $Q_{areaT5.25} = 2.295\,\frac{ft^3}{sec}$

$Q_{areaT5.100} := c_{areaT5.T} \cdot i_{areaT5.100} \cdot A_{T5.T}$ $\quad$ $Q_{areaT5.100} = 2.652\,\frac{ft^3}{sec}$

7.5.3 Trench Drain T-5

The runoff from the contributory area of Trench Drain T-5 was used to design Trench Drain T-5. The FlowMaster program was used for the design with the following inputs:

Manning's Roughness Coefficient (Concrete Trench) = 0.013 $\quad$ (Ref. 2.4, Appendix D)
Trench Slope = 0.00554 ft/ft
Bottom Width of the Trench = 2 ft
Design Discharge Flow in the Trench (Q_{25}) = 2.295 cfs
Check Discharge Flow in the Trench (Q_{100}) = 2.652 cfs
Road (Paved) Centerline Elevation = 81.50
Road (Paved) Edge Elevation = 81.25
Maximum Allowable Headwater Elevation = 81.25
Trench Drain Inlet Invert Elevation = 80.85
Trench Drain Outlet Invert Elevation = 80.70
Trench Drain Length = 27.10 ft

The FlowMaster design report for Trench Drain T-5 is shown in Appendix B of this calculation. A 2 ft wide Trench is sufficient to keep the design headwater and check headwater below the maximum allowable headwater elevation.

Trench Drain T-5 = 2' wide concrete trench

7.6 Trench Drain T-6

7.6.1 Time of Concentration (No Other Contributing Areas)

Sheet Flow Inputs: $i := 1..3$

Flow Segment One

$L_{sheet_1} := 50.75$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_1} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_1} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_1} := .0020$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Flow Segment Two

$L_{sheet_2} := 80.13$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_2} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_2} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_2} := .0050$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Flow Segment Three

$L_{sheet_3} := 169.12$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_3} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_3} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_3} := 0.0050$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Sheet Flow Calculation:

$$T_1 := \sum_i \left[0.007 \cdot \frac{\left(n_{sheet_i} \cdot L_{sheet_i}\right)^{0.8}}{\left(P_{2yr24hr_i}\right)^{0.5} \cdot \left(s_{sheet_i}\right)^{0.4}} \right]$$

$T_1 = 0.092$ hr

$T_1 \cdot 60 = 5.539$ min

Shallow Concentrated Flow Inputs: $i := 1 .. 1$

$L_{scf_1} := 24.76$	ft	Length of shallow concentrated flow segment	(Ref. 2.5, Appendix A)
$s_{scf_1} := 0.0050$	ft/ft	Slope of watershed for shallow concentrated flow segment	(Ref. 2.5, Appendix A)
$Surface_1 := 1$		Surface designation for segment (paved=1, unpaved=0)	

Shallow Concentrated Flow Calculation: (Ref. 2.2, eq. 3-1)

$$V_{scf_i} := \text{if}\left[Surface_i = 0, 16.1345\cdot\left(s_{scf_i}\right)^{0.5}, 20.3282\cdot\left(s_{scf_i}\right)^{0.5}\right]$$

$$V_{scf} = (1.437)\ \frac{ft}{sec}$$

$$T_2 := \sum_i \frac{L_{scf_i}}{3600\cdot V_{scf_i}} \qquad T_2 = 4.785\times 10^{-3}\ \text{hr} \qquad T_2\cdot 60 = 0.287\ \text{min}$$

Open Channel Flow Inputs:

No inputs.

Total Time of Concentration: (Ref. 2.2, eq. 3-2)

$$T_c := T_1 + T_2 \qquad T_c = 0.097\ \text{hr} \qquad T_c\cdot 60 = 5.826\ \text{min}$$

7.6.2 Storm Water Runoff (Rational Method)

Composite Runoff Coefficient

Area (A) ***c*** ***A*c***

Area T6a: Impervious Areas (paved streets & roads, paved parking lots & driveways, roofs, etc.)

$A_{T6a} := 42322.31\cdot ft^2$ $\qquad c_{areaT6a} := 0.95$ $\qquad Ac_{areaT6a} := A_{T6a}\cdot c_{areaT6a}$

$A_{T6a} = 1.518\times 10^{-3}\ mi^2$ $\qquad Ac_{areaT6a} = 40206.2\ ft^2$

Area T6b:Self-Contained Areas $\qquad c_{areaT6b} := 0$

$A_{T6b} := (1408.00 + 844.48 + 150.75 + 446.59)ft^2$ $\qquad Ac_{areaT6b} := A_{T6b}\cdot c_{areaT6b}$

$A_{T6b} = 1.022\times 10^{-4}\ mi^2$ $\qquad Ac_{areaT6b} = 0\ ft^2$

Total:

$A_{T6.T} := A_{T6a} - A_{T6b}$ $\qquad$ $Ac_{areaT6.T} := Ac_{areaT6a}$

$A_{T6.T} = 0.0014\,mi^2$ $\qquad$ $Ac_{areaT6.T} = 40206.2\,ft^2$

Composite c Value:

$c_{areaT6.T} := \dfrac{Ac_{areaT6.T}}{A_{T6a}}$ $\qquad$ $c_{areaT6.T} = 0.95$

Time of Concentration

Time of Concentration, t_c (hr):

$t_{c.areaT6} := T_c$ $\qquad$ $t_{c.areaT6} = 0.097$ hr $\qquad$ (This calculation - See above)

Intensity (An 8 minute intensity will be used since that's the shortest duration shown on the chart)

$i_{areaT6.25} := 9.0 \cdot \dfrac{in}{hr}$ $\qquad$ $i_{areaT6.100} := 10.4 \cdot \dfrac{in}{hr}$ $\qquad$ (Ref. 2.3, Appendix D)

Runoff

$Q_{areaT6.25} := c_{areaT6.T} \cdot i_{areaT6.25} \cdot A_{T6.T}$ $\qquad$ $Q_{areaT6.100} := c_{areaT6.T} \cdot i_{areaT6.100} \cdot A_{T6.T}$

$Q_{areaT6.25} = 7.812\,\dfrac{ft^3}{sec}$ $\qquad$ $Q_{areaT6.100} = 9.028\,\dfrac{ft^3}{sec}$

7.6.3 Trench Drain T-6

The runoff from the contributory area of Trench Drain T-6 was used to design Trench Drain T-6. The FlowMaster program was used for the design with the following inputs:

Manning's Roughness Coefficient (Concrete Trench) = 0.013 $\qquad$ (Ref. 2.4, Appendix D)
Trench Slope = 0.00556 ft/ft
Bottom Width of the Trench = 2 ft
Design Discharge Flow in the Trench (Q_{25}) = 7.812 cfs
Check Discharge Flow in the Trench (Q_{100}) = 9.028 cfs
Road (Paved) Centerline Elevation = 81.50
Road (Paved) Edge Elevation = 81.25
Maximum Allowable Headwater Elevation = 81.25
Trench Drain Inlet Invert Elevation = 80.03
Trench Drain Outlet Invert Elevation = 79.85
Trench Drain Length = 32.36 ft

The FlowMaster design report for Trench Drain T-6 is shown in Appendix B of this calculation. A 2 ft wide Trench is sufficient to keep the design headwater and check headwater below the maximum allowable headwater elevation.

Trench Drain T-6 = 2' wide concrete trench

7.7 Culvert C-1

7.7.1 Time of Concentration (Culvert C-1 Contributory Area New Trench Drains T-1, T-3 and Existing Unit 3 Trench Drains T-2, T-5, T-4)

The runoff from the contributory area Existing T-2, T-5, and T-4 govern the TOC for C-1. Runoff from both Unit 4 T-1 and T-3 and Unit 3 T-2, T-5, and T-4 were used to size C-1.

Sheet Flow Inputs: $i := 1 .. 1$

Flow Segment One

$L_{sheet_1} := 49.95$	ft	Flow length	(Ref. 2.5, Appendix A)
$n_{sheet_1} := 0.011$		Manning's Roughness Coef. for sheet flow	(Ref. 2.2, pg. 3-3, Smooth surfaces)
$P_{2yr24hr_1} := 4.75$	in	2-yr, 24-hr rainfall depth	(Ref. 2.1, Appendix D)
$s_{sheet_1} := .0070$	ft/ft	Slope of watershed for sheet flow	(Ref. 2.5, Appendix A)

Sheet Flow Calculation:

$$T_1 := \sum_i \left[0.007 \cdot \frac{\left(n_{sheet_i} \cdot L_{sheet_i}\right)^{0.8}}{\left(P_{2yr24hr_i}\right)^{0.5} \cdot \left(s_{sheet_i}\right)^{0.4}} \right]$$

$T_1 = 0.014$ hr

$T_1 \cdot 60 = 0.869$ min

Shallow Concentrated Flow Inputs: $i := 1 .. 1$

$L_{scf_1} := 92.11$	ft	Length of shallow concentrated flow segment	(Ref. 2.5, Appendix A)
$s_{scf_1} := 0.0065$	ft/ft	Slope of watershed for shallow concentrated flow segment	(Ref. 2.5, Appendix A)
$Surface_1 := 1$		Surface designation for segment (paved=1, unpaved=0)	

Shallow Concentrated Flow Calculation: (Ref. 2.2, eq. 3-1)

$$V_{scf_i} := \text{if}\left[Surface_i = 0,\ 16.1345 \cdot \left(s_{scf_i}\right)^{0.5},\ 20.3282 \cdot \left(s_{scf_i}\right)^{0.5}\right]$$

$$V_{scf} = (1.639)\ \frac{ft}{sec}$$

$$T_2 := \sum_i \frac{L_{scf_i}}{3600 \cdot V_{scf_i}}$$

$T_2 = 0.016$ hr $\qquad T_2 \cdot 60 = 0.937$ min

Open Channel Flow Inputs: $i := 1..9$

*Flow Segment One - **Unit 3 Trench Drain T-1***

$L_{ocf_1} := 30.00$ ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_1} := 0.0130$ ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_1} := 0.011$	Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_1} := 1.70$ ft	Wetted perimeter of open channel cross section	
$fa_{ocf_1} := .35$ ft^2	Flow area of open channel cross section	

*Flow Segment Two - **Unit 3 Trench Drain T- 2***

$L_{ocf_2} := 60$ ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_2} := 0.0033$ ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_2} := 0.011$	Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_2} := 2.5$ ft	Wetted perimeter of open channel cross section	
$fa_{ocf_2} := .75$ ft^2	Flow area of open channel cross section	

*Flow Segment Three - **Existing Ditch From Unit 3 Trench Drain T-2 to Unit 3 Trench Drain T-5***

$L_{ocf_3} := 100.3455$ ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_3} := .0020$ ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_3} := 0.011$	Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_3} := 11.32$ ft	Wetted perimeter of open channel cross section	
$fa_{ocf_3} := 8$ ft^2	Flow area of open channel cross section	

*Flow Segment Four - **Unit 3 Trench Drain T-5***

$L_{ocf_4} := 30.00$ ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_4} := .0067$ ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_4} := 0.011$	Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_4} := 4.5$ ft	Wetted perimeter of open channel cross section	
$fa_{ocf_4} := 1.75$ ft^2	Flow area of open channel cross section	

Flow Segment Five - ***Existing Ditch From Unit 3 Trench Drain T-5 to Unit 3 Trench Drain T-4***

$L_{ocf_5} := 40.9183$	ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_5} := .0049$	ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_5} := 0.011$		Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_5} := 9.74$	ft	Wetted perimeter of open channel cross section	
$fa_{ocf_5} := 6.42$	ft^2	Flow area of open channel cross section	

Flow Segment Six - ***Unit 3 Trench Drain T-4***

$L_{ocf_6} := 42.00$	ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_6} := .0071$	ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_6} := 0.011$		Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_6} := 5.3$	ft	Wetted perimeter of open channel cross section	
$fa_{ocf_6} := 2.15$	ft^2	Flow area of open channel cross section	

Flow Segment Seven - ***New Ditch From Unit 3 Trench Drain T-4 to Unit 4 Culvert C-1, Part A***

$L_{ocf_7} := 274.6903$	ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_7} := .0020$	ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_7} := 0.033$		Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_7} := 15.58$	ft	Wetted perimeter of open channel cross section	(Appendix B)
$fa_{ocf_7} := 17.83$	ft^2	Flow area of open channel cross section	(Appendix B)

Flow Segment Eight - ***New Ditch From Unit 3 Trench Drain T-4 to Unit 4 Culvert C-1, Part B***

$L_{ocf_8} := 102.4070$	ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_8} := .0024$	ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_8} := 0.033$		Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_8} := 15.03$	ft	Wetted perimeter of open channel cross section	(Appendix B)
$fa_{ocf_8} := 16.55$	ft^2	Flow area of open channel cross section	(Appendix B)

Flow Segment Nine - ***New Ditch From Unit 3 Trench Drain T-4 to Unit 4 Culvert C-1, Part C***

$L_{ocf_9} := 80.3584$	ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf_9} := .0030$	ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf_9} := 0.033$		Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf_9} := 15.84$	ft	Wetted perimeter of open channel cross section	(Appendix B)
$fa_{ocf_9} := 15.89$	ft^2	Flow area of open channel cross section	(Appendix B)

Open Channel Flow Calculation:

$$V_{ocf_i} := 1.49 \cdot \left(\frac{fa_{ocf_i}}{wp_{ocf_i}}\right)^{\frac{2}{3}} \cdot \left(s_{ocf_i}\right)^{0.5} \cdot \frac{1}{n_{ocf_i}} \qquad V_{ocf} = \begin{pmatrix} 5.385 \\ 3.487 \\ 4.806 \\ 5.907 \\ 7.181 \\ 6.255 \\ 2.209 \\ 2.359 \\ 2.478 \end{pmatrix} \begin{matrix} \text{Segment One} \\ \text{Segment Two} \\ \text{Segment Three} \\ \text{Segment Four} \\ \text{Segment Five} \\ \text{Segment Six} \\ \text{Segment Seven} \\ \text{Segment Eight} \\ \text{Segment Nine} \end{matrix} \quad \frac{ft}{sec}$$

$$T_3 := \sum_i \frac{L_{ocf_i}}{3600 \cdot V_{ocf_i}} \qquad T_3 = 0.073 \ \ hr \qquad T_3 \cdot 60 = 4.355 \ \ min$$

Total Time of Concentration: $i := 1 .. 3$ (Ref. 2.2, eq. 3-2)

$$T_c := \sum_i T_i \qquad T_c = 0.103 \ \ hr \qquad T_c \cdot 60 = 6.161 \ \ min$$

7.7.2 Storm Water Runoff (Rational Method)

Composite Runoff Coefficient

Area (A)	***c***	***A*c***

Area C1a: Unit 3 Impervious Areas Draining to Unit 3 T-1, T-2, T-4, and T-5

$A_{C1a} := 74260 \cdot ft^2$ $\qquad c_{areaC1a} := 0.95$ $\qquad Ac_{areaC1a} := A_{C1a} \cdot c_{areaC1a}$

$A_{C1a} = 2.664 \times 10^{-3} \, mi^2$ $\qquad Ac_{areaC1a} = 70547 \, ft^2$

Area C1b:Impervious Areas Directly Draining to Culvert C-1

$A_{C1b} := 23520 \cdot ft^2$ $\quad c_{areaC1b} := 0.95$ $\quad Ac_{areaC1b} := A_{C1b} \cdot c_{areaC1b}$

$A_{C1b} = 8.437 \times 10^{-4}\, mi^2$ $\quad Ac_{areaC1b} = 22344\, ft^2$

Area C1c:Self-contained areas (Unit 3 and Unit 4 Cooling Tower)

$A_{C1c} := 36268 \cdot ft^2$ $\quad c_{areaC1c} := 0$ $\quad Ac_{areaC1c} := A_{C1c} \cdot c_{areaC1c}$

$A_{C1c} = 1.301 \times 10^{-3}\, mi^2$ $\quad Ac_{areaC1c} = 0\, ft^2$

Area C1d:Aggregate areas

$A_{C1d} := 38082 \cdot ft^2$ $\quad c_{areaC1d} := .75$ $\quad Ac_{areaC1d} := A_{C1d} \cdot c_{areaC1d}$

$A_{C1d} = 1.366 \times 10^{-3}\, mi^2$ $\quad Ac_{areaC1d} = 28561.5\, ft^2$

Total:

$$A_{C1.T} := A_{T1.T} + A_{T3.T} + A_{C1a} + A_{C1b} + A_{C1c} + A_{C1d}$$

$$Ac_{areaC1.T} := Ac_{areaT1.T} + Ac_{areaT3.T} + Ac_{areaC1a} + Ac_{areaC1b} + Ac_{areaC1c} + Ac_{areaC1d}$$

$A_{C1.T} = 0.0079\, mi^2$ $\quad Ac_{areaC1.T} = 163156.8\, ft^2$

Composite c Value:

$c_{areaC1.T} := \dfrac{Ac_{areaC1.T}}{A_{C1.T}}$ $\quad c_{areaC1.T} = 0.74$

Time of Concentration

Time of Concentration, t_c (hr):

$t_{c.areaC1} := T_c$ $\quad t_{c.areaC1} = 0.103\ hr$ (This calculation - See above)

Intensity (An 8 minute intensity will be used since that's the shortest duration shown on the chart)

$i_{areaC1.25} := 9.0 \cdot \dfrac{in}{hr}$ $\quad i_{areaC1.100} := 10.4 \cdot \dfrac{in}{hr}$ (Ref. 2.3, Appendix D)

Runoff

$Q_{areaC1.25} := c_{areaC1.T} \cdot i_{areaC1.25} \cdot A_{C1.T}$ $\quad Q_{areaC1.100} := c_{areaC1.T} \cdot i_{areaC1.100} \cdot A_{C1.T}$

$Q_{areaC1.25} = 33.991\, \dfrac{ft^3}{sec}$ $\quad Q_{areaC1.100} = 39.278\, \dfrac{ft^3}{sec}$

7.7.3 Culvert C-1

The runoff from the contributory area of Culvert C-1, T-1, T-3, Unit 3 T-1, Unit 3 T-2, Unit 3 T-4, and Unit 3 T-5 were used to design Culvert C-1. The CulvertMaster program was used for the design with the following inputs:

Manning's Roughness Coeff. of Outlet Ditch (aggregate-lined ditch) = 0.033 (Ref. 2.4, Appendix D)
Outlet Ditch Slope = 0.005 ft/ft
Outlet Ditch Side Slopes = 3H:1V
Outlet Ditch Bottom Width = 3 ft
Design Discharge Flow in the Culvert (Q_{25}) = 33.991 cfs
Check Discharge Flow in the Culvert (Q_{100}) = 39.278 cfs
Road (Paved) Centerline Elevation = 81.50
Road (Paved) Edge Elevation = 81.25
Maximum Allowable Headwater Elevation = 81.25
Culvert Inlet Invert Elevation = 77.75
Culvert Outlet Invert Elevation = 77.50
Culvert Length = 48.50 ft

The CulvertMaster design report for Culvert C-1 is shown in Appendix C of this calculation. A double barrel 24" diameter CHDPE culvert (smooth interior) is sufficient to keep the design headwater and check headwater below the maximum allowable headwater elevation.

Culvert C-1 = 2 - 24" CHDPE Culverts (smooth interior)

7.8 Culvert C-2

7.8.1 Time of Concentration (Culvert C-2 Contributory Area New Trench Drains T-4 and T-5)

The runoff from the contributory area for Culvert C-1 govern the TOC for C-2. Runoff from C-1, T-4, and T-5 were used to size C-1.

Sheet Flow Inputs:

No Inputs.

Shallow Concentrated Flow Inputs:

No Inputs.

Open Channel Flow Inputs:

Flow Segment One - ***New ditch from Culvert C-1 to Culvert C-2 Part A***

$L_{ocf.C2_1} := 183.85$ ft — Length of open channel flow segment (Ref. 2.5, Appendix A)

$s_{ocf.C2_1} := 0.0027$ ft/ft — Slope of watershed for open channel flow segment (Ref. 2.5, Appendix A)

$n_{ocf.C2_1} := 0.033$ — Manning's Roughness Coef. for open channel flow segment (Ref. 2.4, Appendix D)

$wp_{ocf.C2_1} := 19.99$ ft — Wetted perimeter of open channel cross section (Appendix C)

$fa_{ocf.C2_1} := 25.64$ ft^2 — Flow area of open channel cross section (Appendix C)

Flow Segment Two - ***New ditch from Culvert C-1 to Culvert C-2 Part B***

$L_{ocf.C2_2} := 96.45$ ft	Length of open channel flow segment	(Ref. 2.5, Appendix A)
$s_{ocf.C2_2} := 0.0078$ ft/ft	Slope of watershed for open channel flow segment	(Ref. 2.5, Appendix A)
$n_{ocf.C2_2} := 0.033$	Manning's Roughness Coef. for open channel flow segment	(Ref. 2.4, Appendix D)
$wp_{ocf.C2_2} := 15.64$ ft	Wetted perimeter of open channel cross section	(Appendix C)
$fa_{ocf.C2_2} := 16.91$ ft^2	Flow area of open channel cross section	(Appendix C)

Open Channel Flow Calculation: $i := 1..2$

$$V_{ocf.C2_i} := 1.49 \cdot \left(\frac{fa_{ocf.C2_i}}{wp_{ocf.C2_i}}\right)^{\frac{2}{3}} \cdot \left(s_{ocf.C2_i}\right)^{0.5} \cdot \frac{1}{n_{ocf.C2_i}} \qquad V_{ocf.C2} = \begin{pmatrix} 2.77 \\ 4.201 \end{pmatrix} \begin{array}{l} \text{Segment One} \\ \text{Segment Two} \end{array} \frac{\text{ft}}{\text{sec}}$$

$$T_1 := \sum_i \frac{L_{ocf.C2_i}}{3600 \cdot V_{ocf.C2_i}} \qquad T_1 = 0.025 \text{ hr}$$

$$T_1 \cdot 60 = 1.489 \text{ min}$$

Total Time of Concentration: (Ref. 2, eq. 3-2)

$T_c := T_1$ $\quad T_c = 0.025$ hr $\quad T_c \cdot 60 = 1.489$ min

7.8.2 Storm Water Runoff (Rational Method)

Composite Runoff Coefficient

Area (A) ***c*** ***A*c***

Area C2a: Impervious Areas Draining to Culvert C-2

$A_{C2a} := 29078 \cdot ft^2$ $\quad c_{areaC2a} := 0.95$ $\quad Ac_{areaC2a} := A_{C2a} \cdot c_{areaC2a}$

$A_{C2a} = 1.043 \times 10^{-3}\, mi^2$ $\quad Ac_{areaC2a} = 27624.1\, ft^2$

Area C2b:Aggregate Areas Draining to Culvert C-2

$A_{C2b} := 107034 \cdot ft^2$ $\quad c_{areaC2b} := 0.75$ $\quad Ac_{areaC2b} := A_{C2b} \cdot c_{areaC2b}$

$A_{C2b} = 3.839 \times 10^{-3}\, mi^2$ $\quad Ac_{areaC2b} = 80275.5\, ft^2$

Total:

$$A_{C2.T} := A_{T4.T} + A_{T5.T} + A_{C1.T} + A_{C2a} + A_{C2b}$$

$$Ac_{areaC2.T} := Ac_{areaT4.T} + Ac_{areaT5.T} + Ac_{areaC1.T} + Ac_{areaC2a} + Ac_{areaC2b}$$

$$A_{C2.T} = 0.0139\,mi^2 \qquad Ac_{areaC2.T} = 299922\,ft^2$$

Composite c Value:

$$c_{areaC2.T} := \frac{Ac_{areaC2.T}}{A_{C2.T}} \qquad c_{areaC2.T} = 0.775$$

Time of Concentration

Time of Concentration, t_c (hr): (This calculation - See above)

$$t_{c.areaC2} := T_c + t_{c.areaC1} \qquad t_{c.areaC2} = 0.127\ hr$$ (Conclusion 6.2)

Intensity

$$i_{areaC2.25} := 8.8 \cdot \frac{in}{hr} \qquad i_{areaC2.100} := 10.2 \cdot \frac{in}{hr}$$ (Ref. 2.3, Appendix D)

Runoff

$$Q_{areaC2.25} := c_{areaC2.T} \cdot i_{areaC2.25} \cdot A_{C2.T} \qquad Q_{areaC2.100} := c_{areaC2.T} \cdot i_{areaC2.100} \cdot A_{C2.T}$$

$$Q_{areaC2.25} = 61.095\,\frac{ft^3}{sec} \qquad Q_{areaC2.100} = 70.815\,\frac{ft^3}{sec}$$

7.8.3 Culvert C-2

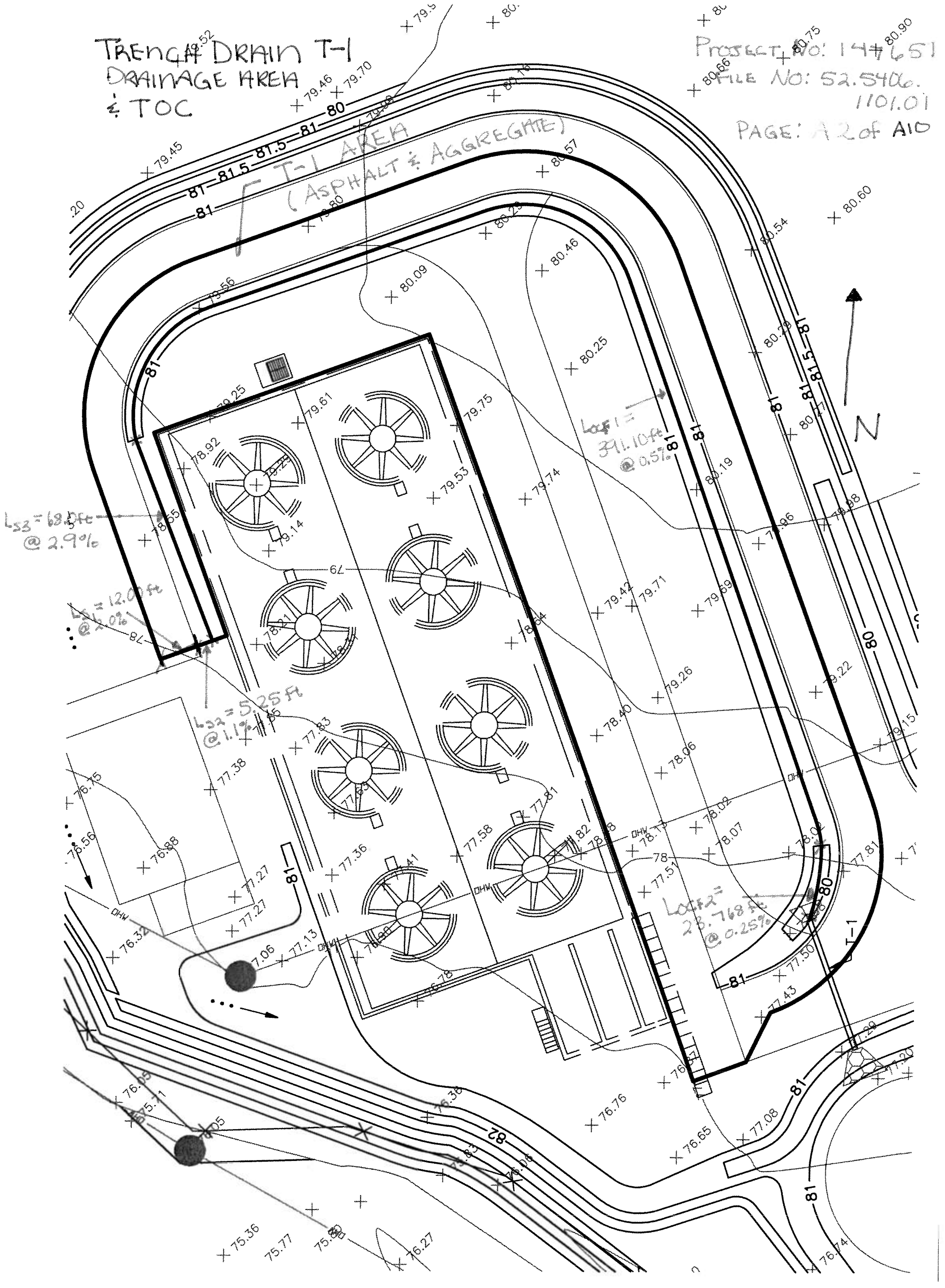
The runoff from the contributory area of Culvert C-1 and C-2 and Trench Drains T-4 and T-5 were used to design Culvert C-2. The CulvertMaster program was used for the design with the following inputs:

Design Discharge Flow in the Culvert (Q_{25}) = 61.095 cfs
Check Discharge Flow in the Culvert (Q_{100}) = 70.815 cfs
Road (Paved) Centerline Elevation = 81.50
Road (Paved) Edge Elevation = 81.25
Maximum Allowable Headwater Elevation = 81.25
Culvert Inlet Invert Elevation = 76.75
Culvert Outlet Invert Elevation = 76.33
Culvert Length = 56.00 ft

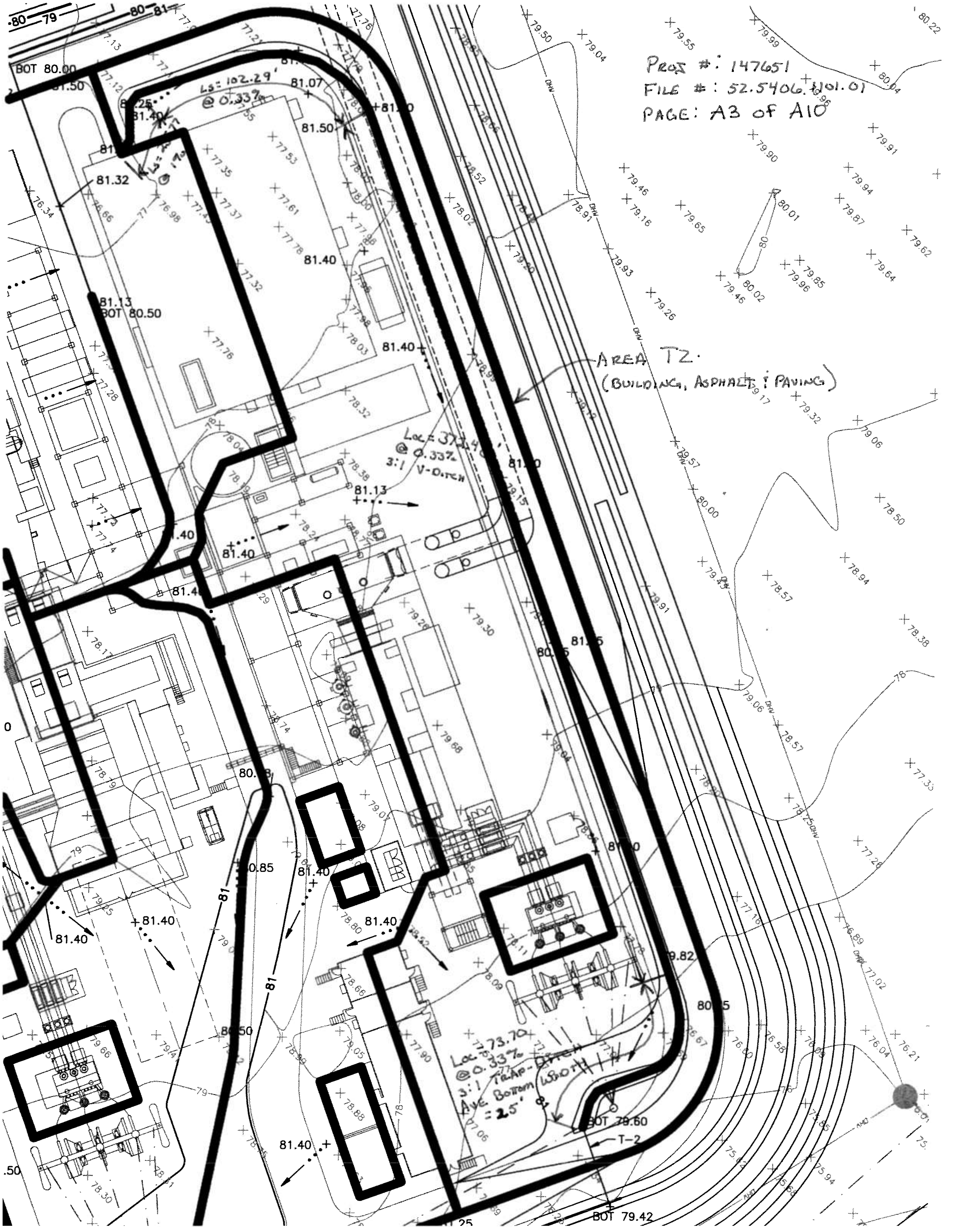
The CulvertMaster design report for Culvert C-2 is shown in Appendix C of this calculation. A triple barrel 24" diameter CHDPE culvert (smooth interior) is sufficient to keep the design headwater and check headwater below the maximum allowable headwater elevation.

Culvert C-2 = 3 - 24" CHDPE Culverts (smooth interior)

APPENDIX A
Time of Concentration Figures

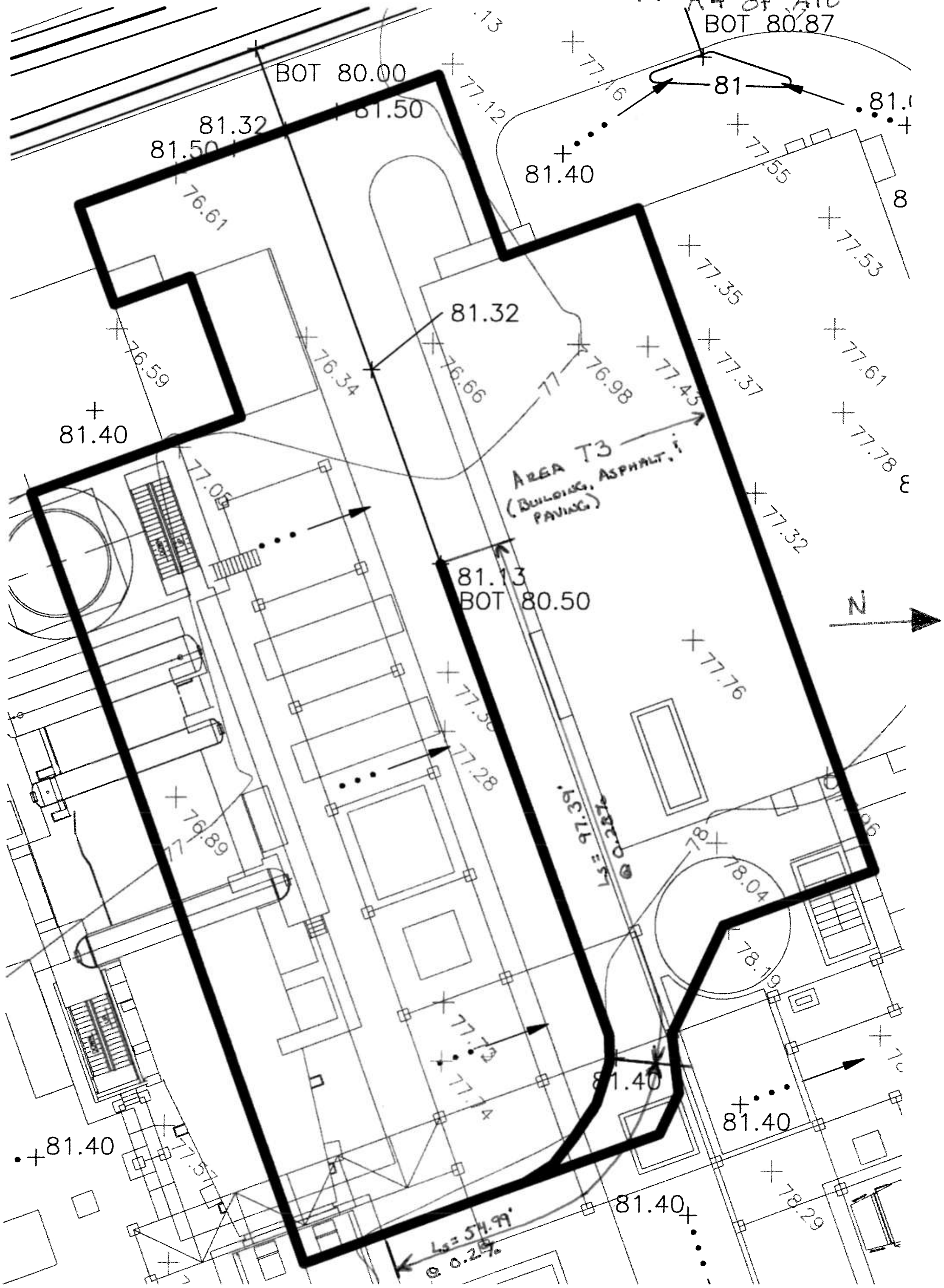


TRENCH DRAIN T-1
DRAINAGE AREA
& TOC
PROJECT NO: 147651
FILE NO: 52.5406.
1101.01
PAGE: A2 of A10
T-1 AREA
(ASPHALT & AGGREGATE)
N
L_{OF1} = 391.10ft @ 0.57%
L_{S3} = 68.0ft @ 2.9%
L_{S1} = 12.00 ft @ 2.0%
L_{S2} = 5.25 ft @ 1.1%
L_{OF2} = 23.768 ft @ 0.25%
T-1
OHW
81
81.5
80
82
79
78

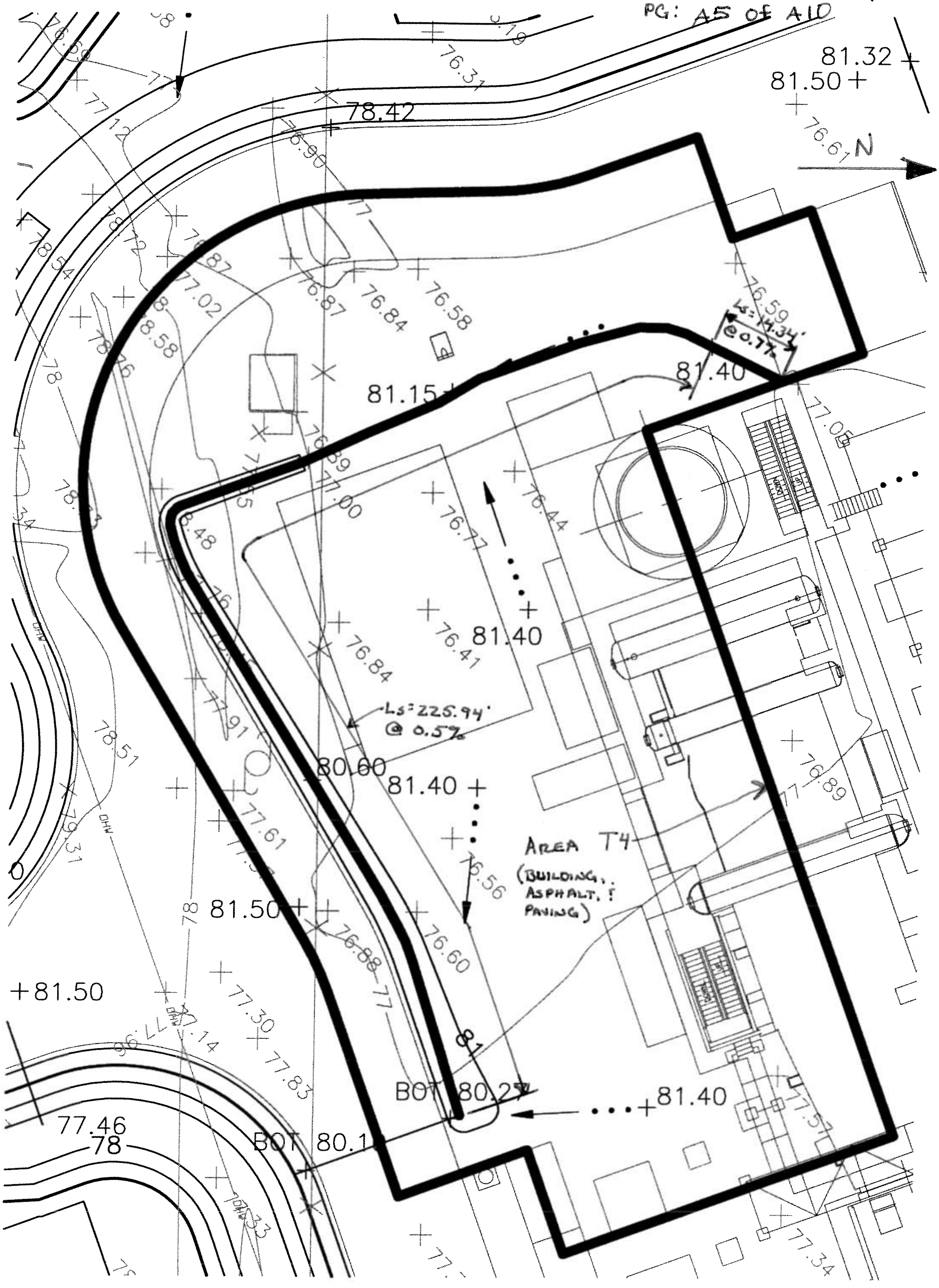


PROJ #: 147651
FILE #: 52.5406.001.01
PAGE: A3 OF A10
AREA TZ.
(BUILDING, ASPHALT, PAVING)
Ls: 102.29'
@ 0.33%
Loc = 372.4
@ 0.33%
3:1 V-DITCH
Loc = 73.70
@ 0.33% TRAP-DITCH
3:1
AVE Bottom WIDTH = 2.5'
BOT 80.00
81.13
BOT 80.50
BOT 79.60
BOT 79.42
T-2

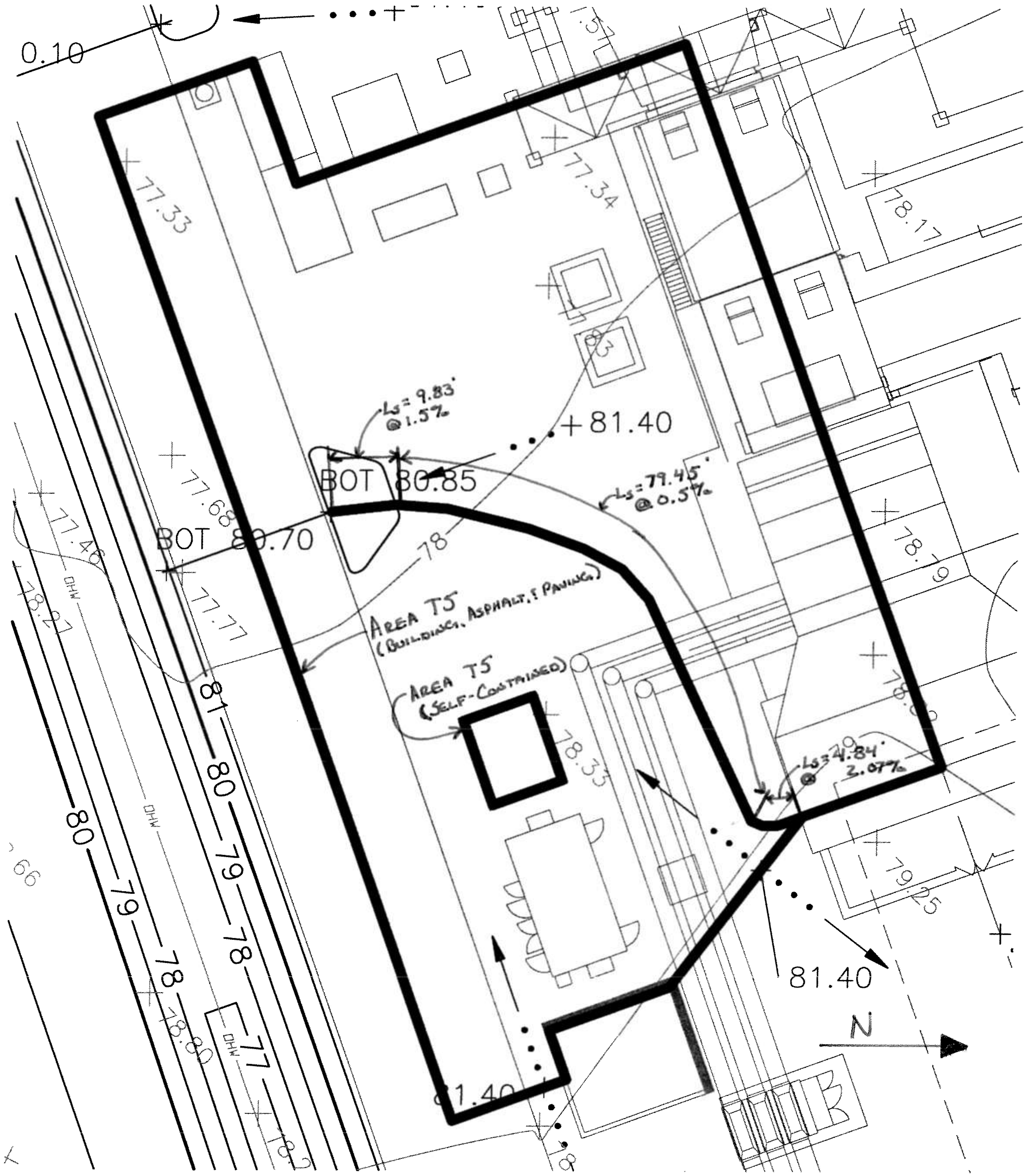
PROJ # 147651
FILE # 52.5406.1101.01
PG: A4 OF A10



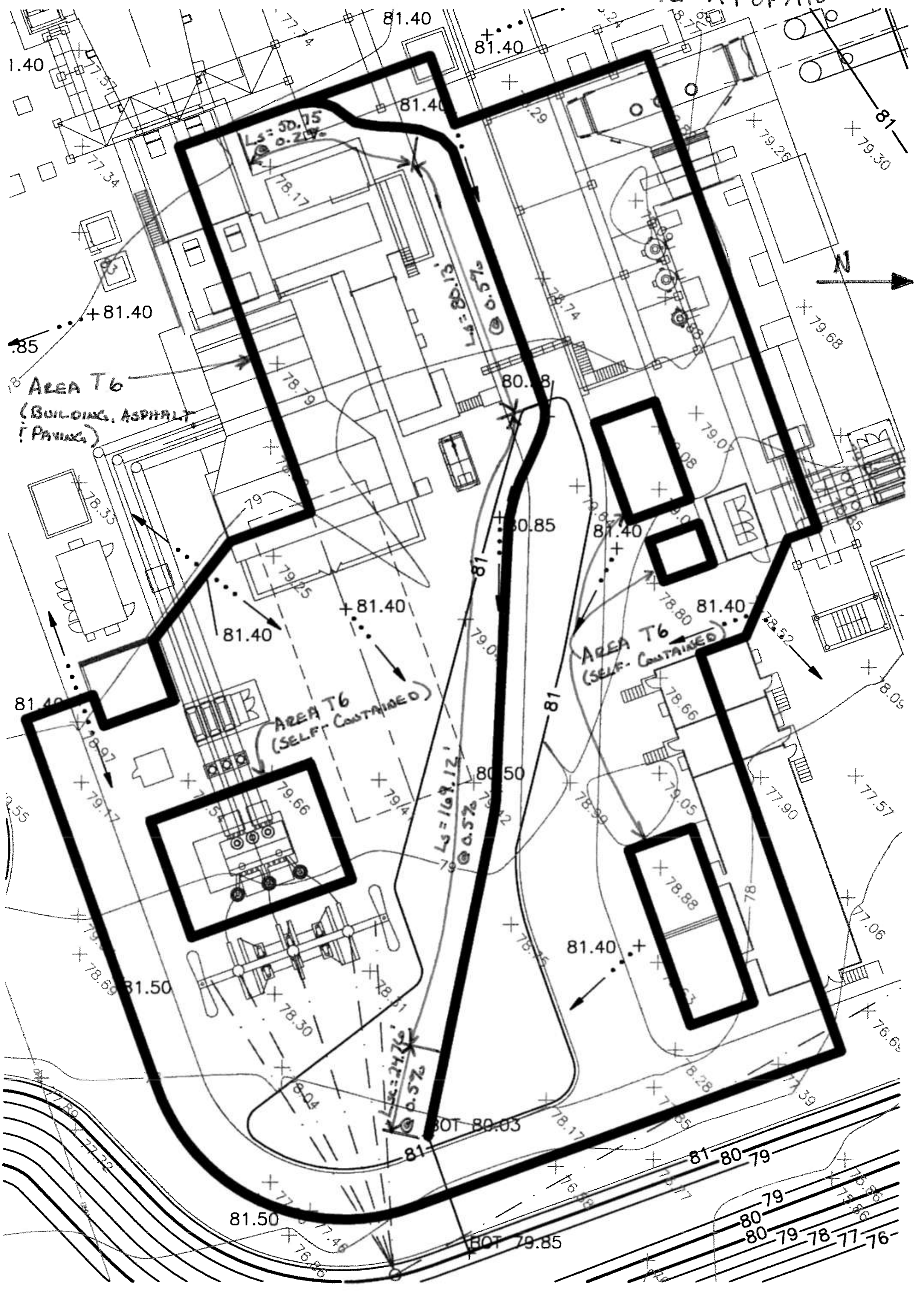
PROJ #: 147651
FILE #: 52.5406.1101.01
PG: A5 OF A10

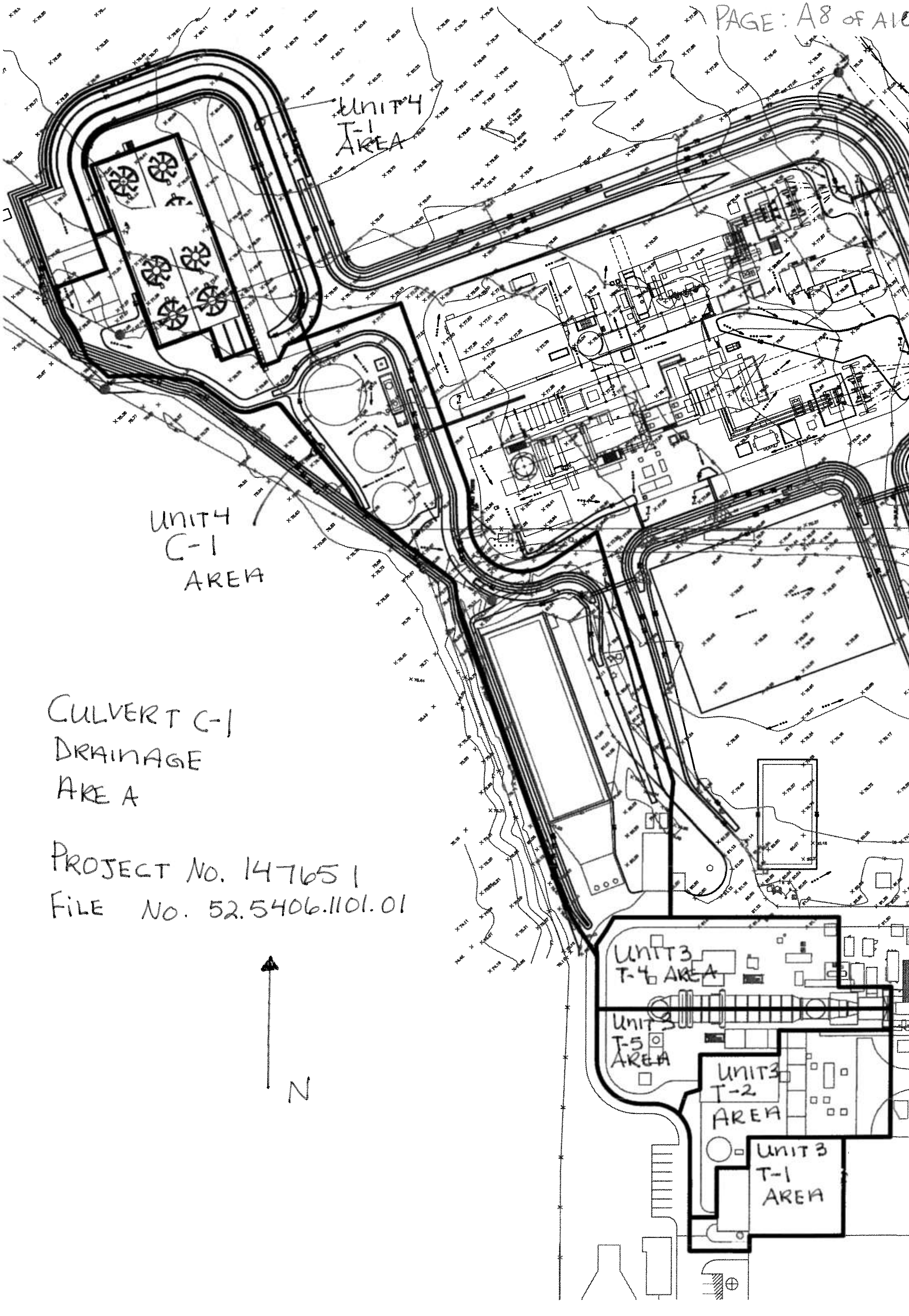


PROJ # 147651
FILE # 52.5406.1101.01
PG: A6 OF A10



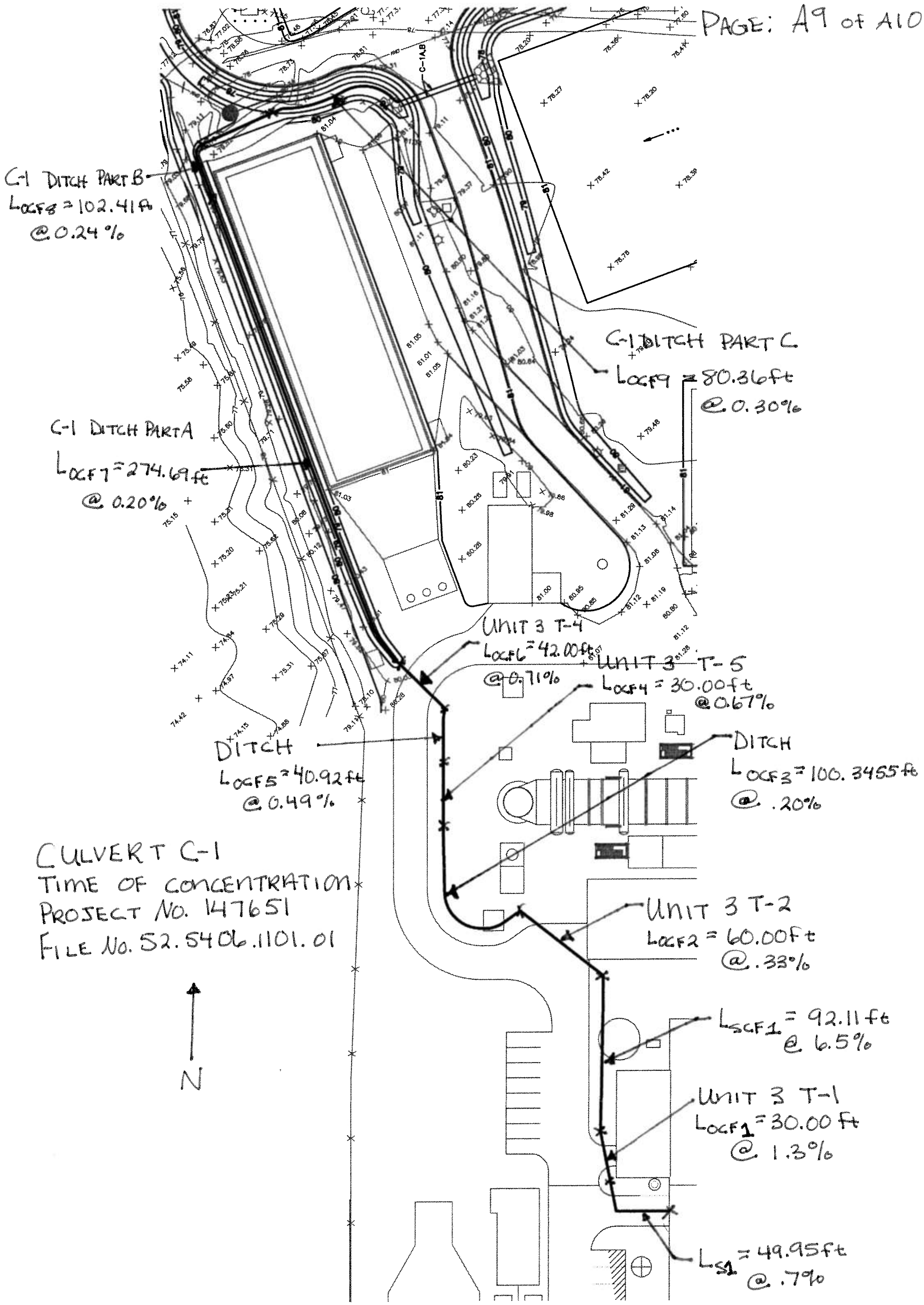
PROJ # 147651
FILE # 52.5406.1101.01
PG: A7 OF A10



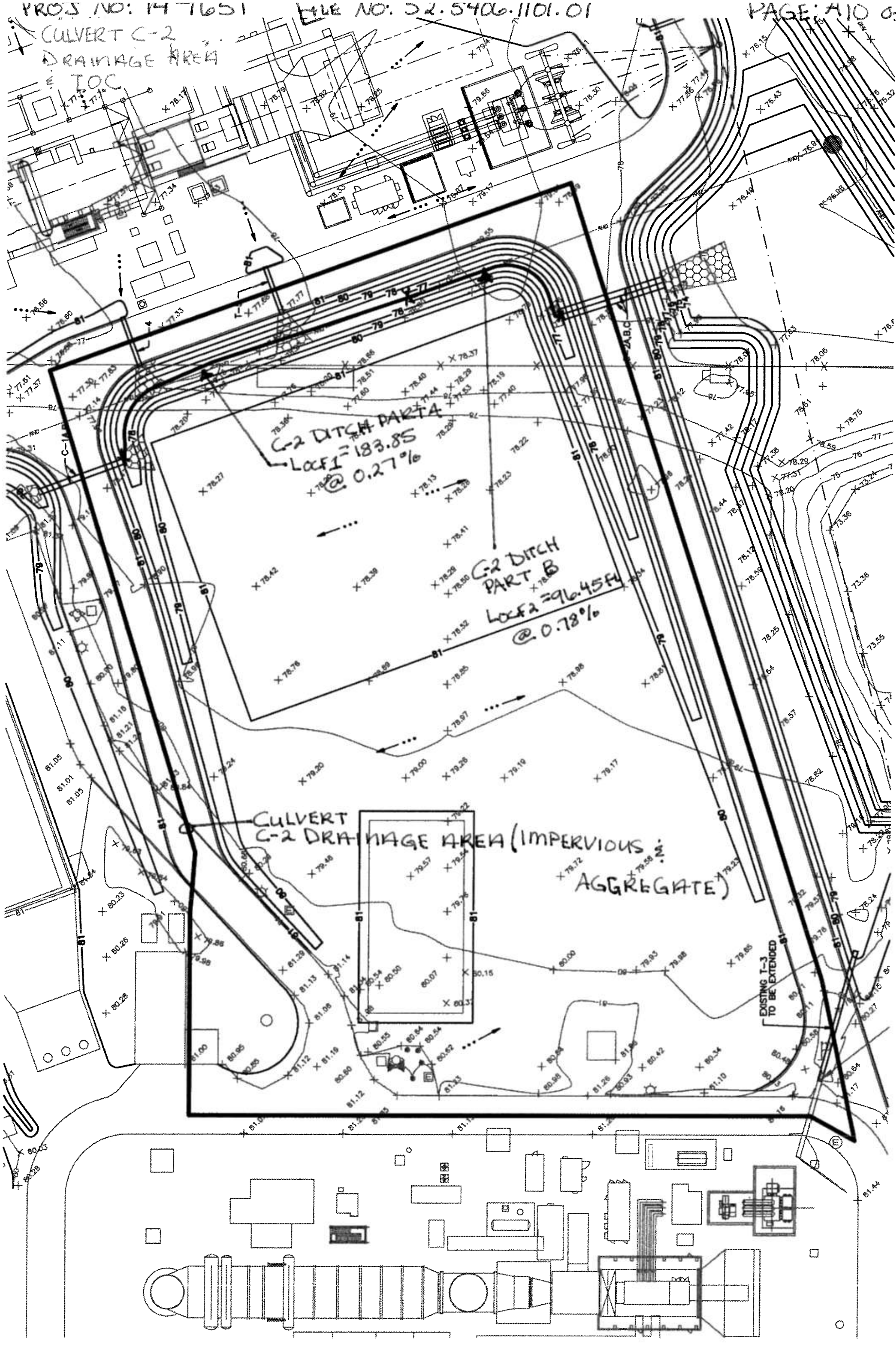


CULVERT C-1
DRAINAGE
AREA A

PROJECT NO. 147651
FILE NO. 52.5406.1101.01



CULVERT C-1
TIME OF CONCENTRATION
PROJECT No. 147651
FILE No. 52.5406.1101.01


CULVERT C-2
DRAINAGE AREA
& TOC
C-2 DITCH PART A
Locf1 = 183.85
@ 0.27%
C-2 DITCH
PART B
Locf2 = 96.45 ft
@ 0.78%
CULVERT
C-2 DRAINAGE AREA (IMPERVIOUS &
AGGREGATE)
EXISTING T-3
TO BE EXTENDED

APPENDIX B
FlowMaster Output

BLACK & VEATCH

Owner: Florida Municipal Power Agency
Plant: Cane Island Power Park **Unit:** 4
Project No. 147651
File No. 52.5406.1101.01
Title: Trench Drain and Culvert Design and Time of Concentration

Prepared by: A. L. MORGAN
Date: 03/07/08
Verified by: RMS
Date: 03/12/08
Page No. B2 of B22
Calc Rev: 0

Worksheet for T-1 Ditch Part A

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.033	
Channel Slope	0.00500	ft/ft
Left Side Slope	3.00	ft/ft (H:V)
Right Side Slope	3.00	ft/ft (H:V)
Bottom Width	5.00	ft
Discharge	5.41	ft³/s

Results

Normal Depth	0.49	ft
Flow Area	3.18	ft²
Wetted Perimeter	8.10	ft
Top Width	7.94	ft
Critical Depth	0.31	ft
Critical Slope	0.02508	ft/ft
Velocity	1.70	ft/s
Velocity Head	0.05	ft
Specific Energy	0.54	ft
Froude Number	0.48	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.49	ft
Critical Depth	0.31	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.02508	ft/ft

Worksheet for T-1 Ditch Part B

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.033	
Channel Slope	0.00250	ft/ft
Left Side Slope	3.00	ft/ft (H:V)
Right Side Slope	3.00	ft/ft (H:V)
Bottom Width	5.00	ft
Discharge	5.41	ft³/s

Results

Normal Depth	0.59	ft
Flow Area	4.03	ft²
Wetted Perimeter	8.76	ft
Top Width	8.57	ft
Critical Depth	0.31	ft
Critical Slope	0.02508	ft/ft
Velocity	1.34	ft/s
Velocity Head	0.03	ft
Specific Energy	0.62	ft
Froude Number	0.35	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.59	ft
Critical Depth	0.31	ft
Channel Slope	0.00250	ft/ft
Critical Slope	0.02508	ft/ft

Worksheet for T-1 25 yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.013	
Channel Slope	0.00500	ft/ft
Bottom Width	1.50	ft
Discharge	4.69	ft^3/s

Results

Normal Depth	0.74	ft
Flow Area	1.12	ft^2
Wetted Perimeter	2.99	ft
Top Width	1.50	ft
Critical Depth	0.67	ft
Critical Slope	0.00660	ft/ft
Velocity	4.19	ft/s
Velocity Head	0.27	ft
Specific Energy	1.02	ft
Froude Number	0.86	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.74	ft
Critical Depth	0.67	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.00660	ft/ft

Worksheet for T-1 100 yr

Project Description

Friction Method	Manning Formula	
Solve For	Normal Depth	

Input Data

Roughness Coefficient	0.013	
Channel Slope	0.00500	ft/ft
Bottom Width	1.50	ft
Discharge	5.41	ft³/s

Results

Normal Depth	0.83	ft
Flow Area	1.25	ft²
Wetted Perimeter	3.16	ft
Top Width	1.50	ft
Critical Depth	0.74	ft
Critical Slope	0.00680	ft/ft
Velocity	4.35	ft/s
Velocity Head	0.29	ft
Specific Energy	1.12	ft
Froude Number	0.84	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.83	ft
Critical Depth	0.74	ft
Channel Slope	0.00500	ft/ft
Critical Slope	0.00680	ft/ft

Worksheet for T-2 25 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00549	ft/ft
Bottom Width:	2.00	ft
Discharge:	9.112	ft³/s
Results		
Normal Depth:	0.89	ft
Flow Area:	1.78	ft²
Wetted Perimeter:	3.78	ft
Top Width:	2.00	ft
Critical Depth:	0.86	ft
Critical Slope:	0.00593	ft/ft
Velocity:	5.12	ft/s
Velocity Head:	0.41	ft
Specific Energy:	1.30	ft
Froude Number:	0.96	
Flow Type:	Subcritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.89	ft
Critical Depth:	0.86	ft
Channel Slope:	0.00549	ft/ft
Critical Slope:	0.00593	ft/ft

Worksheet for T-2 100 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00549	ft/ft
Bottom Width:	2.00	ft
Discharge:	10.529	ft^3/s
Results		
Normal Depth:	0.99	ft
Flow Area:	1.98	ft^2
Wetted Perimeter:	3.98	ft
Top Width:	2.00	ft
Critical Depth:	0.95	ft
Critical Slope:	0.00611	ft/ft
Velocity:	5.32	ft/s
Velocity Head:	0.44	ft
Specific Energy:	1.43	ft
Froude Number:	0.94	
Flow Type:	Subcritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.99	ft
Critical Depth:	0.95	ft
Channel Slope:	0.00549	ft/ft
Critical Slope:	0.00611	ft/ft

Worksheet for T-2 Ditch1

Project Description		
Flow Element:	Triangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00330	ft/ft
Left Side Slope:	3.00	ft/ft (H:V)
Right Side Slope:	3.00	ft/ft (H:V)
Discharge:	10.529	ft^3/s
Results		
Normal Depth:	0.95	ft
Flow Area:	2.72	ft^2
Wetted Perimeter:	6.02	ft
Top Width:	5.72	ft
Critical Depth:	0.95	ft
Critical Slope:	0.00339	ft/ft
Velocity:	3.87	ft/s
Velocity Head:	0.23	ft
Specific Energy:	1.19	ft
Froude Number:	0.99	
Flow Type:	Subcritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.95	ft
Critical Depth:	0.95	ft
Channel Slope:	0.00330	ft/ft
Critical Slope:	0.00339	ft/ft

Worksheet for T-2 Ditch2

Project Description		
Flow Element:	Trapezoidal Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00330	ft/ft
Left Side Slope:	3.00	ft/ft (H:V)
Right Side Slope:	3.00	ft/ft (H:V)
Bottom Width:	2.50	ft
Discharge:	10.529	ft³/s
Results		
Normal Depth:	0.64	ft
Flow Area:	2.81	ft²
Wetted Perimeter:	6.53	ft
Top Width:	6.32	ft
Critical Depth:	0.63	ft
Critical Slope:	0.00337	ft/ft
Velocity:	3.74	ft/s
Velocity Head:	0.22	ft
Specific Energy:	0.86	ft
Froude Number:	0.99	
Flow Type:	Subcritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.64	ft
Critical Depth:	0.63	ft
Channel Slope:	0.00330	ft/ft

Worksheet for T-3 25 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00495	ft/ft
Bottom Width:	2.00	ft
Discharge:	4.003	ft^3/s
Results		
Normal Depth:	0.51	ft
Flow Area:	1.02	ft^2
Wetted Perimeter:	3.02	ft
Top Width:	2.00	ft
Critical Depth:	0.50	ft
Critical Slope:	0.00533	ft/ft
Velocity:	3.91	ft/s
Velocity Head:	0.24	ft
Specific Energy:	0.75	ft
Froude Number:	0.96	
Flow Type:	Subcritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.51	ft
Critical Depth:	0.50	ft
Channel Slope:	0.00495	ft/ft
Critical Slope:	0.00533	ft/ft

Worksheet for T-3 100 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00495	ft/ft
Bottom Width:	2.00	ft
Discharge:	4.626	ft^3/s
Results		
Normal Depth:	0.57	ft
Flow Area:	1.13	ft^2
Wetted Perimeter:	3.13	ft
Top Width:	2.00	ft
Critical Depth:	0.55	ft
Critical Slope:	0.00539	ft/ft
Velocity:	4.08	ft/s
Velocity Head:	0.26	ft
Specific Energy:	0.83	ft
Froude Number:	0.96	
Flow Type:	Subcritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.57	ft
Critical Depth:	0.55	ft
Channel Slope:	0.00495	ft/ft
Critical Slope:	0.00539	ft/ft

Worksheet for T-4 25 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00545	ft/ft
Bottom Width:	2.00	ft
Discharge:	3.689	ft^3/s
Results		
Normal Depth:	0.47	ft
Flow Area:	0.94	ft^2
Wetted Perimeter:	2.94	ft
Top Width:	2.00	ft
Critical Depth:	0.47	ft
Critical Slope:	0.00530	ft/ft
Velocity:	3.94	ft/s
Velocity Head:	0.24	ft
Specific Energy:	0.71	ft
Froude Number:	1.02	
Flow Type:	Supercritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.47	ft
Critical Depth:	0.47	ft
Channel Slope:	0.00545	ft/ft
Critical Slope:	0.00530	ft/ft

BLACK & VEATCH

Owner: Florida Municipal Power Agency
Plant: Cane Island Power Park Unit 4
Project No.: 147651 File No.: 52.5406.1101.01
Title: Trench Drain & Culvert Design

Computed By: JMS
Date: 03/07/08
Verified By: [signature]
Date: 3/12/08
Page: B13 of B22

Worksheet for T-4 100 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00545	ft/ft
Bottom Width:	2.00	ft
Discharge:	4.263	ft^3/s
Results		
Normal Depth:	0.52	ft
Flow Area:	1.03	ft^2
Wetted Perimeter:	3.03	ft
Top Width:	2.00	ft
Critical Depth:	0.52	ft
Critical Slope:	0.00535	ft/ft
Velocity:	4.12	ft/s
Velocity Head:	0.26	ft
Specific Energy:	0.78	ft
Froude Number:	1.01	
Flow Type:	Supercritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.52	ft
Critical Depth:	0.52	ft
Channel Slope:	0.00545	ft/ft
Critical Slope:	0.00535	ft/ft

Worksheet for T-5 25 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00554	ft/ft
Bottom Width:	2.00	ft
Discharge:	2.295	ft³/s
Results		
Normal Depth:	0.34	ft
Flow Area:	0.68	ft²
Wetted Perimeter:	2.68	ft
Top Width:	2.00	ft
Critical Depth:	0.34	ft
Critical Slope:	0.00521	ft/ft
Velocity:	3.40	ft/s
Velocity Head:	0.18	ft
Specific Energy:	0.52	ft
Froude Number:	1.03	
Flow Type:	Supercritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.34	ft
Critical Depth:	0.34	ft
Channel Slope:	0.00554	ft/ft
Critical Slope:	0.00521	ft/ft

Worksheet for T-5 100 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00554	ft/ft
Bottom Width:	2.00	ft
Discharge:	2.652	ft^3/s
Results		
Normal Depth:	0.37	ft
Flow Area:	0.74	ft^2
Wetted Perimeter:	2.74	ft
Top Width:	2.00	ft
Critical Depth:	0.38	ft
Critical Slope:	0.00522	ft/ft
Velocity:	3.56	ft/s
Velocity Head:	0.20	ft
Specific Energy:	0.57	ft
Froude Number:	1.03	
Flow Type:	Supercritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.37	ft
Critical Depth:	0.38	ft
Channel Slope:	0.00554	ft/ft
Critical Slope:	0.00522	ft/ft

Worksheet for T-6 25 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00556	ft/ft
Bottom Width:	2.00	ft
Discharge:	7.812	ft^3/s
Results		
Normal Depth:	0.79	ft
Flow Area:	1.58	ft^2
Wetted Perimeter:	3.58	ft
Top Width:	2.00	ft
Critical Depth:	0.78	ft
Critical Slope:	0.00577	ft/ft
Velocity:	4.94	ft/s
Velocity Head:	0.38	ft
Specific Energy:	1.17	ft
Froude Number:	0.98	
Flow Type:	Subcritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.79	ft
Critical Depth:	0.78	ft
Channel Slope:	0.00556	ft/ft
Critical Slope:	0.00577	ft/ft

BLACK & VEATCH

Owner: Florida Municipal Power Agency
Plant: Cane Island Power Park Unit 4
Project No.: 147651 File No.: 52.5406.1101.01
Title: Trench Drain & Culvert Design

Computed By: JMS
Date: 03/07/08
Verified By: AZM
Date: 3/12/08

Worksheet for T-6 100 yr

Project Description		
Flow Element:	Rectangular Channel	
Friction Method:	Manning Formula	
Solve For:	Normal Depth	
Input Data		
Roughness Coefficient:	0.013	
Channel Slope:	0.00556	ft/ft
Bottom Width:	2.00	ft
Discharge:	9.028	ft^3/s
Results		
Normal Depth:	0.88	ft
Flow Area:	1.76	ft^2
Wetted Perimeter:	3.76	ft
Top Width:	2.00	ft
Critical Depth:	0.86	ft
Critical Slope:	0.00592	ft/ft
Velocity:	5.14	ft/s
Velocity Head:	0.41	ft
Specific Energy:	1.29	ft
Froude Number:	0.97	
Flow Type:	Subcritical	
GVF Input Data		
Downstream Depth:	0.00	ft
Length:	0.00	ft
Number Of Steps:	0	
GVF Output Data		
Upstream Depth:	0.00	ft
Profile Description:		
Profile Headloss:	0.00	ft
Downstream Velocity:	Infinity	ft/s
Upstream Velocity:	Infinity	ft/s
Normal Depth:	0.88	ft
Critical Depth:	0.86	ft
Channel Slope:	0.00556	ft/ft
Critical Slope:	0.00592	ft/ft

Worksheet for C-1 New Ditch Part A

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.033	
Channel Slope	0.00200	ft/ft
Left Side Slope	3.00	ft/ft (H:V)
Right Side Slope	3.00	ft/ft (H:V)
Bottom Width	3.00	ft
Discharge	39.28	ft³/s

Results

Normal Depth	1.99	ft
Flow Area	17.83	ft²
Wetted Perimeter	15.58	ft
Top Width	14.93	ft
Critical Depth	1.20	ft
Critical Slope	0.01817	ft/ft
Velocity	2.20	ft/s
Velocity Head	0.08	ft
Specific Energy	2.06	ft
Froude Number	0.36	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.99	ft
Critical Depth	1.20	ft
Channel Slope	0.00200	ft/ft
Critical Slope	0.01817	ft/ft

Worksheet for C-1 New Ditch Part B

Project Description

Friction Method	Manning Formula	
Solve For	Normal Depth	

Input Data

Roughness Coefficient	0.033	
Channel Slope	0.00244	ft/ft
Left Side Slope	3.00	ft/ft (H:V)
Right Side Slope	3.00	ft/ft (H:V)
Bottom Width	3.00	ft
Discharge	39.28	ft³/s

Results

Normal Depth	1.90	ft
Flow Area	16.55	ft²
Wetted Perimeter	15.03	ft
Top Width	14.41	ft
Critical Depth	1.20	ft
Critical Slope	0.01817	ft/ft
Velocity	2.37	ft/s
Velocity Head	0.09	ft
Specific Energy	1.99	ft
Froude Number	0.39	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.90	ft
Critical Depth	1.20	ft
Channel Slope	0.00244	ft/ft
Critical Slope	0.01817	ft/ft

Worksheet for C-1 New Ditch Part C

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.033	
Channel Slope	0.00300	ft/ft
Left Side Slope	3.00	ft/ft (H:V)
Right Side Slope	3.00	ft/ft (H:V)
Bottom Width	6.75	ft
Discharge	39.28	ft³/s

Results

Normal Depth	1.44	ft
Flow Area	15.89	ft²
Wetted Perimeter	15.84	ft
Top Width	15.37	ft
Critical Depth	0.89	ft
Critical Slope	0.01852	ft/ft
Velocity	2.47	ft/s
Velocity Head	0.09	ft
Specific Energy	1.53	ft
Froude Number	0.43	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.44	ft
Critical Depth	0.89	ft
Channel Slope	0.00300	ft/ft
Critical Slope	0.01852	ft/ft

BLACK & VEATCH

Owner: Florida Municipal Power Agency
Plant: Cane Island Power Park **Unit:** 4
Project No. 147651
File No. 52.5406.1101.01
Title: Trench Drain and Culvert Design and Time of Concentration

Prepared by: A. L. MORGAN
Date: 03/07/08
Verified by: JMS
Date: 3/12/08
Page No. B21 of B22
Calc Rev: 0

Worksheet for C-2 New Ditch Part A

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.033	
Channel Slope	0.00270	ft/ft
Left Side Slope	3.00	ft/ft (H:V)
Right Side Slope	3.00	ft/ft (H:V)
Bottom Width	8.25	ft
Discharge	70.82	ft³/s

Results

Normal Depth	1.86	ft
Flow Area	25.64	ft²
Wetted Perimeter	19.99	ft
Top Width	19.38	ft
Critical Depth	1.14	ft
Critical Slope	0.01709	ft/ft
Velocity	2.76	ft/s
Velocity Head	0.12	ft
Specific Energy	1.97	ft
Froude Number	0.42	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.86	ft
Critical Depth	1.14	ft
Channel Slope	0.00270	ft/ft
Critical Slope	0.01709	ft/ft

Worksheet for C-2 New Ditch Part B

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.033	
Channel Slope	0.00780	ft/ft
Left Side Slope	3.00	ft/ft (H:V)
Right Side Slope	3.00	ft/ft (H:V)
Bottom Width	5.00	ft
Discharge	70.82	ft³/s

Results

Normal Depth	1.68	ft
Flow Area	16.91	ft²
Wetted Perimeter	15.64	ft
Top Width	15.10	ft
Critical Depth	1.39	ft
Critical Slope	0.01684	ft/ft
Velocity	4.19	ft/s
Velocity Head	0.27	ft
Specific Energy	1.96	ft
Froude Number	0.70	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.68	ft
Critical Depth	1.39	ft
Channel Slope	0.00780	ft/ft
Critical Slope	0.01684	ft/ft

APPENDIX C
CulvertMaster Output

BLACK & VEATCH

Owner: Florida Municipal Power Agency
Plant: Cane Island Power Park **Unit:** 4
Project No. 147651
File No. 52.5406.1101.01
Title: Trench Drain and Culvert Design and Time of Concentration

Prepared by: A. L. MORGAN
Date: 03/07/08
Verified by: RMS
Date: 3/12/08
Page No. C2 of C3
Calc Rev: 0

Solve For: Headwater Elevation

CULVERT C-1

Culvert Summary

Allowable HW Elevation	81.25 ft	Storm Event	Check
Computed Headwater Eleva	80.36 ft	Discharge	39.28 cfs
Headwater Depth/Height	1.31	Tailwater Elevation	79.12 ft
Inlet Control HW Elev.	80.36 ft	Control Type	Inlet Control
Outlet Control HW Elev.	80.35 ft		

Grades

Upstream Invert	77.75 ft	Downstream Invert	77.50 ft
Length	48.50 ft	Constructed Slope	0.005155 ft/ft

Hydraulic Profile

Profile	M2	Depth, Downstream	1.62 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	1.59 ft
Velocity Downstream	7.22 ft/s	Critical Slope	0.006781 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.012
Section Material	Corrugated HDPE (Smooth Interior)	Span	2.00 ft
Section Size	24 inch	Rise	2.00 ft
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	80.35 ft	Upstream Velocity Head	0.69 ft
Ke	0.20	Entrance Loss	0.14 ft

Inlet Control Properties

Inlet Control HW Elev.	80.36 ft	Flow Control	Submerged
Inlet Type	Groove end projecting	Area Full	6.3 ft²
K	0.00450	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	3
C	0.03170	Equation Form	1
Y	0.69000		

BLACK & VEATCH

Owner: Florida Municipal Power Agency
Plant: Cane Island Power Park Unit: 4
Project No. 147651
File No. 52.5406.1101.01
Title: Trench Drain and Culvert Design and Time of Concentration

Prepared by: A. L. MORGAN
Date: 03/07/08
Verified by: JMS
Date: 3/12/08
Page No. C3 of C3
Calc Rev: 0

Solve For: Headwater Elevation

CULVERT C-2

Culvert Summary

Allowable HW Elevation	81.25 ft	Storm Event	Check
Computed Headwater Eleva	79.91 ft	Discharge	70.81 cfs
Headwater Depth/Height	1.58	Tailwater Elevation	0.00 ft
Inlet Control HW Elev.	79.91 ft	Control Type	Inlet Control
Outlet Control HW Elev.	79.74 ft		

Grades

Upstream Invert	76.75 ft	Downstream Invert	76.33 ft
Length	56.00 ft	Constructed Slope	0.007500 ft/ft

Hydraulic Profile

Profile	M2	Depth, Downstream	1.72 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	1.72 ft
Velocity Downstream	8.20 ft/s	Critical Slope	0.008564 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.012
Section Material	Corrugated HDPE (Smooth Interior)	Span	2.00 ft
Section Size	24 inch	Rise	2.00 ft
Number Sections	3		

Outlet Control Properties

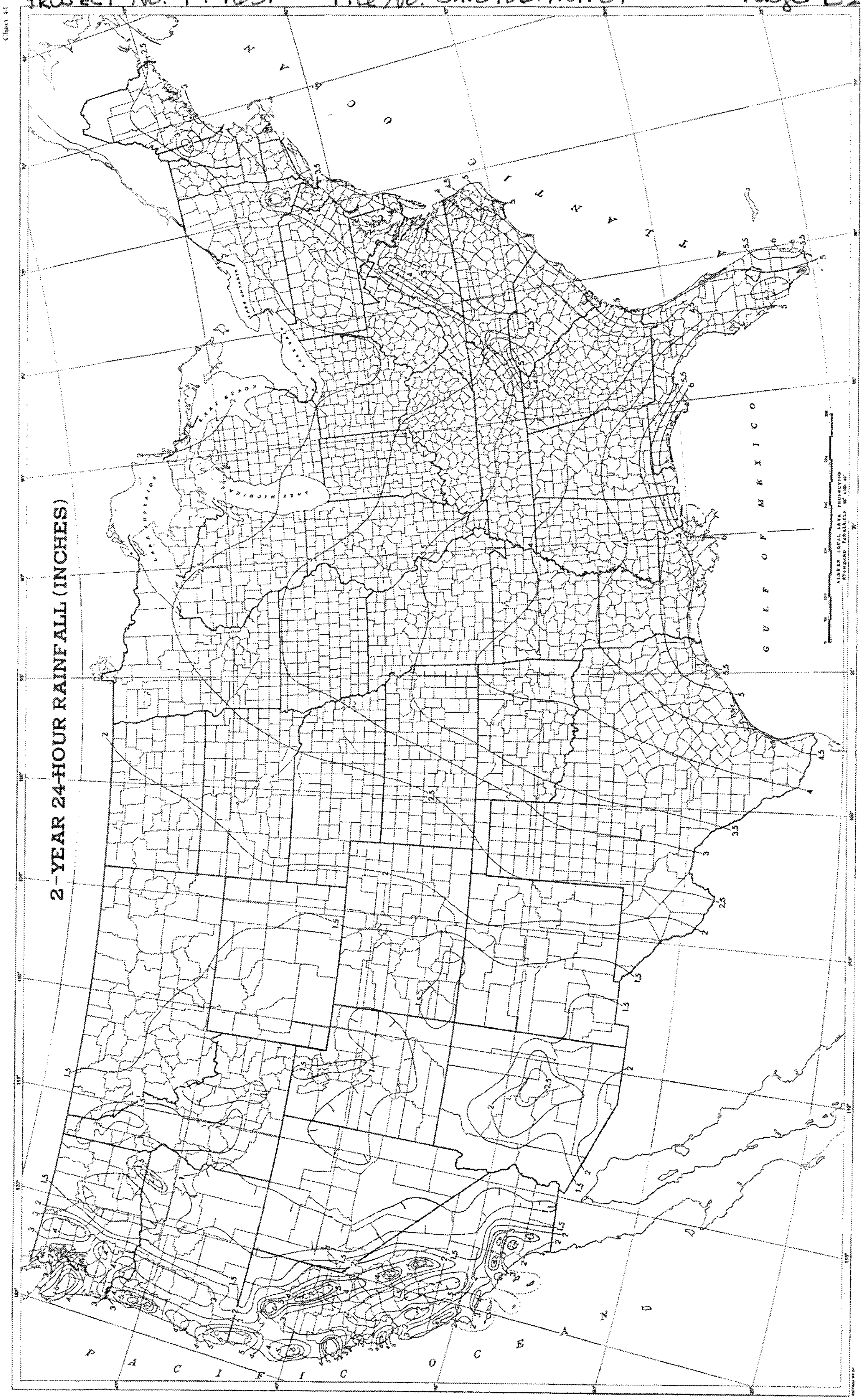
Outlet Control HW Elev.	79.74 ft	Upstream Velocity Head	0.92 ft
Ke	0.20	Entrance Loss	0.18 ft

Inlet Control Properties

Inlet Control HW Elev.	79.91 ft	Flow Control	Submerged
Inlet Type	Groove end projecting	Area Full	9.4 ft²
K	0.00450	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	3
C	0.03170	Equation Form	1
Y	0.69000		

APPENDIX D
Reference
Figures and Tables

PROJECT No: 147651 File No: 52.5406.1101.01 Page D2 of D5



Determination of Top Width

Values of $\frac{T}{D}$

$\frac{y}{D}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0	.000	.199	.280	.341	.392	.436	.457	.510	.543	.572
.1	.600	.626	.650	.673	.694	.714	.733	.751	.768	.785
.2	.800	.815	.828	.842	.854	.866	.877	.888	.898	.908
.3	.917	.925	.933	.940	.947	.954	.960	.966	.971	.975
.4	.980	.984	.987	.990	.993	.995	.997	.998	.999	1.000
.5	1.000	1.000	.999	.998	.997	.995	.993	.990	.987	.984
.6	.980	.975	.971	.966	.960	.954	.947	.940	.933	.925
.7	.917	.980	.898	.888	.877	.866	.854	.842	.828	.815
.8	.800	.785	.768	.751	.733	.714	.694	.673	.650	.626
.9	.600	.572	.543	.510	.475	.436	.392	.341	.280	.199
1.0	.000									

i.e. Given y = 3 ft., D = 4 ft., $\frac{y}{D} = 0.75$,

From tables; $\frac{A}{D^2} = 0.632$, $\frac{R}{D} = 0.302$, and $\frac{T}{D} = 0.866$

Determination of Hydraulic Radius

Values of $\frac{R}{D}$

$\frac{y}{D}$	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0	.000	.007	.013	.020	.026	.033	.039	.045	.051	.057
.1	.063	.070	.075	.081	.087	.093	.099	.104	.110	.115
.2	.121	.126	.131	.136	.142	.147	.152	.157	.161	.166
.3	.171	.176	.180	.185	.189	.193	.198	.202	.206	.210
.4	.214	.218	.222	.226	.229	.233	.236	.240	.243	.247
.5	.250	.253	.256	.259	.262	.265	.268	.270	.273	.275
.6	.278	.280	.282	.284	.286	.288	.290	.292	.293	.295
.7	.296	.298	.299	.300	.301	.302	.302	.303	.304	.304
.8	.304	.304	.304	.304	.304	.303	.303	.302	.301	.299
.9	.298	.296	.294	.292	.289	.286	.283	.279	.274	.267
1.0	.250									

PROJECT No. 147651
File No. 52.5406.1101.01

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OF D5

FRICTION LOSSES

In North America, the Manning and Kutter equations are commonly used to estimate the friction gradient for turbulent flow in storm sewers. In both equations fully developed rough turbulent flow is assumed so that the head loss per unit length of conduit is approximately proportional to the square of the discharge (or velocity). Both equations use an empirical coefficient 'n' to describe the roughness of the channel boundary. Tables 4.9 and 4.10 give suggested values for 'n' for various corrugation profiles and linings.

Manning Equation

The Manning Equation is one of a number of so-called exponential equations. It is widely used in open channel flow but can also be applied to closed conduit flow. The equation is not dimensionally homogeneous and a correction factor must be applied depending upon the system of units being used.

$$V = \frac{M}{n} R^{2/3} S^{1/2}$$

Where M = 1.486
V = average velocity (ft/s)
Q = discharge (cfs)
R = hydraulic radius = A/P (ft)
A = cross-sectional area (sq. ft)
P = wetted perimeter (ft)
S_f = friction gradient or slope of energy line
n = Manning's roughness coefficient (see Tables 4.8, 4.9, 4.10)

TABLE 4.8 Effective Absolute Roughness and Friction Formula Coefficients[3]

Conduit Material	Manning n
Closed conduits	
Asbestos-cement pipe	0.011-0.015
Brick	0.013-0.017
Cast iron pipe	
Uncoated (new)	—
Asphalt dipped (new)	—
Cement-lined & seal coated	0.011-0.015
Concrete (monolithic)	
Smooth forms	0.012-0.014
Rough forms	0.015-0.017
Concrete pipe	0.011-0.015
Plastic pipe (smooth)	0.011-0.015
Vitrified clay	
Pipes	0.011-0.015
Liner plates	0.013-0.017
Open channels	
Lined channels	
a. Asphalt	0.013-0.017
b. Brick	0.012-0.018
c. Concrete	0.011-0.020
d. Rubble or riprap	0.020-0.035
e. Vegetal	0.030-0.40
Excavated or dredged	
Earth, straight and uniform	0.020-0.030
Earth, winding, fairly uniform	0.025-0.040
Rock	0.030-0.045
Unmaintained	0.050-0.14
Natural Channels (minor streams, top width at flood stage < 100 ft.)	—
Fairly regular section	0.03 -0.07
Irregular section with pools	0.04 -0.10

PROJECT No: 147651
FILE No: 52.5406.1101.01

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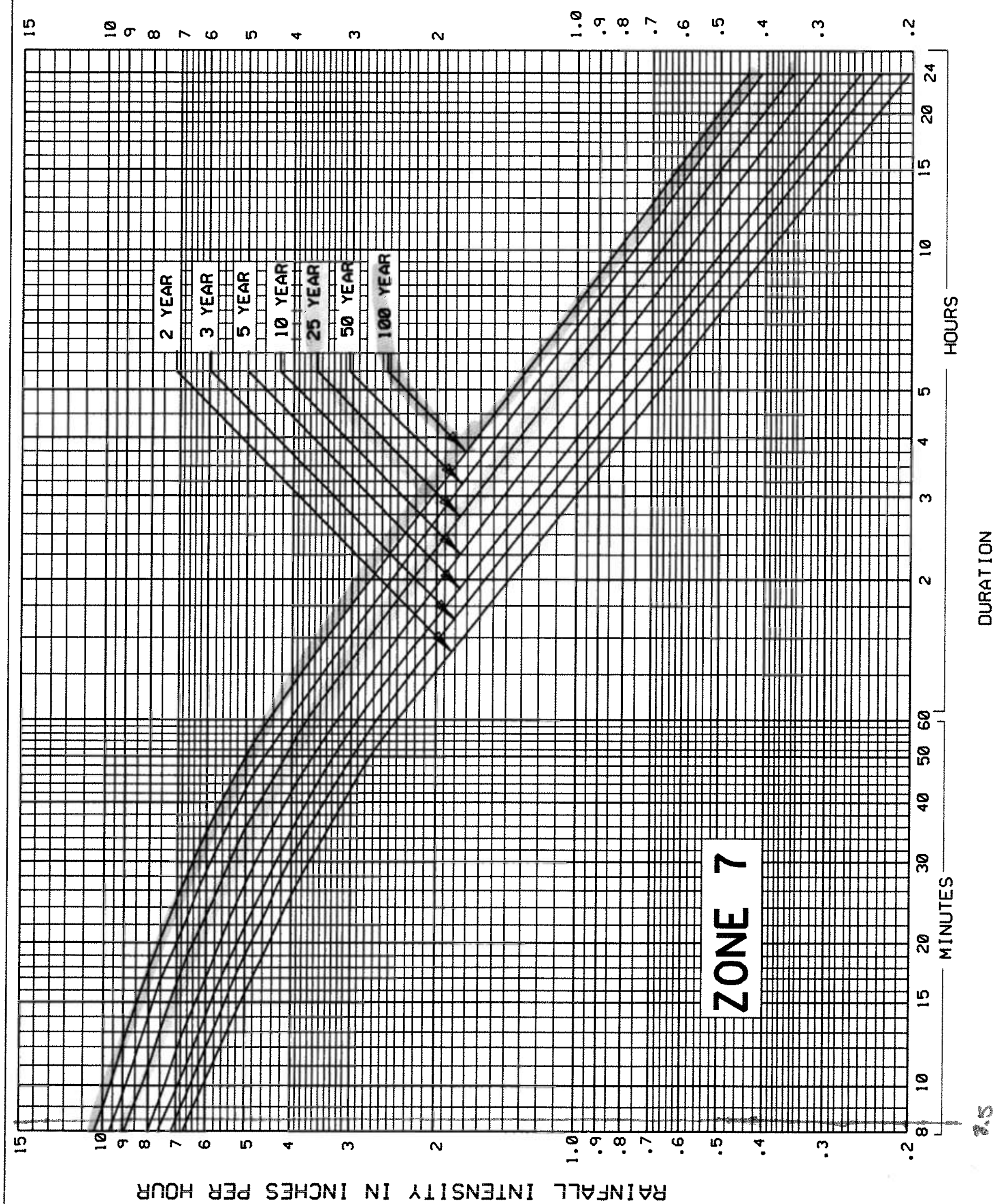
STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

DRAINAGE MANUAL

OFFICE OF DESIGN, DRAINAGE SECTION January 2006
TALLAHASSEE, FLORIDA



RAINFALL INTENSITY-DURATION-FREQUENCY CURVES
ZONE 7