APPENDIX G

Mill Brook Culvert Sizing Report

<u>MILL BROOK CULVERT SIZING REPORT</u>

THE EASTERN TRAIL
A MULTI-USE TRAIL CONSTRUCTION PROJECT
MILL BROOK CROSSING
OLD ORCHARD BEACH, MAINE

Prepared for:

The Eastern Trail Management District (ETMD) as a Locally Administered Project through the Maine Department of Transportation
c/o Robert Hamblen, President, ETMD
Saco City Hall, Planning Department
300 Main Street
Saco, Maine 04072

MDOT Pin: 13340.00

County: York

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October 2009

MILL BROOK CULVERT SIZING REPORT

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Project PIN: 13340.00
Project Location: Old Orchard Beach York County

Check	Item	Comments
✓	**Checklist**	Completed
✓	**Statement of Supervision**	In cover letter
✓	**Executive Summary**	
✓	**Introduction**	
✓	**Hydrologic Site Description**	
✓	*Supporting Documentation*	
✓	Figures for Site Description	8.5x11 or 11x17; to same scale
✓	Site location	On USGS quad map
✓	Site map	Soils, watershed bounds, drainage features, topo
✓	Site map	Land use, watershed bounds, drainage features
✓	Site map	Watershed bounds, principal flow paths, t_c info
N/A	Aerial photos	If used in analysis; marked appropriately
✓	Other photos	If informative; annotate or describe
✓	Tables for Site Description	
✓	Land uses, soil types, C/RCN by area within watersheds	
✓	Land use, soil types total areas	
✓	Time of concentration calcs	
✓	**Model Description**	
✓	*Supporting Documentation*	
✓	Figures for Model	Show model components with basic site info
✓	Tables for Model	Summarize model parameters
✓	**Model Calibration**	Sensitivity analysis, anecdotal info
✓	**Results &Interpretation**	Identify implications for design & stormwater control
✓	**Appendices**	Model input files printout; all computer files on digital media
✓	**Submittal**	Paper report; all computer files in native formats and as [PDF] files on CD

MILL BROOK CULVERT SIZING REPORT

1.0 MDOT HYDROLOGIC REPORT CHECKLIST

See previous page for completed checklist.

2.0 STATEMENT OF SUPERVISION

The preliminary design of this culvert crossing for Mill Brook has been supervised by Mr. Stephen Bushey, P.E. #7429 within the State of Maine. The cover of this document will be stamped and signed by Mr. Bushey as part of the Preliminary Design Report (PDR).

3.0 EXECUTIVE SUMMARY

The Eastern Trail Management District (ETMD) as a locally administered project through the Maine Department of Transportation (MDOT) plans to construct an extension of the Eastern Trail from Milliken Mills Road in Old Orchard Beach to Thornton Academy in Saco, Maine on an abandoned railroad bed. This potential trail extension will cross over Mill Brook where currently no culverts exist. This report has been written as part of the PDR in anticipation of a submission to the MDOT for this project and the design of a culvert serving Mill Brook under the potential trail extension. This report is a summary of the design methods implemented for this preliminary culvert sizing in conformance with MDOT Highway Design Guide – Chapter 12 Standards dated January 2008.

The following design methods were implemented to calculate the peak discharge rate within the Mill Brook watershed at the potential culvert crossing location:

1. USGS Regression Method – MDOT Highway Design Guide – Chapter 12, Section 2.04
2. Peak Flow Regression Method – Estimating the magnitude of peak flows for streams in Maine for Selected Recurrence Intervals Report by Glenn Hodgkins of the U.S. Geological Survey dated 1999-Section 5: Estimating Peak Flows for Ungauged, Unregulated Streams in Urbanized Drainage Basins.
3. SCS TR-20/TR-55 Method – USDA Soil Conservation Service's Technical Releases No. 20 and 55.

The use of these design methods resulted in the following peak discharge rates:

TABLE 1 – SUMMARY OF PEAK DISCHARGE RATES (CFS)			
Storm Event	USGS Regression	Peak Flow Regression	SCS TR-20/TR-55
2-Year	117.68	123.95	100.23
10-Year	265.57	287.30	277.24
25-Year	358.22	377.19	382.63
50-Year	434.00	466.69	466.29
100-Year	516.55	547.10	553.03

The Mill Brook culvert crossing is identified on the FEMA Flood Panel as being within a Zone A designated Flood Hazard Area (No Base Flood Elevation Determined). Per the direction of the Town of Old Orchard Beach Zoning Administrator, the proposed culvert crossing should be designed to convey the 100-year storm event flow. On this basis, an average flow of 538 cfs has been selected for the analysis.

The following culvert options for this crossing have been considered by our office:

TABLE 2 – POSSIBLE CULVERT RECOMMENDATIONS FOR MILL BROOK CROSSING	
Structure Table	Structure Size
Circular Culvert (Non-Embedded)	8.0' diameter (96 inches)
Circular Culvert (Embedded 12-inches)	10' diameter (120 inches)
Elliptical Culvert (Embedded 12-inches)	10'-8" Span and 6'-11" Rise
Structural Plate Pipe Arch (Non-Embedded)	9'-9" Span and 6'-7" Rise

Selection of any of these structures would result in adequate sizing for the 1.929 square mile Mill Brook Watershed meeting the MDOT Highway Design Guide – Chapter 12 – Culvert Sizing Requirements.

4.0 INTRODUCTION

The Eastern Trail in Southern Maine is a 60-mile off-road transportation corridor proposed to connect Kittery and South Portland. Only non-motorized means of transportation are permitted on the trail system, including, but not limited to, walking, running, bicycling, snowshoeing, skiing, and horseback riding. After 100 years of operation, the Eastern Railroad was derailed in 1944. Tracks and bridges were literally removed, leaving a cleared, level corridor utilized by public utilities. The Eastern Trail is in the process of moving from the current configuration o paved roadways to off-road routes, primarily utilizing the abandoned Eastern Railroad corridor for this new off-road route.

Mill Brook flows from the western side of Interstate-195, north of Innis Brook (a tributary of Goosefare Brook) and south of Cascade Brook in the southwesterly direction to Saco Bay. The proposed Eastern Trail segment, as part of this project which extends from Milliken Mills Road in Old Orchard Beach to Thornton Academy in Saco, crosses over Mill Brook north of Old Cascade Road and east of Milliken Mills Road in the existing former railroad bed (see USGS map in Attachment A for detailed location). This Hydrologic Culvert Sizing Report is warranted for this project to properly size a culvert to discharge Mill Brook flows under the proposed trail extension. The former railroad bed contains an existing gravel trail of varying width along the majority of its length. The trail has no culvert at the Mill Brook crossing at this time. The original granite box culvert under the former rail line was washed out during a peak rainfall within the past ten years. As part of this project, this ravine will be filled in and a culvert will be constructed to discharge Mill Brook under the proposed trail.

Photo 1: Mill Brook on north side of crossing looking along the former railroad bed (southwest)

This report is a summary of the design methods used to size this culvert to assure that no adverse impacts are created as a result of this project.

The report has been formatted to meet MDOT Highway Design Standards – Chapter 12 for a Hydrology Report.

5.0 HYDROLOGIC SITE DESCRIPTION

Mill Brook flows at the proposed trail location from southwest to northeast at a varying depth of 6 inches to 18 inches deep and the stream bed width at the crossing ranges from 8 feet to 16 feet wide. There are steep slopes on both the northeastern and southwestern sides of Mill Brook that slope down from the existing railroad bed. These slopes are in excess of 20 feet high and slope down at approximately a 2:1 slope, based on the field survey by Dow & Coulombe. The Mill Brook watershed upstream consists of approximately 1.929 square miles (see Attachment B for a detailed map). The watershed is mostly wooded but has some areas of commercial development, specifically along the U.S. Route 1 corridor and some large areas of residential development. Please find pictures following this page of the existing Mill Brook Stream Crossing and two upstream roadway crossing structures as documentation of the existing site conditions.

A few points of interest to specify within the pictures, on the next page, include what looks like the remnants of the former stone box culvert crossing as seen on either side of Mill Brook in Photo 1. Notice the sandy soil conditions evident on the steep slopes down to the existing stream crossing as shown in Photos 3 and 4. As part of the review of this site the existing stream crossings immediately upstream were reviewed and documented in Photos 5 thru 8. A review of these crossings will be considered later as a check within this report when sizing the culvert for the proposed Mill Brook culvert crossing (see Section 9.1 below).

The soils within the Mill Brook crossing area consist of a Saco Mucky Silt Loam per the York County Soil Survey from the USDA dated June 1982 (see map in Attachment E). This hydric soil is nearly level, very poorly drained and deep. It is found on flood plains along rivers and streams. The soil has moderate permeability and has a high water capacity. However, surface runoff is slow and the water table is near the surface for extended periods during the growing season according to the USDA Medium Intensity Soils mapping.

According to FEMA Flood Panel 230153 0002 B for the Town of Old Orchard Beach, the Mill Brook crossing is located within a Zone A Flood Hazard Area (No Base Flood Elevations determined). The Zone A area extends upstream only to the Old Cascade Road crossing, less than 200' upstream. The FEMA panel contains no further stream bed profile information. Additional upstream and downstream survey data collection may be required during the final design phase.

Photos Taken 9-18-09 by Andy Morrell, EIT

Photo 2: Mill Brook at crossing looking downstream (southeast)

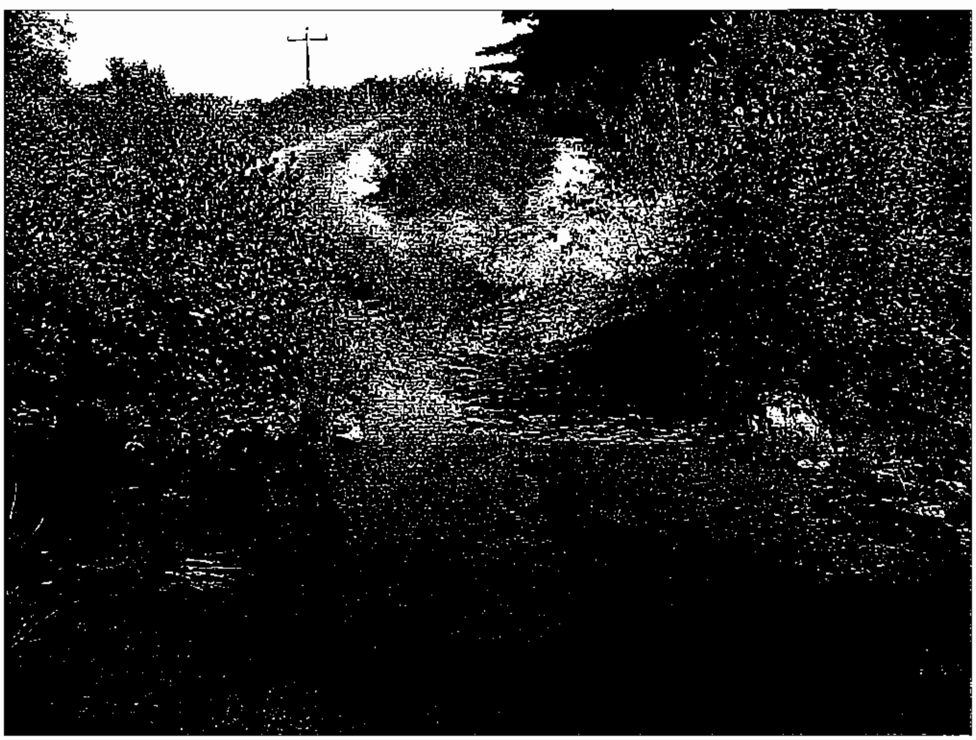


Photo 3: Mill Brook on south side of crossing looking along the former railroad bed (northeast)

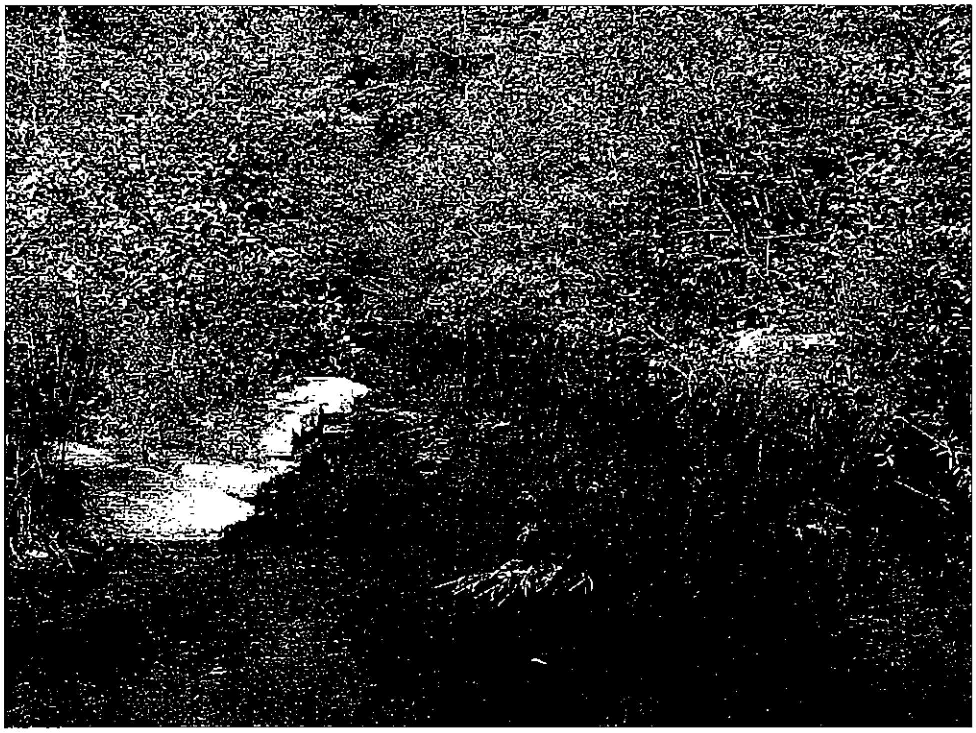


Photo 4: Mill Brook at crossing looking upstream (northwest)

Photo 5: Mill Brook box culvert outlet (7' wide by 7' tall) under Old Cascade Road approximately 300 feet southwest (upstream) of proposed culvert.

Photo 6: Mill Brook box culvert inlet (7' wide by 7' tall) under Old Cascade Road approximately 360 feet southwest (upstream) of proposed culvert.

Photo 7: Mill Brook 72-inch CMP culvert inlet under Cascade Road (Route 98) approximately 720 feet southwest (upstream) of proposed culvert.

<u>Photo 8</u>: Mill Brook 72-inch CMP culvert outlet under Cascade Road (Route 98) approximately 650 feet southwest (upstream) of proposed culvert.

6.0 CONCEPTUAL MODEL

The design of the Mill Brook culvert, under the proposed trail extension, will be completed in conformance with the Maine DOT Highway Design Guide – Chapter 12 dated January 2008. This report has been prepared to conform to the standards outlined within this design manual. The following design techniques have been used as part of this report to properly determine the peak discharge rate at this culvert and thus ultimately determine the required culvert size:

1. USGS Regression Method – MDOT Highway Design Guide Chapter 12, Section 2.04.
2. Peak Flow Regression Method – *Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals Report* by Glenn Hodgkins of the U.S. Geological Survey dated 1999.
3. SCS TR-20/TR-55 Method – USDA Soil Conservation Service's Technical Releases No. 20 and 55 (SCS TR-20 and TR-55 – calculated using HydroCAD)

The MDOT Highway Design Guide recommends that the use of the rational method be excluded for watersheds greater than 100 acres; therefore, this analysis was not completed as part of this report.

The peak discharge rate generated within the Mill Brook watershed has been calculated for the 2, 10, 25, 50 and 100-year storm events at the proposed culvert crossing as part of this report. The MDOT Highway Design Guide requires the culvert be sized for the 50-year storm event and that the 100-year storm event be checked for potential adverse impacts. However, since the crossing is located within a Zone A Flood Hazard Area, the Town of Old Orchard Beach Zoning Administrator has requested the culvert be sized based on the 100-year storm event.

The following sections consist of a conceptual model for each of the three methods utilized as part of this report. The conceptual model summarizes all approximations and assumptions used within this report as well as give a basis for the culvert design.

6.1 USGS Regression Method (MDOT)

This analysis was completed based on the MDOT Highway Design Guide – Section 12.2.04.

Table 12.2-2 was used to determine the values for b, a, and w which are coefficients dependent on the design storm event.

The value for the percentage (%) wetlands as determined from National Wetland Inventory (NWI) maps (known as W) was estimated to be 3.8 %. This information came from Table 2 from the report by Glenn Hodgkins – *Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals* dated 1999 (see table in Attachment C). This value was used similarly in the Peak Flow Regression Method below. A copy of the NWI Map for this watershed can also be found in Attachment C.

6.2 Peak Flow Regression Method (Hodgkins)

This peak discharge rate analysis was completed based on the report by Glenn Hodgkins – *Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals Report* dated 1999 – Section 5 (pg. 32) Estimating Peak Flows for Ungauged, Unregulated Streams in Urbanized Drainage Basins.

This report contains analysis based on available gauging data from a location approximately 2,750 feet downstream of the Eastern Trail crossing. The following flow values are presented in the report:

TABLE 3 – GAUGING STATION FLOWS	
Storm Event	**Peak Flow at Gauging Station**
2-year	90.7 cfs
10-year	177.6 cfs
25-year	226.4 cfs
50-year	264.1 cfs
100-year	303.7 cfs

This report also provides estimated peak flows based on the regression analysis prepared by the author and it also provides a weighted peak flow value based on the results of the gauging station and regression analysis. The values are as follows for the Mill Brook gauging station:

TABLE 4 – PEAK FLOW VALUE SUMMARY – HODGKINS REPORT		
Storm Event	**Regression Value (cfs)**	**Weighted Value (cfs)**
2-year	128.9 cfs	96.8 cfs
10-year	289.9 cfs	204.8 cfs
25-year	392.0 cfs	274.4 cfs
50-year	473.2 cfs	331.6 cfs
100-year	561.5 cfs	395.5 cfs

The watershed area to the gauging station was reported as approximately 2.15 square miles.

For our analysis, Figure 4 (Attachment D) was used to determine the rainfall, in inches, for the 2-hour, 2-year occurrence (R2).

The Basin Development Factors (BDF) were calculated based on a schematic completed by our office which can be found in Attachment D. It was assumed that the middle third portion of the Mill Brook Watershed contained more than 50% storm drains within the secondary tributaries of this watershed. It was also assumed that the middle third portion of the Mill Brook Watershed contained more than 50% of the area as urbanized and more than 50% of the streets had been constructed with curbs and gutters. This resulted in a Basin Development Factor of 2 for the Mill Brook Watershed (see detailed calculations in Attachment D).

Based on the USGS Map (Attachment A) the Impervious Area (IA) within the Mill Brook Watershed was estimated to be 4%.

6.3 SCS TR-20/TR-55 Method (USDA)

The hydrologic analyses for the runoff conditions represented in the Mill Brook Watershed have also been calculated based upon the methodology contained in the USDA Soil Conservation Service's Technical Releases No. 20 and 55 (SCS TR-20 and TR-55). For York County, Maine, a 24-hour SCS Type III storm distribution was used for the analysis using the following storm frequencies and rainfall amounts for Old Orchard Beach and Saco, Maine:

TABLE 5 – RAINFALL VALUES	
Storm Event	24-Hour Rainfall
2-Year	3.0 inches
10-Year	4.6 inches
25-Year	5.4 inches
50-Year	6.0 inches
100-Year	6.6 inches

The HydroCAD Version 8.50 computer program was used in the analysis. This program analyzes the critical points of the project watershed and uses SCS TR-20 methodology for evaluation of the anticipated conditions at these points. Drainage areas are defined with runoff curve numbers, times of concentration, and travel time data based on methods outlined in the USDA TR-55 manual. To assess storage and kinematic effects of runoff, the model uses reservoirs and pipes to imitate actual conditions. Specific hydrologic characteristics including travel times, storage capacity, and the effects of hydraulic head are considered for analysis with this program.

To model any watershed, the drainage system is represented by a system network consisting of three basic components:

- **Subcatchment:** A relatively homogenous area of land that drains into a single reach or pond. Each subcatchment generates a runoff hydrograph.
- **Reach:** A uniform stream, channel, or pipe that conveys water from one point to another reach or pond. The outflow of each reach is determined by a hydrograph routing calculation.
- **Pond:** A pond, swamp, dam, or other impoundment which fills with water from one or more sources and empties in a manner determined by a weir, culvert or other device(s) at its outlet. A pond may empty into a reach or into another pond. The outflow of each pond is also determined by a hydrograph routing calculation.

In order to determine the general watershed characteristics using this method some general assumptions had to be made to model this watershed. The following assumptions have been made for land cover types within the Mill Brook Watershed based on a review of the USGS Maps in Attachment A and aerial mapping within the watershed (see www.google.com).

TABLE 6 – LAND COVER TYPE ASSUMPTIONS WITHIN MILL BROOK WATERSHED	
Land Cover Type	**Assumed Percentage of Watershed**
Commercial and Business	10%
Residential (1 acre)	25%
Woods (good)	45%
Impervious Area	5%
Grass (good)	15%
Total	**100%**

The following assumptions have also been made for the soil types within the Mill Brook Watershed based on the Soils Map included in Attachment E:

TABLE 7 – SOILS HYDROLOGIC GROUPS WITHIN MILL BROOK WATERSHED	
Hydrologic Soil Group	**Assumed Percentage of Watershed**
A	20%
B	25%
C	40%
D	15%

A combined effect of the results from Tables 6 and 7 above were utilized along with the total watershed area to determine approximate watershed land cover types and soils characteristics. The Mill Brook watershed was modeled as one single subcatchment with a Time of Concentration Route modeled for the longest hydrologic flow time. It was assumed the Mill Brook stream bed had a typical cross section along its entire length of 8 feet wide by 2 feet deep to model the channel flow portion of the Time of Concentration Route. Time of Concentration routes were established off the Watershed Map in Attachment B.

7.0 MODEL CALIBRATION

Please find below a summary of the techniques used to calculate the peak discharge rate for each of the design methods implemented as part of this report.

7.1 USGS Regression Method (MDOT

A spreadsheet has been utilized to calculate the Peak Discharge Rate as part of this analysis. The calculations can be found in Attachment C.

Please find the following as a breakdown of how each of the columns within this spreadsheet was determined:

Column 1: Given coefficient based on design storm event (T)

Column 2: Given coefficient based on design storm event (T)

Column 3: Given coefficient based on design storm event (T)

Column 4: Watershed size based on Watershed Map in Attachment B is 1.929 square miles=5.00 square kilometers.

Column 5: Assumed Value

Column 6: Using the above variables the equation for Peak Discharge Rate in Section 12-2.04 of the MDOT Highway Design Guide was used to calculate the Peak Discharge rate in cubic meters per second.

Column 7: Column 6 converted to cubic feet per second for each storm event.

7.2 Peak Flow Regression Method (Hodgkins)

A spreadsheet has been utilized to calculate the peak discharge rate as part of this analysis. The calculation can be found in Attachment D.

Please find the following as a breakdown of how each of the columns within this spreadsheet was determined:

Column 1: Watershed Area in square miles

Column 2: Main Channel Slope (SL) was estimated to be 2.4 miles long and to drop 80 feet over that distance based on the USGS map shown in Attachment B, thus resulting in SL=33.33 feet.

Column 3: Given National Weather Service 2-hour, 2-year rainfall for Maine (R2).

Column 4: Assumed value

Column 5: Calculated Basin Development Factor

Column 6: Assumed value

Column 7: Calculated peak flow, in cubic meters per second, for an equivalent rural drainage basin. The equations from Table 3 in Section 2 of the Glenn Hodgkins (USGS) Report were utilized to calculate these totals. These are the same totals found in Column 6 of the USGS Regression Method (MDOT) calculations found in Attachment C.

Column 8: Column 7 converted to cubic feet per second.

Column 9: Using the above variables the equations for Peak Discharge Rate summarized in Table 9 of Section 5 of the Glenn Hodgkins (USGS) Report were utilized to determine the Peak Discharge Rate in cubic feet per second.

7.3 SCS TR-20/TR-55 Method (USDA)

A HydroCAD analysis of the Mill Brook Watershed was completed with the assumptions mentioned above. The HydroCAD calculations can be found in Attachment E.

8.0 MODEL RESULTS

Please find below the following sections are a breakdown of the results for the Peak Discharge Rates calculated with the above described three methods within this report.

8.1 USGS Regression Method (MDOT)

The above described analysis resulted in the following Peak Discharge Rate from the Mill Brook Watershed at the proposed culvert crossing for the design storm events:

TABLE 8 – USGS REGRESSION METHOD PEAK FLOW RATES	
Storm Event	Peak Flow Rate (cfs)
2-Year	117.68
10-Year	265.57
25-Year	358.22
50-Year	434.00
100-Year	516.55

8.2 Peak Flow Regressions Method (Hodgkins)

The above described analysis resulted in the following Peak Discharge Rate from the Mill Brook Watershed at the proposed culvert crossing for the design storm events:

TABLE 9 – PEAK FLOW REGRESSION METHOD PEAK FLOW RATES	
Storm Event	Peak Flow Rate (cfs)
2-Year	123.95
10-Year	287.30
25-Year	377.19
50-Year	466.69
100-Year	547.10

8.3 SCS TR-20/TR-55 Method (USDA)

The above described analysis resulted in the following Peak Discharge Rate from the Mill Brook Watershed at the proposed culvert crossing for the design storm events:

TABLE 10 – SCS TR-20/TR-55 METHOD PEAK FLOW RATES	
Storm Event	Peak Flow Rate (cfs)
2-Year	100.23
10-Year	277.24
25-Year	382.63
50-Year	466.29
100-Year	553.03

9.0 RECOMMENDATIONS

The following table summarizes the Peak Discharge Rates for each of the three design methods used as part of this report:

TABLE 11 – SUMMARY OF PEAK DISCHARGE RATES (CFS)			
Storm Event	USGS Regression	Peak Flow Regression	SCS TR-20/TR-55
2-Year	117.68	123.95	100.23
10-Year	265.57	287.30	277.24
25-Year	358.22	377.19	382.63
50-Year	434.00	466.69	466.29
100-Year	516.55	547.10	553.03

Based on these Peak Discharge Rates, the average of these peak rates is recommended for the purpose of the design to be conservative in the sizing of the Mill Brook Culvert Crossing. Therefore, the Peak Discharge Rate for design is assumed to be 538 cfs for the 100-year storm event.

DeLuca-Hoffman Associates, Inc. has considered the use of three types of culverts; for this application a circular culvert, an elliptical culvert and a pipe arch structure, both for un-embedded and embedded conditions. Please find the following summary of the design of these structures at this crossing.

9.1 Culvert Sizing Design

Now that the Peak Discharge Rate for design has been determined to be 538 cfs, the specification of specific conveyance structures can begin.

Using MDOT Highway Design Guide – Chapter 12 – Section 4.03 as a design aide:

Hw/D = 1.5 (Standard MDOT policy for this application).
Ac = 0.622 for projecting inlet types, therefore,
$D = AcQ^{0.4} = 0.622\ (538)^{0.4} = 7.69$ ft. = 92.31 inches

This calculation can be verified by using Table 12.4.1 (see Attachment F).

Based on the culvert sizes readily available within this area, an 8.0-foot dia. (96-inch dia.) culvert is required for this application if un-bedded.

This culvert results in an Open End Area of 50.24 $ft.^2$, therefore, assumed to be 50 $ft.^2$.

It is assumed that the culvert used in this application will be embedded 12 inches during installation. Therefore, using Table 12-4.19 (see Attachment F) the specified culvert diameter would need to be 10 feet (120 inches) for this embedded depth to match the Open End Area of 50 $ft.^2$, required within this watershed.

If an embedded 12-inch elliptical pipe was to be used the culvert size would have to consist of a span of 10.67 feet and a rise of 6.92 feet to meet the required 50 $ft.^2$ open end area according to Table 12-4.20 (see Attachment F).

A check of the two immediate upstream Mill Brook roadway crossings shown in the photos above under Old Cascade Road and Cascade Road (Route 98) reveals the following comparison: (see photos 5 thru 8).

TABLE 12 – UPSTREAM CULVERT SUMMARY COMPARISON			
Mill Brook Road Crossing	Culvert Size	Culvert Type	Area ($ft.^2$)
Old Cascade Road	7' wide by 7' tall	Box Culvert	49
Cascade Road (Rte 98)	6' dia.	CMP Culvert	28.3*
Proposed Eastern Trail Crossing	7.5' dia.	CMP Culvert**	44

* This portion of Mill Brook is upstream of the connection with a tributary which collects roughly 1/5 of the total Mill Brook Watershed.

** As discussed above there are many options available for this structure

9.2 Pipe Arch Sizing Design

Based on the above analysis, the stormdrain structure used for this site needs an Open End Area of 50 $ft.^2$.

Using Table 12-4.10 (Attachment G) shows that a pipe arch structure would need to span 9'-9" with a rise of 6'-7" to meet this Open End Area.

9.3 Construction

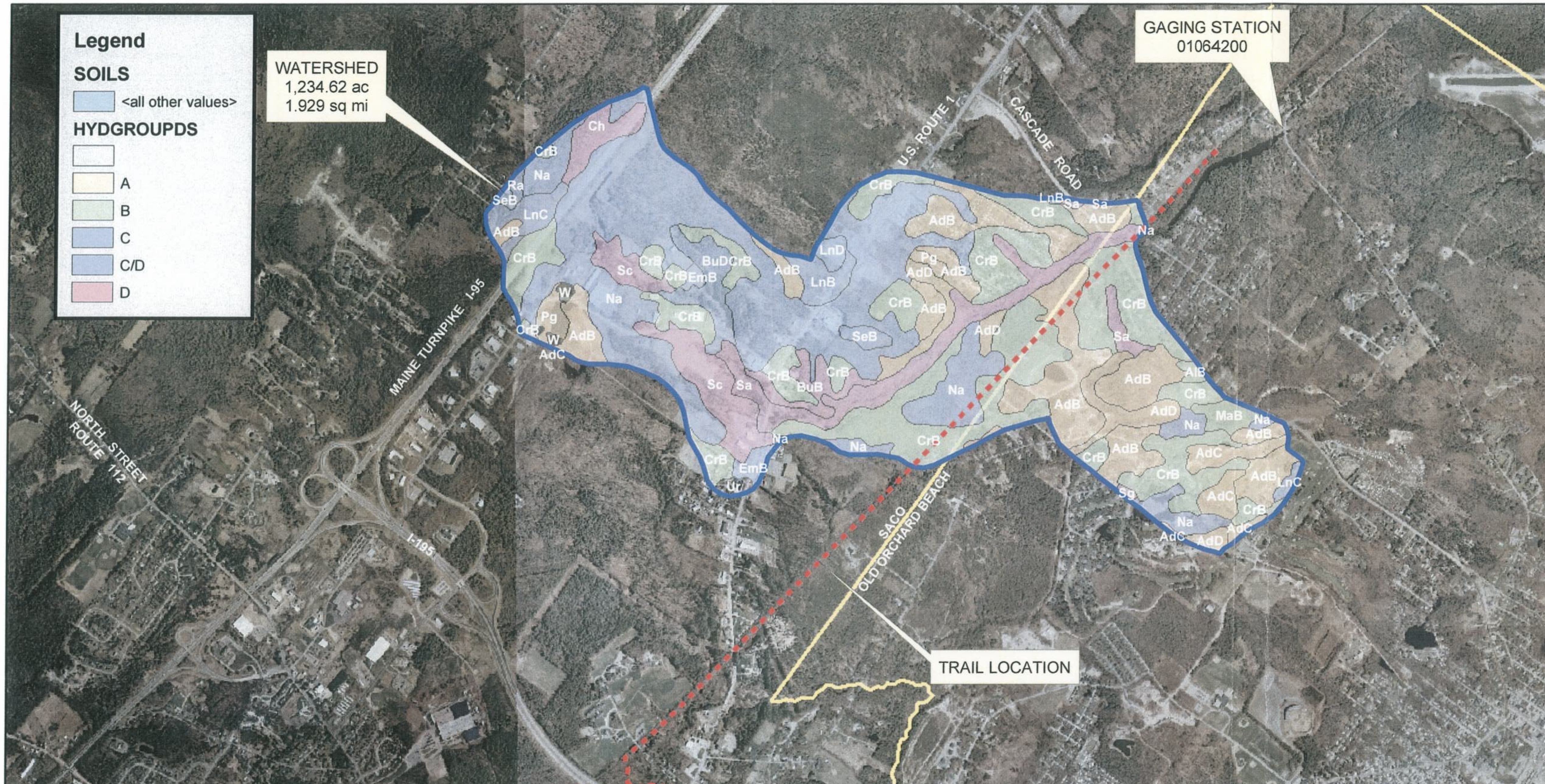
The proposed culvert installation will involve placement of the culvert to maintain the natural substrate bottom since Mill Brook contains a brook trout fishery. The culvert placement will include embankment backfill to allow the trail's crossing profile to match with the existing on each side. The existing 8" natural gas line will need to be observed and the culvert and trail alignment placed to minimize impacts to the pipeline. Construction access will be off Old Cascade Road. Preliminary plans for the culvert crossing are contained within the plan set accompanying the Preliminary Design Report.

ATTACHMENT A

USGS Maps

ATTACHMENT B

Mill Brook Watershed Map



N W E S

WATERSHED BOUNDARY MAP

EASTERN TRAIL MANAGEMENT
SACO AND OLD ORCHARD BEACH, MAINE

SOURCE: MAINE OFFICE OF GIS

DeLuca-Hoffman Associates, Inc.
778 MAIN STREET, SUITE 8
SOUTH PORTLAND, ME 04106
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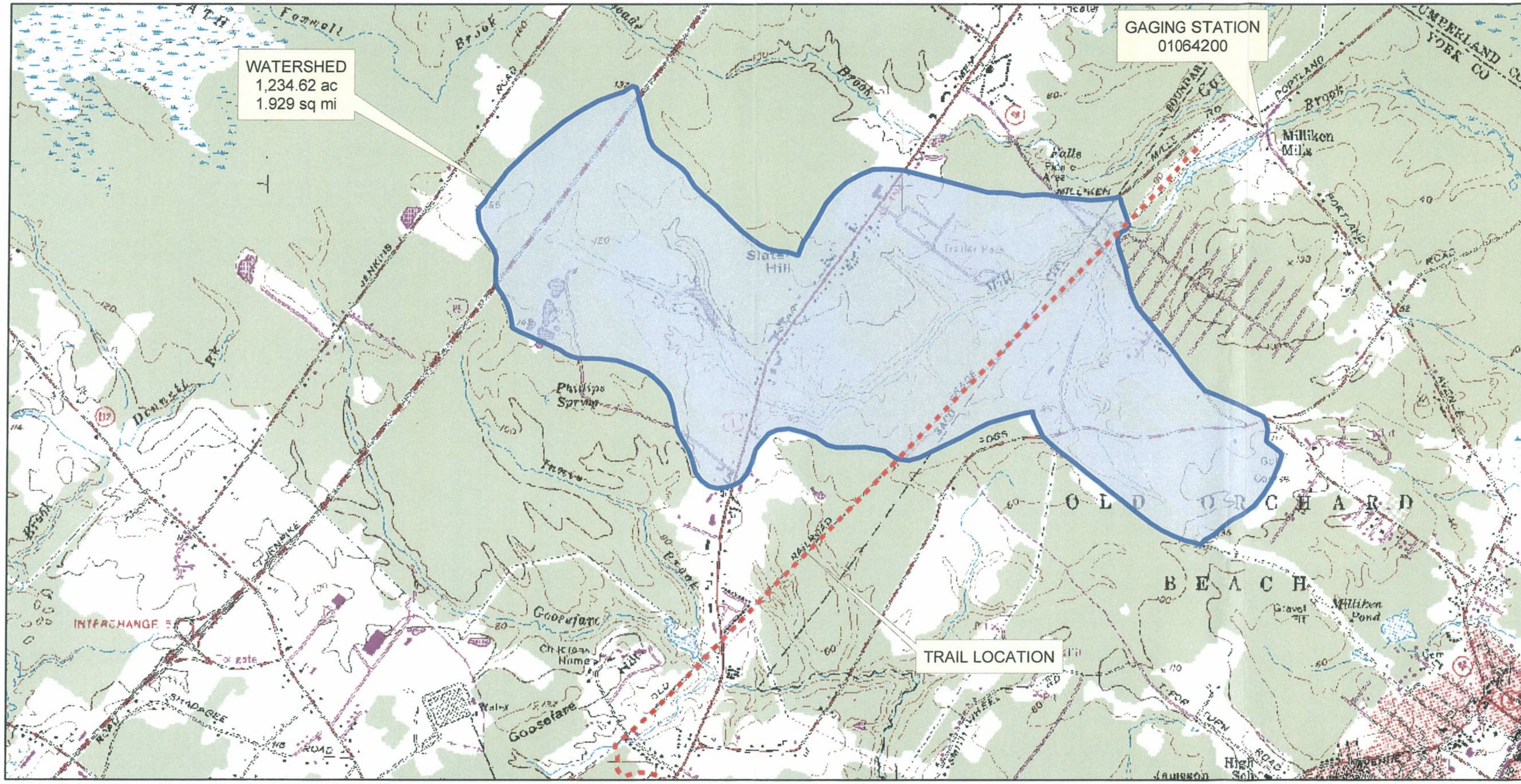
www.delucahoffman.com

DRAWN: DED
CHECKED: AJM
DATE: SEPT 2009
FILENAME: WSHD_SOILS
SCALE: 1 inch = 2,000 feet

FIGURE 1



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W E
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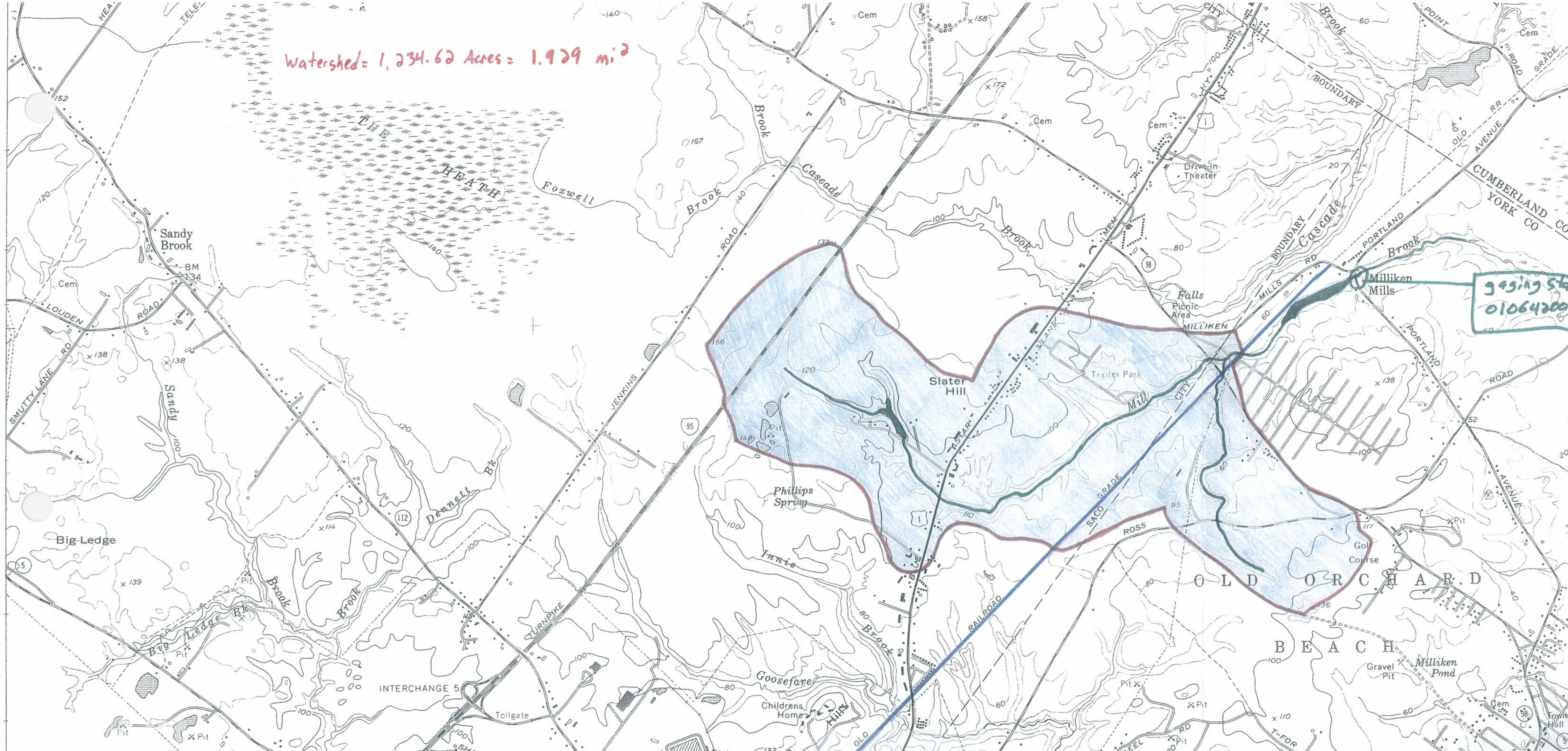
WATERSHED BOUNDARY MAP
EASTERN TRAIL MANAGEMENT
SACO AND OLD ORCHARD BEACH, MAINE

SOURCE: MAINE OFFICE OF GIS

DeLuca-Hoffman Associates, Inc.
778 MAIN STREET, SUITE 8
SOUTH PORTLAND, ME 04106
207-775-1121
www.delucahoffman.com

DRAWN:	DED
CHECKED:	AJM
DATE:	SEPT 2009
FILENAME:	WSHD_USGS
SCALE:	1 inch = 2,000 feet

FIGURE
1



0°30' 379 1.3 MI. TO INTERCHANGE 4 381 420 000 FEET 27'30" BIDDEFORD 0.8 MI. KENNEBUNK 9 MI. 383 (BIDDEFORD) 6970 IV NW BIDDEFORD POOL 8.2 MI. 385 25' 386 387 CAMP ELLIS 2.2 MI. 388000m E. 70°

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1983

Mapped by the Army Map Service
Edited and published by the Geological Survey

Control by USGS and USC&GS

Culture and drainage in part compiled from aerial photographs taken 1943. Topography by planetable surveys 1944
Culture revised by the Geological Survey 1956

Hydrography compiled from USC&GS chart 231 (1954)

Polyconic projection. 1927 North American datum
10,000-foot grid based on Maine coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 19, shown in blue

Red tint indicates areas in which only landmark buildings are shown

Unchecked elevations are shown in brown

MN GN 17° 302 MILS 0°59' 17 MILS

UTM GRID AND 1970 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Map photoinspected 1975
No major culture or drainage changes observed

SCALE 1:24 000 1" = 2,000'

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 8.8 FEET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY
DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

MAINE
QUADRANGLE LOCATION

Revisions shown in purple compiled by the Geological Survey from aerial photographs taken 1970. This information not field checked

ROAD CLASSIFICATION
Heavy-duty Light-duty
Medium-duty Unimproved dirt
U. S. Route State Route
Interstate Route

OLD ORCHARD BEACH, ME
SW/4 PORTLAND 15' QUADRANGLE
N4330—W7022.5/7.5
PHOTOINSPECTED 1975
1956
PHOTOREVISED 1970
AMS 6971 III SW—SERIES V811

ATTACHMENT C

USGS Regression Method Calculations and Supporting Documentation:

- Table 2 from Glenn Hodgkins (USGS) Report
- NWI Wetlands Map
- Calculations of Peak Flow (Spreadsheet)

Table 2. Drainage areas and percentage of basin wetlands for 70 gaging stations used in regression equations—Continued

USGS gaging-station number	Gaging-station name	Drainage area (square kilometers)	Areal percentage of wetlands in drainage basin
01064200	Mill Brook near Old Orchard Beach, Maine	5.57	3.8
01064380	East Branch Saco River near Lower Bartlett, New Hampshire	82.8	0.7
01064500	Saco River near Conway, New Hampshire	997	2.1
01065000	Ossipee River at Effingham Falls, New Hampshire	855	10.3
01065500	Ossipee River at Cornish, Maine	1,170	9.8
01066000	Saco River at Cornish, Maine	3,350	8.6
01066100	Pease Brook near Cornish, Maine	12.4	5.4
01066500	Little Ossipee River near South Limington, Maine	435	12.2
01067000	Saco River at West Buxton, Maine	4,070	9.4
01069700	Branch Brook near Kennebunk, Maine	26.7	11.3
01072850	Mohawk Brook near Center Strafford, New Hampshire	23.0	8.3
01073000	Oyster River near Durham, New Hampshire	31.3	10.8

[a]Station formerly published as Cold Brook near Northern Maine Junction, Maine

Generalized least squares (GLS) regression techniques (Stedinger and Tasker, 1985; Tasker and Stedinger, 1989) were used to compute the final coefficients and the measures of accuracy for the regression equations, using the computer program GLSNET (G.D. Tasker, K.M. Flynn, A.M. Lumb, and W.O. Thomas Jr., U.S. Geological Survey, written commun., 1995). Stedinger and Tasker found that GLS regression equations are more accurate (and provide a better estimate of the accuracy of the equations) than OLS regression equations when streamflow records at gaging stations are of different and widely varying lengths and when concurrent flows at different stations are correlated. GLS regression techniques give less weight to streamflow-gaging stations that have shorter periods of record than other stations. Less weight is also given to those stations whose concurrent peak flows are correlated with other stations.

Application of the technique

Peak-flow regression equations for recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years are presented in table 3. The variables used in the equations are described in the text that follows the table. These regression equations are referred to as the "full" regression equations. The average standard error of prediction, the PRESS statistic, and the average equivalent years of record are discussed in "Limitations and accuracy of the technique" at the end of this section.

All of the regression equations in this report are statistical models. They are not based directly on rainfall-runoff processes. For this reason, when applying these equations, the explanatory variables should be computed by the same methods that were used in the development of the equations. Using "more accurate" methods of computing the explanatory variables (for example, determining the basin wetland variable by making field delineations) will result in peak-flow estimates of unknown accuracy.

N
W E
S

NWI MAP

EASTERN TRAIL MANAGEMENT
SACO AND OLD ORCHARD BEACH, MAINE

SOURCE: MAINE OFFICE OF GIS

DeLuca-Hoffman Associates, Inc.
778 MAIN STREET, SUITE 8
SOUTH PORTLAND, ME 04106
207-775-1121
www.delucahoffman.com

DRAWN:	DED
CHECKED:	AJM
DATE:	SEPT 2009
FILENAME:	2869-NWI
SCALE:	1 inch = 2,500 feet

FIGURE

1

USGS Regression Method (MDOT)
Per Highway Design Guide by Maine DOT-Chapter 12

Storm Event	b	a	w	A (km ^2)	W (%)	Q (m^3/s)	Q (ft^3/s)
2-year	1.075	0.848	0.0266	5.00	3.8	3.3347	117.68
10-year	2.674	0.806	0.0300	5.00	3.8	7.5254	265.57
25-year	3.740	0.790	0.0312	5.00	3.8	10.1507	358.22
50-year	4.637	0.780	0.0320	5.00	3.8	12.2980	434.00
100-year	5.629	0.771	0.0326	5.00	3.8	14.6372	516.55
Column	1	2	3	4	5	6	7

ATTACHMENT D

Peak Flow Regression Method Calculations and Supporting Documentation:

- **Figure 4 from Glenn Hodgkins (USGS) Report**
- **BDF Calculations and Watershed Map**
- **Calculations of Peak Flow (Spreadsheet)**

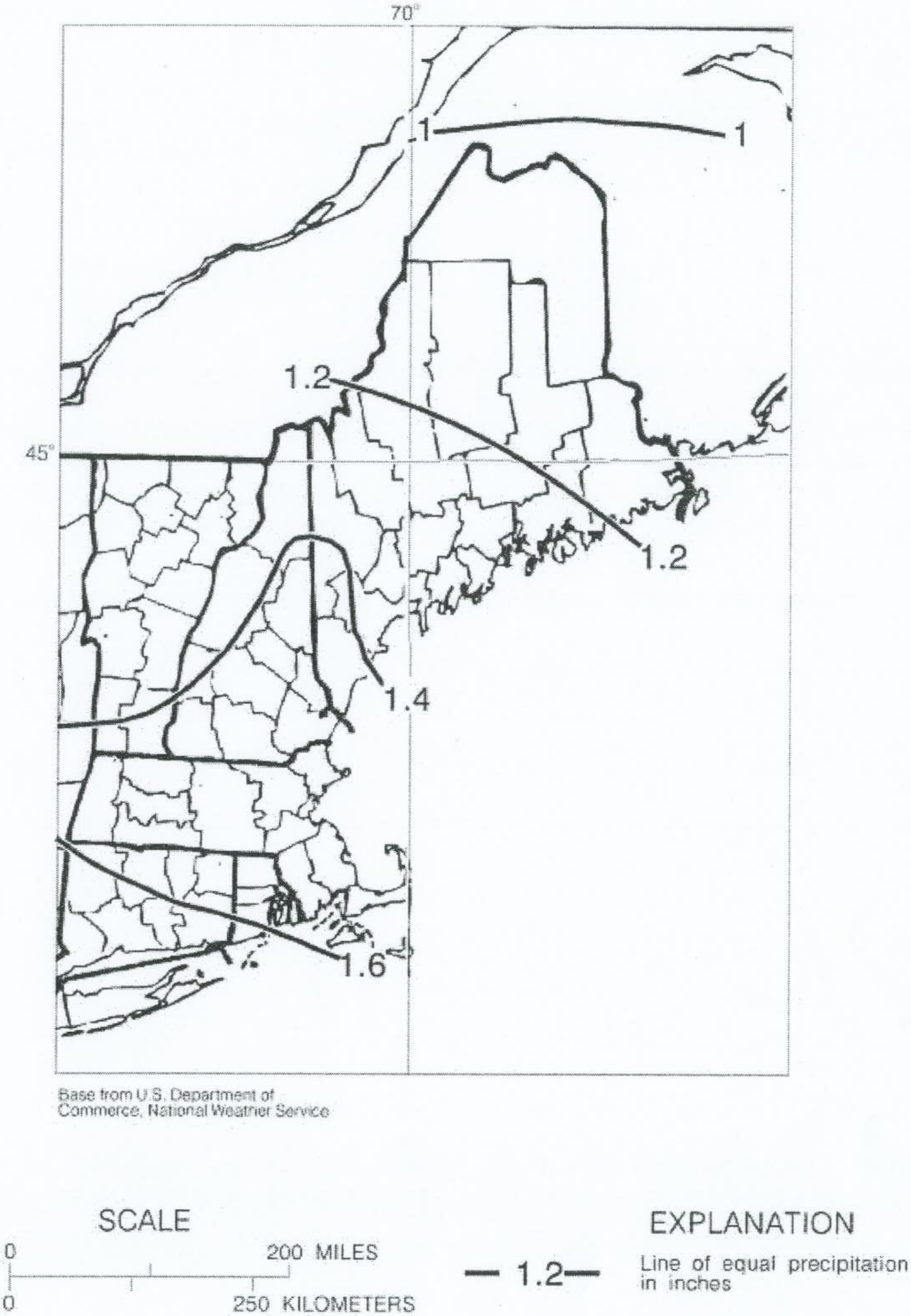
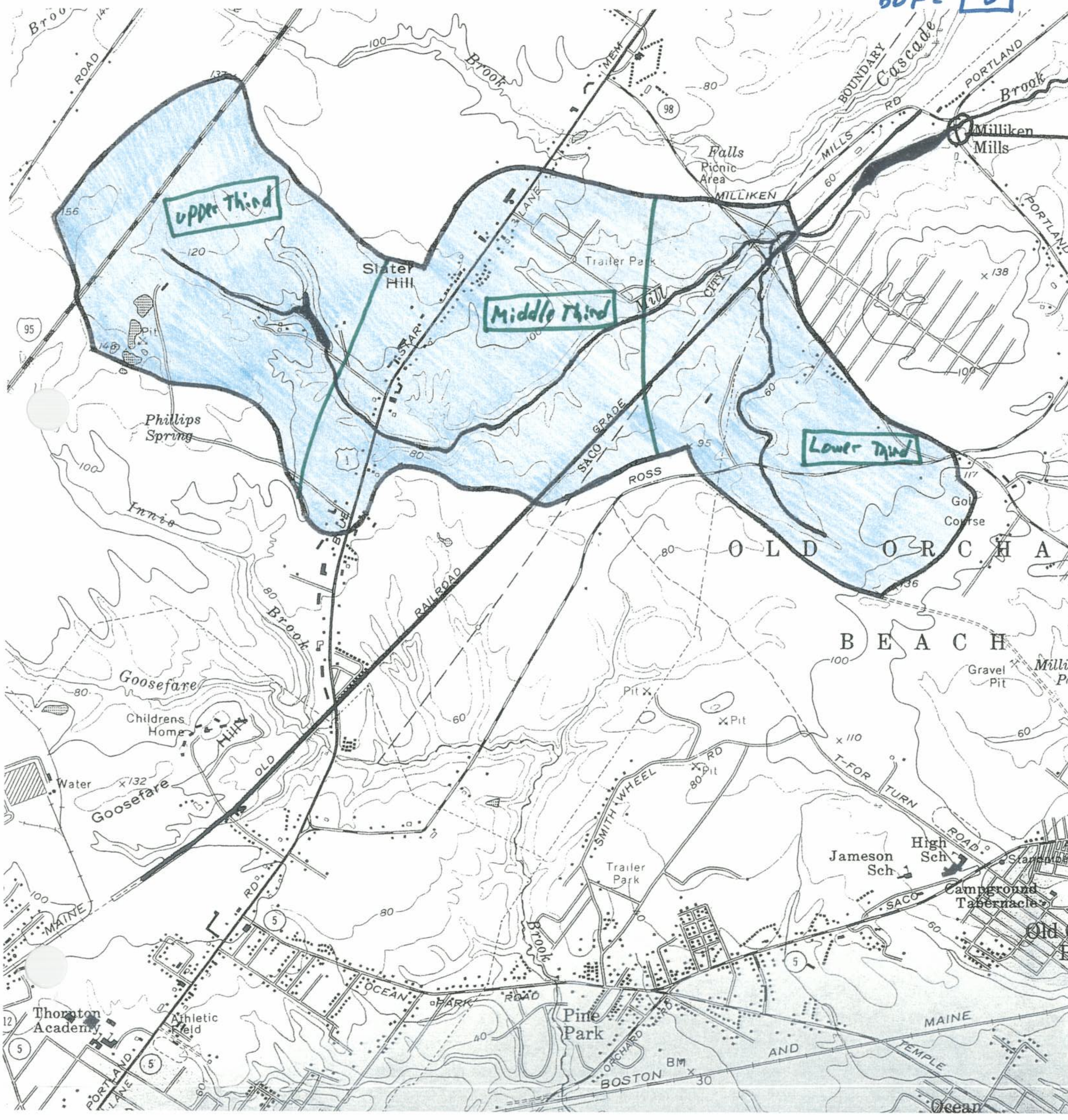


Figure 4. National Weather Service 2-hour, 2-year rainfall for Maine.

	Upper Third	Middle Third	Lower Third	Totals
) Channel Modifications	0	0	0	0
) Channel Linings	0	0	0	0
) Storm drains	0	1	0	1
) Curbs and gutters	0	1	0	1

BDF = 2



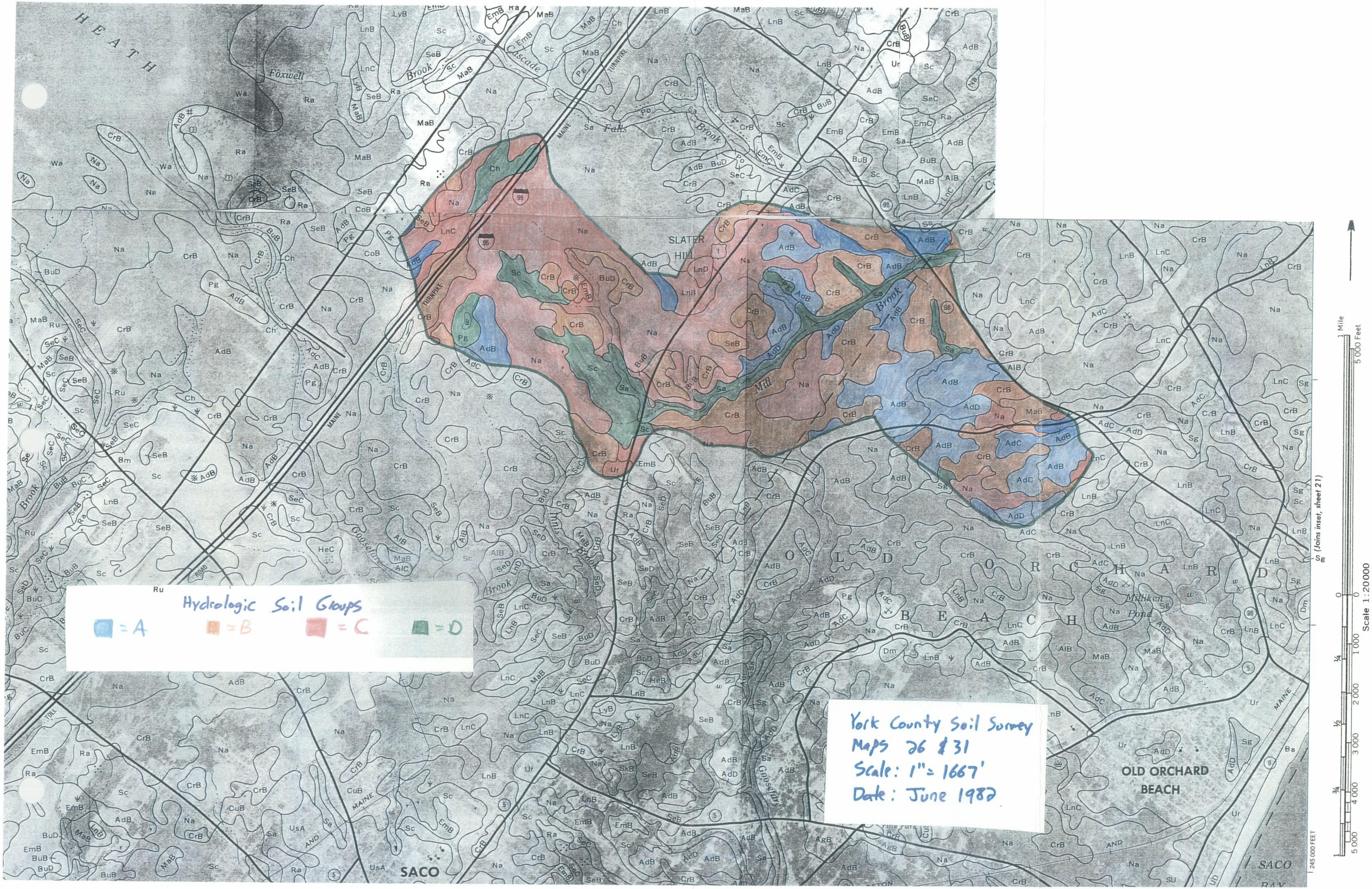
Peak-Flow Regression Method (Hodgkins)
Per USGS Study by Glenn Hodgkins dated 1999

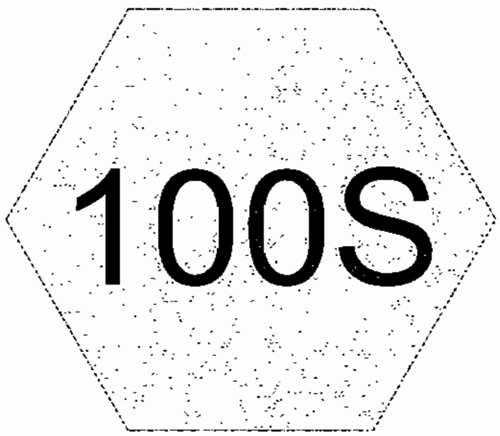
Storm Event	A (mi^2)	SL (ft/mi)	R2 (in.)	ST (%)	BDF	IA (%)	RQ (m^3/s)	RQ (ft^3/s)	Q (ft^3/s)
2-year	1.930	33.33	1.4	3.8	2	4	3.33	117.68	123.95
10-year	1.930	33.33	1.4	3.8	2	4	7.53	265.57	287.30
25-year	1.930	33.33	1.4	3.8	2	4	10.15	358.22	377.19
50-year	1.930	33.33	1.4	3.8	2	4	12.30	434.00	466.69
100-year	1.930	33.33	1.4	3.8	2	4	14.64	516.55	547.10
Column	1	2	3	4	5	6	7	8	9

ATTACHMENT E

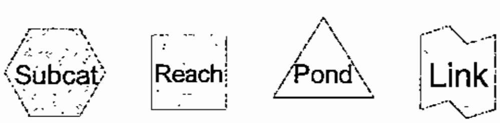
SCS TR-20/TR-55 Method Results and Supporting Documentation:

- **Hydrologic Soils Group Map**
- **Calculations of Peak Flows (HydroCAD)**


Hydrologic Soil Groups
= A
= B
= C
= D
York County Soil Survey
Maps 26 & 31
Scale: 1" = 1667'
Date: June 1982
SLATER HILL
OLD ORCHARD BEACH
SACO
HEATH
OLD ORCHARD BEACH
Mill Brook
Scale 1:20 000
1 Mile
5 000 Feet
(Joins inset, sheet 21)
SACO BAY



Mill Brook Watershed



Drainage Diagram for 2869-Mill Brook Culvert Sizing
Prepared by DeLuca-Hoffman Associates, Inc., Printed 9/29/2009

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
111.000	30	Woods, Good, HSG A (100S)
37.000	39	>75% Grass cover, Good, HSG A (100S)
62.000	51	1 acre lots, 20% imp, HSG A (100S)
139.000	55	Woods, Good, HSG B (100S)
46.000	61	>75% Grass cover, Good, HSG B (100S)
77.000	68	1 acre lots, 20% imp, HSG B (100S)
222.000	70	Woods, Good, HSG C (100S)
74.000	74	>75% Grass cover, Good, HSG C (100S)
84.000	77	Woods, Good, HSG D (100S)
124.000	79	1 acre lots, 20% imp, HSG C (100S)
27.000	80	>75% Grass cover, Good, HSG D (100S)
46.000	84	1 acre lots, 20% imp, HSG D (100S)
25.000	89	Urban commercial, 85% imp, HSG A (100S)
31.000	92	Urban commercial, 85% imp, HSG B (100S)
50.000	94	Urban commercial, 85% imp, HSG C (100S)
18.000	95	Urban commercial, 85% imp, HSG D (100S)
62.000	98	Paved parking & roofs (100S)
1,235.000		**TOTAL AREA**

Soil Listing (all nodes)

Area (acres)	Soil Goup	Subcatchment Numbers
235.000	HSG A	100S
293.000	HSG B	100S
470.000	HSG C	100S
175.000	HSG D	100S
62.000	Other	100S
1,235.000		**TOTAL AREA**

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 100S: Mill Brook Watershed Runoff Area=1,235.000 ac 18.56% Impervious Runoff Depth>0.39"
Flow Length=15,622' Tc=315.7 min CN=68 Runoff=100.23 cfs 40.015 af

Total Runoff Area = 1,235.000 ac Runoff Volume = 40.015 af Average Runoff Depth = 0.39"
81.44% Pervious = 1,005.800 ac 18.56% Impervious = 229.200 ac

Summary for Subcatchment 100S: Mill Brook Watershed

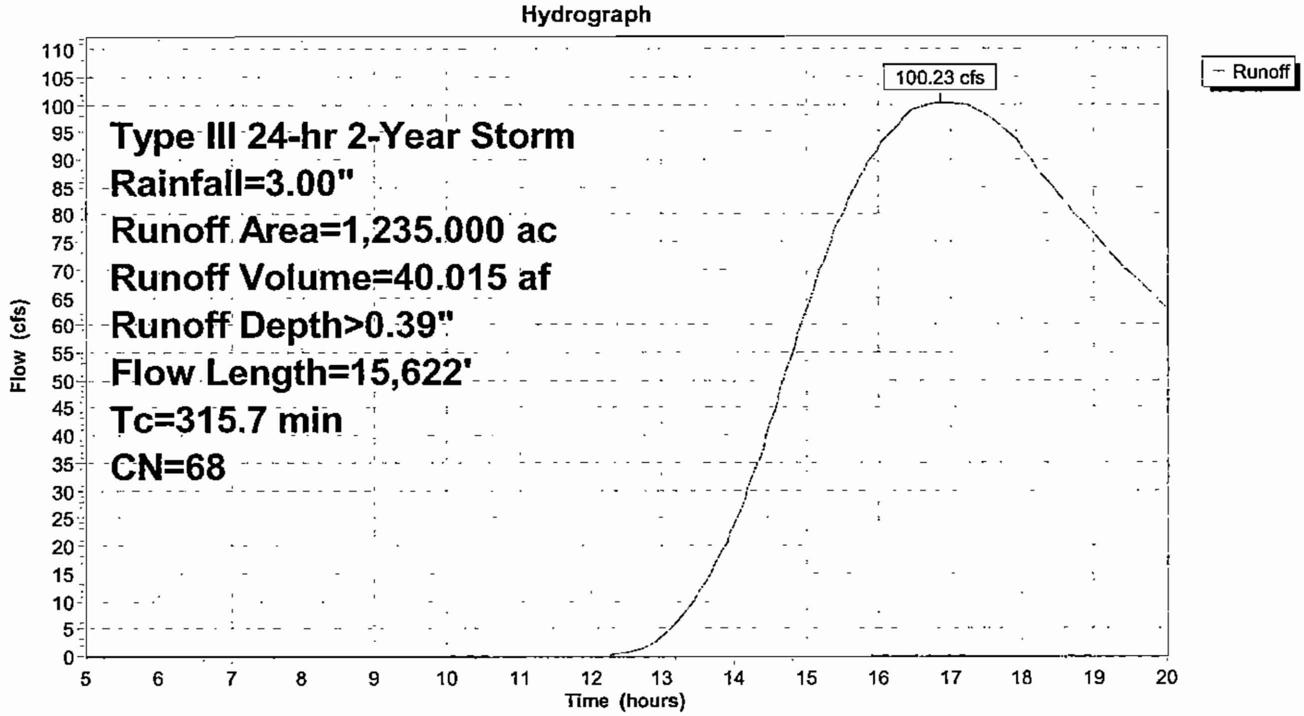
Runoff = 100.23 cfs @ 16.87 hrs, Volume= 40.015 af, Depth> 0.39"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 2-Year Storm Rainfall=3.00"

Area (ac)	CN	Description
25.000	89	Urban commercial, 85% imp, HSG A
31.000	92	Urban commercial, 85% imp, HSG B
50.000	94	Urban commercial, 85% imp, HSG C
18.000	95	Urban commercial, 85% imp, HSG D
62.000	51	1 acre lots, 20% imp, HSG A
77.000	68	1 acre lots, 20% imp, HSG B
124.000	79	1 acre lots, 20% imp, HSG C
46.000	84	1 acre lots, 20% imp, HSG D
111.000	30	Woods, Good, HSG A
139.000	55	Woods, Good, HSG B
222.000	70	Woods, Good, HSG C
84.000	77	Woods, Good, HSG D
62.000	98	Paved parking & roofs
37.000	39	>75% Grass cover, Good, HSG A
46.000	61	>75% Grass cover, Good, HSG B
74.000	74	>75% Grass cover, Good, HSG C
27.000	80	>75% Grass cover, Good, HSG D
1,235.000	68	Weighted Average
1,005.800		Pervious Area
229.200		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
40.5	150	0.0100	0.06		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.00"
208.7	2,800	0.0080	0.22		**Shallow Concentrated Flow,** Forest w/Heavy Litter Kv= 2.5 fps
66.5	12,672	0.0063	3.18	50.80	**Channel Flow, Mill Brook** Area= 16.0 sf Perim= 12.0' r= 1.33' n= 0.045
315.7	15,622	Total			

Subcatchment 100S: Mill Brook Watershed



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 100S: Mill Brook Watershed Runoff Area=1,235.000 ac 18.56% Impervious Runoff Depth>1.08"
Flow Length=15,622' Tc=315.7 min CN=68 Runoff=277.24 cfs 110.821 af

Total Runoff Area = 1,235.000 ac Runoff Volume = 110.821 af Average Runoff Depth = 1.08"
81.44% Pervious = 1,005.800 ac 18.56% Impervious = 229.200 ac

Summary for Subcatchment 100S: Mill Brook Watershed

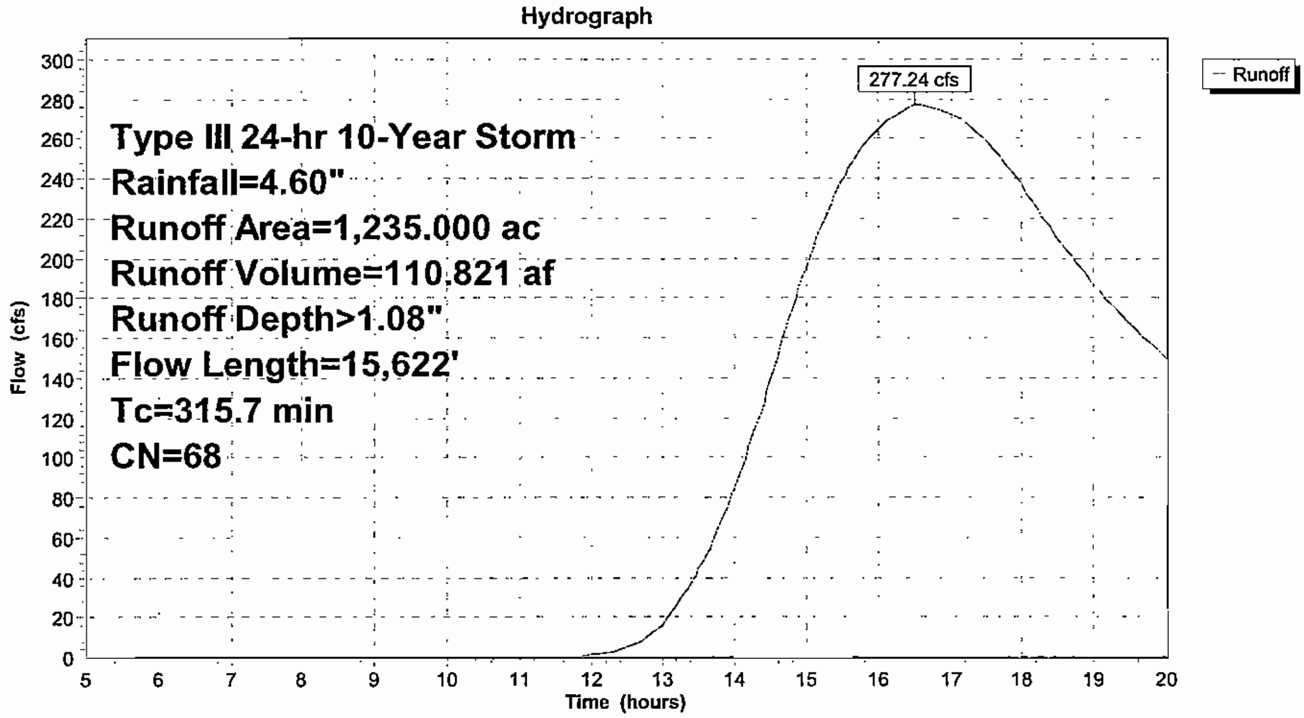
Runoff = 277.24 cfs @ 16.51 hrs, Volume= 110.821 af, Depth> 1.08"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 10-Year Storm Rainfall=4.60"

Area (ac)	CN	Description
25.000	89	Urban commercial, 85% imp, HSG A
31.000	92	Urban commercial, 85% imp, HSG B
50.000	94	Urban commercial, 85% imp, HSG C
18.000	95	Urban commercial, 85% imp, HSG D
62.000	51	1 acre lots, 20% imp, HSG A
77.000	68	1 acre lots, 20% imp, HSG B
124.000	79	1 acre lots, 20% imp, HSG C
46.000	84	1 acre lots, 20% imp, HSG D
111.000	30	Woods, Good, HSG A
139.000	55	Woods, Good, HSG B
222.000	70	Woods, Good, HSG C
84.000	77	Woods, Good, HSG D
62.000	98	Paved parking & roofs
37.000	39	>75% Grass cover, Good, HSG A
46.000	61	>75% Grass cover, Good, HSG B
74.000	74	>75% Grass cover, Good, HSG C
27.000	80	>75% Grass cover, Good, HSG D
1,235.000	68	Weighted Average
1,005.800		Pervious Area
229.200		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
40.5	150	0.0100	0.06		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.00"
208.7	2,800	0.0080	0.22		**Shallow Concentrated Flow,** Forest w/Heavy Litter Kv= 2.5 fps
66.5	12,672	0.0063	3.18	50.80	**Channel Flow, Mill Brook** Area= 16.0 sf Perim= 12.0' r= 1.33' n= 0.045
315.7	15,622	Total			

Subcatchment 100S: Mill Brook Watershed



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 100S: Mill Brook Watershed Runoff Area=1,235.000 ac 18.56% Impervious Runoff Depth>1.49"
Flow Length=15,622' Tc=315.7 min CN=68 Runoff=382.63 cfs 153.456 af

Total Runoff Area = 1,235.000 ac Runoff Volume = 153.456 af Average Runoff Depth = 1.49"
81.44% Pervious = 1,005.800 ac 18.56% Impervious = 229.200 ac

Summary for Subcatchment 100S: Mill Brook Watershed

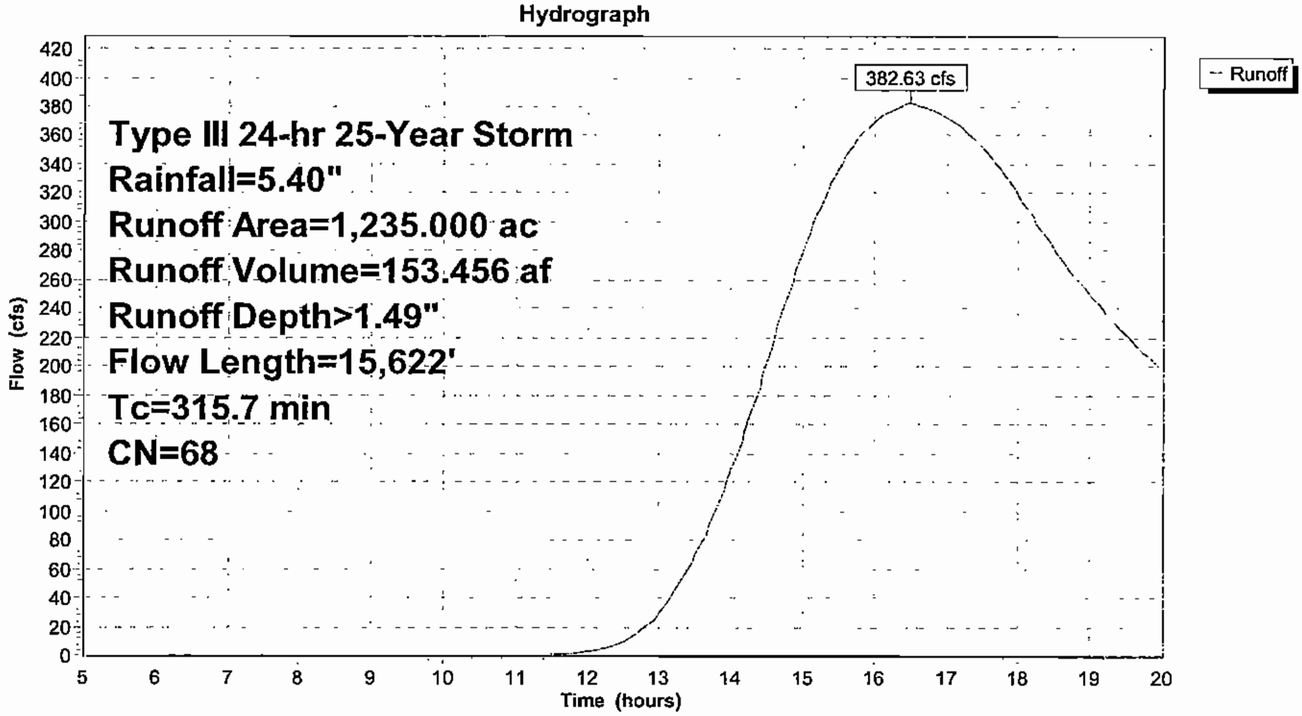
Runoff = 382.63 cfs @ 16.50 hrs, Volume= 153.456 af, Depth> 1.49"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 25-Year Storm Rainfall=5.40"

Area (ac)	CN	Description
25.000	89	Urban commercial, 85% imp, HSG A
31.000	92	Urban commercial, 85% imp, HSG B
50.000	94	Urban commercial, 85% imp, HSG C
18.000	95	Urban commercial, 85% imp, HSG D
62.000	51	1 acre lots, 20% imp, HSG A
77.000	68	1 acre lots, 20% imp, HSG B
124.000	79	1 acre lots, 20% imp, HSG C
46.000	84	1 acre lots, 20% imp, HSG D
111.000	30	Woods, Good, HSG A
139.000	55	Woods, Good, HSG B
222.000	70	Woods, Good, HSG C
84.000	77	Woods, Good, HSG D
62.000	98	Paved parking & roofs
37.000	39	>75% Grass cover, Good, HSG A
46.000	61	>75% Grass cover, Good, HSG B
74.000	74	>75% Grass cover, Good, HSG C
27.000	80	>75% Grass cover, Good, HSG D
1,235.000	68	Weighted Average
1,005.800		Pervious Area
229.200		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
40.5	150	0.0100	0.06		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.00"
208.7	2,800	0.0080	0.22		**Shallow Concentrated Flow,** Forest w/Heavy Litter Kv= 2.5 fps
66.5	12,672	0.0063	3.18	50.80	**Channel Flow, Mill Brook** Area= 16.0 sf Perim= 12.0' r= 1.33' n= 0.045
315.7	15,622	Total			

Subcatchment 100S: Mill Brook Watershed



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 100S: Mill Brook Watershed Runoff Area=1,235.000 ac 18.56% Impervious Runoff Depth>1.82"
Flow Length=15,622' Tc=315.7 min CN=68 Runoff=466.29 cfs 187.700 af

Total Runoff Area = 1,235.000 ac Runoff Volume = 187.700 af Average Runoff Depth = 1.82"
81.44% Pervious = 1,005.800 ac 18.56% Impervious = 229.200 ac

Summary for Subcatchment 100S: Mill Brook Watershed

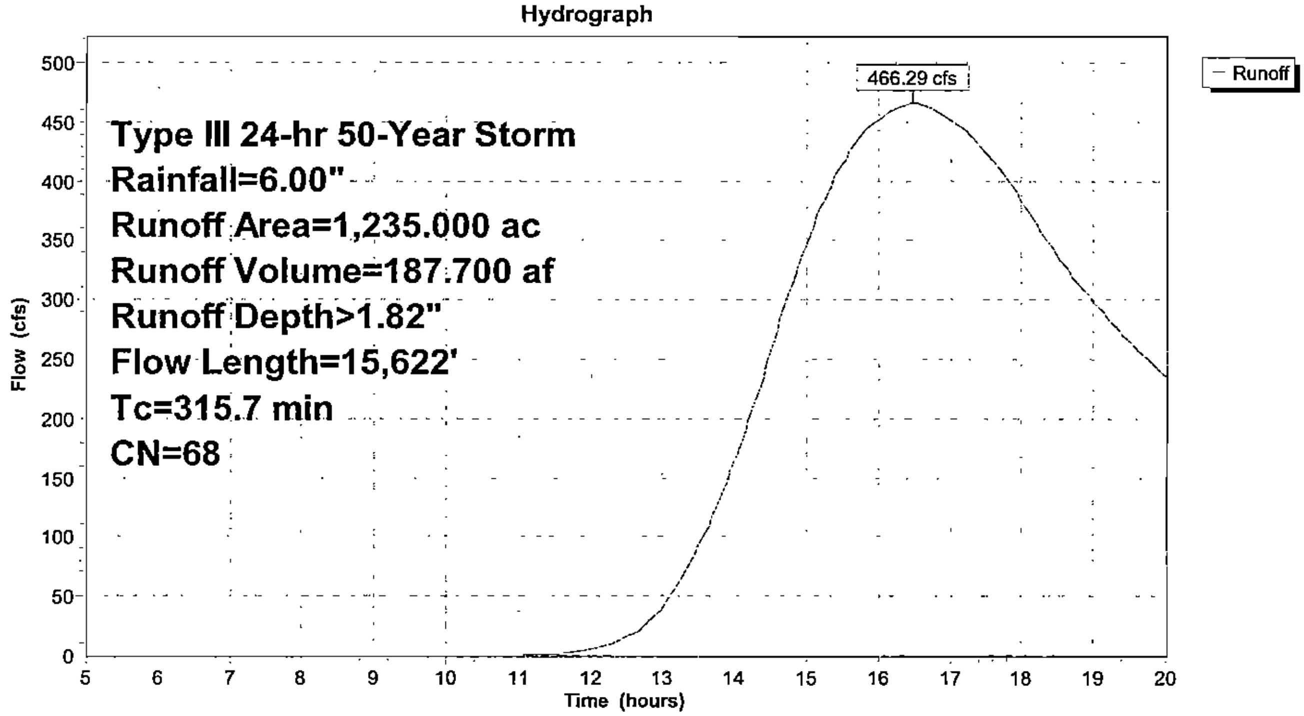
Runoff = 466.29 cfs @ 16.49 hrs, Volume= 187.700 af, Depth> 1.82"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 50-Year Storm Rainfall=6.00"

Area (ac)	CN	Description
25.000	89	Urban commercial, 85% imp, HSG A
31.000	92	Urban commercial, 85% imp, HSG B
50.000	94	Urban commercial, 85% imp, HSG C
18.000	95	Urban commercial, 85% imp, HSG D
62.000	51	1 acre lots, 20% imp, HSG A
77.000	68	1 acre lots, 20% imp, HSG B
124.000	79	1 acre lots, 20% imp, HSG C
46.000	84	1 acre lots, 20% imp, HSG D
111.000	30	Woods, Good, HSG A
139.000	55	Woods, Good, HSG B
222.000	70	Woods, Good, HSG C
84.000	77	Woods, Good, HSG D
62.000	98	Paved parking & roofs
37.000	39	>75% Grass cover, Good, HSG A
46.000	61	>75% Grass cover, Good, HSG B
74.000	74	>75% Grass cover, Good, HSG C
27.000	80	>75% Grass cover, Good, HSG D
1,235.000	68	Weighted Average
1,005.800		Pervious Area
229.200		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
40.5	150	0.0100	0.06		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.00"
208.7	2,800	0.0080	0.22		**Shallow Concentrated Flow,** Forest w/Heavy Litter Kv= 2.5 fps
66.5	12,672	0.0063	3.18	50.80	**Channel Flow, Mill Brook** Area= 16.0 sf Perim= 12.0' r= 1.33' n= 0.045
315.7	15,622	Total			

Subcatchment 100S: Mill Brook Watershed



Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment 100S: Mill Brook Watershed Runoff Area=1,235.000 ac 18.56% Impervious Runoff Depth>2.17"
Flow Length=15,622' Tc=315.7 min CN=68 Runoff=553.03 cfs 223.541 af

Total Runoff Area = 1,235.000 ac Runoff Volume = 223.541 af Average Runoff Depth = 2.17"
81.44% Pervious = 1,005.800 ac 18.56% Impervious = 229.200 ac

Summary for Subcatchment 100S: Mill Brook Watershed

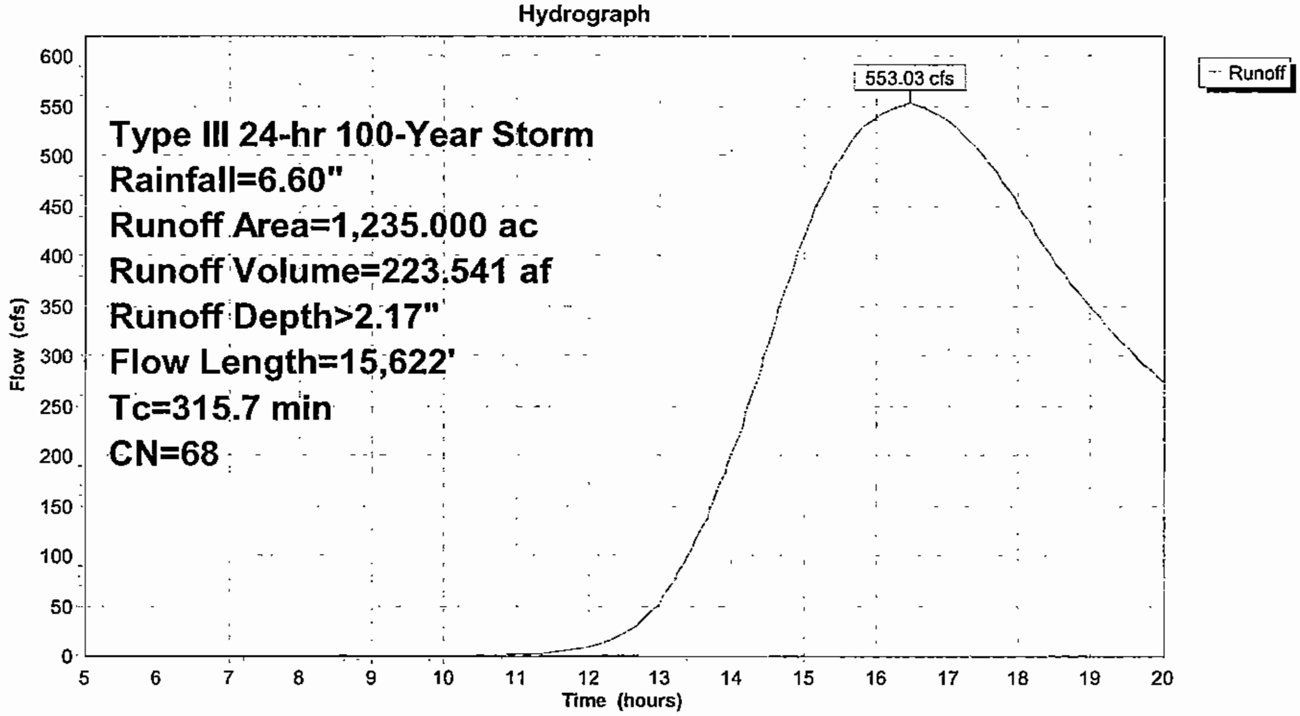
Runoff = 553.03 cfs @ 16.49 hrs, Volume= 223.541 af, Depth> 2.17"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr 100-Year Storm Rainfall=6.60"

Area (ac)	CN	Description
25.000	89	Urban commercial, 85% imp, HSG A
31.000	92	Urban commercial, 85% imp, HSG B
50.000	94	Urban commercial, 85% imp, HSG C
18.000	95	Urban commercial, 85% imp, HSG D
62.000	51	1 acre lots, 20% imp, HSG A
77.000	68	1 acre lots, 20% imp, HSG B
124.000	79	1 acre lots, 20% imp, HSG C
46.000	84	1 acre lots, 20% imp, HSG D
111.000	30	Woods, Good, HSG A
139.000	55	Woods, Good, HSG B
222.000	70	Woods, Good, HSG C
84.000	77	Woods, Good, HSG D
62.000	98	Paved parking & roofs
37.000	39	>75% Grass cover, Good, HSG A
46.000	61	>75% Grass cover, Good, HSG B
74.000	74	>75% Grass cover, Good, HSG C
27.000	80	>75% Grass cover, Good, HSG D
1,235.000	68	Weighted Average
1,005.800		Pervious Area
229.200		Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
40.5	150	0.0100	0.06		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.00"
208.7	2,800	0.0080	0.22		**Shallow Concentrated Flow,** Forest w/Heavy Litter Kv= 2.5 fps
66.5	12,672	0.0063	3.18	50.80	**Channel Flow, Mill Brook** Area= 16.0 sf Perim= 12.0' r= 1.33' n= 0.045
315.7	15,622	Total			

Subcatchment 100S: Mill Brook Watershed



ATTACHMENT F

Culvert Sizing Design Information (MDOT):

- **Figure 12-4.1 Design Chart for Sizing Simple CMP Culverts Under Inlet Control from MDOT Highway Design Guide – Chapter 12**
- **Table 12-4.19 Open End Areas for Embedded Circular Pipes from MDOT Highway Design Guide – Chapter 12**
- **Table 12-4.20 Open Area in Embedded Elliptical Pipe from MDOT Highway Design Guide – Chapter 12**

Using Figure 12-4.2, draw a line connecting $H_w/D = 1.5$ and $Q = 1.87$ m^3/s to the diameter axis, giving D = 1000 mm; the next largest stock sizes are 1050 and 1200 mm. The H_w/D ratios for the 900 mm pipe can be checked by drawing a line through D = 900 mm and Q = 1.87 m^3/s. This gives ratios of 1.8 (headwall) and 2.2 (mitred and projecting). Note that the mitred and projecting values are projected onto the headwall axis for reading.

Figure 12-4.1
Design Chart for Sizing Simple CMP Culverts Under Inlet Control

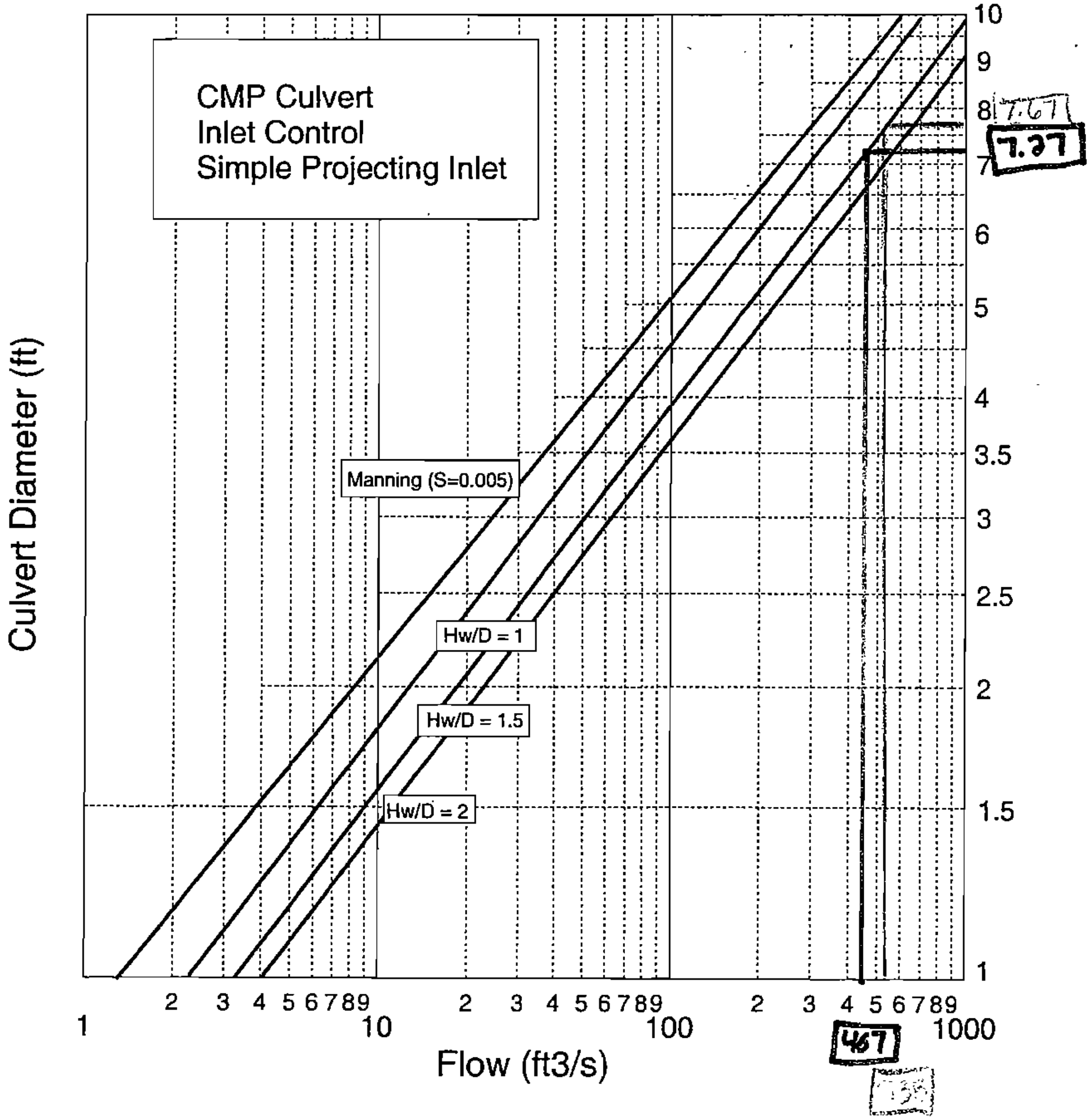


Table 12-4.19: Open End Areas (ft^2) for Embedded Circular Pipes

	Embedded Depth (in)					Embedded Depth (in)			
Dia (in)	3	6	9	12	Dia (in)	3	6	9	12
12	0.415	0.393	0.370	0.000	66	17.645	15.568	14.236	13.383
18	1.015	0.898	0.884	0.869	72	21.277	18.857	17.305	16.233
24	1.923	1.661	1.581	1.571	78	25.263	22.483	20.670	19.392
30	3.153	2.710	2.525	2.463	84	29.605	26.448	24.360	22.865
36	4.714	4.058	3.738	3.592	90	34.303	30.753	28.379	26.655
42	6.612	5.716	5.237	4.981	96	39.359	35.402	32.729	30.764
48	8.850	7.691	7.032	6.646	102	44.774	40.395	37.412	35.197
54	11.434	9.989	9.131	8.596	108	50.550	45.734	42.429	39.954
60	14.364	12.613	11.539	10.839	114	56.686	51.421	47.783	45.039
					120	63.185	57.457	53.475	50.452

(These equations and tables for embedded pipes can also be used to evaluate pipes flowing partially full. Then the depth of embedment is analogous to the depth of flow. This is discussed in further detail in Section 12-5.03.)

<u>Example</u>: *Hydrologic analysis indicates that a nominal 36 in pipe is needed to convey the 50-yr event. It is required that the pipe be embedded by 6 inches. What size pipe should be used?*

A 36 in pipe has an end area of $\pi(1.5\ ft)^2 = 7.07\ ft^2$. *Use Table 12-4.19 under the column for 6 in embedding to find the size with open end area closest to* $7.07\ ft^2$. *The needed size is 48 in.*

There are two situations where embedding is not generally recommended. In the case of an equalizer pipe where sluggish standing water is observed under low water conditions, the pipe need only be placed so that the invert is at the natural stream bottom elevation. In the case of steep streams, embedding may propagate a head upstream of the culvert. Therefore, simply matching the pipe invert to natural stream bottom is suggested. Staff with special expertise should be consulted in those instances where significant outlet drops have developed.

Table 12-4.20
OPEN AREA IN EMBEDDED ELLIPTICAL PIPE

Corner Radius	Span (ft)	Rise (ft)	Open Area (ft²) 0 in	6 in	9 in	12 in
			Depth of Embedding (in)			
Corner Radius = 18 in	6.08	4.58	22.03	19.95	18.64	17.24
	6.33	4.75	24.00	22.17	20.83	19.37
	6.75	4.92	26.17	24.47	23.06	21.54
	7.00	5.08	28.29	26.36	24.88	23.29
	7.25	5.25	30.53	28.38	26.82	25.15
	7.67	5.42	32.94	30.94	29.34	27.60
	7.92	5.58	35.23	33.01	31.32	29.51
	8.17	5.75	37.70	35.20	33.41	31.51
	8.58	5.92	40.27	38.01	36.27	34.27
	8.83	6.08	42.87	40.34	38.44	36.40
	9.33	6.25	45.78	43.48	41.59	39.50
	9.50	6.42	48.44	46.02	43.89	41.72
	9.75	6.58	51.29	48.42	46.29	44.02
	10.25	6.75	54.32	51.82	49.74	47.43
	10.67	6.92	57.48	55.11	52.96	51.00
	10.92	7.08	60.61	58.04	55.90	53.49
	11.42	7.25	64.01	61.61	59.61	57.25
	11.58	7.42	67.08	64.49	62.24	59.83
	11.83	7.58	70.40	67.59	65.24	62.61
	12.33	7.75	74.09	71.47	69.30	66.73
	12.50	7.92	77.40	74.58	72.15	69.51
	12.67	8.08	80.93	77.85	75.59	72.39
	12.83	8.33	85.48	82.07	79.33	76.38
	13.42	8.42	88.44	85.39	82.84	79.89
	13.92	8.58	92.52	89.67	87.30	84.50
	14.08	8.75	96.25	93.19	90.55	87.65
	14.25	8.92	100.07	96.76	84.16	90.84
	14.83	9.08	104.57	101.50	98.95	96.21
	15.33	9.25	108.90	106.02	103.61	100.77

Corner Radius	Span (ft)	Rise (ft)	Open Area (ft²) 0 in	6 in	9 in	12 in
			Depth of Embedding (in)			
	15.50	9.42	112.93	109.86	107.30	104.28
	15.67	9.58	117.09	113.81	111.08	105.54
	15.83	9.83	122.64	119.11	116.17	112.73
	16.42	9.92	126.19	122.91	120.18	116.96
	16.58	10.08	130.55	127.05	124.13	120.68
Corner Radius = 31 in	13.25	9.33	97.69	95.03	92.68	90.27
	13.50	9.50	101.79	98.94	96.58	93.90
	14.00	9.67	106.29	103.59	101.34	98.70
	14.17	9.83	110.24	107.38	104.96	102.24
	14.42	10.00	114.53	111.46	108.91	106.01
	14.92	10.17	119.28	116.39	113.98	111.14
	15.33	10.33	123.84	121.07	118.76	116.05
	15.58	10.50	128.39	125.47	123.03	120.17
	15.83	10.67	133.08	129.89	127.23	124.10
	16.25	10.83	137.80	134.85	132.39	129.51
	16.50	11.00	142.60	139.49	136.89	133.86
	17.00	11.17	147.81	144.67	142.06	138.99
	17.17	11.33	150.80	147.65	145.03	141.94
	17.42	11.50	157.56	154.24	151.47	148.22
	17.92	11.67	163.02	159.86	157.23	154.12
	18.08	11.83	167.92	164.60	161.83	158.56
	18.58	12.00	173.54	170.36	167.71	164.58
	18.75	12.17	178.64	175.30	172.52	169.23
	19.25	12.33	184.47	181.25	178.57	175.42
	19.50	12.50	190.01	186.63	183.83	180.52
	19.67	12.67	195.37	191.82	188.91	185.44
	19.92	12.83	201.11	197.39	194.29	190.63
	20.42	13.00	207.17	203.64	200.69	197.21
	20.58	13.17	212.72	209.00	205.91	202.25

ATTACHMENT G

Pipe Arch Design Information (MDOT):

- **Table 12-4.10 Steel Structural Plate Pipe Arches from MDOT Highway Design Guide – Chapter 12**

Table 12-4.10
STEEL STRUCTURAL PLATE PIPE ARCHES

(Corrugations of 6" x 2")

Span (ft-in)	Rise (ft-in)	Area (ft^2)	Corner Plate Radius (in)	Min Fill ft-in	Height of Fill Above Top of Pipe Arches (ft)											
					2	3	4	5-7	8	9	10	11	12	13	14	15
					For Steel Thickness (Inches)											
6-1	4-7	22	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
6-4	4-9	24	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
6-9	4-11	26	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
7-0	5-1	28	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138
7-3	5-3	31	18	2-0	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138	0.138
7-8	5-5	33	18	2-0	0.138	0.138	0.138	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.138	0.138
7-11	5-7	35	18	2-0	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
8-2	5-9	38	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
8-7	5-11	40	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
8-10	6-1	43	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
9-4	6-3	46	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
9-6	6-5	49	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138
9-9	6-7	52	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.168
10-3	6-9	55	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.168	0.168
10-8	6-11	58	18	2-6		0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.138	0.168	0.168	0.168
10-11	7-1	61	18	2-6		0.168	0.168	0.138	0.138	0.138	0.138	0.138	0.138	0.168	0.168	0.188
11-5	7-3	64	18	2-6		0.168	0.168	0.168	0.138	0.138	0.138	0.138	0.168	0.168	0.168	0.188
11-7	7-5	67	18	2-6		0.168	0.168	0.168	0.138	0.138	0.138	0.138	0.168	0.168	0.188	0.188
11-10	7-7	71	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188
12-4	7-9	74	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188
12-6	7-11	78	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188
12-8	8-1	81	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188	
12-10	8-4	85	18	2-6		0.168	0.168	0.168	0.168	0.168	0.168	0.188	0.188	0.188	0.188	
13-5	8-5	89	18	2-6		0.188	0.168	0.168	0.168	0.168	0.168	0.188	0.188	0.188	0.188	
13-11	8-7	93	18	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188		
14-1	8-9	97	18	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188		
14-3	8-11	101	18	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.218			
14-10	9-1	105	18	2-6		0.188	0.188	0.188	0.188	0.188	0.218	0.218	0.218			
15-4	9-3	109	18	2-6		0.218	0.188	0.188	0.188	0.188	0.218	0.218	0.218			USE
15-6	9-5	113	18	2-6		0.218	0.218	0.188	0.188	0.188	0.218	0.218				
15-8	9-7	118	18	2-6		0.218	0.218	0.188	0.188	0.188	0.218	0.218				31 in RADIUS
15-10	9-10	122	18	2-6		0.218	0.218	0.188	0.188	0.188	0.218	0.218				
16-5	9-11	126	18	2-6		0.218	0.218	0.218	0.218	0.218	0.218					STRUCTURES
16-7	10-1	131	18	2-6		0.218	0.218	0.218	0.218	0.218	0.218					
13-3	9-4	98	31	2-6		0.188	0.168	0.168	0.168	0.168	0.168	0.188	0.188	0.188	0.188	0.188
13-6	9-6	102	31	2-6		0.188	0.168	0.168	0.168	0.168	0.168	0.188	0.188	0.188	0.188	0.188
14-0	9-8	106	31	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
14-2	9-10	110	31	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188
14-5	10-0	115	31	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.218	0.218
14-11	10-2	119	31	2-6		0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.218	0.218
15-4	10-4	124	31	2-6		0.218	0.188	0.188	0.188	0.188	0.188	0.188	0.188	0.218	0.218	0.218
15-7	10-6	129	31	2-6		0.218	0.218	0.188	0.188	0.188	0.188	0.188	0.188	0.218	0.218	0.218
15-10	10-8	133	31	2-6		0.218	0.218	0.188	0.188	0.188	0.188	0.188	0.218	0.218	0.218	0.218
16-3	10-10	138	31	2-6		0.218	0.218	0.218	0.188	0.188	0.188	0.188	0.218	0.218	0.218	0.218
16-6	11-0	143	31	2-6		0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	
17-0	11-2	148	31	3-6			0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	
17-2	11-4	153	31	3-6			0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218	
17-5	11-6	158	31	3-6			0.218	0.218	0.218	0.218	0.218	0.218	0.218	0.218		
17-11	11-8	163	31	3-6			0.218	0.218	0.218	0.218	0.218	0.218	0.249	0.249		
18-1	11-10	168	31	3-6			0.218	0.218	0.218	0.218	0.218	0.249	0.249	0.249		
18-7	12-0	174	31	3-6			0.218	0.218	0.218	0.218	0.218	0.249	0.249	0.249		
18-9	12-2	179	31	3-6			0.218	0.218	0.218	0.218	0.249	0.249	0.249			
19-3	12-4	185	31	3-6			0.218	0.218	0.218	0.218	0.249	0.249	0.249			
19-6	12-6	190	31	3-6			0.218	0.249	0.249	0.249	0.249	0.249	0.249			
19-8	12-8	196	31	3-6			0.218	0.249	0.249	0.249	0.249	0.249				
19-11	12-10	202	31	3-6			0.218	0.249	0.249	0.249	0.249	0.249				
20-5	13-0	208	31	3-6			0.249	0.249	0.249	0.249	0.249	0.249				
20-7	13-2	214	31	3-6			0.249	0.249	0.249	0.249	0.249	0.249				

Note: for abrasion/corrosion resistance, use next heavier thickness (max. .280" thickness) for bottom and corner plates.