DRAFT

Campus Stormwater Master Plan
Eastern Connecticut State University
Willimantic, Connecticut

Project No.:
Contract No.:
MMI #1266-27-1

July 6, 2012

Prepared for:

Connecticut Department of Construction Services
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Hartford, Connecticut 06106

Prepared by:

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1.0 INTRODUCTION

Eastern Connecticut State University (ECSU), a campus of the Connecticut State University System, is located at 83 Windham Street in the town of Willimantic, Connecticut. Figure 1-1 is a site location map. The State University System in Connecticut is managed by a voluntary Board of Trustees that oversees Eastern as well as Western, Central, and Southern Connecticut State Universities.

ECSU is primarily centered on its main campus, with a small portion of the campus separated to the south by Prospect Street and the Kramer building (Town of Willimantic) and the Mansfield Campus Annex to the north of Route 6, which contains most of the university's athletic fields and facilities. The ECSU campus comprises approximately 182 acres, with the Mansfield Campus (Athletic Complex) making up 73 of those acres. The main campus includes approximately 42 buildings, two multistory parking garages, eight large parking lots, and five internal campus roads. A printed campus map and digital copy on CD are included in Appendix A. ECSU's land use is reflective of its status as an educational institution with residential capacity. The campus is bounded to the north by a residential neighborhood and undeveloped woodland with wetland features, and to the south, east, and west by public secondary schools including Windham High School and Windham Technical High School. The athletics facility is located on a separate parcel on the north side of Route 6. The subject Stormwater Master Plan focuses specifically on the main campus area and does not include the sports complex.

1.1 Master Plan of Development

The Campus Master Plan prepared by Symmes Maini & McKee Associates (SMMA, October 2008) includes a schedule for completion of campus expansion and improvements. A number of these improvements have been completed while some are in design, and still others are in preliminary planning stages. Table 1-1 provides a summary of the improvements scheduled to be completed as part of the Campus Master Plan and the status of their implementation.

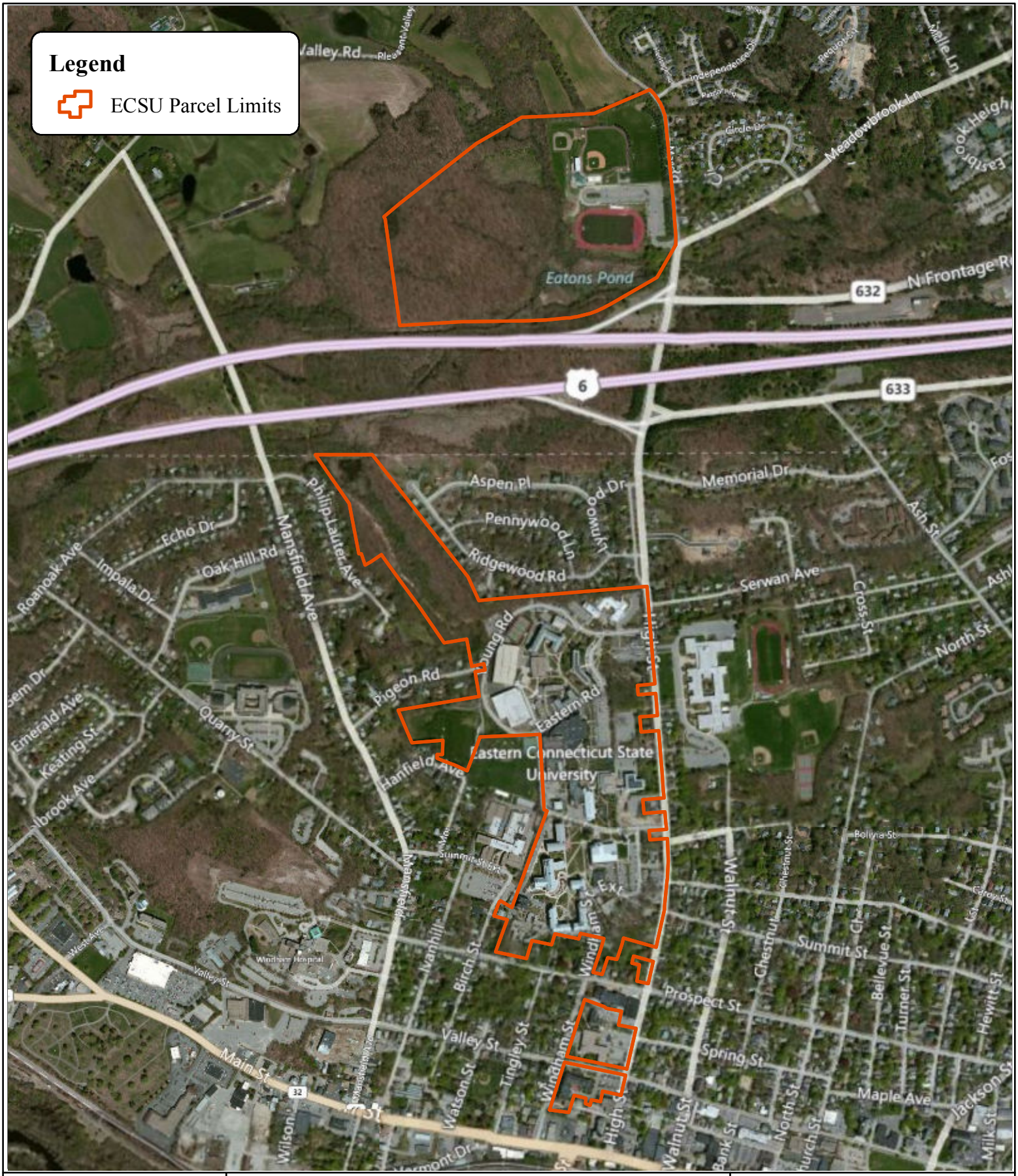

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Figure 1-1: Site Location Map

LOCATION:
Willimantic, CT

N

ECSU Stormwater Master Plan

Map By: BAM
MMI#: 1266-27
MXD: H:\1266-27\Gis\Maps\Figure1_Location.mxd
1st Version: XX/XX/201X
Revision: 6/22/2012
Scale: 1 inch = 1,000 feet

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TABLE 1-1
Summary of Master Plan Improvements as Outlined in 2008 Master Plan

Implementation Period	Scheduled Improvements	2012 Status of Improvements
1998	Fine Arts Instructional Center and new open space quad; new library	Constructed
In Progress	Four new residence halls	In planning phase
In Progress	Data Center	In planning phase
In Progress	Sports Center addition; temporary athletic building	In planning phase
	Three parking garages; new gateway; new admissions building; Early Childhood Center; campus Police Station	Gateway, admissions, Early Childhood Center, and campus Police Station constructed; three parking garages in planning phase
	New warehouse; Goddard renovation; media renovation; heat plant upgrade	In planning phase
	New academic technology/classroom building	Constructed
1998-1999	Residential housing (Mead and Niejadlik)	Constructed
	Facilities management	Constructed
2007	Expand Student Center	Constructed
2008	Public Safety building	Constructed
2009	850-car garage	Constructed
2009	Fine Arts Instructional Center	In planning phase
2010	Facilities warehouse	In planning phase
2016	Sports Center addition and renovation	In planning phase

1.2 Project Scope and Purpose

Milone & MacBroom, Inc. (MMI) has been retained by the State of Connecticut Department of Construction Services (DCS) to prepare this Campus Stormwater Master Plan. The plan is intended to provide the necessary documentation to support a Flood Management Certification (FMC) application to be filed with the Connecticut Department of Energy & Environmental Protection (CT DEEP). ECSU has obtained a number of Flood Management Certificates for various improvements on the campus. The intent for future permitting is to address stormwater management as a whole, rather than for individual construction activities as has been done in the past.

The following is a summary of the goals and objectives of this plan:

- Map the existing stormwater system using available data for pipe sizes and catch basin locations supplemented with field verification
- Analyze stormwater runoff for the watershed and for the campus to determine peak flow rates under existing conditions, historic conditions (1984), and full buildout conditions (2017)
- Estimate increases in the volume of runoff that may occur as a result of the proposed campus improvement plan and recommend mitigation measures to offset increases in downstream flow rates if necessary

- Provide specific recommendations for best management practices for stormwater management at the campus and for maintaining runoff rates as computed for the 1984 condition
- Develop a comparison of impervious coverage for the years 1984, 2012, and 2017
- Recommend Low Impact Development (LID) techniques where applicable to mitigate increased flows from proposed campus improvements

1.3 Existing Permits and Associated Reports

Table 1-2 lists permits previously secured in support of the master plan implementation.

TABLE 1-2
Summary of Existing Permits

Permit Type and ID	Project Number	Approval Date	Description
Flood Management Certification FM-2002-105		April 17, 2002	North parking "Cervantes" garage
Flood Management Certification FM-2004-189	BI-RW-244A	February 16, 2005	New science and classroom building
Flood Management Certification FM-200702019	BI-RW-291	August 5, 2008	Woman's NCAA softball field and facilities (Mansfield Campus) project replaced the fields that were eliminated due to the construction of the south parking garage.
STC No. 172-0706-01	BI-RW-260		New police facility
FM-200802066	DTC 03-227-136 BI-RW-282DB	March 16, 2009; amended October 27, 2009	South parking "Shakespeare" garage

2.0 CAMPUS WATERSHEDS

ECSU is located within two regional drainage basins, with the divide splitting the campus into northern and southern sub-basins. Figure 2-1 depicts the subregional drainage basin divide. The majority of the site, approximately 77%, slopes to the north and west into the valley and toward Route 6. This area is located within the Natchaug regional basin. Sawmill Brook is a tributary of the Natchaug River. The southern portion of the campus is located in the Willimantic River regional basin.

MMI compiled available *AutoCAD* mapping of the main campus to develop a single layer of existing information on storm drainage facilities. Base mapping was compiled from the following drawings:

- 1986 historical aerial available from Connecticut Department of Environmental Protection
- 2000 2-foot LiDar contours for the State of Connecticut

- Record Drawing ECSU Parking Garage by Manafort Brothers, Inc.; scale 1"=30'; dated October 8, 2002
- Site Utility Plan prepared for State of Connecticut Department of Public Works; prepared by ADD Inc.; scale 1"=40'; revised through March 25, 2004
- Preliminary Plan of Proposed Turning Lane, ECSU Proposed New Parking Structure CT DPW Design Building Program Documents Project #BI-RW-282-DB; prepared by Diversified Technology Consultants; scale 1:20; revised through September 13, 2006
- As Built Documents Eastern Connecticut State University Addition & Renovations to Student Center (Existing Conditions Plan, Site Utility Demolition Plan, Site Utility Plan, Site Drainage Soil Erosion and Sedimentation Control Plan); prepared by Svigals + Partners Architects; scale 1"=20'; dated October 15, 2007
- Data Accumulation Plan Showing As Built Locations New Science and Classroom Building Eastern Connecticut State University Prepared For O&G Industries, Inc. by O'Brien Associates, Inc; scale 1"=20'; dated November 13, 2008
- Sedimentation and Erosion Control Plan New Science and Classroom Building, Eastern Connecticut State University; prepared by the S/L/A/M Collaborative; scale 1"=20'; dated January 30, 2009
- Campus Master Plan for the year 2017 (Section 9, Page 4) by SMMA

MMI personnel performed a field walk-through of the campus to field check mapping and locate drainage structures not indicated on available mapping. Structures and impervious surfaces not shown on prior base mapping were field located and added. The walk-through included observations and photodocumentation of stormwater outfalls that drain campus property. Channels upstream and downstream of the outfalls were observed for scour and erosion. The roadway crossing at Prospect Street was also located and measured. Drainage mapping produced as part of this effort is included on the CD in Appendix A.

Watershed areas that drain to each outfall on campus and subwatersheds for each watershed were delineated using available topographic and storm drainage system mapping and field observation. Stormwater from the ECSU campus discharges to two watercourses via two primary outfalls: the northern portion of the campus drains to Arboretum Brook while the southern portion drains to a tributary of the Willimantic River. Figure 2-1 depicts the subregional drainage basins.

A small area in the southeast corner of the campus is located outside either of the above-referenced watersheds. This approximately 5.04-acre area contains a portion of Windham Street Extension, the Knight House, Counseling Services, Institute of Sustainable Energy, the Honors House, and associated driveways. This portion of the campus drains overland to Prospect Street and eventually to the same unnamed tributary of the Willimantic River. Street drainage in Prospect Street also discharges to this culvert. The entire subwatershed discharging runoff from east of the culvert to the culvert structure is 11.37 acres.

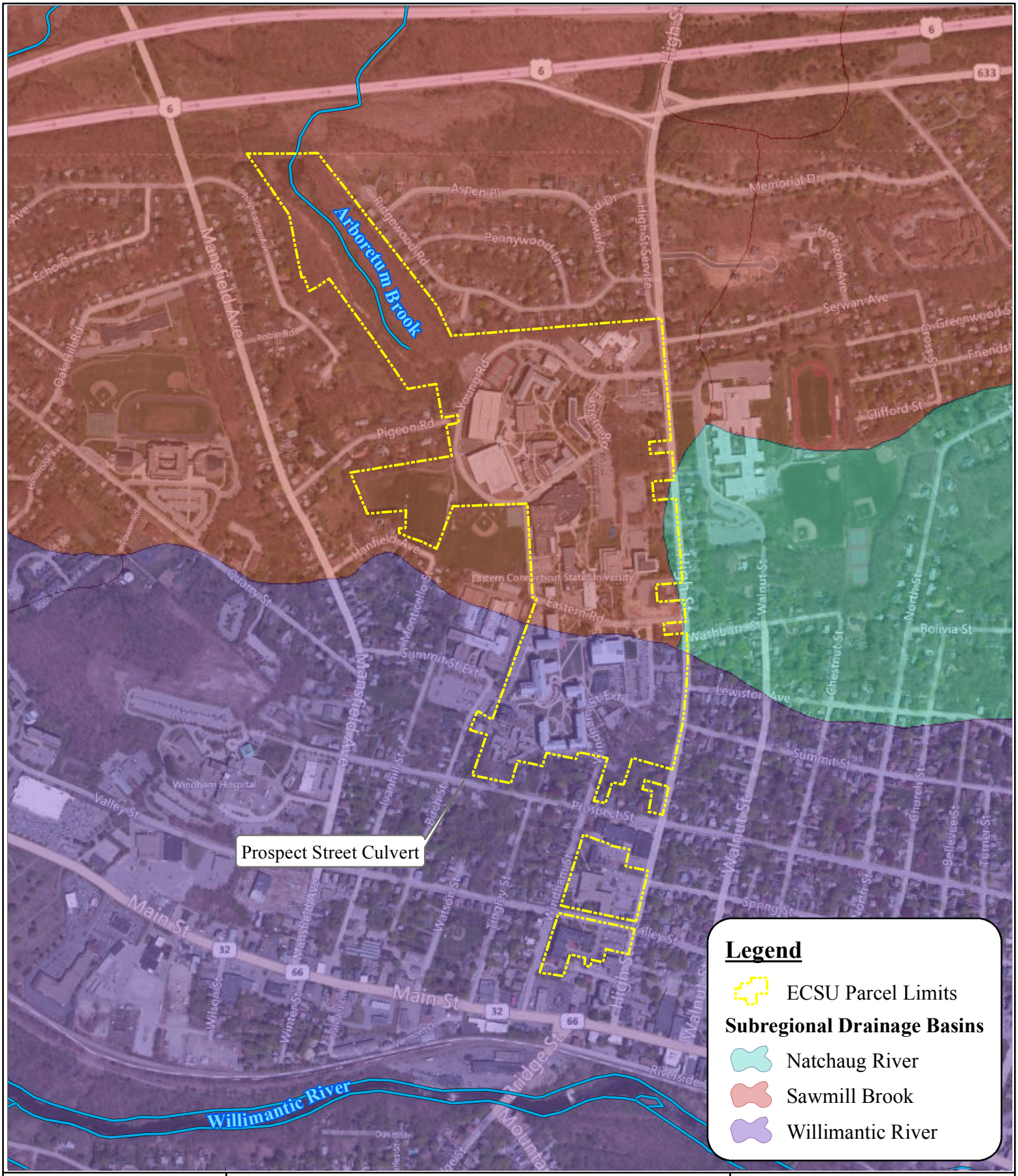

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Figure 2-1: Subregional Drainage Basins

LOCATION:
Willimantic, CT

N

ECSU Stormwater Master Plan

Map By: BAM
MMI#: 1266-27
MXD: H:\1266-27\Gis\Maps\Figure2-1_DrainageBasin.mxd
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2.1 Arboretum Brook

The northern 77% of the ECSU campus is located in the Natchaug River drainage basin (CT DEEP #3208-02-1-L1). An unnamed tributary of Sawmill Brook (aka Arboretum Brook) receives stormwater from the northern portion of the ECSU campus including the parking garages and several of the large parking lots. All runoff discharges directly to the brook through a single outfall located at the northwest corner of the campus. The watercourse flows northward under Route 6 to its confluence with Conantville Brook approximately 2,900 feet downstream of the outfall. Conantville Brook discharges to Sawmill Brook approximately 5,700 feet downstream of this confluence at the southern edge of the ECSU athletic complex property. The photograph to the right shows the broken 60" reinforced concrete pipe (RCP) outfall to the brook at the ECSU campus.

Outfall to Arboretum Brook

2.2 Tributary to Willimantic River

The southern 23% of the ECSU campus is located in the Willimantic River drainage basin (CT DEEP #3100-00-4-R2). The south end of the campus drains to a culvert at Prospect Street through a combination of piped systems and open channel. In addition to a portion of the campus, the watercourse flowing under Prospect Street receives runoff from Quarry Street, Mansfield Avenue, Handfield Avenue, Monticello Street, Summit Street Extension, and Ivanhill Street. Eventually, this watercourse empties to the Willimantic River, approximately 2,000 feet south of ECSU. The photograph to the right is taken looking upstream at the Prospect Street culvert.

Channel downstream of Prospect Street culvert

2.3 FEMA Floodplain Delineations

The Federal Emergency Management Agency (FEMA) in its Flood Insurance Study (FIS) of the Town of Windham (effective November 6, 1998) has defined a regulatory floodplain for Conantville Brook near the ECSU athletic complex north of Route 6 (Community Panel Number 090119 00004 D). There are no designated floodplains within the main campus.

2.4 Impervious Coverage Comparison

A major stormwater management goal for the ECSU campus is to maintain 1984 flows for all future improvements by incorporating LID techniques where applicable to mitigate increased flows from proposed campus improvements. Full buildout conditions result in a decrease in total impervious coverage due to inclusion of recreation areas, increased lawn areas, replacement of parking lots with parking garages, and improved internal pedestrian mobility via the removal of central campus roads. Table 2-1 provides a summary of impervious areas on campus for the 1984 (historic), 2012 (existing), and 2017 (future) conditions. Figures 2-2, 2-3, and 2-4 depict the coverages.

TABLE 2-1
Summary of Impervious Area on Campus
by Subwatershed (acre)

Subwatershed ID	Total Area (acres)	Area on Campus (acres)	1984	2012	2017
10	2.01	2.01	0.07	1.67	1.67
20	33.88	9.01	0.00	1.37	1.37
30	14.63	13.12	2.43	7.17	6.91
33	45.49	40.74	13.62	28.44	23.44
50	45.58	0.30	0.00	0.15	0.15
51	3.75	3.70	0.77	2.36	1.78
52	4.24	4.24	1.60	2.59	2.24
55	0.37	0.37	0.24	0.25	0.31
60	11.37	5.47	0.85	1.63	1.63
Total			***19.58***	***45.63***	***39.50***
Southern Parcels					
70	2.12	2.08	1.74	1.74	1.60
80	1.62	1.51	1.00	1.00	1.00
90	1.81	1.15	0.39	0.39	0.40
100	2.09	2.09	1.86	1.86	1.86
200	0.38	0.30	0.04	0.04	0.04
Total			***5.03***	***5.03***	***4.90***

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SITE PLAN - IMPERVIOUS COVERAGE (1984)

EASTERN CONNECTICUT STATE UNIVERSITY FLOOD MANAGEMENT CERTIFICATE

WILLIMANTIC, CONNECTICUT

DESIGNED	DRAWN	CHECKED
–	BAM	NEB

SCALE: 1"=300'

DATE: 6/30/2012

PROJECT NO.: 1266-27

SHEET NO.: Fig. 2-2

SHEET NO. Fig. 2-3	PROJECT NO. 1266-27	DATE 6/30/2012	SCALE 1"=300'
DESIGNED I	DRAWN BAM	CHECKED NEB	

SITE PLAN - CURRENT IMPERVIOUS COVERAGE (2012)

EASTERN CONNECTICUT STATE UNIVERSITY
FLOOD MANAGEMENT CERTIFICATE

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N E S W

Drawing: P:\1266-27\DESIGN\CAD\CURRENT\ECSU-2012.DWG Layout tab:IMPERVIOUS
Plotted by: BECKYM On this date: Tue, 2012 June 26 - 10:36am

Drawing: P:\1266-27\DESIGN\CAD\CURRENT\ECSU-2017.DWG Layout tab:IMPERVIOUS Plotted by: BECKYM On this date: Mon, 2012 June 25 - 12:29pm

SHEET NO. **Fig. 2-4**

PROJECT NO. 1266-27

DATE 6/30/2012

SCALE 1"=300'

DESIGNED I

DRAWN BAM

CHECKED NEB

SITE PLAN - IMPERVIOUS COVERAGE (2017 FULL BUILD-OUT)

EASTERN CONNECTICUT STATE UNIVERSITY
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2.5 Hydraflow Model Input

Details of each drainage system are presented in subsequent sections of this report. The Hydraflow Hydrographs Extension of the *AutoCAD Civil 3D* program was used to predict the peak surface water runoff rates (hydrographs) generated by the watersheds contributing to each of the analyzed outfalls. The program is capable of analyzing the hydrologic properties of complex watersheds, determining runoff from historical and synthetic storms, and planning or modeling flood control measures, such as detention ponds. The following narrative describes model input and methodology.

2.5.1 Rainfall Data

The input data for rainfall events with statistical recurrence frequencies of 50%, 10%, 4%, 2%, and 1% annual chance events were obtained from the Extreme Precipitation in New York & New England website, a joint collaboration of the Natural Resources Conservation Service (NRCS) and the Northeast Regional Climate Center (NRCC). The site includes estimates of extreme rainfall for various durations (from five minutes to 10 days) and recurrence intervals (one year to 500 years) at specific locations throughout New England.

Previous campus drainage analyses utilized the precipitation data referenced in the Connecticut Department of Transportation *Drainage Manual* Appendix B, taken from the "Rainfall Frequency Atlas of the United States" Technical Paper No. 40 (TP-40), by the U.S. Department of Commerce, Weather Bureau. These data have been categorized by county and are lower than the more recent estimates from the Extreme Precipitation site.

MMI utilized the more conservative rainfall data for all drainage analyses described in the following sections. MMI also performed drainage analyses using the TP-40 values as well, the results of which can be found in Appendices C, E, and G. Table 2-2 provides a summary of both rainfall data.

TABLE 2-2
Rainfall Data

Annual Chance Storm Event	NRCS 24-Hour Rainfall (inches)	TP-40 24-Hour Rainfall Windham County (inches)
50%	3.22	3.2
10%	4.71	4.8
4%	5.84	5.5
2%	6.88	6.2
1%	8.11	6.9

2.5.2 Land Use

The impervious coverage for each subwatershed was determined from MMI-compiled mapping, site visits, aerial photographs, and CT DEEP 2002 land use Geographic Information System (GIS) mapping. In general, the primary land use and coverage is developed, with either impervious (sidewalk/pavement/building) or lawn area in the campus sections of the sub-basins. Additional watershed that extends into the surrounding areas can be characterized as deciduous forest (at the northwest limits of the campus property), turf and grass, and barren.

2.5.3 Soils

Soils are classified by the U.S. NRCS based upon the ability of the soil to allow stormwater to infiltrate. Soils with low infiltration capacities tend to promote the runoff of stormwater and consequently generate greater stormwater volumes in the watershed. Soils are classified as A, B, C, or D 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 NRCS Web Soil Survey was used to determine soil classifications for the ECSU subwatersheds. Soils within the watersheds consist primarily of the smoothed Udorthents soil group, varying in hydrologic soil groups B, C, and D with moderate to low infiltration rates. For analysis, MMI assumed a soil group C for areas characterized as lawn over Udorthents. Hydrologic soil group mapping is shown in Figure 2-5.

2.5.4 Runoff Curve Number

The runoff curve number (CN value) is an empirical system used to determine surface water runoff volumes from a specified rainfall. Hydrologic soil group, land use, hydrologic condition, and the antecedent moisture condition determine CN values. Curve numbers are published by the NRCS in "Urban Hydrology for Small Watersheds (TR-55)" (June 1986).

CN values were developed for the ECSU campus sub-basins using NRCS TR-55 and TR-20 manuals, field data, and the *National Engineering Handbook N. 4* (NEH-4). The CN values are based on average antecedent moisture conditions (AMC-II). The following assumptions were made in developing CN values that are specifically adjusted for the ECSU watershed:

- ✓ 1/8-acre residential areas are of high connectivity. Roads have curbs and storm drains, no dry wells or infiltration units exist, and roof runoff is connected to storm drains or streets.

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Figure 2-5: Hydrologic Soil Group Mapping

LOCATION:
Willimantic, CT

N

ECSU Stormwater Master Plan

Map By: BAM
MMI#: 1266-27
MXD: H:\1266-27\Gis\Maps\Figure2-5_Soils.mxd
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- ✓ ¼-acre residential areas are of average connectivity. Roads have curbs and storm drains, no dry wells or infiltration units exist, and few roof drains are connected to the street.
- ✓ 1/3-acre residential areas are of moderate connectivity. Roads are usually lacking in storm drains, some swales and ditches are used, few dry wells or infiltration units exist, and pervious areas are assumed to be 25% wooded.
- ✓ Cultivated land is assumed to be row crops in straight rows with good hydrologic conditions.
- ✓ Meadows are assumed to be 100% grass mowed for hay.
- ✓ Wooded areas are assumed to be typical of disturbed wood lots in residential areas.
- ✓ Forest areas are assumed to have four inches of humus cover on the floor.
- ✓ Open spaces are assumed to be representative of parks, golf courses, ball fields, cemeteries, etc. in excellent hydrologic condition.
- ✓ Commercial areas are assumed to be 85% impervious.

For ease in comparison, the CN computations differentiated between CNs off campus and CNs on campus. It is assumed for both the future buildout and historic conditions scenarios that the contributing watershed off campus remains constant. This allows for direct comparison of the runoff rates from the ECSU campus.

2.5.5 Time of Concentration

The time of concentration (T_c) is the amount of time (hours) that is required for rainwater falling within a drainage basin to travel from the most hydrologically distant point to the basin outlet. Flow through a watershed can consist of sheet flow, overland flow, channel flow, or pipe flow. A long time of concentration will distribute and attenuate the storm runoff leading to smaller peaks while a short time of concentration will result in a high peak flow. The time of concentration is a function of the roughness of the flow surface, the slope of the terrain, and the length of travel. For example, removing vegetation and increasing the amount of smooth paved surfaces during urbanization reduces time of concentration due to increased overland flow velocities.

2.5.6 Reach Storage

Long, wide flat streams may temporarily detain runoff or delay its downstream movements by preventing the free flow of water through them (i.e., reach routing). The amount of time required for the water to reach the watershed outlet depends upon several factors, including the size, shape, slope, and roughness of the channel. This time delay is important because it can significantly affect the peak rate of runoff at the watershed outlet. There are no stream channel storage sections identified within the ECSU watersheds.

3.0 ARBORETUM BROOK HYDROLOGY

As noted in Section 2, the Arboretum Brook watershed encompasses the largest drainage area on the campus and also a large residential area to the west of the campus. Subwatersheds described in the following sections are routed through two underground detention systems prior to discharging to a single 60" RCP outfall. MMI utilized the compiled base and storm drainage mapping to determine watersheds to key discharge points and subwatersheds to these detention basins.

Three hydrologic models of the campus were developed using Hydraflow to predict changes in peak runoff from historic and potential future development. Models include storage at detention ponds and underground systems. For comparative purposes, MMI assumed that the existing conditions (2012) watershed boundaries are valid for both the 1984 and 2017 scenarios. This assumption allows for a direct comparison of predicted runoff rates.

3.1 Existing Conditions (2012) Hydraflow Model

The northern portion of campus was divided into four sub-basins for hydrologic analysis. A watershed schematic in Figure 3-1 illustrates the network of sub-basins, junctions, and storage areas where reservoir routing was performed. Table 3-1 lists the subwatersheds and their sizes.

TABLE 3-1
Arboretum Brook Subwatershed Areas

Reference Number	Subwatershed Name	Size (acres)
10	South Parking Garage	2.01
20	North Parking Garage (West)	33.88
30	North Parking Garage (East-A)	14.63
33	North Parking Garage (East-B)	45.49

3.1.1 Runoff Curve Number

An overall CN value was derived for each subwatershed within the Arboretum Brook system based on the CN values calculated for each area of land use and soil hydrologic group. Subwatershed CN values are listed in Table 3-2. Calculations used to derive the overall CN values are included in Appendix B of this report.

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SITE PLAN - ARBORETUM BROOK SUBWATERSHEDS (2012)

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TABLE 3-2
Arboretum Brook
Subwatershed CN Values (2012)

Reference Number	Subwatershed Name	CN Value
10	South Parking Garage	94
20	North Parking Garage (West)	79
30	North Parking Garage (East-A)	83
33	North Parking Garage (East-B)	89

3.1.2 Time of Concentration

The time of concentration is influenced by the surface roughness and slope of the terrain as well as the length of the water's travel path. The time of concentration was calculated for each Arboretum Brook subwatershed by estimating the longest flow path to the basin outlet. The flow path was then subdivided into reaches based upon the type of flow expected to be observed in the reach (i.e., sheet flow or channelized flow) as well as the flow velocities. The time of concentration determined for each subwatershed is listed in Table 3-3. Calculations are included in Appendix B of this report. As with the CN computations, the T_c is maintained for the future buildout and historic conditions scenarios. Given the lack of historical mapping, it would be guesswork to determine an accurate T_c for the campus as it existed in 1984. Assuming constant T_c for each of the subwatersheds allows for a direct comparison of the three campus conditions scenarios and the effect of additional impervious surface.

TABLE 3-3
Time of Concentration for Subwatersheds
in the Arboretum Brook Basin

Reference Number	Subwatershed Name	Time of Concentration (T_c in minutes)
10	South Parking Garage	5
20	North Parking Garage (West)	28
30	North Parking Garage (East-A)	35
33	North Parking Garage (East-B)	15

3.1.3 Reservoir Storage

The existing detention systems in the two parking garages were designed to store significant amounts of runoff. These systems were modeled as reservoir routing under existing conditions. Stage-storage-discharge calculations were developed using data from past design reports and studies, town topography, and survey. Reservoir routing involves developing a hydrograph to determine the volume of runoff into the structure and routing the flow through the structure to determine both the outflow hydrograph and the maximum storage levels. The hydrologic analysis completed by the consulting firm

BVH Integrated Services, Inc. (BVH) during design of the structures included design data for both the northern and southern parking garage underground detention structures in the form of stage-storage tables. These values were input into Hydraflow to replicate the storage capacity of these structures.

3.1.4 Results of Hydrologic Model

The peak discharge rate and the time at which the peak discharge occurs for each of the Arboretum Brook subwatersheds were determined for rainfall events with statistical recurrence frequencies of 50%, 10%, 4%, 2%, and 1%.

Based on the MMI-computed subwatershed characteristics, the Hydraflow program could not route the predicted flow through the northern garage detention structure for the 2% and 1% annual chance storm events. The model indicates that the system is undersized for the predicted peak flows.

In order to run the route runoff through the system and obtain an overall discharge to the channel, MMI incorporated a diversion at the junction of the three subwatersheds and the outflow from the southern garage detention system. By using an iterative process, MMI determined the maximum capacity of the north garage storage system and the amount of flow predicted to bypass the structure. Table 3-4 summarizes these flow reductions for the larger design storms. Peak discharge rates are presented in Table 3-5. These peak discharges to Arboretum Brook take into account the diversions summarized in Table 3-4.

TABLE 3-4
Required Diversion for Operation of
North Parking Garage Detention Structure
Arboretum Brook Watershed

Annual Chance Storm Event	2012 Required Diversion NRCS Rainfall Q (cubic feet per second)
2%	52
1%	118

TABLE 3-5
2012 Peak Discharge Rate (cubic feet per second)
Arboretum Brook Watershed

Location	Annual Chance Storm Event (NRCS)				
	50%	10%	4%	2%	1%
Inflow to South Garage	5	8	10	11	14
Outflow from South Garage	3	6	8	10	12
Inflow to North Garage	123	213	283	295	306
Outflow from North Garage	105	165	240	244	244
Discharge to Arboretum Brook*	105	165	240	281	362

*Note: This discharge includes the diverted flow noted in Table 3-4.

3.2 Historic Conditions (1984) Hydraflow Model

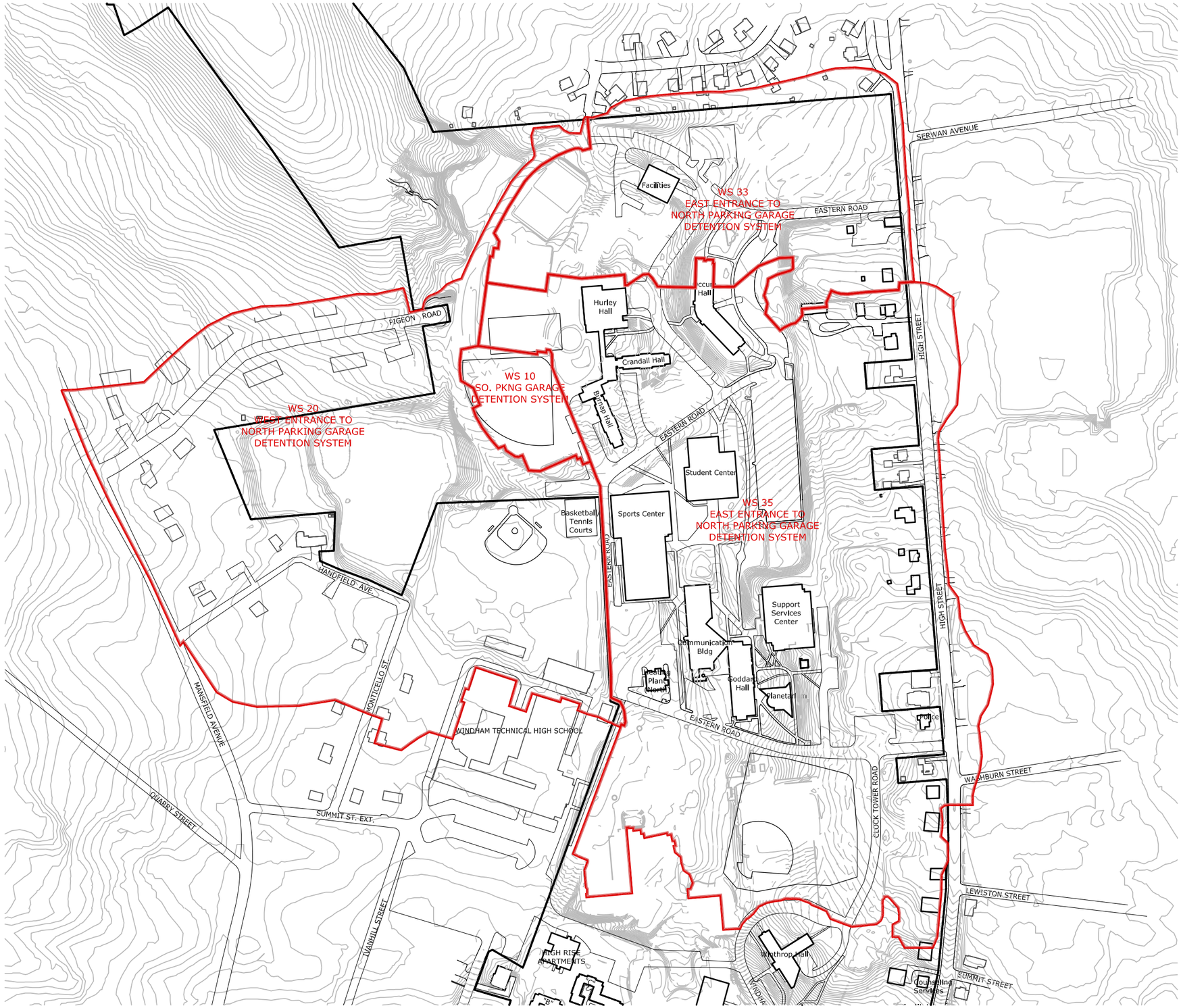
The comparison of existing campus conditions to the 1984 conditions shows significant change in impervious coverage and CN values. There were approximately 27 buildings on the 1984 campus as compared to the existing 48. In addition, the lack of parking garage structures also means lack of detention structures. The hydrologic analysis of the 1984 Arboretum Brook watershed is therefore a simple combination of the four subwatershed hydrographs. Figure 3-2 depicts 1984 campus conditions as modeled by MMI.

TABLE 3-6
Arboretum Brook
Comparison of 2012 to 1984 Subwatershed CN Values

Reference Number	Subwatershed Name	2012 CN Value	1984 CN Value
10	South Parking Garage	94	75
20	North Parking Garage (West)	79	78
30	North Parking Garage (East-A)	83	72
33	North Parking Garage (East-B)	89	80

TABLE 3-7
Arboretum Brook Watershed
1984 Peak Discharge Rate (cubic feet per second)

Location	Annual Chance Storm Event (NRCS)				
	50%	10%	4%	2%	1%
WS 10	2	4	6	8	11
WS 20	30	58	81	102	128
WS 30	8	19	27	36	46
WS 33	53	101	138	174	216
Outflow to Arboretum Brook	104	192	261	325	401



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3.3 Future Conditions (2017) Hydraflow Model

No improvements are proposed in the Campus Master Plan within WS 10 or WS 20. Master Plan improvements in WS 30 include the construction of a new residence hall and an expansion to the facilities building. Proposed improvements in WS 33 include an expansion to Hurley Hall (dining hall), construction of a new residence hall in conjunction with the demolition of Crandall and Burnap Halls, construction of a new Fine Arts Instructional Center, an expansion of the Sports Center and north heating plant, replacement of Eastern Hall with a new academic technology building, and construction of a new academic building. Figure 3-3 depicts the proposed changes in the Arboretum Brook watershed. Overall, these improvements result in the net loss of approximately 5.26 acres of impervious cover within the watershed and, therefore, a reduction of impervious coverage/CN value for the Arboretum Brook watershed. The Master Plan also calls for the rearrangement of many of the sidewalks and quadrangle formations in addition to new lawn/landscape areas. Most notable is the proposed removal of the Eastern Road vehicular access through the center of the campus.

TABLE 3-8
Arboretum Brook
Comparison of 2012 to 2017 Subwatershed CN Values

Reference Number	Subwatershed Name	2012 CN Value	2017 CN Value
10	South Parking Garage	94	94
20	North Parking Garage (West)	79	79
30	North Parking Garage (East-A)	83	82
33	North Parking Garage (East-B)	89	86

The same technique for evaluating required reduction of runoff for the northern garage detention system utilized in the 2012 analysis was applied in the 2017 analysis. Table 3-9 summarizes the required flow reductions for the 2% and 1% annual chance storm events for the 2017 full buildout condition. Peak discharge volumes are presented in Table 3-10. These discharges take into account the diversions summarized in Table 3-9.

TABLE 3-9
Required Diversion for Operation of
North Parking Garage Detention Structure
Arboretum Brook Watershed

Annual Chance Storm Event	2017 Required Diversion (NRCS) Q (cubic feet per second)
2%	44
1%	111

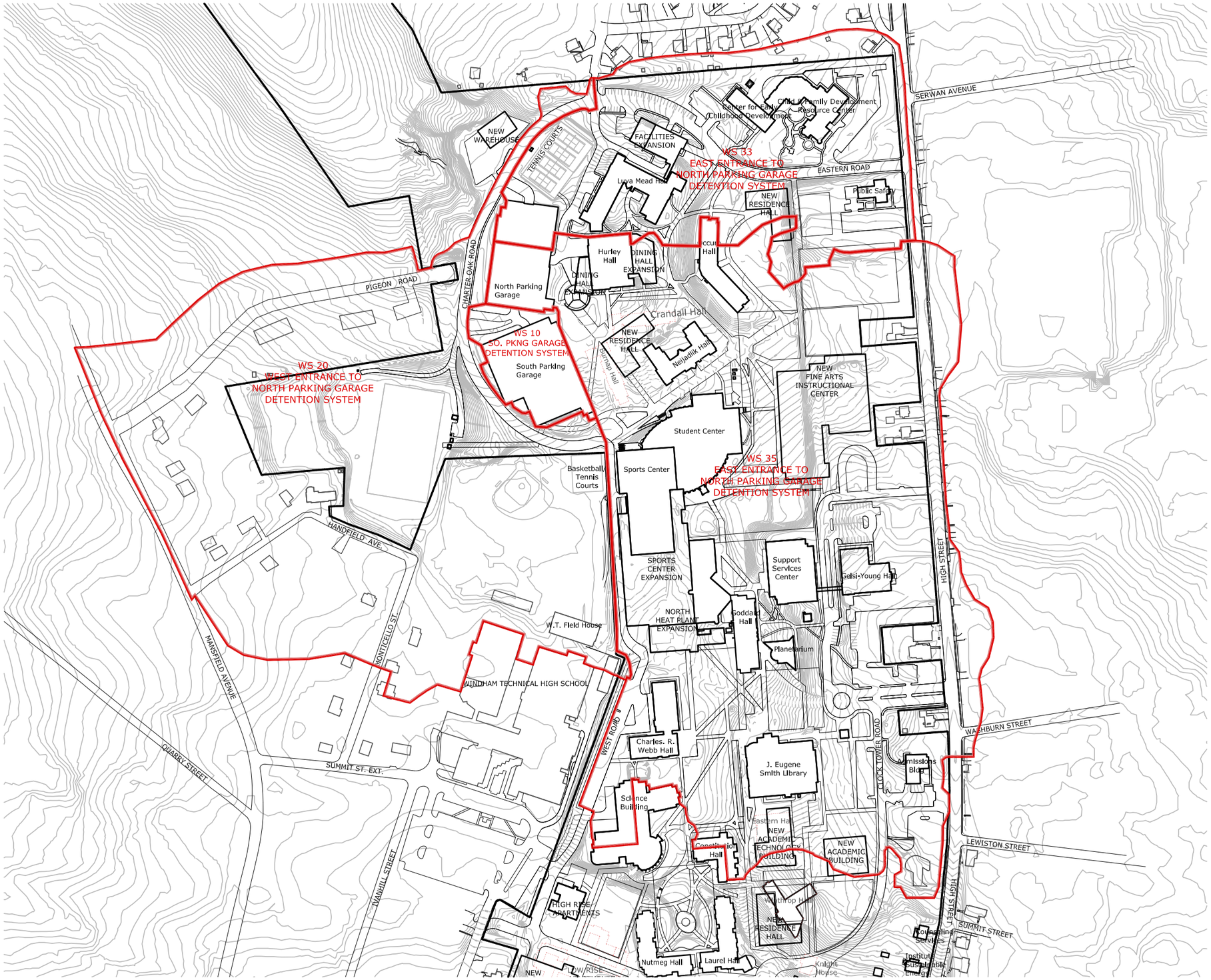

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TABLE 3-10
2017 Peak Discharge Volume (cubic feet per second)
Arboretum Brook Watershed

Location	Annual Chance Storm Event (NRCS)				
	50%	10%	4%	2%	1%
Inflow to South Garage	5	8	10	11	14
Outflow from South Garage	3	6	8	10	12
Inflow to North Garage	114	204	273	294	304
Outflow from North Garage	98	159	230	244	244
Discharge to Arboretum Brook*	98	159	230	288	355

*Note: This discharge includes the diverted flow noted in Table 3-9.

3.4 Comparison of Peak Runoff From 1984, 2012, and 2017 Condition

Table 3-11 presents a summary of estimated peak flows for 2012, 1984, and 2017 conditions. These flows include the required diversions from the north parking garage detention structures noted in the previous sections. Based on this comparison, the existing detention facilities are adequate for maintaining 1984 flood flows for all future development as contemplated in the master plan. Estimated peak flows for the 2017 full buildout condition are lower than both existing and historic conditions. This can be attributed to the reduction in impervious coverage between 2012 and 2017 conditions and the inclusion of both detention systems in the north and south parking garages (with assumed diversions). A discussion of the options for reducing peak flows to the existing detention systems is presented in Section 6.0 of this plan.

TABLE 3-11
2012, 1984, and 2017 Peak Discharge Rate (cubic feet per second)
to Arboretum Brook

Condition	Annual Chance Storm Event (NRCS)				
	50%	10%	4%	2%	1%
Existing (2012)	105	165	240	281	362
Historic (1984)	104	192	261	325	401
Future (2017)	98	159	230	288	355

4.0 PROSPECT STREET CULVERT HYDROLOGY

Approximately 9.22 acres of the southern third of the ECSU campus are located within the watershed of an unnamed tributary to the Willimantic River. The analysis point is the upstream inlet of the Prospect Street culvert. This southern subwatershed encompasses the new science building, Constitution Hall, Winthrop Hall, Nutmeg Hall, Laurel Hall, Health Services, the high-rise apartments, and the low-rise apartments. The majority of this watershed is located off campus, collecting drainage from the adjacent residential roadway network including Quarry Street, Mansfield Avenue, Summit Street Extension,

Ivanhill Street, and Windham Technical High School. Figure 4-1 depicts this watershed and the campus improvements located within it.

The Prospect Street culvert is located at a low point in Prospect Street and collects street drainage from Prospect Street east to High Street. The western limits of the street drainage were not evaluated in this analysis as development within the campus is the focus of the exercise. The culvert was treated as a junction of the two contributing subwatersheds to determine an estimated outflow from the watersheds that encompass the university.

The photographs below show the upstream and downstream faces of the culvert, which have been modified over the years. The primary structure is composed of three parallel 24-inch RCPs. Widening of the roadway to allow for sidewalks was accommodated via the construction of concrete extensions with openings at either end. The upstream face is a 48-inch wide by 42-inch high arch opening while the downstream face is a 60-inch wide by 38-inch high rectangular opening. Street drainage discharges out of the downstream face via a six-inch polyvinyl chloride (PVC) pipe.

Upstream face of Prospect Street culvert

Downstream face of Prospect Street culvert

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SITE PLAN - PROSPECT STREET CULVERT SUBWATERSHEDS (2012)

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4.1 Existing Conditions (2012) Hydraflow Model

The Prospect Street culvert conveys stormwater runoff from a relatively large watershed that encompasses the lower third of the ECSU campus in addition to residential and industrial areas to the west. For this analysis, the full watershed to the culvert was not evaluated as the large off-site street drainage system is outside the ESCU campus. MMI focused on the watersheds contributing to three outfalls that collect runoff from the ECSU campus and discharge to the watercourse conveyed through the culvert, in addition to the remaining southeast portion of the campus that discharges to the Prospect Street drainage system.

4.1.1 Runoff Curve Number

An overall CN value was derived for each subwatershed to the Prospect Street culvert based on the CN values calculated for each area of land use and soil hydrologic group. Calculations used to derive the overall CN values are included in Appendix D of this report.

4.1.2 Time of Concentration

The T_c is influenced by the surface roughness and slope of the terrain as well as the length of the water's travel path. The T_c was calculated for each Prospect Street culvert subwatershed by estimating the longest flow path to the outlet. The flow path was then subdivided into reaches based upon the type of flow expected to be observed in the reach (i.e., sheet flow or channelized flow) as well as the flow velocities. Calculations are included in Appendix D of this report. As with the CN computations, the T_c is maintained for the future buildout and historic conditions scenarios. Given the lack of historical mapping, it would be guesswork to determine an accurate T_c for the campus as it existed in 1984. Assuming a constant T_c for each of the subwatersheds allows for a direct comparison of the three campus conditions scenarios.
Hydrologic characteristics for each of the subwatersheds are summarized in Table 4-1.

TABLE 4-1
Prospect Street Culvert
Existing (2012) Hydrologic Analysis Parameters

Reference Number	Subwatershed Name	Size (acres)	CN	T_c (minutes)
50	Off-Site Western WS to 24" Outfall	45.58	83	42
51	On-Site WS to 15" Outfall	3.75	89	5
52	On-Site WS to Low-Rise Apartments Detention Basin	4.24	89	5
55	On-Site WS to 24" Outfall	0.37	90	5
60	Southeast WS to Prospect Street Culvert Catch Basins	11.37	82	10

4.1.3 Reservoir Storage

An existing detention basin located to the southeast of the low-rise apartments (Building "E") provides some measure of peak flow mitigation for runoff from WS 52. Design plans provided by ECSU were utilized to estimate reservoir capacity based on contour areas and dimensions of the outlet structure at its western edge. The bottom of the basin was estimated to be at elevation 322.0 feet, having a total depth of three feet. The outlet structure consists of a v-notch weir and 24-inch high density polyethylene (HDPE) outlet pipe. The basin was included in the model runs but did not effectively attenuate flows during storm events. This, combined with the fact that the basin is eliminated in the campus buildout and did not exist in 1984, led us to delete it from the modeling.

4.1.4 Results of Hydrologic Model

The peak discharge rate and the time at which the peak discharge occurs for each of the Prospect Street subwatersheds was determined for rainfall events with statistical recurrence frequencies of 50%, 10%, 4%, 2%, and 1%. Peak discharge rates are presented in Table 4.2.

TABLE 4-2
Prospect Street Culvert
2012 Peak Discharges (cubic feet per second)

Reference Number	Annual Chance Storm Event (NRCS)				
	50%	10%	4%	2%	1%
50	42	75	101	126	154
51	8	13	17	20	24
52	9	15	19	23	28
55	1	1	2	2	2
Inflow to Culvert	47	83	112	138	169
60	16	30	40	50	61

4.2 Historic Conditions (1984) Hydraflow Model

As with the northern campus watersheds, the delineated southern subwatersheds and T_c were held constant for the historic conditions analysis. Changes in impervious coverage and campus buildings are evidenced in the computation of the subwatershed CNs. 1984 campus conditions in the southern campus area were significantly different from existing conditions. Much of the central portion of the campus was open field or athletic fields in 1984. The 1984 southern campus consisted of Winthrop Hall, the high-rise apartments, the low-rise apartments, and the various converted residential buildings built in the 1940s. The detention basin located behind Building E of the low-rise apartments was not present in 1984. Figure 4-2 depicts 1984 campus conditions as modeled by MMI.

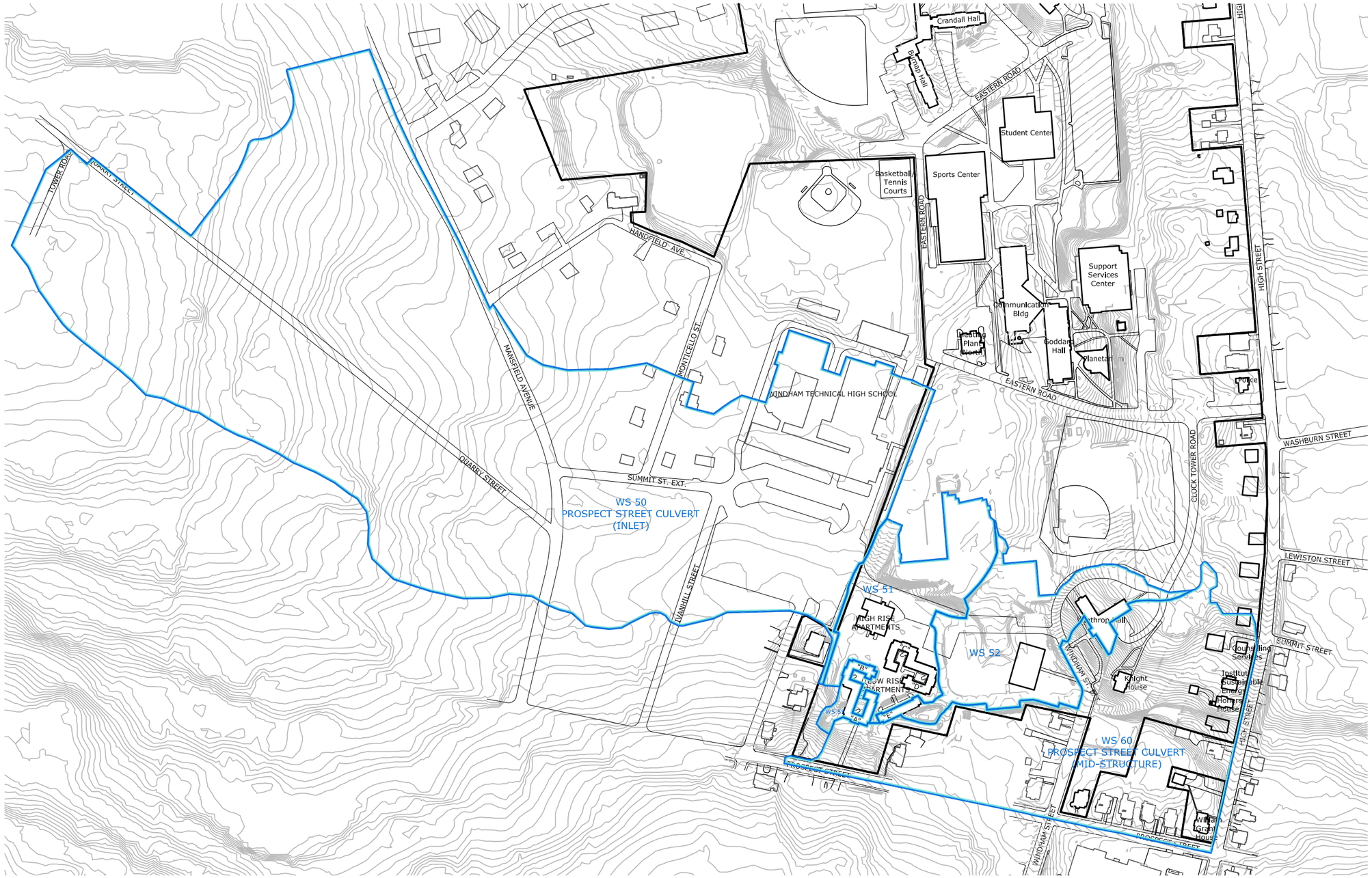

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TABLE 4-3
Prospect Street Culvert
Comparison of 2012 to 1984 Subwatershed CN Values

Reference Number	Subwatershed Name	2012 CN Value	1984 CN Value
50	Off-Site Western WS to 24" Outfall	83	83
51	On-Site WS to 15" Outfall	89	79
52	On-Site WS to Low-Rise Apartments Detention Basin	89	83
55	On-Site WS to 24" Outfall	90	90
60	Southeast WS to Prospect Street Culvert Catch Basins	82	80

4.3 Future Conditions (2017) Hydraflow Model

Proposed improvements as presented in the Campus Master Plan within WS 50 include the construction of a new parking garage and academic space, construction of a new student wellness center, removal of the low-rise apartments, and the construction of an academic technology building, new residence hall, and new academic building (the latter three located partially in the watershed). Improvements in WS 60 include a portion of the southwest parking garage, a portion of a new residence hall, and an additional parking garage. Figure 4-3 depicts 2017 campus conditions as modeled by MMI.

Proposed improvements will result in the construction of a building over the current location of the existing detention basin to the rear of the low-rise apartment buildings. This basin provides storage for runoff from WS 52. Table 4-4 presents CN values for existing and future proposed conditions. Tables 4-5 and 4-6 present modeling results.

TABLE 4-4
Prospect Street Culvert
Comparison of 2012 to 2017 Subwatershed CN Values

Reference Number	Subwatershed Name	2012 CN Value	2017 CN Value
50	Off-Site Western WS to 24" Outfall	83	83
51	On-Site WS to 15" Outfall	89	86
52	On-Site WS to Low-Rise Apartments Detention Basin	89	87
55	On-Site WS to 24" Outfall	90	94
60	Southeast WS to Prospect Street Culvert Catch Basins	82	82

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SITE PLAN - PROSPECT STREET CULVERT SUBWATERSHEDS (2017)

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TABLE 4-5
2012, 1984, and 2017 Peak Discharge Rate (cubic feet per second)
to Prospect Street Culvert (WS 50-55)

Condition	Annual Chance Storm Event (NRCS)				
	50%	10%	4%	2%	1%
Existing (2012)	47	83	112	138	169
Historic (1984)	46	82	111	137	168
Future (2017)	46	83	111	138	169

TABLE 4-6
2012, 1984, and 2017 Peak Discharge Rate (cubic feet per second)
to Prospect Street Culvert (WS 60)

Condition	Annual Chance Storm Event (NRCS)				
	50%	10%	4%	2%	1%
Existing (2012)	16	30	40	50	61
Historic (1984)	15	28	38	48	59
Future (2017)	16	30	40	50	61

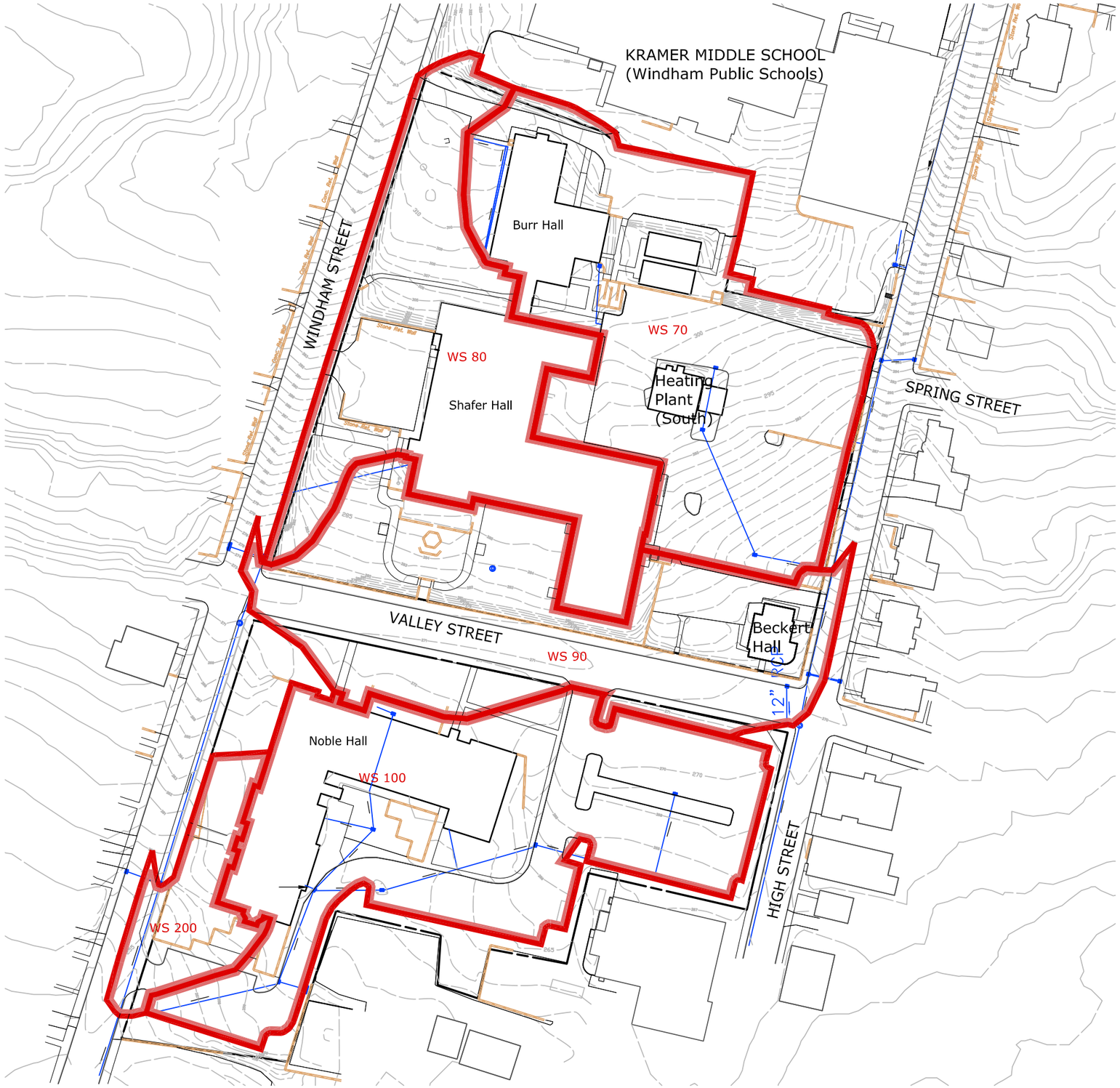
5.0 HIGH STREET AND WINDHAM STREET STORM SEWERS HYDROLOGY

The ECSU main campus includes two noncontiguous parcels south of Prospect Street and Kramer Middle School. These two parcels are separated to the north and south by Valley Street and contain Burr Hall, Shafer Hall, and the south heating plant on the northern 4.5-acre parcel and Noble Hall on the southern 3.1-acre parcel. Stormwater runoff discharges to public drainage systems within either Windham Street to the west or High Street to the east. Both of the parcels are located within the Willimantic River regional watershed. Figure 5-1 depicts the subwatersheds modeled by MMI.

Hydrologic analysis of the stormwater runoff from these parcels for the 1984, 2012, and 2017 conditions involve simple hydrographs for each of the subwatersheds. Channel or reservoir routings are not required to compare the various conditions.

5.1 Existing Conditions (2012) Hydraflow Model

The delineation of the subwatersheds for the two ECSU southern parcels reflects the relatively simple configuration of roof leaders and pavement runoff to storm sewers in the surrounding public streets. The northern parcel, containing Burr Hall, Shafer Hall, and the south heating plant, has been divided into three subwatersheds. Stormwater runoff from Burr Hall and the south heating plant, along with associated paved parking areas and sidewalks, discharges to High Street at the east of the parcel. Stormwater runoff from Shafer Hall and its associated parking area accessed via Windham Street discharges to the Windham Street storm drainage system. The lawn area to the south of Shafer Hall as well as Beckert Hall discharge stormwater to Valley Street, the dividing



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SITE PLAN - HIGH ST. & WINDHAM ST. SUBWATERSHEDS (2012/1984)

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line between the northern and southern parcels. Valley Street slopes eastward, and its storm drainage piping connects to the system in High Street. The southern parcel contains Noble Hall and its associated parking area. Stormwater runoff from this parcel discharges to the drainage system in Windham Street, to the west of the parcel.

5.1.1 Runoff Curve Number

There is very little variation in land use within the subwatersheds for the two southern parcels. Land cover is either impervious (building, pavement) or lawn. CN values for each of the subwatersheds were computed based on these characteristics.

5.1.2 Time of Concentration

Given the small subwatershed areas and the predominance of impervious coverage, the T_c for each of the subwatersheds was computed to be the minimum five minutes.

5.1.3 Reservoir Storage

There are no detention structures within either of the southern two parcels.

Hydrologic characteristics for each of the subwatersheds are summarized in Table 5-1.

TABLE 5-1
High Street and Windham Street Storm Sewers
Existing (2012) Hydrologic Analysis Parameters

Reference Number	Subwatershed Name	Size (acres)	CN	T_c (minutes)
70	Burr Hall/Heating Plant to High Street	2.12	94	5
80	Shafer Hall to Windham Street	1.62	90	5
90	Valley Street	1.81	88	5
100	Noble Hall and Parking Lot to Windham Street	2.09	95	5
200	Noble Hall to Windham Street	0.38	82	5

5.1.4 Results of Hydrologic Model

The peak discharge rate and the time at which the peak discharge occurs for each of the High Street and Windham Street subwatersheds were determined for rainfall events with statistical recurrence frequencies of 50%, 10%, 4%, 2%, and 1%. Peak discharge rates are presented in Table 5-2.

TABLE 5-2
High Street and Windham Street Storm Sewers
2012 Peak Discharges (cubic feet per second)

Reference Number	Annual Chance Storm Event				
	50%	10%	4%	2%	1%
70	5	8	10	12	14
80	4	6	7	9	11
90	4	6	8	10	12
100	5	8	10	12	14
200	1	1	1	2	2

5.2 Historic Conditions (1984) Hydraflow Model

As with the main campus watersheds, the delineated subwatersheds and T_c for the parcels south of the main campus were held constant for the historic conditions analysis. Changes in impervious coverage and campus buildings are evidenced in the computation of the subwatershed CNs. Based on aerial mapping, it appears that there was little to no difference between the 1984 conditions at these southern parcels and the 2012 existing conditions. Runoff CNs and peak discharges therefore remain constant for the comparison of 1984 to present.

5.3 Future Conditions (2017) Hydraflow Model

Proposed improvements from the Campus Master Plan include the construction of a parking garage to the east of Shafer Hall, which encompasses the existing south heating plant, and the creation of a recreational area in the location of an existing parking lot to the east of Noble Hall. The garage is proposed in an area currently utilized as a paved parking lot. The reduction in the parking lot at Noble Hall decreases impervious coverage in subwatershed WS 100. As the majority of both parcels are and have been (i.e., since 1984) characterized by impervious cover, the proposed modifications will have no effect on the curve numbers under future buildout conditions. Figure 5-2 depicts 2017 campus conditions as modeled by MMI.

TABLE 5-3
High Street and Windham Street Storm Sewers
Comparison of 2012 to 2017 Subwatershed CN Values

Reference Number	Subwatershed Name	2012 CN Value	2017 CN Value
70	Burr Hall/Heating Plant to High Street	94	93
80	Shafer Hall to Windham Street	90	90
90	Valley Street	88	88
100	Noble Hall and Parking Lot to Windham Street	95	95
200	Noble Hall to Windham Street	82	82

0' 50' 100'
0 1/2" 1"

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SITE PLAN - HIGH ST. & WINDHAM ST. SUBWATERSHEDS (2017)

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Fig. 5-2

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Table 5-4 summarizes the computed runoff rates for the 2017 full buildout conditions based on the changes in CN summarized in Table 5-3. Changes from the 2012 existing conditions are shown in bold. The runoff rate for WS 70 decreases by nine cubic feet per second (cfs) for the 100-year storm. Therefore, no detention should be required to maintain peak flow rates for the full buildout conditions.

TABLE 5-4
High Street and Windham Street Storm Sewers
2017 Peak Discharges (cubic feet per second)

Reference Number	Annual Chance Storm Event				
	50%	10%	4%	2%	1%
70	5	8	10	12	14
80	4	6	7	9	11
90	4	6	8	10	12
100	5	8	10	12	14
200	1	1	1	2	2

6.0 CONCLUSIONS AND RECOMMENDATIONS

The goal of maintaining 1984 flows for 2017 conditions has been achieved through the two existing detention areas below the parking garages. Although these structures are modeled in our analysis as being undersized to fully detain the 2% and 1% annual chance events, the overall peak discharge from the campus to Arboretum Brook is still less than in 1984. A number of options exist for mitigation of the flows that bypass the detention structures. The Campus Master Plan affords many opportunities for low impact and "green" technology in addition to the proposed decrease in impervious coverage between 2012 and 2017 site conditions through the removal of roadways and other paved areas in the central portion of the campus. These are explored further below.

6.1 Low Impact Development

LID addresses predicted changes in the portion of rainfall that does not contribute to surface runoff, or rainfall abstraction. By incorporating LID design methods into proposed improvements, predevelopment conditions can be maintained by compensating for losses of rainfall abstraction through maintenance of infiltration potential, evapotranspiration, and surface storage, as well as increased travel time to reduce excess runoff. In addition to control of stormwater quantity, LID has the potential to increase the stormwater quality of a site ("Low-Impact Development Design Strategies, An Integrated Design Approach" Prince George's County, Maryland Department of Environmental Resources Programs and Planning Division, June 1999.*)* Low-impact development practices can include:

- Bioretention facilities (rain gardens)
- Drywells

- Filter/buffer strips and other multifunctional landscape areas
- Grassed swales, bioretention swales, and wet swales
- Rain barrels
- Cisterns
- Infiltration trenches

One aspect of LID is to preserve infiltratable soils by minimizing disturbance of soils with high infiltration rates and placing impervious areas on more impermeable soils. Soil types identified in Section 2.5.3 are primarily Udorthents-Urban land complex throughout the majority of the campus. A narrow section of Hydrologic Soil Group B soils is located through the center of the site according to NRCS mapping; however, it can be assumed that past development has disturbed site soils so that underlying materials cannot be assumed to reflect typical infiltration values of a B soil.

The LID hydrologic evaluation requires that the postdevelopment (2017 full buildout scenario) T_c be maintained close to the predevelopment (2012 existing conditions) T_c. Techniques for achieving this that may be applicable at ECSU include:

- Maintaining predevelopment flow path length by dispersing and redirecting flows through open swales
- Increasing surface roughness (vegetated swales)
- Detaining flows (open swales, rain gardens)
- Disconnecting impervious areas (eliminating curb/gutter and redirecting downspouts)

6.1.1 Rain Gardens

Rain gardens are a popular form of bioretention practice, typically used to directly infiltrate runoff from roof leaders via a soil bed and planting material instead of discharging the runoff directly to a storm sewer. In addition to providing minor retention of stormwater, rain gardens provide water quality treatment. Rain gardens can be incorporated into areas surrounding buildings or in landscaped islands within large parking areas. Pretreatment areas are required where there is a potential for significant debris or suspended material. Grass buffer strips or vegetated swales can be incorporated into the system design to provide pretreatment for high debris areas such as parking lots.

Design of a rain garden requires a certain level of infiltration in the in-situ soil in addition to augmented planting soil and appropriate plantings. They typically require only routine landscape maintenance.

6.1.2 Pervious Pavement

Pervious pavement allows for infiltration of surface water into underlying gravel and often incorporates biofiltration islands within large parking areas. The University of

Rhode Island recently experimented with the use of porous pavement in their 800-car parking lot expansion. Continued monitoring has indicated that infiltration areas have been affected by vegetation growth, and infiltration capacity of the pavement itself can be easily affected by snow stockpiles and sanding/salting (which should not be allowed in porous pavement parking areas). Although the parking area is generally performing as designed, the ECSU Campus Master Plan does not call for an expansion of surface parking areas. Therefore, pervious pavement is not a viable option for campus improvements.

6.1.3 Green Roof Technology

Green roof technology has evolved from basic sod roofs to more advanced systems that can be incorporated into building design and that require minor maintenance. In addition to peak flow reduction, green roofs also help to keep buildings cool in summer and warmer in winter, an energy conservation practice that would benefit ECSU.

A green roof absorbs stormwater until the growth media becomes saturated, at which point water begins to flow from the rooftop. Research conducted at Southern Illinois University, Edwardsville, has shown that a green roof with four inches of growth media is capable of retaining over 50% of annual rainfall (*Forrester et al. 2007).* Green Roof Blocks are proprietary products with a relatively simple ease of installation and maintenance. The photographs below are from the company website.

The Campus Master Plan includes the construction of three new parking garages, four new residence halls, dining hall expansions, Sports Center expansion, and three new academic buildings. Because these structures are still in the design phase, there is an opportunity for incorporating green roof technology. However, this would provide a relatively minor offset to peak flows.

6.1.4 Roof Runoff Retention

Rain barrels are a low cost and easily maintainable retention device. They operate by retaining a predetermined volume of rooftop runoff, with an overflow pipe providing some detention beyond the capacity of the barrel itself. Retained rainfall can be used later for irrigation during drier months. They would have only minor effects on the total watershed runoff.

Stormwater runoff cisterns operate in a similar fashion to rain barrels, providing retention storage volume in underground storage tanks. Again, stored rainwater can later be reused, conserving water and reducing water utility costs. Individual cisterns can be installed beneath each downspout, or larger storage volumes can be provided in large, common cisterns.

6.2 LID Options for North Parking Garage Detention System Flow Diversion

As discussed in Section 3.1.4, the existing detention system in the north parking garage is undersized for anticipated flows from its large contributing watershed. The following sections discuss options for reduction of flows to the underground detention system. Figure 6-1 depicts schematics for diversion options within Watershed 20.

6.2.1 Pigeon Road Subwatershed (WS 20)

A large portion of off-campus stormwater runoff is conveyed into the north garage detention system via a drainage swale from the northern end of the Pigeon Road cul-de-sac. If this drainage system were diverted from the detention structure and instead directed to an independent detention basin or bioretention basin at the northwest corner of the campus, it would remove approximately 5.24 acres of contributing watershed to the northern garage detention system. The basin could be designed to provide detention and water quality treatment for this stormwater runoff and discharge to Arboretum Brook.

Eliminating the 5.24-acre off-campus watershed would result in a reduction of peak flows to the parking garage detention structure. MMI estimated the peak runoff rate expected from this contributing watershed area by utilizing a CN of 83. This CN is based on a general land use of ¼-acre residential over C-type soils (CN of 83) as noted in the TR-55

manual. Table 6-1 summarizes the estimation of flows for the 50% through 1% annual chance rainfall events based on the 5.24-acre watershed. The resulting flow reduction would only be a partial offset for the required diversion computed in Section 3.1.4.

TABLE 6-1
Estimated Peak Flows From Pigeon Road Subwatershed

Annual Chance Rainfall Event	Q (cubic feet per second)
50%	9
10%	16
4%	21
2%	26
1%	32

6.2.2 Athletic Fields Subwatershed (WS 20)

A bituminous paved swale, located in WS 20, conveys stormwater runoff from the adjacent athletic fields to a catch basin that discharges to the northern parking garage detention system. As shown in the photograph to the right, there is ample area between the fence line and the playing fields for construction of a vegetated swale, a bioretention area, or an infiltration trench. Disconnecting this watershed from the contributing area to the northern garage detention system would also decrease peak flows to the structure. It may be possible to infiltrate all of the runoff from this area into a trench, or it could be connected to a future detention basin used for control of the Pigeon Road runoff. The contributing area to this drainage swale and small series of catch basins in the athletic fields is approximately 4.48 acres. Figure 6-1 depicts a schematic for this diversion option.

If the off-campus and athletic field area to the west of the campus were to be hydraulically separated from the detention system in the northern parking garage, a total area of 31.81 acres of watershed could be diverted to a separate detention/water quality facility. An estimated CN for this area is 80 based on the land use, and T_c is 10 minutes. Using Hydraflow, this watershed produces a 2% annual chance flow of 133.5 cfs and a 1% annual chance flow of 165.61 cfs. A summary of estimated runoff rates is presented in Table 6-2. Recall from Section 3.1.4 that diversions of 44 cfs and 111 cfs are required for the 2% and 1% annual chance rainfall events, respectively, for the proper operation of

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Fig. 6-1

SHEET NO.

the detention system under 2017 full buildout conditions. The diversion of runoff from this off-campus and field area is more than enough to reduce flows to the north garage detention structure required to function properly.

TABLE 6-2
Estimated Peak Flows From Athletic Field Subwatershed

Annual Chance Rainfall Event	Q (cubic feet per second)
50%	41
10%	78
4%	106
2%	133
1%	166

6.2.3 Rain Gardens at Individual Buildings

Impervious areas in the watersheds contributing to the northern garage detention system are primarily composed of buildings, sidewalks, and roadways. The configuration of ECSU buildings presents a viable opportunity for the incorporation of rain gardens at roof leader locations. As much of the parking is provided in the two large parking garages and will be further increased via additional parking garages in the full buildout condition, there are fewer opportunities for parking area bioretention.

Bioretention areas require a minimum surface area range of 50 to 200 square feet, a minimum depth of two to four feet, and a soil permeability of at least 0.27 inches/hour. Soil infiltration limitations can be overcome with use of underdrains. Rain gardens should be located a minimum distance of 10 feet downgradient from buildings and foundations.

Rain gardens are effective for reducing peak flows for more frequent, smaller storms but may become inundated during larger storm events. They would not provide a significant peak flow offset as part of the ECSU campus complex.

6.2.4 Green Roof Technology

The conversion of "impervious building" to "lawn" could also be achieved through the use of green roof technology. This option may not be as feasible for existing buildings but could potentially be incorporated into the design of the 2017 improvements.

Recent studies conducted in North Carolina determined the equivalent CN for a green roof during storms larger than a 1.5 inch rainfall is 88. ("A North Carolina Field Study to Evaluate Greenroof Runoff Quantity, Runoff Quality, and Plant Growth," Amy Moran, Dr. Bill Hunt, Dr. Greg Jennings; www.bae.ncsu.edu/greenroofs).

The Campus Master Plan calls for the construction of a Facilities building expansion, dining hall expansion, four new residence halls, a Fine Arts Instructional Center, a Sports Center expansion, two new academic buildings, and three new parking garages. All but the three parking garages and one new residence hall are located within a watershed contributing runoff to the detention systems in the northern parking garage. This means that they are potential candidates for green roofs in order to lessen the peak flows to the existing detention structure.

If all proposed structures in WS 30 and WS 33 were to be constructed with green roofs, only the predicted CN value for WS 33 would be reduced from 86 to 85. This reduction would not be sufficient for reducing peak flows required to allow the north parking garage detention structure to operate as designed.

6.3 Conclusions

As stated in Section 1.2, a goal of this ECSU Campus Stormwater Management Plan was to determine the required reduction in runoff rates to maintain 1984 peak flows for the 2017 full buildout conditions. In each of the subsequent sections, MMI completed an analysis for each subwatershed within the ECSU parcel boundaries. These analyses identified flow reduction needs for the Arboretum Brook watershed and the Prospect Street culvert watershed. The 1984 conditions for the southern parcels will not be drastically affected by Campus Master Plan improvements and, as such, will not require any flow mitigation. Table 6-3 summarizes the peak 1% annual chance event flows for each of the analyzed watersheds. Note that the flow reductions required do not take into account the storage provided by the north garage detention basin.

TABLE 6-3
Summary of 1% Annual Chance Storm Event
Peak Flows by Watershed (cubic feet per second)

Watershed ID	1984	2012	2017	Reduction to Maintain 1984 Flows
Arboretum Brook				
10	11	14	14	3
20	128	131	131	3
30	46	57	56	10
33	216	246	237	21
Prospect Street Culvert				
50	154	154	154	0
51	21	24	23	2
52	26	28	27	1
55	2	2	3	1
60	59	61	61	2
Windham and High Streets				
70	14	14	14	0
80	11	11	11	0
90	12	12	12	0
100	14	14	14	0
200	2	2	2	0

The required flow reductions for the Prospect Street culvert subwatersheds can easily be achieved through the incorporation of rain gardens at roof leaders or via the incorporation of green roofs at the proposed buildings in the southern portion of campus.

As noted in Section 3, flows to the northern garage detention system must be reduced for the system to function for the 2% and 1% annual chance storm events. Table 3-9 noted that a flow of 44 cfs must be diverted for the 2% annual chance storm, and a flow of 111 cfs must be diverted for the 1% annual chance storm. Once these flows are removed from the contributing watershed, 2017 peak flows will be less than those experienced in 1984. Table 6-4 compares the 1984 to 2017 peak flows to Arboretum Brook, taking into account the detention systems in the parking garages.

TABLE 6-4
1984 and 2017 Peak Discharge Rates
to Arboretum Brook With Detention (cubic feet per second)

Condition	Annual Chance Storm Event				
	50%	10%	4%	2%	1%
Historic (1984)	104	192	261	325	401
Future (2017)	98	159	230	288	355

Based on the stormwater runoff analysis completed, MMI recommends that stormwater be diverted from the existing northern detention basin by traditional means such as an open detention basin or series of basins. Although the opportunities for green development technology would be compatible with the Master Plan, these LID methods would not be sufficient for diverting the necessary volume of water from the detention system.

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