Long Hill Watershed Study

Town of Groton, Connecticut

April 1998

Prepared for:

Town of Groton
45 Fort Hill Road
Groton, Connecticut

Prepared by:

Milone & MacBroom, Inc.
716 South Main Street
Cheshire, Connecticut 06410
(203) 271-1773

Milone & MacBroom

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Executive Summary

This study has been prepared for the Town of Groton to analyze the Long Hill watershed and its associated drainage problems. The 862-acre watershed includes extensive urban areas with commercial and residential land uses.

The analysis of the southern portion of the Long Hill watershed was divided into five major stormwater drainage systems, referred to as follows: the Buddington Road/Laurelwood Road System, the Shopping Plaza System, the Southern Long Hill Road System, the Northern Long Hill Road System, and the Meridian Street System. The recommended drainage improvements within these systems were selected based on their cost effectiveness and their ability to reduce flood flows. Improvements were not recommended for areas where the flooding was tolerable, such as street gutter flow and small amounts of ponding within parking lots during a 25-year design storm event.

The Buddington Road/Laurelwood Road System extends from Buddington Road to an outlet at the Groton Shopper's Mart. Replacement of a portion of pipe in this area was recommended.

The Shopping Plaza System was determined to be undersized for the 25-year storm event. Construction of two berms (one north of the Post Office area and one at the intersection of Long Hill Road and Poquonnock Avenue) was recommended to attenuate stormwater and reduce the peak volume of runoff in this system. Construction of an overflow channel along the southern side of the Groton Shopper's Mart was also recommended to increase the capacity of the trunk line through this shopping area.

The Southern Long Hill Road System contains two pipes which are undersized for the 25-year design storm. In lieu of replacing these pipes, it was recommended that gutter flow along Route 1 be permitted and the intake capacity of downstream catch basins be improved by the installation of slotted drain.

The Northern Long Hill Road System was generally found to be within capacity except for a reduction in pipe size at the outlet behind Wendy's Restaurant. The 30" RCP reduces down to a 24" CMP at this outlet causing water to back up into piping on Route 1. It was recommended that this 24" pipe be replaced with a 30" pipe.

The Meridian Street System was found to be of adequate size to handle the flows of a 25-year storm event. The only recommendation in this system pertains to the stream which flows near the north end of the Charter Oak Credit Union property. This stream should be realigned or the existing berm raised to prevent the stream from overtopping its banks during rainstorms.

The total cost of the recommended improvements is $192,600. The improvements recommended by FGA in 1986 totaled $1,461,800 ($2,625,190 in 1998 dollars adjusted for inflation).

1.0 Introduction

This study has been prepared for the Town of Groton to analyze the Long Hill watershed and its associated drainage problems. The 862-acre watershed is located in the south central part of Groton, roughly between I-95 and U.S. Route 1. The watershed includes extensive urban areas with commercial and residential land uses.

Previous studies by others had recommended extensive drainage improvements, but there are very limited drainage problems. Consequently, one objective of this project was to independently verify the need, extent, and priority of drainage improvements.

The report format is similar to the order in which the analysis was performed. The Town of Groton provided general data, previous studies, and GIS information at the project initiation. A detailed field investigation and survey were undertaken so that the existing conditions within the watershed could be clearly defined.

A combination of field investigation and GIS mapping provided information for the detailed hydrologic model. The U.S. Department of Agriculture (USDA), Soil Conservation Service's (SCS) TR-20 model was used to estimate storm runoff rates for existing and potential future and proposed conditions. The proposed conditions TR-20 model calculates the flow reductions due to increasing detention.

The hydraulic analysis was performed utilizing the Rational Method, Manning's Equation, and flows from the TR-20 model. Additionally, pipe profiles were prepared on all of the trunk lines and critical lateral lines to determine effective slopes and critical elevations to which the system could be surcharged. These pipe profiles have been included in this study. An additional hydraulic analysis was prepared for the recommended pipe improvements to determine potential sizes for pipe replacement.

GIS technology and mapping were used throughout the study to insure more accurate modeling results and to enhance the presentation of the material. All of the GIS files will be presented to the Town of Groton along with this study.

The recommended drainage improvements were selected based on their cost effectiveness and their ability to reduce flood flows. Improvements were not recommended for areas where the flooding was tolerable, such as street gutter flow and small amounts of ponding within parking lots during a 25-year design storm event.

2.0 **Existing Conditions**

2.1 Preliminary Data Collection

The Long Hill Drainage Study was initiated in January 1997. Early emphasis focused on collection of available data and the conducting of field investigations and surveys needed to map the drainage system and set up the watershed models. This data has been incorporated into the hydrologic and hydraulic models so that they will accurately represent the drainage conditions within the Long Hill watershed.

The following tasks were performed to define existing watershed conditions:

- Review of the Long Hill Watershed Drainage Study report conducted by Flaherty Giavara Associates, Inc. (FGA) dated January 1986.
- The Survey Control Data provided by the Town of Groton was utilized to determine horizontal and vertical controls for a new field survey of the storm drainage system within the watershed.
- Review of the Road and Drainage Construction Standards provided by the Town of Groton.
- Recently developed areas (since 1986) were identified and sketched on to a copy of the GIS maps. Where possible, plans for these new developments and roads were obtained from the Town.
- GIS base maps were created for the Long Hill watershed using data provided by the Town of Groton.
- The most recent 500-scale aerial photographs of the study area were acquired and reviewed (April 1996).

- A review of the Department of Environmental Protection's (DEP) Natural Diversity Database was undertaken to determine whether threatened or endangered wildlife species or species of special concern are present within the study area. A GIS map is enclosed as Figure 2.1-1 showing potential areas of concern. Some areas of concern were identified within the Long Hill Road watershed area. The areas shown on the map were identified by the DEP by determining the point location of the species of concern. The location was then moved up to 500 feet and buffered by ¼ mile. The resultant polygon covers the location of the endangered species without divulging its exact location. The Natural Resources Center at the DEP should be contacted prior to performing any work in the highlighted area.

- USGS topographic maps were obtained for the watershed.

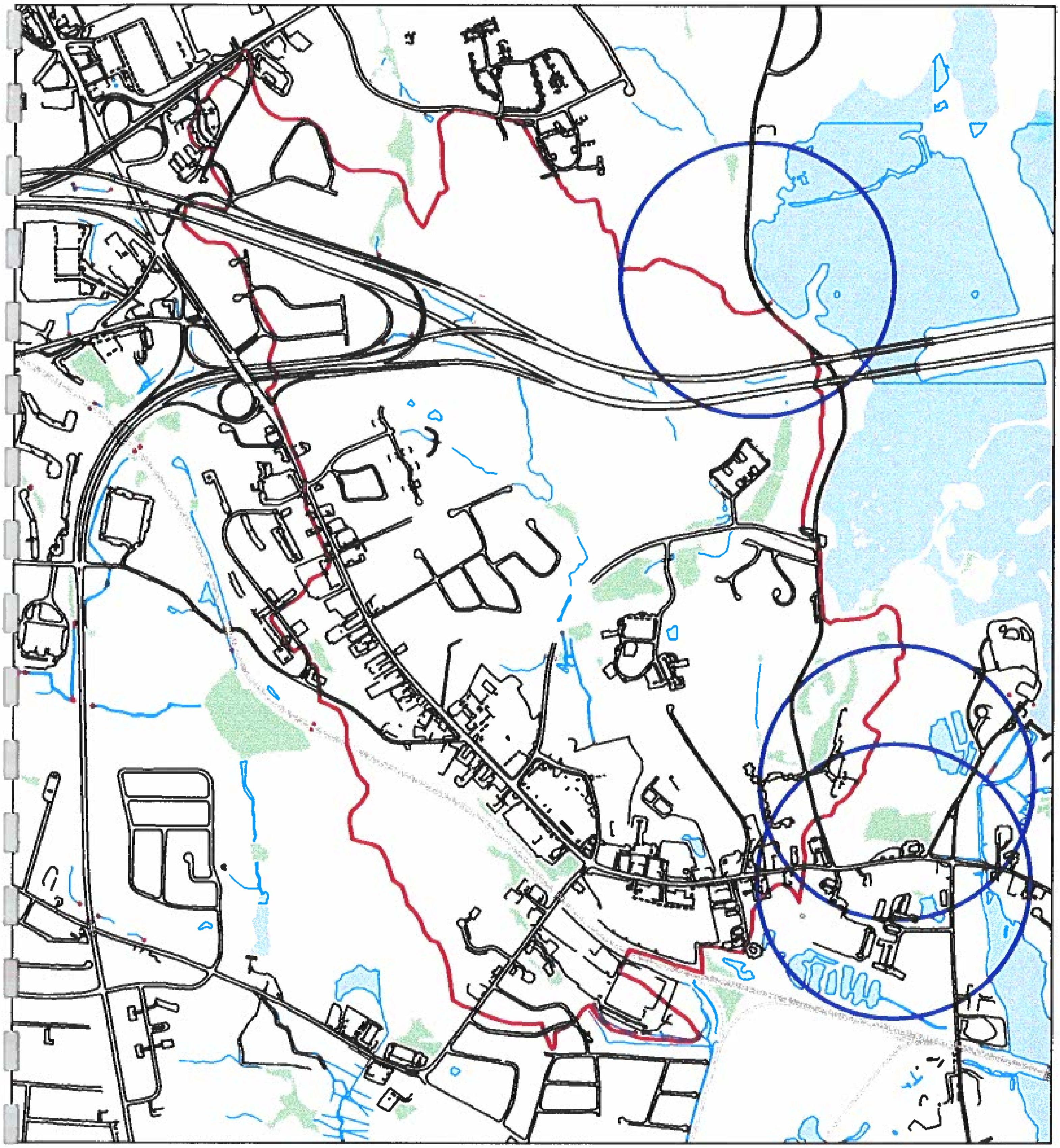
- A list of local flooding complaints was reviewed.

2.2 Field Survey

An extensive field survey was conducted to obtain data on drainage structures and pipes within the Long Hill watershed. The direction of flow, size and type of pipes have been documented, as well as the top-of-grate and pipe invert elevations. Observations on structure and pipe condition, including an inventory of pipes that have been damaged or obstructed by sand and debris, have been included.

Top-of-grate elevations and inverts of outfall pipes were surveyed with electronic survey instruments and all data was imported into a GIS database. Inverts of pipes within catch basins and manholes were measured manually from the top-of-grate. Pipe sizes were also measured manually. This information was also incorporated into the GIS database.

All surveys are based upon the National Geodetic Vertical Datum (NGVD) dated 1929 and the State Plane Coordinate System dated 1983 (NAD 83), so as to coordinate with the existing Town GIS mapping.



Water

Swamp/Marsh

Long Hill Drainage Basin

= DEP Natural Diversity Data Base Areas of Special Concern

N S W E

Natural Diversity Database Map

Figure 2.1-1
Groton, Connecticut

Milone & MacBroom, Inc.

3.0 GIS Data and Applications

The Geographic Information System (GIS) was used extensively for several applications as part of the Groton Long Hill Drainage Study. Initially, the GIS coverage provided by the Town of Groton was plotted as large-scale maps and utilized as base mapping for fieldwork, survey, and the drainage system inventory. The GIS base coverage was also used during the hydrologic analysis as base maps for calculating time of concentration (T_c), runoff curve number (CN) and storage volumes for the stormwater detention areas.

Land uses, soil hydrologic groups, and the 23 sub-basins were digitized using the coverages provided by the Town of Groton as a base layer. The digitized information was then incorporated into the GIS system and used to derive input data for the TR-20 model, including weighted runoff curve numbers and sub-basin sizes.

Survey points for catch basins, manholes, pipe inverts, and other structures were imported into the GIS. Pipe system connectivity was then digitized and incorporated into the GIS system along with attribute information for pipes, manholes, catch basins, and other structures. All coverages were exported from the GIS into ARC/INFO format in the form of *.E00 files.

The GIS coverages created for the Long Hill drainage study are as follows:

- Longhill.E00
- Sub_bas.E00
- Soils.E00
- Landuse.E00
- Strctr.E00
- Pipes.E00

A summary of these files follows.

3.1 Long Hill Drainage Basin

The Long Hill drainage basin boundary was delineated using the base topographic mapping provided by the Town of Groton. A detailed effort was made to field verify the drainage basin boundary. The Long Hill drainage basin was then digitized and imported into the GIS for the purpose of the study. This coverage has been converted to ARC/INFO format with the filename Longhill.E00. Attribute information for the Longhill.E00 coverage includes basin area and perimeter for the Long Hill drainage basin.

3.2 Project Sub-Basins

The Long Hill drainage basin was divided into 23 sub-basins for the purpose of the hydrologic analysis. The sub-basins were digitized and have been converted to the file Sub_bas.E00. Attribute information for the Sub_bas.E00 coverage includes the sub-basin number, area, and perimeter for the 23 sub-basins.

3.3 Soil Hydrologic Groups

Soil hydrologic groups were digitized using USDA SCS mapping as a base. This base information was field checked and updated to include areas of new development. An explanation of the soil hydrologic group criteria has been included in the Hydrology section of this report. The soil hydrologic group coverage has been converted to the file Soils.E00. Attribute information includes the area, perimeter, and hydrologic group for each soil unit within the Long Hill drainage basin.

3.4 Land Use

Land use within the Long Hill drainage basin was characterized using aerial photographs, USGS topographic mapping, and field reconnaissance. The land use coverage was digitized and converted to the file Landuse.E00. Attribute information includes the area, perimeter, and land use characterization for each land use unit.

3.5 Drainage Structures

Drainage structures within the Long Hill drainage basin, including catch basins, manholes, outfall pipe inverts, detention structures and yard drains, were surveyed using horizontal and vertical datum specified by Town of Groton survey control data. The survey points were imported as a GIS coverage and converted to the file Strctr.E00. Attribute information includes each structure's reference number, type of structure, top of structure elevation, invert elevation of pipes at the structure, direction of pipes at the structure, and any comments pertaining to the structure. Structures designated as type INV are outfall pipes and the top of structure elevation refers to the invert elevation of the pipe.

3.6 Storm Drains

A field inventory was conducted of storm drains within the Long Hill drainage basin. This included mapping of pipe location, measurement of pipe diameter, and analysis of pipe material and condition. Pipe locations were digitized and imported into the GIS and converted to the file Pipes.E00. Pipe attribute information includes length of pipe, pipe material, pipe diameter (in inches), and pipe condition.

4.0 Hydrology

The principal method of predicting the surface water runoff rates utilized for this report is a computer program entitled TR-20 Hydrology. This program was developed by the SCS for conducting hydrology studies.

The TR-20 computer program forecasts the rate of surface water runoff and river flow rates based upon several factors. The input data includes information on land use, soil types, vegetation, watershed areas, time of concentration, rainfall data, storage volumes, and hydraulic capacities of structures. The computer model predicts the amount of runoff as a function of time, including the attenuation affect due to dams, lakes, large wetlands, and floodplains. Runoff rates during specific rainstorms may vary due to different assumptions concerning soil moisture, water levels in ponds, snowmelt, and rainfall patterns.

Existing and future conditions were modeled with the TR-20 computer program. A revised TR-20 model was then run to determine the effects of the proposed recommendations to increase in detention. These models have been included in the Appendix of this report.

The input data for rainfalls with statistical recurrence frequencies of 2, 10, 25, 50, and 100 years was obtained from the U.S. Weather Bureau Technical Papers. A standard 24-hour duration type III rainfall pattern was used.

4.1 Watershed Size and Location

The Long Hill watershed is located in the Town of Groton, New London County, Connecticut. The drainage area is 862 acres in size and is bordered by Buddington Road to the east, Winding Hollow Road to the north, Long Hill and Poquonnock Roads to the west. and Ginger Drive to the south. Interstate 95 cuts across the watershed east to west.

4.2 Land Use

Existing land use within the Long Hill watershed is highly variable. The area north of Interstate 95 consists primarily of low to moderate density residential neighborhoods and wooded parcels. South of Interstate 95, the watershed is more densely developed, with many commercial businesses located along Long Hill Road (Route 1). Several industrial establishments, such as Wyman-Gordon, Inc., are located in the southern portion of the watershed.

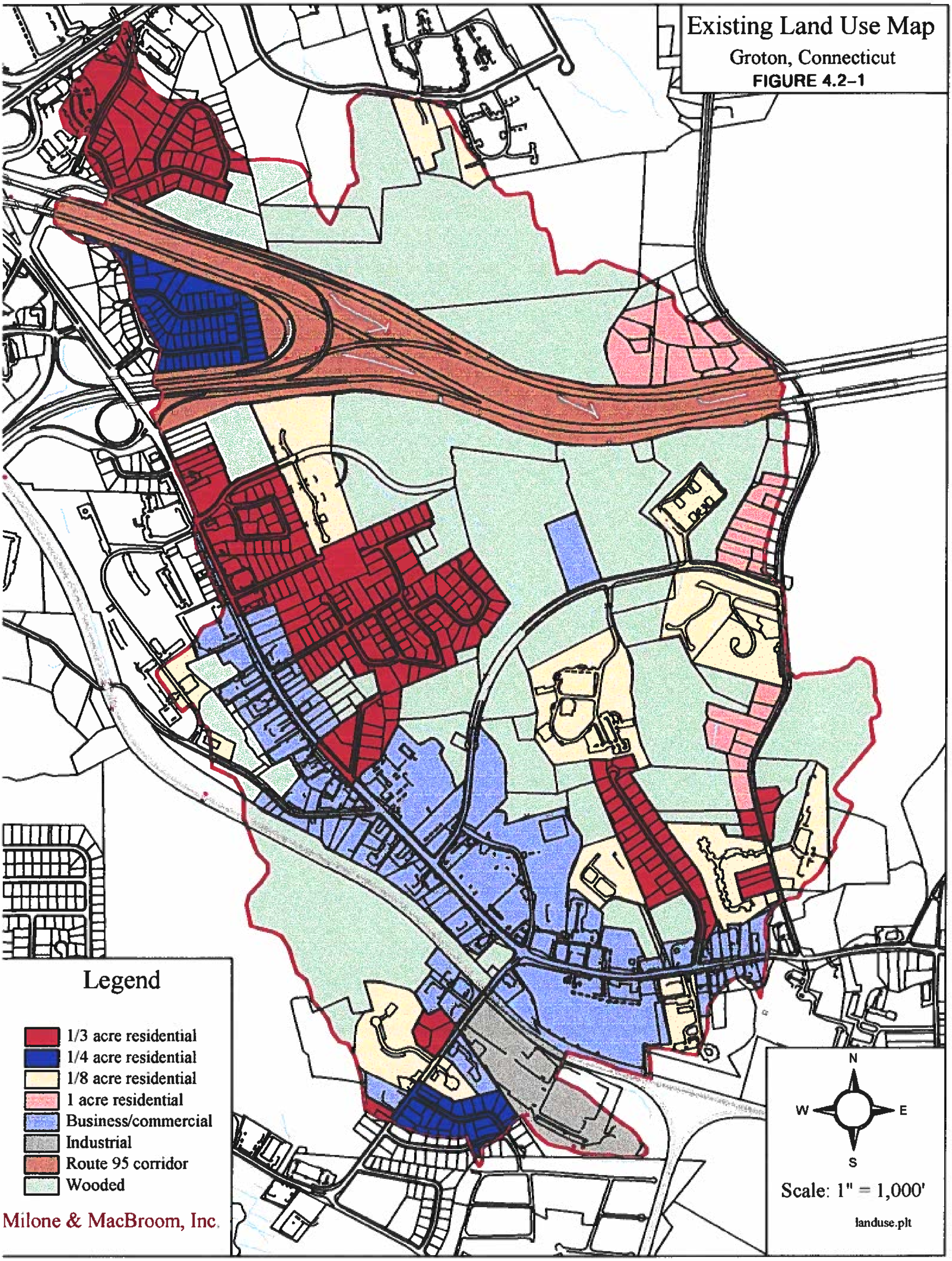
For the purpose of the TR-20 model, existing and future land uses within the Long Hill watershed were identified and delineated on GIS mapping. Existing land use identification was accomplished based upon field inspection, current aerial photographs, and USGS 1:24,000 scale topographic maps. Future land uses were projected utilizing Town zoning maps. The following standard TR-20 categories were used for classification of land use:

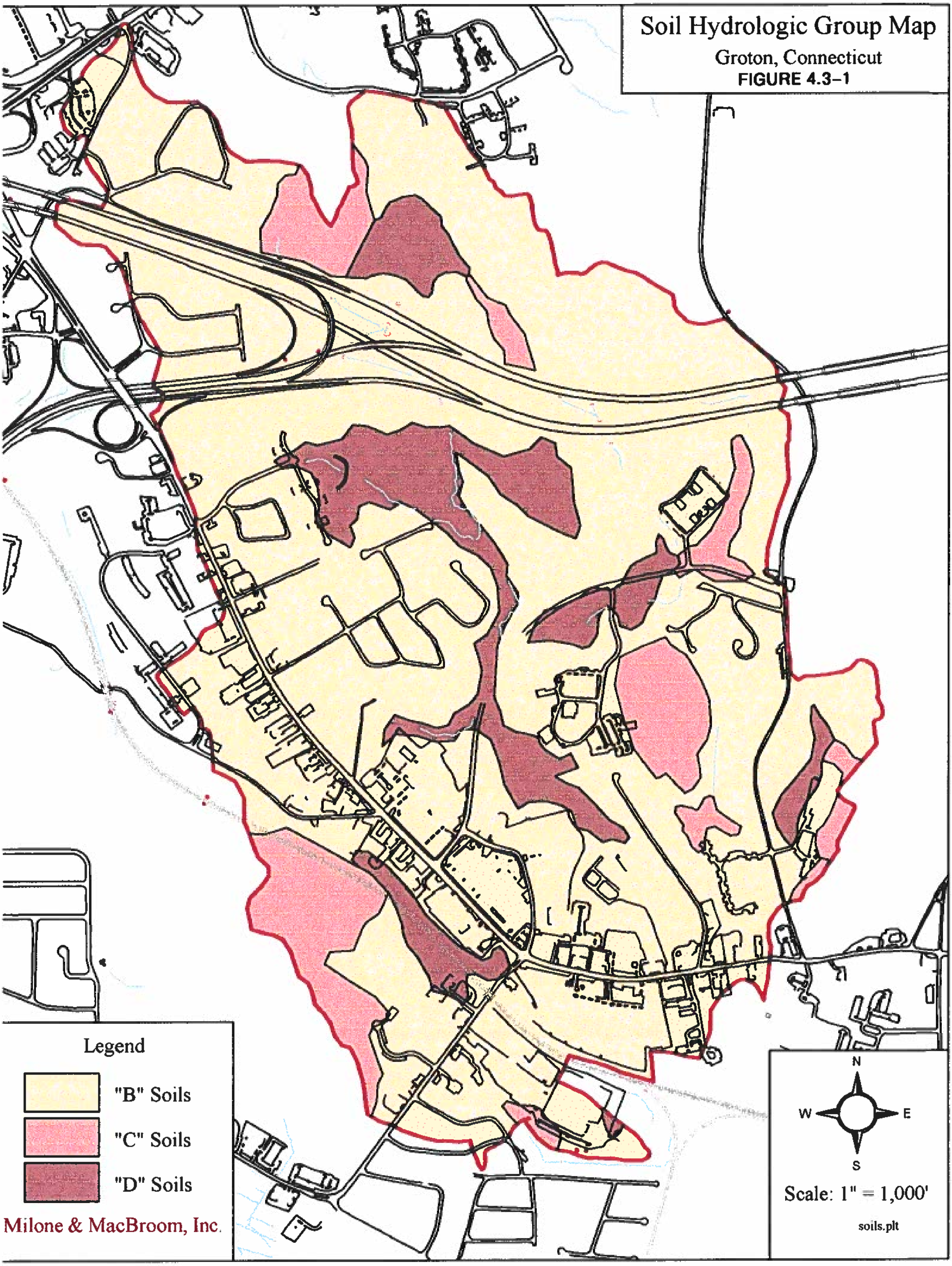
- 1/8 acre residential
- 1/4 acre residential
- 1/3 acre residential
- 1 acre residential
- Industrial
- Business/Commercial
- Wooded
- Route 95 corridor

Land use within the Long Hill watershed is presented as Figure 4.2-1.

4.3 Soils

The SCS New London County Soil Survey has defined criteria for hydrologic soil groups within the Long Hill watershed based upon the runoff potential for each group. This base information was reviewed by Milone & MacBroom, Inc. (MMI) staff and updated to include areas of new development, then digitized and incorporated into the GIS system.


Existing Land Use Map
Groton, Connecticut
FIGURE 4.2-1
Legend
1/3 acre residential
1/4 acre residential
1/8 acre residential
1 acre residential
Business/commercial
Industrial
Route 95 corridor
Wooded
Milone & MacBroom, Inc.
N
W
E
S
Scale: 1" = 1,000'
landuse.plt


Soil Hydrologic Group Map
Groton, Connecticut
FIGURE 4.3-1
Legend
"B" Soils
"C" Soils
"D" Soils
Milone & MacBroom, Inc.
N
W
E
S
Scale: 1" = 1,000'
soils.plt

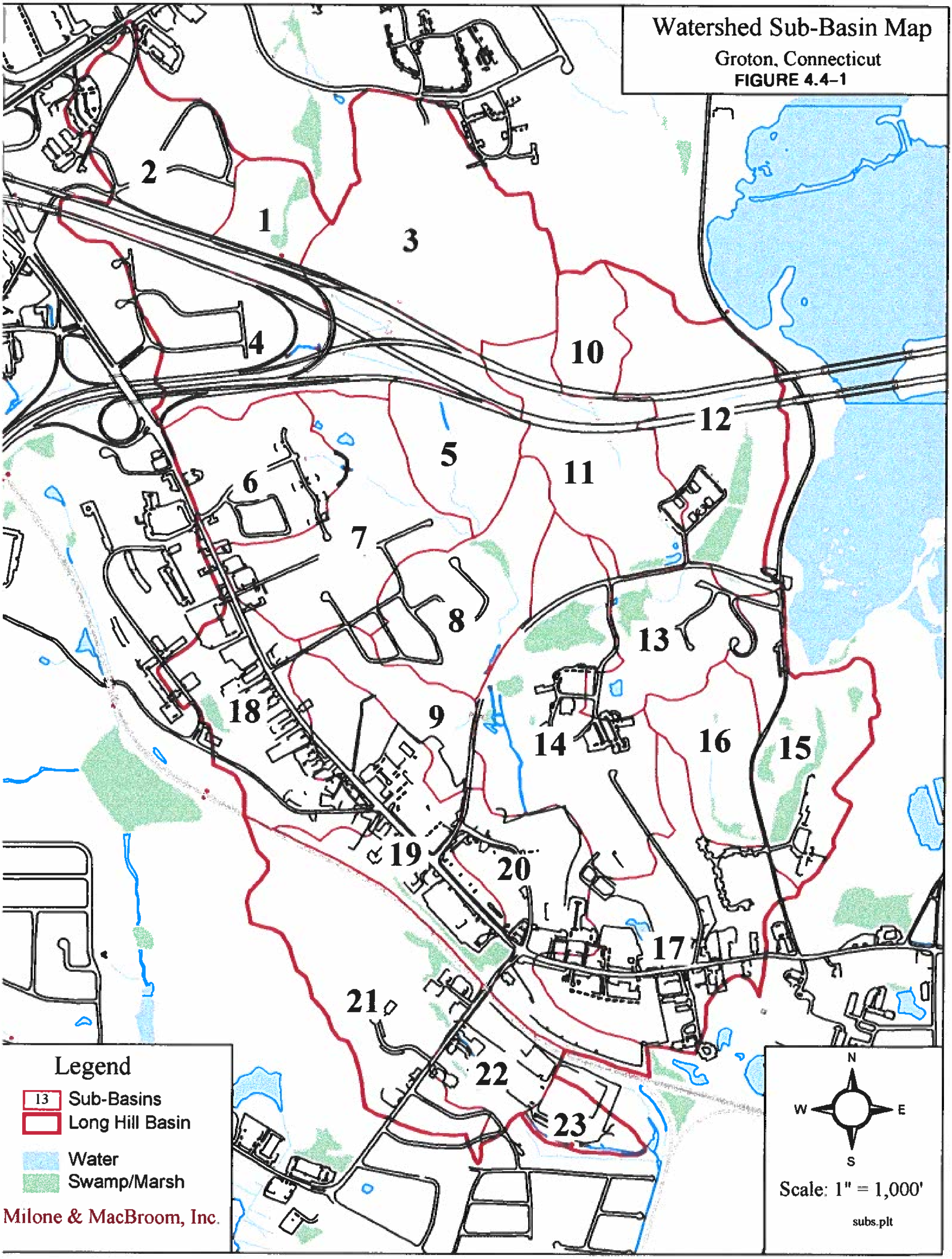
Hydrologic soil group values are as follows:

A	Soils with low runoff potential
B	Soils with moderate runoff potential
C	Soils with high runoff potential
D	Soils with severe runoff potential

The predominant soil hydrologic group in this watershed is hydrologic group B. Hydrologic group B soils cover 698.8 acres, or approximately 81%, of the watershed. Hydrologic group C soils cover 75.6 acres (9%) of the watershed and hydrologic group D soils cover 87.2 acres (10%) of the watershed. Hydrologic group A soils do not occur within the Long Hill watershed. A hydrologic soil map of the Long Hill watershed has been included as Figure 4.3-1.

4.4 Subwatersheds

For the purpose of hydrologic analysis, the Long Hill watershed was divided into 23 subwatersheds. The subwatersheds were divided based on critical analysis points such as road crossings, brook confluences, and individual drainage systems. An effort was made to divide watersheds to result in homogeneous watersheds with similar soils, land use, and topography. The subwatersheds do not directly correspond to the subwatersheds used in the 1986 FGA study. Subwatersheds are presented as Figure 4.4-1. Subwatershed sizes are presented in Table 4.4-1.



Watershed Sub-Basin Map
Groton, Connecticut
FIGURE 4.4-1
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21
22
23
Legend
13 Sub-Basins
Long Hill Basin
Water
Swamp/Marsh
Milone & MacBroom, Inc.
N
W
E
S
Scale: 1" = 1,000'
subs.plt

Table 4.4-1

Sub-Basin Areas

Sub-basin	***Area (acres)***	***Area (sq. miles)***
Sub-basin 1	13.55	0.0212
Sub-basin 2	43.45	0.0679
Sub-basin 3	67.12	0.1049
Sub-basin 4	61.77	0.0965
Sub-basin 5	22.44	0.0351
Sub-basin 6	31.26	0.0488
Sub-basin 7	45.75	0.0715
Sub-basin 8	36.10	0.0564
Sub-basin 9	18.18	0.0284
Sub-basin 10	13.26	0.0207
Sub-basin 11	38.88	0.0608
Sub-basin 12	54.25	0.0848
Sub-basin 13	28.06	0.0438
Sub-basin 14	62.11	0.0970
Sub-basin 15	37.28	0.0583
Sub-basin 16	21.10	0.0330
Sub-basin 17	58.87	0.0920
Sub-basin 18	40.09	0.0626
Sub-basin 19	46.85	0.0732
Sub-basin 20	36.15	0.0565
Sub-basin 21	59.01	0.0922
Sub-basin 22	17.55	0.0274
Sub-basin 23	8.54	0.0133
Total:	**861.62**	**1.3463**

4.5 Runoff Curve Number

The runoff curve number (CN value) is an empirical system used to determine surface runoff volumes from a specified rainfall. CN values are part of the input data used in the TR-20 model. Each unique area within the Long Hill drainage basin was assigned a CN value based on its land use classification and its hydrologic soil group. These are presented in Table 4.5-1.

Table 4.5-1
CN Values for Long Hill Watershed

Land Use	***Soil Hydrologic Group***			
	A	***B***	***C***	***D***
Residential				
1/8 acre residential	52	68	78	84
1/4 acre residential	50	68	77	84
1/3 acre residential	47	67	77	83
1 acre residential	43	64	75	81
Urban Districts				
Industrial	81	88	91	93
Business/Commercial	89	92	94	95
Other				
Wooded	24	50	60	67
Route 95 Corridor	46	64	76	82

A weighted CN value was then derived for each sub-basin for existing conditions. A future condition CN value was also calculated for each sub-basin. In calculating future condition CN values, it was assumed that undeveloped parcels will be developed to their maximum allowable capacity based upon existing zoning regulations. The existing condition CN values and the future condition CN values are presented in Table 4.5-2 below. Calculations used to derive CN values are included in Appendix A.

Table 4.5-2
CN Values - Long Hill Watershed Sub-Basins

Sub-basin	***CN Value - Existing Condition***	***CN Value - Future Condition***
Sub-basin 1	55.8	70.4
Sub-basin 2	64.8	66.1
Sub-basin 3	61.8	69.9
Sub-basin 4	64.9	65.6
Sub-basin 5	60.2	74.7
Sub-basin 6	65.9	77.9
Sub-basin 7	66.0	71.8
Sub-basin 8	62.4	71.0

Table 4.5-2 (continued)
CN Values - Long Hill Watershed Sub-Basins

Sub-basin	*CN Value - Existing Condition*	*CN Value - Future Condition*
Sub-basin 9	65.3	79.9
Sub-basin 10	52.6	65.8
Sub-basin 11	58.6	69.1
Sub-basin 12	61.1	67.0
Sub-basin 13	64.1	72.1
Sub-basin 14	65.8	74.5
Sub-basin 15	60.6	69.7
Sub-basin 16	60.3	69.3
Sub-basin 17	75.1	81.2
Sub-basin 18	78.1	84.0
Sub-basin 19	82.3	88.4
Sub-basin 20	89.9	90.3
Sub-basin 21	65.1	75.8
Sub-basin 22	84.0	83.9
Sub-basin 23	88.1	88.7

4.6 Time of Concentration

The time of concentration (T_c) is the amount of time, in hours, that is required for rainwater falling within a drainage basin to flow out of the basin outlet. Because of the variations in distance that each drop of water must travel, the runoff from a storm is distributed over a period of time. A long time of concentration will spread out the storm runoff, while a short time of concentration will result in a higher peak flow at the outlet.

The time of concentration values are influenced by the surface roughness of the terrain, slope, and length of travel. Urbanization increases flow velocities by removing vegetation and increasing the amount of smooth paved surfaces. This creates a shorter time of concentration which, in turn, causes storm runoff to occur in a shorter period of time with higher peak runoff rates.

Tc's are important input values for the TR-20 model. The Tc values for each sub-basin are presented in Table 4.6-1 below. T_c worksheets are included in Appendix A.

Table 4.6-1
T_c Values

Sub-basin	***T_c Value (hours)***
Sub-basin 1	0.941
Sub-basin 2	0.882
Sub-basin 3	0.969
Sub-basin 4	1.283
Sub-basin 5	1.043
Sub-basin 6	2.381
Sub-basin 7	1.062
Sub-basin 8	0.705
Sub-basin 9	1.184
Sub-basin 10	0.873
Sub-basin 11	1.596
Sub-basin 12	1.539
Sub-basin 13	1.381
Sub-basin 14	1.663
Sub-basin 15	0.746
Sub-basin 16	1.083
Sub-basin 17	1.432
Sub-basin 18	0.764
Sub-basin 19	1.166
Sub-basin 20	0.430
Sub-basin 21	1.466
Sub-basin 22	0.347
Sub-basin 23	1.198

4.7 Stormwater Storage

Stormwater storage areas such as wetlands, ponds, constricted areas, and detention basins delay runoff and can greatly influence the final results of the TR-20 model. Stage-storage-discharge curves were derived for eight detention areas within the Long Hill watershed. Calculations used to derive storage and discharge at each detention area are included in Appendix A.

Stormwater storage locations included in the TR-20 analysis are listed below.

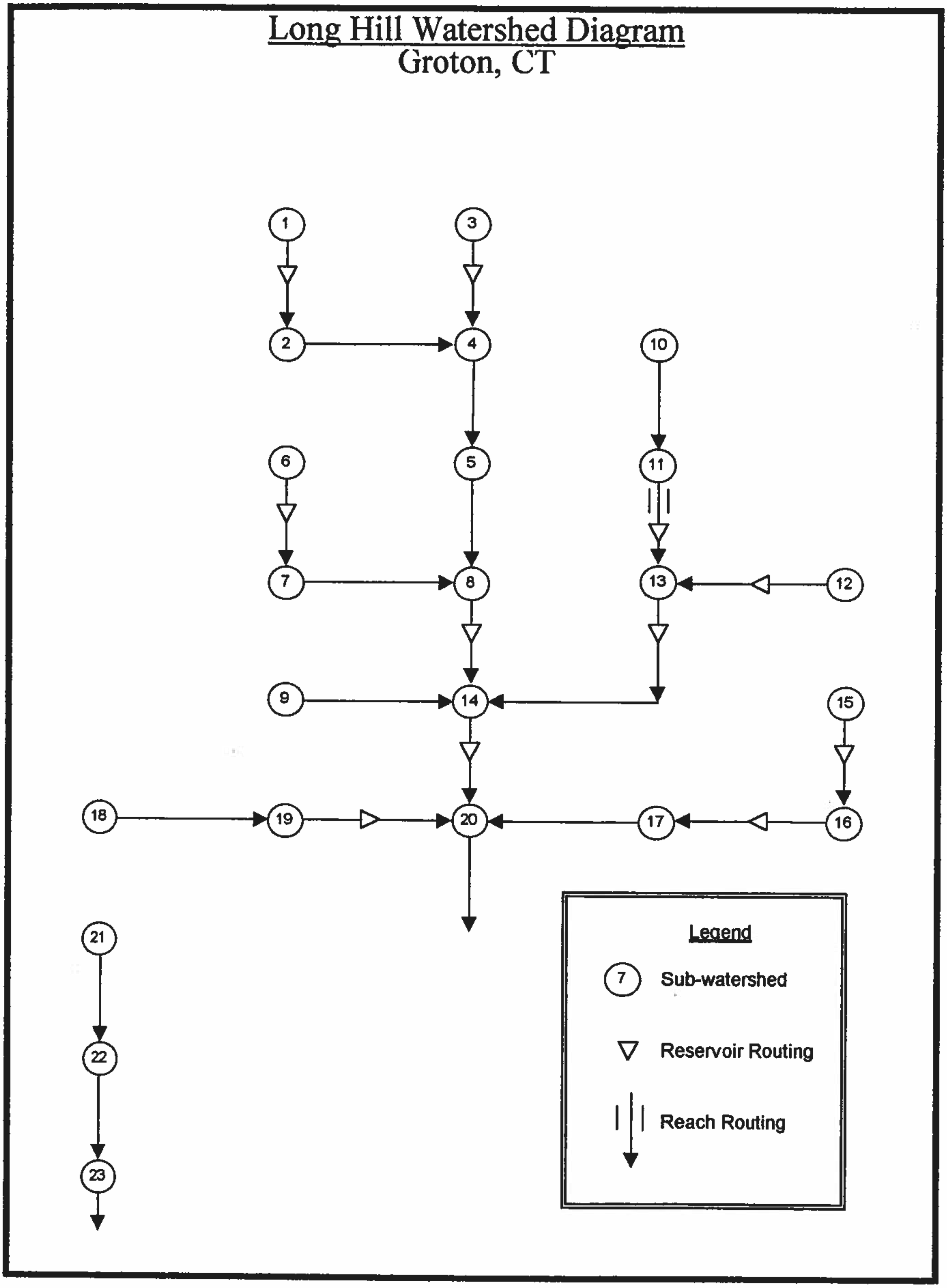
- Sub-basin 15: 24-inch RCP at Laurel Glenn Apartments on Buddington Road
- Sub-basin 11: triple 24-inch pipe west of Windham Estates at Drozdyk Drive
- Sub-basin 13: triple 24-inch pipe at Michelle Road off of Drozdyk Drive
- Sub-basin 6: v-notch structure behind Tall Woods Condominiums
- Sub-basin 16: 24-inch pipe west of Buddington Road
- Sub-basin 12: v-notch weir structure on Drozdyk Drive
- Sub-basin 14: 48-inch culvert at the Post Office
- Sub-basin 8: triple box culvert at Drozdyk Drive
- Sub-basin 3: 72-inch pipe at Route 95
- Sub-basin 1: 36-inch pipe at Route 95
- Sub-basin 19: 42-inch pipe at Long Hill and Poquonnock Roads

Detention basins (or wetlands utilized for detention) are judged on their effectiveness to detain flows during large rainfall events. A highly effective detention basin will have an outflow that is significantly smaller than the inflow to the basin. The peak inflow and outflow for a 25-year storm event at each detention area, along with the maximum water surface elevation reached during that event, have been tabulated in Table 4.7-1.

Table 4.7-1
Storage Area Inflow and Outflow

Detention Area Sub-basin Number	*Inflow (cfs)*	*Outflow (cfs)*	*% Flow Reduction*	*Max. WSEL (ft)*
01	8	5	38 %	86.86
03	53	48	9 %	56.00
06	17	11	35 %	86.60
08	224	165	26 %	22.39
11	22	19	14 %	24.60
12	32	10	69 %	23.93
13	36	27	25 %	22.33
14	228	100	56 %	21.46
15	32	3	91 %	23.31
16	16	7	56 %	24.32
19	135	68	50 %	18.96

Figure 4.7-1 provides a schematic of the watershed with the locations of reach and reservoir routing shown.



Milone & MacBroom, Inc.

FIGURE 4.7-1

4.8 Future Flows

Future flows were projected with the TR-20 model by assuming maximum development according to the Town of Groton zoning maps. The primary change was that of existing wooded land to fully developed residential areas. If these areas were allowed to be developed with no regard to on-site detention, then flooding would be increased in the presently stressed drainage systems in the southern portion of the watershed. It is recommended that future development throughout the entire watershed abide by the watershed management plan specified in the 1986 FGA report. This watershed plan will minimize the risk of future flooding due to increased watershed development. Figure 4.8-1 provides a map of the watershed with the potential future land uses delineated.

The watershed management plan described in the FGA report divides the Long Hill watershed into three hydrologic locations: upper, central, and lower. The report then classifies each subwatershed into one of five overall conditions, referred to as "watershed sensitivity index." These indexes range from I to V. A subwatershed management plan was then specified based on the subwatershed's hydrologic location and watershed sensitivity index. There are six different subwatershed management plans described in the FGA report (Plan A through Plan F). The subwatersheds used for analysis in this report vary from the subwatersheds used in the 1986 FGA report. This is due to the availability of improved base mapping and the collection of additional data. The FGA table (Table 6, Page 54 of the FGA report) outlining the management plan selected for each subwatershed has, therefore, been adjusted as follows to account for the new subwatershed boundaries.

Table 4.8-1
Long Hill Watershed Management Plan

MMI Subwatershed	*Hydrologic Location*	*Watershed Sensitivity Index*	*Management Plan*
1-7	Upper	III	D
8, 10-13, 18-19, 21	Central	IV	D
9	Central	V	E
14	Central	III-V	D
15,16	Central	III	D
17	Lower	III	B,*
20	Lower	V	*
22-23	Lower	IV	F

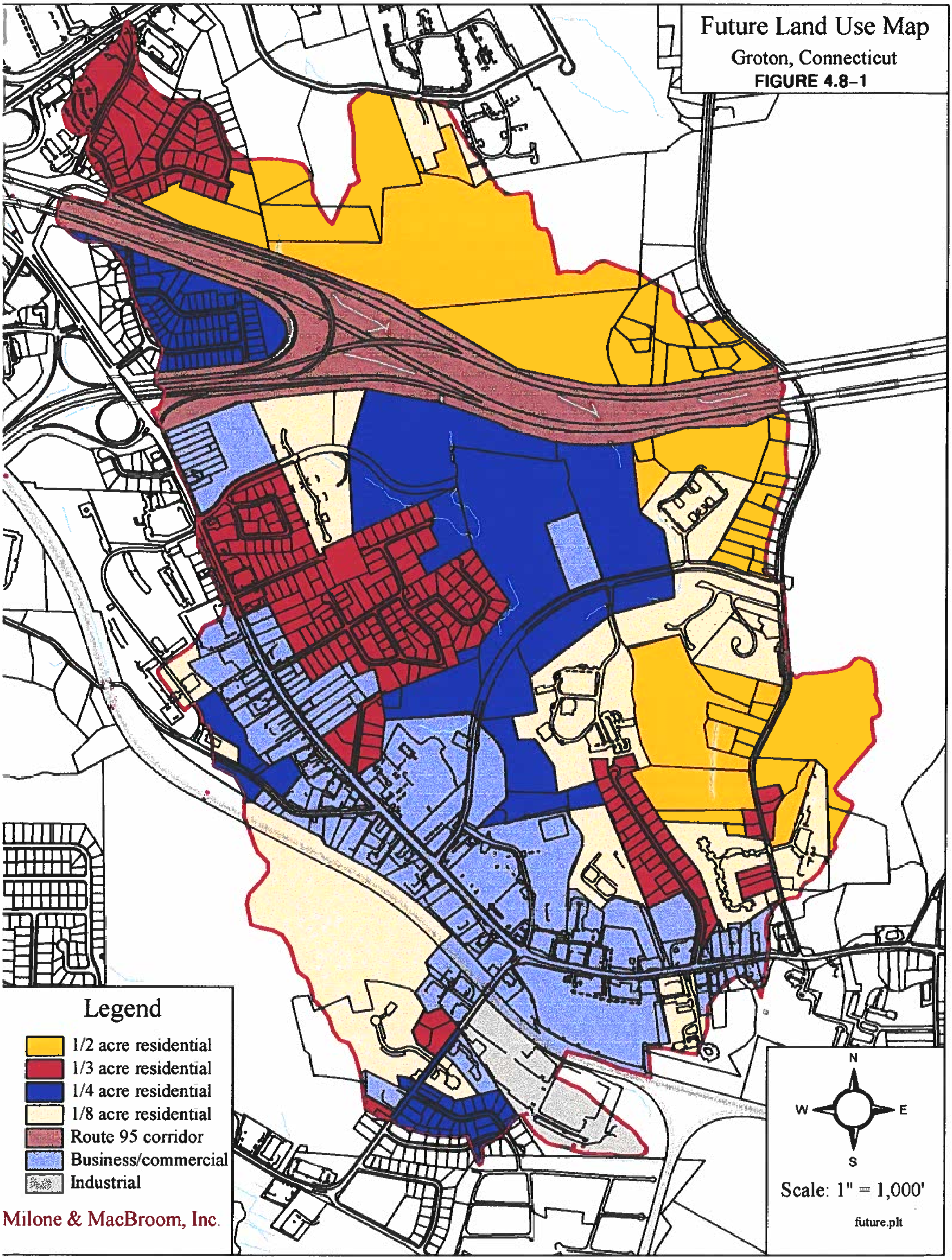
*As described in Table 6 of the 1986 FGA report.

Note: The management plans referenced above are described in the 1986 FGA report.

Following is a table of existing and potential future flows if the watershed management plan was not followed. The percent increase in flow at the outlet of each sub-basin has been calculated in the far right column of the table. The flows listed in this table were calculated with the TR-20 model and represent a 25-year design storm.

Table 4.8-2
Existing and Future Flows for a 25-Year Design Storm

Sub-Basin Number	*Existing Flow (cfs)*	*Future Flow Without Watershed Management Plan (cfs)*	*% Increase*
1	5	11	120%
2	45	52	16%
3	48	61	27%
4	138	158	15%
5	153	187	22%
6	11	20	82%
7	43	55	28%
8	165	227	38%
9	15	26	73%
10	6	13	117%
11	19	36	90%
12	10	16	60%
13	27	46	70%
14	100	128	28%
15	3	4	33%
16	7	12	71%
17	70	87	24%
18	68	80	18%
19	68	74	9%
20	206	256	24%
21	43	66	54%
22	63	78	24%
23	73	91	25%



Future Land Use Map
Groton, Connecticut
FIGURE 4.8-1
Legend
1/2 acre residential
1/3 acre residential
1/4 acre residential
1/8 acre residential
Route 95 corridor
Business/commercial
Industrial
Milone & MacBroom, Inc.
N
W
E
S
Scale: 1" = 1,000'
future.plt

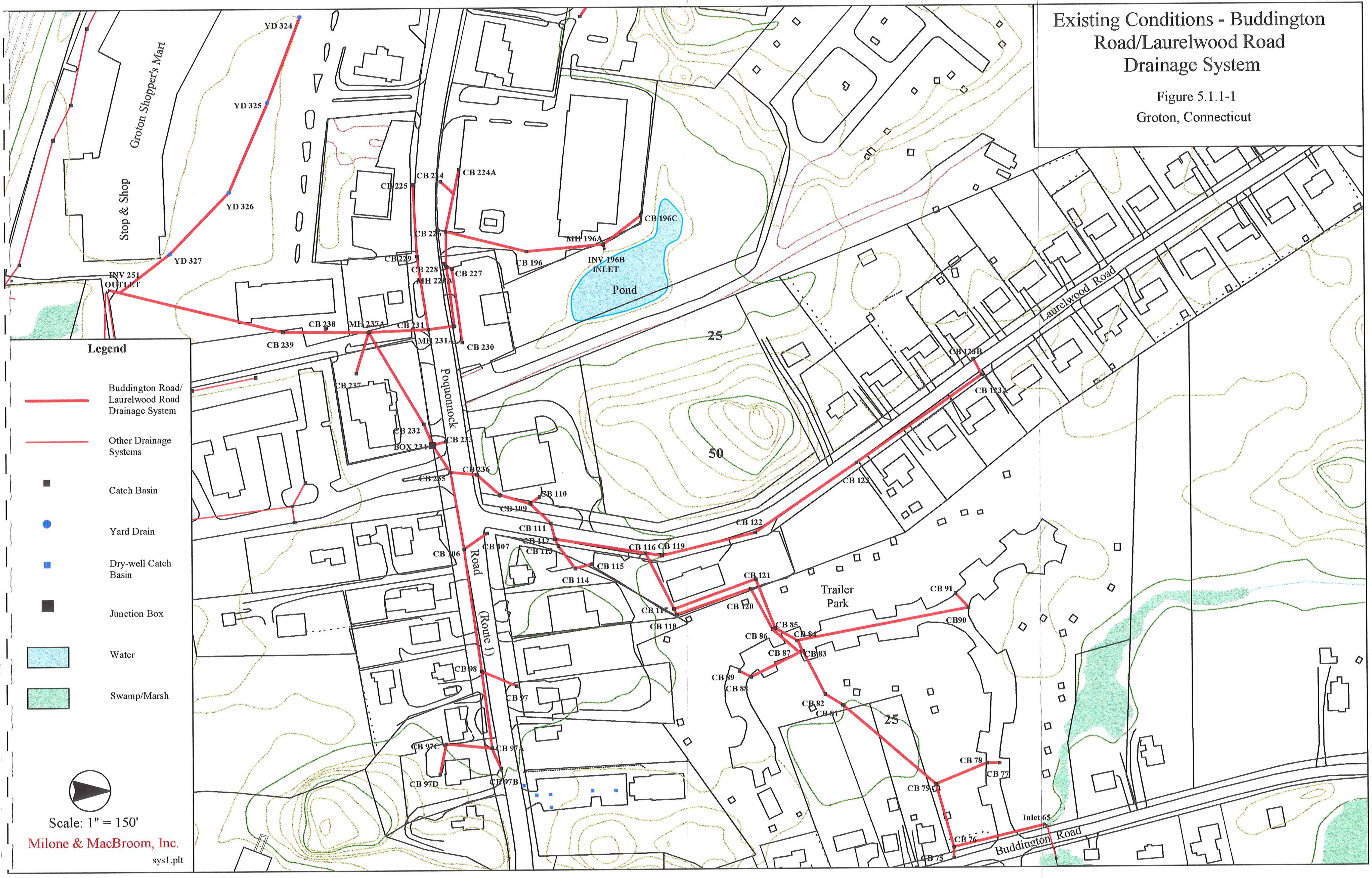
5.0 Hydraulics

5.1 Storm Drainage Systems

The southern portion of the Long Hill watershed was divided into five major stormwater drainage systems. Figure 5.1-1 delineates each drainage system. Each system is comprised of catch basins, manholes, and junction boxes, interconnected with drainage pipes. A hydraulic analysis of each of these systems was performed for this study. The five major drainage systems are described as follows:

5.1.1 **The Buddington Road/Laurelwood Road System** extends from Buddington Road to an outlet at the Groton Shopper's Mart (next to Stop & Shop) and collects drainage from the Buddington/Laurelwood Road areas, Route 1, as well as 0.09 square miles of the Long Hill watershed to the north. Figure 5.1.1-1 details this system. The Buddington Road/Laurelwood Road System is within sub-basin 17 and collects flows from subwatersheds 15 and 16. This system is old and has been repaired in a patchwork manner for many years. Sediment within catch basins and pipes is common due to the relatively flat topography and adverse slopes on several of the pipes within the system. Figure 5.1.1-2 shows a profile of the main trunk line of this system. Figures 5.1.1-3 and 5.1.1-4 provide profiles of lateral lines. Parallel pipe systems in the Briarcliff Mobile Home Park/Laurelwood Road area and along Route 1 have been installed in an attempt to increase system capacities.

5.1.2 **The Shopping Plaza System** extends from the northwestern corner of the Post Office shopping plaza to the southeastern corner of the Groton Shopper's Mart (Stop & Shop shopping plaza). This system collects drainage from both shopping plazas, Route 1, and 0.84 square miles of the Long Hill watershed to the north as well as an additional 0.14 square miles of watershed drainage to the west. Figure 5.1.2-1 details this system. Runoff enters the system by way of a stream near the Groton Post Office and the western drainage enters the system through a small wetland, near the intersection of Long Hill Road and Poquonnock Road. The Shopping Plaza System



Existing Conditions - Buddington Road/Laurelwood Road Drainage System

Figure 5.1.1-1

Groton, Connecticut

Long Hill Watershed Study - Buddington/Laurelwood Road System Trunk Line

Inv 65 to Inv 251

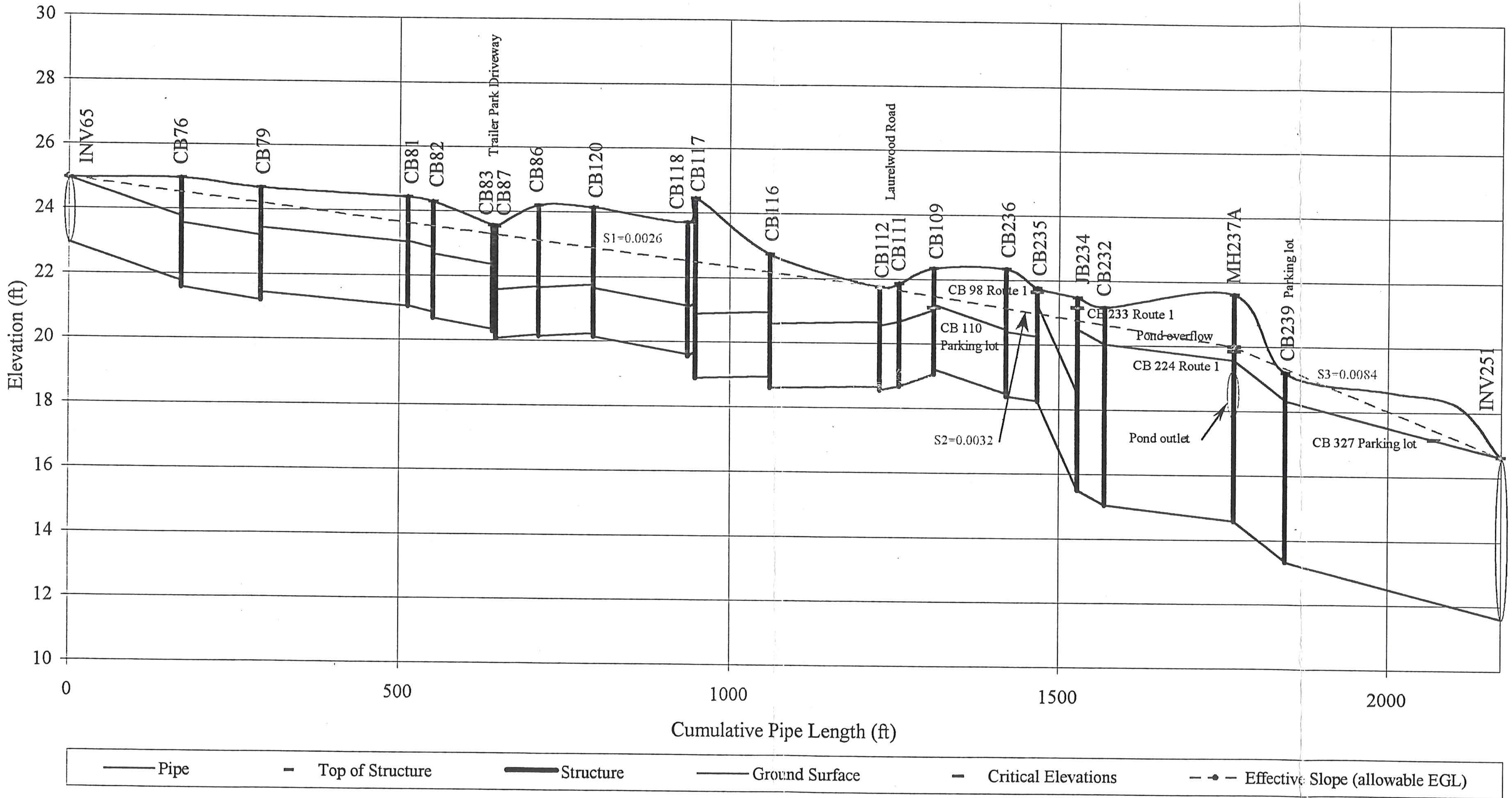


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FIGURE 5.1.1-2

Long Hill Watershed Study - Buddington/Laurelwood Road System
Inv196B to MH237A

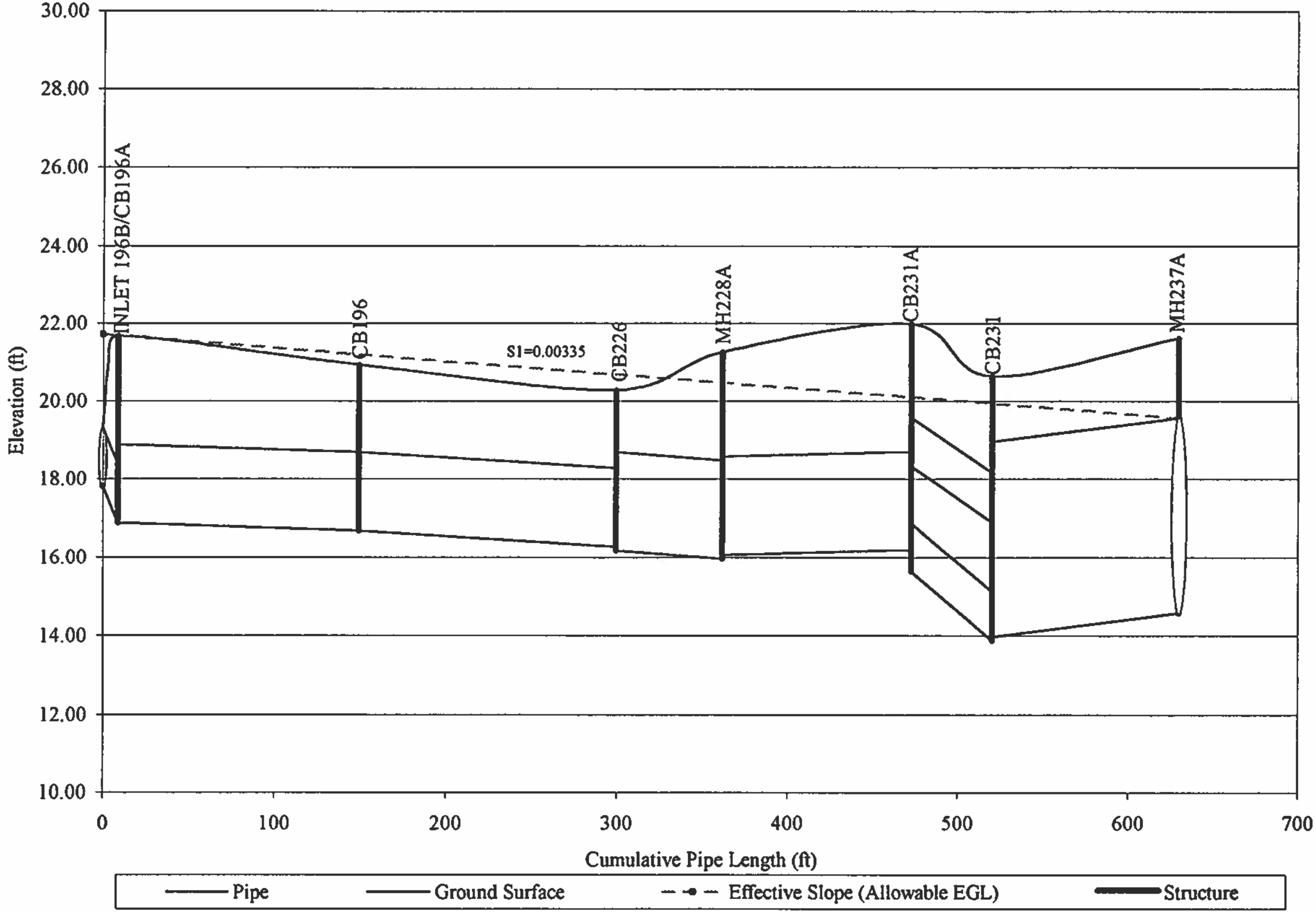

Figure 5.1.1-3

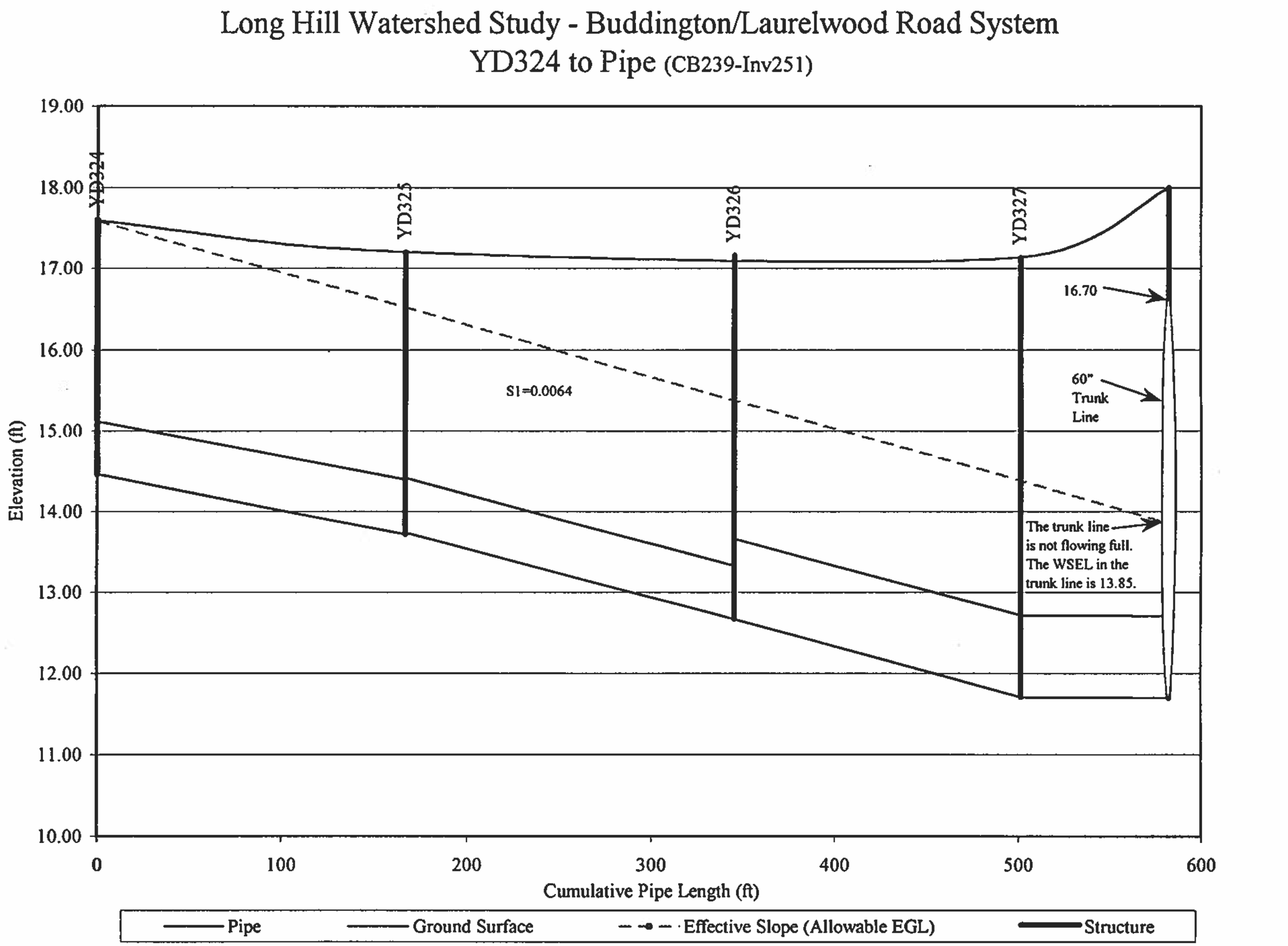

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Figure 5.1.1-4

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Pipe Calculations - Buddington/Laurelwood Road System

Long Hill Watershed Study - Groton, CT

25 year flows for trunk line taken from TR-20, 25 year flows for laterals taken from Rational Method (marked with *)

LINE SEGMENT	SEGMENT TYPE	SYSTEM Q (cfs)	PIPE SIZE (in)	PIPE (ft) LENGTH	Effective Slopes (allowable energy grade line) SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK	Actual Slopes SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK
Inlet65-CB76	I	7.00	24	171.2	0.0026	3.67	11.54	0.0130	WITHIN CAPACITY	0.0070	6.02	18.93	0.0130	WITHIN CAPACITY
CB76-CB79	C	8.50	24	119.2	0.0026	3.67	11.54	0.0130	WITHIN CAPACITY	0.0200	10.18	31.99	0.0130	WITHIN CAPACITY
CB79-CB81	C	10.60	24	222.5	0.0026	3.67	11.54	0.0130	WITHIN CAPACITY	0.0020	3.22	10.12	0.0130	INCREASE CAPACITY
CB81-CB82	C	14.10	24	38.0	0.0026	3.67	11.54	0.0130	INCREASE CAPACITY	0.0020	3.22	10.12	0.0130	INCREASE CAPACITY
CB82-CB83	C	17.70	24	88.2	0.0026	3.67	11.54	0.0130	INCREASE CAPACITY	0.0040	4.55	14.31	0.0130	INCREASE CAPACITY
CB83-CB87	C	9.50	36	4.8	0.0026	4.81	34.01	0.0130	WITHIN CAPACITY	0.0000	0.00	0.00	0.0130	INCREASE CAPACITY
CB87-CB86	C	10.60	18	65.6	0.0026	3.03	5.36	0.0130	INCREASE CAPACITY	-0.0040			0.0130	NEGATIVE SLOPE
CB86-CB120	C	12.38	18	83.7	0.0026	3.03	5.36	0.0130	INCREASE CAPACITY	0.0003	1.03	1.82	0.0130	INCREASE CAPACITY
CB120-CB118	C	14.15	18	142.6	0.0026	3.03	5.36	0.0130	INCREASE CAPACITY	0.0040	3.76	6.64	0.0130	INCREASE CAPACITY

SEGMENT	TYPE	Q (cfs)	SIZE (in)	LENGTH	(ft/ft)	(fps)	(cfs)	'n'	CHECK	(ft/ft)	(fps)	(cfs)	'n'	CHECK
CB118-CB117	C	15.95	18	11.6	0.0026	3.03	5.36	0.0130	INCREASE CAPACITY	-0.0290			0.0130	NEGATIVE SLOPE
CB83-CB84	C	9.50	24	21.8	0.0010	2.28	7.15	0.0130	INCREASE CAPACITY	0.0010	2.28	7.15	0.0130	INCREASE CAPACITY
CB90-CB84*	I	6.18	12	317.5	0.0077	3.98	3.13	0.0130	INCREASE CAPACITY	0.0077	3.99	3.13	0.0130	INCREASE CAPACITY
CB84-CB85	C	12.38	24	46.2	0.0026	3.67	11.54	0.0130	INCREASE CAPACITY	-0.0004			0.0130	NEGATIVE SLOPE
CB85-CB121	C	14.15	24	95.9	0.0026	3.67	11.54	0.0130	INCREASE CAPACITY	0.0050	5.09	16.00	0.0130	WITHIN CAPACITY
CB121-CB117	C	15.95	24	158.7	0.0026	3.67	11.54	0.0130	INCREASE CAPACITY	0.0010	2.28	7.15	0.0130	INCREASE CAPACITY
CB117-CB116	C	39.00	24	114.1	0.0026	3.67	11.54	0.0130	INCREASE CAPACITY	0.0080	6.44	20.23	0.0130	INCREASE CAPACITY
CB116-CB112	C	42.10	24	167.1	0.0026	3.67	11.54	0.0130	INCREASE CAPACITY	0.0000	0.00	0.00	0.0130	INCREASE CAPACITY
CB112-CB111	C	45.20	24	30.0	0.0032	4.07	12.80	0.0130	INCREASE CAPACITY	0.0010	2.28	7.15	0.0130	INCREASE CAPACITY
CB111-CB109	C	48.30	24	52.2	0.0032	4.07	12.80	0.0130	INCREASE CAPACITY	-0.0090			0.0130	NEGATIVE SLOPE
CB109-CB236	C	51.40	24	109.7	0.0032	4.07	12.80	0.0130	INCREASE CAPACITY	0.0070	6.02	18.93	0.0130	INCREASE CAPACITY

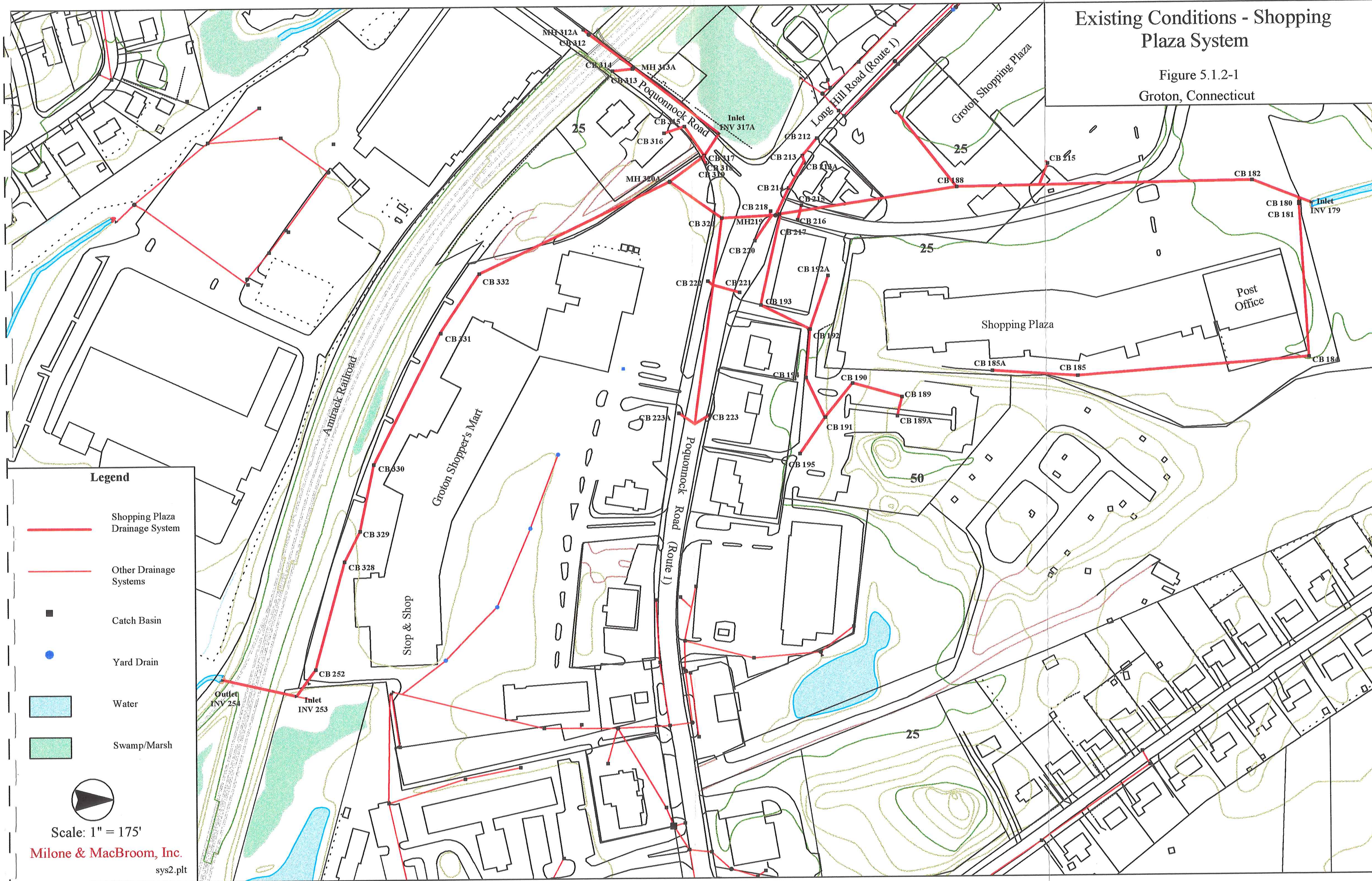
SEGMENT	TYPE	Q (cfs)	SIZE (in)	LENGTH	(ft/ft)	(fps)	(cfs)	'n'	CHECK	(ft/ft)	(fps)	(cfs)	'n'	CHECK
CB236-CB235	C	54.50	24	47.6	0.0032	4.07	12.80	0.0130	INCREASE CAPACITY	-0.0002			0.0130	NEGATIVE SLOPE
CB235-JB234	C	57.60	36	59.5	0.0032	5.34	37.73	0.0130	INCREASE CAPACITY	0.0320	16.88	119.31	0.0130	WITHIN CAPACITY
JB234-CB232	C	60.70	60	41.8	0.0032	7.50	147.33	0.0130	WITHIN CAPACITY	0.0320	23.73	465.89	0.0130	WITHIN CAPACITY
CB232-MH237A	C	63.80	60	195.4	0.0032	7.50	147.33	0.0130	WITHIN CAPACITY	0.0020	5.93	116.47	0.0130	WITHIN CAPACITY
Inlet196B-CB196A*	I	11.31	18	8.9	0.0052	4.29	7.57	0.0130	INCREASE CAPACITY	0.1040	19.17	33.88	0.0130	WITHIN CAPACITY
CB196A-CB196*	C	13.74	24	140.7	0.0052	5.19	16.31	0.0130	WITHIN CAPACITY	0.0010	2.28	7.15	0.0130	INCREASE CAPACITY
CB196-CB226*	C	15.32	24	150.2	0.0052	5.19	16.31	0.0130	WITHIN CAPACITY	0.0030	3.94	12.39	0.0130	INCREASE CAPACITY
CB226-MH228A*	C	20.63	30	62.5	0.0052	6.03	29.58	0.0130	WITHIN CAPACITY	0.0030	4.58	22.47	0.0130	WITHIN CAPACITY
MH228A-MH231A*	C	22.53	30	110.3	0.0052	6.03	29.58	0.0130	WITHIN CAPACITY	-0.0010			0.0130	NEGATIVE SLOPE
MH231A-CB231*	C	24.19	18	47.9	0.0052	3.10	21.88	0.0180	INCREASE CAPACITY	0.0370	8.26	58.37	0.0180	WITHIN CAPACITY
CB231-MH237A*	C	31.15	60	109.4	0.0052	9.56	187.81	0.0130	WITHIN CAPACITY	-0.0060			0.0130	NEGATIVE SLOPE

SEGMENT	TYPE	Q (cfs)	SIZE (in)	LENGTH	(ft/ft)	(fps)	(cfs)	'n'	CHECK	(ft/ft)	(fps)	(cfs)	'n'	CHECK
CB237A-CB239	C	66.90	60	79.0	0.0084	12.16	238.70	0.0130	WITHIN CAPACITY	0.0080	11.86	232.95	0.0130	WITHIN CAPACITY
CB239-Outlet251	C	70.00	60	325.5	0.0084	12.16	238.70	0.0130	WITHIN CAPACITY	0.0050	9.38	184.16	0.0130	WITHIN CAPACITY
YD324-YD325*	I	21.55	8	166.6	0.0064	2.77	0.97	0.0130	INCREASE CAPACITY	0.0040	2.19	0.76	0.0130	INCREASE CAPACITY
YD325-YD326*	C	33.43	8	178.7	0.0064	2.77	0.97	0.0130	INCREASE CAPACITY	0.0060	2.68	0.94	0.0130	INCREASE CAPACITY
YD326-YD327*	C	42.57	12	155.8	0.0064	3.64	2.86	0.0130	INCREASE CAPACITY	0.0060	3.51	2.76	0.0130	INCREASE CAPACITY
YD327-Pipe* (between CB239 & Out251)	C	51.89	12	81.3	0.0064	3.64	2.86	0.0130	INCREASE CAPACITY	0.0010	1.43	1.13	0.0130	INCREASE CAPACITY

is within sub-basin 20 and collects flows from subwatersheds 1 through 14 to the north and flows from subwatersheds 18 and 19 to the west.

The Shopping Plaza System consists primarily of one 48" inch RCP trunk line, as shown in Figure 5.1.2-2. Profiles of laterals are included as Figures 5.1.2-3 through 5.1.2-5. The storm drain has a mild gradient with slopes ranging from 0.01 ft/ft to adverse slopes. The mild slopes limit the flow capacity of this storm drain. The trunk line, therefore, does not always flow full during large rainfall events. The slope of the trunk line is controlled by the elevation of the incoming stream and its associated wetlands to the north, as well as the 90" culvert at the downstream crossing of the railroad tracks. Even under partially full conditions, the flow in the trunk line backwaters into the wetland connecting from the west. In addition, Poquonnock Road near the railroad bridge is prone to flooding due to backwater in the trunk line via low catch basin grates. Replacing this trunk line would be difficult and costly due to its length and location under two large parking lots and its crossing of Route 1. All efforts have been made in this study to look at alternative solutions for improving this system.

The outlet of the Shopping Plaza System is a culvert located under the railroad tracks behind Stop & Shop. This culvert accepts flow from the Buddington/Laurelwood Road System via the open channel north of the railroad culvert. The railroad culvert consists of a 90" concrete pipe with a 60" tapered inlet. Analysis of this culvert indicates the 60" inlet has sufficient capacity to handle the present and future flows of a 100-year storm from the Buddington/ Laurelwood Road System (as checked with Manning's Equation and the inlet control nomographs for circular concrete culverts). This 60" portion of the culvert has a capacity of 162 cfs when flowing full. Flows from all five systems are combined within the railroad culvert as the Shopping Plaza System (which has already acquired flows from the Meridian Street, Northern Long Hill Road and Southern Long Hill Road Systems) enters the 90" portion of the culvert from the west via a 48" pipe. The capacity of the 90" portion of the culvert was determined by Manning's Equation to be 478 cfs when flowing full, which demonstrates that the culvert is adequately sized to handle the flows from the 100-



Existing Conditions - Shopping Plaza System

Figure 5.1.2-1

Groton, Connecticut

Long Hill Watershed Study - Shopping Plaza System Trunk Line

Inv179 to RR Culvert

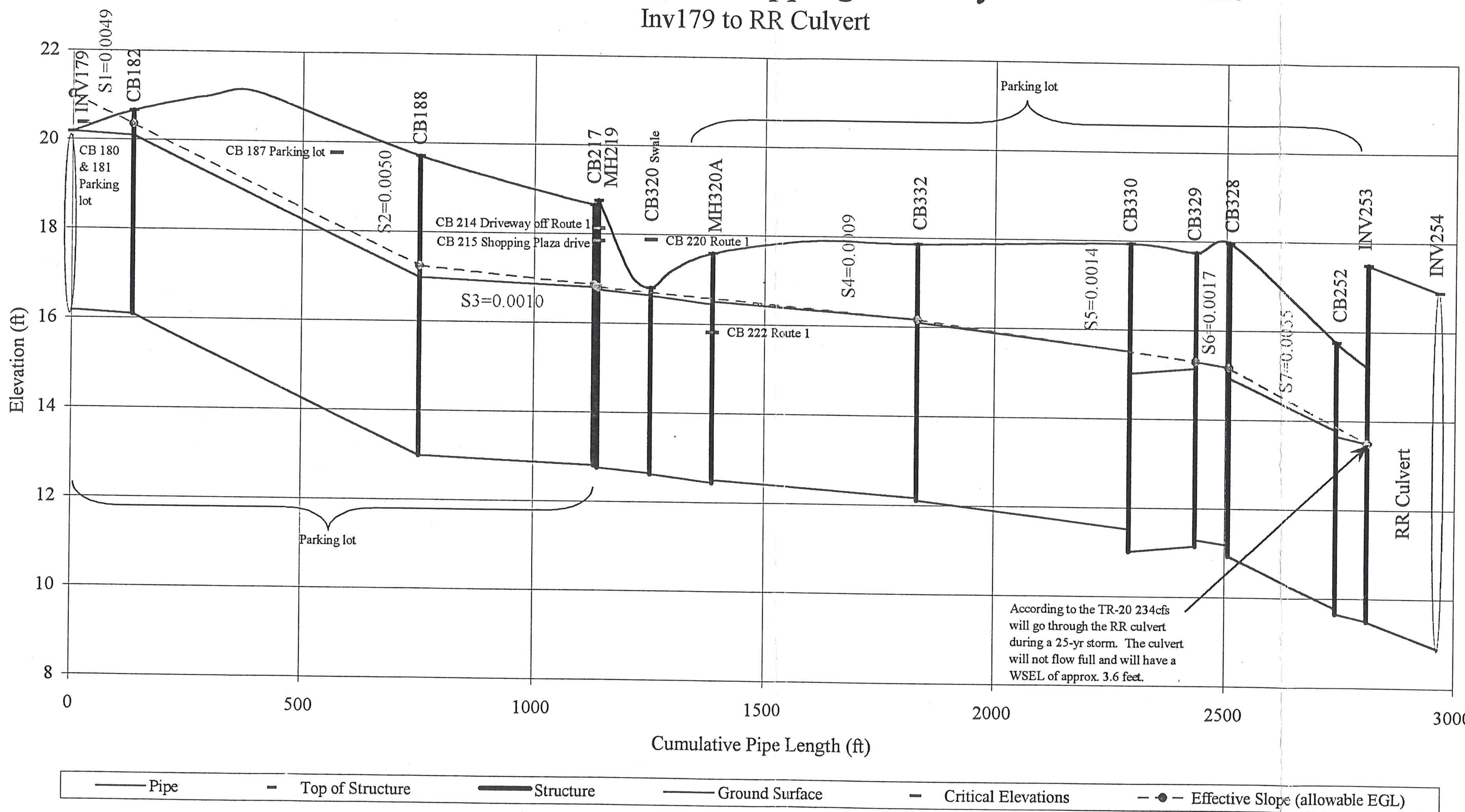


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FIGURE 5.1.2-2

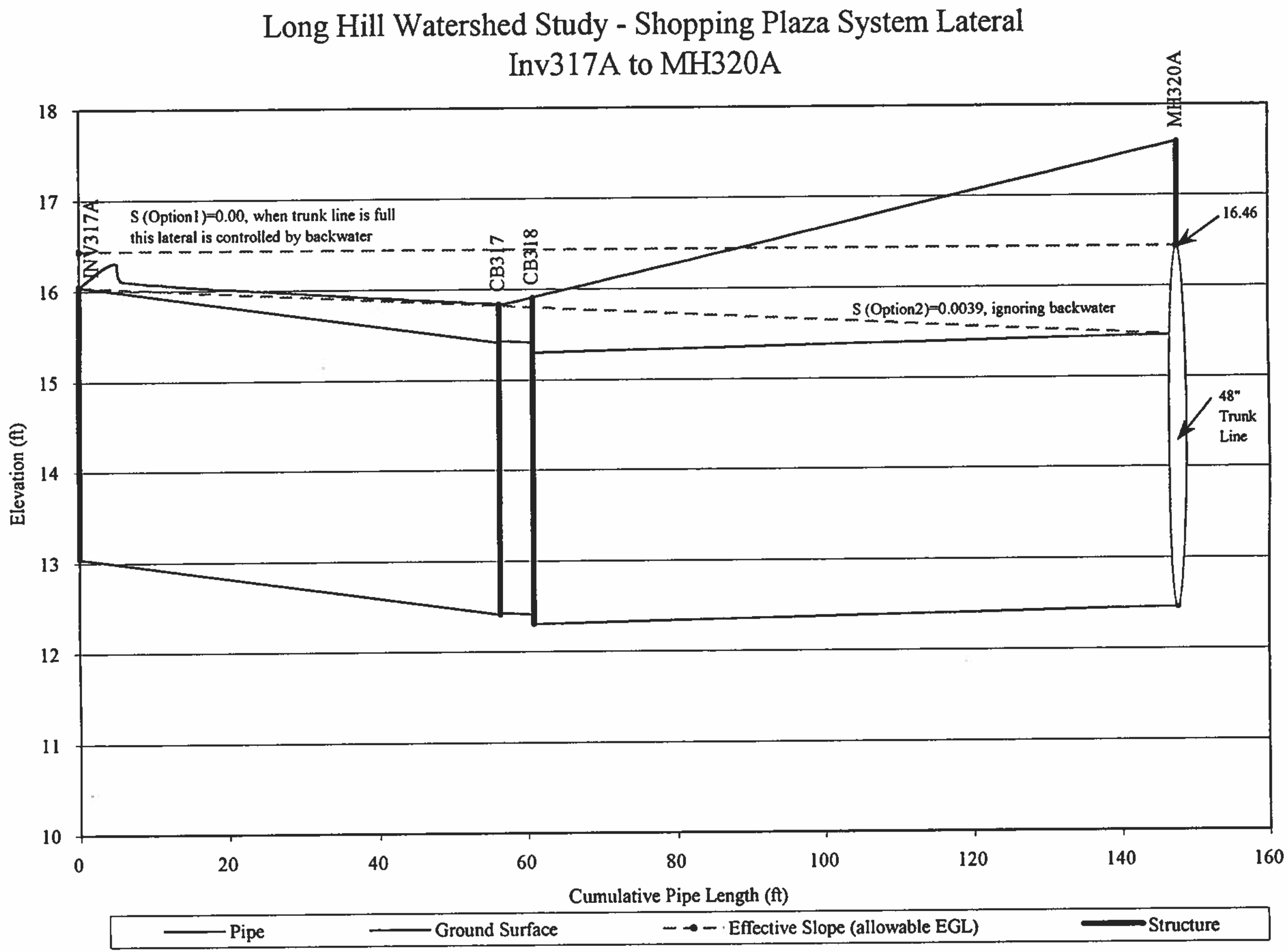

Figure 5.1.2-3

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Long Hill Watershed - Shopping Plaza System Lateral
CB185A to Pipe (Inv179-CB182)

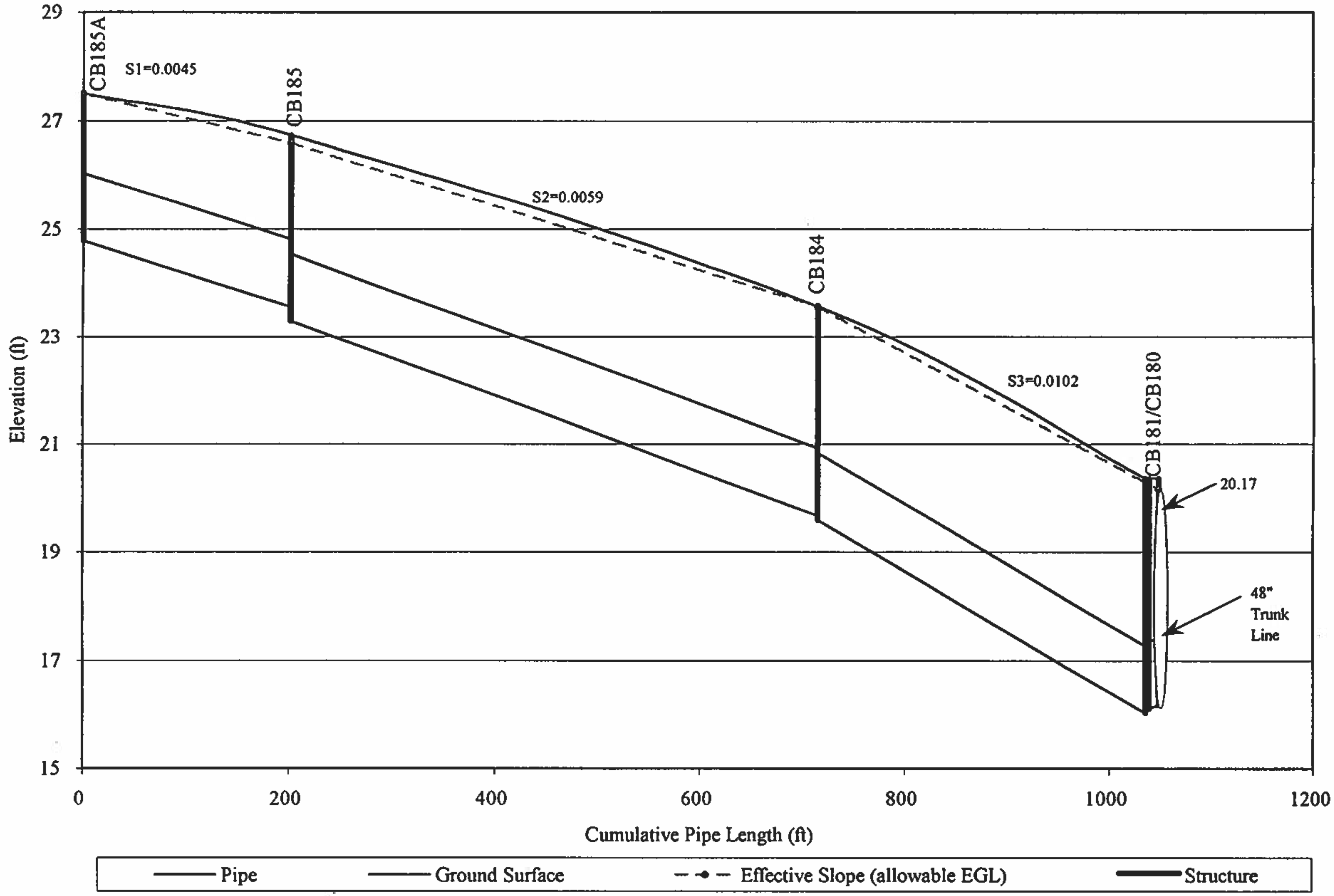

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Figure 5.1.2-4

Milone & MacBroom, Inc.

Long Hill Watershed Study - Shopping Plaza System Lateral
CB191 to Pipe (CB188-CB217)

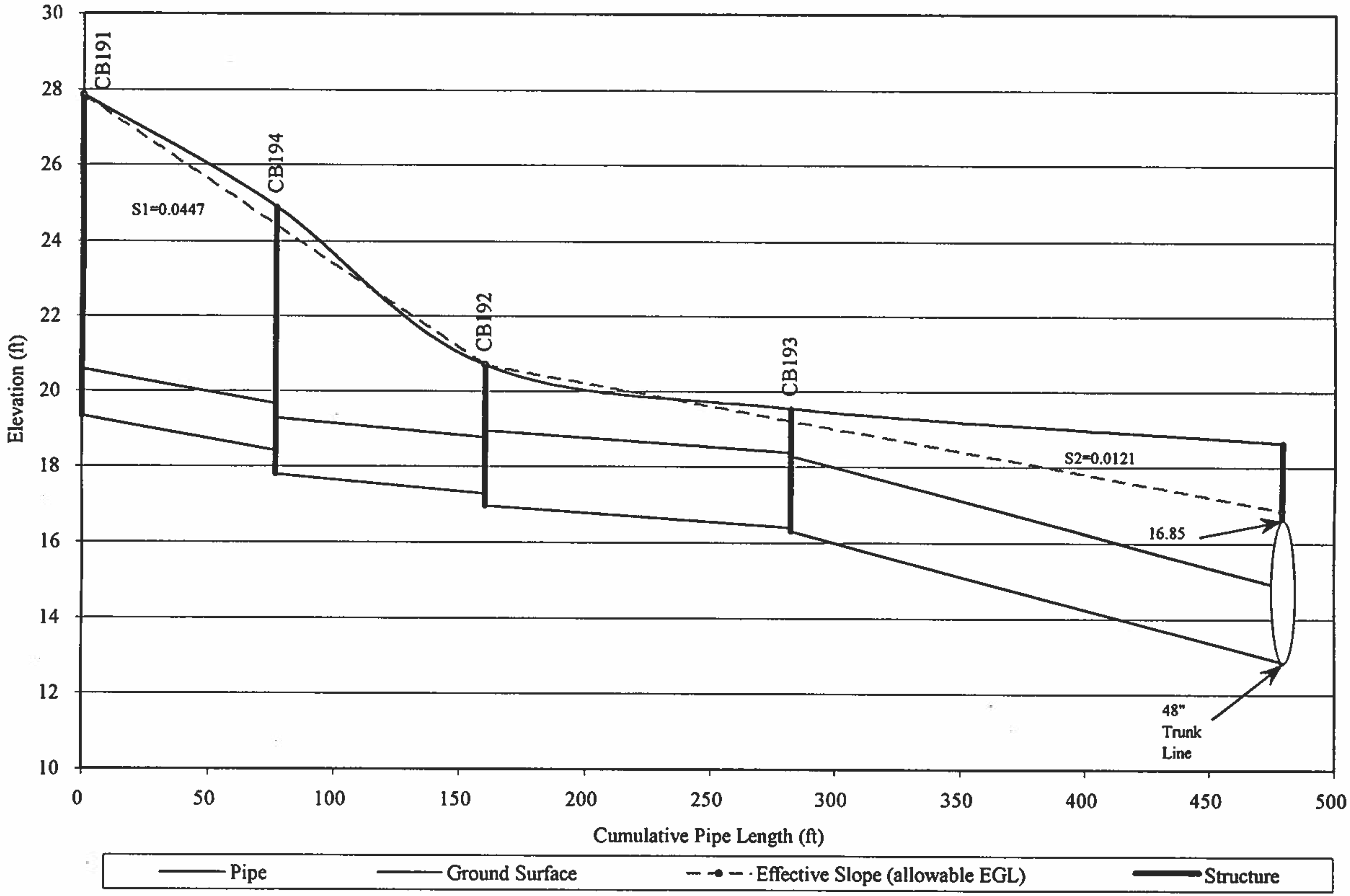

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Figure 5.1.2-5

Milone & MacBroom, Inc.

Pipe Calculations - Shopping Plaza System

Long Hill Watershed Study - Groton, CT

25 year flows for trunk line taken from TR-20, 25 year flows for laterals taken from Rational Method (marked with *)

					Effective Slopes(allowable energy grade line)					Actual Slopes				
LINE SEGMENT	SEGMENT TYPE	SYSTEM Q (cfs)	PIPE SIZE (in)	PIPE (ft) LENGTH	SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK	SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK
CB185A-CB185*	I	4.32	15	201.9	0.0045	3.53	4.33	0.0130	WITHIN CAPACITY	0.0060	4.08	5.00	0.0130	WITHIN CAPACITY
CB185-CB184*	C	8.28	15	513.4	0.0059	4.04	4.96	0.0130	INCREASE CAPACITY	0.0070	4.40	5.40	0.0130	INCREASE CAPACITY
CB184-CB181*	C	24.84	15	319.4	0.0102	5.32	6.53	0.0130	INCREASE CAPACITY	0.0010	1.66	2.04	0.0130	INCREASE CAPACITY
CB181-CB180*	C	25.72	15	3.8	0.0102	5.32	6.53	0.0130	INCREASE CAPACITY	-0.0210			0.0130	NEGATIVE SLOPE
CB180-Pipe* (INV179-CB182)	C	35.40	15	9.5	0.0102	5.32	6.53	0.0130	INCREASE CAPACITY	0.0000	0.00	0.00	0.0130	INCREASE CAPACITY
INV179-CB182	I	100.00	48	133.4	0.0049	8.00	100.55	0.0130	WITHIN CAPACITY	0.0010	3.61	45.42	0.0130	INCREASE CAPACITY
CB182-CB188	C	101.02	48	621.5	0.0050	8.08	101.57	0.0130	WITHIN CAPACITY	0.0053	8.32	104.57	0.0130	WITHIN CAPACITY
CB188-CB217	C	102.52	48	376.8	0.0010	3.61	45.42	0.0130	INCREASE CAPACITY	0.0005	2.56	32.12	0.0130	INCREASE CAPACITY
CB191-CB194*	I	10.76	15	76.8	0.0447	11.12	13.65	0.0130	WITHIN CAPACITY	0.0120	5.77	7.08	0.0130	INCREASE CAPACITY

SEGMENT	TYPE	Q (cfs)	SIZE (in)	LENGTH	(ft/ft)	(fps)	(cfs)	'n'	CHECK	(ft/ft)	(fps)	(cfs)	'n'	CHECK
CB194-CB192*	C	12.28	18	83.5	0.0447	12.56	22.20	0.0130	WITHIN CAPACITY	0.0060	4.60	8.14	0.0130	INCREASE CAPACITY
CB192-CB193*	C	16.41	24	122.1	0.0121	7.92	24.87	0.0130	WITHIN CAPACITY	0.0050	5.09	16.00	0.0130	INCREASE CAPACITY
CB193-Pipe (CB188-CB217)*	C	17.27	24	196.5	0.0121	7.92	24.87	0.0130	WITHIN CAPACITY	0.0120	7.89	24.78	0.0130	WITHIN CAPACITY
CB217-MH219	C	107.66	48	8.4	0.0057	8.63	108.45	0.0130	WITHIN CAPACITY	0.0120	12.52	157.35	0.0130	WITHIN CAPACITY
MH219-CB320	C	109.19	48	113.7	0.0009	3.48	43.73	0.0130	INCREASE CAPACITY	0.0010	3.61	45.42	0.0130	INCREASE CAPACITY
CB320-MH320A	C	110.77	48	133.8	0.0009	3.48	43.73	0.0130	INCREASE CAPACITY	0.0010	3.61	45.42	0.0130	INCREASE CAPACITY
INV317A-CB317	I	68.00	36	56.3	0.0039	5.91	41.80	0.0130	INCREASE CAPACITY	0.0110	9.90	69.95	0.0130	WITHIN CAPACITY
CB317-CB318	C	69.64	36	4.5	0.0039	5.91	41.80	0.0130	INCREASE CAPACITY	0.0040	5.97	42.18	0.0130	INCREASE CAPACITY
CB318-MH320A	C	70.54	36	86.9	0.0039	5.91	41.80	0.0130	INCREASE CAPACITY	-0.0020			0.0130	NEGATIVE SLOPE
MH320A-CB332	C	158.35	48	445.0	0.0009	3.48	43.73	0.0130	INCREASE CAPACITY	0.0010	3.61	45.42	0.0130	INCREASE CAPACITY
CB332-CB330	C	160.85	48	460.1	0.0014	4.34	54.57	0.0130	INCREASE CAPACITY	0.0010	3.61	45.42	0.0130	INCREASE CAPACITY

LINE SEGMENT	SEGMENT TYPE	SYSTEM Q (cfs)	PIPE SIZE (in)	PIPE (ft) LENGTH	SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK	SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK
CB330-CB329	C	161.20	48	142.9	0.0014	4.34	54.57	0.0130	INCREASE CAPACITY	-0.0009			0.0130	NEGATIVE SLOPE
CB329-CB328	C	161.93	48	72.6	0.0017	4.65	58.40	0.0130	INCREASE CAPACITY	0.0020	5.11	64.24	0.0130	INCREASE CAPACITY
CB328-CB252	C	163.02	48	234.8	0.0055	8.51	106.94	0.0130	INCREASE CAPACITY	0.0050	8.08	101.57	0.0130	INCREASE CAPACITY
CB252-Pipe (Inv253-Inv254)	C	164.00	48	68.3	0.0054	8.42	105.85	0.0130	INCREASE CAPACITY	0.0020	5.11	64.24	0.0130	INCREASE CAPACITY
Inv253-Inv254	I	234.00	90	155.0	0.00386	10.80	477.07	0.0130	WITHIN CAPACITY	0.004	10.99	485.64	0.0130	WITHIN CAPACITY

year storm event under all conditions modeled. The flows contributing to the railroad culvert are tabulated below.

Table 5.1.2-1
Flow Data for the Railroad Culvert

I. **Location**	***Storm Event***	***Flow (cfs)***		
		Existing Conditions	***Proposed Conditions***	***Future Conditions***
60" Inlet (north)*	25 yr.	70	68	87
	100 yr.	103	101	122
48" Pipe (west)**	25 yr.	164	197	116
	100 yr.	220	244	152
90" Outlet (south)	25 yr.	206	256	148
	100 yr.	294	337	201

* Flows from the Buddington/Laurelwood Road System.

** Flows from the Meridian Street, Northern Long Hill Road, Southern Long Hill Road, and Shopping Plaza Systems.

The depth of flow in the 60" pipe was determined for each condition. The water surface elevation in the culvert during the 25-year storm under present conditions is expected to be approximately 2.3 feet. Under future conditions, the water elevation in the culvert will be approximately 2.65 feet during the 25-year storm. Flow during the 100-year storm under future conditions will result in a water elevation of 3.25 feet in the culvert.

The 48" pipe from the Shopping Plaza System was determined to be undersized for the existing 25-year storm as previously discussed.

5.1.3 **The Southern Long Hill Road System** extends from Drozdyk Drive along Long Hill Road (Route 1) and discharges into the wetland at the intersection of Long Hill Road and Poquonnock Road as shown in Figure 5.1.3-1. The system collects

Existing Conditions - Southern Long Hill Road System

Figure 5.1.3-1

Groton, Connecticut

Long Hill Watershed Study - Southern Long Hill Road System Trunk Line

CB 370 to INV 211

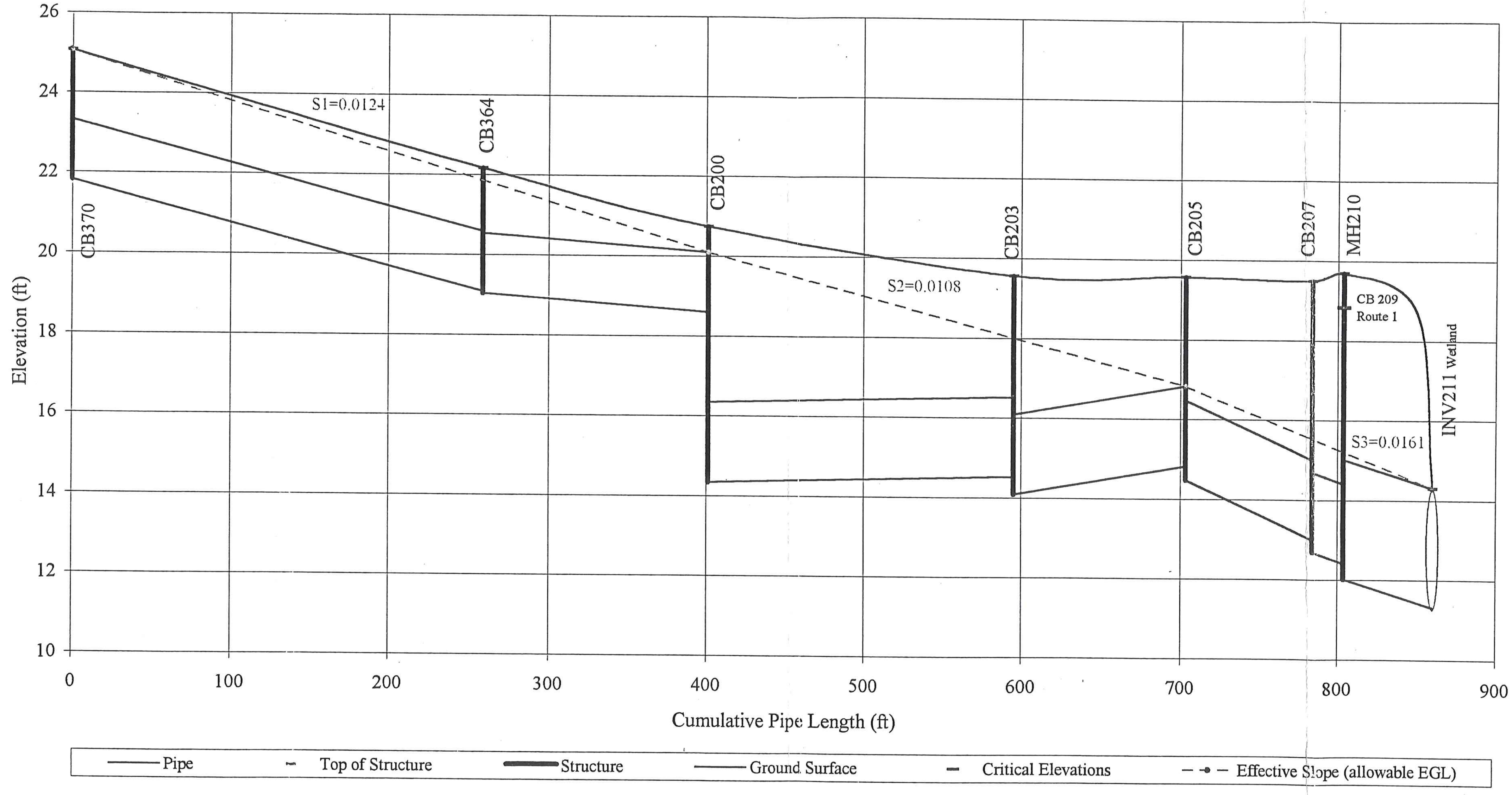

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FIGURE 5.1.3-2

Long Hill Watershed Study - Southern Long Hill Road System

CB374-CB200

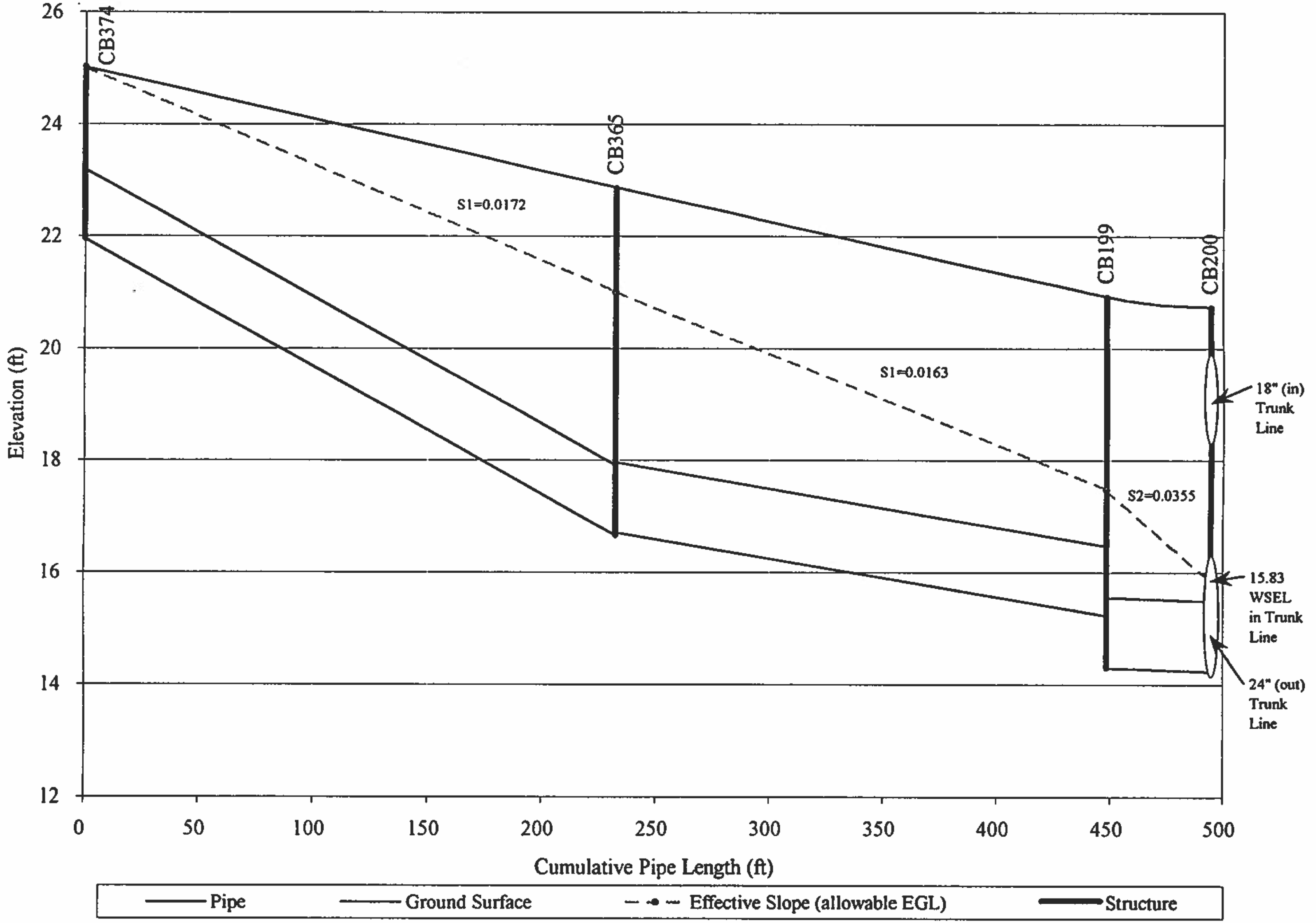

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Figure 5.1.3-3

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Long Hill Watershed Study - Southern Long Hill Road System

CB199A to MH210

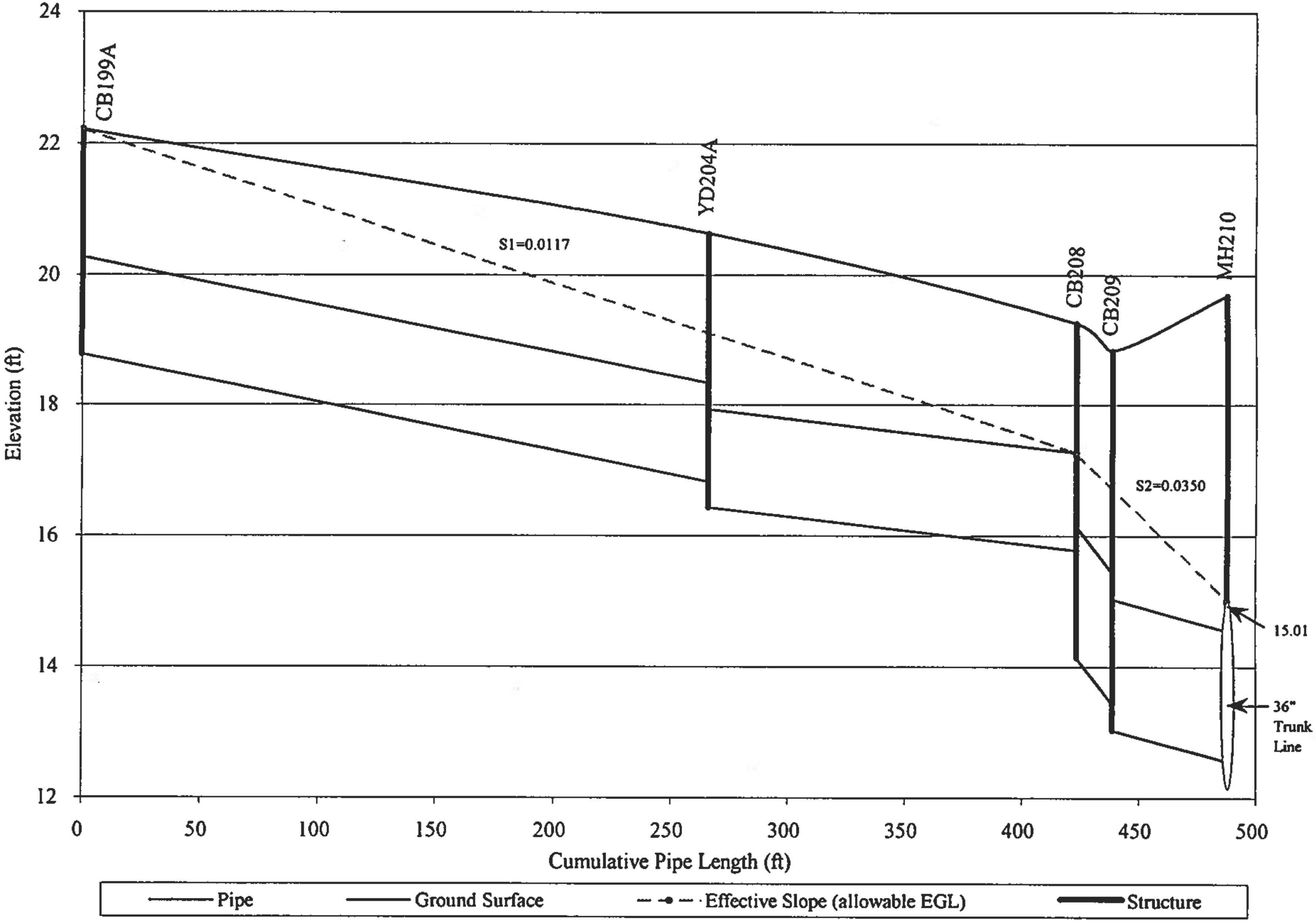

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Figure 5.1.3-4

Milone & MacBroom, Inc.

Pipe Calculations - Southern Long Hill Road System

Long Hill Watershed Study - Groton, CT

25 year flows for laterals taken from Rational Method

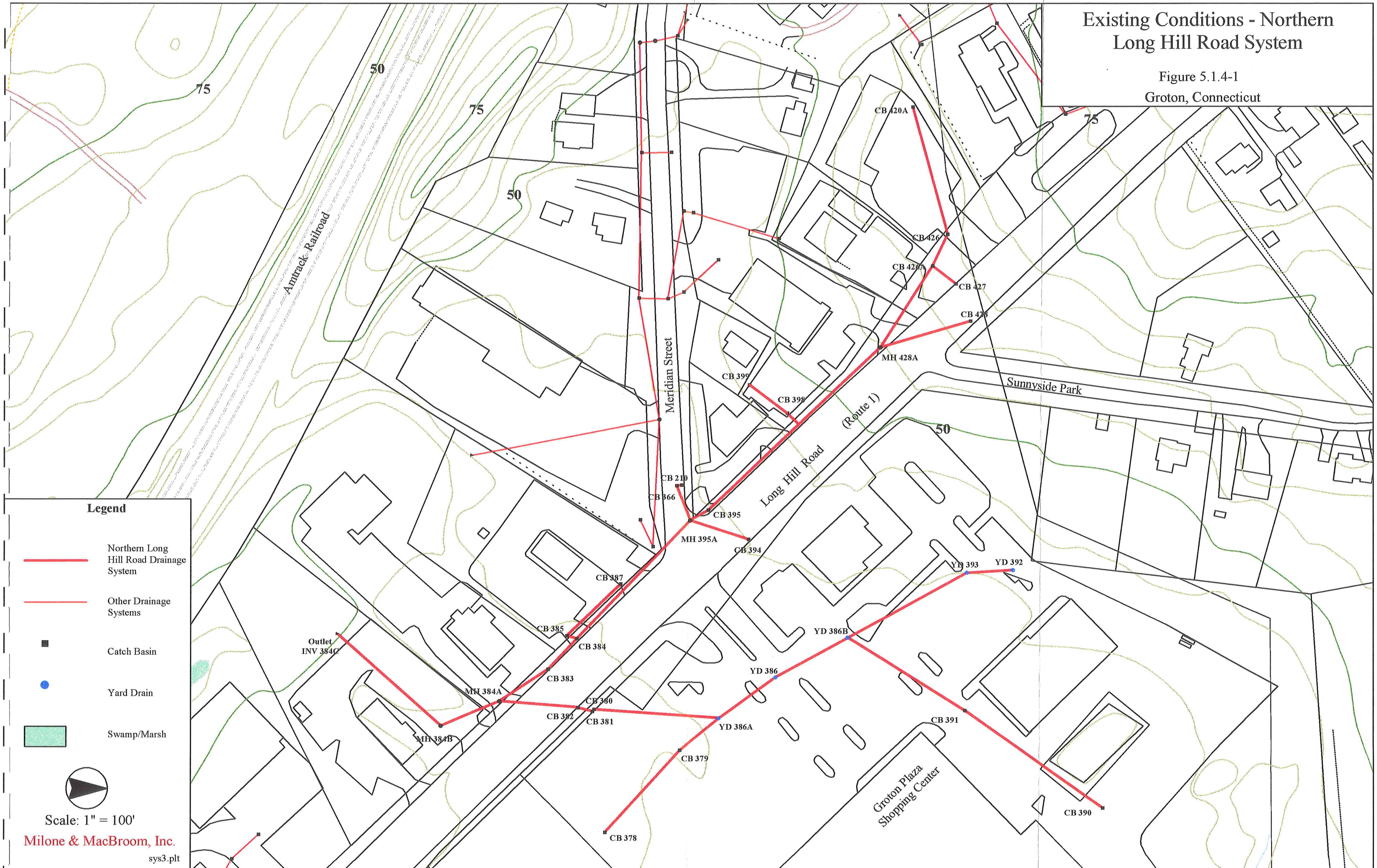
LINE SEGMENT	SEGMENT TYPE	SYSTEM Q (cfs)	PIPE SIZE (in)	PIPE (ft) LENGTH	Effective Slopes (allowable energy grade line) SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK	Actual Slopes SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNING 'n'	CAPACITY CHECK
CB370-CB364	I	3.67	18	259.0	0.0124	3.91	6.90	0.0220	WITHIN CAPACITY	0.0110	3.68	6.51	0.0220	WITHIN CAPACITY
CB364-CB200	C	6.64	18	142.3	0.0124	6.61	11.68	0.0130	WITHIN CAPACITY	0.0030	3.26	5.75	0.0130	INCREASE CAPACITY
CB374-CB365	I	8.45	15	232.5	0.0172	6.90	8.47	0.0130	WITHIN CAPACITY	0.0230	7.98	9.80	0.0130	WITHIN CAPACITY
CB365-CB199	C	12.67	15	215.9	0.0163	6.72	8.25	0.0130	INCREASE CAPACITY	0.0070	4.40	5.40	0.0130	INCREASE CAPACITY
CB199-CB200	C	13.30	15	46.5	0.0355	9.92	12.17	0.0130	INCREASE CAPACITY	0.0020	2.35	2.89	0.0130	INCREASE CAPACITY
CB200-CB203	C	21.24	24	194.0	0.0108	7.49	23.54	0.0130	WITHIN CAPACITY	-0.0010			0.0130	NEGATIVE SLOPE
CB203-CB205	C	22.57	24	108.1	0.0108	7.49	23.54	0.0130	WITHIN CAPACITY	-0.0070			0.0130	NEGATIVE SLOPE
CB205-CB207	C	25.36	24	80.7	0.0161	9.13	28.68	0.0130	WITHIN CAPACITY	0.0180	9.66	30.35	0.0130	WITHIN CAPACITY
CB207-MH210	C	26.80	24	19.9	0.0161	9.13	28.68	0.0130	WITHIN CAPACITY	0.0150	8.82	27.71	0.0130	WITHIN CAPACITY

LINE SEGMENT	SEGMENT TYPE	SYSTEM Q (cfs)	PIPE SIZE (in)	PIPE (ft) LENGTH	SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK	SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNING 'n'	CAPACITY CHECK
CB199A-CB204A	I	5.89	18	266.1	0.0117	6.42	11.35	0.0130	WITHIN CAPACITY	0.0070	4.97	8.79	0.0130	WITHIN CAPACITY
CB204A-CB208	C	9.92	18	157.1	0.0117	6.42	11.35	0.0130	WITHIN CAPACITY	0.0040	3.76	6.64	0.0130	INCREASE CAPACITY
CB208-CB209	C	12.25	24	15.4	0.0350	11.67	36.67	0.0150	WITHIN CAPACITY	0.0460	13.39	42.05	0.0150	WITHIN CAPACITY
CB209-MH210	C	13.85	24	49.2	0.0350	11.67	36.67	0.0150	WITHIN CAPACITY	0.0100	6.24	19.61	0.0150	WITHIN CAPACITY
MH210-INV211 (OUT)	C	40.41	36	56.2	0.0161	11.96	84.55	0.0130	WITHIN CAPACITY	0.0130	10.76	76.05	0.0130	WITHIN CAPACITY

drainage from the commercial areas along the southern portion of Long Hill Road, Route 1. The Southern Long Hill Road System is within the southeastern portion of sub-basin 19 and does not collect flows from any other subwatersheds. The upper portion of this system is difficult to follow. Several pipes extend out into the center of Route 1 from catch basins along the gutter line, but there is no visible manhole or catch basin within the road. It has been assumed for the purpose of this study that the pipes connect into a trunk line in the road which cannot be located because one or more manhole covers have been paved over. Two of the pipes in the trunk line have adverse slopes and, therefore, a tendency to collect sediments. Figure 5.1.3-2 provides a profile of the trunk line for this system. Figures 5.1.3-3 and 5.1.3-4 provide a profile of the laterals.

5.1.4 **The Northern Long Hill Road System** extends from parking lots just upstream of the Sunnyside Park/Route 1 intersection, along Long Hill Road (Route 1) to an outlet pipe exiting on the southwest side of Route 1. Figure 5.1.4-1 shows the location of this drainage system. The outlet pipe extends through a commercial lot located along Route 1, between Sunnyside Park and Drozdyk Drive. Stormwater flows are collected from the commercial areas along the northern portion of Long Hill Road. The Northern Long Hill Road System is within the northwestern portion of sub-basin 19 and does not collect flows from other subwatersheds. There is one pipe in the system with an adverse slope. This system transitions to a smaller pipe at its outlet, which creates a backup of flows in the system. A profile of the trunk line of this system is shown in Figure 5.1.4-2. The lateral system is shown in Figure 5.1.4-3.

5.1.5 **The Meridian Street System** extends approximately 1,300 feet along Meridian Street and collects stormwater drainage from the residential and commercial properties along Meridian Street as shown in Figure 5.1.5-1. The Meridian Street System is within sub-basin 18 and does not collect flows from other subwatersheds. No pipes with adverse slopes were found within the system as shown on the pipe profile of the trunk line (Figure 5.1.5-2). A small brook enters the system about midway along the trunk line. This brook was observed at the initiation of the project



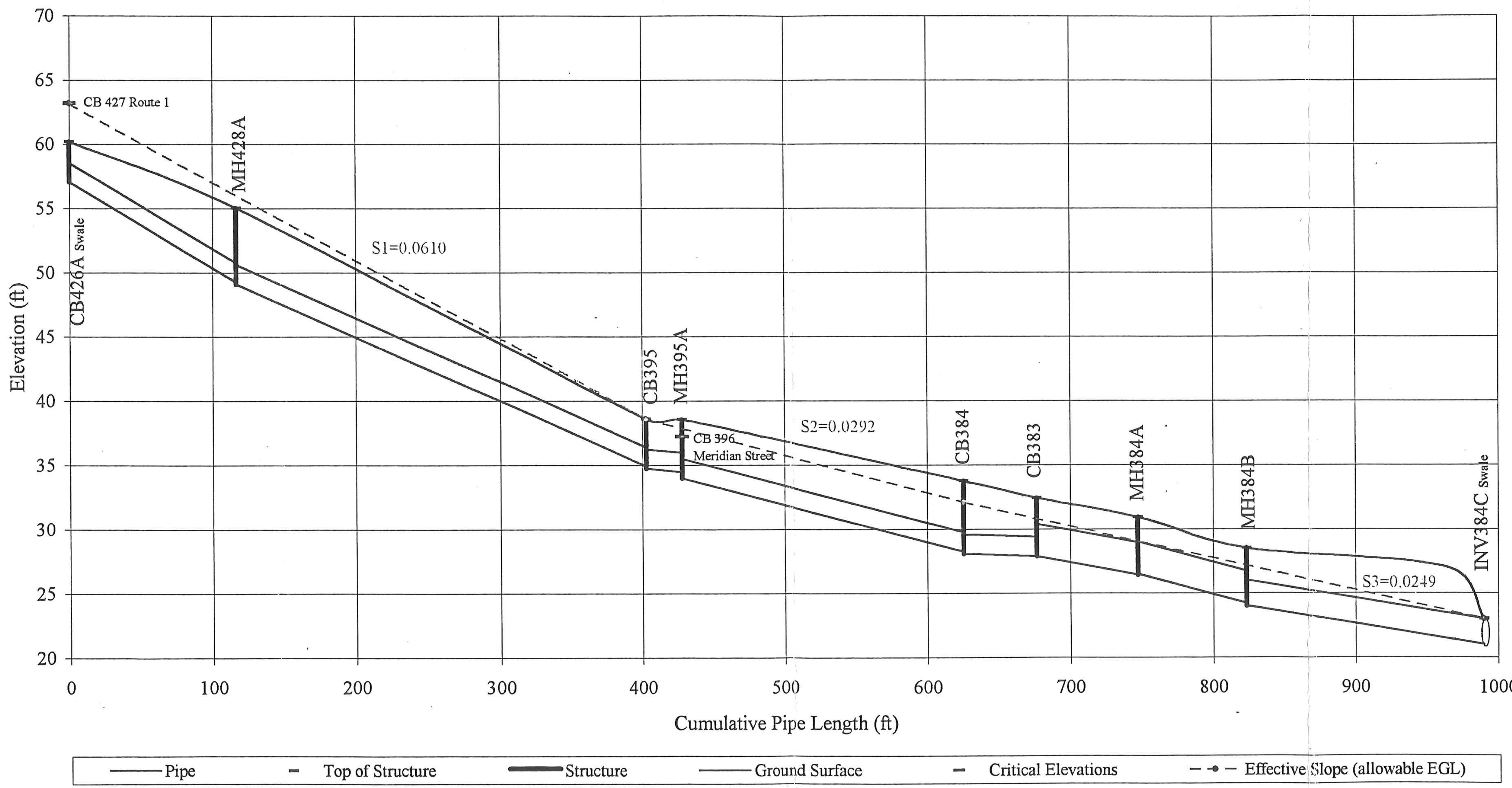
Existing Conditions - Northern Long Hill Road System

Figure 5.1.4-1

Groton, Connecticut

Long Hill Watershed Study - Northern Long Hill Road System Trunk Line

CB 426A to INV 384C



Milone & MacBroom, Inc.

FIGURE 5.1.4-2

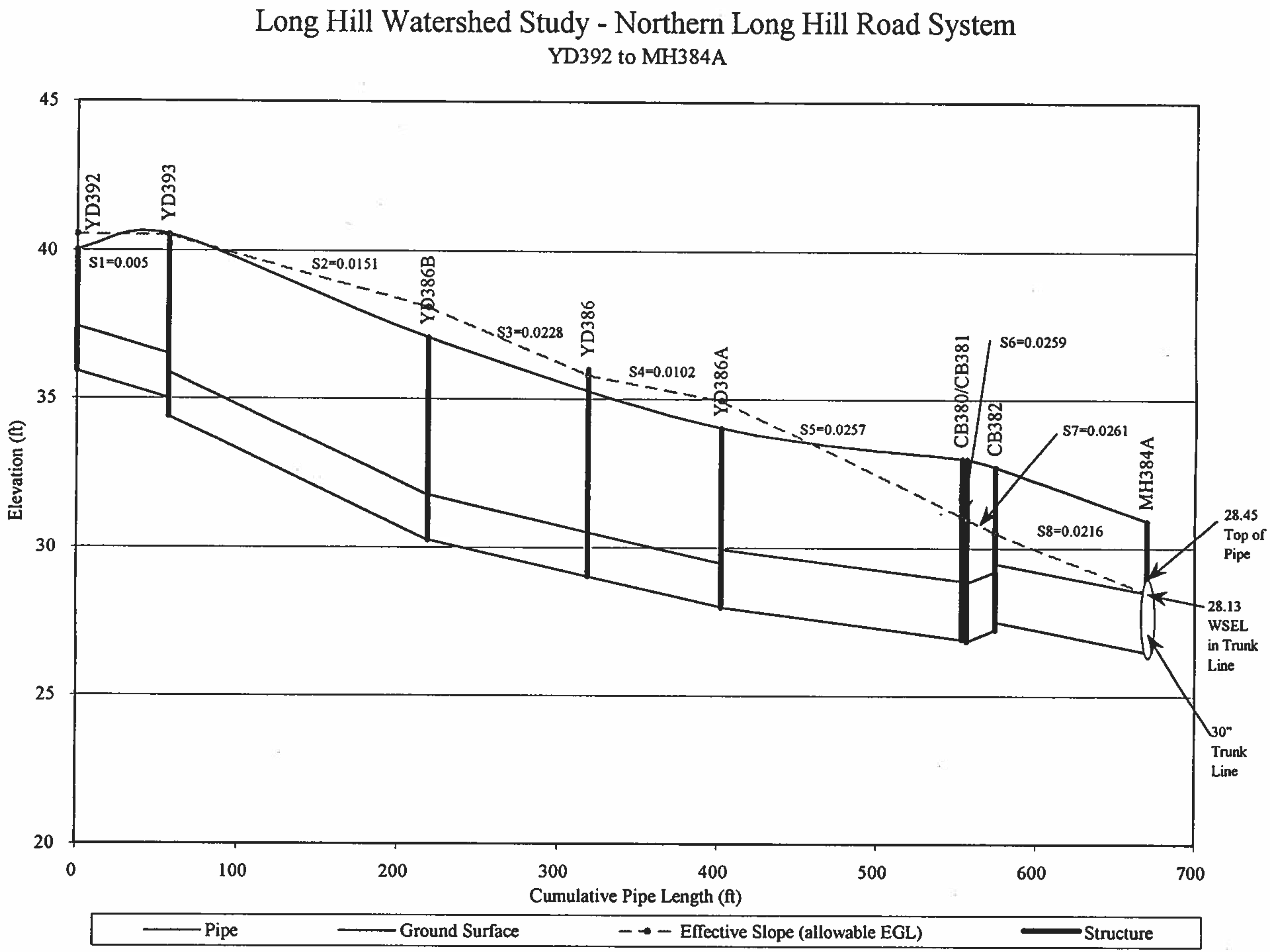


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Figure 5.1.4-3

Milone & MacBroom, Inc.

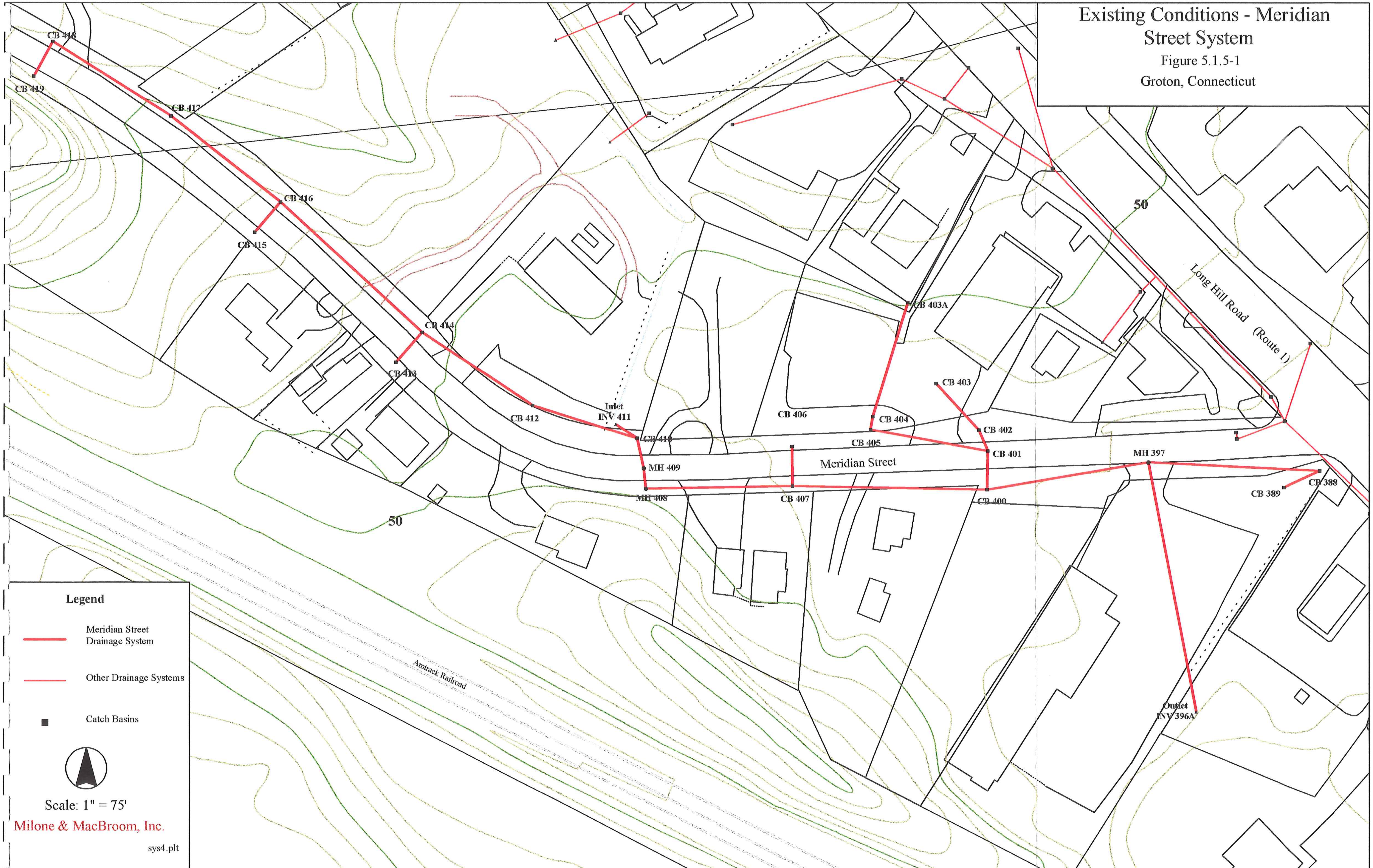
Pipe Calculations - Northern Long Hill Road System

Long Hill Watershed Study - Groton, CT

25 year flows taken from Rational Method

LINE SEGMENT	SEGMENT TYPE	SYSTEM Q (cfs)	PIPE SIZE (in)	PIPE (ft) LENGTH	Effective Slopes (allowable energy grade line) SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK	Actual Slopes SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK
C426A-MH428A	I	6.10	18	116.6	0.0610	8.68	15.33	0.0220	WITHIN CAPACITY	0.0670	9.09	16.07	0.0220	WITHIN CAPACITY
MH428A-CB395	C	9.03	18	286.2	0.0610	11.93	21.08	0.0160	WITHIN CAPACITY	0.0500	10.80	19.08	0.0160	WITHIN CAPACITY
CB395-MH395A	C	14.74	18	25.1	0.0292	10.16	17.95	0.0130	WITHIN CAPACITY	0.0110	6.23	11.02	0.0130	INCREASE CAPACITY
CB394-MH395A	I	10.91	18	74.0	0.0300	10.30	18.19	0.0130	WITHIN CAPACITY	0.0300	10.30	18.19	0.0130	WITHIN CAPACITY
MH395A-CB384	C	17.94	18	197.8	0.0292	10.16	17.95	0.0130	WITHIN CAPACITY	0.0292	10.16	17.95	0.0130	WITHIN CAPACITY
CB384-CB383	C	20.11	18	51.1	0.0249	9.38	16.57	0.0130	INCREASE CAPACITY	0.0040	3.76	6.64	0.0130	INCREASE CAPACITY
CB383-MH384A	C	20.40	24	70.6	0.0249	11.36	35.70	0.0130	WITHIN CAPACITY	0.0200	10.18	31.99	0.0130	WITHIN CAPACITY
YD392-YD393	I	2.08	18	56.7	0.0005	1.33	2.35	0.0130	WITHIN CAPACITY	0.0160	7.52	13.29	0.0130	WITHIN CAPACITY
YD393-YD386B	C	4.80	18	161.9	0.0151	7.31	12.92	0.0130	WITHIN CAPACITY	0.0260	9.58	16.94	0.0130	WITHIN CAPACITY

SEGMENT	TYPE	Q (cfs)	SIZE (in)	LENGTH	(ft/ft)	(fps)	(cfs)	'n'	CHECK	(ft/ft)	(fps)	(cfs)	'n'	CHECK
YD386B-YD386	C	15.85	18	100.0	0.0228	8.98	15.86	0.0130	WITHIN CAPACITY	0.0120	6.51	11.51	0.0130	INCREASE CAPACITY
YD386-YD386A	C	22.66	24	83.7	0.0102	7.27	22.85	0.0130	WITHIN CAPACITY	0.0120	7.89	24.78	0.0130	WITHIN CAPACITY
YD386A-CB380	C	36.24	24	151.2	0.0257	11.54	36.27	0.0130	WITHIN CAPACITY	0.0074	6.19	19.46	0.0130	INCREASE CAPACITY
CB380-CB381	C	36.32	24	3.2	0.0259	11.59	36.41	0.0130	WITHIN CAPACITY	0.0190	9.93	31.18	0.0130	INCREASE CAPACITY
CB381-CB382	C	36.52	24	17.7	0.0261	11.63	36.55	0.0130	WITHIN CAPACITY	-0.0220			0.0130	NEGATIVE SLOPE
CB382-MH384A	C	38.29	24	95.0	0.0216	10.59	33.27	0.0130	INCREASE CAPACITY	0.0110	7.55	23.73	0.0130	INCREASE CAPACITY
MH384A-MH384B	C	49.57	30	75.7	0.0249	13.18	64.72	0.0130	WITHIN CAPACITY	0.0239	12.92	63.41	0.0130	WITHIN CAPACITY
MH384B-INV384C	C	49.57	24	166.9	0.0249	6.71	21.09	0.0220	INCREASE CAPACITY	0.0239	6.58	20.67	0.0220	INCREASE CAPACITY



Existing Conditions - Meridian Street System

Figure 5.1.5-1

Groton, Connecticut

Long Hill Watershed Study - Meridian Street System Trunk Line

CB 418 to INV 396A

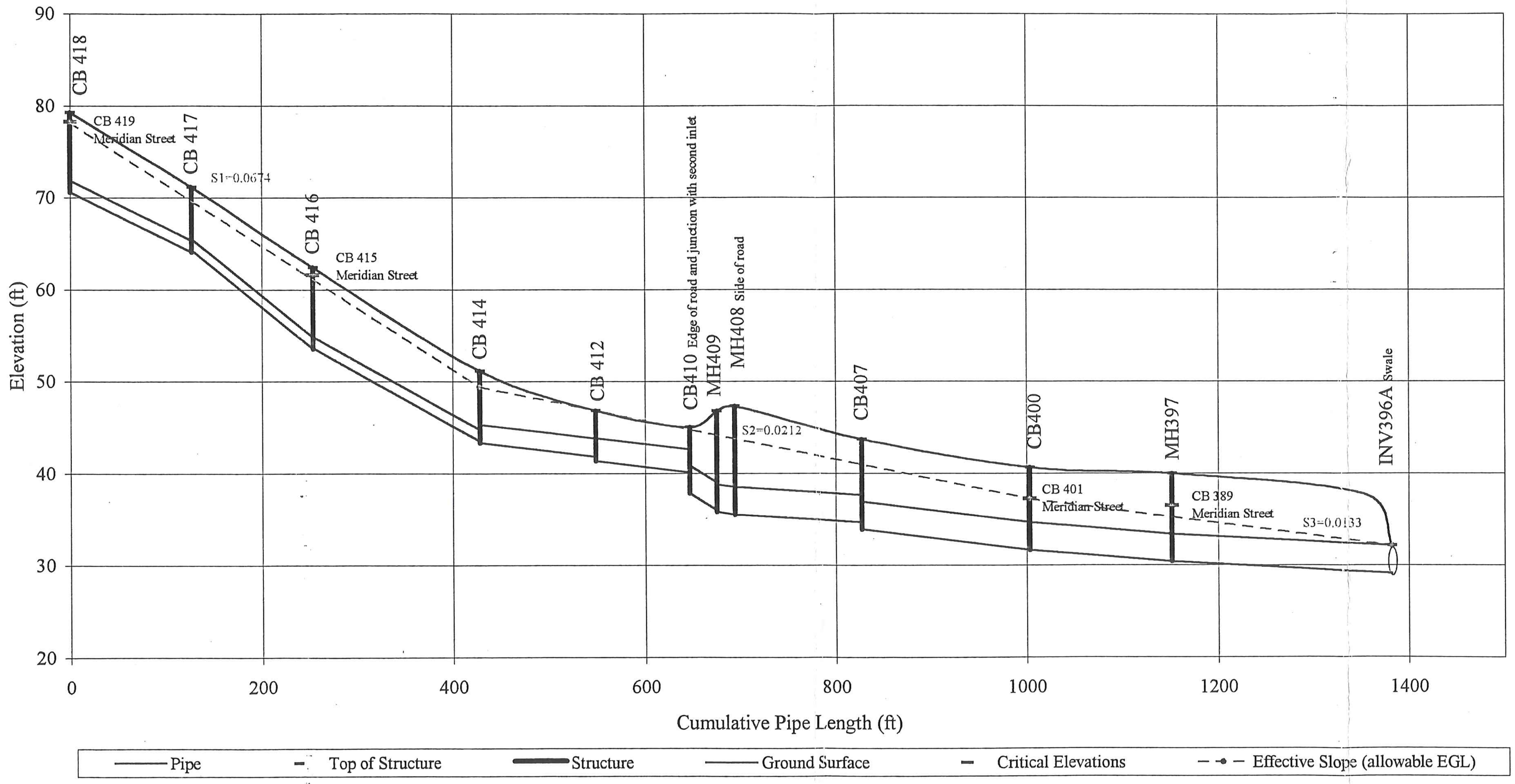


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FIGURE 5.1.5-2

Pipe Calculations - Meridian Street System

Long Hill Watershed Study - Groton, CT

25 year flows for trunk line taken from TR-20, 25 year flows for laterals taken from Rational Method (marked with *)

					Effective Slopes (allowable energy grade line)					Actual Slopes				
LINE SEGMENT	SEGMENT TYPE	SYSTEM Q (cfs)	PIPE SIZE (in)	PIPE (ft) LENGTH	SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK	SLOPE (ft/ft)	Vfull (fps)	Qfull (cfs)	MANNINGS 'n'	CAPACITY CHECK
CB418-CB417*	I	3.84	15	126.9	0.0674	13.67	16.77	0.0130	WITHIN CAPACITY	0.0511	11.90	14.60	0.0130	WITHIN CAPACITY
CB417-CB416*	C	5.00	15	126.7	0.0674	13.67	16.77	0.0130	WITHIN CAPACITY	0.0850	15.35	18.83	0.0130	WITHIN CAPACITY
CB416-CB414*	C	7.73	15	174.6	0.0674	13.67	16.77	0.0130	WITHIN CAPACITY	0.0579	12.67	15.54	0.0130	WITHIN CAPACITY
CB414-CB412*	C	9.77	24	119.6	0.0212	10.48	32.93	0.0130	WITHIN CAPACITY	0.0130	8.21	25.79	0.0130	WITHIN CAPACITY
CB412-CB410*	C	11.41	24	99.5	0.0212	10.48	32.93	0.0130	WITHIN CAPACITY	0.0124	8.02	25.19	0.0130	WITHIN CAPACITY
CB410-MH409*	C	53.78	36	28.0	0.0212	13.73	97.08	0.0130	WITHIN CAPACITY	0.0500	21.10	149.14	0.0130	WITHIN CAPACITY
MH409-MH408*	C	53.78	36	18.6	0.0212	13.73	97.08	0.0130	WITHIN CAPACITY	0.0151	11.58	81.82	0.0130	WITHIN CAPACITY
MH408-CB407*	C	57.02	36	133.4	0.0212	13.73	97.08	0.0130	WITHIN CAPACITY	0.0070	7.89	55.80	0.0130	INCREASE CAPACITY
CB407-CB400*	C	59.03	36	176.0	0.0212	13.73	97.08	0.0130	WITHIN CAPACITY	0.0130	10.76	76.05	0.0130	WITHIN CAPACITY
CB400-MH397*	C	63.34	36	148.8	0.0133	10.89	77.01	0.0130	WITHIN CAPACITY	0.0090	8.95	63.28	0.0130	INCREASE CAPACITY
MH397-INV396A (OUT)	C	68.00	36	230.0	0.0133	10.89	77.01	0.0130	WITHIN CAPACITY	0.0053	6.87	48.56	0.0130	INCREASE CAPACITY

to be heavily overgrown with a poorly defined channel. The brook takes a sharp bend as it exits from behind some commercial properties along Route 1 and heads toward the Meridian Street System. According to Town reports, this small brook will sometimes jump out of its banks at this bend and create a nuisance overland flow condition. The brook was upgraded during recent construction activities at the Charter Oak Credit Union located to the south of the brook. During construction activities, some debris and brush were removed from this brook. A berm was created to buffer the parking lot from overland flow. However, a low point remains in the vicinity of the bend that will likely allow water to continue to flow into the parking lot during storm events. Additionally, the condition of the channel upstream of the bank property was not improved and still contains a large amount of debris and brush.

5.2 Hydraulic Analysis Methodology

Both TR-20 and Rational Method flows were used during the hydraulic analysis of the major drainage systems in the southern portion of the Long Hill watershed. Flows calculated with the more detailed TR-20 analysis were used to analyze the trunk lines of the major drainage systems. Flows calculated with the Rational Method were used to analyze the smaller lateral lines connecting into the major trunk lines. A storm event with an average return frequency of 25 years was used to determine the peak design flows, for both the lateral and trunk lines, as outlined in the Town of Groton Road & Drainage Construction Standards. This is a relatively high standard for storm drains. The TR-20 and Rational Method flows used in hydraulic analysis are listed in Tables 5.2-1 through 5.2-5. The TR-20 model and the Rational Method calculations have been included in Appendix A of this study.

Storm drain capacities were calculated with Manning's equation. The input variables for Manning's equation include pipe length, size, slope, and roughness coefficient. Initial computations, utilizing actual pipe slopes, revealed that many of the pipes in the five major drainage systems were undersized when flowing "just full," even though few complaints are on file.

The profiles of key storm drains were plotted to facilitate a review of effective and allowable energy grade lines. Several of the storm drains have irregular profiles, combining pipes with steep slopes next to pipes with flat or even negative slopes. In addition, some storm drains do not have inverts or crowns that line up from one pipe to the next at catch basins or manholes. Therefore, determining the flow capacity of each segment, based upon its individual slope, results in misleading results.

The effective slopes (allowable energy grade lines) were then determined along all of the trunk lines and critical lateral lines to determine the maximum allowable pipe capacities with surcharges. Critical elevations were located by determining the water surface elevation that could be tolerated under backwater conditions in the pipes. These critical elevations depended on location, site topography, and top of structure elevations. These elevations were then used as a guide to help determine maximum allowable pipe capacities. This analysis is graphically shown on the pipe profiles that have been included in this study. Effective and actual pipe slopes along with critical elevations are shown on the pipe profiles. Shallow, short duration ponding of water was allowed in parking lot areas to maximize the existing pipe capacity. This reduced the need to replace many of the pipes that were shown to be undersized in the initial hydraulic computations. Proposed pipe sizes were calculated using Manning's equation and have been included in this study on Tables 5.2-1 to 5.2-5.

6.0 Findings

The following is a summary of findings of hydraulic conditions at each drainage system. The analysis and findings are based on flows for the existing 25-year storm. It is assumed that all future development within the watershed will be required to demonstrate "zero increase" in runoff via on-site detention. "Zero increase" requirements for future development will reduce the flow through the southern portion of the system and minimize the pipes which will need to be replaced and/or upgraded.

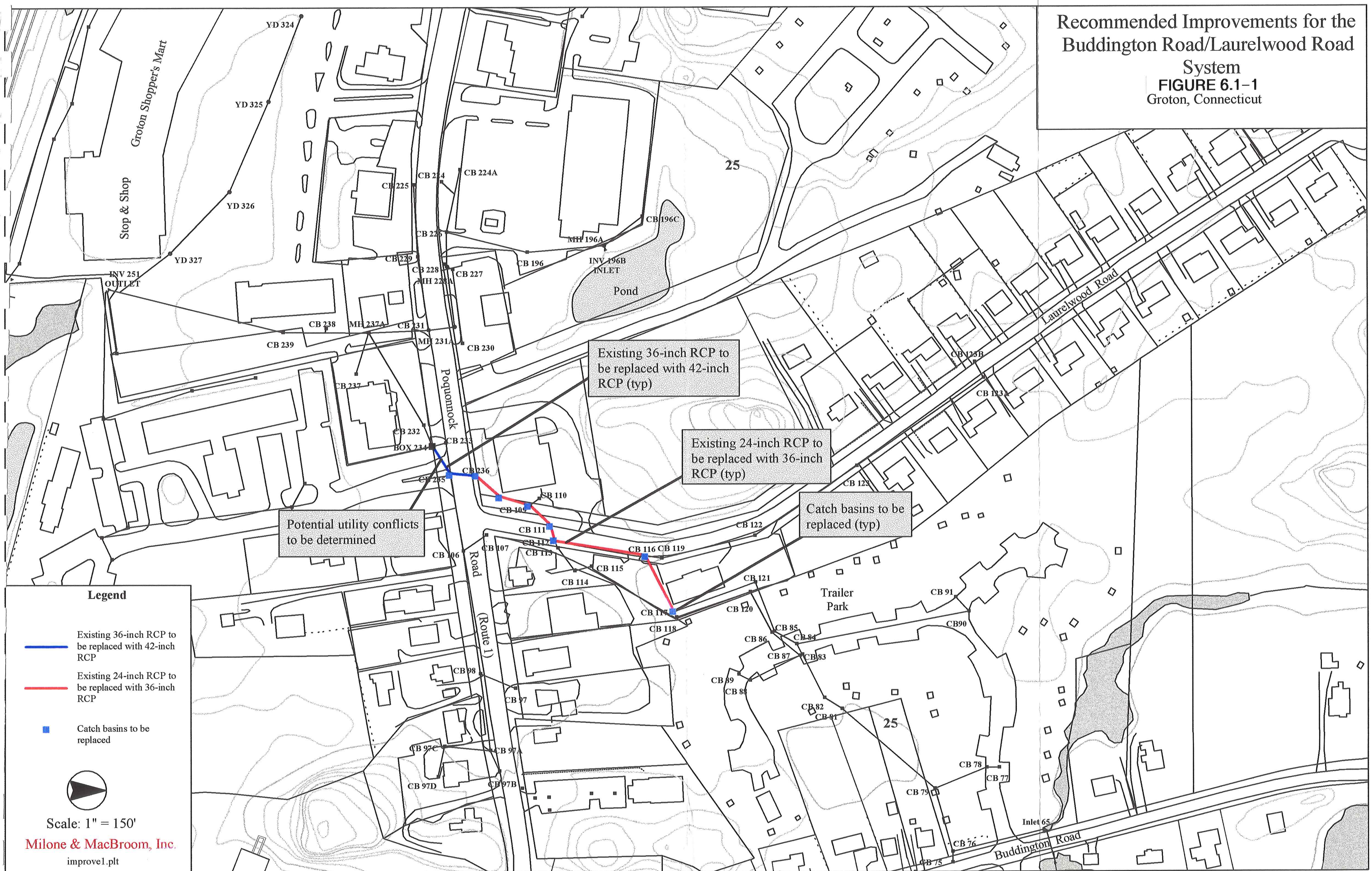
6.1 The Buddington Road/Laurelwood Road System

Many of the pipes in the Buddington Road/Laurelwood Road System were found to be undersized for the 25-year frequency storm event. Flows calculated with TR-20 were used to check the capacity of the trunk line from Inlet 65 to the outlet at INV251. The capacity of the lateral lines was checked with flows calculated with the Rational Method. The following is a list of problem areas along with potential solutions for the Buddington Road/Laurelwood Road System. These areas are highlighted in Figure 6.1-1.

Trunk Line CB81 to JB234 – Briarcliff Mobile Home Park to Laurelwood Road

Approximately 1,000 linear feet of pipe, starting at the Briarcliff mobile home park (CB81) and extending down Laurelwood Road and across Route 1 (JB234), does not have the capacity to handle design flows. The drainage system in this area is old and has been connected in a "patch work" fashion. The pipe profile is very flat and several of the pipes have adverse slopes, as seen previously in Figure 5.1.1-2. The capacity of the system through the mobile home park was previously increased by installing a parallel pipe system. Even with this parallel pipe, the system is still undersized. This section of the Buddington Road/ Laurelwood Road System is a trunk line and receives flow from a portion of the Long Hill watershed to the north.

Additional detention in the wetlands to the north of this system would help to reduce flows to the trunk line. However, the runoff volume from the northern portion of the watershed is small in relation to the local drainage area contributing to the trunk line in this area.



Recommended Improvements for the Buddington Road/Laurelwood Road System
FIGURE 6.1-1
Groton, Connecticut
Existing 36-inch RCP to be replaced with 42-inch RCP (typ)
Existing 24-inch RCP to be replaced with 36-inch RCP (typ)
Catch basins to be replaced (typ)
Potential utility conflicts to be determined
Legend
Existing 36-inch RCP to be replaced with 42-inch RCP
Existing 24-inch RCP to be replaced with 36-inch RCP
Catch basins to be replaced
Scale: 1" = 150'
Milone & MacBroom, Inc.
improve1.plt
Groton Shopper's Mart
Stop & Shop
Poquonnock Road (Route 1)
Laurelwood Road
Buddington Road
Pond
Trailer Park
25
YD 324
YD 325
YD 326
YD 327
INV 251 OUTLET
CB 224
CB 224A
CB 225
CB 226
CB 227
CB 228
MH 228A
CB 229
CB 230
CB 231
MH 231A
CB 232
BOX 234
CB 233
CB 235
CB 236
CB 237
MH 237A
CB 238
CB 239
CB 196
CB 196C
MH 196A
INV 196B INLET
CB 106
CB 107
CB 109
CB 110
CB 111
CB 112
CB 113
CB 114
CB 115
CB 116
CB 117
CB 118
CB 119
CB 120
CB 121
CB 122
CB 123
CB 123A
CB 123B
CB 91
CB90
CB 85
CB 84
CB 86
CB 87
CB 83
CB 89
CB 88
CB 82
CB 81
CB 98
CB 97
CB 97A
CB 97B
CB 97C
CB 97D
CB 78
CB 77
CB 79
CB 76
CB 75
Inlet 65

Therefore, increasing detention in these northern wetlands would only minimally reduce flows in the trunk line and would not decrease flows enough to keep the pipes within capacity.

Replacement of this entire section of the trunk line with a large pipe size is a possibility, but would be an expensive alternative. If some ponding would be allowable in the Briarcliff mobile home park area during a 25-year storm event, a less costly alternative would be to replace only a portion of the trunk line from CB117 to JB234. This section of the trunk line has a segment (CB117 to CB109) at an adverse slope, creating a "raised" profile in this area. This portion of the system could be brought to capacity for a 25-year storm event by replacing the pipe from CB117 to CB236 with a 36" RCP at a slope of 0.01. The pipe from CB236 to JB234 is to be replaced with a 42" RCP. A potential for utility conflicts exists with this alternative due to the crossing of the trunk line under Route 1 from CB236 to CB235.

Lateral CB90 to CB84 – Briarcliff Mobile Home Park Drainage

This small lateral off of the main trunk line in the mobile home park area is undersized for a 25-year storm event by 3.06 cfs. This lateral is most likely considered part of a private system. If left undersized, a portion of the mobile home park would pond during a 25-year storm event. This should not create a significant flooding problem due to the raised nature of the homes in the mobile home park. This lateral pipe could be brought to capacity by replacing it with an 18" RCP.

Lateral INV196B to MH237A - Pond to Route 1

A small pond contributes flow to the Buddington Road/Laurelwood Road System at the northern end of the lateral that extends from INV196B to MH 237A. The outlet to this pond is undersized for a 25-year storm, according to the Rational Method calculations. The fact that this outlet does not pass a 25-year storm event is actually helpful to the system. The water will be backed up into the pond and the pond will be utilized for additional storage during a 25-year storm event. This additional storage will reduce the flows in the rest of the connecting system. Therefore, the pipe from MH231A to CB231, which is shown to be undersized with the Rational Method analysis, is acceptable. This lateral system, as shown on Figure 5.1.1-3, is therefore sized properly and there are no recommendations for improvements.

Lateral YD324 to Pipe (CB239-Inv251) - Stop & Shop Parking Lot

This lateral system picks up drainage from the Shop & Stop front parking lot and appears to be a private system. The entire lateral from YD324 to the intersection with the trunk line is undersized according to the Rational Method analysis, for a 25-year storm.

Alternatives for improving the capacity of this lateral include increasing the pipe sizes to 30" and 36" or installation of infiltration wells. If the yard drains were replaced with infiltration wells, the connecting pipe system could be left in place to be utilized as an overflow system. Additionally, this lateral could be left undersized as there is no known damage. This would result in occasional ponding of the Stop & Shop parking lot during large rainfall events.

6.2 The Shopping Plaza System

The Shopping Plaza System is of concern because it is very flat and consequently undersized for the design flows of a 25-year storm event. Ponding of water has been a problem along Poquonnock Road in the area of the railroad bridge. The upstream part of the system is primarily under the parking lots of two large shopping plazas. Ponded water in these areas is less of a problem due to sloping parking lots. The following is a list of problem areas along with potential solutions for this area. Improvement areas are highlighted in Figure 6.2-1.

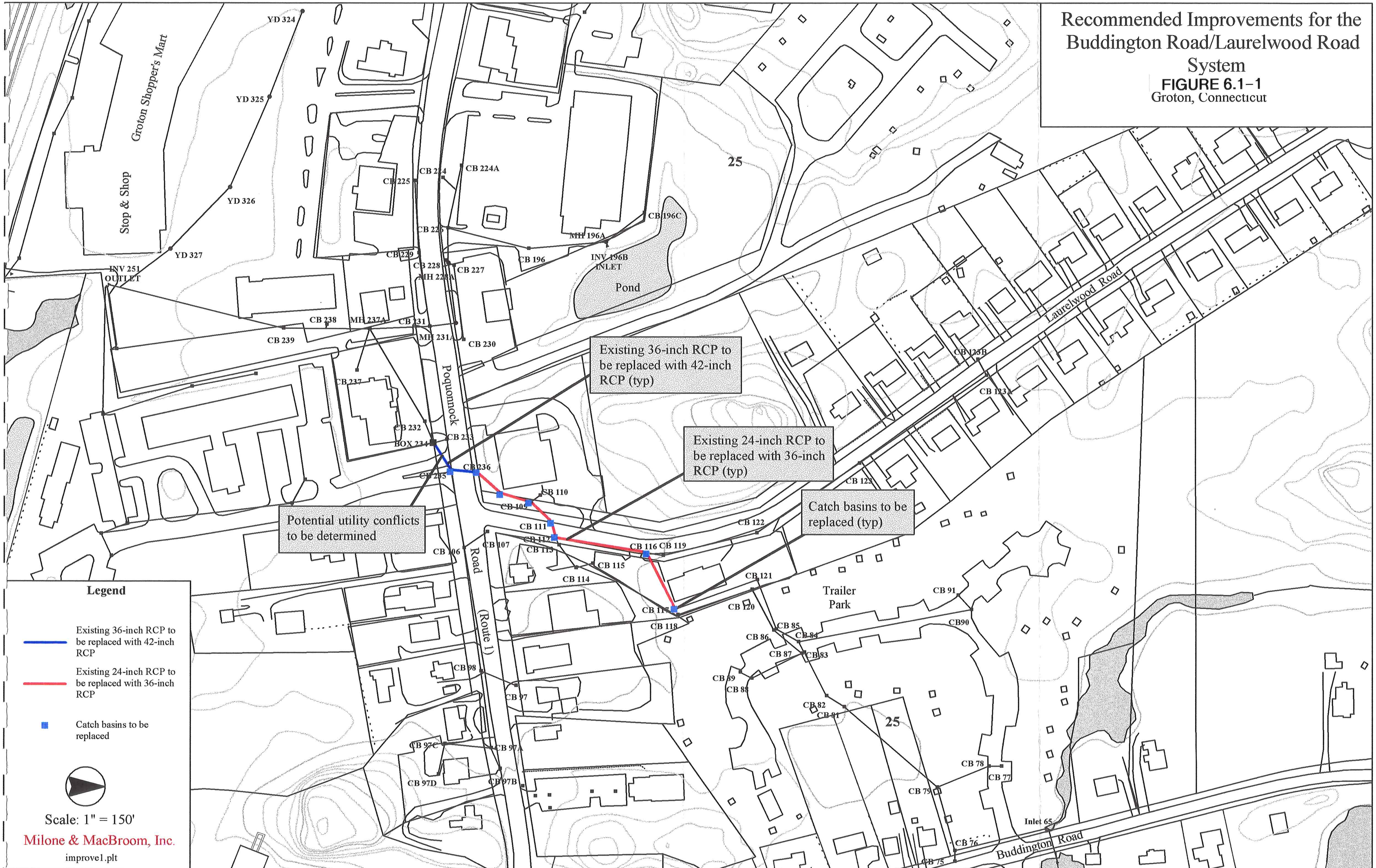
Lateral CB185A to Pipe (INV179 to CB182) - Behind Post Office

A portion of the lateral that runs behind the Groton Post Office and shopping plaza is undersized. This private system pipe could be brought up to capacity by replacing the two pipes (CB185A-CB184) with a 24" RCP and replacing the last segment (CB184-trunk line) with a 30" RCP. Another option would be to leave the lateral as it is and either allow ponding in the post office rear parking lot or direct excess flow to the wetland to the north. A final option would be to install infiltration wells along this lateral and leave the connecting pipe system in place, to be used for overflow.

Recommended Improvements for the Buddington Road/Laurelwood Road System

FIGURE 6.1-1

Groton, Connecticut



Trunk Line CB188 to Pipe (INV253 to INV254) - Shopping Plaza Trunk Line

The main 48" trunk line through the Shopping Plaza system is undersized due to the flat nature of the topography through this area. However, the peak flows reaching this point are partially attenuated by storage of runoff in the adjacent upstream wetlands. The pipe inlet and approach channel are both prone to partial blockage by debris, inadvertently reducing peak flows (and downstream problems) by forcing water to pond in the wetland. The only way to alleviate the problems in this system, other than replacing the 48" trunk line with an exceptionally large conduit, is to artificially decrease the amount of flow getting to it. This can be done in several different ways.

The first option is to provide additional stormwater detention in the wetland/vacant lot area just north of the Groton Post Office. The detention in this area can be increased by constructing a berm to an elevation of 26 NGVD and installing a catch basin riser outlet to control the amount of flow released during storm events. This would reduce the 25-year peak flows from 100 cfs to 31 cfs. Storage capacity can be further increased by lowering the elevation of the vacant lot next to the post office to an elevation similar to that of the upstream wetland.

The storage capacity can also be increased in the small wetland at the intersection of Long Hill Road and Poquonnock Road. The Town of Groton has planned to create a park on this property. Using this area to increase storage will require the construction of a berm or retaining wall along the eastern edges of the wetland. The berm will need to be placed at an elevation of 21 NGVD. This would potentially reduce the flows for a 25-year storm event from 68 to 21 cfs.

Decreasing input flows to the system would alleviate some capacity problems from CB188 to CB320 but would not address the entire trunk line. Additional measures would need to be taken if the entire trunk line behind the Groton Shopper's Mart is to handle a 25-year storm event. One option would be to replace the lower portion of the trunk line, CB320A to the intersection with the 90" railroad culvert, with a 66" RCP, or with a parallel storm drain.

Placement of the large conduit may be difficult due to the limited vertical clearance on the existing trunk line. A second alternative would be to create an overflow channel along the southern side of the Groton Shopper's Mart. This channel would start next to the western entrance of the shopping plaza, at Poquonnock Road, and extend to the existing 90" railroad culvert, along the northern side of the railroad right-of-way. Construction of the overflow channel could be difficult due to the railroad right-of-way and, therefore, might require slight modification of the Stop & Shop parking lot in order to accommodate construction of the overflow channel. The overflow channel would be approximately 1,550 feet long, four feet wide, at a slope of 0.0016 ft/ft and at depths ranging from four to six feet deep. The capacity of the overflow channel will range from 100 to 200 cfs depending on the depth, width, and freeboard.

The channel downstream of the 90" railroad culvert does not presently receive the full peak flow predicted by the TR-20 model (206 cfs 25-year storm present conditions) due to the limited capacity of the 48" pipe connecting into the culvert from the Stop & Shop Plaza. The existing flow through the railroad culvert is limited to approximately 160 cfs, during the 25-year storm. Proposed conditions will increase the quantity of flow in the railroad culvert and the downstream channel.

FGA completed a backwater analysis of the channel downstream of the culvert using a HEC-2 water surface profile model. The result of the FGA analysis predicted the future water surface elevation in the channel to be 11.97 NGVD during the 25-year storm and 12.57 NGVD during the 100-year storm. In this study, the water surface elevations in the downstream channel were determined by interpolation, using the MMI flow rates and the FGA water surface profile analysis. The resulting water surface elevations for the downstream channel were lower than those predicted previously by the FGA study. Therefore, similarly to the FGA findings, it is concluded that the increase in flow under proposed conditions will not increase flooding or erosion in the downstream channel.

Table 6.2-1

Water Surface Elevations in

Channel Downstream of the Railroad Culvert

Storm Event	*MMI Interpolated Water Surface Elevation*	*FGA Predicted Water Surface Elevation*
Existing 25-year	11.25	11.57
Future 25-year	11.49	11.97
Future 100-year	11.99	12.57

The proposed improvements within the watershed should result in improved water quality in this channel. The reduction of sediments and contamination obtained through the application of best management practices will improve the downstream water quality.

Lateral INV317A to MH320A - Poquonnock Road System

The storm drain lateral that extends from the small wetland west of Poquonnock Road (INV317A) to the trunk line is undersized for a 25-year storm event, due to the backwater from the trunk line. Additionally, Poquonnock Road in the area of the railroad bridge to the intersection with Long Hill Road experiences shallow ponding at low catch basin grates, due to the high backwater conditions. The construction of additional detention in the wetland and an overflow channel, as discussed in the previous paragraph, would greatly decrease flooding of this area. Increasing pipe sizes in this area would not reduce flooding because it would not reduce backwater elevations. The catch basins under the railroad bridge have filled completely with sediments. Maintenance of these catch basins is essential because sand tends to settle in this area.

Lateral CB191 to Pipe (CB188-CB217) - Eastern Commercial District Lateral

The initial hydraulic analysis of this lateral using actual slopes of pipes indicates that several of the pipes were undersized. A more detailed analysis and pipe profile were then prepared using effective slopes. This final analysis showed that the lateral system has capacity for a 25-year design storm event, with limited surcharge. Therefore, there are no recommended improvements along this lateral. Figure 5.1.2-5 graphically depicts the pipe profile for this lateral.

6.3 The Southern Long Hill Road System

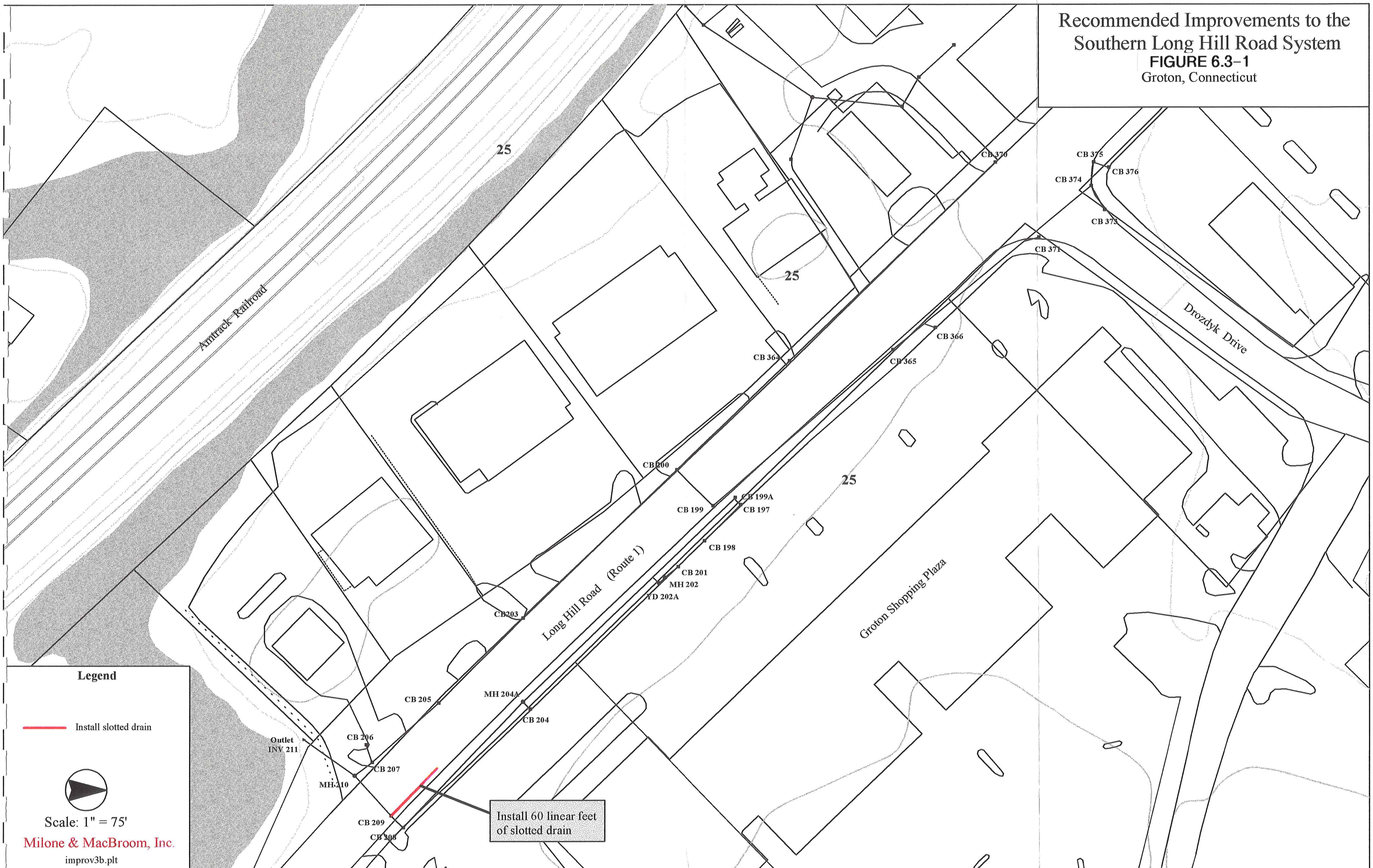
Three pipe profiles were created for the Southern Long Hill Road System. The first pipe profile, Figure 5.1.3-2, extends along the trunk line from CB370 to the outlet at INV211. The hydraulic analysis of the trunk line showed that the system has capacity for the 25-year design storm. The second pipe profile, Figure 5.1.3-3, extends along a lateral to the trunk line, from CB374 to CB200. Two of the pipes in this system were shown to be undersized for the 25-year design storm and are discussed below. The final pipe profile, Figure 5.1.3-4, extended along a lateral, from CB199A to MH210. All the pipes in this lateral are able to handle the flows for a 25-year storm. The following is a list of problem areas along with potential solutions for the Southern Long Hill Road System:

Lateral CB365 to CB200 - Long Hill Road

The two pipes from CB365 to CB200 are undersized for the 25-year design storm. The first pipe from CB365 to CB199 is undersized by 4.4 cfs and the second pipe from CB199 to CB200 is undersized by 1.1 cfs. These pipes could be replaced with large pipes, but the less expensive alternative would be to leave the pipes in place and accept gutter flow along Route 1 during a 25-year storm event. The gutter flow could then be picked up at the next catch basin down hill, CB209. A modified inlet could be constructed to handle the full 5.5 cfs by installing a slotted drain along the gutter line of Route 1, connecting into CB209. The slotted drain would extend 50 feet along Route 1 from CB209, parallel to the curbing. Catch basin 209 could also be modified into double catch basins, which could handle a portion of the 5.5 cfs of gutter flow. The excess gutter flow could be allowed to continue down Route 1 to the Shopping Plaza System. However, the Shopping Plaza System is already severely undersized and all efforts should be made to avoid directing excess flow toward it. Figure 6.3-1 shows the recommended improvements for this drainage area.

6.4 The Northern Long Hill Road System

The Northern Long Hill Road System is in relatively good condition with few undersized pipes. The system does, however, transition into a smaller pipe at its outlet creating a small

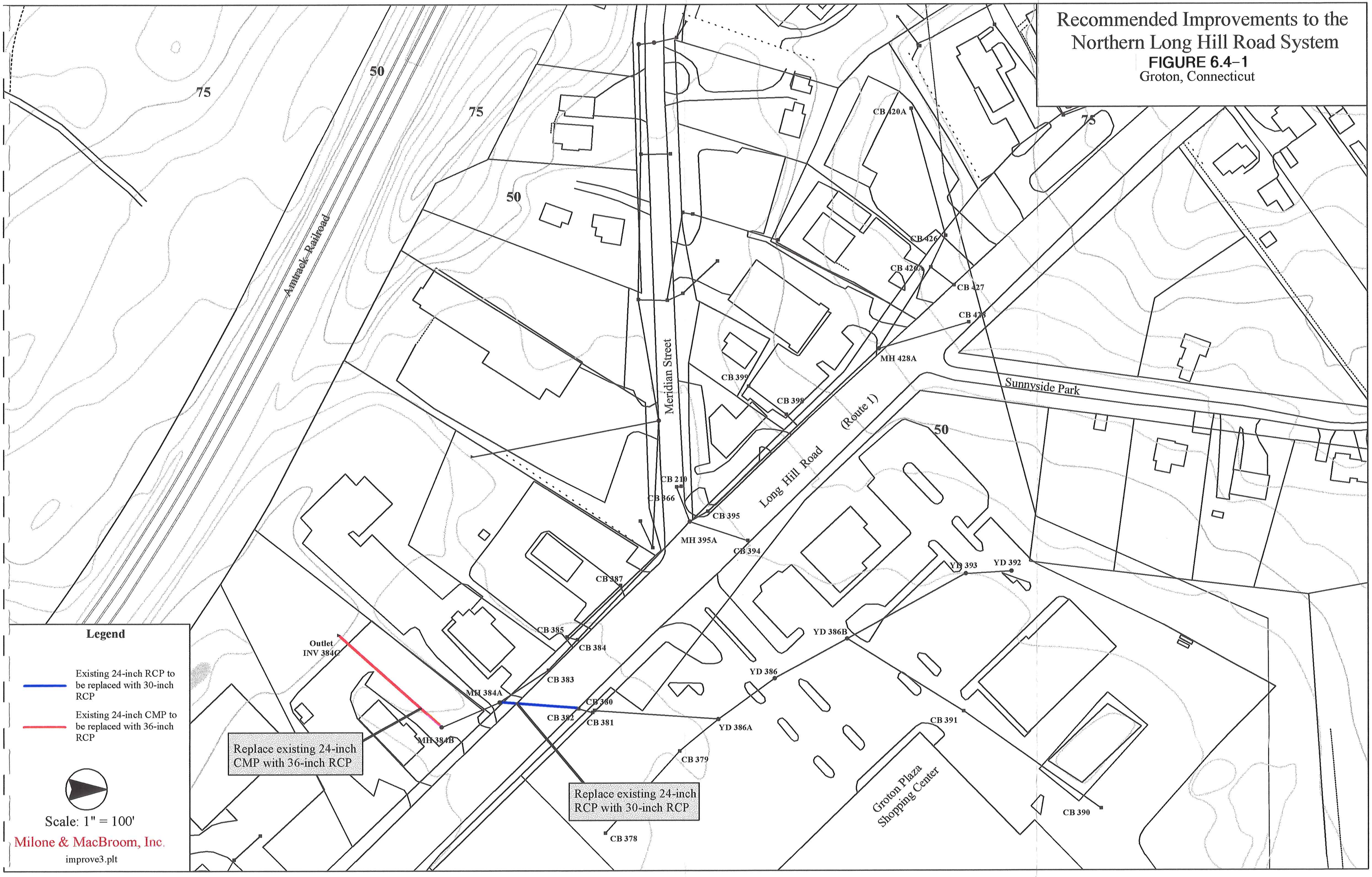


Recommended Improvements to the Southern Long Hill Road System
FIGURE 6.3–1
Groton, Connecticut

Recommended Improvements to the Northern Long Hill Road System

FIGURE 6.4–1

Groton, Connecticut



"bottle neck" condition. Figure 6.4-1 shows the recommended improvements for this drainage basin. The following is a list of problem areas along with potential solutions for the Northern Long Hill Road System:

Trunk line CB384 to CB383 - Route 1

The pipe extending from CB384 to CB383 is undersized by 3.5 cfs for a 25-year design storm event. This pipe could be replaced with a larger pipe or the excess flow could be allowed to continue down Route 1 as gutter flow. Approximately 2 cfs of the gutter flow will be picked up at the next catch basin, CB383. Catch basin 383 could be modified into a double catch basin to handle the full 3.5 cfs of gutter flow or the excess 1.5 cfs of gutter flow could be allowed to flow down to the Southern Long Hill Road System. The pipes farther down on Route 1 in the Southern Long Hill Road System can easily handle the excess flow without modification. As a result, although theoretically undersized, this drainage system is unlikely to cause damage or generate complaints.

Trunk line MH384B to INV384C – Outlet

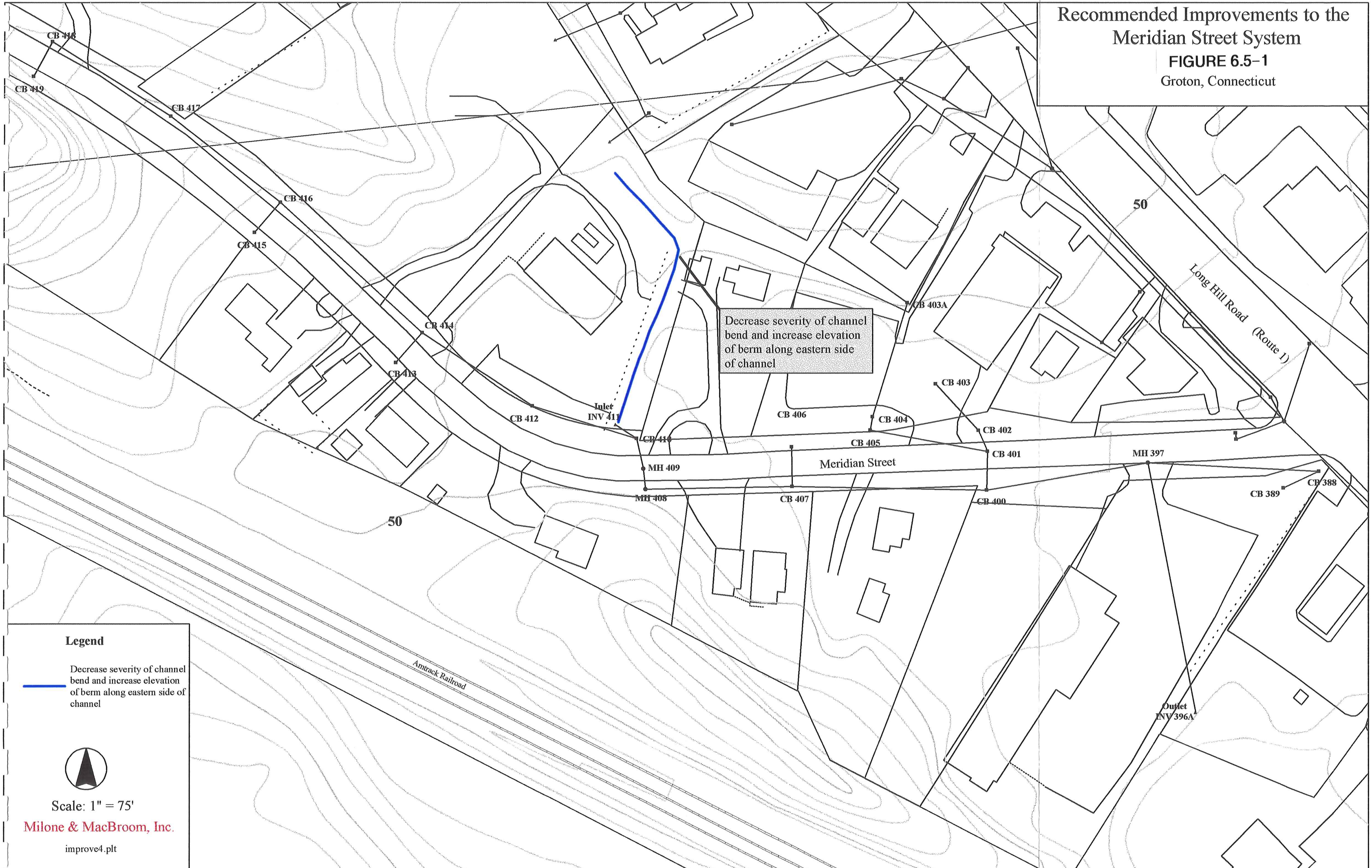
The main trunk line in the Northern Long Hill Road System transitions from a 30" RCP down to a 24" CMP at its outlet behind Wendy's restaurant. This transition creates a "bottle neck" condition. The 24" CMP outlet pipe is undersized for the 25-year design flows by 28.48 cfs. If left as is, the system could back up and the excess flows will most likely escape out of CB383 and CB382. This amount of gutter flow is not acceptable. This system could be fixed by replacing the outlet pipe with a 36" RCP or by installing a small parallel pipe next to the existing outlet pipe.

Lateral CB382 to MH384A - Route 1

A pipe profile was prepared for the lateral extending from YD392 through a commercial parking lot to MH384A (Figure 5.1.4-3). It was assumed in calculating the effective slopes for this lateral system that ponding of one-half foot to one foot would be allowable within the parking lot. The pipe extending from CB382 across Route 1 to MH384A was shown to be undersized by 5 cfs, under design flows. This excess flow could be allowed as gutter flow, which would continue down Route 1 to the Southern Long Hill Road System. The pipes on the northeastern side of Route 1 in the Southern Long Hill Road System are already undersized, and would not be able to convey the excess flows from the Northern Long Hill Road System. The gutter flows would continue on to the severely undersized Shopping Plaza System. All efforts should be made to keep excess flows from this system. Replacement of the pipe extending from CB382 to MH384A with a 30" RCP is another option. This option would help to protect the systems further down Route 1.

6.5 The Meridian Street System

The Meridian Street System is in good condition and was found to be of adequate size to handle a 25-year design storm event. The only potential problem along this system, relates to a small stream that flows into the system at INV411. Although the condition of the stream was improved during activities at the Charter Oak Credit Union, the improvements were not likely to be sufficient to prevent the brook from jumping its bank during storm events. The stream should be realigned with a more gentle radius at the bend and cleared of excess debris upstream of the credit union. Figure 6.5-1 details the recommended improvements to this area.


Recommended Improvements to the Meridian Street System
FIGURE 6.5-1
Groton, Connecticut
CB 418
CB 419
CB 417
CB 416
CB 415
CB 414
CB 413
CB 412
Inlet
INV 411
CB 410
MH 409
MH 408
CB 407
CB 406
CB 405
CB 404
CB 403A
CB 403
CB 402
CB 401
CB 400
MH 397
CB 389
CB 388
Outlet
INV 396A
Decrease severity of channel bend and increase elevation of berm along eastern side of channel
Meridian Street
Long Hill Road (Route 1)
Amtrack Railroad
50
50
Legend
Decrease severity of channel bend and increase elevation of berm along eastern side of channel
Scale: 1" = 75'
Milone & MacBroom, Inc.
improve4.plt

7.0 Best Management Practices

7.1 General BMP's

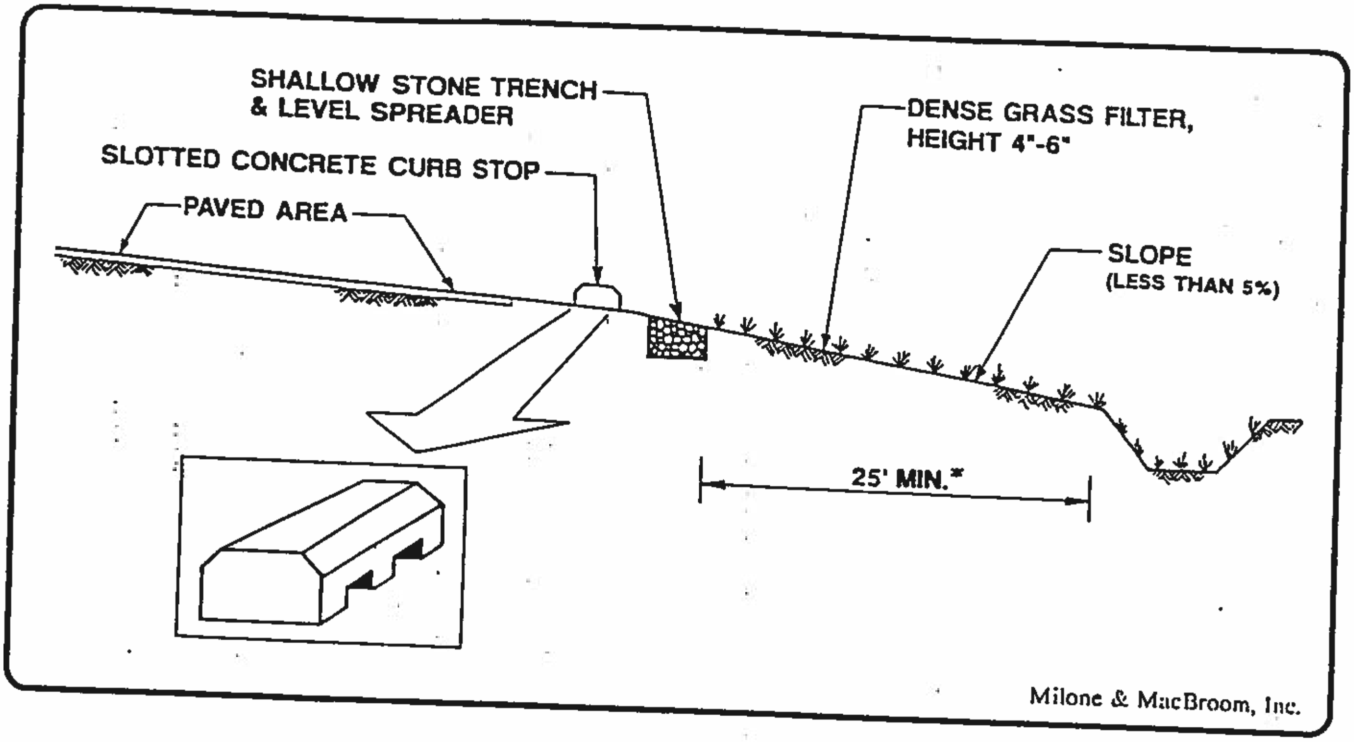
There is growing concern over the presence of contaminants in surface water bodies that are the result of non-point source pollution. Non-point source pollutants originate from land use and man's activities. They include stormwater runoff, agricultural runoff and chemicals, soil erosion and sediment, and sanitary landfill leachate. These discharges generally enter surface waters from a great many dispersed sources which are frequently associated with rainfall events. Non-point source pollution can be reduced either through the use of Best Management Practices (BMP's) or by source reduction. BMP's are defined as practices that reduce or prevent the discharge of pollutants into surface and groundwater. Catch basins and storm drainage systems act as conduits for non-point source pollution and carry pollutants into surface water bodies. Non-point source pollution can be controlled by installing measures within the system to prevent the migration of contaminants to surface waters.

BMP's have been shown to improve the quality of urban runoff. Many BMP's act to promote pollutant filtration, adsorption, and microbiological decomposition as well as provide groundwater recharge. Use of infiltration will also act to reduce the volume of peak runoff. The groundwater recharge provided by infiltration can provide base flow to rivers, streams, and wetlands.

Source reduction should be considered as part of any BMP for storm drainage systems. Source reduction measures minimize the generation of contaminants that may reach storm drains and surface water bodies. These measures can be applied throughout the whole watershed including the upper portions. Typical source reduction measures to be considered include:

- Leaf collection
- Recycling of tires, cans, plastics
- Erosion control
- Trash racks on pipe inlets
- Collection of waste oils, oil traps
- Reduction in lawn fertilizers
- Limit deicing chemicals
- Public education
- Elimination of combined sewer overflows
- Prevention of illegal dumping

FIGURE 7-1
VEGETATIVE FILTER



DESIGN CRITERIA

- Depth of water should not exceed grass height
- Select vegetation via use of CT Guidelines for Sediment and Erosion Control and Appendix B
- Serve a contributing area of 5 acres or less
- Uniformly grade to avoid depressions or swales
- Grass height should be 4" to 6"
- Performance best on slopes less than 5%
- Filters should receive only sheet flow
- Minimum length of 25', 50' to 75' optimal plus 4 ' for each additional percent slope
- Recommended in topsoils of loamy sand to silt loam
- Combine with forested strips where possible
- A longer strip length provides more filtration

APPLICATIONS

- Immediately abutting impervious surfaces
- Downstream of level spreaders
- Place in areas with high particulate loads, organics and metals
- Pre-treatment step for infiltrative systems

ADVANTAGES

- Reduces pollutant loads
- Increases time of concentration
- Protects soil from erosion
- May double for aesthetic/recreational use
- Can provide wildlife habitat

LIMITATIONS

- Mowing maintenance
- Channels formed from non-sheet flow may short-circuit filter
- Periodic sediment accumulation at top of strip

Public education is an important tool in achieving source reduction of contaminants. Residents should be advised against the disposal of any liquids or wastes into the catch basins. Activities such as car washing should be performed on grass areas where wash water can be filtered by grass and soil prior to entering the groundwater supply. The use of fertilizers should also be minimized to prevent the migration of chemicals into water bodies. A brochure detailing appropriate treatment of catch basins may educate citizens and minimize the volume of contaminants from residential sources.

Source reduction can be also achieved in many areas by the placement of vegetative buffers to absorb contaminants prior to discharge into catch basins. Where appropriate, runoff should be allowed to flow through grass areas or other vegetated areas where some water will infiltrate and contaminants will be removed by biofiltration. Biofiltration is the process of reducing pollutant concentrations in water by filtering the polluted water through vegetation. Biofiltration facilities have been shown to be effective at removing a significant amount of the total suspended solids, fine sediments, as well as some non-soluble heavy metals and nutrients. It may be possible to promote biofiltration throughout much of the Long Hill watershed by replacing curbing on parking lots with vegetative filters as shown in Figure 7.1-1.

In high traffic areas such as Route 1 sediments and sand accumulate on the roadside quickly. During storm events, the sand and sediments are transferred to the catch basins via runoff. Sediments then accumulate in the piping and limit the hydraulic capacity of the system. Regular street sweeping can minimize the transfer of sediments into the drainage system in these areas. While the largest amounts of sediments are typically found in the early spring after roads have been sanded during the winter, sediments do accumulate during the summer months as well. Street sweeping should be completed more often than once per year in order to minimize the amount of sediments accumulating in the catch basins.

A number of areas were observed throughout the study area where the capacity of catch basins and pipes has been reduced due to the accumulation of debris, sediment and leaves in catch basins. This accumulation hinders the hydraulic capacity of the catch basins and promotes flooding during major storm events. Regular cleaning of all catch basins and drainage structures should be completed to maintain maximum capacity of all structures.

Additionally, the pipe located below the v-notch weir in the sediment basin at the Tall Woods condominium complex was found to be 80% blocked by rocks. These rocks are shown on the original plans for the condominium complex as a temporary erosion control measure to be removed upon completion of the project. The rocks should be removed to maximize the flow capacity of the pipe.

Additionally, several pipes in the Long Hill watershed have adverse slopes. Sediments will tend to accumulate in pipes with adverse slopes. These pipes should be cleaned regularly to maintain the capacity of the drainage system.

BMP's for each specific watershed were identified during the course of the study. The following BMP's may be useful at reducing the volume of contaminants found in the storm drains.

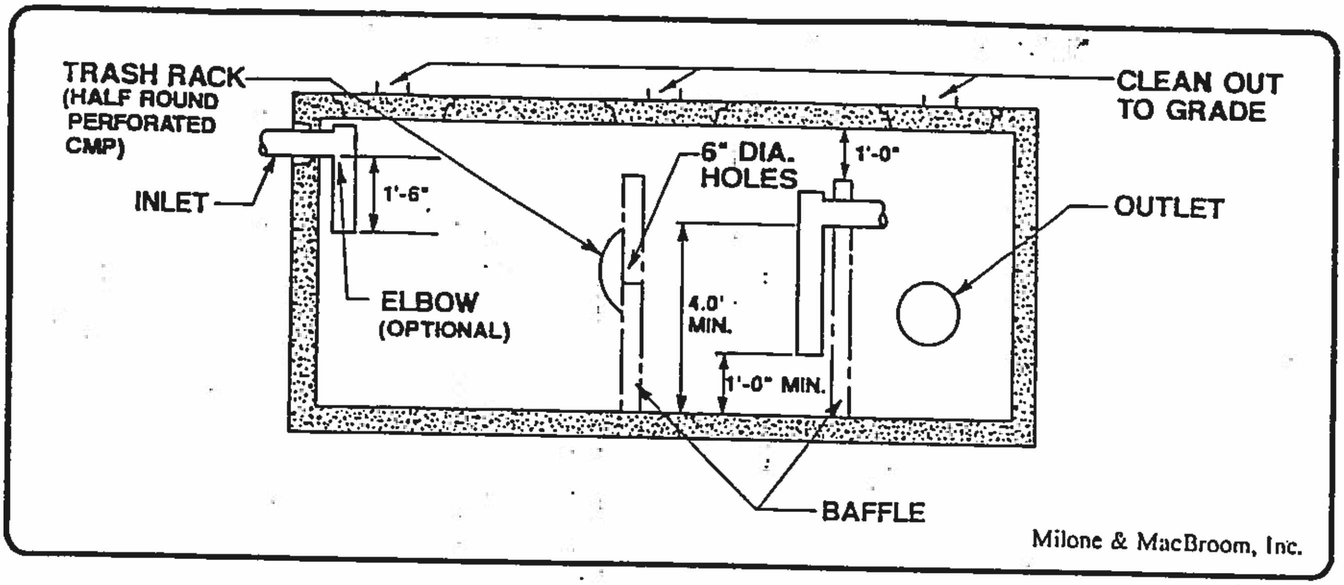
7.2 Buddington/Laurelwood Road System

The inlets to the Buddington Road area drainage system, north of the Briarcliff mobile home park, were observed to be partially blocked with debris and sediment. These inlets should be cleaned and the sediment removed to maximize the flow through the drainage system.

Further down in the system at Laurelwood Road the pipes were determined to have adverse slopes and the catch basins were filled with sediments. If the pipe slopes are not corrected as recommended in Section VI of this report, then care should be taken to prevent the excessive accumulation of sediment in them. Regular cleaning should be adequate to achieve this.

Road sand and salts are carried to the open channel outlet at INV 251 from the catch basins near Route 1 due to the high volume of traffic in this area. A sedimentation chamber, similar to that shown in Figure 7.2-1, should be installed downstream of Route 1 to trap sediments and prevent their migration into the open channel in this area. It may be possible to retrofit JB234 as a sedimentation basin by removing the bottom of the box and excavating a sump below the box. The bottom could then be left open to the underlying soil, which will increase infiltration of stormwater, as well as settling of sediments. This settling chamber will need to

FIGURE 7-2
SEDIMENT CHAMBER



DESIGN CRITERIA

Provide 400 cubic feet of storage per acre of contributing impervious area
Minimize contributing area to 1 acre or less per unit
Provide a high flow bypass where possible

APPLICATIONS

Small and large parking areas with large hydrocarbon and sediment loads and vehicular traffic
Use as a pretreatment prior to infiltrative systems to prevent clogging

ADVANTAGES

Removes coarse sediments
Removes floatables
Removes various hydrocarbon films

LIMITATIONS

Must inspect 3 times yearly
Limited pollutant removal capacity
Possible re-suspension of fine settled pollutants

be cleaned and sediments removed regularly in order to maintain maximum efficiency of the chamber. A settling chamber may be installed further downstream near CB239 in lieu of the retrofit of JB234. The chamber can most easily be installed by placing it next to the existing piping in this area. Piping would connect to the chamber and then connect the chamber back to the existing system. This parallel installation will allow water to flow through the chamber during low flow conditions but to by-pass the chamber during major storm events.

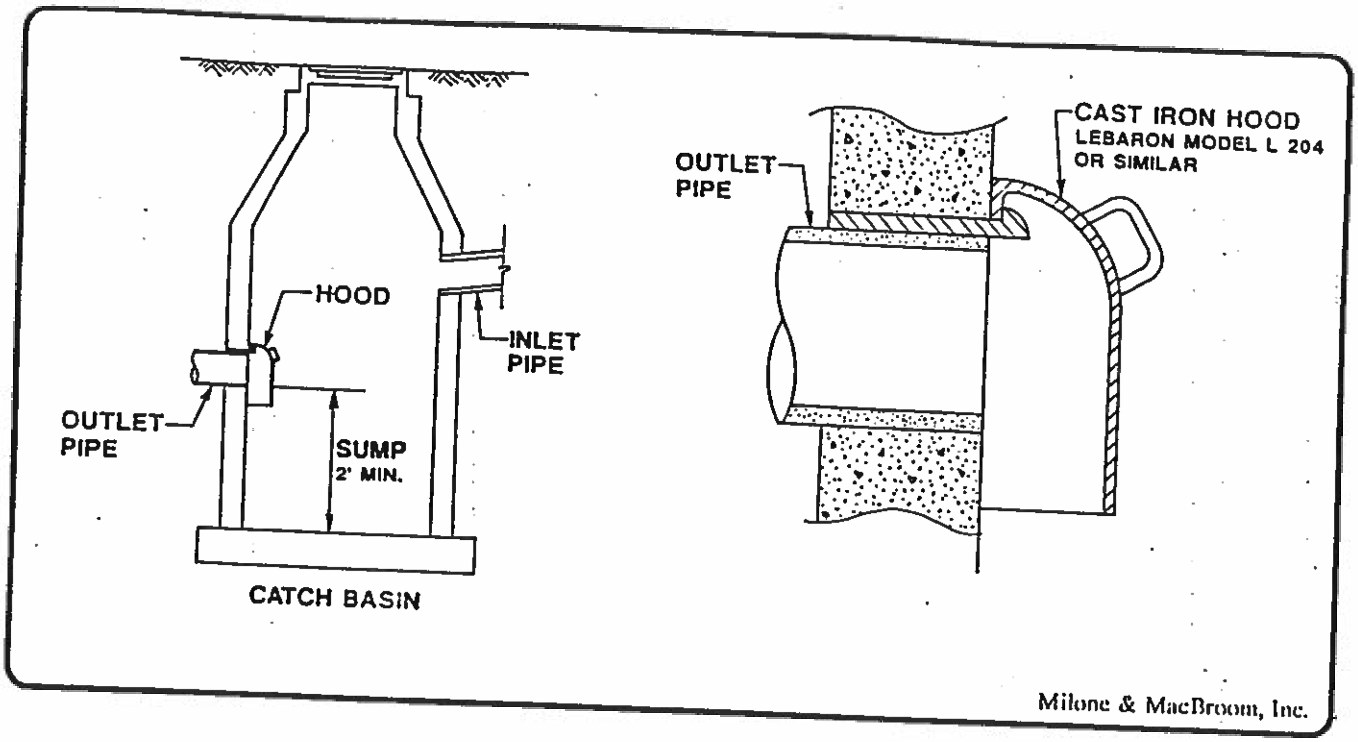
Infiltration chambers can also be installed in the Stop & Shop parking lot as recommended in Section 8.0. The chambers can promote the infiltration of water directly to the ground instead of carrying the water to the open channel. This will minimize flooding in the parking lot and settle solids. The chambers would remain connected by pipes so that during major storm events excess water can still be carried to the open channel. The installation of an oil/water separator should also be considered in this parking lot area. Parking lots are primary sources of oils in surface water bodies and every effort should be made to minimize their migration during runoff. The oil/water separator and filtration chambers will require regular cleaning to continue to function efficiently.

The outlet at INV251 should be cleaned in order to maximize flow out of the three pipes that exit here. All three pipes in this area are partially blocked with rocks, sediments and/or debris.

7.3 Shopping Plaza System

Flow into the upstream portion of this drainage system can be minimized by the installation of infiltration chambers behind the post office, as recommended in Section 8.0. Piping connecting CB185A, CB185, and CB184 is currently undersized. Retrofitting these catch basins as infiltration chambers will minimize the volume of water entering the piping and will prevent the accumulation of sediments in the catch basins, piping, and the wetland area behind the post office.

FIGURE 7–3
CATCH BASIN
SUMP & HOODED OUTLET



DESIGN CRITERIA

None

APPLICATIONS

Large commercial/industrial parking areas
Systems having direct discharge to waterways, water bodies and wetlands
Areas with potential petroleum inputs

ADVANTAGES

Floating hydrocarbons captured
Adsorbed hydrocarbons settle with particles
2 foot sump traps coarse sediments
Floatables prevented from exiting
Simple to retrofit hood
Low cost

LIMITATIONS

Emulsified and dissolved hydrocarbons difficult to trap mechanically
Maintenance - sump cleaning 3 times yearly to maintain effectiveness
Organics and stagnant water may be flushed out upon subsequent flow without routine cleaning

The installation of a berm north of the post office, as recommended in Section 8.0, will increase stormwater detention and allow many contaminants which may enter the area from north of this system to be removed by biofiltration in the wetland area. Currently, stockpiles of construction debris including asphalt, concrete, and sand are located in this area. This debris should be removed prior to the construction of the berm. The removal of this debris should help to prevent the runoff of pollutants into the adjacent surface water.

The installation of hoods, as shown in Figure 7-3, should be completed on all catch basins within the shopping center parking lot. A distinct petroleum odor was noticed in these catch basins during field investigations. The installation of hoods should minimize the migration of any petroleum constituents into surface water bodies. Additionally, a sediment chamber or infiltration gallery should be installed at CB188 to settle out any sediments which accumulate from the parking lot runoff. This chamber can be installed parallel to the existing catch basin as previously described for the Stop & Shop parking lot.

The construction of a berm around the existing wetland at the intersection of Poquonnock Road and Long Hill Road will increase stormwater detention and the ability of the wetland to remove pollutants via biofiltration. The increased storage capacity will also reduce peak flows in the downstream drainage system.

Several catch basins and two culverts along Poquonnock Road, in the area of the railroad bridge crossing, are severely clogged with sediment. The catch basins directly under the railroad bridge are almost 100% full of sediment, which contributes to flooding along Poquonnock Road. The low gradient drainage system in this area tends to quickly fill with sediments. Particular attention needs to be paid to this portion of the drainage system with regard to regular maintenance and removal of accumulated sediments.

The construction of the overflow channel south of the Groton Shopper's Mart will result in a successful BMP for this area. The vegetated channel will act as a biofilter for many contaminants which may be in the runoff. Although not specified as a recommendation in this report, one option to increase biofiltration of the stormwater runoff would be to utilize the overflow channel as a primary channel. The existing pipe system through the rear of the

Shopper's Mart parking lot would then be connected to the open channel and utilized only as an overflow conduit for runoff in excess of the channel capacity. The open channel would convey flows to the 90" culvert at the railroad tracks under non-storm event conditions. The existing pipe system would remain in place to convey the overflow during significant storm events.

A sediment chamber should be installed parallel to the pipe system near CB252 behind the Shopper's Mart if the overflow channel is not utilized. This will allow sediments to settle out prior to entering the culvert under the railroad tracks. Regular maintenance will need to be performed on the basin to maintain its effectiveness at reducing sediment loading.

7.4 Southern Long Hill Road System

A number of catch basins in the Southern Long Hill System were identified as having adverse slopes. These pipes should be replaced as recommended in Section 8.0. However, if replacement is not completed, these pipes should be maintained regularly to remain free of sediments. Pipes with adverse slopes act as collection points for sediments and eventually will result in diminished flow capacity and blocked pipes.

A sediment chamber should be installed at MH210 to prevent the accumulation of excessive amounts of sediments in the wetland area near the outlet. This chamber will need to be maintained regularly to continue to operate adequately.

The existing outlet at INV211 should be cleaned to remove debris and sediment that has accumulated there. This debris currently restricts the outflow from the pipe.

At the upper end of this drainage system near Drozdyk Drive catch basins CB373, CB374, CB375, and CB376 were observed to be full of sediment. These should be cleaned to maximize the flow of water through the basins, thereby minimizing gutter flow down Route 1.

Installation of a sediment chamber may be required in this area if these catch basins continue to fill with sediment.

7.5 Northern Long Hill Road System

The parking lot of the Groton Plaza Shopping Center is the most likely source of non-point source pollutants in the northern Long Hill Road area. Potential contaminants in this area should be addressed by installation of an oil/water separator in the parking lot to prevent the movement of oils into surface water bodies. Catch basins YD386A or CB381 may be retrofit to accommodate an oil/water separation system for the parking lot. This chamber will need to be maintained regularly. However, since it will be located and serve a privately owned parking lot, the Town of Groton might consider having the responsibility for maintenance be placed on the property owner. Adverse slopes on the pipes found in this area that are not corrected should be cleaned regularly to prevent blockage due to accumulation of sediment.

The storm drainage in this area discharges to a wetland area located behind Wendy's restaurant located on Route 1. This wetland area acts as a biofilter for potential non-point source pollutants and, therefore, improves the overall removal efficiency of the system.

7.6 Meridian Street System

As with the Northern Long Hill Road area, the Meridian Street system discharges into a wetland corridor. The Meridian Street system only accepts flow from the area of sub-basin 18, which is largely residential properties and should have minimal contaminants other than road sand and salt. The wetland acts as a biofilter for potential pollutants which may be carried down Meridian Street to the outlet point.

8.0 Recommendations/Cost Estimate

8.1 Summary

A summary of the recommended drainage improvements and their construction costs is listed below. Recommended improvements were selected based on potential for flooding damage and cost effectiveness. A more detailed list of the recommended drainage improvements and their associated cost estimates have been included after the summary table.

Table 8.1-1
Summary of Recommendations and Cost Estimates

Drainage System	*Activity*	*Cost in $**
Buddington Road/ Laurelwood Road System	Replace Pipe - Laurelwood Rd Area	64,100
Shopping Plaza System	Northern Detention Area	29,000
Shopping Plaza System	Western Detention Area (Earthen Berm Option)	27,500
Shopping Plaza System	Overflow Channel	46,100
Southern Long Hill Road System	Slotted Drain	2,900
Northern Long Hill Road System	Replace Pipe - Outlet	6,900
Northern Long Hill Road System	Replace Pipe - Route 1	13,800
Meridian Street System	Realign & Clear Stream	2,300
	Total Cost =	192,600

* Includes 25% contingency

8.2 Recommendations and Cost Estimates

The following is a detailed listing of the recommended drainage improvements and their associated cost estimates. Brief descriptions of the recommended improvements have been included. For more detailed information at each site, see Section V - Findings. The cost estimates are based on preliminary investigation only. Actual construction prices are expected to vary depending on final design, utility conflicts, easements, etc. In some cases, using Town labor and supplies or parallel pipes to supplement rather than fully replace existing undersized pipes could reduce cost.

The Buddington Road/Laurelwood Road System

Trunk Line CB81 to JB234 - Mobile Home Park to Laurelwood Road

1. The existing 24" RCP extending from CB117 to CB236 is to be replaced with a 36" RCP. The existing 36" RCP extending from CB236 to JB234 is to be replaced with a 42" RCP. The potential for utility conflicts exists due to the crossing of the trunk line under Route 1 from CB236 to CB235. The portion of the trunk line that extends through the mobile home park would remain undersized, allowing for minor ponding of the area during large rainfall events. Flooding damage would remain minimal due to the raised nature of the trailers.

Table 8.2-1
Buddington/Laurelwood Road System Trunk Line Improvement Cost

Activity	*Unit*	*Amount*	*$/Unit*	*Cost in $*
Replace Catch Basins	EA	8	1,500.00	12,000
Trenching & Backfill	CY	350	6.50	2,300
Pipe Removal (24" RCP)	LF	521	8.90	4,600
Pipe Removal (36" RCP)	LF	60	11.85	700
36" RCP	LF	481	51.00	24,500
42" RCP	LF	107	67.00	7,200
			Subtotal =	51,300
			25% Contingency =	12,800
			Total Cost =	64,100

Assumes: - junction box can be retrofit to accommodate new pipe sizes
- no utility conflicts

Lateral CB90 to CB84 - Mobile Home Park Drainage

2. This lateral in the mobile home park area appears to be a private system. It is, therefore, not recommended that the Town assume the responsibility to improve this pipe. Flood damage would remain minimal due to the raised nature of the trailers.

   Estimated Cost: Not applicable

Lateral YD324 to Pipe (CB239-Inv251) - Stop & Shop Parking Lot

3. This lateral system picks up drainage from the Shop & Stop parking lot and appears to be a private system. It is, therefore, not recommended that the town take on the responsibility to improve this pipe system. Leaving the system as is would result in occasional ponding of the Stop & Shop parking lot during large rainfall events.

   Estimated Cost: Not applicable

The Shopping Plaza System

Lateral CB185 to Pipe (INV179 to CB182) - Behind Post Office

4. This lateral system picks up drainage from behind the post office shopping plaza and would most likely be considered a private system. It is, therefore, not recommended that the Town take on the responsibility to improve this pipe system. Leaving the lateral undersized will allow the continuation of ponding in the post office shopping plaza parking lot.

   Estimated Cost: Not applicable

Trunk Line CB188 to Pipe(INV253 to INV254) - Shopping Plaza Trunk Line and Lateral INV317A to MH320A - Poquonnock Road System

5. Provide additional detention in the wetland/vacant lot area just north of the Groton Post Office. Constructing a berm to elevation 26 NGVD can increase the detention storage volume in this area and installing a catch basin riser outlet to control the amount of flow released during storm events. This would reduce the potential 25-year peak flows from 100 cfs to 31 cfs.

Table 8.2-2
Shopping Plaza System Trunk Line Improvement Cost

Activity	*Unit*	*Amount*	*$/Unit*	*Cost in $*
Bank excavation & fill	CY	775	20.00	15,500
Outlet structure	EA	1	3,000.00	3,000
Topsoil	CY	67	10.00	700
Mobilization/ Demobilization	LS	1	4,000.00	4,000
			Subtotal =	23,200
			25% Contingency =	5,800
			Total Cost =	29,000

Assumes: - no utility conflicts

6. Provide increased storage capacity in the small wetland at the intersection of Long Hill Road and Poquonnock Road. To increase storage and detention in this wetland, a concrete wall or earthen berm should be constructed along the eastern edges of the wetland to an elevation of 21 NGVD. This would potentially reduce the peak flows for a 25-year storm event from 68 to 21 cfs.

Table 8.2-3
Shopping Plaza System Storage Construction Cost

Option 1: Concrete Wall

Activity	*Unit*	*Amount*	*$/Unit*	*Cost in $*
Concrete	CY	128	600.00	76,800
Excavation	CY	242	8.50	2,100
Mobilization/ Demobilization	LS	1	4,000.00	4,000
			Subtotal =	82,900
			25% Contingency =	20,700
			Total Cost =	103,600

Assumes: - wall dimensions 2' above grade, 12" thick reinforced concrete
- no utility conflicts

Option 2: Earthen Berm

Activity	*Unit*	*Amount*	*$/Unit*	*Cost in $*
Bank excavation & fill	CY	725	20.00	14,500
Outlet structure	EA	1	3,000.00	1,700
Topsoil	CY	183	10.00	1,800
Mobilization/ Demobilization	LS	1	4,000.00	4,000
			Subtotal =	22,000
			25% Contingency =	5,500
			Total Cost =	27,500

Assumes: - no utility conflicts

7. Create an overflow channel along the southern side of the Stop & Shop shopping plaza. This channel would start next to the western entrance of the Stop & Shop shopping plaza, off of Poquonnock Road, and would extend to a proposed conduit that would intersect with the 96" railroad culvert, along the northern side of the railroad right-of-way.

Construction of the overflow channel might be difficult due to the railroad right-of-way and, therefore, might require slight modification of the Stop & Shop parking lot in order to fit the overflow channel. The overflow channel would be approximately 1550 feet long, four feet wide, at a slope of 0.0016 ft/ft and at depths ranging from four to six feet deep. The capacity of the overflow channel will range from 100 to 200 cfs depending on the depth, width, and freeboard.

Table 8.2-4
Shopping Plaza System Overflow Channel Construction Cost

Activity	*Unit*	*Amount*	*$/Unit*	*Cost in $*
Excavation	CY	1,607	8.50	13,700
Pavement Removal	SY	1,206	6.00	7,200
Erosion Control	LF	112	85.00	9,500
Stabilize With Seed	1,000SF	10.85	594.00	6,500
			Subtotal	36,900
			25% Contingency =	9,200
			Total Cost =	46,100

Assumes: - placement of silt fence every 100' in channel
- no pavement excavation necessary
- no utility conflicts

8. Maintenance of the catch basins and culverts, along Poquonnock Road in the area of the railroad bridge, should be increased so that sediment does not block them entirely.

Estimated Cost: Not Applicable (can be done by Town Public Works Department as part of regularly scheduled maintenance)

The Southern Long Hill Road System

Lateral CB365 to CB200 - Long Hill Road

9. Allow gutter flow and install a slotted drain along the gutter line of Route 1, connecting to CB209. The slotted drain would extend 60' up Route 1 from CB209.

Table 8.2-5
Southern Long Hill Road System Lateral CB365 to CB200
Improvement Costs

Activity	*Unit*	*Amount*	*$/Unit*	*Cost in $*
Slotted drain	LF	60	31.70	1,900
Trenching	LF	60	6.00	400
			Subtotal =	2,300
			25% Contingency =	600
			Total Cost =	2,900

Assumes: - 12" diameter subgrade drain pipe
- assumes capacity approximately 5.5 cfs
- no utility conflicts

The Northern Long Hill Road System

Trunk line CB384 to CB383 - Route 1

10. Allow gutter flow to extend down to CB383. The Southern Long Hill Road System will pick up excess gutter flows not picked up by CB383.

Estimated Cost: Not applicable

Trunk Line MH384B to INV384C - Outlet

11. Replace the undersized 24" CMP outlet pipe with a 36" RCP.

Table 8.2-6
Northern Long Hill Road System Improvement Costs

Activity	*Unit*	*Amount*	*$/Unit*	*Cost in $*
Remove ex. 24" pipe	LF	95	8.90	800
Trenching & Backfill	CY	85	6.50	600
30" RCP	LF	95	43.00	4,100
			Subtotal =	5,500
			25% Contingency =	1,400
			Total Cost =	6,900

Assumes: - Catch basins and manholes can be retrofit to accommodate new pipe size.
- no utility conflicts

Lateral CB382 to MH384A - Route 1

12. Replace the pipe extending from CB382 to MH384A with a 30" RCP.

Table 8.2-7
Northern Long Hill Road System Lateral CB382 to MH384A
Improvement Cost

Activity	*Unit*	*Amount*	*$/Unit*	*Cost in $*
Remove ex. 24" pipe	LF	167	8.90	1,500
Trenching & Backfill	CY	148	6.50	1,000
36" RCP	LF	167	51.00	8,500
			Subtotal =	11,000
			25% Contingency =	2,800
			Total Cost =	13,800

Assumes: - Catch basins and manholes can be retrofit to accommodate new pipe size.
- no utility conflicts

The Meridian Street System

13. The stream that flows into the system at INV411 should be realigned with a gentler radius at the bend and cleared of excess debris.

Table 8.2-8
Meridian Street Improvement Cost

Activity	*Unit*	*Amount*	*$/Unit*	*Cost in $*
Excavation	CY	127	6.50	825
Erosion Control	LF	32	0.79	25
Stabilization	1,000SF	1.6	594.00	950
		Subtotal =		1,800
		25% Contingency =		500
		Total Cost =		2,300

Assumes: - placement of silt fence every 50' in channel
- stabilization with seed

9.0 Comparison with FGA Recommendations

9.1 Hydrologic Analysis Comparison

The following is a comparison of the MMI recommendations with the 1986 FGA recommendations. Some of the differences between the MMI recommendations and the FGA recommendations are due to differences in the respective hydrologic/hydraulic analyses. The construction of Drozdyk Drive is a very significant addition to the Long Hill watershed since the completion of the FGA report. This resulted in increased impervious surface, but also increased stormwater storage due to the addition of new road culverts. These culverts have the effect of restricting flow at the road crossings, thereby increasing storage.

Table 9.1-1 is a comparison of FGA and MMI flows at similar locations within the Long Hill watershed:

Table 9.1-1
Comparison of Hydrologic Analyses

Runoff Location	*Subwatersheds*	*MMI Area (sq. mi.)*	*MMI Peak Discharge (cfs)*				*FGA Area (sq. mi.)*	*FGA Peak Discharge (cfs)*			
			Ex. 10 year	*Ex. 25 year*	*Ex. 50 year*	*Ex. 100 year*		*10 year*	*25 year*	*50 year*	*100 year*
Northern portion of watershed	MMI: 1-5 FGA: A	0.33	118	153	189	233	0.35	136	196	247	302
Inlet to culvert north of P.O. prior to routing	MMI: 1-14 FGA: A-E	0.84	166	228	300	391	0.82	172	252	318	391
Inlet to culvert north of P.O. after routing	MMI: 1-14 FGA: A-E	0.84	80	100	121	141	0.82	19	27	28	29
Inlet to R.R. culvert	MMI: 1-20 FGA: A-R	1.21	166	206	248	294	1.18	171	233	286	343

One reason for differences between the MMI and FGA TR-20 model output results is differences in discharge-storage relationships, especially at the storage area just upstream of the post office. The FGA model uses lower discharge rates and less storage volume in their TR-20 model. The FGA report does not provide storage-discharge calculations. It is, therefore, difficult to determine why their peak flows differ from those calculated in this report.

9.2 Hydraulic Analysis Comparison

For the purposes of this hydraulics comparison, the FGA recommendations have been converted to correspond to one of the five drainage systems laid out in the MMI study. The MMI costs have been grouped by system as well. FGA cost estimates often combine a number of recommendations into one cost. Individual costs for each MMI recommendation were provided previously in Section 8. The costs estimates completed by FGA are based on 1986 dollars and include a 25% contingency on each recommendation. The MMI cost estimates in this report are based on 1998 dollars and include a 25% contingency on each recommendation. The following table summarizes the costs of the two studies.

Table 9.2-1
Cost Comparison Summary

Area of Recommended Improvement	*1986 FGA Cost*	*Escalation of 1986 FGA Cost to 1998 @ 5%*	*1998 MMI Cost*
Buddington/Laurelwood Rd. System	$53,000	$95,180	$64,100
The Shopping Plaza System	$1,178,000	$2,115,520	$102,600
The Southern Long Hill Rd. System	$9,800	$17,600	$2,900
The Northern Long Hill Rd. System	$98,000	$176,000	$20,700
The Meridian Street System	$0	$0	$2,300
Orbit, Arwood, Village Rd. Outfalls	$123,000	$220,890	$0
Totals:	$1,461,800	$2,625,190	$192,600

Note: All costs include a 25% contingency fee

Buddington/Laurelwood Road System

<u>Trunk Line CB81 to JB234 – Briarcliff Mobile Home Park to Laurelwood Road</u>

The primary recommendation for this system by MMI is the replacement of a portion of the existing 24" trunk line from CB117 to CB236 with a 36" RCP. The trunk line from CB236 to JB234 is to be replaced with a 42" RCP. FGA recommended the replacement of a portion of this section of pipe from CB235 to CB111 with 36" RCP. FGA did not recommend the replacement of the sections of pipe from CB111 to CB117. MMI recommended replacing this length of pipe due to its adverse slope and tendency to collect sediment.

Lateral INV196B to MH237A – Pond to Route 1

MMI and FGA both acknowledged the pipe from INV196B (at the pond outlet) to MH237A is undersized. FGA recommended replacement of this pipe with a 30" RCP. MMI recommends leaving the existing undersized pipes in place and allowing stormwater to back up into the pond during the 25-year storm event. The undersized pipes in this area increase the pond's storage potential, thereby decreasing the peak flow that contributes to the downstream system during a storm event.

Lateral CB90 to CB84 – Briarcliff Mobile Home Park Drainage

The drainage system through the Briarcliff mobile home park was determined to be undersized by MMI. However some ponding may be acceptable in this area due to the raised nature of the surrounding structures. It is likely this system is privately owned. MMI recommended no action for this area at the present time. FGA did not address this area in their 1986 report.

Lateral YD324 to Pipe (CB239-Inv251) – Stop & Shop Parking Lot

MMI analysis indicated that the lateral located in the Stop & Shop parking lot (YD324 to Pipe (CB239-INV251)) is undersized for the 25-year storm. This section could be improved by replacing the existing piping with a 30" or 36" pipe or by replacing the existing catch basins with infiltration wells. This system is likely a private system and it is recommended to leave this lateral as is and allow some ponding in the Stop & Shop parking lot. FGA did not make recommendations for this area.

FGA provided a cost of $53,000 to complete their recommended improvements in the Buddington/Laurelwood Road system, which translates to a 1998 cost of approximately

$95,180, assuming a 5% increase in cost annually. The FGA cost included a 25% contingency. MMI estimated that the improvements in the Buddington/Laurelwood Road system will cost approximately $64,100, which also includes a 25% contingency.

The Shopping Plaza System

Trunk Line CB188 to Pipe (INV253 to INV254) – Shopping Plaza Trunk Line

The trunk line in the Shopping Plaza system was determined to be undersized by MMI and FGA. MMI has recommended a number of alternatives to address this problem, which include increasing upstream detention north of the Groton Post Office by constructing a berm at the outlet of the wetland area north of the post office. MMI also recommends to construct a berm near the intersection of Long Hill Road and Poquonnock Road to increase upstream detention. FGA recommended replacing the culvert from CB320 to CB217 with a 6' x 4' box culvert.

The capacity of trunk line behind the Groton Shopper's Mart needs to be increased. MMI recommends the construction of an overflow channel in this area to handle excess flows. FGA recommended replacing the trunk line behind the Groton Shopper's Mart with a 6' x5' box culvert.

Lateral CB185A to Pipe (INV179 to CB182) – Behind Post Office

MMI found the system located behind the Post Office (CB185A to Pipe (INV179 to CB182)) to be undersized for the 25-year storm. This system could be brought to capacity by replacing the existing pipe with a 24" and 30" RCP or by allowing ponding in this area. MMI recommends allowing ponding in this area. FGA recommended construction of a detention pond in this area.

Lateral INV317A to MH320A – Poquonnock Road System

MMI found a portion of pipe from MH317A to MH320A to be undersized due to backwater conditions in the trunk line. As mentioned previously, MMI recommends the construction of a berm at the intersection of Poquonnock Road and Long Hill

Road to increase detention and reduce downstream peak flows. Increasing the pipe size in this area will not assist in increasing the pipe capacity, due to the fact that this pipe is under backwater control. FGA recommended replacing this section of pipe with a larger 48" pipe.

MMI estimates the cost to create detention north of the post office to be $29,000. FGA estimated this cost to be $203,000. FGA recommended the construction of a larger berm area and the creation of channels from the existing outlet to the proposed detention area. The cost to construct detention at the intersection of Long Hill Road and Poquonnock Avenue was estimated by MMI based on the construction of either an earthen berm or a concrete berm. The cost was estimated to be $103,600 for a concrete berm and $27,500 for an earthen berm. The cost to construct the overflow channel behind Shopper's Mart was estimated by MMI at $46,100. The total MMI cost estimate for improvements in the Shopping Plaza system, assuming construction of an earthen berm at Long Hill Road and Poquonnock Avenue, is $102,600. The total cost for the improvements recommended by FGA was estimated at $1,078,000, with an estimated 1998 value of $2,115,520. This includes the cost of culvert removal and replacement and the construction of detention behind the post office as outlined above.

The Southern Long Hill Road System

Lateral CB365 to CB200 – Long Hill Road

MMI found two pipes in this area to be undersized for the 25-year storm: CB365 to CB199 and CB199 to CB200. Replacement of these pipes could be avoided by allowing for gutter flow along Route 1 in this area. The gutter flow can be picked up at CB209 by increasing its inlet capacity. This can be accomplished by the placement of a slotted drain upgradient of the catch basin.

MMI estimated the cost of placement of slotted drain upstream of the catch basin to be $2,900. FGA did not address this area. However, FGA did recommend improvements at the outlet of this drainage area (FGA "Bank Outfall"). FGA recommended the replacement of the existing 27" outfall with a new outfall pipe and the construction of 180 linear feet of channel at the outlet. FGA estimated this improvement to cost $9,800, with an estimated 1998 value of $17,600. MMI did not recommend the replacement of this outfall pipe because it is within hydraulic capacity during the 25-year storm event.

The Northern Long Hill System

<u>Trunk Line CB384 to CB383 – Route 1</u>

MMI found the pipe from CB384 to CB383 to be undersized for the 25-year flow. This pipe is undersized by 3.5 cfs. Therefore, replacement of the pipe is not recommended by MMI. The excess flow can be allowed to travel down Route 1 by gutter flow and will be picked up by the catch basins further down the system. FGA recommended replacing the pipe from CB384 to CB384A with a 30" pipe.

<u>Trunk Line MH384B to INV384C – Outlet</u>

The trunk line from MH384B to INV384C is undersized due to the transition from a 30" pipe to a 24" pipe at the outlet. MMI recommends the replacement of the 24" outlet pipe with a 36" pipe. FGA also recommended replacing this pipe with a 36" pipe.

<u>Lateral CB382 to MH384A – Route 1</u>

MMI recommends the replacement of the lateral from CB382 to MH384A with 30" RCP to prevent gutter flow down Route 1, due to the undersized nature of the adjacent drainage system. FGA recommended replacing the lateral line within the Groton Plaza Shopping Center (YD392 to MH384A) with 24" and 30" pipe.

FGA estimated a cost of $98,000 for all work in this area, with an estimated 1998 value of $176,000. MMI estimated a cost of $20,700 for the work detailed above.

The Meridian Street System

MMI recommends the improvement of the existing stream in this area. The cost for these channel improvements was estimated at $2,300. FGA did not recommend improvements in the Meridian Street area.

Other Recommended Improvement Areas

Additional improvements recommended by FGA were in the areas of Orbit Outfall ($17,000), Maxson Road Outfall ($40,000 but is a residential improvement; therefore, no cost to Town), Arwood Outfall ($99,000), and Village Road Outfall ($7,000). The total estimated cost of these improvements by FGA was $123,000, with an estimated 1998 value of $220,890. The Orbit and Arwood Outfalls serve only small commercial properties and do not cross any Town roads. Therefore, there were no recommended improvements on these systems in the MMI study. The culvert under Poquonnock Road at the Village Road Outfall is severely blocked with sediment. The MMI recommendation is to regularly maintain this culvert keeping it free of debris. The Town's Public Works Department can do this. Therefore, no separate cost was included in the MMI study for this recommendation.

10.0 **Funding**

There are a limited number of state and federal programs available that provide financial assistance for drainage and flood control programs as described below:

10.1 U.S. Natural Resource Conservation Service (NRCS)

The PL-566 Small Watershed Program has provided technical and financial assistance for numerous flood control projects in Connecticut. It is limited to communities with less than 50,000 people and watersheds less than 250,000 acres. The program generally requires extensive local participation and local funds for land, utilities, and some types of structures. This program was used extensively in the 1960's and 1970's, with less funding in recent years. It does not emphasize urban drainage.

A key criteria for this program is that the project must have a benefit cost ratio greater than one. This means that the average annual damages prevented by the project must be greater than the annual cost of the project. Since only extremely valuable or frequently flooded properties have high damages, it is unlikely that the Long Hill watershed program would qualify.

Contact: Phillip Renn
NRCS, STORRS, CT (860) 429-9361

10.2 CTDEP Flood and Erosion Control Program

The Connecticut Department of Environmental Protection receives annual funds for flood control, dam safety, and erosion control as authorized by Chapter 477, Section 25-69 the Connecticut General Statutes. The program is administered through the Water Management Bureau. The program is applied to both state and municipal facilities, as long as the municipal projects have two or more abutting beneficiaries. There is a cost sharing formula based upon the percentage of the abutting land that is in public ownership. Cost sharing varies from 1/3 to 2/3 of the project cost.

In order to apply, the community must have a Flood and Erosion Control Board to serve as the applicant and program manager.

Contact: Chuck Berger
DEP Inland Water Management (860) 424-3872

10.3 CTDEP River Restoration Program

The CTDEP manages the River Restoration Program as per Public Act 94-154. This program focuses on providing grants to municipalities for site specific projects and planning. Eligible projects that may be funded include restoration of degraded conditions due to channelization, erosion, limited access, water quality, sediment deposition, and for habitat improvements.

The DEP issues an annual request for grant applications, ranks them, and selects grant recipients.

Most of the recommended improvements in the Long Hill watershed concern conventional subsurface storm drains and catch basins. Consequently, it is unlikely that they would qualify for CTDEP River Restoration Program assistance.

Contact: Jay Northrop
DEP Water Management Bureau (860) 424-3877

10.4 Section 319, 1987 Clean Water Act

The 1987 reauthorization of the Clean Water Act included Section 319, which provides funding from the US Environmental Protection Agency for local projects that reduce non-point sources of pollution. In Connecticut, it is administered by the CTDEP.

The program has awarded funds for numerous demonstration projects, including modification of urban drainage systems to incorporate sediment basins and other management practices.

Contact: Stan Zaremba
CT DEP, Nonpoint Program (860) 424-3730

10.5 Voluntary Impact Fee Program

Following the completion of the 1986 FGA Long Hill Watershed Drainage Study, a voluntary impact fee program was initiated for the Long Hill watershed. The following is an excerpt from the Town of Groton, Public Works Department's outline of the program entitled *Policy for the Assignment of Recoverable Cost for Drainage Improvements Longhill Watershed, July 1988*:

> *General: It is the intention of the Town of Groton to assign and collect the cost of certain drainage improvements required by ongoing commercial developments in the Longhill drainage area deemed necessary by the Town's Consulting Engineers as reported in referenced study (1986 FGA Long Hill Watershed Drainage Study) to assure adequate control of increase storm water run off thereby reducing impact of damage to said development by the increased storm water run off.*
>
> *Method of Assignment of Cost: The cost of the recommended drainage improvements will be assigned on a per acre charge to those commercial and industrial zoned parcels (CA-12; CA-40; IA-40; IB-40; OMF; DDD) and other parcels or portions of parcels that the Town determines derives a direct benefit from the installation of said drainage improvements. The per acre charge will be determined by taking the total*

cost for said improvements escalated to January 1990 ($1,776,827) divided by the number of acres (297 acres) in the said commercial and industrial zones as shown in red on the attached map entitled "Map Showing Longhill Watershed and Various Zones: Highlighted in Color Delineating Commercial and Industrial Zones in Red and Residential Zones in Yellow - DPW June 1988 Scale 1"=1000' " (The calculations do not include any residentially zoned properties).

In the case of large parcels (10 acres of greater) with existing development at the time of additional development the acreage to be used to establish the assigned cost will be determined by the Town to reflect the area being developed and receiving direct or indirect benefits from the recommended drainage system.

<u>Per Acre Charge:</u> *$1,776,827/297 Acres = $5,982.58/Acre*
Use $6,000 Per Acre

This voluntary impact fee program provides a viable way of paying for the proposed Long Hill Drainage Improvement Project. However, due to the rate that development has occurred within the watershed and the limited amount of fees collected to date, this program has not yet provided sufficient funding for the drainage improvements. There may be a potential for supplemental funding from the Town or one of the sources outlined previously in this section. If the current voluntary impact fee program is continued, it should be adjusted to reflect the updated project costs provided in this report. However, a reduced per acre charge will further delay the collection of the full cost required to implement this project. The watershed flood damage risk could increase as the watershed continues to be developed, unless the watershed management measures recommended in this report and the 1986 FGA study are applied. Therefore, the accumulation of funds is appropriate for future preventive measures such as watershed management or downstream drainage improvements.

The updated costs and per acre charge utilizing the existing formula are summarized below.

Drainage System	Updated Cost for Improvements
Buddington/Laurelwood Rd. System	$64,100
The Shopping Plaza System	$102,600
The Southern Long Hill Rd. System	$2,900
The Northern Long Hill Rd. System	$20,700
The Meridian Street System	$2,300
Orbit, Arwood, Village Rd. Outfalls	$0
Totals:	$192,600

Updated Per Acre Charge:

$ 192,600 / 297 Commercial and Industrial Zoned Acres = $ 648.49/Acre

Use $650.00 Per Acre

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Long Hill Watershed and Drainage System
Groton, Connecticut
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Legend
Long Hill Drainage Basin
Sub-Basins
Pipe
Catch Basin
Dry-Well Catch Basin
Yard Drain
Junction Box
Water
Swamp/Marsh
N
W
E
S
Milone & MacBroom, Inc.
Groton Long Hill Watershed
Scale = 1:3,600 (1" = 300')
300
0
300
600
900 Feet