Connecticut Department of Transportation

Climate Change and Extreme Weather Vulnerability Pilot Project

Final Report December 2014

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This report presents the results of a Climate Resilience Pilot Project conducted by Connecticut Department of Transportation (CTDOT) and sponsored in part by the Federal Highway Administration (FHWA). CTDOT was awarded a pilot to conduct a systems-level vulnerability assessment of bridge and culvert structures six feet to 20 feet in length from inland flooding associated with extreme rainfall events. The project focused on structures in the northwest corner of the state. The Department chose to conduct a vulnerability assessment of inland flooding because in recent years extreme precipitation events have been more frequent and intense, resulting in damage to the Department's infrastructure in several locations in the State. While this damage has not been significantly widespread, it poses safety concerns and can be costly to repair or replace.

The Scope of Work for this project included the following main elements: data collection and field review, hydrologic and hydraulic evaluation, criticality assessment and hydraulic design criteria evaluation. Identification of structures six feet to 20 feet in length in the northwest corner of the state and data collection was accomplished using the state's bridge inventory. This inventory included over 176 structures on the state system. This inventory was pared down to 60 structures identified for field evaluation. Of the 60 identified for field evaluation, 52 were selected for hydrologic and hydraulic evaluations.</td></tr>
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Executive Summary

This report represents the work and findings of the Connecticut Department of Transportation's 2013 Climate Change and Extreme Weather Vulnerability Pilot Project. The project was conducted during the Spring of 2013 through Fall of 2014. The project was completed by the Department utilizing staff from multiple units, primarily the Bureau of Engineering's Hydraulics and Drainage Office, the Bureau of Policy and Planning's Office of Strategic Planning and Projects, and the Bureau of Finance's Office of Capital Services. Multiple other units supported the study team including Roadways Information systems, Bridge Maintenance, Environmental Planning, Traffic Monitoring, and the Highway Design units. Additional outreach and support was conducted and provided by the State Department of Energy and Environmental Protection, the Department of Emergency Services and Public Protection, the Northwest Connecticut Council of Governments and the area's emergency responders.

The Connecticut Department of Transportation (CTDOT) has conducted numerous assessments of its facilities both independently and jointly with other state agencies in the past. CTDOT is also currently part of the tri-state Hurricane Sandy *Follow-up and Vulnerability Assessment and Adaption Analysis* with New York and New Jersey, which is focusing on coastal assets and adaptation efforts.

The scope of this project was identified in response to the U.S. Department of Transportation's 2012 *Solicitation for Pilot Projects: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options Analyses*, which was jointly sponsored by the Office of Environment, Planning, and Realty and the Office of Infrastructure. The solicitation sought applications that conducted analyses related to climate change and extreme weather adaptation in one of the following two manners:

1) Assessment of transportation vulnerability to climate change and/or extreme weather events, or

2) Development of options for improving resiliency of transportation facilities or systems to climate changes and/or extreme weather events.

The CTDOT was awarded a pilot to conduct a systems-level vulnerability assessment of bridge and culvert structures six feet to 20 feet in length from inland flooding associated with extreme rainfall events. The project focused on structures in the northwest corner of the state.

The Department chose to conduct a vulnerability assessment of inland flooding because in recent years extreme precipitation events have been more frequent and intense, resulting in damage to the Department's infrastructure in several locations in the State. While this damage has not been significantly widespread, it poses safety concerns and can be costly to repair or replace.

The Scope of Work for this project included the following main elements: data collection and field review, hydrologic and hydraulic evaluation, criticality assessment and hydraulic design criteria evaluation.

Identification of structures six feet to 20 feet in length in the northwest corner of the state and data collection was accomplished using the state's bridge inventory. This inventory included over 176 structures on the state system. This inventory was pared down to 60 structures identified for field evaluation. Of the 60 identified for field evaluation, 52 were selected for hydrologic and hydraulic evaluations.

Together, the hydrologic and hydraulic evaluations indicate the adaptive capacity of the structure and its ability to convey additional flows that may result from increased precipitation. Using the hydraulic evaluation results along with spatial and social factors, a matrix was developed to rate the criticality and vulnerability of the structures. Finally, based on the design experience of the project staff as well as the investigations performed for this project, recommendations regarding the hydraulic design criteria in consideration of extreme events and climate change are presented.

Some of the evaluation results, key findings and recommendations of the report can be summarized as follows:

1. The results of the hydraulic evaluations show that of the 52 structures evaluated, **34 structures or 65 percent** satisfied the design water surface elevation criteria for the specified design frequency discharge based on the current precipitation estimates; however, 13 of these structures may require some corrective action due to scour. **18, or 35 percent** of the 52 structures do not satisfy the hydraulic design criteria and **are therefore hydraulically inadequate** based on the current precipitation estimates.

2. The procedures used by engineers in hydrologic and hydraulic design have a certain level of conservativeness built in. In addition, the current hydraulic design criteria and standards also provide some conservativeness and resiliency to the design which will allow for some potential future variations in the precipitation and discharge estimates. **However, when exceptions to one or more of the design standards are made for such reasons as site constraints, reducing environmental and property impacts, project scope and funding limitations, the structures may become less adaptable and resilient.**

3. The results of the hydraulic evaluations for this project should not be equated to the adequacy of the current hydraulic design criteria and standards. The structures evaluated in this project have been in service ranging from approximately 60- to 100-years. There is no clear indication that the Department's existing structures, which were previously designed using older data and methods, are now significantly under-designed since having been subjected to the increased rainfall and changing climate conditions occurring over the last few decades. **Most of the structures evaluated under this project are approaching the end of their useful service life. Age and deteriorating condition are likely more of a concern than climate change.**

4. Compliance with the stream crossing requirements of the U.S. Army Corps of Engineers' general permit typically results in upsizing of structures beyond what is needed to satisfy hydraulic requirements. Currently, floodplain and storm water management regulations may restrict the hydraulic design to maintaining "existing conditions" in the case of a structure that is significantly undersized and hydraulically inadequate by design

standards, where "opening up" the restriction with a larger structure would significantly increase downstream peak discharge and result in a potential adverse impact during flood events. In the past, this issue tended to arise with town or privately owned downstream crossings that are undersized, where the Department has no jurisdiction. **If upsizing structures becomes the preferred approach to address climate trends, it cannot be done on a unilateral basis, there needs to be a common understanding of purpose among all stakeholders.**

5. **A "blanket" adjustment (stricter) of design flood frequencies is not recommended at this time to address potential climate change trends.** A risk evaluation coupled with an economic cost analysis as specified in the Drainage Manual could better address the risks and costs associated with extreme flood events at critical highway structures.

6. The criticality assessments in this report use social, spatial, and hydraulic criteria. These factors support the identification and prioritization of structures most critical to preserve life and safety in the event of an emergency event. **However, there is an increasing need to also examine and develop a cost factor into criticality assessments.**

Background

Project Selection

In response to the U.S. Department of Transportation, Federal Highway Administration's (FHWA) 2012 *Solicitation for Pilot Projects: Climate Change and Extreme Weather Vulnerability Assessments and Adaptation Options Analyses*, which was jointly sponsored by the Office of Environment, Planning, and Realty and the Office of Infrastructure, the Department submitted an application through the FHWA Connecticut Division office and was selected to participate in the pilot program. Funds for the CTDOT pilot project were allocated in March 2013. The overall purpose of the program was to pilot a framework to assess climate change and extreme weather vulnerability for transportation infrastructure, which will help improve understanding on how to better manage assets in current and future climate conditions. The CTDOT pilot project chose to study an aspect of inland flooding and extreme precipitation.

Historically in Connecticut, inland flooding associated with extreme precipitation has been the predominant weather event that threatens infrastructure, safety, and health. Recent studies indicate an increasing trend in the occurrence of extreme precipitation events and rainfall intensity in the Northeastern United States. Such events have the potential to increase the frequency and severity of flooding leading to more frequent infrastructure damage and even failures, which in turn could lead to emergency declarations and subsequent reconstruction/repair projects. Emergency projects typically result in significantly higher construction costs and lengthy detours, both in travel time and duration, which impacts the quality of life for the residents, poses a risk for delayed emergency response, impacts area businesses and places unplanned financial burden on the Department's budget.

The decision to study inland flooding was also made in response to the most recent impacts of Storm Sandy. Private property along the coastline was significantly damaged from the storm surge; however, damage to the transportation system from wave action and coastal inundation was not as severe as other inland flooding events have been over the past five (5) years. Additionally, the Department has a relatively high degree of knowledge of its most vulnerable shoreline assets through historical event data and comprehensive eastern seaboard sea level rise and inundation mapping. The Tri-state Hurricane Sandy study will also help further identify shoreline asset vulnerability.

Project Scope and Objectives

The proposed scope and objectives of the CTDOT pilot project was to produce a systems-level vulnerability assessment of CTDOT bridge and culvert structures six feet to 20 feet in length from inland flooding associated with extreme precipitations events. The vulnerability assessment includes hydraulic evaluation of the structures and a criticality assessment of the roadway system. The results of the vulnerability assessment will assist the Department in identifying and prioritizing replacement and reconstruction efforts where needed.

The main elements or tasks in the scope for this project are outlined below:

- Stakeholder/Partner Outreach
- Data Collection and Field Reviews
- Hydrologic and Hydraulic Evaluations
- Criticality/Vulnerability Assessment

Each of these tasks and methodologies used, are further described in this report.

A description of the hydraulic design criteria for these structures and recommendations regarding these criteria are also included in this report.

Project Location

The geographic area of focus of the project was within select towns and regional planning areas in the northwest quadrant of the State, which is primarily rural. In rural areas, road closures impact the daily lives of residents more so than urban areas by cutting off major routes for commuters and potentially eliminating access from one end of a community to the other. Rural areas typically have less redundancy in the roadway network to accommodate detours and options for re-routing traffic within a short distance of the original route. For example, in rural areas, a closed road can result in lengthy daily school bus trips for children, often times more than double the usual time. Unexpected road closures can also restrict access to hospitals, necessities, and pose a serious risk of added time to emergency response.

Figure 1 shows the geographic region of the project. **Table 1** lists the towns within the project limits.

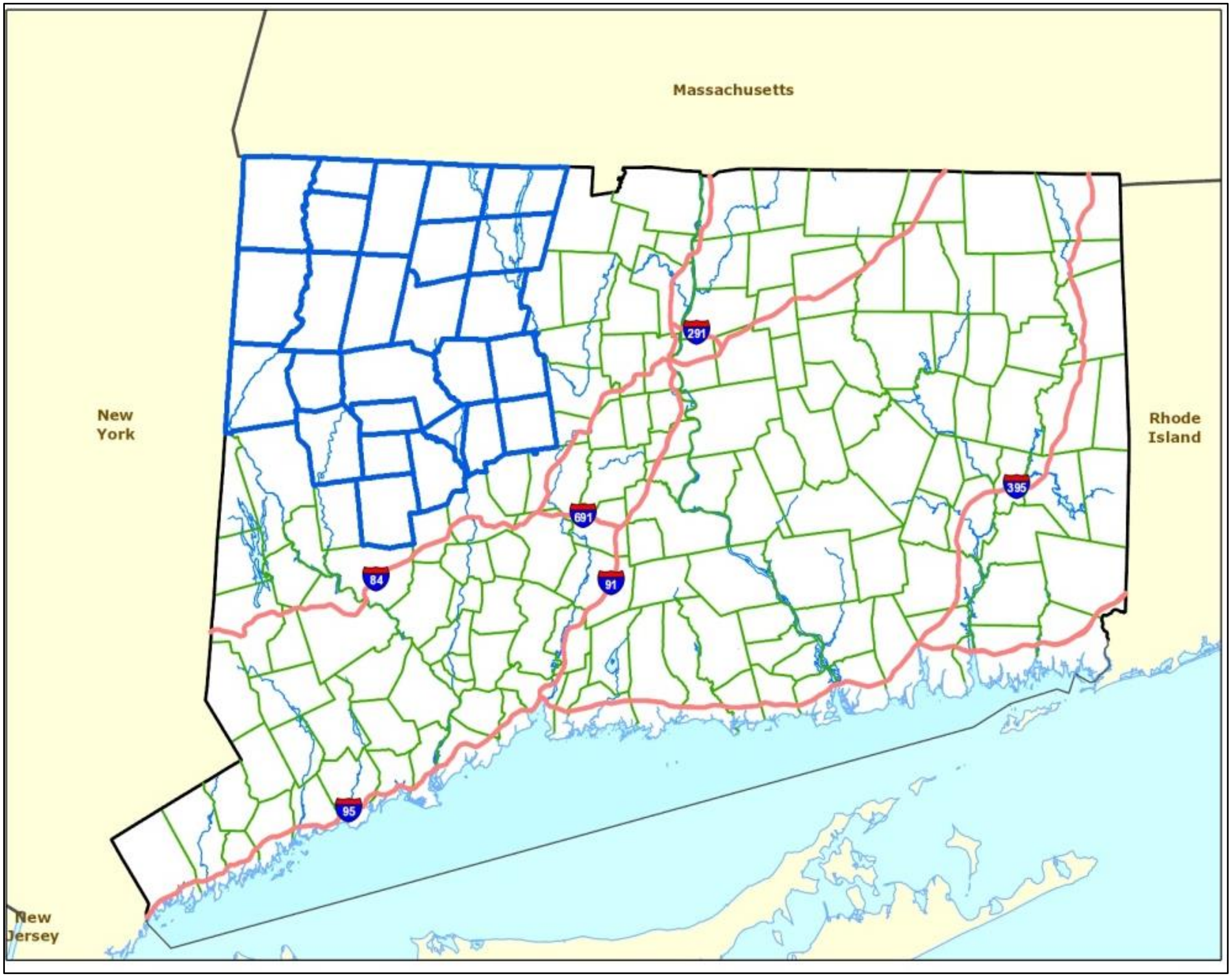


Figure 1 – Study Region (in blue outline)

Table 1 – Pilot Project Towns

DOT Town No.	Town Name	County	DOT Maintenance District	Regional Planning Organization	Square Miles
5	Barkhamsted	Litchfield	4	Litchfield Hills	38.7
10	Bethlehem	Litchfield	4	Central Naugatuck Valley	19.6
17	Bristol	Hartford	1	Central Connecticut	26.8
20	Burlington	Hartford	4	Central Connecticut	30.5
21	Canaan	Litchfield	4	Northwestern Connecticut	33.1
29	Colebrook	Litchfield	4	Litchfield Hills	32.9
31	Cornwall	Litchfield	4	Northwestern Connecticut	46.4
54	Goshen	Litchfield	4	Litchfield Hills	45.2
64	Hartland	Hartford	4	Litchfield Hills	34.3
65	Harwinton	Litchfield	4	Litchfield Hills	31.1
67	Kent	Litchfield	4	Northwestern Connecticut	49.7
73	Litchfield	Litchfield	4	Litchfield Hills	56.9
86	Morris	Litchfield	4	Litchfield Hills	18.7
91	New Hartford	Litchfield	4	Litchfield Hills	38.1
97	Norfolk	Litchfield	4	Litchfield Hills	46.3
99	North Canaan	Litchfield	4	Northwestern Connecticut	19.5
110	Plymouth	Litchfield	4	Central Connecticut	22.3
121	Salisbury	Litchfield	4	Northwestern Connecticut	60.2
125	Sharon	Litchfield	4	Northwestern Connecticut	59.7
140	Thomaston	Litchfield	4	Central Naugatuck Valley	12.1
143	Torrington	Litchfield	4	Litchfield Hills	40.3
149	Warren	Litchfield	4	Northwestern Connecticut	27.5
150	Washington	Litchfield	4	Northwestern Connecticut	38.6
153	Watertown	Litchfield	4	Central Naugatuck Valley	29.6
162	Winchester	Litchfield	4	Litchfield Hills	33.9
168	Woodbury	Litchfield	4	Central Naugatuck Valley	36.7

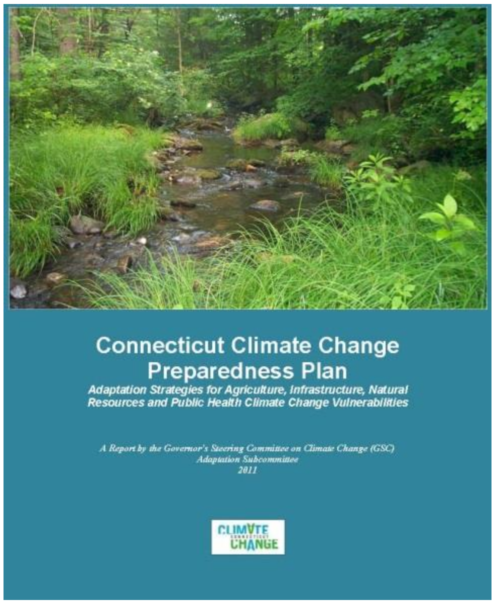
Existing Adaption Efforts

CTDOT has conducted numerous assessments of its facilities and assets both independently and jointly with other state agencies. This pilot study, with its dual components of vulnerability assessment and criticality analysis, was completed for an area which has not been studied comprehensively, and which has very limited alternative detour and accessibility options in an event of a structure failure.

The scope of this project was identified in the Connecticut Climate Change Preparedness Plan which was a product of a statewide effort that took place from 2005 through 2011. The creation of the preparedness plan included a collaborative planning process among the New England region and statewide partners to build from an earlier statewide Governors Steering Committee (GSC) on Climate Change. The GSC produced the Connecticut Climate Change Action Plan in 2005 with a goal to "*reduce greenhouse gas emissions to 1990 levels by the year 2010 and an additional 10% below that by the year 2020*." The GSC included subcommittees on transportation and land use, residential, commercial, and industrial sectors, agriculture, forestry, solid waste, and utility sectors. Each subcommittee made recommendations, primarily for regulatory changes through policy implementations that would reduce greenhouse gas (GHG) emissions.

Building on the success of interstate and interagency coordination, the 2011 Connecticut Climate Change Preparedness Plan focused on adaptation strategies for agriculture, infrastructure, natural resources, and public health. A significant portion of this plan was dedicated to transportation infrastructure adaptation strategies, including a summary of the most at-risk transportation assets from coastal inundation increases from sea level rise and inland flooding height increases due to rainfall intensity and frequency. One of the highest priorities of the Transportation Adaption Subcommittee was to further study and identify the vulnerability of the State's smaller bridge and culvert structures. More specifically, the recommendation was:

"A locational study could be conducted to determine the transportation [infrastructure] that is most at risk from potential coastal and/ or inland flooding increases and to identify alternative routes and sources of transportation for evacuation and commerce. Culverts and culvert size should be inventoried throughout the state to identify those that should be replaced or retrofitted to facilitate, and not impede, natural resource adaptation and to reduce projected flooding impacts. Furthermore, state transportation planning should incorporate the effect of climate change projections on meeting state transportation needs and the synergistic effect of new transportation and climate change on natural resources should be included." (2011, CT Climate Change Preparedness Plan)



CTDOT was the lead agency for the transportation infrastructure working group, providing technical and planning support. Several members of CTDOT's engineering and planning staff, who were instrumental in both the original Governors Steering Committee's 2005 report and the 2011 Preparedness Plan, were team leaders on this project, creating linkages to the historic planning efforts and building on existing relationships with other State and regional agencies for support.

Hydraulic Design Standards and Criteria

Introduction

The policies, procedures, practices and criteria related to hydraulic and drainage design for Department facilities are specified in the Department's Drainage Manual. The current version of the Drainage Manual was published in the year 2000 with some subsequent minor revisions; however, there has been no major update of the manual since the original publication. The Drainage Manual was produced using the American Association of State and Highway Transportation Officials' (AASHTO) 1991 version of the Model Drainage Manual as a base from which it was customized to reflect policies and procedures specific to Connecticut. The Drainage Manual is available on the Department's website (Connecticut Department of Transportation 2000, last updated 2003).

The Code of Federal Regulations (CFR) Title 23-Highways, Chapter I-Federal Highway Administration, Department of Transportation, Part 650 Bridges, Structures, and Hydraulics, Subpart A—Location and Hydraulic Design of Encroachments on Flood Plains (Code of Federal Regulations 1992), Section 650.115 prescribes design standards for the hydraulic design of highway encroachment on flood plains for federal-aid projects. Since both the AASHTO and Department Drainage Manuals were written to be consistent with the applicable federal regulations, conformance to the standards set forth in the Department's Drainage Manual results in compliance with the federal standards.

Structure Classification

Due to their type and size, the structures being evaluated under this project are considered to function hydraulically as culverts. Chapter 8 of the Department Drainage Manual (DM) provides design procedures and criteria for the hydraulic design of highway culverts which are based on FHWA Hydraulic Design Series Number 5 (HDS5), "Hydraulic Design of Highway Culverts" (James Schall 2012). It should be noted, however, that some of the criteria common to both culverts and bridges may be referenced in Chapter 9, "Bridges".

A culvert is defined as the following:

- A structure which is usually designed hydraulically to take advantage of submergence to increase hydraulic capacity.
- A structure used to convey surface runoff or a watercourse through an embankment.
- A structure, as distinguished from bridges, which is usually covered with embankment and is composed of structural material around the entire perimeter, although some are supported on spread footings with the streambed serving as the bottom of the culvert (open bottom culvert).
- Requires a structural design. In addition to its hydraulic function, it must also carry construction and highway traffic and earth loads.

The Drainage Manual classifies both culverts and bridges based on whether the structure conveys a watercourse and by the size of the drainage area. Some of the hydraulic design criteria vary by the structure classification. The Drainage Manual structure classifications are titled "Minor", "Small", "Intermediate", "Large" and "Monumental".

The structures being evaluated under this project fall within the "Small" and "Intermediate" classifications, which are defined below:

- Small Structures include culverts or bridges providing waterways for the drainage of areas of less than one square mile in which there is an established watercourse (DM Section 9.3.4).
- Intermediate Structures include culverts or bridges providing waterway for the drainage of areas larger than one square mile and less than ten square miles (DM Section 9.3.5).

Hydraulic Design Criteria

Criteria for the hydraulic design of culverts from the Department's Drainage Manual are summarized below. It should be noted that not all of the criteria outlined below were evaluated in detail (quantitatively with calculations) by this project; however, the information is being presented as having some relevance in the overall discussion of the adequacy of the hydraulic design criteria considering extreme weather events and climate change.

Allowable Headwater

Section 8.3.3 defines allowable headwater as the depth of water that can be ponded at the upstream end of the culvert during the design flood which will be limited by one or more of the following:

- non-damaging to upstream property
- one foot below the established hydraulic control (freeboard)
- equal to an headwater depth to diameter or span ratio (HW/D**)** no greater than 1.5
- the elevation where flow is diverted from the area tributary to the culvert

Freeboard

Freeboard is defined as the vertical distance between the design water surface and the upstream control such as the low point of the roadway edge, sill of a building or other controlling element.

Review Headwater

Section 8.3.4 specifies that the culvert should be analyzed for a storm of greater magnitude (check frequency) to ensure the level of inundation is tolerable to the upstream property and the roadway.

Maximum Velocity

Section 8.3.8 specifies that the maximum velocity at the culvert outlet shall be consistent with the velocity in the natural channel or shall be mitigated with outlet protection measures, energy dissipation and if required, channel stabilization.

Backwater

In general, backwater resulting from the structure should not exceed one foot above that which would have been obtained in the natural channel if the highway embankment were not constructed ("Natural Condition") for the design flood frequency. The backwater criteria typically apply to new or replacement structures only and is not being assessed in the hydraulic evaluations of this project.

Flood Frequency

Section 8.3.11 specifies that the flood frequency used to design or review culverts shall be based on:

- the level of risk associated with failure of the crossing, increasing backwater, or redirection of the floodwaters
- an economic assessment or analysis to justify the flood frequencies greater or lesser than the minimum flood frequencies listed herein (see Risk Evaluation below)
- location of FEMA mapped floodplains
- CTDOT design criteria (**Table 2**)

Table 2 - Summary of Hydraulic Design Criteria for Culverts

CONNDOT STRUCTURE CLASS	DRAINAGE AREA (mi^2)	DESIGN FREQUENCY (year)	CHECK FREQUENCY (year)	BACKWATER (ft)	MINIMUM FREEBOARD (ft)
Minor	< 1 (no established watercourse)	25	-	-	1
Small	< 1	50	100	-	1
Intermediate	$\geq$ 1 < 10	100	500	$\leq$ 1	1
Large	$\geq$ 10 < 1000	100	500	$\leq$ 1	1

In addition to the criteria summarized in **Table 2,** the flood frequencies for Small and Intermediate Structures are further described as follows:

- Small Structures shall be designed to pass a 50-year frequency discharge. However, at locations where the stream has been studied in detail by a FEMA Flood Insurance Study (FIS), a 100-year return frequency shall be used for the design discharge. The effects of a discharge equal to the 100-year flood passing through the proposed construction shall be investigated. Where a likelihood of danger to persons, extensive property damage or other than temporary interruption of traffic will exist under these conditions, increases in waterway or other improvements shall be provided to alleviate the danger.

- Intermediate Structures shall be designed to pass a discharge equal to the 100-year flood with low chord under clearance not less than one foot (not required for culverts) and a backwater usually not to exceed one foot above that which would have been obtained in the natural channel if the highway embankment were not constructed. The effects of a discharge equal to the 500-year flood passing through the proposed construction shall be investigated. Where a likelihood of danger to persons, extensive property damage or other than temporary interruption of traffic will exist under these conditions, increases in waterway or other improvements shall be provided to alleviate the danger, whenever possible.

Figure 2 presents a schematic illustrating some of the hydraulic design criteria terminology.

Scour

Scour is defined as the erosion of streambed or bank material due to flowing water and is of primary concern at the foundation supporting a span or open bottom structure that crosses a waterway. The general criteria outlined in Section 9.3.2 specifies that foundations be designed for scour considering:

- the magnitude of flood, including the one percent event, which generates the maximum scour depth
- The foundation shall be evaluated by geotechnical and structural engineers for both a design event (100-yr. storm) and an extreme event (500 year) to insure that the appropriate stability criteria are met.

The Drainage Manual directs users to FHWA publication Hydraulic Engineering Circular No. 18 (HEC-18), “Evaluating Scour at Bridges” for further guidance in evaluating and designing for scour at bridges. While erosion and scour can be a concern at culverts that are “enclosed conduits” (pipes, boxes, etc.), especially at the outlets, the types and mechanisms of scour described in HEC-18 and related to the above criteria, are applicable to open bottom structures only.

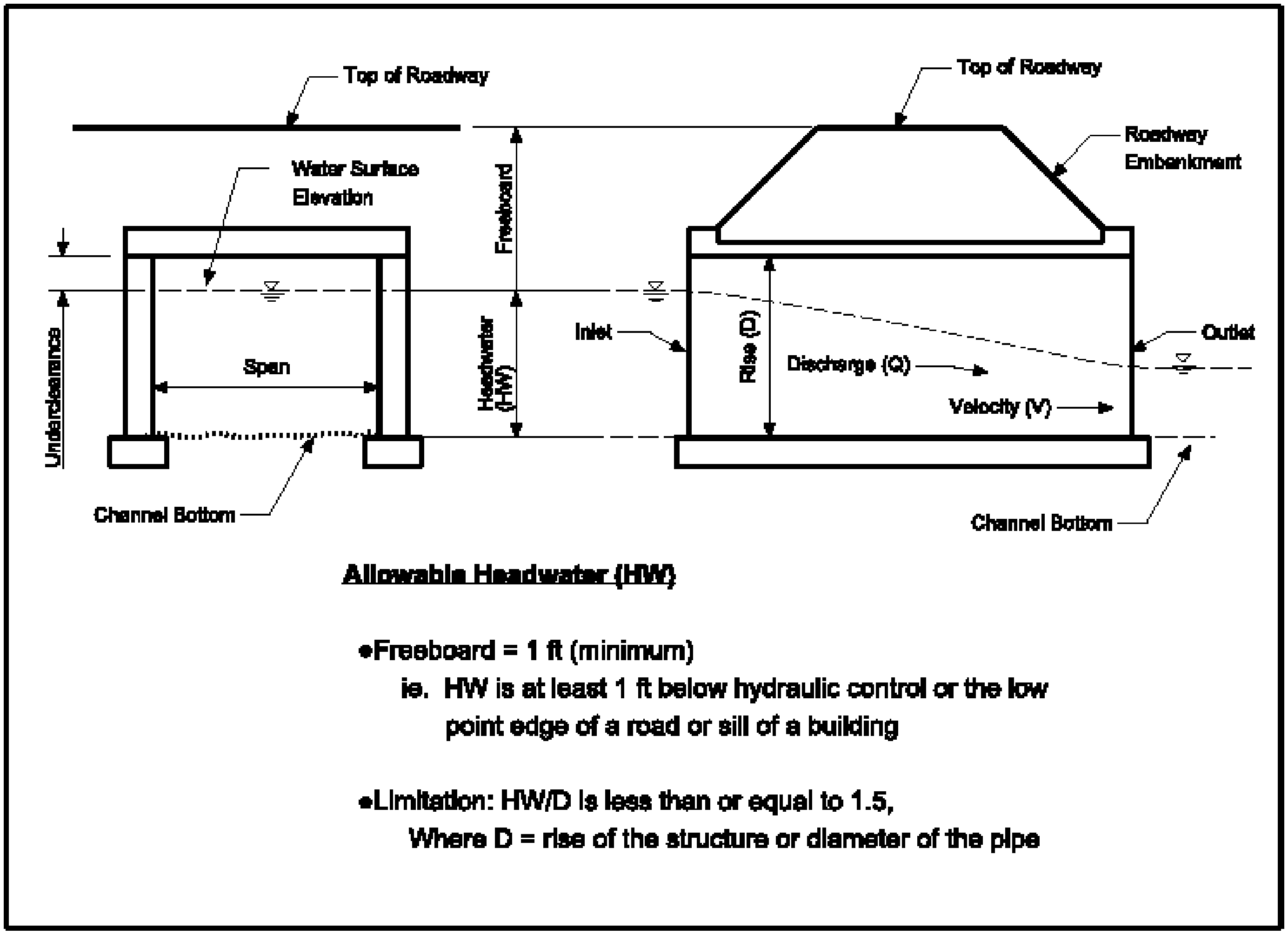


Figure 2 - Culvert Hydraulic Design Criteria Terminology

Risk Evaluation

Section 9.3.2 includes Risk Evaluation in the list of general criteria and specifies that a least total expected cost (LTEC) design alternative should be developed in accordance with FHWA HEC-17 (*Design of Encroachments on Flood Plains Using Risk Analysis*) (M.L. Corry 1981) where a need for this type of analysis is indicated by a risk assessment. The risk evaluation, including the LTEC analysis, is a tool by which site specific design criteria can be developed in lieu of applying predetermined design standards. Section 9.6.7 further describes the risk evaluation.

For federal-aid projects, risk evaluation is a requirement in the design standards for the hydraulic design of highway encroachment on flood plains prescribed in the federal regulations (23 CFR 650.115(a)(1). The FHWA has issued the following additional guidance (Code of Federal Regulations 1992) to 23 CFR 650.115(a)(1)):

> *The intent of the statement, "as appropriate, a risk analysis or assessment," in Section 23 CFR 650.115(a)(1) is to allow judgment as to the detail of design studies. Where site conditions or structural requirements substantially limit practicable design alternatives, the conventional hydraulic analysis coupled with a risk assessment should meet the requirements of the design standards. Where site conditions permit a range of design alternatives and flood losses are anticipated, an abbreviated or partial risk analysis may be appropriate. We would anticipate that use of the full scale detailed economic (risk) analysis as described in HEC-17* (4) *would not be necessary for normal stream crossings, but would apply to unusual, complex, or high cost encroachments involving flood losses*.

Other

Regulatory Requirements

In addition to the Department's hydraulic design criteria, there are certain regulatory requirements that may affect the sizing of a new or replacement bridge or culvert. Although not all regulatory requirements are outlined here, the requirements believed to be most noteworthy in the context of this project (i.e. criteria affecting the sizing of culverts) are described below.

Army Corps of Engineers (ACOE)

The activities related to the construction of a new or replacement watercourse crossing would require that a permit be obtained from the ACOE (33 CFR 323) to comply with Section 404 of the Clean Water Act (33 U.S.C. 1344). The ACOE has developed more streamlined, general permits on a nationwide and regional basis for categories of activities that are considered substantially similar in nature and cause only minimal individual and cumulative environmental impacts.

In the New England District of the ACOE, the nationwide permits have been suspended and replaced with State general permits. The State general permits use a tiered approach with categories linked to impact thresholds, which determine the level of review necessary from the ACOE perspective. In order to qualify for the general permit authorized by the ACOE for Connecticut, projects involving bridge or culvert structures must meet certain requirements depending on level of wetland impact, FEMA floodway involvement, drainage area size and whether the structure is a bridge (has an open bottom) or a culvert (has an artificial bottom).

The general permit requirements for bridges include the following:

- Structure spans at least 1.2 times the watercourse bank full width
- Structure has an openness ratio equal to or greater than 0.25 meters
- Structure allows for continuous flow and does not result in a change of the normal surface elevation of the upstream waters, waterway or wetland
- Structure incorporates a riparian bank on at least one side for wildlife passage

The general permit requirements for culverts include the following:

- Structure has an openness ratio equal to or greater than 0.25 meters
- Structure gradient is less than or equal to the streambed gradient upstream and downstream of the culvert
- Structure invert is set at least one foot below streambed elevation; (for double box crossings, at least one box is set one foot below, for culverts where one foot is not practicable, 25 percent of the pipe must be depressed)
- Structure allows for continuous flow and does not result in a change of the normal surface elevation of the upstream waters, waterway or wetland
- Structure does not impede the passage of fish

Figure 3 is a flow chart that was developed to aid in navigating the above general permit requirements.

The incorporation of the of the current general permit requirements for bridges and culverts tends to increase the size of these structures beyond the size necessary to satisfy the Department's hydraulic design criteria alone.

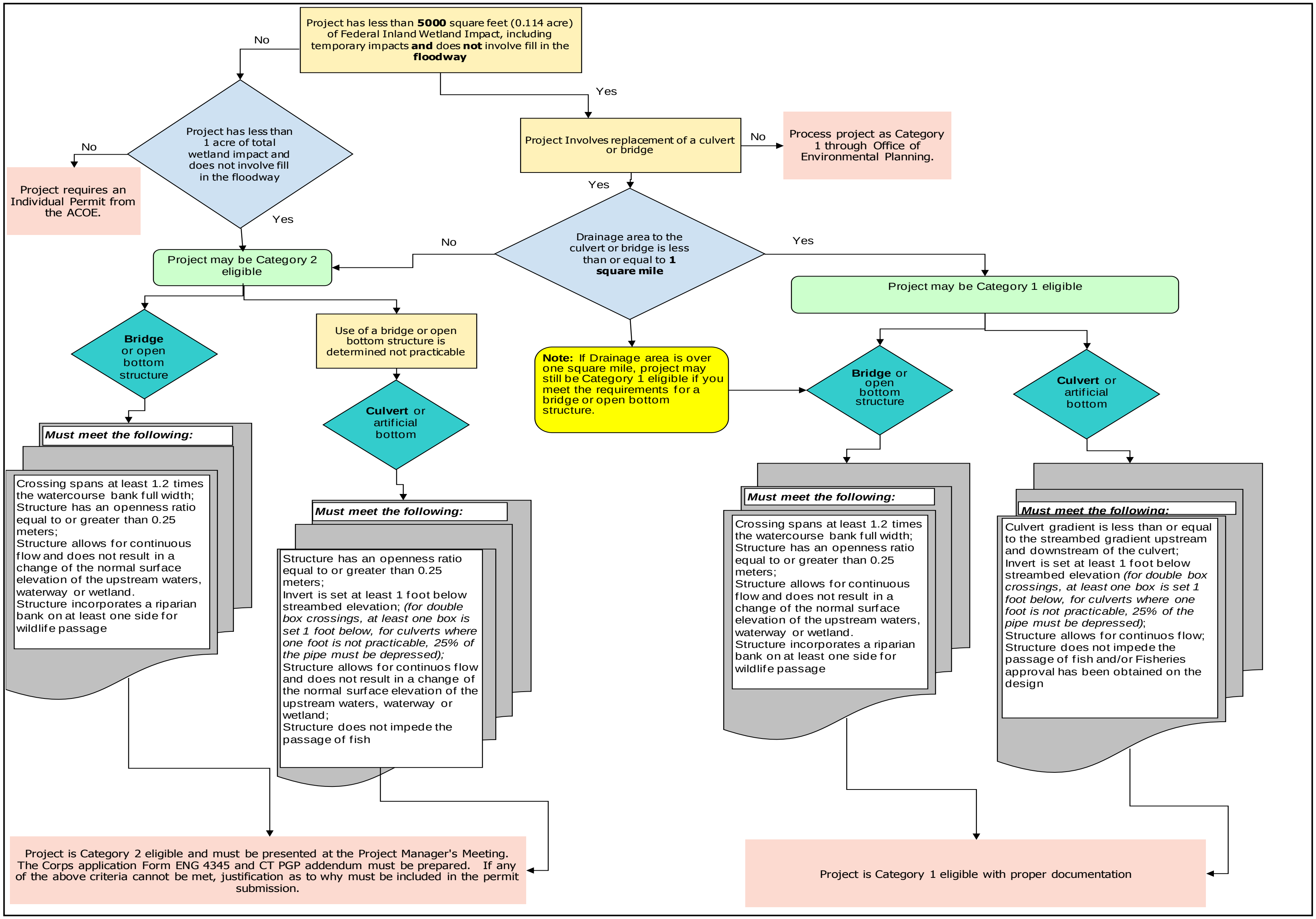


Figure 3 – Army Corps of Engineers Connecticut General Permit – Bridge/Culvert Requirements

Flood Management – Loss of Flood Storage

In the case of an existing bridge or culvert that is significantly undersized and hydraulically inadequate by design standards, replacement with a substantially larger structure satisfying all of the hydraulic design and regulatory criteria may be limited if it is determined that the replacement would significantly increase downstream peak discharge and result in a potential adverse impact during flood events. For example, an adverse impact may be an increase in peak discharge to a downstream area known to be prone to flooding.

Depending on the upstream topography and the flood storage capacity of the inundation area, a structure that restricts flow and creates significant backwater during flood events, can have the effect of attenuating or metering out the flow, thus decreasing the peak discharge downstream of the structure. Therefore, the replacement of the existing structure with a larger one that “opens up” the crossing may increase peak discharge downstream of the structure. At a minimum, environmental permitting applications require that this potential change in flood storage capacity be assessed qualitatively. In some cases, a more detailed flood routing analysis may be required to demonstrate potential impact/non-impact

Precipitation (Rainfall)

Precipitation Data Overview

TP-40 and HYDRO-35

The current Drainage Manual references two sources of rainfall data for the design of storm drainage facilities, including culvert crossings. These sources are "Technical Paper No. 40, Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years (Hershfield 1963)" (TP-40), published May 1961 by the U.S. Department of Commerce, Weather Bureau and "NOAA Technical Memorandum NWS HYDRO-35, Five to 60-Minute Precipitation Frequency for the Eastern and Central United States" (National Oceanic and Atmospheric Administration 1977), published June 1977 by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Weather Service. The HYDRO-35 data is used for storm durations 60 minutes or less. The TP-40 data is used for storm durations one to 24 hours, inclusive.

Figures C-1 and **C-2**, in **Appendix C** show sample maps from TP-40 and HYDRO-35, respectively. **Table C-1**, in **Appendix C** of this report, shows the HYDRO-35 and TP-40 data for Connecticut. This information can also be found in Chapter 6, Appendix B of the Drainage Manual.

Figure C-3 is a graph plotting precipitation Depth-Duration-Frequency (D-D-F) curves for the TP-40 data. **Figure C-4** is a graph plotting precipitation Intensity-Duration-Frequency (I-D-F) curves for the HYDRO-35/TP-40 data.

USGS Regression Equations

A third source of rainfall information in the Drainage Manual was developed by the U.S. Geologic Survey (USGS) in the late 1970's-early 1980's, however, this information was to be used exclusively in regression equations, also developed by the USGS (ca. 1983), for estimating peak flows in rural watersheds with areas greater than one square mile. This information has since been superseded by the current (2004) version of the regression equations.

The USGS revised the regression equations (E. A. Ahearn 2004) for estimating flood flows in Connecticut in 2004. The regression equations include 24-hour precipitation as an estimating variable. The USGS regression equation publication indicates that the 24-hour precipitation values were estimated across the state by the Northeast Regional Climate Center. The 2004 regression equations, including the updated 24-hour precipitation data, were incorporated into the USGS "StreamStats" for Connecticut (The StreamStats Program- Connecticut 2014).

StreamStats is a Web-based Geographic Information Systems (GIS) application which computes stream flow statistics at any point on a stream network. It should be noted here that the precipitation information developed for the use of the regression equations should only be used for that application.

NRCC – NRCS ("Precip.net")

Around 2010, the Northeast Regional Climate Center (NRCC) at Cornell University and the United States Department of Agriculture (USDA), National Resources Conservation Service (NRCS) began operating a website (Northeast Regional Climate Center 2014)("Precip.net") which featured a collaborative project between the two organizations entitled "Extreme Precipitation in New York & New England".

The NRCC-NRCS project produced an interactive web tool for extreme precipitation analysis for the subject region and is currently operational. Documentation indicates that the analysis period for this project extended through 2008.

Figure C-5 is a map product from the precip.net web tool showing the 100-year, 24-hour precipitation estimate for the State of Connecticut. **Table C-2** is a data product from the precip.net web tool showing the point precipitation estimates for the various storm frequencies-durations taken near Burlington, CT (Latitude 41.775, Longitude 72.991).

Figure C-6 is a graph plotting precipitation Depth-Duration-Frequency (D-D-F) curves using the Precip.net data. **Figure C-7** is a graph plotting precipitation Intensity-Duration-Frequency (I-D-F) curves using the Precip.net data.

NOAA Atlas 14

In the spring of 2012, NOAA began work on a project to update the precipitation frequency estimates for the Northeastern States. This work is being funded by the participating Northeastern State DOTs, including Connecticut, as an FHWA pooled fund project and is part of NOAA's effort to complete "NOAA Atlas 14, Precipitation-Frequency Atlas of the United States", which will replace the older precipitation data throughout the country.

The current schedule indicates that the project will be completed in September 2015 with the precipitation-frequency estimates being published in Volume 10 of Atlas 14. It is anticipated that the precipitation estimates of Atlas 14 will be similar to those determined by the NRCCNRCS Precip.net.

TP-40 vs. Precip.net

There are differences in the precipitation estimates from the two data sources, which were compiled at different time frames and by different entities. The precipitation estimates also vary by location across the State. For example, **Figure C-5** shows how the Precip.net, 100-year, 24-hour precipitation estimate varies within the State of Connecticut.

Table 3 compares the approximate minimum and maximum values of the 24-hour precipitation estimates within the State by data source and storm frequency.

Table 3 – Approx. Minimum/Maximum Precipitation Estimates Within CT

	24-Hour Precipitation (Inches)									
	2-Year		10-Year		25-Year		50-Year		100-Year	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
TP-40 (1961)	3.2	3.4	4.7	5.0	5.5	5.7	6.2	6.4	6.9	7.2
Precip.net (2010)	3.0	3.5	4.6	5.1	5.7	6.4	6.7	7.7	7.9	9.1

Table 3a compares the approximate minimum and maximum values of the 24-hour precipitation estimates for the 50- and 100-year storm frequency within the project limits by data source.

Table 3a – Approx. Min./Max. Precipitation Estimates Within Project

	24-Hour Precipitation (Inches)			
	50-Year		100-Year	
	Min.	Max.	Min.	Max.
TP-40	6.2	6.2	7.0	7.0
Precip.net	7.0	7.5	8.3	9.0
Difference (%)	*12.9*	*21.0*	*18.6*	*28.6*

Figures C-8 and C-9, in Appendix C, also show the difference between the NRCC (Precip.net) and TP-40 10-Year and 100-Year, 24-Hour precipitation, respectively, in approximate percent.

The following tables compare the TP-40 and Precip.net precipitation estimates taken near Burlington, CT (Latitude 41.775, Longitude 72.991) in more detail.

Table 4 – TP-40 vs. Precip.net Precipitation Estimates

PRECIPITATION ESTIMATES (INCHES)													
DURATION (hour)	TP-40						"PRECIP.NET"*						
	Frequency (Year)						Frequency (Year)						
	2	5	10	25	50	100	2	5	10	25	50	100	500
0.5	1.00	1.35	1.60	1.80	2.00	2.25	*0.95*	*1.15*	*1.34*	*1.61*	*1.88*	*2.19*	**3.15**
1	1.30	1.70	2.00	2.30	2.55	2.80	*1.03*	*1.28*	*1.5*	*1.86*	*2.19*	*2.58*	**3.8**
2	1.60	2.15	2.50	2.85	3.20	3.50	*1.38*	*1.7*	*1.99*	*2.44*	*2.86*	*3.35*	**4.85**
3	1.80	2.40	2.80	3.25	3.60	4.00	*1.73*	*2.17*	*2.58*	*3.25*	**3.88**	**4.62**	**6.92**
6	2.25	2.95	3.40	4.00	4.40	5.00	*2.15*	*2.71*	*3.24*	**4.09**	**4.88**	**5.83**	**8.77**
12	2.75	3.55	4.10	4.85	5.35	6.00	*2.67*	*3.37*	*4.02*	**5.09**	**6.07**	**7.25**	**10.92**
24	3.25	4.20	4.95	5.75	6.35	7.00	**3.32**	*4.18*	*4.98*	**6.27**	**7.48**	**8.91**	**13.43**
*Latitude 41.775, Longitude 72.991													

Table 4a – TP-40 vs. Precip.net 24-Hour Precipitation Estimates

Frequency (Year)	24-HR PRECIPITATION (INCHES)		TP-40 VS. PRECIP.NET	
	TP-40	"PRECIP.NET"*	Difference (in.)	Difference (%)
2	3.25	3.32	0.07	2.2
5	4.20	4.18	-0.02	-0.5
10	4.95	4.98	0.03	0.6
25	5.75	6.27	0.52	9.0
50	6.35	**7.48**	1.13	17.8
100	**7.00**	8.91	1.91	27.3
*Latitude 41.775, Longitude 72.991				

Table 4 compares the TP-40 with the Precip.net precipitation estimates for various storm durations and frequency. The Precip.net estimates shown in italics indicate an estimated value approximately the same or less than the TP-40 estimate. The values shown in bold indicate precipitation estimates greater than TP-40. As can be seen from the table, the differences between the Precip.net and TP-40 estimates become larger as the storm frequency becomes more remote (decreases in probability) and precipitation depth more extreme.

It should be noted that no TP-40 estimate is shown for the 500-year storm frequency, as this information is not provided in the TP-40 document. An attempt to extrapolate the 500-year estimate from the other data produced questionable results when compared to the Precip.net estimates and is therefore not presented.

It should also be noted that the Precip.net estimates are more sensitive to geographic location because the web tool is GIS driven whereas the TP-40 estimates were obtained by the user by interpolating from isopluvial lines on paper maps.

Table 4a focuses in on a comparison of the TP-40 and Precip.net 24-hour storm duration, precipitation estimates. The 24-hour storm duration is presented because it is the duration required by the hydrologic analysis methodologies used by the Department and to comply with state storm water and flood management standards.

As highlighted (bold) on the table, the Precip.net data is showing that the older TP-40 100-year frequency estimate is now less than the 50-year frequency (approximately 40-year frequency) by the newer estimate at this location.

Table 5 below compares the precipitation intensity (inches/hour) of the HYDRO-35/TP-40 based estimates from the Drainage manual to the “Precip.net” estimates. The Precip.net estimates shown in italics indicate an estimated value approximately the same or less than the TP-40 estimate. The values shown in bold indicate precipitation estimates greater than TP-40.

As can be seen from the table, the differences between the Precip.net and TP-40 estimates become larger as the storm frequency becomes more remote (decreases in probability) and more intense.

While the increases in the tables may reflect some component of climate change (i.e. increase in extreme or more intense precipitation), there may be other factors. The addition of many more years of data and likely higher quality data and improved statistical techniques may account for the differences in the estimates. For example, a longer period of record is required to obtain a more accurate estimate for the more remote 100-year than the two-year storm frequency event.

Table 5 HYDRO-35/TP-40 vs. "Precip.net" Precipitation Intensity Estimates

PRECIPITATION INTENSITY (INCHES/HOUR)										
Duration (min)	HYDRO-35/TP-40 Based*					"PRECIP.NET"**				
	Frequency (Year)					Frequency (Year)				
	2	10	25	50	100	2	10	25	50	100
5	4.6	6.0	6.7	7.3	7.8	*4.50*	*6.06*	**7.25**	**8.30**	**9.59**
10	3.6	4.8	5.5	6.0	6.5	*3.48*	*4.66*	*5.53*	**6.32**	**7.24**
15	2.8	4.0	4.6	5.1	5.5	*2.86*	*3.84*	*4.58*	**5.25**	**6.04**
20	2.5	3.6	4.2	4.6	5.1	*2.40*	*3.27*	*3.93*	*4.51*	**5.20**
25	2.2	3.2	3.7	4.2	4.6	*2.12*	*2.92*	*3.53*	*4.07*	**4.70**
30	1.9	2.8	3.3	3.7	4.1	*1.93*	*2.69*	*3.27*	**3.77**	**4.36**
40	1.7	2.5	2.9	3.3	3.6	*1.56*	*2.21*	*2.71*	*3.15*	**3.68**
50	1.4	2.1	2.5	2.8	3.2	*1.34*	*1.93*	*2.38*	*2.78*	**3.27**
60	1.2	1.8	2.1	2.4	2.7	*1.19*	*1.74*	*2.15*	**2.54**	**2.99**
70	1.1	1.6	2.0	2.2	2.5	*1.05*	*1.53*	*1.89*	*2.23*	**2.63**
80	1.0	1.5	1.8	2.0	2.3	*0.95*	*1.38*	*1.70*	*2.00*	**2.35**
90	0.9	1.4	1.7	1.9	2.1	*0.87*	*1.26*	*1.55*	*1.82*	*2.14*
100	0.9	1.3	1.6	1.8	2.0	*0.80*	*1.16*	*1.43*	*1.68*	*1.97*
*Source: Drainage Manual						** Latitude 41.775, Longitude 72.991				

National Climate Assessment (NCA) 2014

Chapter 16 Northeast (R. Horton 2014), Climate Change Impacts in the United States, prepared for the U.S. National Climate Assessment, U.S. Global Change Research Program, indicates the following observed and projected climate changes relative to precipitation for the Northeast U.S.:

- Annual precipitation has increased by approximately five inches, or more than 10% (0.4 inches per decade) (K.E. Kunkel 2013), between 1895 and 2011.

- Extreme precipitation has recently increased more than in any other region in the United States. Between 1958 and 2010, there has been more than a 70% increase in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) (P.Y. Groisman 2013).

- Projections of precipitation changes are less certain than projections of temperature increases.[19] Winter and spring precipitation is projected to increase, especially but not exclusively in the northern part of the region.[19] (U.S. Army Corps of Engineers, New England District n.d.), (T.R. Karl 2009) A range of model projections for the end of this century under a higher emissions scenario (A2), averaged over the region, suggests about 5% to 20% (25th to 75th percentile of model projections) increases in winter precipitation. Projected changes in summer and fall, and for the entire year, are generally small at the end of the century compared to natural variations.[19]

- The frequency of heavy downpours is projected to continue to increase as the century progresses

- Severe storms in the Northeast that were projected in the 1950s to occur only once in 100 years, now are projected to occur once every 60 years. (DeGaetano 2009)

Data Collection - Structures

The National Bridge Inspection Standards (NBIS) of the Code of Federal Regulations (23 CFR[1] 650.3) requires periodic inspection, inventory and reporting of structures having a span length greater than 20 feet, which is the minimum length for a structure carrying traffic loads to be included as a "bridge" in the National Bridge Inventory (NBI). All structures in the NBI are inspected on a biennial basis. The Department performs this inspection, inventory and reporting for all State and Town road structures meeting the "greater than twenty feet criteria".

In addition to the federal requirement, the Department periodically inspects the condition and maintains an inventory of State road structures having a span length six feet or greater. The inspections, condition ratings and inventory for these structures are performed to the same standards as the NBIS; however, only the structures over twenty feet are reportable as part of the NBI.

Databases

The inventory data for the "NBI structures" (span length greater than 20-ft) and the "Non-NBI structures" (span length 6 to 20-ft), including condition ratings, are maintained in an internally developed database called the Structure Information System (SIS) and the "AASHTOWare" Bridge Management software "BrM" (formerly Pontis) (American Association of State Highway and Transportation Officials 2001).

The SIS database includes a large amount of attributes, some of which are collected during the regular structure inspections. The SIS database was the primary source of the structure data collection for the project. **Table 6** shows a list of the data fields downloaded from the SIS database that were considered most relevant for the structure selection and evaluations to be conducted for this project. The table shows the SIS data field description and the related NBI data item number, where applicable. For further descriptions of these data items and condition ratings, see the NBI coding guide, "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" (Federal Highway Administration 1995)[2] and the Connecticut Department of Transportation's Bridge Inspection Manual, Version 2.1 with Revisions (Connecticut Department of Transportation 2000, last updated 2003), originally published in September 2001.

[1] http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title23/23tab_02.tpl
[2] See also Errata Sheet http://www.fhwa.dot.gov/bridge/errata.pdf

Inspection Reports

Detailed inspection reports (most recent and past inspections) are available for all the structures inspected by the Department. In addition to the numerical condition ratings and inventory information that can be obtained from the SIS database, the inspection reports include a more detailed description of the conditions and any deficiencies found by the inspectors. The reports may also include plans, sketches and measurements taken at the inspection. The inspection reports were another source of information that was used during the field reviews and for the hydraulic evaluations of the project.

Field Reviews

Field reviews of the structures selected for evaluation under this project began in the spring and were completed in the fall of 2013. The field reviews were conducted to gather additional site information, assess the site conditions, verify watershed limits, and obtain measurements for the hydraulic evaluations.

In addition, the field reviews included observations of the structure conditions for select NBI items that may be affected by any changing or varying hydraulic conditions at the site. The observed NBI items are Substructure (Item 60), Channel and Channel Protection (Item 61), Waterway Adequacy (Item 71) and Scour Critical Bridges (Item 113). The observed conditions for these items as well as the overall structure condition rating, Structure Evaluation (Item 67), were noted and taken into consideration in the hydraulic evaluations

.

Table 6 - Selected SIS Database Fields

NBI Item No.	SIS Data Field Description
	TownName
5	B5D RouteNo
6	B6A FeaturesIntersected
7	B7 FeatureCarried
8	StructureNo
19	B19 BypassDetourLength
26	FunctionalClass
27	B27 YearBuilt
28	B28A LanesOn
29	B29 ADT
30	B30 YearADT
32	B32 ApproachRoadwayWidth
34	B34 Skew
	StructureTypeMaterial (See NBI Item 43)
	StructureTypeDesign (See NBI Item 43)
45	B45 NumberSpans
48	B48 LengthMaxSpan
49	B49 StructLength
51	B51 RoadwayWidthCtoC
52	B52 DeckWidthOtoO
60	B60 SubstructureCondition
61	W61 ChannelProtection
62	B62 CulvertsCondition
67	B67 StructuralEvaluation
70	B70 BridgePosting
71	B71 WaterwayAdequacy
72	B72 ApproachRoadwayAlignment
90	B90 InspectionDate
100	B100 DefenseHighwayDesignation
106	B106 YearRebuilt
109	B109 TruckADT
110	B110 DesignatedNationalNetwork
113	W113 ScourCritical
	SufficiencyRating (See Coding Guide Appendix B)

Methodology

Structure Selection

Structure Population

Based on queries of the SIS database, **Table 7** shows the number of roadway structures (*those included in the Department inventory*) located within the 26 towns selected for this project.

Table 7 – Number of Inventory Structures within Project Limits

Structure Description	Number of Structures
All Structures including Town Roads	639
All Structures over Water including Town Roads	559
All State Road Structures over Water	351
State Road Structures over Water 6 to 20-Ft	176
State Road Structures over Water 6 to 20-Ft with Pending Projects	18
State Road Structures over Water 6 to 20-Ft Eligible for Evaluation	158

As can be seen in **Table 7**, there are 176 structures within the project limits that meet the scope criteria, which is State road structures that convey watercourses and have a span length of six to 20 feet. **Table A-1** in **Appendix A**, "State Road Structures over Water 6 to 20-Ft, 176 within Project Limits", shows the structure population with select fields from the database noted above.

Further investigation of these structures determined that there is an active design project or a project in the scoping phase for 18 of these structures. These 18 structures were therefore excluded from further evaluation under this project, leaving the number of structures available for selection and evaluation at 158.

Structure Selection

At first, 30 structures were selected for field review and possible hydraulic evaluation under this project. These structures were selected as the ones having the lowest structural condition ratings (Item 67, Structural Evaluation) at the time of the original database query and selection. The scale of structure rating is from one to nine and is broken down based on the conditions and descriptions shown in **Table 8** below. Structures with a rating of five or less indicate a condition that the structure will be in need of more intense maintenance or preservation activities in the near future.

Table 8 – CT DOT General Structure Condition Rating Scale

Rating(Code)	Condition	Description
9	Excellent	New.
8	Very Good	No problems noted.
7	Good	Some minor problems.
6	Satisfactory	Structural elements show some minor deterioration.
5	Fair	All primary structural elements are sound, but may have minor section loss, cracking, spalling or scour.
4	Poor	Advanced section loss, deterioration, spalling or scour.
3	Serious	Loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	Critical	Advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	Imminent Failure	Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic, but corrective action may put back in light service.
0	Failed	Out of service-beyond corrective action.

The selected structures predominantly had a rating of “5” (fair) with one structure having a rating of “4” (poor). It should be noted; however, at the time of preparing this report, some of the structure ratings have changed due to more recent re-inspection and evaluation. Structure No. 02082, which had the Item 67 rating of “4” was upgraded to “6”, and Structure Nos. 02965 and 02966, which had the Item 67 ratings of “5” were upgraded to “6”. Field reviews of the thirty (30) selected structures were conducted in the spring of 2013.

Following a field review of the 30 selected structures, a determination was made to eliminate four from further evaluation under the project. The structures were determined to be not suitable for the project for various reasons, such as their evaluation would require more extensive hydrologic/hydraulic modeling beyond the scope of this project. The field team also made the decision to replace one of the structures with structure 02205. Therefore, a total of 27 structures were advanced to the hydraulic evaluation.

After completing preliminary hydraulic evaluations and draft summary reports for several of the structures, it was estimated that a total of approximately 50 to 60 structures could be evaluated within the budget and schedule of the project. As a result, 34 additional structures were selected for possible hydraulic evaluation under the project. This second selection of structures, with the exception of structure 05418, was based on the following database queries:

- Highest average daily traffic (ADT) but not recently built or reconstructed (20 structures).
- On a “Designated National Network” (national network for trucks), NBI Item 110, but not previously selected, recently built or reconstructed (four structures).
- Remaining structures having a Waterway Adequacy (NBI Item 71) rating of 5 or less.

Structure No. 05418 was included because it was concurrently being investigated for a potential scour issue.

Field reviews for the 34 structures were completed in the fall of 2013. Following these field reviews, a determination was made to eliminate nine of the selected structures from further evaluation under the project. Similar to the structures selected in the “first round”, these structures were determined to be not suitable for the project for various reasons, such as their evaluation would require more extensive hydrologic/hydraulic modeling beyond the scope of this project. As a result, an additional 25 structures were advanced to the hydraulic evaluation, for a total of 52 structures.

Table A-2, “Structure Inventory Population and Selection”, in **Appendix A**, shows the 176 State Road structures over water within the project limits, 6 to 20-feet in length, broken down into those selected and eliminated for further evaluation under the project, those with pending projects and the remaining structure population.

Table A-3, “Structures Eliminated from Further Hydraulic Evaluation”, in **Appendix A**, shows the structures with brief notes indicating the reasons for elimination.

Table A-4, in **Appendix A**, is a table showing the selected structures.

As part of the structure selection, it was desired that the selected structures would have a varied range in drainage areas which would facilitate the use of the different hydrologic methodologies employed by the Department. This may also allow the Department to make comparisons based on structure and drainage area/watershed similarity. Drainage areas for the structures were initially determined using the USGS StreamStats (The StreamStats Program- Connecticut 2014) application and were revised as necessary following the field reviews, when the hydrologic and hydraulic calculations were performed. The drainage areas for the selected structures were determined to cover a sufficient range in size desired for the project. The drainage areas ranged from approximately a tenth (0.1) to six square miles.

Table A-4a, in **Appendix A**, is a summary table, which includes the drainage area tributary to the subject structures.

Hydraulic Evaluations

The structures selected for this project were evaluated for hydraulic adequacy based on the current design criteria as outlined in this report. In order to conduct the hydraulic evaluations, estimates of the peak discharges from the structures watershed are required. These estimates are determined by hydrologic calculations based on methodologies that the Department currently uses to design these structures.

Hydrologic Calculations

The hydrologic calculations were performed for this project using the following methods:

- Rational Method
- SCS Unit Hydrograph
- USGS Regression Equations

A detailed explanation of each of these methods is not included in this report. These methods are outlined in Chapter 6, Hydrology, of the Department's Drainage Manual. Additional details regarding these methods may also be found in the FHWA publication, "Highway Hydrology", Hydraulic Design Series No. 2, Second Edition, October 2002 (Richard McCuen 2002). Information specific to the regression equations for Connecticut can be found in the USGS publication "Regression Equations for Estimating Flood Flows for the 2-, 10-, 25-, 50-, 100-, and 500-Year Recurrence Intervals in Connecticut", (E. A. Ahearn 2004) Scientific Investigations Report 2004-5160, dated 2004. The 2004 regression equations were incorporated into the USGS "StreamStats" for Connecticut. (The StreamStats Program- Connecticut 2014) StreamStats is a Web-based Geographic Information Systems (GIS) application which computes stream flow statistics at any point on a stream network.

In general, the size of the drainage area and/or the type of analysis needed determines the hydrologic method to be used. The Drainage Manual restricts the use of the Rational Method for drainage areas 200 acres or less. USGS cautions that the regression equations should only be used when the site input variables fall within the range of the variables used to develop the equations, otherwise the accuracy of the discharge estimate is unknown. The range in drainage area used in the development of the regression equations was 1.7 to 715 square miles. The SCS Unit Hydrograph method is typically used when the other methods do not apply, when a hydrograph analysis is required, for instance for flood routing or as an additional method when the results of multiple methods are compared in the determination of design discharges.

All of the above methodologies utilize precipitation (rainfall) as an input parameter. Peak discharge estimates at the structures were determined based on current precipitation data. The Structure Classification dictates the design and check flood frequencies and hence the design and check flood discharges for the structure. For example, the design and check flood frequencies for an “Intermediate Structure” are the 100- and 500-year, respectively; therefore, the 100- and 500-year discharges are the design and check flood discharges, respectively.

The sensitivity of the design discharge estimates was examined based on changes in the precipitation parameter. For each structure, a graph was prepared showing how the design discharge would increase based on varying increases in the precipitation parameter. An example of one of these graphs is shown in **Figure 4,** which is a plot of the increase in the 100-year precipitation versus the increase in the100-year discharge for Structure No. 02423.

The peak discharge estimates for Structure No. 02423 were determined using StreamStats. Structure No. 02423 is classified as an Intermediate Structure; therefore, the design discharge for the structure is the 100-year discharge, which was estimated as 881 cubic feet per second (cfs), based on a 24-hour, 100-year precipitation of 8.4 inches. To illustrate the use of the graph, **Figure 4a** has been annotated showing a 2-inch or approximately 24 percent increase in 100-year precipitation. This increase in precipitation would increase the discharge estimate by 366-cfs from 881cfs to 1,247-cfs, a 41.5 percent increase in peak discharge.

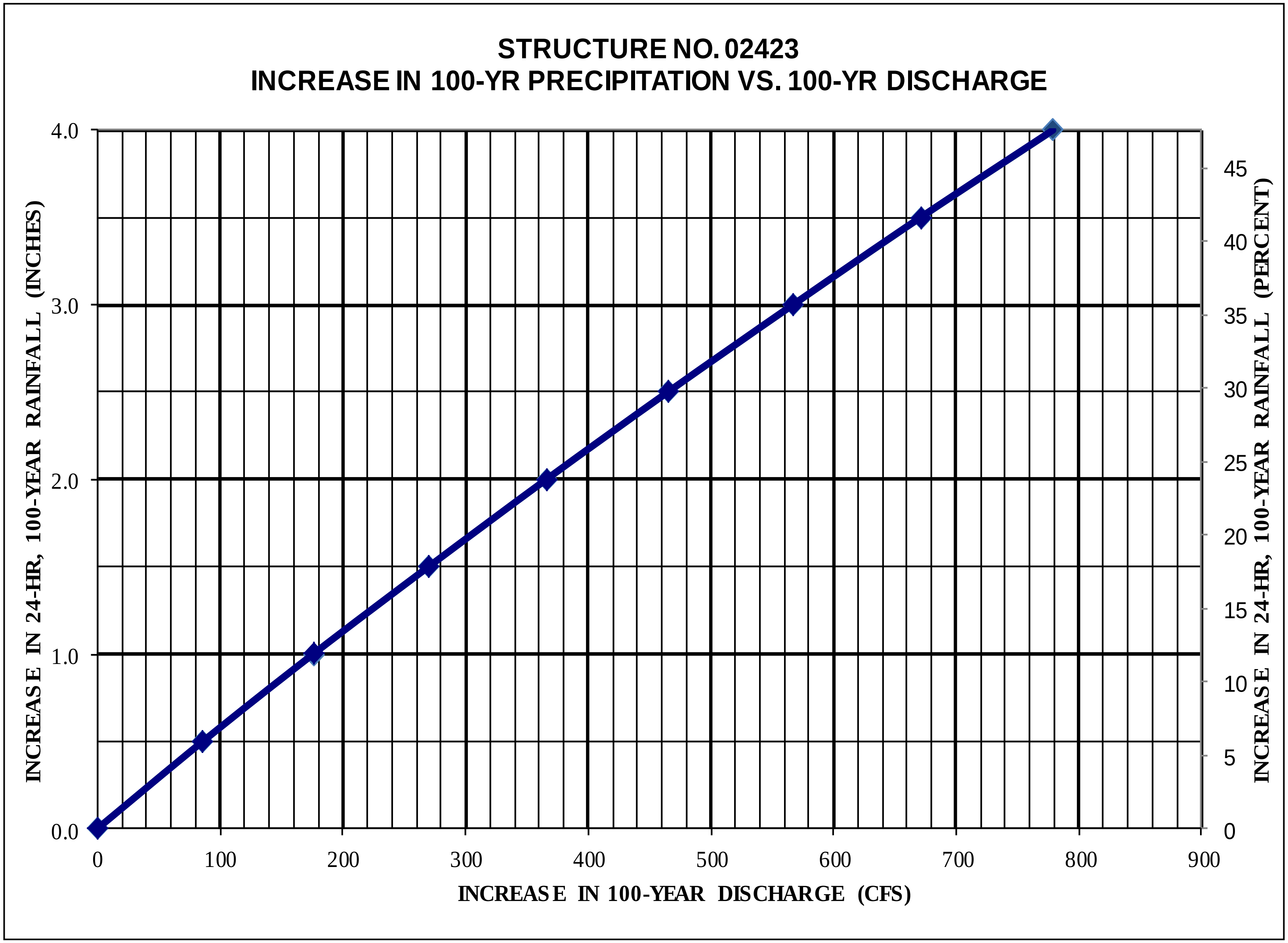


Figure 4 – Increase in 100-Yr (Design) Discharge vs. Increase in 100-Yr Precipitation for Structure No. 02423

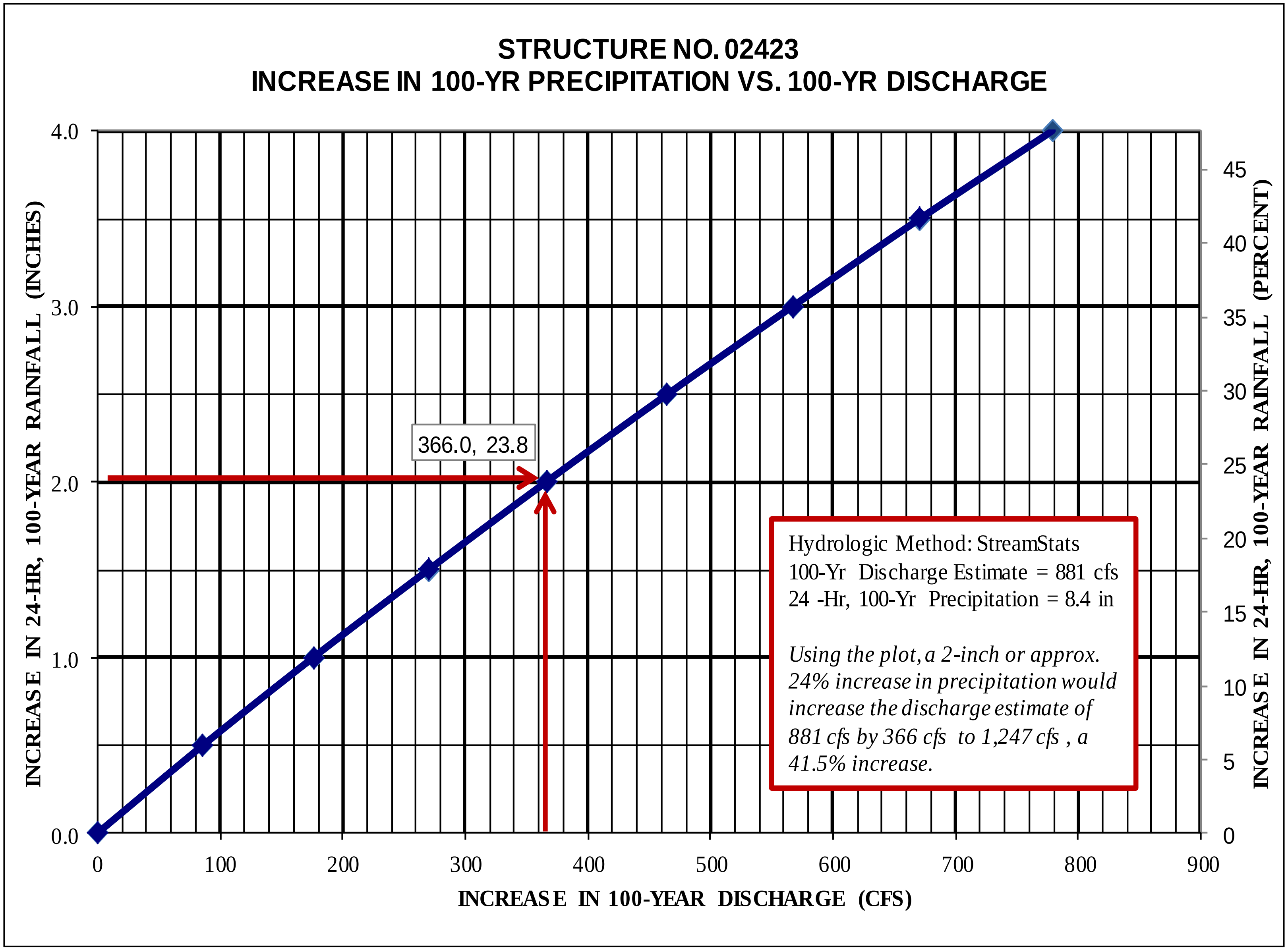


Figure 4a – Increase in 100-Yr (Design) Discharge vs. Increase in 100-Yr Precipitation for Structure No. 02423

Hydraulic Calculations

The FHWA's Culvert Analysis Program HY-8 was used to evaluate the hydraulic adequacy and to develop rating (performance) curves showing the hydraulic performance of the project structures over a range of flow conditions. HY-8 incorporates the hydraulic theory and procedures described in FHWA HDS5. Rating curves for the structures were developed showing Headwater Depth versus Peak Discharge and Outlet Velocity versus Peak Discharge.

The hydraulic adequacy of the structures was determined based on whether the hydraulic design criteria would be satisfied for the current design discharge estimate. If a structure was determined to be hydraulically adequate based on the current design discharge estimate, an assessment was made as to whether the structure has additional hydraulic capacity that would make it more adaptive to variations in the discharge estimate. This additional hydraulic capacity is desirable in that it provides a "cushion" for uncertainties in the hydrologic/hydraulic calculations or in the case of climate change and extreme weather events, may make the structure more adaptive to increases in peak discharge associated with increases in precipitation estimates, should such increases occur over the remaining service life of the structure.

In these evaluations, the hydraulic performance of the structures under a range of flows was determined and the resultant headwater (flood) elevations in relation to the roadway or any adjacent buildings were examined as well as the flow velocity in relation to potential erosion and scour. As a part of the assessment of the adaptive capacity of the structures and the current hydraulic design criteria, the degree to which increases in the design precipitation could change the design discharge was examined in relation to "key points" in the hydraulic performance of the structure. Depending on the hydraulic adequacy and capacity of the structure, these "key points" in the hydraulic performance would include:

- Design discharge
- Check discharge
- Discharge where inlet submergence begins
- Discharge at 1.5 HW/D
- Discharge at 1-Ft freeboard
- Discharge where overtopping begins

Figures 5 and 6 are examples of the headwater and velocity rating curves that were developed for the project showing the hydraulic performance of the structures over a range of flow conditions. These rating curves can be used to evaluate the hydraulic adequacy and assess the adaptive capacity of a structure.

Figure 5a is an annotated plot of the Headwater Depth versus Peak Discharge for Structure No. 02423. Continuing with the example presented in **Figure 4a**, a 2-inch or an approximate 24% increase in the 100-year, 24-hour precipitation would increase the current 100-year peak discharge estimate of 881-cfs by 366-cfs to 1,247-cfs (horizontal scale), a 41.5% increase in peak discharge. As illustrated by the rating curve, a 2-inch increase in precipitation would move the 100-year peak discharge estimate slightly above the current 500-year peak discharge estimate of 1,221-cfs. The resulting headwater depth would increase by approximately 1.9 feet, from 6.9 feet to 8.8 feet (vertical scale).

Figure 6a is an annotated plot of the Outlet Velocity versus Peak Discharge for Structure No. 02423.Continuing with the example presented in **Figures 4a** and **5a**, a 2-inch increase in the 100-year, 24-hour precipitation would increase the current 100-year peak discharge estimate as noted above. Using the rating curve, the resulting outlet velocity would increase by approximately 1.4-fps, from 18.8-fps at 881-cfs to 20.2-fps at 1,247-cfs, a 13% increase in velocity.

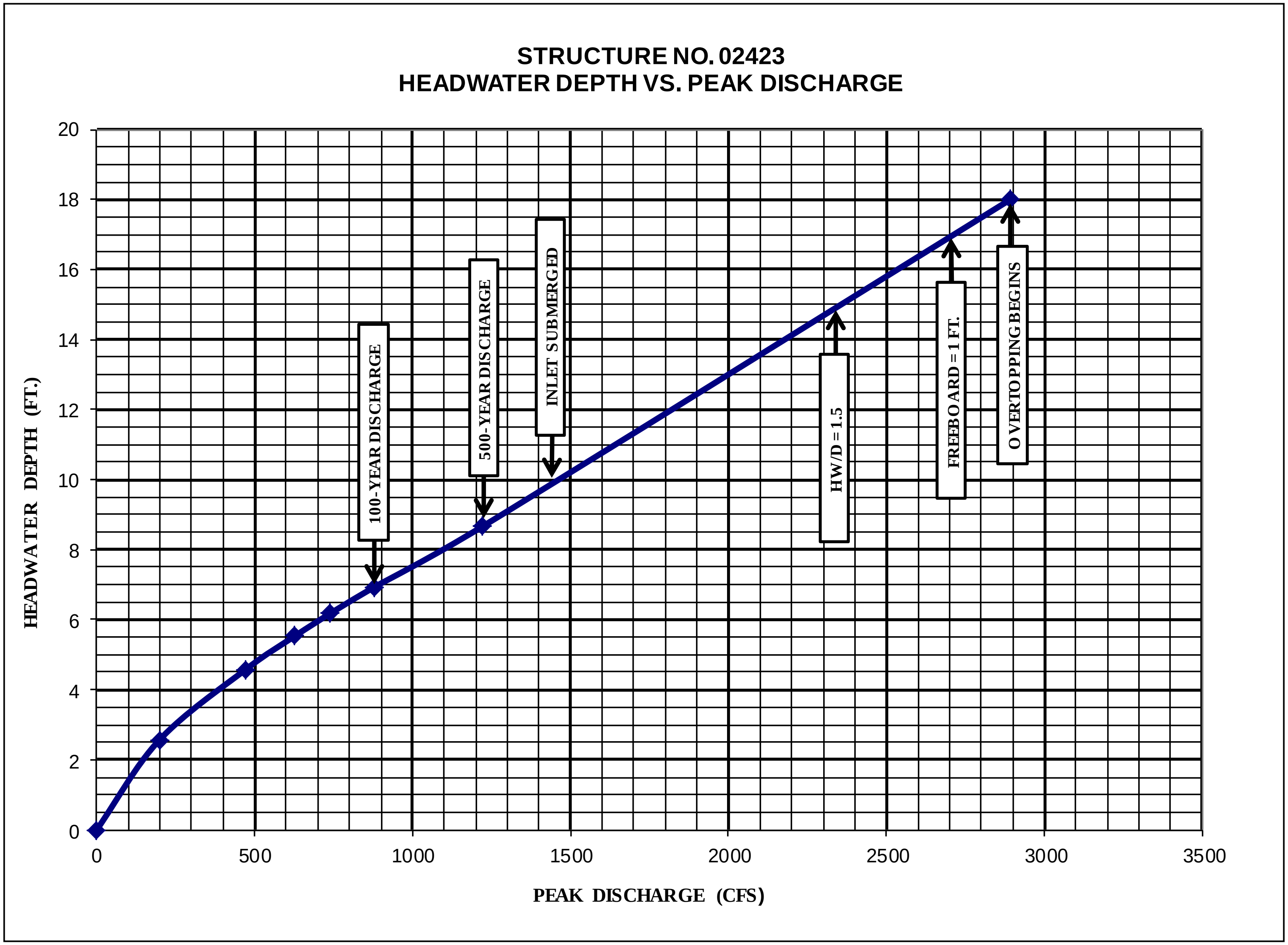


Figure 5 – Headwater Depth vs. Peak Discharge for Structure No. 02423

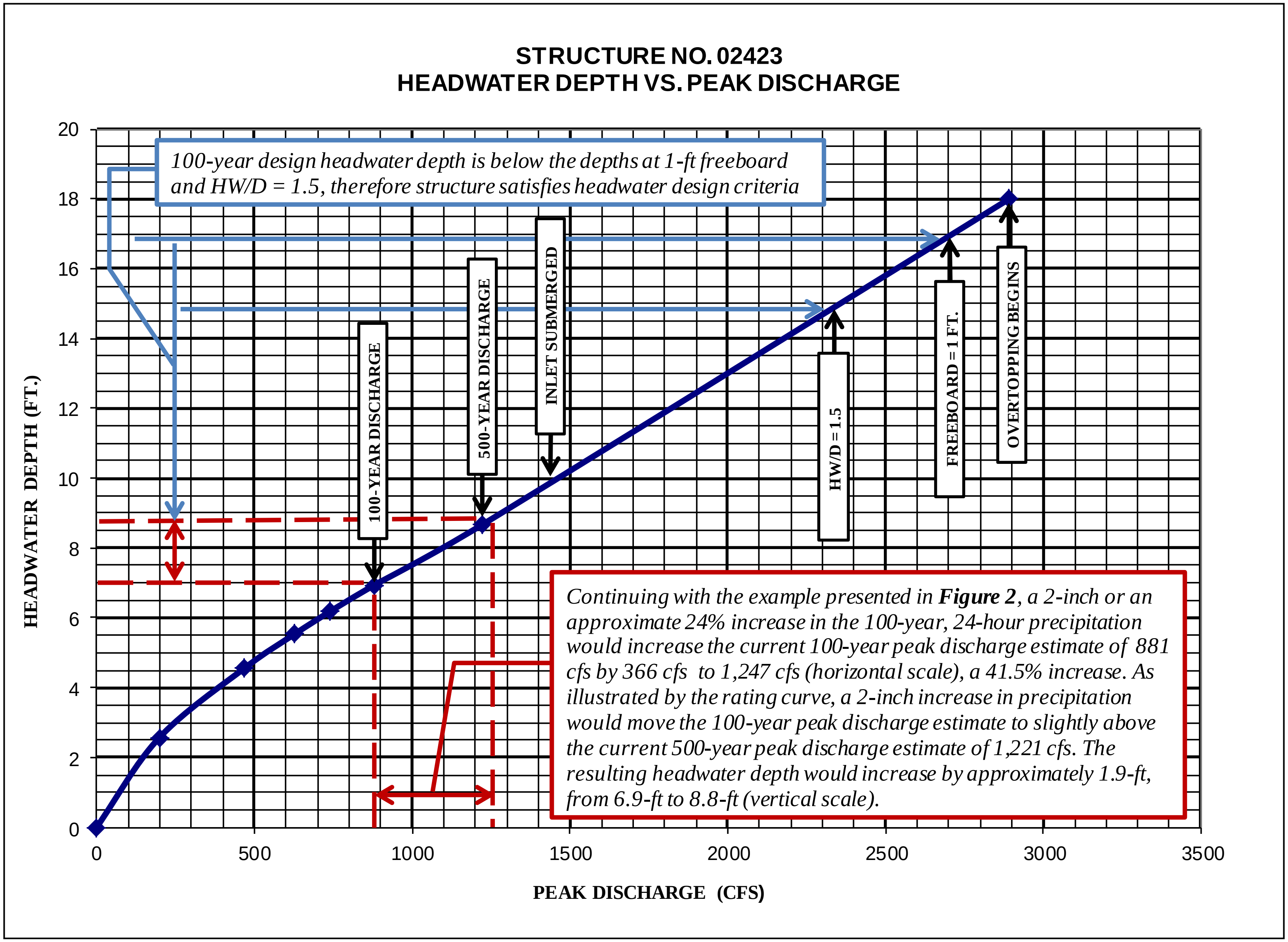


Figure 5a – Headwater Depth vs. Peak Discharge for Structure No. 02423

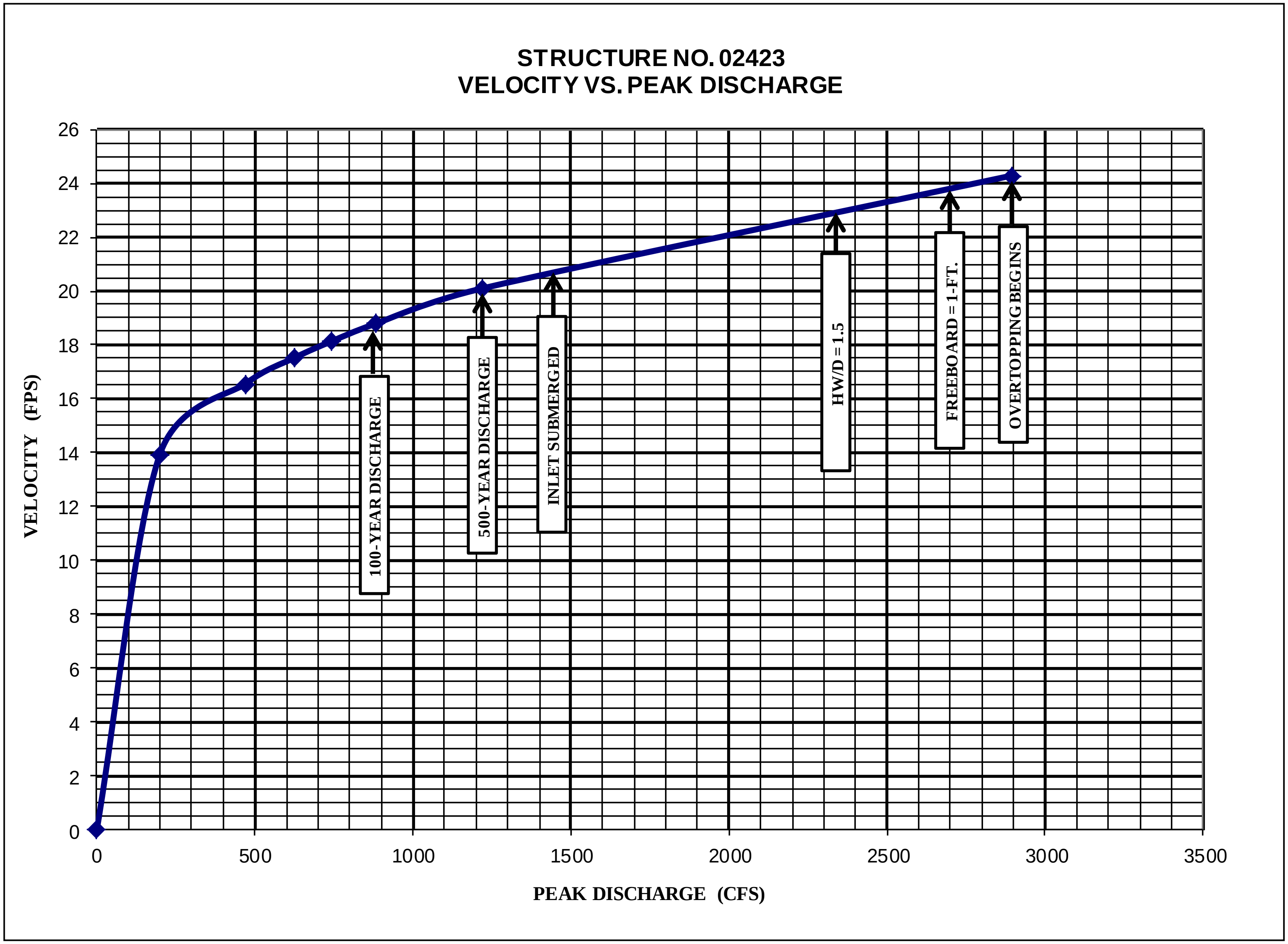


Figure 6 – Outlet Velocity vs. Peak Discharge for Structure No. 02423

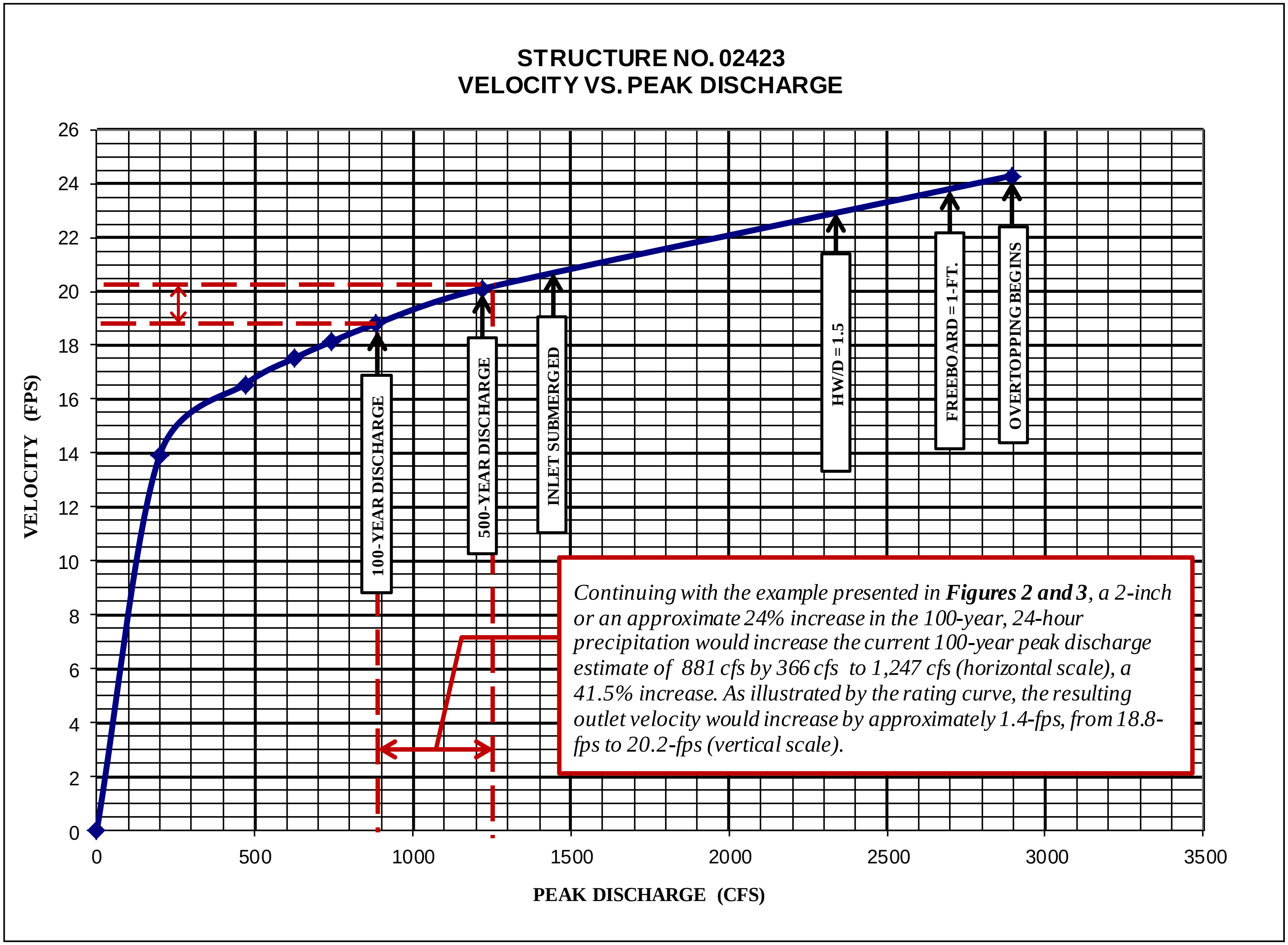


Figure 6a – Outlet Velocity vs. Peak Discharge for Structure No. 02423

Condition Ratings

As previously indicated, the field reviews included observations of the structure conditions for the NBI items Substructure (Item 60), Channel and Channel Protection (Item 61), Waterway Adequacy (Item 71) and Scour Critical Bridges (Item 113). As part of the hydraulic evaluation for each structure, the conditions observed during the field review were compared to the ratings and conditions described in the most recent inspection report. The potential impacts of increased precipitation/discharge relative to these items and the need for action were assessed. The overall structure condition rating, Structure Evaluation (Item 67), was also noted and taken into consideration in the evaluations. The following table was used to facilitate the condition assessment:

Condition Rating Category	Rating from Recent Bridge Inspection Report	Condition Observed in Field	Potential Impact of Increased Discharge	Probable/ Recommended Action Required by Increased Discharge	Prioritize or Immediate Action Required?
Substructure (Item 60)					
Channel and Channel Protection (Item 61)					
Structure Evaluation (Item 67)					
Waterway Adequacy (Item 71)					
Scour Critical Bridges (Item 113)					

Results

Hydraulic evaluations were performed for this project for 52 structures. In the hydraulic evaluations, it is being assumed that the NRCC-NRCS "Precip.net" precipitation estimates are the "current" estimates and that the pending NOAA Atlas 14 estimates will be similar. The TP-40 precipitation estimates were also included in the hydraulic evaluations for comparative purposes.

16 of the structures evaluated were "enclosed conduit" (box, pipe, pipe arch) culverts, 35 open bottom (span) culverts and one was an open bottom culvert with a continuous concrete floor installed through the structure.

The results show that of the 52 structures evaluated, 18, or 35% of the 52 structures evaluated, failed to satisfy the design water surface elevation criteria and roadway overtopping would occur at the design frequency discharge or less. These structures are therefore considered hydraulically inadequate. Four of these structures would have been considered hydraulically adequate based on the TP-40 precipitation estimates. It should be noted here; however, that most of the structures evaluated in this project pre-date the 1961 TP-40 data, and the methods and standards used to design them, including if precipitation was an input, are unknown. By hydrologic method, the discharges for 11 of the 18 structures were determined by the SCS Unit Hydrograph method, six by the USGS Regression Equations (StreamStats) and one by the Rational Method.

34 structures or 65% satisfied the design water surface elevation criteria for the specified design frequency discharge based on the current precipitation estimates. Additionally, 26 of these structures would satisfy design water surface elevation criteria for the specified check frequency discharge. All of these structures would be considered hydraulically adequate; however, the velocity through the structures would exceed 14 feet per second (fps) in 14 of these structures [seven open bottom] for the specified design frequency discharge and in 17 structures [nine (9) open bottom] under the specified check frequency discharge. Velocities in the excess of 14-fps are in the high range and potential scour and erosion would be a concern, particularly in the case of an open bottom culvert.

Of the seven open bottom structures with velocities in the excess of 14-fps, a scour condition was noted in the previous inspection reports of six of the structures. For the remaining structure, the field review indicated that the streambed was "naturally" armored.

A scour condition was also identified in the evaluation for seven additional structures where the velocity for the specified design frequency discharge did not exceed 14-fps. Two of these structures had been previously rated as "scour critical".

If a structure was determined to be hydraulically adequate based on the current design discharge estimate and the design water surface elevation criteria, an assessment was made as to whether the structure has additional hydraulic capacity that would make it more adaptive to variations in the discharge estimate. This additional hydraulic capacity is desirable in that it provides a "cushion" for uncertainties in the hydrologic/hydraulic calculations or in the case of climate change and extreme weather events, may make the structure more adaptive to increases in peak discharge associated with increases in precipitation estimates, should such increases occur over the remaining service life of the structure. Based on the hydraulic evaluations, 16 of the 34 hydraulically adequate structures were determined to have sufficient additional capacity and considered to be adaptive to potential increases in discharge. Most of the structures that were not considered adaptive had sufficient additional headwater capacity; however, increased velocity and potential scour was a concern.

An individual summary report was prepared for each structure evaluated under the project. The summary reports include:

- Location plan
- Narrative and tables describing the results and conclusions of the evaluation
- Rating curves (Precipitation Increase vs. Design Discharge Increase, Headwater Depth versus Peak Discharge, Outlet Velocity versus Peak Discharge)
- Aerial photograph of structure location
- Site photographs
- Aerial photograph with LIDAR contours showing general topography of site
- Criticality assessment sheet

The results of the hydraulic evaluations are also summarized in the following tables located in **Appendix E**:

Table E-1, **"**Results of Hydraulic Evaluations – Hydraulic Adequacy and Adaptive Capacity Determinations" indicates whether the structure is hydraulically adequate based on current precipitation/discharge estimates and design standards and whether the structure is considered to be adaptable to potential increases in the precipitation/discharge estimates.

Table E-2, **"**Results of Hydraulic Evaluations – Discharge Comparison" shows the peak discharge estimates based on the current precipitation estimates for the design and check discharges and depending on the hydraulic adequacy and capacity of the structure, the discharges at inlet submergence, 1.5 HW/D, 1-Ft freeboard and overtopping. For comparison, the table also shows how the design discharge estimate would change based on selected incremental increases in the precipitation input.

Table E-3, "Results of Hydraulic Evaluations – Velocity Comparison" shows the velocity estimates based on the current precipitation estimates for the design and check discharges and depending on the hydraulic adequacy and capacity of the structure, the discharges at inlet submergence, 1.5 HW/D, 1-Ft freeboard and overtopping. For comparison, the table also shows how the design velocity estimate would change based on selected incremental increases in the precipitation input.

When reviewing the above tables, please recall that the design and check discharges for structures having drainage areas less the one square mile is the 50- and 100-year flood frequency events, respectively. For structures having drainage areas one square mile or greater, the design and check discharges is the 100- and 500-year flood frequency events, respectively

Commentary on Results

The structures in this project were evaluated for hydraulic adequacy based on the current hydraulic design criteria and discharges determined by the hydrologic methods used by the Department with current precipitation estimates. These hydrologic methods include the Rational Method, SCS Unit Hydrograph, and the USGS Regression Equations (StreamStats). Although there may be other factors, the selected method typically depends on watershed size. Precipitation is a required input parameter in each of these methods. The 24-hour rainfall depth in inches is used in the Regression Equations and the SCS Hydrograph Method, while the rainfall intensity in inches/hour is used in the Rational Method.

If a structure was determined to be hydraulically adequate based on the current precipitation and design discharge estimates determined by the aforementioned methods, an assessment was made as to whether the structure has additional hydraulic capacity that would make it more adaptive to variations in the discharge estimate or future stressors, such as climate change or unregulated development. The assessments of the adaptive capacity of the structures examined the amount of additional flow capacity, or the difference between the design discharge estimate and the discharges where the hydraulic design criteria would be violated or where overtopping would occur. For example, say a structure has a design discharge of 500-cfs and overtopping would begin at 700-cfs, the structure has an additional flow capacity of 200-cfs before overtopping occurs. Alternately said, the overtopping discharge is 40% higher than design discharge in this example, therefore, the structure could accommodate up to a 40% increase in the design discharge without flooding the road. Increases in headwater depth and outlet velocities associated with increases in discharge were also evaluated in these assessments.

In addition, the sensitivity of the design discharge estimates to changes in the precipitation parameter was examined by incrementally increasing the precipitation parameter in the hydrologic methods used and plotting the results on a graph. While this simplified procedure provided a rough correlation between increases in precipitation to increases in design discharge in the methods used, the following limitations are acknowledged:

1. Regression Equations – If the precipitation value is increased too much beyond the current value, it falls outside of the range used to develop the equations and the accuracy of the discharge estimates from the equations is unknown.

2. SCS Unit Hydrograph – Following current design practice in this project, the 24-hour precipitation depths, the standard 24-hour, Type III rainfall distribution, and Antecedent Moisture Condition II were used in the hydrologic models developed by this method.

    a. This method can produce overly conservative results unless there is good information (flood history and/or stream flow statistics) to calibrate the hydrologic model against, or unless flood storage throughout the watershed is considered. Additionally, where this method was used, the drainage areas fell outside of the range where the regression equations could be applied as an alternate method or to compare results. Flood storage was considered and included in the hydrologic analyses where possible. However, due to the lack of specific flood history information or stream flow statistics, calibration of the hydrologic models for this project was limited and therefore, by experience, the results are considered conservative. In other words, the computed 100-year design discharge is likely more than the “true” 100-year discharge.
    b. Per the Department’s design practice, this project utilized the Type III rainfall distribution throughout, which results in the assumption that the shape of the distribution curve would remain the same as precipitation increased. However, rainfall distributions from actual storm events can vary widely in shape from this design (synthetic) distribution. The Type III storm is more intense (steeper) in its center which is typically rare in nature and can lead to overestimating peak discharge. NOAA Atlas 14 provides a broad range of temporal distributions of heavy precipitation based on regional precipitation frequency estimates that could be considered in hydrologic models; however, this document is not yet complete for the Northeastern states and therefore was not utilized for this study. The

USDOT Gulf Coast Study, Phase 2 performed a case study for a culvert in which the SCS method was used and the various NOAA temporal distributions were considered. In the Gulf Coast study, the SCS model and the selected distribution were calibrated/validated with the regression equation results, which have a statistical basis.[3] (U.S. DOT 2014)

Ultimately, the assessment of adaptive capacity of the structures was based on the amount of additional discharge capacity that would be available. The assessments did not rely on the correlation to increase in precipitation, referred to above and discussed on pages 35-38 of this report.

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[3] U.S. Department of Transportation (USDOT). 2014. The Gulf Coast Study, Phase 2, Impacts of Climate Change and Variability on Transportation Systems and Infrastructure. https://www.fhwa.dot.gov/environment/climate_change/adaptation/ongoing_and_current_research/gulf_coast_study/phase2_task3/task_3.2/task2phase3.pdf

Criticality & Vulnerability Assessment

Background

The Litchfield Hills region of Connecticut has been hit by intense storms in the past few years that have cost the state and municipalities millions of dollars in emergency repair and replacement costs. In late August of 2011, Tropical Storm Irene highlighted the vulnerability of transportation system assets to the effects of heavy rains and high winds. In Connecticut, bridges were closed, roads failed, and Metro North service was halted for nearly a week. Debris cluttered roads throughout the state, rendering many roads, including the Merritt and Wilbur Cross parkways, impassable for significant periods. Similar damage to the transportation infrastructure in New York State compounded the problems for commuters and commercial operators alike. More than 760,000 residents were without power at the peak loss of service, with many of those residents, particularly in rural areas, left without power or water for over a week.

Figure 7 – Damage from Hurricane Irene, Bemis Street, Plymouth
Copyright: Foothills Media Group

The Federal Emergency Management Agency (FEMA) made an emergency declaration for Connecticut on August 27th, one of five FEMA emergency declarations/major disaster declarations made for Connecticut during 2011. Likewise, CTDOT's Commissioner approved Emergency Declaration funds to repair transportation assets damaged following Hurricane Irene. The projects initiated in the Litchfield Hills under the Commissioner's Emergency Declaration are listed in **Table 9** below.

Table 9 - 2011 Connecticut Emergency Declaration Projects

Town	Project #	Project Description
Bristol	170-3134	Route 72 various locations
Bristol	17-185	Route 72 Site 2 Permanent Repairs
Bridgewater	16-Maint	Route 133 Failed Retaining Wall
Morris	86-Maint	Grout Bag Installation under footing
Thomaston	140-Maint	Drainage Pipe Invert Repair
Washington	150-Maint.	Route 109 over Mallory Brook

Extreme weather events highlight the importance of maintaining the transportation system to modern standards. To begin to identify the transportation assets, particularly bridge and culvert structures, most at risk from storms such as Irene, CTDOT engineers performed the hydraulic analyses that were discussed in-depth in the preceding chapters. In order to gain an understanding of how other DOTs are approaching the problem of asset criticality, CTDOT planners studied Washington Department of Transportation's (WSDOT) 2011 *Climate Impacts Vulnerability Assessment* report and then conducted criticality assessments of the same study structures. Criticality is defined as the importance of an asset relative to the system it functions within, particularly in terms of monitoring and maintenance needs. The key components of criticality are the significance of the structure within the system, its risk of failure, and the costs associated with repair or replacement. Using the WSDOT framework [See Figure 7] and an analysis of localized, context dependent factors, CTDOT created a criticality matrix for the study structures in the Litchfield Hills. WSDOT's asset management based approach is focused on qualitative analysis of the importance of various structures, as it has usefulness at several stages of the asset management process, serving as:

1. "An initial screening or review of assets and vulnerability to the climate change effects under consideration
2. The preferred approach when information is limited or only available in the form of intuition, personal judgment, or subjective opinions, and/or when a lengthy quantitative analysis is more than is required
3. A quick assessment" (Washington State Department of Transportation 2011)

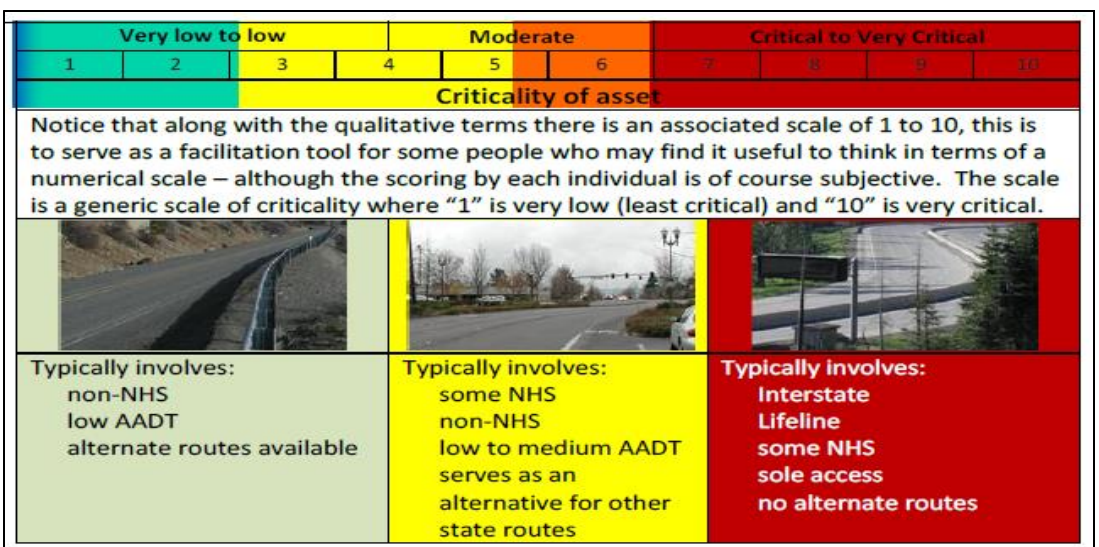

Exhibit 2-4 Rating Scale for Asset Criticality

Figure 8 – WSDOT Criticality Matrix

In creating its own Criticality Matrix **(See Table 10)**, the study team included both quantitative and qualitative aspects, grouped under three categories that pertain directly to the capacity and characteristics of the structures themselves: Hydraulic, Spatial, and Social. CTDOT's criticality analysis combined WSDOT's methods and rationale of qualitative analysis with quantitative analysis based on the sensitivity and vulnerability assessments as well as factors related to the Department's performance measures. The three categories of the criticality matrix are meant to be understood as follows:

- **Spatial factors** encompass key characteristics of the wider physical area around a structure, such as FEMA flood zones, concentrations of impervious surfaces, and overall development patterns.

- **Social factors** show how a roadway is understood and utilized by drivers, and include some of the measurements utilized by CTDOT for regular operations and performance measurement, such as volume-to-capacity ratio (V/C) and Average Annual Daily Traffic (AADT), as well as National Highway System designations (NHS). Proximity to social services such as Police and Fire stations, Emergency shelters, and Hospitals was also included. Data such as the age of a structure and population density of the study towns were also considered for each structure, but because their impact was ultimately judged to be negligible in the overall analysis, these factors were left out of the final criticality matrix.

- **Hydraulic Factors** are comprised of the results of the vulnerability assessments and include a structure's level of adaptive capacity, its history of performance (i.e. history of closures), its fulfillment of Water Surface Elevation criteria, and its status as, or adjacency to, scour critical structures.

While many of the inputs into the criticality matrix were quantitative in nature, the overall judgment of a structure's criticality was qualitative, due to the subjective nature of weighing many types of factors within both scientific and social contexts. Merely providing numerical weights to various factors did not allow for nuanced and context sensitive understanding of the criticality of each structure within the system. Based on the combined values of each factor, structures were given overall Criticality Rankings of Low, Moderate, or Critical.

Table 10 - CTDOT Criticality Matrix

	Very Low to Low			Moderate				Critical to Very Critical		
	1	2	3	4	5	6	7	8	9	10
Hydraulic	High adaptive capacity			Moderate adaptive capacity				Low adaptive capacity		
Hydraulic	No history of closure			History of periodic closures				Significant history of closure		
Hydraulic								Scour critical		
Hydraulic	Satisfies WSE criteria			Adjacent to scour critical structures				Does not satisfy WSE criteria		
Spatial	Outside FEMA flood zones			Within 500 year FEMA flood zone				Within 100 year FEMA flood zone		
Spatial	Low concentration of impervious surfaces			Moderate concentration of impermeable surfaces				High concentration of impermeable surfaces		
Social	Low ADT & V/C			Moderate ADT & V/C				High ADT & V/C		
Social	0-1 accidents			2 or more accidents				Emergency route		
Social	Non-NHS, non-emergency route			NHS route				Emergency services cluster		

Criticality Rationale

The criticality assessment applied to each study structure was informed by the criticality matrix, as shown in **Table 10** and discussed above. In order to give each structure a criticality score, the data for the hydraulic, spatial, and social factors were collected and analyzed. The most crucial element of the criticality assessment was the hydraulic evaluation of the structures, which provided the key facts about a structure, including its ability to perform at or above its design standard, its capacity for additional flows and velocities, and its physical condition. Although hydraulic factors were weighted more heavily than spatial and social factors in the overall analysis, spatial and social factors were used to compare hydraulically similar structures.

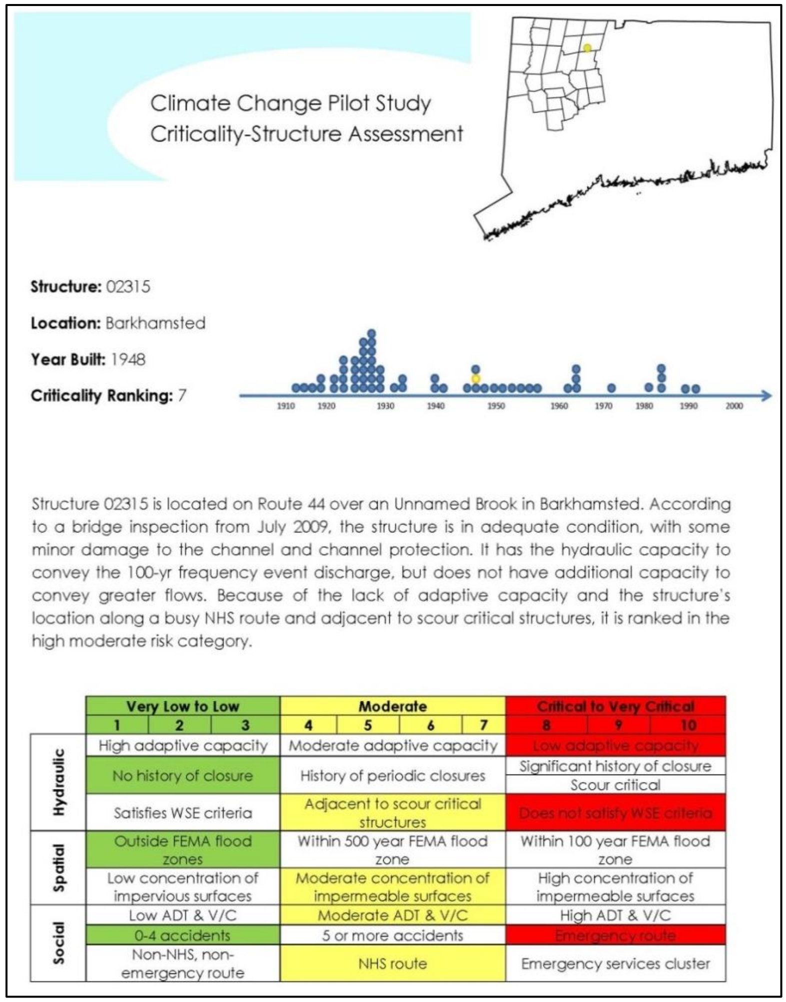

Figure 9 – Criticality, Structure Assessment Sheet (example)

Most of the factors in the criticality matrix were mapped using ESRI ArcGIS software. The ability to visualize played an important role in understanding the relationships between the hydraulic, spatial, and social factors. For example, a structure's location near emergency services or FEMA flood zones could be conceptualized using distance values, and overlaid on layers depicting land use patterns. **Figure 10** is a map of structure #02315, located in the town of Barkhamsted. While the structure is not located directly within a flood zone, its low adaptive capacity and proximity to scour critical structures, along with its location along an NHS route, resulted in a criticality rating of Moderate. See **Figure 9,** structure #02315's Criticality Assessment sheet. The criticality analysis of the structures is portrayed in the individual assessment sheets, which accompany the Structure Overview reports. **Appendix F** contains key maps of the study region, and **Appendix G** contains the Criticality Assessment sheets for each study structure.

The criticality assessments considered the hydraulic factors as their most basic element. The hydraulic evaluations completed by the Engineering team studied the adaptive capacity of the study structures to carry increased rainfall and peak discharges occurring during typical rainfall conditions and extreme weather events. The evaluations also identified those structures that are at a higher risk of being damaged, scoured, or washed out during rain events. The criticality assessments weighted structures with higher adaptive capacity as less critical than those without adaptive capacity. Factors such as scour risk related to water velocity and water surface elevation were also included in the criticality matrix, with the scour category extended to Scour Critical structures nearby a study structure. CTDOT's engineers maintain a list of bridges that have significant scour issues and need to be monitored more frequently and thoroughly than other structures. These scour critical structures were considered to be existing Critical structures in terms of overall system risk and vulnerability.

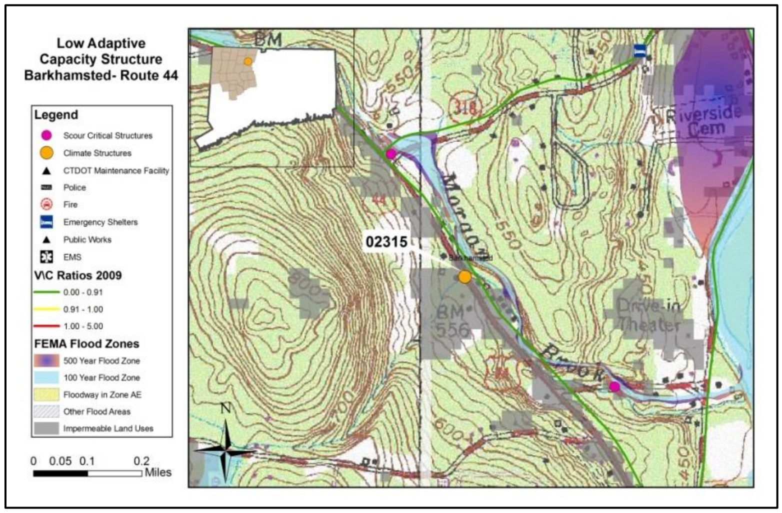

Figure 10 – Map of Structure #02315

The list of Social factors changed throughout the study process. Some factors, such as population density and density of disabled populations, were calculated, mapped, and evaluated, only to be later removed from the final analysis. Areas with high populations of at-risk groups, such as children, the elderly, disabled, and non-English speakers were specially considered at the outset of the project, as it is important to include a variety of needs when planning emergency access to shelters, hospitals, and other services during climate related events. However, after analyzing the density of general and at-risk populations, it was determined their impact on traffic and travel patterns was better understood by factors such as V/C and AADT, which more accurately reflect actual usage of the road system. Traffic volumes and patterns are important factors that can indicate which sections of the road network are utilized most heavily and which may need special attention during an extreme weather event. One factor in particular, AADT, is helpful in indicating the amount of traffic on a roadway section, expressed as an average of the daily traffic over one year. While AADT is not a perfect measurement, it gives a standardized picture of vehicle volumes along roads of different classification (i.e. Principal Arterial vs. Rural Connector).

Another roadway usage dataset is the V/C ratio, which indicates whether or not a road is operating below, approaching, or above its engineered capacity. The V/C ratio evidences congestion and overall usage levels of the asset. Both the AADT and V/C datasets used were from 2009 and provided by the Trip & Traffic Analysis and Roadway Inventory units.

In order to assign proper weights, in relation to the study region, to AADT and V/C values, the individual data points for these two factors were averaged to find mean AADT and V/C values for the study region. Each structure's individual data points were then compared with the mean. Roadway segments were then assigned low, moderate, or high AADT and V/C levels based on their relation to the mean for the study area. The averaging process was introduced in order to control for the rural context of the Northwest Hills. Generally, this area experiences lower traffic volumes than other areas of the state. For comparison, the statewide mean AADT in 2009 was 21,216, and the statewide V/C in 2009 was .573. The average AADT and V/C values of the study region were considerably lower than the statewide averages. **See Table 11** for mean, minimum, and maximum values of AADT and V/C in the study area.

Table 11- Study Area: AADT and V/C Mean, Min, and Max Values

	Mean	Min	Structure/Location	Max	Structure/Location
AADT	5,938	400	02204 Hartland	19,800	03333 Harwinton
V/C	0.327	0.040	02204 Hartland	0.940	01985 Plymouth

In addition to congestion and traffic pattern factors, accident locations illuminate safety concerns on the roadway network. Accident information for this study was from 2008 and provided by the Highway Safety unit, and mapped for the study region. More recent data has not yet been geo-located by the Department. Accidents that are associated with structures are considered to be those that occurred within a one-half mile radius of the study structure. Of note, the total number of 2008 accidents that occurred within a one-half mile radius of a study structure is extremely low - out of 62,967 incidents statewide, 449 accidents are near a study structure, or 0.713%. Within the study area, there were 3,456 total incidents, making incidents within one half mile of a study structure about 13% of the study area total.

Although accidents in themselves do not necessarily contribute to the condition of the study structures, knowing where accidents frequently occur within the road network may help identify potentially critical system flaws. It is beyond the scope of this study to identify the underlying causes of accident hotspots, but it is within the scope to understand the history of the area around each structure and to note factors that should be taken into account by emergency planning personnel. A higher concentration of accidents may indicate an area that should receive special attention during extreme weather events. **Table 12** shows the top five accident hotspots associated with structure locations. The top two spots, in Watertown, should be given further consideration in safety studies.

Table 12- Top Five Accident Hotspots in Study Region					
Asset	**Town**	**Criticality Score**	**Accidents (2008)**	**AADT (2009)**	**V/C (2009)**
06712	Watertown	4	34	7,400	0.44
02414	Watertown	4	19	14,100	0.9
03333	Harwinton	10	18	19,800	0.27
02078	Thomaston	3	17	2,800	0.25
01985	Plymouth	7	13	14,900	0.94

*Note- The colors in the Criticality Score column reflect criticality rankings of Low, Moderate, or Critical, and the orange color in the Accidents and AADT columns reflect values equal to or higher than the study region mean values.

Proximity and routing to emergency services are a related safety concern, particularly during and after extreme weather events. Location along emergency routes and emergency services were factors evaluated under the Social category. While the locations of emergency services may be decided on bureaucratic designations such as County and Town jurisdictional boundaries, inland flooding and other events related to a changing climate are not determined by such paper borders. Understanding their spatial relation to the study structures may help determine where such services may need to be directed in the future. The following emergency services were mapped along with the study culvert and bridge structures:

- Fire stations
- Police stations and barracks
- Emergency medical services
- Hospitals
- Public Works Departments
- Emergency shelters

Emergency routes were classified as either National Highway System Routes or those routes in areas without roadway redundancy to handle emergency vehicle traffic. *Emergency service clusters* are areas in which two or more emergency services are located near a study structure. The term 'near' is purposely vague, in order to allow subjective interpretation by communities. A radius measurement (i.e. facilities within a two-mile radius of a structure) may not encompass a facility that is five miles down the same road and frequently used by ambulances. Where roadway connectivity and redundancies are in place, a radial measurement of nearness may be appropriate. An effective method of measuring nearness could be to calculate the average travel time to or from an emergency service, but this method was not available to the study team.

Finally, the opinions and ideas of public works staff and town officials can be very important in identifying the history of an area and its infrastructure and were considered in the Social analysis. These groups can be intimately aware of specific issues that may not turn up in periodic bridge evaluation. The study team conducted public outreach to the elected leaders, emergency responders and public works department in the study region to learn about the anecdotal or local perspective on which structures were more critical than others that may not be evident through the roadway or hydrography datasets.

Figure 11 – Flood waters rush under a bridge in Washington, CT
Copyright: Washington Ambulance

The Spatial factors analyzed for the criticality assessment included FEMA flood zones and permeability and associated land uses. FEMA flood zone maps are used for many types of review processes in Connecticut, from home insurance to state-mandated flood management practices. Both 100 and 500 year storm flood levels were mapped, revealing structures that may be at increased risk from pooling or flooding of nearby areas. When overlaid on a map of impervious land use, areas of risk become more apparent. Because the goal of mapping land use was to discover at-risk areas, swamps, forests, and other permeable landscapes were excluded from the criticality maps, while land uses associated with human development, such as Commercial, Industrial, High Density Residential, and exposed soil, were merged into an *impervious land use* shapefile. Permeability is used here to indicate the capacity of an area to retain water from rainfall events. It is accepted that areas with high concentrations of asphalt pavement, building structures, and human settlement typically do not handle storm water runoff as efficiently as “greener” landscapes such as swamps, forests, and meadows. Where study structures were located within FEMA flood zones and impermeable land uses, it was judged that they would be, proportionally, more at risk from extreme weather events.

Results

Compiling and visualizing each piece of the criticality analysis was an organizational necessity. Each structure and the data points for the matrix factors were inputted into an Excel spreadsheet, and color coded based on their relative values. This made it easier to see how each structure compares to all the others. It also assisted in keeping track of study changes, such as structure deletions or additions. The bulk of the structures, 20, were rated moderately critical, while 19 structures were rated Critical or Very Critical- see **Figure 11**. The recommendations and findings, particularly as they relate to Critical structures, are discussed in the next chapter.

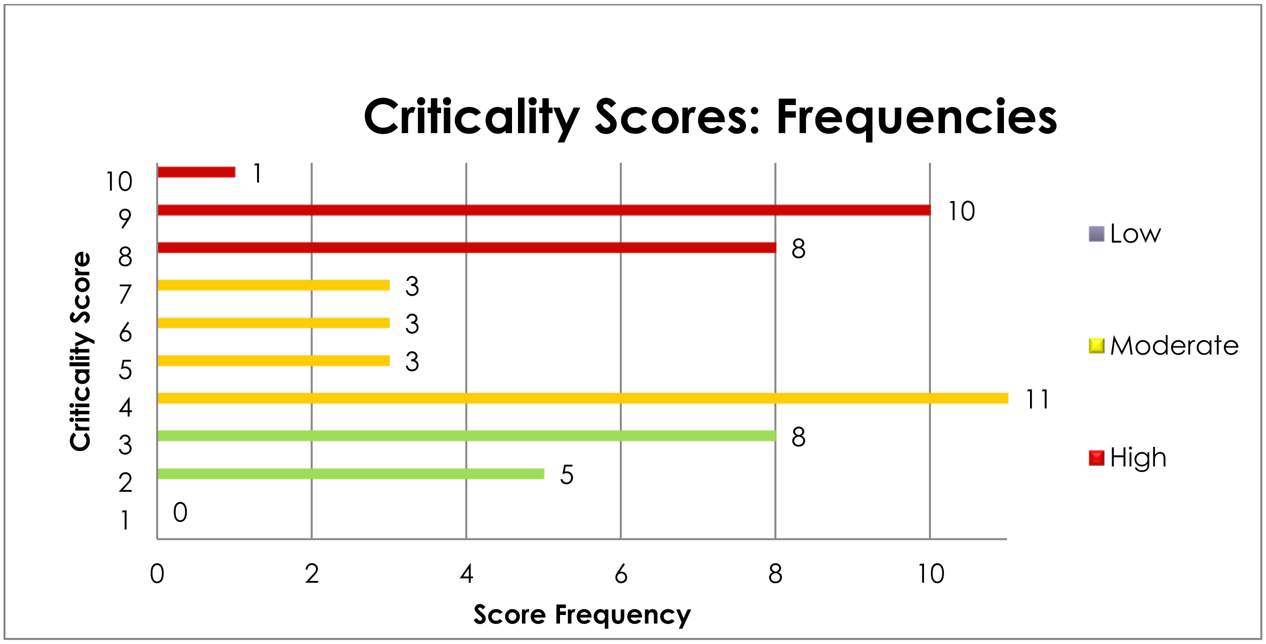

Figure 11- Frequency of Criticality Scores

Findings, Recommendations and Lessons Learned

Findings

1. The results of the hydraulic evaluations show that of the 52 structures evaluated, 34 structures or 65% satisfied the design water surface elevation criteria for the specified design frequency discharge based on the current precipitation estimates; however, 13 of these structures may require some corrective action due to scour. 18, or 35% of the 52 structures do not satisfy the hydraulic design criteria and are therefore hydraulically inadequate based on the current precipitation estimates.

2. Most structures can withstand flood events that exceed their design flood frequency, especially those that have been designed in accordance with "modern" standards, which have been developed and vetted over the years by AASHTO, FHWA and State DOTs. The structures evaluated in this project have been in service ranging from approximately 60- to 100-years. Design data, standards and methodologies change over time. There are no clear observations or signs indicating that the Department's existing structures which were previously designed using older data and methods are now significantly under-designed since they have been subjected to the climate conditions occurring over the last few decades Most of the structures evaluated under this project are approaching their useful service life, which may be some indication of resiliency to varying climate conditions. The effects of climate trends may occur at a gradual rate, so that age and deteriorating condition are more likely to contribute to a structure's vulnerability than climate change.

3. In total, the hydraulic design criteria and standards; *freeboard, underclearance for bridges, headwater limitations (1.5 HW/D), one foot backwater ("natural" conditions), check discharge evaluation, 100-year and 500-year scour design and check,* when applied to the design of structures, should provide enough "cushion" for some potential future variations in the precipitation and discharge estimates. However, when exceptions to one or more of the design standards are made for such reasons as site constraints, reducing environmental and property impacts, project scope and funding limitations, the structures may become less adaptable.

4. Regulatory requirements may dictate the size (waterway opening) of new or replacement structures. The incorporation of the of the current USACE Connecticut general permit

requirements for bridges and culverts tends to increase the size of these structures beyond the size necessary to satisfy the Department's current hydraulic design criteria alone.

Conversely, floodplain and storm water management regulations may sometimes restrict the hydraulic design to maintaining "existing conditions" in the case of a structure that is significantly undersized and hydraulically inadequate by design standards, where "opening up" the restriction with a larger structure would significantly increase downstream peak discharge and result in a potential adverse impact during flood events. An adverse impact may be an increase in peak discharge to a downstream area known to be prone to flooding or to a downstream crossing that is undersized and hydraulically inadequate. In the past, this issue tended to arise with town or privately owned downstream crossings that are undersized, where the Department has no jurisdiction. If sizing structures to accommodate potential climate projections becomes the preferred approach to address potential climate change, it cannot be done on a unilateral basis. There needs to be a common understanding of purpose among all stakeholders, which would likely hold true for any potential solution.

5. There is a level of uncertainty associated with flood frequency discharge and precipitation estimates that are currently used in hydrologic analysis and hydraulic design. Flood frequency discharge estimates at USGS stream gaging stations can be used for hydraulic design when the facility is located on the gaged stream or the estimates can be used as part of a regression analysis to develop equations for estimating peak discharges at un-gaged stream sites. Precipitation frequency estimates are required input variables in the hydrologic analysis methods used to estimate design discharges for hydraulic structures.

   Confidence limits are typically provided with or can be determined for USGS stream gage discharge estimates, peak discharge estimates from regression equations and precipitation estimates, at the 5-percent chance exceedance (upper confidence limit) and the 95-percent chance exceedance (lower confidence limit). The upper and lower confidence limits when combined band both sides of the mean estimate, forming a 90% confidence interval. The confidence interval gives an indication of how much uncertainty there is in the estimation of the true mean, the narrower the confidence interval , the more precise the estimate.

   In practical use, the 90 % confidence interval indicates that the estimate can be expected to fall within the confidence interval 90% of the time; there is a 5% chance that the estimate will exceed the upper confidence limit and a 5% percent chance that the estimate will be less than the lower confidence limit or 95% chance that the lower limit will be exceeded.

   Examples of confidence limits provided with or determined for USGS stream gage discharge estimates, peak discharge estimates from regression equations and precipitation estimates, are shown in Appendix D. As can be seen from the examples provided in Appendix D, a significant level of uncertainty in the accuracy of the estimates of the extreme events (low probability) needed for hydrologic analysis and hydraulic design currently exists. Recent discussions challenging the underlying assumption of stationarity in frequency analysis, in particular as related to climate change, adds another level of uncertainty. In current practice, a designer typically selects the estimate for use in the hydraulic design and more or less disregards the potential error and uncertainty information provided. The uncertainty in the accuracy of the estimates at the time of design should be considered and should not be lost in the focus to project a future estimate considering climate change.

6. The criticality assessments in this report use social, spatial, and hydraulic criteria. These factors support the identification and prioritization of structures most critical to preserve life and safety in the event of an emergency event. *But there is an increasing need to also examine and develop a cost factor into criticality assessments*. This would add to the "risk" of the structure in monetary terms and would provide an additional criterion in assessing the value of, or prioritizing the replacement of structures through the use of a financial risk factor. In Connecticut, the experience with emergency repairs and replacements has both positive and negative financial impacts. Emergency decelerations can oftentimes lead to reducing project delivery schedules due to the need for immediate replacement of structures. However, these unplanned capital expenditures can impact the larger capital budget through the need to redirect human and financial resources.

Recommendations and Lessons Learned

1. Keep precipitation data, stream gage data and regression equations as up to date as possible.

    a. **Precipitation**

    NOAA is currently scheduled to complete precipitation estimates for the Northeastern U.S. in September 2015 as a part of Atlas 14. The NOAA study was funded in part by the Department as part of a pooled fund project with the FHWA and other Northeastern State DOTs. When the NOAA study is released, the Drainage Manual will be revised to require NOAA Atlas 14 as the source for precipitation data for the design of Department facilities.

    In the interim, hydraulic designs being performed for or funded by the Department should be, at a minimum, considering the NRCC-NRCS "Precip.net" precipitation estimates where the TP-40 data had been used. For Department funded projects, clear direction regarding this matter needs to go out to Consultants and Town Engineers otherwise it will not likely be included in scope of services and not be considered in project design.

    In regard to future precipitation updates, it is not clear what a practical time period between updates is or what is a practical time period to expect for NOAA to complete such work. This may be a point of future discussion between stakeholders and NOAA as well as if further guidance is needed regarding the appropriate use of other data that is not from NOAA, if independent data subsequently shows precipitation differences or trends.

    b. **Stream Gages**

    The long term operation of USGS stream gaging stations provides valuable information to a variety of stakeholders; researchers, water resource planners, hydraulic engineers and emergency management and operations personnel, to name a few. The operation of the stream gaging stations is often affected by budgetary cuts. Given the amount of effort and money being expended to try to understand the potential impacts of climate change and extreme weather events, the importance of maintaining funding and operation of stream gaging stations, and possibly adding more gages to the network, needs to be stressed.

    The information provided by these stations, especially long-term stations, could pay off in identifying time related trends in stream flow conditions and potential effects of climate change. The flow statistics from these gages are also used to develop the regression equations for determining flood flow estimates as well as low flow, which are used extensively by the Department and other stakeholders for hydraulic design and other water resource analyses.

The USGS last computed and published peak-flow frequency estimates for stream flow gaging stations in Connecticut in 2003 (E. Ahearn 2003) in advance of developing and publishing the currently used regression equations in 2004. The peak flow frequency estimates are based on the analyses of annual peak flow data through water year ending 2001. The Department should pursue an update of the peak flow frequency estimates in conjunction with an update of the regression equations (see Regression Equations below).

In the interim, for Department project designs that use information from stream gaging stations that were active after 2001, the peak flow frequency estimates should be recalculated, especially for stream gages that have experienced major storm events since the last estimates. These calculations should be performed using the "Guidelines for Determining Flood-Flow Frequency" (Bulletin 17B) (Interagency Advisory Commitee on Water Data 1982) with a generalized skew coefficient of 0.34 with a standard error of prediction of 0.51 for Connecticut per the 2003 USGS report[26]. Public domain software is available to perform these calculations.

In addition, designers could consider the referenced research and guidance suggested in the NOAA document "*Flood Frequency Estimates for New England River Restoration Projects: Considering Climate Change in Project Design*" (National Marine Fisheries Service 2011) when reviewing peak flow estimates at long term stream gaging stations. This document highlights research indicating upward trends in annual flood magnitudes at twenty five (25) out of twenty eight (28) long term stream gaging stations throughout New England.

This research also suggests that a hydro-climatic shift occurred in New England around 1970, which coincides with a pronounced warming trend in the Northeast since 1970 and a global warming trend attributed to greenhouse gas emissions beginning in the 1970s. However, NOAA indicates that this upward trend in annual flood magnitudes also coincided with a change in the North Atlantic Oscillation (NAO), which is of natural variability and not related to anthropogenic climate change.

The NOAA guidance recommends that three flood frequency curves be computed for stream gaging stations in New England that have a substantial period of record prior to 1970 and are still operating .The three curves should be based on data pre-1970, post-1970 and for the full period of record. The most conservative of peak flow estimates should be considered per the guidance.

Appendix D of this report includes a plot of the Annual Peak Discharge (Streamflow) and an example of the set of three flood frequency curves that were computed at USGS stream gaging station number 01188000, Bunnell (Burlington) Brook near Burlington, CT, which is within the project limits. The period of record for the gage extends from 1932-present and the drainage area at the gage is approximately 4.2 square miles.

c. **Regression Equations**

When the NOAA precipitation estimates for the Northeast are released, the Department should pursue another update of the regression equations with the USGS; or if not before, to begin the process. Assuming precipitation will remain a variable in the equations, using the NOAA precipitation will provide an update and a consistency in the source of data.

2. For the hydraulic design of structures, the Drainage Manual requires that the effects of the check frequency discharge passing through the structure be investigated and states that where a likelihood of danger to persons, extensive property damage or other than temporary interruption of traffic will exist under these conditions, increases in waterway or other improvements shall be provided to alleviate the danger, whenever possible. The purpose of this recommendation is to strongly emphasize that the check frequency discharge should be carefully examined by the designer to assess the potential impacts of a storm event more extreme than the design storm event and to what extent design changes could be made to make the structure more resilient in the case of these events. In other words, the designer may want to consider assigning more weight to the check frequency in the design depending on the importance and complexity of the asset. Ensuring that a structure has some additional hydraulic capacity or that the design considers potential overtopping to provide upstream flood relief will also help compensate for the uncertainties in the design discharge estimates and the climate change trends.

3. Risk evaluation is included as a general design criterion in the Drainage Manual; however, it is not used since most State road design projects comply with predefined flood frequencies specified in the Drainage Manual and all projects comply with flood management regulations. A "blanket" adjustment (stricter) of design flood frequencies is not recommended to address potential climate change trends. A risk evaluation coupled with an economic cost analysis as specified in the Drainage Manual could be better implemented to document the risks and costs associated with extreme flood events at "critical" highway structures (Interstates, evacuation, emergency services routes). Improved guidelines, examples and tools to conduct risk and cost benefit analyses would be very helpful.

4. There seems to be a general consensus from researchers that the variability in precipitation projections from climate models is too large and uncertain. Therefore, this report does not recommend using the precipitation projections as the basis for a hydraulic design at this time. In addition, the climate information is typically not presented in a usable format for direct

application in hydraulic design. More research and coordination with the FHWA and other agencies regarding this matter is needed.

5. In the mid-1990s, a "Hydrology Committee" was organized by the DEEP to develop consistent or standard practices for Hydrology in CT. This committee consisted of members from the DEEP, DOT, USGS, NRCS, UCONN and Consultant Engineers and has since faded away. The Department could reach out to see if there is interest in re-establishing this committee to develop more consistent practices in Hydrology on a statewide basis as well as addressing climate change, adaptation and resiliency in design.

6. Earlier coordination with local emergency responders. An early meeting was held in the study region with town officials and emergency responders. However, the study team only received a small handful of comments and concerns from this group.

7. At scoping or early in the project, envision and develop an understanding within the team how data will be collected and presented and how the overall project information will be presented and reported. -Automating and integrating the data collection and reporting processes as much as possible will free more time for evaluations and analyzing results.

8. Current hydrologic methods and practices by the Department will need to be reassessed when NOAA Atlas 14 is published for the Northeast. For example, NOAA Atlas 14 will provide a series of temporal distributions with the precipitation frequency estimates that could be considered in addition to the SCS Type III distributions.

Next Steps

In order to incorporate the findings and recommendations into practice, several of the action items below must be presented to the Department's management prior to implementation. Thorough consideration must be given to the items listed below, due to the fact that they may require additional staff time, have fiscal impacts, or require policy changes. The following presents an outline of "next steps" or action items as suggested by the project team to move forward with the results and recommendations of this project.

1. Prepare a technical memorandum to disseminate design related recommendations of the project to Department staff and Consulting Engineers. The memorandum should include the following:

    a. Brief background regarding extreme weather events and the intent of incorporating climate resiliency into design.
    b. Direction regarding the consideration of the NRCC-NRCS "Precip.net" precipitation estimates in design until NOAA Atlas 14 is completed.
    c. Direction regarding the recalculation of the peak flow frequency estimates at USGS stream gages when used in design.
    d. A statement emphasizing that the full range of discharges, including the "check" frequency discharge and the overtopping discharge (*per current Drainage Manual requirements*) should be carefully examined by the designer to identify potential risks and to assess the potential impacts of a storm event more extreme than the design storm event for a hydraulic structure. This analysis could be used to determine what extent design changes could be made to make the structure more resilient in the case of these events.

2. Coordinate the results of the criticality assessments and hydraulic evaluations of this project with the Bridge Management group to determine how this information can be integrated into the bridge inventory for future reference by the Department. One means would be to upload the structure summary reports and criticality sheets prepared under this project into the bridge asset files located in our project management file system, "ProjectWise".

3. Develop (outline) a plan/process on how the Department can better incorporate risk assessment/life cycle cost-benefit analysis into hydraulic design and asset management, which would include identifying the necessary input information and level of effort required. Input from multiple disciplines in the Department would be required. Input from the FHWA

would also be sought. It is anticipated that some guidance regarding risk-cost analysis will be developing through the FHWA's climate initiatives.

a. Hydraulic Design – Use of the anticipated update of Hydraulic Engineering Circular #17 for these assessments.
b. Asset Management – Incorporate vulnerability and risk assessment into the Department's Transportation Assessment Plan.

4. Begin discussion with the USGS regarding an update of the regression equations for estimating stream flows. Obtain a cost estimate and a time frame to complete the work. At the same time, consult with the Department's Research office on possible funding for the project. Also, contact the Department of Energy and Environmental Protection (DEEP) about partnering and cost-sharing for the project.

5. Conduct outreach to determine if there is interest in re-establishing a "Hydrology Committee" to develop more consistent practices in Hydrology on a statewide basis as well as facilitating discussion of climate adaptation and resiliency strategies.

6. Work with municipalities on context dependent adaptation strategies and other tools to expand the adaptive capacity of an at-risk structure.

7. Continue to follow the progress and activities of the Climate Change Pilot projects, as well as stay current with studies, best practices, guidance, and revisions to Federal Highway Administration's *Climate Change and Extreme Weather Vulnerability Assessment Framework*.

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Appendices

Appendix A

Table A-1 “State Road Structures over Water 6 to 20-Ft (176) within Project Limits”

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Material Type Code (43A)	Design Type Code (43B)	Number Spans (45)	Length Max Span (48)	Structure Length (49)	Deck Width Out to Out (52)	Skew (34)	Lanes On (28)	Bridge Posting (70)	Functional Class Code (26)	ADT (29)	Year ADT (30)	Bypass Detour Length (19)	Approach Roadway Width (32)	Roadway Width Curb to Curb (51)	Approach Roadway Alignment (72)	Substructure Condition (60)	Channel Protection (61)	Culverts Condition (62)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Inspection Date (90)	Defense Highway Designation (100)	Truck ADT (109)	Designated National Network (110)
01590	Route 318	Beaver Brook	Barkhamsted	-72.973459	41.914983	1937		1	19	1	20	20	0	0	2	5	7	5,000	2010	2	27	0	8	N	6	6	6	7	8	42.9	10/09/12	0	3	0
01927	Route 361	Beardsley Pond Brook	Sharon	-73.478232	41.885274	1928		1	1	1	10	12	46	0	2	5	7	1,300	2009	2	31	0	8	6	6	N	6	6	6	28.9	04/01/13	0	2	0
01930	Route 4	Guinea Brook	Sharon	-73.419041	41.826232	1933	1986	1	1	1	8	11	35.3	14	2	5	6	2,000	2011	6	35	31	6	6	5	N	5	8	6	30.7	05/01/13	0	4	0
01931	Route 4	Guinea Brook	Sharon	-73.394539	41.822290	1934		1	7	1	15	15	0	0	2	5	6	2,000	2011	22	30	0	8	6	6	N	6	9	6	15	07/09/13	0	4	0
01932	Route 4	Furnace Brook	Cornwall	-73.369078	41.818625	1930	1993	1	19	1	17	17	69.7	40	2	5	6	2,700	2011	3	40	66	8	N	6	6	6	8	8	43.3	01/03/13	0	4	0
01933	Route 4	Bloody Brook	Cornwall	-73.348834	41.840923	1916		1	1	1	12	16	31	0	2	5	6	2,400	2012	3	28	28	6	6	5	N	4	6	6	31.7	12/26/13	0	4	0
01935	Route 4	Stream	Cornwall	-73.342836	41.843454	1916		1	1	1	8	13	31	23	2	5	6	2,700	2011	3	26	28	8	6	6	N	6	7	6	32.5	01/15/13	0	4	0
01937	Route 4	Birdseye Brook	Cornwall	-73.309522	41.847304	1916		1	1	1	6	9	33	0	2	5	6	3,500	2009	2	30	30	8	5	5	N	5	6	3	23.3	01/18/12	0	4	0
01945	Route 4	Catlin Brook	Harwinton	-73.068389	41.771377	1938	1959	1	1	1	10	12	45.3	0	2	5	14	8,700	2011	6	40	40	8	7	7	N	6	8	6	32.5	05/11/13	0	4	0
01946	Route 4	Rock Brook	Harwinton	-73.039661	41.774372	1927		1	19	1	14	14	0	0	2	5	6	12,300	2012	5	28	0	8	N	6	6	6	5	8	30.5	07/10/13	0	4	0
01947	Route 4	Brook	Harwinton	-73.022848	41.776291	1927		1	1	1	12	15	30.6	0	2	5	6	11,800	2012	8	28	29	8	5	5	N	5	6	6	10	07/22/13	0	4	0
01948	Route 4	North Branch Bunnell Bk	Burlington	-72.999821	41.776948	1926		1	19	1	8	8	0	0	2	5	6	10,200	2010	6	31	0	8	N	6	6	6	8	8	32	05/08/12	0	4	0
01949	Route 4	Misery Brook	Burlington	-72.939403	41.776233	1928		1	1	1	8	15	31	0	2	5	14	9,500	2008	3	30	28	6	6	6	N	6	6	6	11	04/24/12	0	4	0
01980	U.S. Route 6	Lewis Atwood Brook	Woodbury	-73.169019	41.595326	1949	1985	1	1	1	16	18	44.8	0	2	5	6	4,900	2011	12	40	39	8	6	5	N	6	7	6	31.1	07/18/12	0	4	0
01981	U.S. Route 6	Lewis Atwood Brook	Woodbury	-73.157097	41.600590	1935		1	1	1	12	14	0	18	2	5	6	4,900	2011	14	29	0	6	6	6	N	5	7	7	14	01/31/13	0	4	0
01982	U.S. Route 6	Lewis Atwood Brook	Watertown	-73.151575	41.598148	1930		1	1	1	6	8	0	26	2	5	14	4,800	2010	5	30	0	6	6	6	N	6	6	6	19.8	05/10/12	0	4	0
01984	U.S. Route 6	Steele Brook	Watertown	-73.115942	41.609605	1926		1	1	1	10	13	45.2	0	2	5	14	7,900	2010	1	30	35	8	6	6	N	6	5	5	40.1	07/16/12	0	4	0
01985	U.S. Route 6	Todd Hollow Brook	Plymouth	-73.040448	41.674361	1929		1	1	1	6	6	0	0	2	5	14	15,700	2012	2	31	0	8	6	5	N	6	6	6	16.7	03/18/14	0	4	0
01987	U.S. Route 6	Cuss Gutter Brook	Bristol	-72.975310	41.681597	1929		1	1	1	8	11	31.3	0	2	5	14	9,900	2010	1	32	28	8	7	5	N	7	4	6	17	03/22/12	0	4	0
02047	U.S. Route 7	Brook	Kent	-73.502696	41.672289	1930		1	1	1	16	20	82	69	2	5	6	2,800	2009	24	29	28	8	6	7	N	6	8	6	12	01/11/12	0	4	0
02048	U.S. Route 7	Cobble Brook	Kent	-73.457236	41.740142	1924		1	1	1	16	19	27.4	0	2	5	6	2,700	2009	19	26	25	8	6	5	N	5	6	6	11.6	01/11/12	0	4	0
02049	U.S. Route 7	Mouwee Brook	Kent	-73.441613	41.754819	1924		1	1	1	8	8	72	0	2	5	6	2,300	2009	20	26	0	6	6	6	N	6	8	6	15	01/11/12	0	4	0
02050	U.S. Route 7	Kent Falls Brook	Kent	-73.418961	41.776571	1924		1	1	1	16	19	53	0	2	5	6	2,200	2010	20	28	28	6	6	7	N	5	8	6	18.5	04/03/12	0	4	0
02051	U.S. Route 7	Deep Brook	Cornwall	-73.408221	41.785699	1924		1	11	1	12	12	0	0	2	5	6	2,100	2011	7	28	0	8	6	6	N	5	9	6	22.3	01/14/13	0	4	0
02053	U.S. Route 7	Bonney Brook	Cornwall	-73.374094	41.814160	1924		1	1	1	11	15	32	0	2	5	6	3,400	2012	14	28	30	8	6	6	N	6	8	6	16	12/26/13	0	4	0
02057	U.S. Route 7	Brook	Sharon	-73.366668	41.874075	1924		1	1	1	6	8	75.5	0	2	5	6	1,900	2011	7	30	32	8	6	6	N	6	9	6	41.2	04/09/13	0	4	0
02058	U.S. Route 7	Brook	Sharon	-73.367723	41.881301	1924		1	1	1	6	9	30	0	2	5	6	1,900	2010	5	26	27	7	6	6	N	6	6	6	29.7	06/28/12	0	4	0
02061	U.S. Route 7	Brook	Canaan	-73.359534	41.945662	1927		1	1	1	8	11	30.5	0	2	5	6	2,700	2012	16	27	29	8	7	6	N	6	8	6	25.2	10/07/13	0	4	0
02062	U.S. Route 7	Brook	Canaan	-73.340969	41.961205	1927		1	1	1	10	13	30.5	0	2	5	6	2,300	2011	2	29	28	8	5	5	N	5	7	6	33	01/10/13	0	5	0
02065	U.S. Route 7	Brook	Canaan	-73.334341	41.970517	1928		1	1	1	12	15	30.5	0	2	5	6	2,900	2010	2	28	28	8	6	6	N	5	5	6	22.6	04/10/12	0	4	0

Table A-1 “State Road Structures over Water 6 to 20-Ft (176) within Project Limits”

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Material Type Code (43A)	Design Type Code (43B)	Number Spans (45)	Length Max Span (48)	Structure Length (49)	Deck Width Out to Out (52)	Skew (34)	Lanes On (28)	Bridge Posting (70)	Functional Class Code (26)	ADT (29)	Year ADT (30)	Bypass Detour Length (19)	Approach Roadway Width (32)	Roadway Width Curb to Curb (51)	Approach Roadway Alignment (72)	Substructure Condition (60)	Channel Protection (61)	Culverts Condition (62)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Inspection Date (90)	Defense Highway Designation (100)	Truck ADT (109)	Designated National Network (110)
02066	U.S. Route 7	Brook	Canaan	-73.334336	41.971377	1924		1	1	1	14	16	31.5	0	2	5	6	2,700	2011	2	29	29	8	6	7	N	6	5	6	34.8	01/10/13	0	4	0
02078	SR 848	Brook	Thomaston	-73.057737	41.618156	1923		1	1	1	8	12	29.5	16	2	5	7	2,200	2012	8	30	27	8	6	6	N	5	7	6	13.8	08/30/13	0	3	0
02079	SR 848	Nibbling Brook	Thomaston	-73.069963	41.629228	1923		1	1	1	12	16	33	7	2	5	7	2,200	2012	8	31	31	8	6	5	N	6	5	6	36.4	08/31/13	0	3	0
02081	SR 800	Brook	Torrington	-73.119669	41.777124	1922		8	1	1	6	6	30.9	0	2	5	17	4,500	2011	4	28	28	8	5	6	N	4	4	8	11.3	04/22/13	0	10	0
02082	SR 800	Brook	Torrington	-73.098622	41.841796	1931	1983	1	1	1	12	12	0	32	2	5	17	5,400	2012	1	30	0	8	6	6	N	6	9	6	27.7	10/17/13	0	4	0
02084	SR 800	Torrington Brook	Torrington	-73.075889	41.881514	1931		1	1	1	6	6	0	0	2	5	17	4,900	2011	5	28	0	8	6	6	N	6	7	6	19.6	04/22/13	0	4	0
02085	SR 800	Brook	Winchester	-73.074853	41.884749	1931		1	19	1	8	8	0	52	2	5	7	4,900	2009		28	0	8	N	7	7	7	7	8	45	07/20/11	0	3	0
02087	Route 8	Brook	Winchester	-73.048257	41.955491	1913		1	1	1	7	10	26.3	0	2	5	6	2,900	2012	35	24	25	7	7	6	N	6	6	6	11	10/22/13	0	4	0
02088	Route 8	Brook	Winchester	-73.049350	41.963936	1913		1	1	1	8	11	25.5	0	2	5	6	3,200	2011	3	23	23	8	7	7	N	6	6	8	20.4	06/06/13	0	4	0
02089	Route 8	Brook	Colebrook	-73.046442	41.975748	1913		1	1	1	8	10	27.5	0	2	5	6	3,200	2009	2	25	25	7	5	5	N	5	6	6	20.9	06/26/12	0	4	0
02091	Route 8	Brook	Colebrook	-73.044671	41.981170	1995		1	19	1	13	18	0	35	2	5	6	2,900	2012	2	26	34	8	N	6	7	7	7	8	42.7	09/04/13	0	4	0
02200	Route 20	Brook	Winchester	-73.046507	41.947546	1915		1	1	1	10	10	40	62	2	5	7	1,900	2011	7	29	30	6	7	6	N	6	4	6	34.6	03/25/13	0	2	0
02202	Route 20	Valley Brook	Hartland	-73.002980	41.986881	1939	1995	1	1	1	16	16	35.2	0	2	5	7	700	2012	8	30	33	8	7	7	N	7	7	6	98.6	06/26/13	0	2	0
02203	Route 20	Brook	Hartland	-72.996927	41.991221	1926		1	1	1	8	12	30.8	10	2	5	7	600	2010	9	28	28	8	6	6	N	6	8	6	42.8	02/06/12	0	2	0
02204	Route 20	Falls Brook	Hartland	-72.966298	42.026695	1940		1	19	1	8	8	0	0	2	5	7	450	2012	9	32	0	8	N	7	5	5	6	8	43.1	01/16/14	0	2	0
02205	Route 20	Brook	Hartland	-72.956250	42.026652	1940		1	19	1	8	8	0	0	2	5	7	400	2011	10	30	0	8	N	7	6	6	6	8	44.2	04/02/13	0	2	0
02206	Route 20	Hurricane Brook	Hartland	-72.925974	42.032928	1940		2	19	2	8	17	0	0	2	5	7	400	2011	20	28	0	8	N	7	6	6	7	8	43.3	05/23/13	0	2	0
02207	Route 20	Brook	Hartland	-72.919441	42.016127	1940		1	19	1	7	7	0	35	2	5	7	450	2012	20	30	0	8	N	7	6	6	8	8	43.1	07/29/13	0	2	0
02208	Route 20	Wright Brook	Hartland	-72.887998	41.975090	1934		1	1	1	10	13	35.5	14	2	5	7	1,600	2011	4	33	30	6	6	6	N	6	6	6	33.2	04/02/13	0	2	0
02230	U.S. Route 202	Hill Brook	Litchfield	-73.263442	41.715259	1933		1	1	1	10	13	35.5	25	2	5	2	6,600	2011	8	32	31	8	6	6	N	5	6	6	13.8	04/18/13	0	6	0
02231	U.S. Route 202	Still Brook	Litchfield	-73.246423	41.723082	1928		1	1	1	12	15	32.1	17	2	5	2	7,900	2011	8	31	30	8	6	7	N	5	9	6	10	04/18/13	0	6	0
02232	U.S. Route 202	Stream	Litchfield	-73.234675	41.724928	1928		1	1	1	6	9	30	0	2	5	2	10,200	2011	8	29	30	8	6	7	3	6	7	8	11	05/20/13	0	6	0
02233	U.S. Route 202	Moulthrop Brook	Litchfield	-73.208444	41.744567	1928		3	2	1	8	12	42	23	2	5	2	11,800	2012	2	33	33	6	6	7	N	6	6	6	96.2	03/06/14	0	6	0
02236	U.S. Route 202	Stream	Litchfield	-73.155751	41.783080	1957		1	19	1	10	10	0	0	2	5	2	8,100	2010	10	41	0	8	N	2	6	6	7	8	30	05/07/12	0	6	0
02238	U.S. Route 202	Gulf Stream	Torrington	-73.138310	41.786830	1952		1	1	1	17	20	45.6	0	2	5	14	6,300	2010	2	40	40	8	6	6	N	5	8	6	40.1	11/28/12	0	4	0
02292	Route 41	Beardsley Pond Brook	Sharon	-73.470589	41.883889	1940		1	19	1	10	10	0	0	2	5	7	5,200	2010	1	36	0	8	N	6	6	6	6	8	43.9	07/03/12	0	3	0
02296	Route 41	Ball Brook	Salisbury	-73.429683	42.016481	1928		1	1	1	6	6	30.5	0	2	5	7	1,400	2012	5	27	28	8	7	6	N	6	7	6	87.9	05/14/13	0	3	0
02297	Route 41	Ball Brook	Salisbury	-73.430016	42.017800	1928		1	1	1	8	11	30.5	37	2	5	7	1,600	2010	2	28	28	8	6	5	N	6	5	6	85.8	06/21/12	0	3	0
02301	Route 43	Hollenbeck River	Cornwall	-73.293477	41.868054	1929		1	1	1	8	11	32.3	0	2	5	7	500	2010	4	28	30	6	3	5	N	3	3	6	34.4	05/07/12	0	2	0
02302	Route 43	Brook	Cornwall	-73.284575	41.890197	1995		1	19	1	10	10	35	0	2	5	7	500	2009	15	30	32	8	N	7	8	8	7	8	43.4	01/04/11	0	3	0

Appendix A

Table A-1 "State Road Structures over Water 6 to 20-Ft (176) within Project Limits"

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Material Type Code (43A)	Design Type Code (43B)	Number Spans (45)	Length Max Span (48)	Structure Length (49)	Deck Width Out to Out (52)	Skew (34)	Lanes On (28)	Bridge Posting (70)	Functional Class Code (26)	ADT (29)	Year ADT (30)	Bypass Detour Length (19)	Approach Roadway Width (32)	Roadway Width Curb to Curb (51)	Approach Roadway Alignment (72)	Substructure Condition (60)	Channel Protection (61)	Culverts Condition (62)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Inspection Date (90)	Defense Highway Designation (100)	Truck ADT (109)	Designated National Network (110)
02305	U.S. Route 44	Burton Brook	Salisbury	-73.438813	41.967732	1873	1973	8	11	1	10	10	29.3	5	2	5	2	8,400	2012	4	35	27	8	6	5	N	5	7	6	10	05/08/13	0	6	0
02306	U.S. Route 44	Garnet Brook	Salisbury	-73.405689	41.997424	1928	1986	1	1	1	8	11	34.8	34	2	5	2	4,700	2010	8	30	32	8	6	5	N	6	6	6	32.5	06/27/12	0	6	1
02307	U.S. Route 44	Brook	North Canaan	-73.344704	42.022730	1919		1	1	1	6	10	31.8	9	2	5	2	4,600	2011	1	28	29	8	6	7	N	6	8	6	25.7	05/29/13	0	6	0
02308	U.S. Route 44	Brook	North Canaan	-73.274194	42.011267	1949		2	19	2	6	14	67	0	2	5	2	4,600	2012	7	41	0	8	N	6	7	6	4	8	35.7	12/30/13	0	6	0
02311	U.S. Route 44	Mill Brook	Colebrook	-73.132772	41.963729	1940		1	19	1	12	12	0	0	2	5	2	4,600	2011	6	38	0	8	N	6	6	6	7	8	39.1	04/01/13	0	6	0
02312	U.S. Route 44	Drainage	Barkhamsted	-73.045336	41.909215	1947		1	19	1	9	9	0	0	2	5	2	14,000	2010		38	0	8	N	6	7	7	8	6	45	04/25/12	0	6	0
02313	U.S. Route 44	Mallory Brook	Barkhamsted	-73.043441	41.909796	1947		1	19	1	12	12	0	8	2	5	2	14,600	2012	3	39	0	8	N	6	7	7	6	8	35.7	07/15/13	0	6	0
02314	U.S. Route 44	Mallory Brook	Barkhamsted	-73.027003	41.912024	1948		1	19	1	17	17	0	30	2	5	2	13,000	2010	4	38	0	8	N	6	6	6	7	8	34	05/04/12	0	6	1
02315	U.S. Route 44	Brook	Barkhamsted	-72.997949	41.905198	1948		1	19	1	8	8	0	0	2	5	2	8,100	2009	4	37	0	8	N	7	7	7	7	8	38.1	07/06/11	0	6	0
02316	U.S. Route 44	Brook	Barkhamsted	-72.989541	41.896604	1948		1	19	1	6	6	0	0	2	5	2	9,800	2009	12	38	0	8	N	7	7	7	6	8	30	07/06/11	0	6	0
02317	U.S. Route 44	Brook	New Hartford	-72.959183	41.859708	1958		1	19	1	12	12	66	0	2	5	2	11,600	2012	12	41	41	8	N	6	7	7	7	8	30	07/01/13	0	6	0
02355	Route 272	Brook	Torrington	-73.149759	41.828789	2009		1	19	1	19	19	138	66	2	5	16	3,100	2012	2	28	0	8	N	7	7	7	6	8	43.7	07/25/13	0	3	0
02358	Route 272	Brook	Goshen	-73.174898	41.898411	1961		1	19	1	8	8	40	20	2	5	7	1,200	2010	20	35	35	6	N	7	6	6	6	8	39.9	02/05/13	0	3	0
02414	Route 63	Wattles Brook	Watertown	-73.100841	41.579809	1941		1	19	1	10	10	28	24	2	5	14	13,800	2012	1	27	0	8	N	7	6	6	8	8	42.1	10/24/13	0	4	0
02418	Route 63	Steele Brook	Watertown	-73.128018	41.615836	1934		1	1	1	12	15	35	30	2	5	14	6,400	2012	3	30	30	8	6	6	N	6	6	6	77.2	09/11/13	0	4	0
02420	Route 63	Stream	Morris	-73.170937	41.671494	1934		1	1	1	10	13	35	0	2	5	6	2,800	2011	8	29	30	8	6	6	N	5	8	6	15.1	03/13/13	0	4	0
02421	Route 63	East Morris Brook	Morris	-73.179567	41.686847	1942		1	19	1	10	10	0	0	2	5	6	2,800	2011	6	28	0	8	N	6	6	6	8	8	41.4	03/13/13	0	4	0
02422	Route 63	Stream	Litchfield	-73.186557	41.715235	1942		1	19	1	8	8	0	0	2	5	6	4,400	2007	5	28	0	8	N	7	7	7	7	8	40.3	10/29/11	0	4	0
02423	Route 63	Brook	Cornwall	-73.267835	41.900720	1950		1	19	1	18	18	53	0	2	5	7	2,400	2011	2	29	0	8	N	6	5	5	9	8	42.9	01/04/13	0	3	0
02444	Route 69	Brook	Bristol	-72.945647	41.701026	2010		1	19	2	5	16	0	26	2	5	16	6,700	2011	1	33	0	8	N	7	8	8	5	6	42.5	08/27/12	0	3	0
02446	Route 69	Whigville Brook	Burlington	-72.969534	41.741399	1962		1	1	1	16	19	36.8	27	2	5	7	4,400	2010	4	33	32	6	6	5	N	6	6	6	92.8	05/01/12	0	3	0
02447	Route 69	Whigville Brook	Burlington	-72.974607	41.748083	1962		1	1	1	13	15	36.4	26	2	5	7	5,600	2012	5	30	30	8	7	6	N	7	8	6	11	07/03/13	0	3	0
02467	Route 72	Poland River	Plymouth	-73.004949	41.693956	1927		1	1	1	10	16	30.8	0	2	5	7	2,500	2011	3	28	29	6	7	6	N	6	5	6	33.5	05/31/13	0	3	0
02469	Route 72	Poland River	Harwinton	-73.013941	41.726082	1927		1	1	1	10	15	30.7	0	2	5	7	2,200	2011	7	28	28	8	7	7	N	7	5	6	30.7	05/01/13	0	3	0
02470	Route 72	Poland River	Harwinton	-73.013933	41.726877	1927		1	1	1	12	17	30.5	0	2	5	7	2,200	2012	7	28	28	8	5	6	N	5	5	6	29.5	05/07/13	0	3	0
02471	Route 72	Poland River	Harwinton	-73.014219	41.730057	1927		1	1	1	13	18	30.5	25	2	5	7	2,200	2009	7	28	28	8	6	6	N	6	5	6	29.5	04/29/13	0	3	0
02473	Route 72	Brook	Harwinton	-73.027812	41.774147	2002		9	19	2	8	16	0	0	2	5	7	2,200	2012	10	41	0	8	N	6	6	6	9	8	40.3	05/29/13	0	3	0
02613	Route 109	Mallory Brook	Washington	-73.289252	41.652373	1934		1	11	1	11	11	25.9	31	2	5	7	1,900	2011	4	20	23	8	6	6	N	5	4	3	16.9	03/14/13	0	3	0
02615	Route 109	East Morris Brook	Morris	-73.187991	41.688219	1929		1	1	1	12	15	31.5	28	2	5	7	3,400	2012	9	30	29	8	6	6	N	5	7	6	12	11/05/13	0	3	0
02616	Route 109	Beaver Brook	Morris	-73.176873	41.687310	1929		1	1	1	6	9	31.5	26	2	5	7	3,300	2010	2	28	29	8	6	5	N	6	5	6	23.5	02/21/12	0	3	0

Table A-1 "State Road Structures over Water 6 to 20-Ft (176) within Project Limits"

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Material Type Code (43A)	Design Type Code (43B)	Number Spans (45)	Length Max Span (48)	Structure Length (49)	Deck Width Out to Out (52)	Skew (34)	Lanes On (28)	Bridge Posting (70)	Functional Class Code (26)	ADT (29)	Year ADT (30)	Bypass Detour Length (19)	Approach Roadway Width (32)	Roadway Width Curb to Curb (51)	Approach Roadway Alignment (72)	Substructure Condition (60)	Channel Protection (61)	Culverts Condition (62)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Inspection Date (90)	Defense Highway Designation (100)	Truck ADT (109)	Designated National Network (110)
02617	Route 109	Brook	Morris	-73.144657	41.673012	1938	1992	2	19	2	9	19	0	36	2	5	7	2,900	2011	5	30	0	8	N	6	5	5	7	8	40.8	05/14/12	0	3	0
02618	Route 109	Stream	Thomaston	-73.124930	41.664592	1939		1	19	1	8	8	0	30	2	5	17	3,600	2012	9	40	0	8	N	6	6	6	9	8	38.1	11/22/13	0	3	0
02630	Route 112	Brook	Salisbury	-73.404360	41.934466	1930		1	1	1	6	6	0	0	2	5	7	2,400	2012	7	27	0	8	6	6	N	6	8	6	22.9	05/14/13	0	3	0
02653	Route 128	Stream	Cornwall	-73.329164	41.870032	1938		1	19	1	11	11	60	44	2	5	7	1,500	2011	7	35	35	8	N	6	6	6	6	8	42.8	01/03/13	0	2	0
02655	Route 132	Wood Creek	Bethlehem	-73.225563	41.627345	1941		1	1	1	14	16	35.2	0	2	5	7	1,300	2011	5	29	30	6	6	6	N	6	9	6	39.2	03/25/13	0	2	0
02764	Route 179	Brook	Hartland	-72.914256	41.980229	1937		1	19	1	9	9	0	15	2	5	7	1,200	2012	8	34	0	8	N	7	6	6	7	8	43	08/21/13	0	2	0
02765	SR 819	Fox Brook	Hartland	-72.884338	42.034007	1933		1	19	1	9	9	0	30	2	5	7	400	2010	10	28	0	8	N	7	7	7	7	8	44.2	08/08/11	0	7	0
02766	Route 182	Brook	Colebrook	-73.117143	41.985060	1939		1	19	1	7	7	0	30	2	5	7	550	2012	3	31	0	8	N	6	7	7	7	8	44.7	07/24/13	0	2	0
02768	Route 183	W Branch Leadmine Brook	Torrington	-73.083250	41.811532	1954		1	1	1	6	6	29.3	0	2	5	17	7,100	2012	3	27	27	8	7	7	N	6	6	6	13.7	09/17/13	0	4	0
02770	Route 183	Colebrook Brook	Winchester	-73.095359	41.946863	1919		1	1	1	12	18	27.5	0	2	5	7	1,300	2011	3	24	26	6	7	7	N	5	5	6	27	03/14/13	0	3	0
02771	Route 183	Colebrook Brook	Winchester	-73.100815	41.955575	1919		1	1	1	12	15	27.7	0	2	5	7	1,300	2011	3	25	26	8	6	6	N	5	6	6	28.8	03/18/13	0	3	0
02848	Route 219	Carter Brook	New Hartford	-72.987138	41.879087	1929	1988	1	1	1	13	13	0	28	2	5	7	4,400	2012	3	34	0	6	N	7	6	6	7	8	24.4	03/05/14	0	3	0
02850	Route 219	Stream	Barkhamsted	-72.930417	41.923837	1933		1	19	1	11	11	0	45	2	5	7	6,200	2012	9	33	0	9	N	6	6	6	8	8	33.1	06/26/13	0	3	0
02851	Route 219	Brook	Barkhamsted	-72.925059	41.926368	1933		1	19	1	6	6	0	34	2	5	7	5,700	2009	7	29	0	8	N	6	7	7	7	8	36.5	09/11/12	0	3	0
02852	Route 219	Brook	Barkhamsted	-72.907784	41.943218	1933		1	19	1	6	6	0	0	2	5	7	4,700	2010	7	31	0	8	N	7	6	6	8	8	38	09/11/12	0	3	0
02855	Route 222	Brook	Plymouth	-73.054491	41.702934	1960		1	19	1	7	9	0	23	2	5	7	750	2011	4	26	0	6	N	6	6	6	7	8	44.4	03/06/13	0	2	0
02871	Route 272	Hall Meadow Brook	Norfolk	-73.208991	41.931526	1920	1992	5	1	1	15	17	36.5	0	2	5	7	1,100	2011	2	33	33	8	6	7	N	6	7	6	98.8	03/21/13	0	3	0
02892	Route 341	Cobble Brook	Kent	-73.455148	41.719719	1933		1	19	1	12	12	47	0	2	5	7	1,600	2011	7	29	0	8	N	6	6	6	9	8	42.6	06/06/13	0	3	0
02893	Route 343	Brook	Sharon	-73.488573	41.874420	1925		1	1	1	8	12	30.8	28	2	5	6	2,600	2009		29	29	6	6	6	N	6	6	6	36.4	04/01/13	0	4	0
02907	SR 827	Womenshenuck Brook	Kent	-73.482127	41.692623	1935		1	19	1	8	14	0	0	2	5	8	1,200	2010	8	30	0	6	N	5	5	5	6	8	41.9	01/31/12	0	2	0
02961	Route 45	Sucker Brook	Warren	-73.349454	41.747280	1930		1	1	1	6	8	36.7	0	2	5	7	1,600	2011	7	30	35	8	5	6	N	5	6	6	85	08/01/13	0	3	0
02962	Route 45	Gunn Brook	Cornwall	-73.361456	41.788465	1930		1	19	1	6	6	0	0	2	5	7	1,200	2011	5	31	0	8	N	6	5	5	8	8	42.7	12/20/12	0	3	0
02965	Route 47	Brook	Washington	-73.299371	41.623612	1928		1	1	1	6	9	31.1	0	2	5	7	2,000	2011	5	26	29	8	6	6	N	6	8	6	88.9	03/14/13	0	3	0
02966	Route 47	Kirby Brook	Washington	-73.307862	41.626846	1928		1	1	1	8	10	30.7	14	2	5	7	2,300	2011	30	27	29	6	6	6	N	6	8	6	81.3	03/14/13	0	3	0
03260	Route 4	Brook	Torrington	-73.169073	41.823805	1926		1	1	1	5	11	33.2	18	2	5	14	6,400	2011	4	31	30	8	6	6	N	5	8	6	15.5	05/02/13	0	4	0
03266	U.S. Route 202	Brook	Torrington	-73.142754	41.786032	1952		1	19	1	9	9	0	30	2	5	14	5,900	2012		42	0	8	N	7	6	6	8	8	45	08/01/13	0		0
03267	Route 43	Brook	Cornwall	-73.307672	41.852806	1996		1	19	1	11	11	37	20	2	5	7	400	2009	1	34	34	8	N	5	7	7	8	8	44.9	08/20/13	0		0
03268	Route 109	Moosehorn Brook	Thomaston	-73.133318	41.668914	1939		1	19	1	10	10	0	30	2	5	7	2,900	2010	9	29	0	7	N	6	6	6	9	8	39.5	07/16/12	0	3	0
03269	Route 182a	Brook	Colebrook	-73.116778	41.987631	1928		1	1	1	6	6	0	0	2	5	7	300	2009	3	31	0	8	7	8	N	7	7	8	29.6	07/13/10	0	3	0
03300	U.S. Route 44	Brook	Salisbury	-73.371132	42.004407	1928		1	1	1	8	12	0	45	2	5	2	4,900	2011	4	39	0	8	6	6	N	6	8	6	20.1	06/27/12	0	6	1
03333	Route 8 & Ramp	Pickett Brook	Harwinton	-73.115297	41.759908	1966		1	19	1	11	11	294	0	6	5	2	19,500	2011	3	0	0	8	N	6	7	7	8	8	32.6	02/07/13	0	6	1

Appendix A

Table A-1 "State Road Structures over Water 6 to 20-Ft (176) within Project Limits"

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Material Type Code (43A)	Design Type Code (43B)	Number Spans (45)	Length Max Span (48)	Structure Length (49)	Deck Width Out to Out (52)	Skew (34)	Lanes On (28)	Bridge Posting (70)	Functional Class Code (26)	ADT (29)	Year ADT (30)	Bypass Detour Length (19)	Approach Roadway Width (32)	Roadway Width Curb to Curb (51)	Approach Roadway Alignment (72)	Substructure Condition (60)	Channel Protection (61)	Culverts Condition (62)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Inspection Date (90)	Defense Highway Designation (100)	Truck ADT (109)	Designated National Network (110)
03756	U.S. Route 202	Bakersville Brook	New Hartford	-73.004118	41.829179	1971		1	19	1	10	10	48.2	0	2	5	2	11,900	2009	3	44	44	8	N	6	7	7	7	8	37.4	07/10/12	0	6	0
03757	U.S. Route 202	South Nepaug Brook	New Hartford	-73.001587	41.829606	1971		1	19	1	10	10	48.2	0	2	5	2	11,100	2009	6	44	44	8	N	8	7	7	7	8	30.9	07/07/11	0	6	0
04339	Route 183	Leadmine Brook	Torrington	-73.085498	41.803660	1980		1	19	1	17	17	0	43	2	5	17	6,200	2010	3	30	0	8	N	7	7	7	7	8	41.1	09/19/11	0	4	0
05372	Route 4	Bierce Brook	Goshen	-73.214972	41.836152	1986		1	1	1	17	18	37.8	10	2	5	6	7,100	2012	2	34	34	8	7	7	N	7	8	6	95.9	07/03/13	0	4	0
05408	Route 4	Punch Brook	Burlington	-72.926099	41.781573	1965		3	19	1	13	13	0	0	2	5	14	11,600	2011	4	42	0	8	N	7	6	6	6	8	35.1	01/14/13	0	4	0
05409	Route 254	Northfield Brook	Thomaston	-73.088029	41.674302	1964		3	19	1	20	20	0	38	2	5	16	3,800	2012	5	42	0	8	N	7	7	7	8	8	41	02/26/14	0	3	0
05410	Route 272	Jacobs Brook	Torrington	-73.167752	41.864471	1957		3	19	1	17	17	0	5	2	5	16	1,500	2011	5	34	0	8	N	5	6	6	8	8	43.4	02/19/13	0	3	0
05416	Route 254	Northfield Brook	Thomaston	-73.086792	41.673773	1970	2006	9	19	1	16	16	0	40	2	5	16	3,200	2010	1	43	0	8	N	8	8	8	9	8	44.3	04/10/12	0	3	0
05417	Route 109	Brook	Morris	-73.253094	41.678924	1956		3	19	1	12	12	62.4	0	2	5	7	1,770	2012	2	36	36	8	N	7	5	5	6	8	43.2	11/05/13	0	3	0
05418	Route 128	Mill Brook	Cornwall	-73.340317	41.875327	1930	1986	1	7	1	16	20	34.5	11	2	5	7	1,500	2011	3	29	31	8	6	5	N	6	9	5	94.8	12/24/12	0	2	0
05423	Route 272	Wood Creek	Norfolk	-73.202232	41.994719	1956	2013	3	19	1	16	16	44.4	3	2	5	7	750	2012		29	41	8	N	6	8	8	8	5	98	02/11/14	0	2	0
05426	Route 254	Turner Brook	Litchfield	-73.105844	41.697186	1961	2006	3	19	1	14	14	0	0	2	5	7	3,800	2012	1	39	0	8	N	6	7	7	8	8	44.2	08/01/13	0	3	0
05445	U.S. Route 7	Brook	Sharon	-73.383113	41.833382	1987		1	1	1	10	14	35.8	26	2	5	6	1,400	2011	5	32	32	8	7	7	N	7	6	6	98.5	05/01/13	0	4	0
05446	U.S. Route 7	Pine Swamp Brook	Sharon	-73.369636	41.866107	1924	1987	1	1	1	13	18	35	27	2	5	6	1,400	2012	10	32	32	6	7	7	N	7	8	6	94.9	09/09/13	0	4	0
05460	U.S. Route 7	Whiting Brook	Canaan	-73.334344	41.970099	1925	1987	5	1	1	14	16	33.7	0	2	5	6	2,900	2011	5	30	30	8	6	6	N	6	6	6	79.6	04/02/13	0	4	0
05461	U.S. Route 6	Lewis Atwood Brook	Watertown	-73.149097	41.598706	1987		1	19	1	9	9	0	32	2	5	6	4,900	2012	1	30	0	7	N	6	7	7	7	8	44	09/11/13	0	4	0
05505	Route 4	West Branch Bantam River	Goshen	-73.238974	41.831075	1987		1	7	1	15	17	37.8	0	2	5	6	6,000	2009	3	33	34	8	7	7	N	7	7	6	96.6	03/14/11	0	4	0
05507	Route 126	Robbins Swamp Area	Canaan	-73.358354	41.970244	1987		3	19	1	16	16	0	0	2	5	7	1,400	2011	3	33	0	8	N	5	7	7	7	8	44.1	08/31/12	0	6	0
05563	Route 222	Brook	Thomaston	-73.067048	41.684630	1988		1	19	1	12	12	31.8	23	2	5	16	1,800	2012	18	28	29	8	N	6	7	7	7	8	36.9	08/02/13	0	4	0
05592	Route 183	Colebrook Brook	Winchester	-73.103114	41.961702	1988		1	19	1	10	10	47	10	2	5	7	1,300	2009	4	26	29	8	N	7	7	7	6	8	42.9	06/13/11	0	2	0
05595	Route 4	Troy Brook	Torrington	-73.118116	41.809574	1988		5	1	1	14	16	44.3	28	2	5	14	12,900	2012	1	30	30	8	7	7	N	7	7	6	76.8	10/09/13	0	4	0
05597	Route 72	Bristol Reservoir	Harwinton	-73.021574	41.748654	1988		5	1	1	7	13	31.5	18	2	5	7	2,000	2010	6	28	28	7	7	7	N	7	7	6	86.1	03/08/12	0	3	0
05598	SR 800	Still River	Torrington	-73.097419	41.849541	1988		1	19	1	19	19	0	50	2	5	17	5,600	2006	3	31	0	8	N	7	7	7	8	8	41.4	04/27/10	0	4	0
05669	U.S. Route 6	North Creek	Bristol	-72.946788	41.681317	1988		1	19	1	14	14	0	0	3	5	12	18,400	2011		45	45	6	N	7	7	7	8	8	45	11/14/12	0	4	0
05715	Route 109	Canoe Brook	Washington	-73.325392	41.644504	1989		1	19	1	10	10	34	38	2	5	7	2,000	2007	6	20	29	8	N	7	7	7	9	8	41.4	05/18/10	0	3	0
05718	U.S. Route 7	Millard Brook	Cornwall	-73.398925	41.792652	1989		1	19	1	14	14	31.9	20	2	5	6	2,200	2009	3	30	29	8	N	7	7	7	8	8	43.6	08/09/11	0	4	0
05724	U.S. Route 7	Eddys Cove	North Canaan	-73.324780	42.022621	1989		1	19	1	20	20	42.7	7	2	5	6	5,800	2007	7	34	34	8	N	7	7	7	8	8	33.8	08/06/10	0	6	0
05770	Route 183	Center Brook	Colebrook	-73.097843	41.991563	1989		5	1	1	13	17	32	9	2	5	7	1,300	2011	6	24	24	6	7	8	N	7	7	6	84.3	03/14/13	0	2	0
05896	U.S. Route 202	Bee Brook	Washington	-73.333111	41.681593	1932	1990	1	1	1	14	16	35.3	0	2	5	2	5,700	2011	1	32	32	8	7	6	N	7	7	6	91.8	06/06/13	0	7	1
05982	Route 63	Brown Brook	Canaan	-73.279748	41.926693	1924	1987	1	1	1	16	20	33.6	0	2	5	7	2,600	2011	6	29	30	8	6	5	N	6	9	6	93	12/18/12	0	3	0

Table A-1 "State Road Structures over Water 6 to 20-Ft (176) within Project Limits"

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Material Type Code (43A)	Design Type Code (43B)	Number Spans (45)	Length Max Span (48)	Structure Length (49)	Deck Width Out to Out (52)	Skew (34)	Lanes On (28)	Bridge Posting (70)	Functional Class Code (26)	ADT (29)	Year ADT (30)	Bypass Detour Length (19)	Approach Roadway Width (32)	Roadway Width Curb to Curb (51)	Approach Roadway Alignment (72)	Substructure Condition (60)	Channel Protection (61)	Culverts Condition (62)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Inspection Date (90)	Defense Highway Designation (100)	Truck ADT (109)	Designated National Network (110)
06239	U.S. Route 7	Wangum Lake Brook	Canaan	-73.334394	41.965840	1993		1	19	2	7	16	32.2	0	2	5	6	3,400	2012		29	28	8	N	7	7	7	7	8	43	10/02/13	0	4	0
06240	Route 132	East Spring Brook	Bethlehem	-73.183487	41.649650	1993		1	7	1	16	16	33.4	10	2	5	7	1,500	2012		27	30	8	7	6	N	7	8	6	40.8	09/04/13	0	2	0
06261	Route 8	Brook	Winchester	-73.050352	41.947260	1994		1	19	1	11	11	36.5	0	2	5	6	4,600	2008	5	32	33	8	N	8	7	7	7	8	37.8	03/16/12	0	4	0
06262	Route 4	Whiting Brook	Torrington	-73.164133	41.823158	1994		1	19	1	12	14	0	0	2	5	14	6,700	2012	2	32	0	8	N	6	7	7	9	8	42.2	09/18/13	0	4	0
06528	Route 4	Taylor Brook	Torrington	-73.106690	41.807657	2002		9	19	1	10	10	0	40	2	5	14	7,700	2010		42	0	8	N	7	8	8	7	8	45	09/10/12	0		0
06538	Route 272	Brook	Goshen	-73.182619	41.911565	1997		1	19	1	11	11	51	15	2	5	7	1,000	2012	6	26	26	8	N	6	7	7	7	8	43.7	10/02/13	0	5	0
06620	Route 72	Yard's Pond	Bristol	-72.905849	41.669294	2009		1	19	1	9	9	112	21	5	5	12	22,200	2012		80	74	8	N	8	7	7	8	6	43	10/30/13	0	5	0
06625	Route 63	Stream	Watertown	-73.112400	41.595948	2004		9	19	1	18	18	0	10	2	5	14	18,700	2011	1	40	0	8	N	7	7	7	6	8	41	12/06/12	0	10	0
06655	Route 4	Mill Brook	Sharon	-73.463713	41.865981	1972		3	11	1	18	18	0	0	2	5	6	2,000	2009	3	29	0	8	6	6	N	6	7		84.5	03/12/12	0	4	0
06656	U.S. Route 202	Brook	Litchfield	-73.171002	41.773357	1950		3	19	1	10	10	0	21	2	5	2	8,400	2012	5	42	42	8	N	5	3	3	6		30.7	12/05/12	0	6	0
06657	U. S. Route 202	Brook	Litchfield	-73.170110	41.774071	1952		3	19	1	10	10	0	21	2	5	2	8,400	2012	6	41	41	8	N	5	3	3	6	8	28.6	12/05/12	0	6	0
06666	Route 20	Brook	Barkhamsted	-73.034374	41.952426	1970		3	19	1	6	6	24.7	0	2	5	1	1,900	2011	9	0	0	8	N	8	6	6	8	8	41.4	04/09/13	0	5	0
06667	Route 69	Negro Hill Brook	Burlington	-72.949793	41.725213	1966		3	19	2	6	16	0	0	2	5	7	4,100	2012	4	28	0	7	N	6	3	3	6	8	37	11/20/13	0	3	0
06668	Route 179	Brook	Burlington	-72.925336	41.793430	1966		3	19	1	9	9	0	41	2	5	7	10,400	2011	5	40	0	8	N	6	6	6	6	8	34	02/07/13	0	4	0
06670	Route 8	Brook	Colebrook	-73.052822	42.018206	1967		3	19	1	8	8	259	0	2	5	6	2,600	2011		45	0	7	N	8	6	6	8	8	45	04/08/13	0	5	0
06671	Route 8	Brook	Colebrook	-73.052648	42.025386	1967		3	19	1	6	6	158	0	2	5	6	2,700	2009		0	0	8	N	8	7	7	8	8	45	04/20/11	0	5	0
06672	Route 8	Brook	Colebrook	-73.056614	42.034242	1967		3	19	1	7	7	164	10	2	5	6	2,600	2011		0	0	8	N	8	6	6	8	8	45	04/08/13	0	5	0
06687	Route 8 NB & SB	Brook	Litchfield	-73.106745	41.730595	1960	2013	3	19	1	8	8	0	0	4	5	2	24,300	2011	1	83	0	8	N	8	7	7	7	8	39.8	04/15/13	0	6	1
06701	Route 254	Brook	Thomaston	-73.098773	41.692227	1961		3	19	1	8	8	0	0	2	5	16	3,800	2012	5	41	0	8	N	6	3	3	6		36.3	03/13/13	0	4	0
06702	Route 109	Brook	Thomaston	-73.109564	41.662529	2005		3	19	1	6	6	0	0	2	5	16	4,500	2012	6	42	0	7	N	6	7	7	8	8	39.3	08/02/13	0	4	0
06707	Route 8	Brook	Torrington	-73.113712	41.815167	1966	2009	0	19	1	7	7	0	22	2	5	2	18,800	2009	4	0	0	8	N	8	7	7	6	8	28	03/17/11	0	5	1
06708	Route 8	Troy Brook	Torrington	-73.107226	41.828070	1966	2009	3	19	1	6	6	0	30	6	5	2	16,600	2011	3	0	0	8	N	5	7	7	6	8	34.4	02/20/13	0	5	1
06712	Route 63	Brook	Watertown	-73.120473	41.609197	1966		3	19	2	8	20	0	32	2	5	14	6,400	2011	2	27	0	8	N	6	5	5	6	8	41.2	03/04/13	0	4	0
06719	SR 855	Brook	Watertown	-73.083551	41.593851	1998		3	19	1	10	10	0	45	2	5	7	5,900	2011	1	30	0	8	N	6	6	6	6	8	43.8	12/06/12	0	2	0
06786	Route 109	Mallory Brook	Washington	-73.302267	41.649304			3	19	2	6	15	0	0	2	5	7	1,900	2012		20	0	8	N	6	3	3	6	6	41	11/07/13	0	5	0

Table A-2 - Structure Inventory Population and Selection

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating
Structures (27) selected for field review in first round and advanced to hydrologic/hydraulic evaluation														
01930	Route 4	Guinea Brook	Sharon	41.826232	-73.419041	1933	1986	11	2,000	6	5	8	6	30.7
01937	Route 4	Birdseye Brook	Cornwall	41.847304	-73.309522	1916		9	3,500	2	5	6	3	23.3
01947	Route 4	Brook	Harwinton	41.776291	-73.022848	1927		15	11,800	8	5	6	6	10
02048	U.S. Route 7	Cobble Brook	Kent	41.740142	-73.457236	1924		19	2,700	19	5	6	6	11.6
02050	U.S. Route 7	Kent Falls Brook	Kent	41.776571	-73.418961	1924		19	2,200	20	5	8	6	18.5
02051	U.S. Route 7	Deep Brook	Cornwall	41.785699	-73.408221	1924		12	2,100	7	5	9	6	22.3
02078	SR 848	Brook	Thomaston	41.618156	-73.057737	1923		12	2,200	8	5	7	6	13.8
02082	SR 800	Brook	Torrington	41.841796	-73.098622	1931	1983	12	5,400	1	6	9	6	27.7
02089	Route 8	Brook	Colebrook	41.975748	-73.046442	1913		10	3,200	2	5	6	6	20.9
02204	Route 20	Falls Brook	Hartland	42.026695	-72.966298	1940		8	450	9	5	6	8	
02205	Route 20	Brook	Hartland	42.026652	-72.956250	1940		8	400	10	6	6	8	44.2
02230	U.S. Route 202	Hill Brook	Litchfield	41.715259	-73.263442	1933		13	6,600	8	5	6	6	13.8
02231	U.S. Route 202	Still Brook	Litchfield	41.723082	-73.246423	1928		15	7,900	8	5	9	6	10
02238	U.S. Route 202	Gulf Stream	Torrington	41.786830	-73.138310	1952		20	6,300	2	5	8	6	40.1
02305	U.S .Route 44	Burton Brook	Salisbury	41.967732	-73.438813	1873	1973	10	8,400	4	5	7	6	10
02420	Route 63	Stream	Morris	41.671494	-73.170937	1934		13	2,800	8	5	8	6	15.1
02423	Route 63	Brook	Cornwall	41.900720	-73.267835	1950		18	2,400	2	5	9	8	42.9
02613	Route 109	Mallory Brook	Washington	41.652373	-73.289252	1934		11	1,900	4	5	4	3	16.9
02615	Route 109	East Morris Brook	Morris	41.688219	-73.187991	1929		15	3,400	9	5	7	6	12

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02617	Route 109	Brook	Morris	41.673012	-73.144657	1938	1992	19	2,900	5	5	7	8	40.8
02770	Route 183	Colebrook Brook	Winchester	41.946863	-73.095359	1919		18	1,300	3	5	5	6	27
02771	Route 183	Colebrook Brook	Winchester	41.955575	-73.100815	1919		15	1,300	3	5	6	6	28.8
02965	Route 47	Brook	Washington	41.623612	-73.299371	1928		9	2,000	5	6	8	6	88.9
02966	Route 47	Kirby Brook	Washington	41.626846	-73.307862	1928		10	2,300	30	6	8	6	81.3
03260	Route 4	Brook	Torrington	41.823805	-73.169073	1926		11	6,400	4	5	8	6	15.5
05417	Route 109	Brook	Morris	41.678924	-73.253094	1956		12	1,770	2	5	6	8	43.2
06712	Route 63	Brook	Watertown	41.609197	-73.120473	1966		20	6,400	2	5	6	8	41.2
Structures (4) selected for field review in first round and eliminated from hydrologic/hydraulic evaluation														
02062	U.S. Route 7	Brook	Canaan	41.961205	-73.340969	1927		13	2,300	2	5	7	6	33
02065	U.S. Route 7	Brook	Canaan	41.970517	-73.334341	1928		15	2,900	2	5	5	6	22.6
02470	Route 72	Poland River	Harwinton	41.726877	-73.013933	1927		17	2,200	7	5	5	6	29.5
02907	SR 827	Womenshenuck Brook	Kent	41.692623	-73.482127	1935		14	1,200	8	5	6	8	41.9
Structures (25) selected for field review in second round and advanced to hydrologic/hydraulic evaluation														
01945	Route 4	Catlin Brook	Harwinton	41.771377	-73.068389	1938	1959	12	8,700	6	6	8	6	32.5
01946	Route 4	Rock Brook	Harwinton	41.774372	-73.039661	1927		14	12,300	5	6	5	8	30.5
01948	Route 4	North Branch Bunnell Bk	Burlington	41.776948	-72.999821	1926		8	10,200	6	6	8	8	32
01949	Route 4	Misery Brook	Burlington	41.776233	-72.939403	1928		15	9,500	3	6	6	6	11
01985	U.S. Route 6	Todd Hollow Brook	Plymouth	41.674361	-73.040448	1929		6	15,700	2	6	6	6	16.7
01987	U.S. Route 6	Cuss Gutter Brook	Bristol	41.681597	-72.975310	1929		11	9,900	1	7	4	6	17

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02079	SR 848	Nibbling Brook	Thomaston	41.629228	-73.069963	1923		16	2,200	8	6	5	6	36.4
02200	Route 20	Brook	Winchester	41.947546	-73.046507	1915		10	1,900	7	6	4	6	34.6
02297	Route 41	Ball Brook	Salisbury	42.017800	-73.430016	1928		11	1,600	2	6	5	6	85.8
02306	U.S. Route 44	Garnet Brook	Salisbury	41.997424	-73.405689	1928	1986	11	4,700	8	6	6	6	32.5
02313	U.S. Route 44	Mallory Brook	Barkhamsted	41.909796	-73.043441	1947		12	14,600	3	7	6	8	35.7
02314	U.S. Route 44	Mallory Brook	Barkhamsted	41.912024	-73.027003	1948		17	13,000	4	6	7	8	34
02315	U.S. Route 44	Brook	Barkhamsted	41.905198	-72.997949	1948		8	8,100	4	7	7	8	38.1
02316	U.S. Route 44	Brook	Barkhamsted	41.896604	-72.989541	1948		6	9,800	12	7	6	8	30
02317	U.S. Route 44	Brook	New Hartford	41.859708	-72.959183	1958		12	11,600	12	7	7	8	30
02414	Route 63	Wattles Brook	Watertown	41.579809	-73.100841	1941		10	13,800	1	6	8	8	42.1
02467	Route 72	Poland River	Plymouth	41.693956	-73.004949	1927		16	2,500	3	6	5	6	33.5
02471	Route 72	Poland River	Harwinton	41.730057	-73.014219	1927		18	2,200	7	6	5	6	29.5
02616	Route 109	Beaver Brook	Morris	41.687310	-73.176873	1929		9	3,300	2	6	5	6	23.5
03300	U.S. Route 44	Brook	Salisbury	42.004407	-73.371132	1928		12	4,900	4	6	8	6	20.1
03333	Route 8 & Ramp	Pickett Brook	Harwinton	41.759908	-73.115297	1966		11	19,500	3	7	8	8	32.6
05408	Route 4	Punch Brook	Burlington	41.781573	-72.926099	1965		13	11,600	4	6	6	8	35.1
05418	Route 128	Mill Brook	Cornwall	41.875327	-73.340317	1930	1986	20	1,500	3	6	9	5	94.8
05896	U.S. Route 202	Bee Brook	Washington	41.681593	-73.333111	1932	1990	16	5,700	1	7	7	6	91.8
06668	Route 179	Brook	Burlington	41.793430	-72.925336	1966		9	10,400	5	6	6	8	34

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Structures (9) selected for field review in second round and eliminated from hydrologic/hydraulic evaluation														
01984	U.S. Route 6	Steele Brook	Watertown	41.609605	-73.115942	1926		13	7,900	1	6	5	5	40.1
02066	U.S. Route 7	Brook	Canaan	41.971377	-73.334336	1924		16	2,700	2	6	5	6	34.8
02233	U.S. Route 202	Moulthrop Brook	Litchfield	41.744567	-73.208444	1928		12	11,800	2	6	6	6	96.2
02236	U.S. Route 202	Stream	Litchfield	41.783080	-73.155751	1957		10	8,100	10	6	7	8	30
02308	U.S. Route 44	Brook	North Canaan	42.011267	-73.274194	1949		14	4,600	7	6	4	8	35.7
02312	U.S. Route 44	Drainage	Barkhamsted	41.909215	-73.045336	1947		9	14,000		7	8	6	45
02469	Route 72	Poland River	Harwinton	41.726082	-73.013941	1927		15	2,200	7	7	5	6	30.7
03756	U.S. Route 202	Bakersville Brook	New Hartford	41.829179	-73.004118	1971		10	11,900	3	7	7	8	37.4
03757	U.S. Route 202	South Nepaug Brook	New Hartford	41.829606	-73.001587	1971		10	11,100	6	7	7	8	30.9
Structures (18) not considered for evaluation due to pending projects														
01933	Route 4	Bloody Brook	Cornwall	-73.348834	41.840923	1916		16	2,400	3	4	6	6	31.7
01981	U.S. Route 6	Lewis Atwood Brook	Woodbury	-73.157097	41.600590	1935		14	4,900	14	5	7	7	14
02081	SR 800	Brook	Torrington	-73.119669	41.777124	1922		6	4,500	4	4	4	8	11.3
02232	U.S. Route 202	Stream	Litchfield	-73.234675	41.724928	1928		9	10,200	8	6	7	8	11
02301	Route 43	Hollenbeck River	Cornwall	-73.293477	41.868054	1929		11	500	4	3	3	6	34.4
02355	Route 272	Brook	Torrington	-73.149759	41.828789	2009		19	3,100	2	7	6	8	43.7
02444	Route 69	Brook	Bristol	-72.945647	41.701026	2010		16	6,700	1	8	5	6	42.5
05416	Route 254	Northfield Brook	Thomaston	-73.086792	41.673773	1970	2006	16	3,200	1	8	9	8	44.3
05423	Route 272	Wood Creek	Norfolk	-73.202232	41.994719	1956	2013	16	750		8	8	5	98

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05426	Route 254	Turner Brook	Litchfield	-73.105844	41.697186	1961	2006	14	3,800	1	7	8	8	44.2
06656	U.S. Route 202	Brook	Litchfield	-73.171002	41.773357	1950		10	8,400	5	3	6		30.7
06657	U. S. Route 202	Brook	Litchfield	-73.170110	41.774071	1952		10	8,400	6	3	6	8	28.6
06667	Route 69	Negro Hill Brook	Burlington	-72.949793	41.725213	1966		16	4,100	4	3	6	8	37
06687	Route 8 NB & SB	Brook	Litchfield	-73.106745	41.730595	1960	2013	8	24,300	1	7	7	8	39.8
06701	Route 254	Brook	Thomaston	-73.098773	41.692227	1961		8	3,800	5	3	6		36.3
06707	Route 8	Brook	Torrington	-73.113712	41.815167	1966	2009	7	18,800	4	7	6	8	28
06708	Route 8	Troy Brook	Torrington	-73.107226	41.828070	1966	2009	6	16,600	3	7	6	8	34.4
06786	Route 109	Mallory Brook	Washington	-73.302267	41.649304			15	1,900		3	6	6	41
Remaining Structures (93)														
01590	Route 318	Beaver Brook	Barkhamsted	-72.973459	41.914983	1937		20	5,000	2	6	7	8	42.9
01927	Route 361	Beardsley Pond Brook	Sharon	-73.478232	41.885274	1928		12	1,300	2	6	6	6	28.9
01931	Route 4	Guinea Brook	Sharon	-73.394539	41.822290	1934		15	2,000	22	6	9	6	15
01932	Route 4	Furnace Brook	Cornwall	-73.369078	41.818625	1930	1993	17	2,700	3	6	8	8	43.3
01935	Route 4	Stream	Cornwall	-73.342836	41.843454	1916		13	2,700	3	6	7	6	32.5
01980	U.S. Route 6	Lewis Atwood Brook	Woodbury	-73.169019	41.595326	1949	1985	18	4,900	12	6	7	6	31.1
01982	U.S. Route 6	Lewis Atwood Brook	Watertown	-73.151575	41.598148	1930		8	4,800	5	6	6	6	19.8
02047	U.S. Route 7	Brook	Kent	-73.502696	41.672289	1930		20	2,800	24	6	8	6	12
02049	U.S. Route 7	Mouwee Brook	Kent	-73.441613	41.754819	1924		8	2,300	20	6	8	6	15
02053	U.S. Route 7	Bonney Brook	Cornwall	-73.374094	41.814160	1924		15	3,400	14	6	8	6	16

Appendix A

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02057	U.S. Route 7	Brook	Sharon	-73.366668	41.874075	1924		8	1,900	7	6	9	6	41.2
02058	U.S. Route 7	Brook	Sharon	-73.367723	41.881301	1924		9	1,900	5	6	6	6	29.7
02061	U.S. Route 7	Brook	Canaan	-73.359534	41.945662	1927		11	2,700	16	6	8	6	25.2
02084	SR 800	Torrington Brook	Torrington	-73.075889	41.881514	1931		6	4,900	5	6	7	6	19.6
02085	SR 800	Brook	Winchester	-73.074853	41.884749	1931		8	4,900		7	7	8	45
02087	Route 8	Brook	Winchester	-73.048257	41.955491	1913		10	2,900	35	6	6	6	11
02088	Route 8	Brook	Winchester	-73.049350	41.963936	1913		11	3,200	3	6	6	8	20.4
02091	Route 8	Brook	Colebrook	-73.044671	41.981170	1995		18	2,900	2	7	7	8	42.7
02202	Route 20	Valley Brook	Hartland	-73.002980	41.986881	1939	1995	16	700	8	7	7	6	98.6
02203	Route 20	Brook	Hartland	-72.996927	41.991221	1926		12	600	9	6	8	6	42.8
02206	Route 20	Hurricane Brook	Hartland	-72.925974	42.032928	1940		17	400	20	6	7	8	43.3
02207	Route 20	Brook	Hartland	-72.919441	42.016127	1940		7	450	20	6	8	8	43.1
02208	Route 20	Wright Brook	Hartland	-72.887998	41.975090	1934		13	1,600	4	6	6	6	33.2
02292	Route 41	Beardsley Pond Brook	Sharon	-73.470589	41.883889	1940		10	5,200	1	6	6	8	43.9
02296	Route 41	Ball Brook	Salisbury	-73.429683	42.016481	1928		6	1,400	5	6	7	6	87.9
02302	Route 43	Brook	Cornwall	-73.284575	41.890197	1995		10	500	15	8	7	8	43.4
02307	U.S. Route 44	Brook	North Canaan	-73.344704	42.022730	1919		10	4,600	1	6	8	6	25.7
02311	U.S. Route 44	Mill Brook	Colebrook	-73.132772	41.963729	1940		12	4,600	6	6	7	8	39.1
02358	Route 272	Brook	Goshen	-73.174898	41.898411	1961		8	1,200	20	6	6	8	39.9
02418	Route 63	Steele Brook	Watertown	-73.128018	41.615836	1934		15	6,400	3	6	6	6	77.2

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02421	Route 63	East Morris Brook	Morris	-73.179567	41.686847	1942		10	2,800	6	6	8	8	41.4
02422	Route 63	Stream	Litchfield	-73.186557	41.715235	1942		8	4,400	5	7	7	8	40.3
02446	Route 69	Whigville Brook	Burlington	-72.969534	41.741399	1962		19	4,400	4	6	6	6	92.8
02447	Route 69	Whigville Brook	Burlington	-72.974607	41.748083	1962		15	5,600	5	7	8	6	11
02473	Route 72	Brook	Harwinton	-73.027812	41.774147	2002		16	2,200	10	6	9	8	40.3
02618	Route 109	Stream	Thomaston	-73.124930	41.664592	1939		8	3,600	9	6	9	8	38.1
02630	Route 112	Brook	Salisbury	-73.404360	41.934466	1930		6	2,400	7	6	8	6	22.9
02653	Route 128	Stream	Cornwall	-73.329164	41.870032	1938		11	1,500	7	6	6	8	42.8
02655	Route 132	Wood Creek	Bethlehem	-73.225563	41.627345	1941		16	1,300	5	6	9	6	39.2
02764	Route 179	Brook	Hartland	-72.914256	41.980229	1937		9	1,200	8	6	7	8	43
02765	SR 819	Fox Brook	Hartland	-72.884338	42.034007	1933		9	400	10	7	7	8	44.2
02766	Route 182	Brook	Colebrook	-73.117143	41.985060	1939		7	550	3	7	7	8	44.7
02768	Route 183	W Branch Leadmine Brook	Torrington	-73.083250	41.811532	1954		6	7,100	3	6	6	6	13.7
02848	Route 219	Carter Brook	New Hartford	-72.987138	41.879087	1929	1988	13	4,400	3	6	7	8	24.4
02850	Route 219	Stream	Barkhamsted	-72.930417	41.923837	1933		11	6,200	9	6	8	8	33.1
02851	Route 219	Brook	Barkhamsted	-72.925059	41.926368	1933		6	5,700	7	7	7	8	36.5
02852	Route 219	Brook	Barkhamsted	-72.907784	41.943218	1933		6	4,700	7	6	8	8	38
02855	Route 222	Brook	Plymouth	-73.054491	41.702934	1960		9	750	4	6	7	8	44.4
02871	Route 272	Hall Meadow Brook	Norfolk	-73.208991	41.931526	1920	1992	17	1,100	2	6	7	6	98.8
02892	Route 341	Cobble Brook	Kent	-73.455148	41.719719	1933		12	1,600	7	6	9	8	42.6

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02893	Route 343	Brook	Sharon	-73.488573	41.874420	1925		12	2,600		6	6	6	36.4
02961	Route 45	Sucker Brook	Warren	-73.349454	41.747280	1930		8	1,600	7	5	6	6	85
02962	Route 45	Gunn Brook	Cornwall	-73.361456	41.788465	1930		6	1,200	5	5	8	8	42.7
03266	U.S. Route 202	Brook	Torrington	-73.142754	41.786032	1952		9	5,900		6	8	8	45
03267	Route 43	Brook	Cornwall	-73.307672	41.852806	1996		11	400	1	7	8	8	44.9
03268	Route 109	Moosehorn Brook	Thomaston	-73.133318	41.668914	1939		10	2,900	9	6	9	8	39.5
03269	Route 182a	Brook	Colebrook	-73.116778	41.987631	1928		6	300	3	7	7	8	29.6
04339	Route 183	Leadmine Brook	Torrington	-73.085498	41.803660	1980		17	6,200	3	7	7	8	41.1
05372	Route 4	Bierce Brook	Goshen	-73.214972	41.836152	1986		18	7,100	2	7	8	6	95.9
05409	Route 254	Northfield Brook	Thomaston	-73.088029	41.674302	1964		20	3,800	5	7	8	8	41
05410	Route 272	Jacobs Brook	Torrington	-73.167752	41.864471	1957		17	1,500	5	6	8	8	43.4
05445	U.S. Route 7	Brook	Sharon	-73.383113	41.833382	1987		14	1,400	5	7	6	6	98.5
05446	U.S. Route 7	Pine Swamp Brook	Sharon	-73.369636	41.866107	1924	1987	18	1,400	10	7	8	6	94.9
05460	U.S. Route 7	Whiting Brook	Canaan	-73.334344	41.970099	1925	1987	16	2,900	5	6	6	6	79.6
05461	U.S. Route 6	Lewis Atwood Brook	Watertown	-73.149097	41.598706	1987		9	4,900	1	7	7	8	44
05505	Route 4	West Branch Bantam River	Goshen	-73.238974	41.831075	1987		17	6,000	3	7	7	6	96.6
05507	Route 126	Robbins Swamp Area	Canaan	-73.358354	41.970244	1987		16	1,400	3	7	7	8	44.1
05563	Route 222	Brook	Thomaston	-73.067048	41.684630	1988		12	1,800	18	7	7	8	36.9
05592	Route 183	Colebrook Brook	Winchester	-73.103114	41.961702	1988		10	1,300	4	7	6	8	42.9
05595	Route 4	Troy Brook	Torrington	-73.118116	41.809574	1988		16	12,900	1	7	7	6	76.8

Table A-2 - Structure Inventory Population and Selection

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating
05597	Route 72	Bristol Reservoir	Harwinton	-73.021574	41.748654	1988		13	2,000	6	7	7	6	86.1
05598	SR 800	Still River	Torrington	-73.097419	41.849541	1988		19	5,600	3	7	8	8	41.4
05669	U.S. Route 6	North Creek	Bristol	-72.946788	41.681317	1988		14	18,400		7	8	8	45
05715	Route 109	Canoe Brook	Washington	-73.325392	41.644504	1989		10	2,000	6	7	9	8	41.4
05718	U.S. Route 7	Millard Brook	Cornwall	-73.398925	41.792652	1989		14	2,200	3	7	8	8	43.6
05724	U.S. Route 7	Eddys Cove	North Canaan	-73.324780	42.022621	1989		20	5,800	7	7	8	8	33.8
05770	Route 183	Center Brook	Colebrook	-73.097843	41.991563	1989		17	1,300	6	7	7	6	84.3
05982	Route 63	Brown Brook	Canaan	-73.279748	41.926693	1924	1987	20	2,600	6	6	9	6	93
06239	U.S. Route 7	Wangum Lake Brook	Canaan	-73.334394	41.965840	1993		16	3,400		7	7	8	43
06240	Route 132	East Spring Brook	Bethlehem	-73.183487	41.649650	1993		16	1,500		7	8	6	40.8
06261	Route 8	Brook	Winchester	-73.050352	41.947260	1994		11	4,600	5	7	7	8	37.8
06262	Route 4	Whiting Brook	Torrington	-73.164133	41.823158	1994		14	6,700	2	7	9	8	42.2
06528	Route 4	Taylor Brook	Torrington	-73.106690	41.807657	2002		10	7,700		8	7	8	45
06538	Route 272	Brook	Goshen	-73.182619	41.911565	1997		11	1,000	6	7	7	8	43.7
06620	Route 72	Yard's Pond	Bristol	-72.905849	41.669294	2009		9	22,200		7	8	6	43
06625	Route 63	Stream	Watertown	-73.112400	41.595948	2004		18	18,700	1	7	6	8	41
06655	Route 4	Mill Brook	Sharon	-73.463713	41.865981	1972		18	2,000	3	6	7		84.5
06666	Route 20	Brook	Barkhamsted	-73.034374	41.952426	1970		6	1,900	9	6	8	8	41.4
06670	Route 8	Brook	Colebrook	-73.052822	42.018206	1967		8	2,600		6	8	8	45
06671	Route 8	Brook	Colebrook	-73.052648	42.025386	1967		6	2,700		7	8	8	45

Table A-2 - Structure Inventory Population and Selection

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating
06672	Route 8	Brook	Colebrook	-73.056614	42.034242	1967		7	2,600		6	8	8	45
06702	Route 109	Brook	Thomaston	-73.109564	41.662529	2005		6	4,500	6	7	8	8	39.3
06719	SR855	Brook	Watertown	-73.083551	41.593851	1998		10	5,900	1	6	6	8	43.8

Table A-3 – Structures Eliminated from Further Hydraulic Evaluation

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Reason/Notes
01984	U.S. Route 6	Steele Brook	Watertown	Very small drainage area. Stonewall/weir obstruction at outlet. Discharges to 18” pipe.
02062	U.S. Route 7	Brook	Canaan	Within vast floodplain/swamp. Shares floodplain with 02065 & 02066.
02065	U.S. Route 7	Brook	Canaan	Within vast floodplain/swamp. Shares floodplain with 02062 & 02066.
02066	U.S. Route 7	Brook	Canaan	Within vast floodplain/swamp. Shares floodplain with 02062 & 02065.
02233	U.S. Route 202	Moulthrop Brook	Litchfield	Series of ponds upstream. Inlet silted.
02236	U.S. Route 202	Stream	Litchfield	Structure silted in.
02308	U.S. Route 44	Brook	North Canaan	Relief structure for Whiting River. Silted in.
02312	U.S. Route 44	Drainage	Barkhamsted	Cattle pass
02469	Route 72	Poland River	Harwinton	Over flow channel from large dam upstream
02470	Route 72	Poland River	Harwinton	Large dam upstream
02907	SR 827	Womenshenuck Brook	Kent	Adjacent to railroad. Relief under roadway bridge
03756	U.S. Route 202	Bakersville Brook	New Hartford	Shares floodplain with 03757
03757	U.S. Route 202	South Nepaug Brook	New Hartford	Shares floodplain with 03756

Table A – 4 Structures Selected for Hydraulic Evaluation

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Material Type Code (43A)	Design Type Code (43B)	Number Spans (45)	Length Max Span (48)	Structure Length (49)	Deck Width Out to Out (52)	Skew (34)	Lanes On (28)	Bridge Posting (70)	Functional Class Code (26)	ADT (29)	Year ADT (30)	Bypass Detour Length (19)	Approach Roadway Width (32)	Roadway Width Curb to Curb (51)	Approach Roadway Alignment (72)	Substructure Condition (60)	Channel Protection (61)	Culverts Condition (62)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Inspection Date (90)	Defense Highway Designation (100)	Truck ADT (109)	Designated National Network (110)
01930	Route 4	Guinea Brook	Sharon	-73.419041	41.826232	1933	1986	1	1	1	8	11	35.3	14	2	5	6	2,000	2011	6	35	31	6	6	5	N	5	8	6	30.7	05/01/13	0	4	0
01937	Route 4	Birdseye Brook	Cornwall	-73.309522	41.847304	1916		1	1	1	6	9	33	0	2	5	6	3,500	2009	2	30	30	8	5	5	N	5	6	3	23.3	01/18/12	0	4	0
01945	Route 4	Catlin Brook	Harwinton	-73.068389	41.771377	1938	1959	1	1	1	10	12	45.3	0	2	5	14	8,700	2011	6	40	40	8	7	7	N	6	8	6	32.5	05/11/13	0	4	0
01946	Route 4	Rock Brook	Harwinton	-73.039661	41.774372	1927		1	19	1	14	14	0	0	2	5	6	12,300	2012	5	28	0	8	N	6	6	6	5	8	30.5	07/10/13	0	4	0
01947	Route 4	Brook	Harwinton	-73.022848	41.776291	1927		1	1	1	12	15	30.6	0	2	5	6	11,800	2012	8	28	29	8	5	5	N	5	6	6	10	07/22/13	0	4	0
01948	Route 4	North Branch Bunnell Bk	Burlington	-72.999821	41.776948	1926		1	19	1	8	8	0	0	2	5	6	10,200	2010	6	31	0	8	N	6	6	6	8	8	32	05/08/12	0	4	0
01949	Route 4	Misery Brook	Burlington	-72.939403	41.776233	1928		1	1	1	8	15	31	0	2	5	14	9,500	2008	3	30	28	6	6	6	N	6	6	6	11	04/24/12	0	4	0
01985	U.S. Route 6	Todd Hollow Brook	Plymouth	-73.040448	41.674361	1929		1	1	1	6	6	0	0	2	5	14	15,700	2012	2	31	0	8	6	5	N	6	6	6	16.7	03/18/14	0	4	0
01987	U.S. Route 6	Cuss Gutter Brook	Bristol	-72.975310	41.681597	1929		1	1	1	8	11	31.3	0	2	5	14	9,900	2010	1	32	28	8	7	5	N	7	4	6	17	03/22/12	0	4	0
02048	U.S. Route 7	Cobble Brook	Kent	-73.457236	41.740142	1924		1	1	1	16	19	27.4	0	2	5	6	2,700	2009	19	26	25	8	6	5	N	5	6	6	11.6	01/11/12	0	4	0
02050	U.S. Route 7	Kent Falls Brook	Kent	-73.418961	41.776571	1924		1	1	1	16	19	53	0	2	5	6	2,200	2010	20	28	28	6	6	7	N	5	8	6	18.5	04/03/12	0	4	0
02051	U.S. Route 7	Deep Brook	Cornwall	-73.408221	41.785699	1924		1	11	1	12	12	0	0	2	5	6	2,100	2011	7	28	0	8	6	6	N	5	9	6	22.3	01/14/13	0	4	0
02078	SR 848	Brook	Thomaston	-73.057737	41.618156	1923		1	1	1	8	12	29.5	16	2	5	7	2,200	2012	8	30	27	8	6	6	N	5	7	6	13.8	08/30/13	0	3	0
02079	SR 848	Nibbling Brook	Thomaston	-73.069963	41.629228	1923		1	1	1	12	16	33	7	2	5	7	2,200	2012	8	31	31	8	6	5	N	6	5	6	36.4	08/31/13	0	3	0
02082	SR 800	Brook	Torrington	-73.098622	41.841796	1931	1983	1	1	1	12	12	0	32	2	5	17	5,400	2012	1	30	0	8	6	6	N	6	9	6	27.7	10/17/13	0	4	0
02089	Route 8	Brook	Colebrook	-73.046442	41.975748	1913		1	1	1	8	10	27.5	0	2	5	6	3,200	2009	2	25	25	7	5	5	N	5	6	6	20.9	06/26/12	0	4	0
02200	Route 20	Brook	Winchester	-73.046507	41.947546	1915		1	1	1	10	10	40	62	2	5	7	1,900	2011	7	29	30	6	7	6	N	6	4	6	34.6	03/25/13	0	2	0
02204	Route 20	Falls Brook	Hartland	-72.966298	42.026695	1940		1	19	1	8	8	0	0	2	5	7	450	2012	9	32	0	8	N	7	5	5	6	8	43.1	01/16/14	0	2	0
02205	Route 20	Brook	Hartland	-72.956250	42.026652	1940		1	19	1	8	8	0	0	2	5	7	400	2011	10	30	0	8	N	7	6	6	6	8	44.2	04/02/13	0	2	0
02230	U.S. Route 202	Hill Brook	Litchfield	-73.263442	41.715259	1933		1	1	1	10	13	35.5	25	2	5	2	6,600	2011	8	32	31	8	6	6	N	5	6	6	13.8	04/18/13	0	6	0
02231	U.S. Route 202	Still Brook	Litchfield	-73.246423	41.723082	1928		1	1	1	12	15	32.1	17	2	5	2	7,900	2011	8	31	30	8	6	7	N	5	9	6	10	04/18/13	0	6	0
02238	U.S. Route 202	Gulf Stream	Torrington	-73.138310	41.786830	1952		1	1	1	17	20	45.6	0	2	5	14	6,300	2010	2	40	40	8	6	6	N	5	8	6	40.1	11/28/12	0	4	0
02297	Route 41	Ball Brook	Salisbury	-73.430016	42.017800	1928		1	1	1	8	11	30.5	37	2	5	7	1,600	2010	2	28	28	8	6	5	N	6	5	6	85.8	06/21/12	0	3	0
02305	U.S. Route 44	Burton Brook	Salisbury	-73.438813	41.967732	1873	1973	8	11	1	10	10	29.3	5	2	5	2	8,400	2012	4	35	27	8	6	5	N	5	7	6	10	05/08/13	0	6	0
02306	U.S. Route 44	Garnet Brook	Salisbury	-73.405689	41.997424	1928	1986	1	1	1	8	11	34.8	34	2	5	2	4,700	2010	8	30	32	8	6	5	N	6	6	6	32.5	06/27/12	0	6	1
02313	U.S. Route 44	Mallory Brook	Barkhamsted	-73.043441	41.909796	1947		1	19	1	12	12	0	8	2	5	2	14,600	2012	3	39	0	8	N	6	7	7	6	8	35.7	07/15/13	0	6	0
02314	U.S. Route 44	Mallory Brook	Barkhamsted	-73.027003	41.912024	1948		1	19	1	17	17	0	30	2	5	2	13,000	2010	4	38	0	8	N	6	6	6	7	8	34	05/04/12	0	6	1
02315	U.S. Route 44	Brook	Barkhamsted	-72.997949	41.905198	1948		1	19	1	8	8	0	0	2	5	2	8,100	2009	4	37	0	8	N	7	7	7	7	8	38.1	07/06/11	0	6	0
02316	U.S. Route 44	Brook	Barkhamsted	-72.989541	41.896604	1948		1	19	1	6	6	0	0	2	5	2	9,800	2009	12	38	0	8	N	7	7	7	6	8	30	07/06/11	0	6	0
02317	U.S. Route 44	Brook	New Hartford	-72.959183	41.859708	1958		1	19	1	12	12	66	0	2	5	2	11,600	2012	12	41	41	8	N	6	7	7	7	8	30	07/01/13	0	6	0

Table A – 4 Structures Selected for Hydraulic Evaluation

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Material Type Code (43A)	Design Type Code (43B)	Number Spans (45)	Length Max Span (48)	Structure Length (49)	Deck Width Out to Out (52)	Skew (34)	Lanes On (28)	Bridge Posting (70)	Functional Class Code (26)	ADT (29)	Year ADT (30)	Bypass Detour Length (19)	Approach Roadway Width (32)	Roadway Width Curb to Curb (51)	Approach Roadway Alignment (72)	Substructure Condition (60)	Channel Protection (61)	Culverts Condition (62)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Inspection Date (90)	Defense Highway Designation (100)	Truck ADT (109)	Designated National Network (110)
02414	Route 63	Wattles Brook	Watertown	-73.100841	41.579809	1941		1	19	1	10	10	28	24	2	5	14	13,800	2012	1	27	0	8	N	7	6	6	8	8	42.1	10/24/13	0	4	0
02420	Route 63	Stream	Morris	-73.170937	41.671494	1934		1	1	1	10	13	35	0	2	5	6	2,800	2011	8	29	30	8	6	6	N	5	8	6	15.1	03/13/13	0	4	0
02423	Route 63	Brook	Cornwall	-73.267835	41.900720	1950		1	19	1	18	18	53	0	2	5	7	2,400	2011	2	29	0	8	N	6	5	5	9	8	42.9	01/04/13	0	3	0
02467	Route 72	Poland River	Plymouth	-73.004949	41.693956	1927		1	1	1	10	16	30.8	0	2	5	7	2,500	2011	3	28	29	6	7	6	N	6	5	6	33.5	05/31/13	0	3	0
02471	Route 72	Poland River	Harwinton	-73.014219	41.730057	1927		1	1	1	13	18	30.5	25	2	5	7	2,200	2009	7	28	28	8	6	6	N	6	5	6	29.5	04/29/13	0	3	0
02613	Route 109	Mallory Brook	Washington	-73.289252	41.652373	1934		1	11	1	11	11	25.9	31	2	5	7	1,900	2011	4	20	23	8	6	6	N	5	4	3	16.9	03/14/13	0	3	0
02615	Route 109	East Morris Brook	Morris	-73.187991	41.688219	1929		1	1	1	12	15	31.5	28	2	5	7	3,400	2012	9	30	29	8	6	6	N	5	7	6	12	11/05/13	0	3	0
02616	Route 109	Beaver Brook	Morris	-73.176873	41.687310	1929		1	1	1	6	9	31.5	26	2	5	7	3,300	2010	2	28	29	8	6	5	N	6	5	6	23.5	02/21/12	0	3	0
02617	Route 109	Brook	Morris	-73.144657	41.673012	1938	1992	2	19	2	9	19	0	36	2	5	7	2,900	2011	5	30	0	8	N	6	5	5	7	8	40.8	05/14/12	0	3	0
02770	Route 183	Colebrook Brook	Winchester	-73.095359	41.946863	1919		1	1	1	12	18	27.5	0	2	5	7	1,300	2011	3	24	26	6	7	7	N	5	5	6	27	03/14/13	0	3	0
02771	Route 183	Colebrook Brook	Winchester	-73.100815	41.955575	1919		1	1	1	12	15	27.7	0	2	5	7	1,300	2011	3	25	26	8	6	6	N	5	6	6	28.8	03/18/13	0	3	0
02965	Route 47	Brook	Washington	-73.299371	41.623612	1928		1	1	1	6	9	31.1	0	2	5	7	2,000	2011	5	26	29	8	6	6	N	6	8	6	88.9	03/14/13	0	3	0
02966	Route 47	Kirby Brook	Washington	-73.307862	41.626846	1928		1	1	1	8	10	30.7	14	2	5	7	2,300	2011	30	27	29	6	6	6	N	6	8	6	81.3	03/14/13	0	3	0
03260	Route 4	Brook	Torrington	-73.169073	41.823805	1926		1	1	1	5	11	33.2	18	2	5	14	6,400	2011	4	31	30	8	6	6	N	5	8	6	15.5	05/02/13	0	4	0
03300	U.S. Route 44	Brook	Salisbury	-73.371132	42.004407	1928		1	1	1	8	12	0	45	2	5	2	4,900	2011	4	39	0	8	6	6	N	6	8	6	20.1	06/27/12	0	6	1
03333	Route 8 & Ramp	Pickett Brook	Harwinton	-73.115297	41.759908	1966		1	19	1	11	11	294	0	6	5	2	19,500	2011	3	0	0	8	N	6	7	7	8	8	32.6	02/07/13	0	6	1
05408	Route 4	Punch Brook	Burlington	-72.926099	41.781573	1965		3	19	1	13	13	0	0	2	5	14	11,600	2011	4	42	0	8	N	7	6	6	6	8	35.1	01/14/13	0	4	0
05417	Route 109	Brook	Morris	-73.253094	41.678924	1956		3	19	1	12	12	62.4	0	2	5	7	1,770	2012	2	36	36	8	N	7	5	5	6	8	43.2	11/05/13	0	3	0
05418	Route 128	Mill Brook	Cornwall	-73.340317	41.875327	1930	1986	1	7	1	16	20	34.5	11	2	5	7	1,500	2011	3	29	31	8	6	5	N	6	9	5	94.8	12/24/12	0	2	0
05896	U.S. Route 202	Bee Brook	Washington	-73.333111	41.681593	1932	1990	1	1	1	14	16	35.3	0	2	5	2	5,700	2011	1	32	32	8	7	6	N	7	7	6	91.8	06/06/13	0	7	1
06668	Route 179	Brook	Burlington	-72.925336	41.793430	1966		3	19	1	9	9	0	41	2	5	7	10,400	2011	5	40	0	8	N	6	6	6	6	8	34	02/07/13	0	4	0
06712	Route 63	Brook	Watertown	-73.120473	41.609197	1966		3	19	2	8	20	0	32	2	5	14	6,400	2011	2	27	0	8	N	6	5	5	6	8	41.2	03/04/13	0	4	0

Table A-4a – Structures Selected for Hydraulic Evaluation with Drainage Area

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Drainage Area (mi^2)
01930	Route 4	Guinea Brook	Sharon	41.82623	-73.419041	1933	1986	11	2,000	6	5	8	6	31	4.09
01937	Route 4	Birdseye Brook	Cornwall	41.8473	-73.309522	1916		9	3,500	2	5	6	3	23	1.27
01945	Route 4	Catlin Brook	Harwinton	41.77138	-73.068389	1938	1959	12	8,700	6	6	8	6	33	1.27
01946	Route 4	Rock Brook	Harwinton	41.77437	-73.039661	1927		14	12,300	5	6	5	8	31	2.50
01947	Route 4	Brook	Harwinton	41.77629	-73.022848	1927		15	11,800	8	5	6	6	10	0.83
01948	Route 4	North Branch Bunnell Bk	Burlington	41.77695	-72.999821	1926		8	10,200	6	6	8	8	32	0.52
01949	Route 4	Misery Brook	Burlington	41.77623	-72.939403	1928		15	9,500	3	6	6	6	11	1.62
01985	U.S. Route 6	Todd Hollow Brook	Plymouth	41.67436	-73.040448	1929		6	15,700	2	6	6	6	17	0.36
01987	U.S. Route 6	Cuss Gutter Brook	Bristol	41.6816	-72.97531	1929		11	9,900	1	7	4	6	17	0.55
02048	U.S. Route 7	Cobble Brook	Kent	41.74014	-73.457236	1924		19	2,700	19	5	6	6	12	3.38
02050	U.S. Route 7	Kent Falls Brook	Kent	41.77657	-73.418961	1924		19	2,200	20	5	8	6	19	5.77
02051	U.S. Route 7	Deep Brook	Cornwall	41.7857	-73.408221	1924		12	2,100	7	5	9	6	22	0.89
02078	SR 848	Brook	Thomaston	41.61816	-73.057737	1923		12	2,200	8	5	7	6	14	0.24
02079	SR 848	Nibbling Brook	Thomaston	41.62923	-73.069963	1923		16	2,200	8	6	5	6	36	2.18
02082	SR 800	Brook	Torrington	41.8418	-73.098622	1931	1983	12	5,400	1	6	9	6	28	0.56
02089	Route 8	Brook	Colebrook	41.97575	-73.046442	1913		10	3,200	2	5	6	6	21	0.40
02200	Route 20	Brook	Winchester	41.94755	-73.046507	1915		10	1,900	7	6	4	6	35	0.31
02204	Route 20	Falls Brook	Hartland	42.026695	-72.966298	1940		8	450	9	5	6	8		0.33
02205	Route 20	Brook	Hartland	42.02665	-72.95625	1940		8	400	10	6	6	8	44	0.44
02230	U.S. Route 202	Hill Brook	Litchfield	41.71526	-73.263442	1933		13	6,600	8	5	6	6	14	0.92

Table A-4a – Structures Selected for Hydraulic Evaluation with Drainage Area

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Drainage Area (mi^2)
02231	U.S. Route 202	Still Brook	Litchfield	41.72308	-73.246423	1928		15	7,900	8	5	9	6	10	2.33
02238	U.S. Route 202	Gulf Stream	Torrington	41.78683	-73.13831	1952		20	6,300	2	5	8	6	40	3.84
02297	Route 41	Ball Brook	Salisbury	42.0178	-73.430016	1928		11	1,600	2	6	5	6	86	2.41
02305	U.S .Route 44	Burton Brook	Salisbury	41.96773	-73.438813	1873	1973	10	8,400	4	5	7	6	10	3.51
02306	U.S. Route 44	Garnet Brook	Salisbury	41.99742	-73.405689	1928	1986	11	4,700	8	6	6	6	33	0.80
02313	U.S. Route 44	Mallory Brook	Barkhamsted	41.9098	-73.043441	1947		12	14,600	3	7	6	8	36	1.40
02314	U.S. Route 44	Mallory Brook	Barkhamsted	41.91202	-73.027003	1948		17	13,000	4	6	7	8	34	3.00
02315	U.S. Route 44	Brook	Barkhamsted	41.9052	-72.997949	1948		8	8,100	4	7	7	8	38	1.48
02316	U.S. Route 44	Brook	Barkhamsted	41.8966	-72.989541	1948		6	9,800	12	7	6	8	30	0.48
02317	U.S. Route 44	Brook	New Hartford	41.85971	-72.959183	1958		12	11,600	12	7	7	8	30	0.70
02414	Route 63	Wattles Brook	Watertown	41.57981	-73.100841	1941		10	13,800	1	6	8	8	42	2.27
02420	Route 63	Stream	Morris	41.67149	-73.170937	1934		13	2,800	8	5	8	6	15	0.63
02423	Route 63	Brook	Cornwall	41.90072	-73.267835	1950		18	2,400	2	5	9	8	43	3.62
02467	Route 72	Poland River	Plymouth	41.69396	-73.004949	1927		16	2,500	3	6	5	6	34	5.56
02471	Route 72	Poland River	Harwinton	41.73006	-73.014219	1927		18	2,200	7	6	5	6	30	2.42
02613	Route 109	Mallory Brook	Washington	41.65237	-73.289252	1934		11	1,900	4	5	4	3	17	1.91
02615	Route 109	East Morris Brook	Morris	41.68822	-73.187991	1929		15	3,400	9	5	7	6	12	0.78
02616	Route 109	Beaver Brook	Morris	41.68731	-73.176873	1929		9	3,300	2	6	5	6	24	0.25
02617	Route 109	Brook	Morris	41.67301	-73.144657	1938	1992	19	2,900	5	5	7	8	41	4.59
02770	Route 183	Colebrook Brook	Winchester	41.94686	-73.095359	1919		18	1,300	3	5	5	6	27	2.33

Table A-4a – Structures Selected for Hydraulic Evaluation with Drainage Area

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating	Drainage Area (mi^2)
02771	Route 183	Colebrook Brook	Winchester	41.95558	-73.100815	1919		15	1,300	3	5	6	6	29	1.72
02965	Route 47	Brook	Washington	41.62361	-73.299371	1928		9	2,000	5	6	8	6	89	0.17
02966	Route 47	Kirby Brook	Washington	41.62685	-73.307862	1928		10	2,300	30	6	8	6	81	0.87
03260	Route 4	Brook	Torrington	41.82381	-73.169073	1926		11	6,400	4	5	8	6	16	0.20
03300	U.S. Route 44	Brook	Salisbury	42.00441	-73.371132	1928		12	4,900	4	6	8	6	20	0.31
03333	Route 8 & Ramp	Pickett Brook	Harwinton	41.75991	-73.115297	1966		11	19,500	3	7	8	8	33	1.48
05408	Route 4	Punch Brook	Burlington	41.78157	-72.926099	1965		13	11,600	4	6	6	8	35	1.66
05417	Route 109	Brook	Morris	41.67892	-73.253094	1956		12	1,770	2	5	6	8	43	2.01
05418	Route 128	Mill Brook	Cornwall	41.87533	-73.340317	1930	1986	20	1,500	3	6	9	5	95	4.50
05896	U.S. Route 202	Bee Brook	Washington	41.68159	-73.333111	1932	1990	16	5,700	1	7	7	6	92	3.49
06668	Route 179	Brook	Burlington	41.79343	-72.925336	1966		9	10,400	5	6	6	8	34	0.11
06712	Route 63	Brook	Watertown	41.6092	-73.120473	1966		20	6,400	2	5	6	8	41	0.82

Appendix B

Table B-1 Scour Critical (NBI Item 113 = 3 or less) Structures within Project Limits

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating
00421	Route 4	Guinea Brook	Sharon	-73.400191	41.821838	1933		28	2000	3	6	8	3	90.8
00462	U.S. Route 6	Nonewaug River	Woodbury	-73.200650	41.555689	1928		68	8100	13	5	6	3	10
00463	U.S. Route 6	Nonewaug River	Woodbury	-73.173518	41.584154	1957	1988	86	3800	13	7	9	3	96.3
00559	Us Route 7	Gunn Brook	Cornwall	-73.385959	41.802807	1924	1996	25	2100	7	6	5	3	88.2
00874	Route 20	Still River	Barkhamsted	-73.019827	41.959867	1953		163	1900	10	6	7	3	93.7
00905	U.S. Route 202	East Aspetuck River	Washington	-73.354806	41.674062	1931		32	7600	10	6	7	3	29
00908	U.S. Route 202	Bantam River	Litchfield	-73.182879	41.756009	1931		68	8300	1	4	5	3	50.6
00965	U.S. Route 44	Spruce Swamp Creek	Salisbury	-73.417267	41.989410	1928		32	4900	6	5	7	3	65.7
00968	U.S. Route 44	Whiting River	North Canaan	-73.273258	42.011388	1949		49	4600	3	6	4	3	94.6
00970	U.S. Rte 44 & Rte 183	Indian Meadow Brook	Winchester	-73.078552	41.929703	1940	1986	49	7900		7	5	3	96
00971	U.S. Rte 44, Rte 183	Still River	Winchester	-73.057830	41.919408	1949		136	21700	3	6	7	3	71.7
01005	Route 47	Shepaug River	Washington	-73.318178	41.639809	1950		75	4500	2	6	9	3	95.3
01038	Route 63	West Br. Bantam River	Litchfield	-73.208714	41.785147	1961		35	4100	7	5	7	3	84.5
01042	Route 63	Hollenbeck River	Canaan	-73.321167	41.949002	1928		47	1600	4	5	5	3	76.8
01109	Route 72	Marsh Brook	Plymouth	-73.000301	41.687104	1927		23	3900	2	4	6	3	51.8
01112	Route 72	Poland River	Harwinton	-73.011546	41.714539	1927		37	2200	4	6	6	3	87.8
01317	Route 112	Salmon Creek	Salisbury	-73.374222	41.929612	1930	1986	43	2700	16	6	8	3	84.9
01323	Route 118	Spruce Brook	Litchfield	-73.136144	41.761590	1960		27	6500	14	6	9	3	89.1
01338	Route 128	Housatonic River	Cornwall	-73.363776	41.871555	1841	1973	173	1500	21	5	8	3	61.2
01339	Route 132	Weekeepeemee River	Woodbury	-73.230854	41.585606	1934	1985	51	1600	5	6	6	3	92.8

Appendix B

Table B-1 Scour Critical (NBI Item 113 = 3 or less) Structures within Project Limits

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating
01490	Route 179	Burlington Brook	Burlington	-72.923127	41.782966	1961	1990	146	9800	5	6	9	3	92.3
01498	Route 183	Sandy Brook	Colebrook	-73.112634	42.014286	1958	1994	65	1000	14	7	7	3	99
01589	Route 318	Morgan Brook	Barkhamsted	-73.000601	41.908442	1947		28	5100	3	6	7	3	23.5
01670	North Main Street	Poland River	Plymouth	-73.002180	41.689456	1931		39	2520	3	4	7	3	63
01937	Route 4	Birdseye Brook	Cornwall	-73.309522	41.847304	1916		9	3200	2	5	6	3	23.6
02468	Route 72	Poland River	Plymouth	-73.009242	41.703714	1927		24	2200	12	6	6	3	28.7
02613	Route 109	Mallory Brook	Washington	-73.289252	41.652373	1934		11	1900	4	5	4	3	16.9
03975	East Albert Street	Naugatuck River	Torrington	-73.117448	41.795823	1959		156	7620	1	6	8	3	77.3
04343	North Shore Road	Bantam River	Litchfield	-73.221986	41.716797	1980		72	415	3	7	6	3	44.7
04433	North Shore Road	Butternut Brook	Litchfield	-73.220345	41.719662	1956		39	572	3	6	4	3	28.8
04480	Louisiana Avenue	Copper Mine Brook	Bristol	-72.913782	41.689721	1900	1952	46	4350	1	4	5	3	67.5
04481	Frederick Street	Copper Mine Brook	Bristol	-72.907324	41.674715	1900	1934	37	2400	1	5	6	3	76.8
04483	Jerome Avenue	Copper Mine Brook	Bristol	-72.927712	41.714317	1956		77	4580	1	7	7	3	81.6
05043	Walnut Hill Rd #2	Northfield Brook	Thomaston	-73.085202	41.673651	1946		40	60	99	4	6	3	61.3
05053	Shingle Mill Road	Rock Brook	Harwinton	-73.048586	41.753515	1975	1989	37	57	1	5	7	3	69
05072	Gillette Road	Torringford Brook	New Hartford	-73.040407	41.834544	1956		35	370	3	7	6	3	80.2
05085	Wall Street	E Branch Naugatuck River	Torrington	-73.117828	41.803367	1961		56	2856	1	6	8	3	94.8
05123	Day Road	Beaver Brook	Barkhamsted	-72.971405	41.928549	1956		47	240	2	6	7	3	33.8
05124	Morgan Brook Road	Morgan Brook	Barkhamsted	-72.992581	41.902285	1957		61	592	1	7	6	3	97
05154	East Street South	Bantam River	Goshen	-73.199492	41.808041	1956		52	520	4	6	3	3	76

Appendix B

Table B-1 Scour Critical (NBI Item 113 = 3 or less) Structures within Project Limits

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating
05158	Tunnel Road	Shepaug River	Washington	-73.325728	41.621738	1956		112	235	5	4	7	3	55.4
05165	Romford Road	Shepaug River	Washington	-73.291984	41.695783	1956		107	360	2	3	6	3	20.2
05166	West Morris Road	Bantam River	Washington	-73.271827	41.687353	1956	1990	94	180	3	6	8	3	83.2
05173	Smokey Hollow Road	Bantam River	Morris	-73.266565	41.688501	1956		90	230	5	4	7	3	56.8
05175	Whites Woods Rd #1	Bantam River	Litchfield	-73.205451	41.725364	1963		70	1020	4	4	7	3	63.3
05184	Milton Road #2	Marshepaug River	Litchfield	-73.267740	41.769970	1915	1992	24	630	2	7	7	3	25.3
05196	Water Street	Housatonic River	Canaan	-73.370671	41.958279	1903	1985	128		10	2	5	3	17
05205	Tobey Hill Road	Whiting River	North Canaan	-73.256571	42.039728	1956		36	233	1	5	7	3	27.6
05206	Sodom Road	Konkapot River	North Canaan	-73.288850	42.045326	1956		68	371	1	7	7	3	80
05324	Sharon Valley Rd	Creek	Sharon	-73.496405	41.877267	1984		25	589	2	5	5	3	29
05373	Blue Swamp Road	W Branch Shepaug River	Litchfield	-73.278730	41.767768	1986		32	170	5	2	9	3	36.8
05388	King Hill Road	Indian Pond Creek	Sharon	-73.491114	41.883623	1986		26	1715	3	6	7	3	23
05659	Canaan Mountain Rd	Wangum Lake Brook	Canaan	-73.279213	41.952976	1988		31	112	11	5	6	3	69.9
05673	U.S. Route 202	Nepaug River	New Hartford	-72.974725	41.825929	1923	1988	71	10600	10	7	7	3	91
05849	Hazel Plain Road	Sprain Brook	Woodbury	-73.240428	41.577270	1920	1989	36	425	4	4	7	3	55.4
05900	Belleview Avenue	Gulf Stream	Torrington	-73.125049	41.790245	1910	1989	28	459	1	6	7	3	95.5
05997	Route 126	Hollenbeck River	Canaan	-73.356883	41.975663	1991		33	1300	10	7	8	3	97
06177	Dalene Drive	West Branch Salmon Brook	Hartland	-72.895539	41.974305	1945		22	115	2	6	7	3	38.9
06379	Basin Main Road	Mad River	Winchester	-73.097607	41.934715	1940		45	40	99	5	6	3	79.7
06380	Main Park Road	Hall Meadow Brook	Torrington	-73.169067	41.886097	1970		69	20	99	5	7	3	80.8

Table B-2 Structures with Scour Countermeasures (NBI Item 113 = 7) within Project Limits

Structure No.	Feature Carried (7)	Features Intersected (6)	Town Name	Latitude	Longitude	Year Built (27)	Year Rebuilt (106)	Structure Length (49)	ADT (29)	Bypass Detour Length (19)	Structural Evaluation (67)	Waterway Adequacy (71)	Scour Critical (113)	Sufficiency Rating
01576	Route 272	W.Branch Naugatuck River	Torrington	-73.157780	41.853713	1954	1996	97	2100	5	7	8	7	99.2
01941	Route 4	Ivy Mountain Brook	Goshen	-73.207374	41.835506	1998		33	7000	2	7	6	7	97.7
01981	U.S. Route 6	Lewis Atwood Brook	Woodbury	-73.157097	41.600590	1935		14	4900	14	5	7	7	14

Table B-3 Known (District Maintenance) State Roadway Flooding Sites within Project Limits

Town	Route	Location	Description
Bristol	72	Pequabuck River	Roadway flooding at Bohemia Street
Canaan	63	o/Hollenbeck River/Flat Brook, north of Route 126	River floods roadway
Canaan	63	o/Hollenbeck River, north of Route 126, Br#1042	River floods roadway
Canaan	7	North of Page Road	Robbins Swamp floods roadway
Canaan	126	West of Johnson Road	Robbins Swamp floods roadway
Canaan	126	East of Page Road	Robbins Swamp floods roadway
Kent	7	At Birch Hill Lane	Housatonic River floods roadway
Kent	7	South of Route 341	Housatonic River floods roadway
Kent	7	North of Bulls Bridge Road	Housatonic River floods roadway
Morris	209	North of Route 109	Bantam Lake floods roadway
North Canaan	7	o/tributary to Blackberry River, south of Clayton Road	Tributary floods roadway
North Canaan	7	o/tributary to Blackberry River, north of North Elm Street	Tributary floods roadway
Plymouth	72	East of School Street	Railroad overpass – overtaxed system
Salisbury	112	West of Indian Mountain Road near Pole #3039	Overland flow, low spot, flooding roadway
Torrington	800	Bogue Road	Tributary to Naugatuck River floods roadway
Watertown	63	o/intermittent watercourse, north of Route 73	Overtaxed system causing roadway flooding
Winchester	263	West of Blue Street	No name swamp, beaver activity floods roadway
Winchester	183	o/Colebrook Brook – 346 Colebrook Road	Roadway flooding. 1986 replacement does not handle 50 yr. storm event

Table B-4 State Road Flooding/Closure Sites Resulting from Tropical Storm Irene (Dist. Maintenance) within Project Limits

Town	Route	Location	Description
Bristol	72	At Old Waterbury Rd. & Br. No. 02391	Roadway Washout/Undermine From Pequabuck River Flooding
Kent (Falls Village)	63	At Rte. 126	Flooding
Kent (Falls Village)	63	Rt3.63 At Rte.126 & Br. No. 01042	Flooding
Kent (Falls Village)	126	Rte.126	Flooding
Kent	7	At Bulls Bridge Rd	Flooding from Housatonic River
Kent/Washington	478	At Town Line	Flooding
Morris	209	Rte. 209 North Of Rte. 109	Flooding
Morris/Bantam	209	At Town Line	Flooding
Thomaston	6	At Lee Ave.	Flooding
Torrington	800	Rte. 800 & Newfield Rd.	Flooding
Warren	45	North Of North Shore Rd.	Washout
Washington (Depot)	47	Rte. 47	Flooding
Washington/Warren	45	At North Shore Rd.	Road Failure
Woodbury	317	From Bear Hill Rd. To Rte. 6	Flooding - 48" Pipe Partially Blocked Due To Beavers
Woodbury	317	Rte. 317 At Bear Hill Rd.	Water Over Road - 40" RCP Overflow Pomperaug River

Appendix C

Table C-1 "HYDRO-35" & "TP-40" Rainfall Data for Connecticut

DURATION	RETURN FREQUENCY (Years)					
	2	**5**	**10**	**25**	**50**	**100**
Min	RAINFALL IN MM (INCHES)					
5	9.1(0.36)	11.4(0.45)	13.0(0.51)	15.2(0.60)	17.2(0.67)	18.5(0.73)
15	18.3(0.72)	22.6(0.89)	25.9(1.02)	30.5(1.20)	34.0(1.34)	37.6(1.48)
60	33.0(1.3)	43.2(1.7)	50.8(2.00)	58.4(2.30)	65.3(2.57)	71.1(2.80)
Hrs						
2	40.6(1.60)	54.6(2.15)	63.5(2.50)	72.4(2.85)	82.6(3.25)	91.4(3.60)
3	44.5(1.75)	61.0(2.40)	69.9(2.75)	82.6(3.25)	90.2(3.55)	101.6(4.00)
6	59.7(2.35)	74.9(2.95)	87.6(3.45)	101.6(4.00)	115.6(4.55)	127.0(5.00)
12	69.9(2.75)	90.2(3.55)	101.6(4.00)	123.2(4.85)	135.9(5.35)	152.4(6.00)
24	82.6(3.25)	106.7(4.20)	125.7(4.95)	146.1(5.75)	161.3(6.35)	177.8(7.00)
	24 HOUR RAINFALL BY COUNTY					
Fairfield	83.8(3.3)	109.2(4.3)	127.0(5.0)	144.8(5.7)	162.6(6.4)	182.9(7.2)
Hartford	81.3(3.2)	104.1(4.1)	119.4(4.7)	139.7(5.5)	157.5(6.2)	175.3(6.9)
Litchfield	81.3(3.2)	104.1(4.1)	119.4(4.7)	139.7(5.5)	157.5(6.2)	177.8(7.0)
Middlesex	83.8(3.3)	106.7(4.2)	127.0(5.0)	142.2(5.6)	160.0(6.3)	180.3(7.1)
New Haven	83.8(3.3)	106.7(4.2)	127.0(5.0)	142.2(5.6)	160.0(6.3)	180.3(7.1)
New London	86.4(3.4)	109.2(4.3)	127.0(5.0)	144.8(5.7)	160.0(6.3)	180.3(7.1)
Tolland	81.3(3.2)	104.1(4.1)	121.9(4.8)	139.7(5.5)	157.5(6.2)	175.3(6.9)
Windham	81.3(3.2)	106.7(4.2)	121.9(4.8)	139.7(5.5)	157.5(6.2)	175.3(6.9)

Sources:

1. "Rainfall Frequency Atlas of the United States", Technical Paper No. 40, U.S. Department of Commerce, Weather Bureau.
2. NOAA Technical Memorandum "NWS Hydro-35", June 1977, U.S. Department of Commerce, National Weather Service.

Table C-2 "Precip.net"

Extreme Precipitation Tables

Northeast Regional Climate Center

Data represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Smoothing	Yes
State	Connecticut
Location	
Longitude	72.991 degrees West
Latitude	41.775 degrees North
Elevation	Unknown/Unavailable
Date/Time	Tue, 05 Aug 2014 16:49:54 -0400

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.32	0.49	0.61	0.80	0.99	1.24	**1yr**	0.86	1.14	1.43	1.78	2.21	2.75	3.08	**1yr**	2.43	2.96	3.45	4.12	4.75	**1yr**
2yr	0.38	0.58	0.72	0.95	1.19	1.50	**2yr**	1.03	1.38	1.73	2.15	2.67	3.32	3.71	**2yr**	2.94	3.57	4.10	4.85	5.50	**2yr**
5yr	0.44	0.69	0.86	1.15	1.48	1.87	**5yr**	1.28	1.70	2.17	2.71	3.37	4.18	4.73	**5yr**	3.70	4.55	5.28	6.11	6.92	**5yr**
10yr	0.50	0.78	0.98	1.34	1.74	2.22	**10yr**	1.50	1.99	2.58	3.24	4.02	4.98	5.68	**10yr**	4.41	5.46	6.41	7.27	8.23	**10yr**
25yr	0.57	0.91	1.17	1.61	2.15	2.79	**25yr**	1.86	2.44	3.25	4.09	5.09	6.27	7.25	**25yr**	5.55	6.97	8.28	9.17	10.37	**25yr**
50yr	0.65	1.05	1.34	1.88	2.54	3.31	**50yr**	2.19	2.86	3.88	4.88	6.07	7.48	8.72	**50yr**	6.62	8.38	10.05	10.93	12.36	**50yr**
100yr	0.74	1.20	1.54	2.19	2.99	3.93	**100yr**	2.58	3.35	4.62	5.83	7.25	8.91	10.49	**100yr**	7.89	10.09	12.21	13.03	14.73	**100yr**
200yr	0.85	1.38	1.79	2.56	3.53	4.66	**200yr**	3.04	3.93	5.49	6.94	8.64	10.63	12.63	**200yr**	9.41	12.14	14.85	15.54	17.56	**200yr**
500yr	1.01	1.67	2.17	3.15	4.40	5.86	**500yr**	3.80	4.85	6.92	8.77	10.92	13.43	16.14	**500yr**	11.88	15.52	19.24	19.62	22.17	**500yr**

Lower Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.25	0.39	0.48	0.64	0.79	0.94	**1yr**	0.68	0.92	1.07	1.44	1.80	2.51	2.58	**1yr**	2.22	2.48	2.97	3.67	4.21	**1yr**
2yr	0.36	0.56	0.69	0.94	1.16	1.38	**2yr**	1.00	1.35	1.58	2.04	2.60	3.21	3.58	**2yr**	2.84	3.45	3.95	4.67	5.31	**2yr**
5yr	0.41	0.63	0.78	1.07	1.36	1.62	**5yr**	1.17	1.58	1.87	2.43	3.05	3.83	4.31	**5yr**	3.39	4.15	4.75	5.54	6.26	**5yr**
10yr	0.44	0.68	0.85	1.18	1.53	1.82	**10yr**	1.32	1.78	2.11	2.75	3.44	4.38	4.95	**10yr**	3.88	4.76	5.40	6.28	7.06	**10yr**
25yr	0.50	0.76	0.95	1.36	1.78	2.14	**25yr**	1.54	2.09	2.46	3.13	4.01	5.20	5.94	**25yr**	4.61	5.71	6.35	7.42	8.27	**25yr**
50yr	0.54	0.83	1.03	1.48	2.00	2.41	**50yr**	1.72	2.36	2.76	3.42	4.51	5.95	6.82	**50yr**	5.26	6.56	7.09	8.39	9.27	**50yr**
100yr	0.60	0.91	1.14	1.64	2.26	2.73	**100yr**	1.95	2.67	3.08	4.38	5.15	6.80	7.82	**100yr**	6.02	7.52	7.83	9.47	10.40	**100yr**
200yr	0.66	0.99	1.26	1.82	2.54	3.10	**200yr**	2.19	3.03	3.44	5.05	5.75	7.76	8.97	**200yr**	6.87	8.63	8.60	10.66	11.61	**200yr**
500yr	0.75	1.12	1.44	2.09	2.98	3.68	**500yr**	2.57	3.59	3.99	6.11	6.63	9.25	10.75	**500yr**	8.19	10.34	9.64	12.46	13.65	**500yr**

Upper Confidence Limits

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr	48hr		1day	2day	4day	7day	10day	
1yr	0.35	0.55	0.67	0.90	1.11	1.29	**1yr**	0.95	1.26	1.52	1.89	2.49	2.96	3.36	**1yr**	2.62	3.23	3.76	4.49	5.17	**1yr**
2yr	0.39	0.60	0.74	1.01	1.24	1.47	**2yr**	1.07	1.43	1.71	2.18	2.76	3.46	3.88	**2yr**	3.06	3.73	4.34	5.07	5.76	**2yr**
5yr	0.48	0.74	0.91	1.25	1.60	1.90	**5yr**	1.38	1.86	2.17	2.82	3.55	4.56	5.21	**5yr**	4.04	5.01	5.79	6.76	7.62	**5yr**
10yr	0.57	0.87	1.08	1.51	1.95	2.31	**10yr**	1.68	2.26	2.63	3.46	4.32	5.63	6.53	**10yr**	4.99	6.28	7.29	8.42	9.46	**10yr**
25yr	0.71	1.08	1.34	1.92	2.53	3.00	**25yr**	2.18	2.93	3.42	4.51	5.58	7.46	8.83	**25yr**	6.60	8.49	9.96	11.30	12.60	**25yr**
50yr	0.84	1.28	1.59	2.29	3.08	3.65	**50yr**	2.65	3.57	4.18	5.50	6.79	9.24	11.07	**50yr**	8.17	10.64	12.65	14.12	15.67	**50yr**
100yr	1.00	1.51	1.90	2.74	3.76	4.44	**100yr**	3.24	4.34	5.10	6.68	8.73	11.45	13.87	**100yr**	10.13	13.34	16.09	17.66	19.45	**100yr**
200yr	1.19	1.79	2.27	3.29	4.59	5.41	**200yr**	3.96	5.29	6.21	8.15	10.69	14.19	17.43	**200yr**	12.55	16.76	20.51	22.11	24.30	**200yr**
500yr	1.51	2.25	2.89	4.20	5.98	7.01	**500yr**	5.16	6.85	8.08	10.59	14.00	18.84	23.58	**500yr**	16.67	22.67	28.31	29.81	32.28	**500yr**

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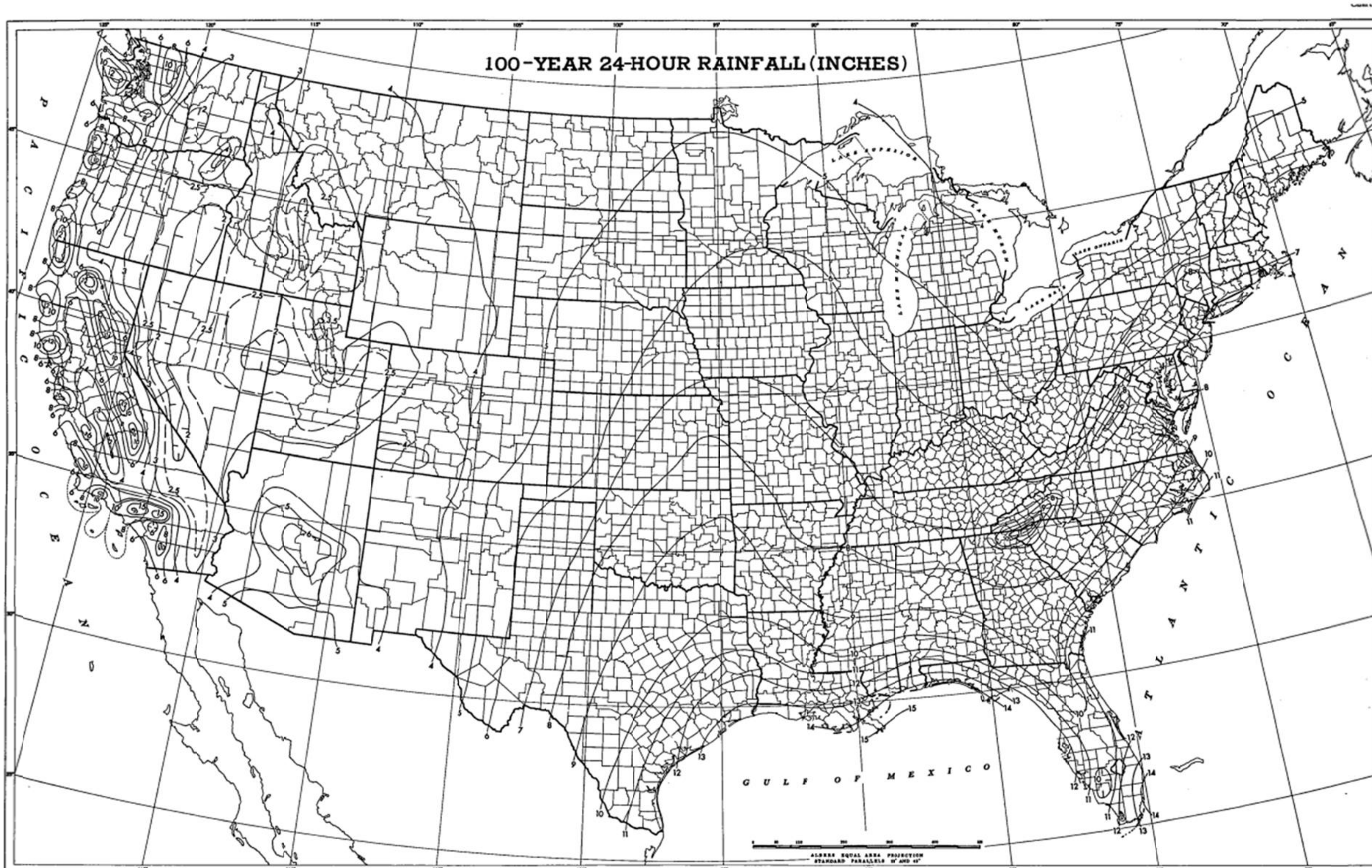

Figure C-1 Sample “TP-40” Map

56

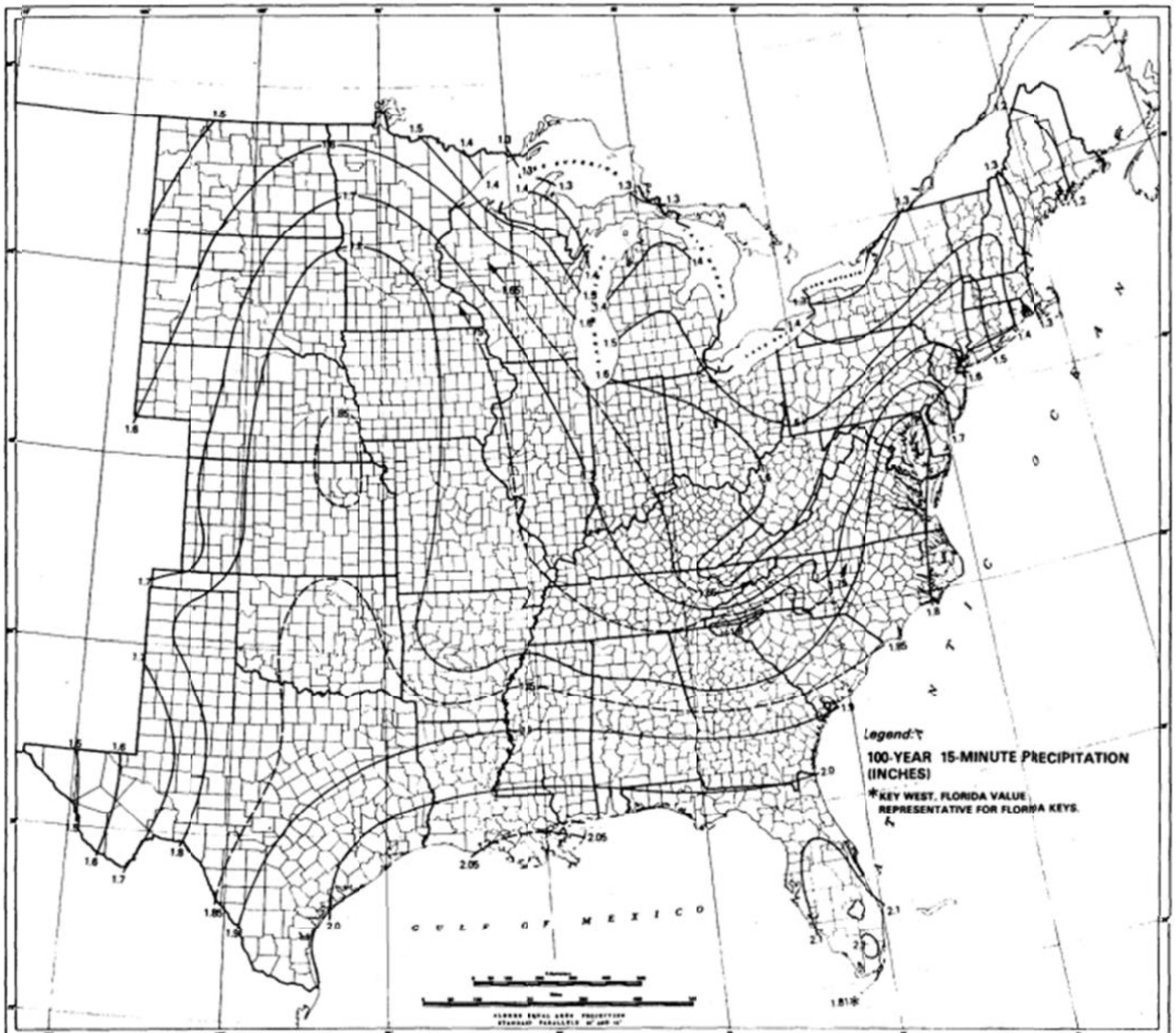

Figure C-2 Sample "HYDRO-35" Map

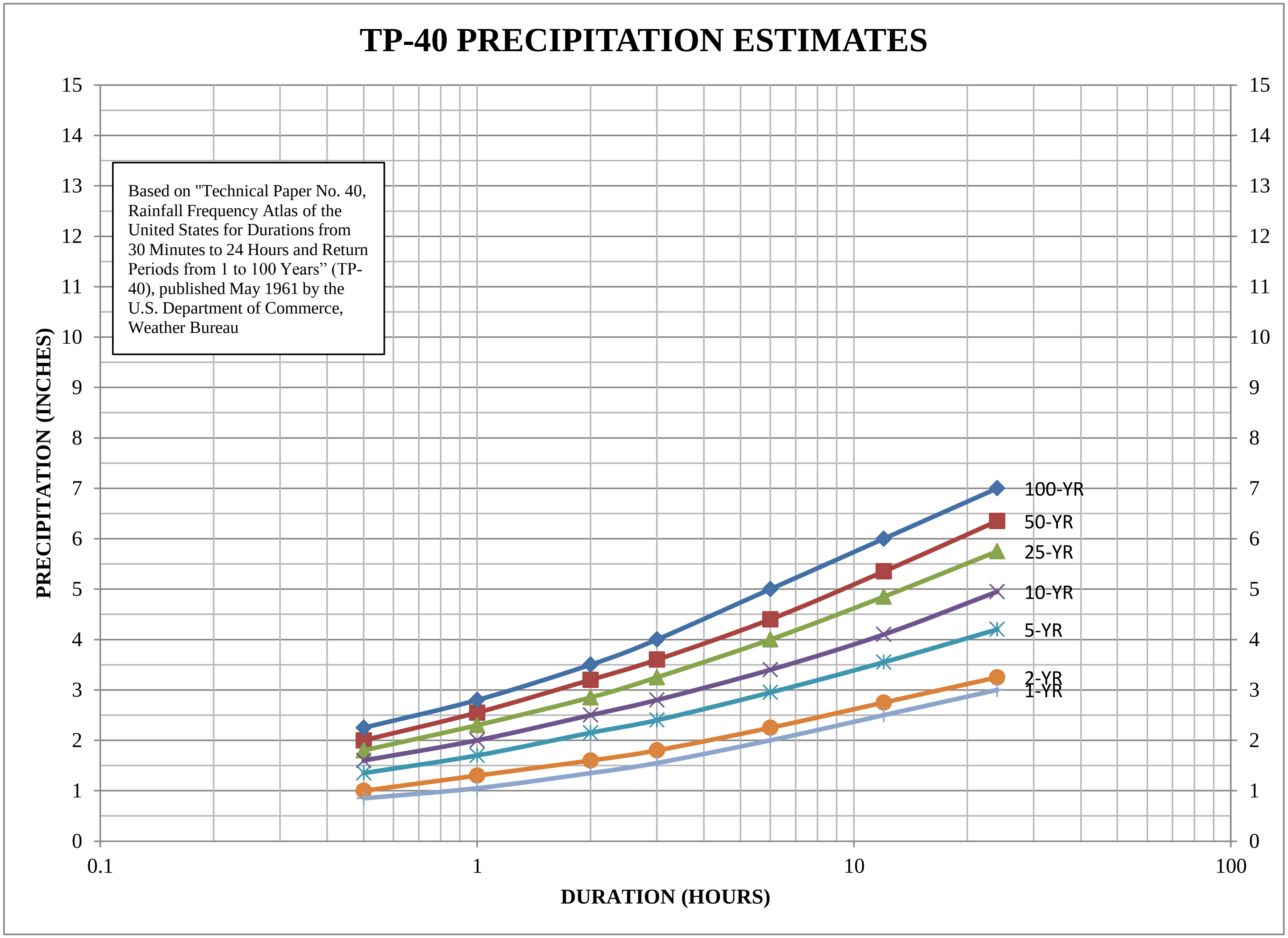

Figure C-3 "D-D-F" Curves "TP-40" Data

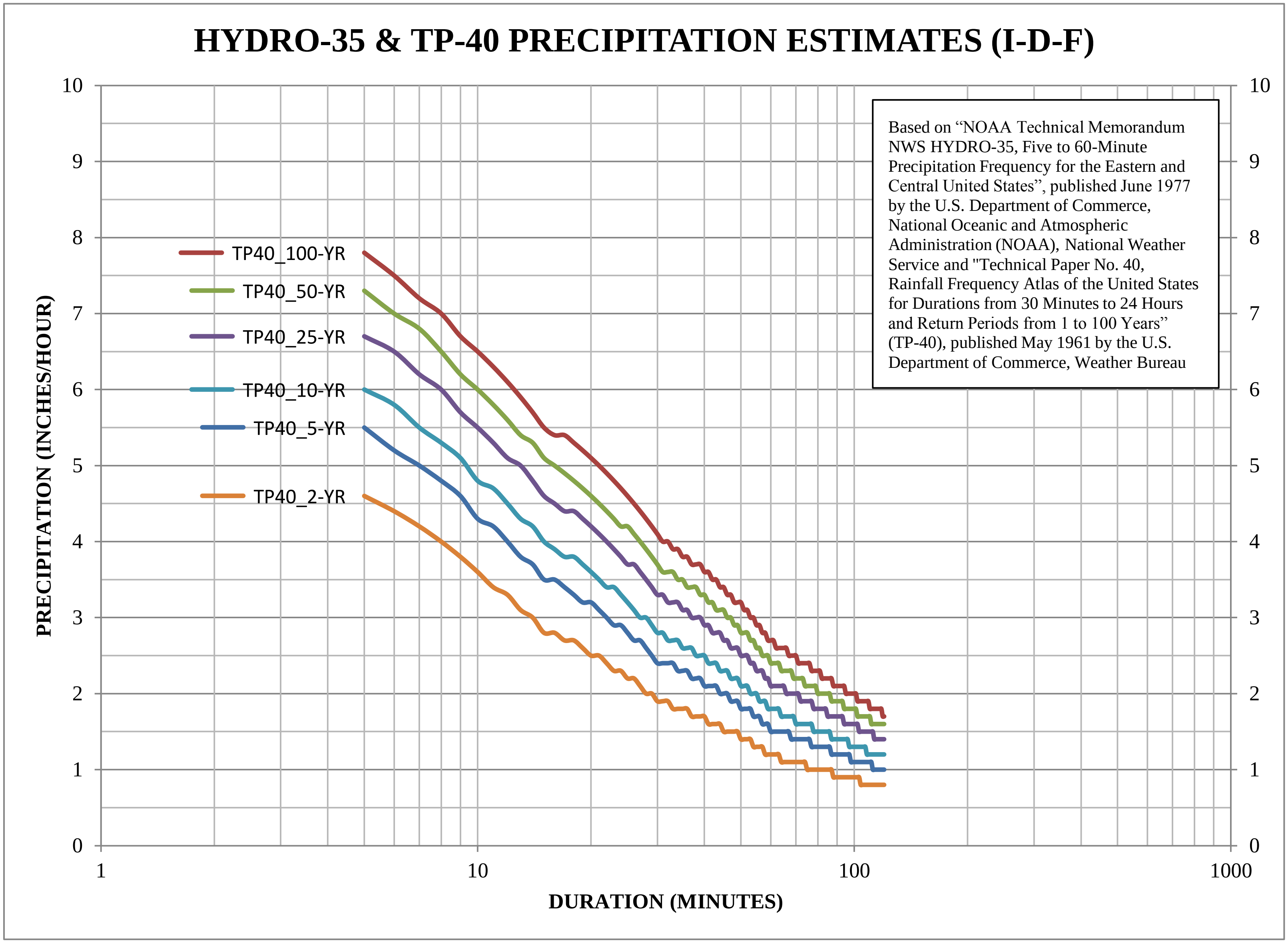

Figure C-4 "I-D-F" Curves Based on "HYDRO-35/TP-40" Data

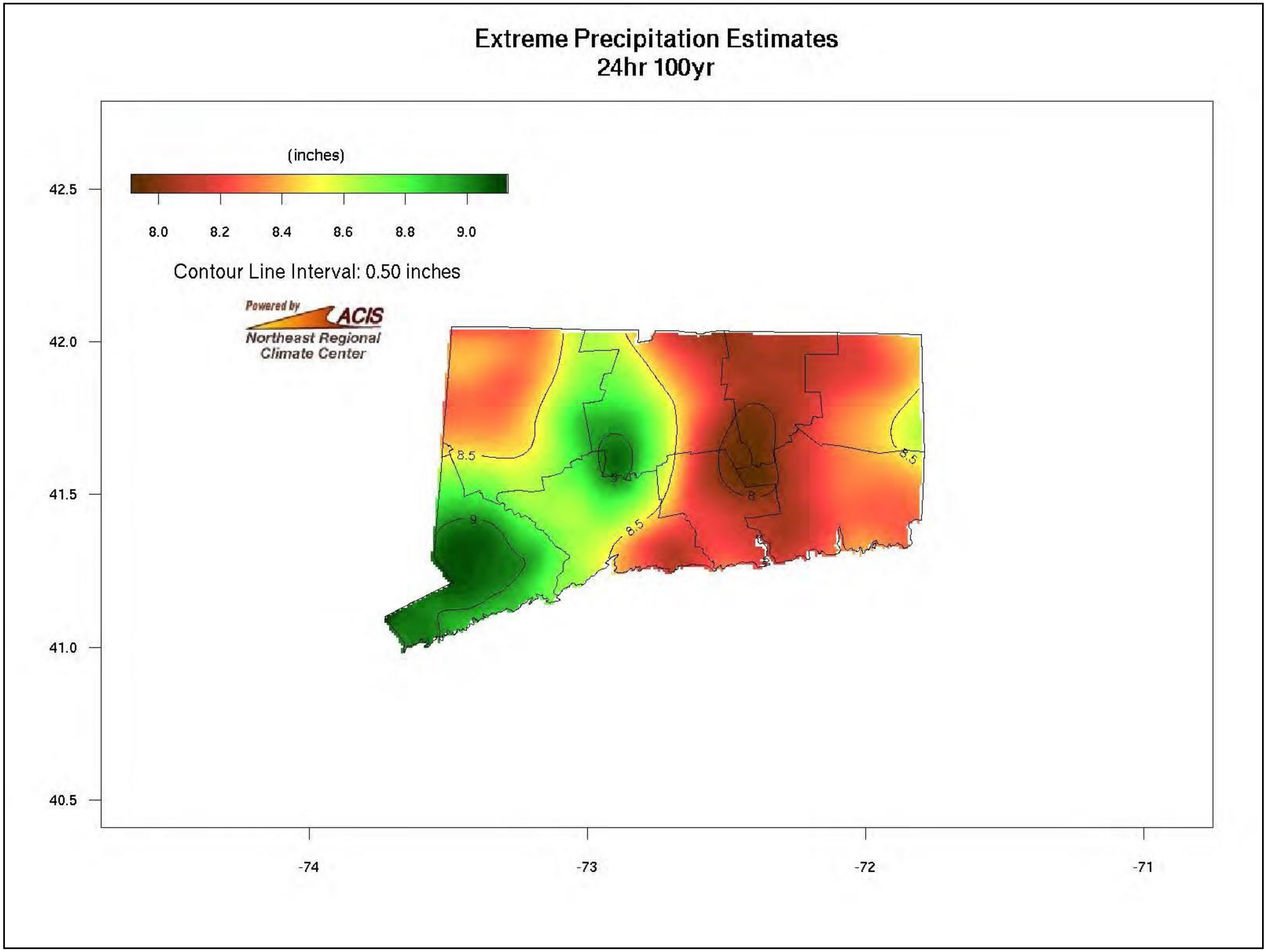
Extreme Precipitation Estimates
24hr 100yr
(inches)
8.0
8.2
8.4
8.6
8.8
9.0
Contour Line Interval: 0.50 inches
Powered by ACIS
Northeast Regional Climate Center
42.5
42.0
41.5
41.0
40.5
-74
-73
-72
-71
8.5
9
8

Figure C-5

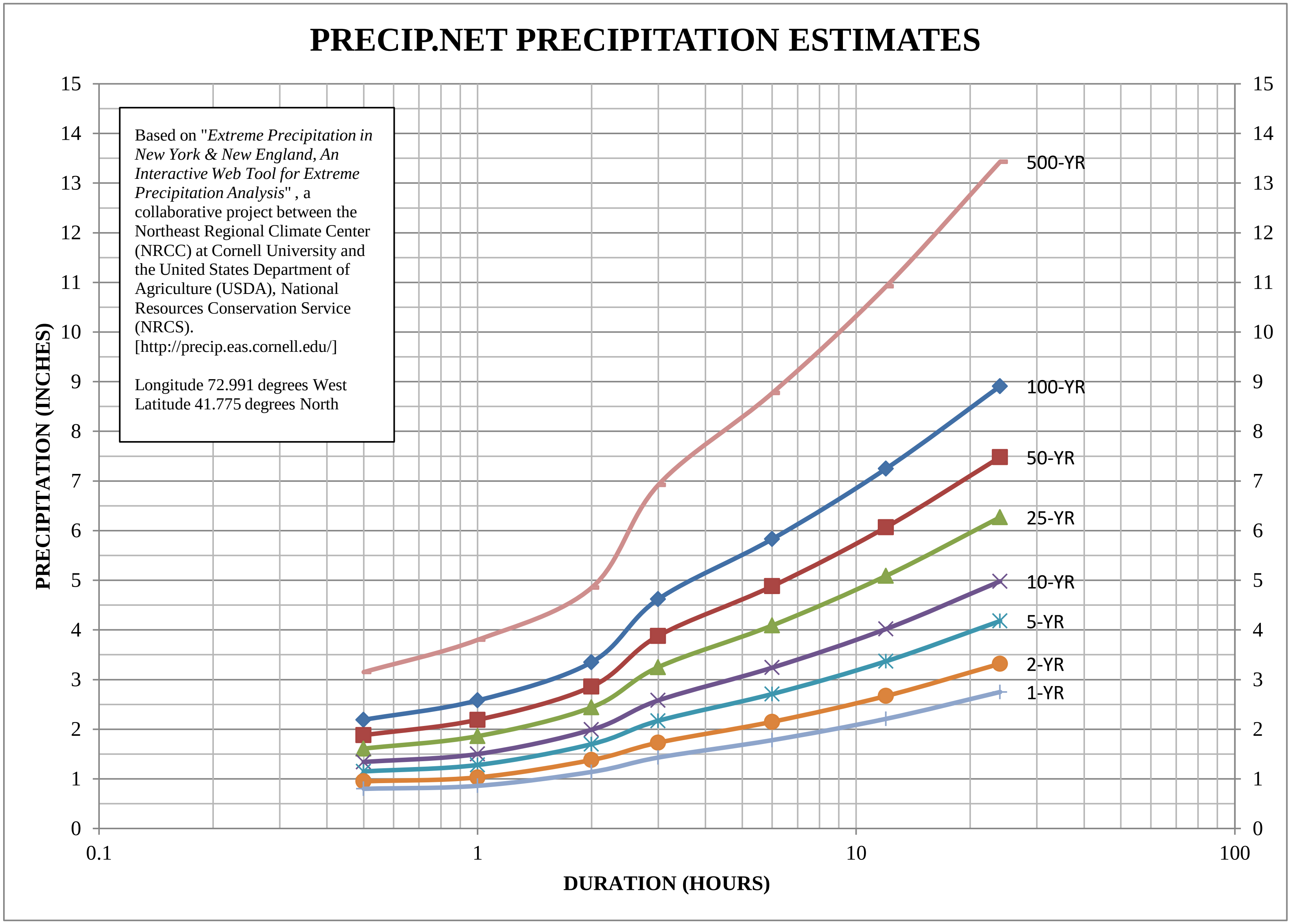

Figure C-6 "D-D-F" Curves "Precip.net" Data

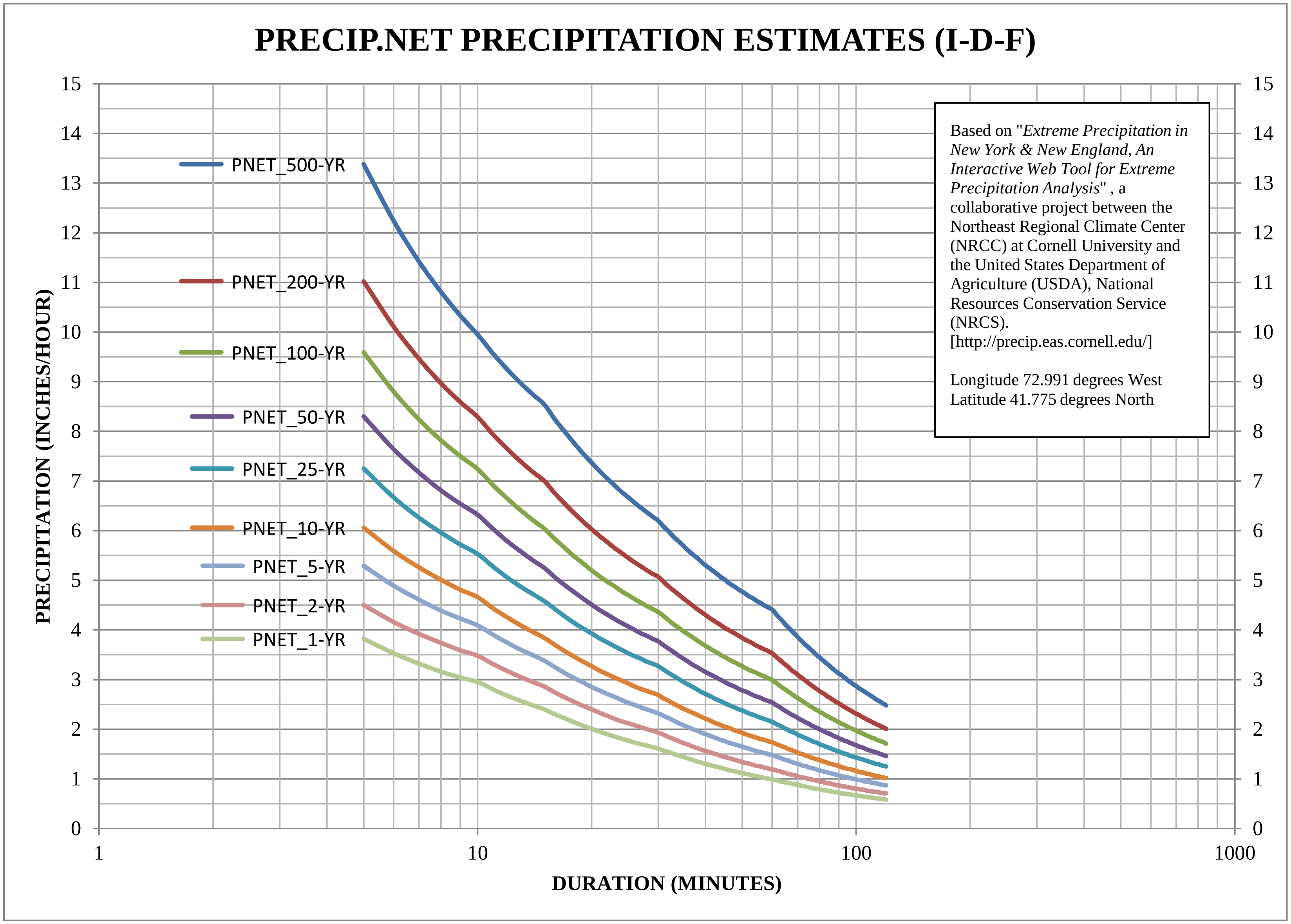

Figure C-7 "I-D-F" Curves Based on "Precip.net" Data

Source: Northeast Regional Climate Center and the Natural Resources Conservation Service

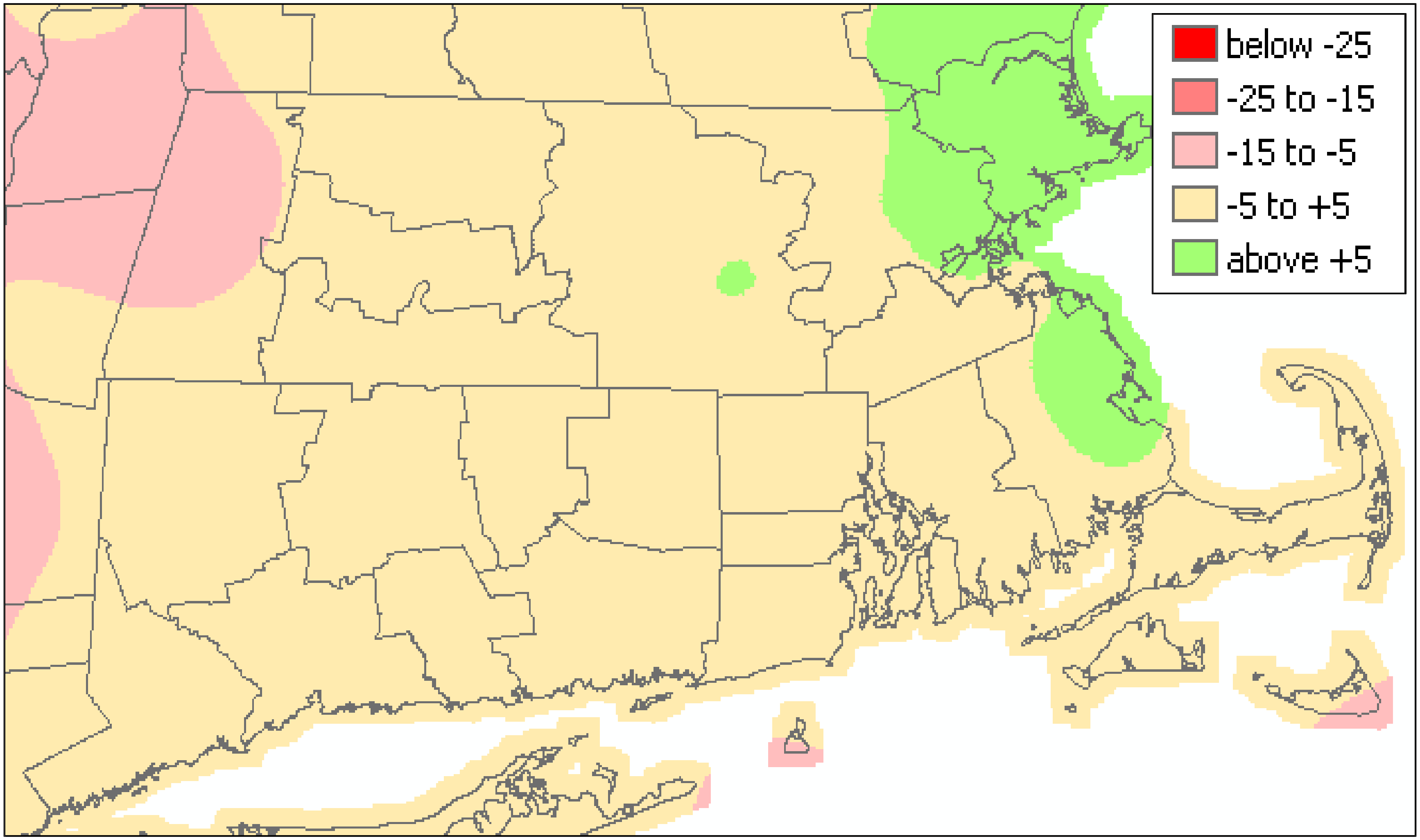

Figure C-8 Difference in 10-Year, 24-Hour Precipitation in Percent NRCC (Precip.net) vs. TP-40

Source: Northeast Regional Climate Center and the Natural Resources Conservation Service

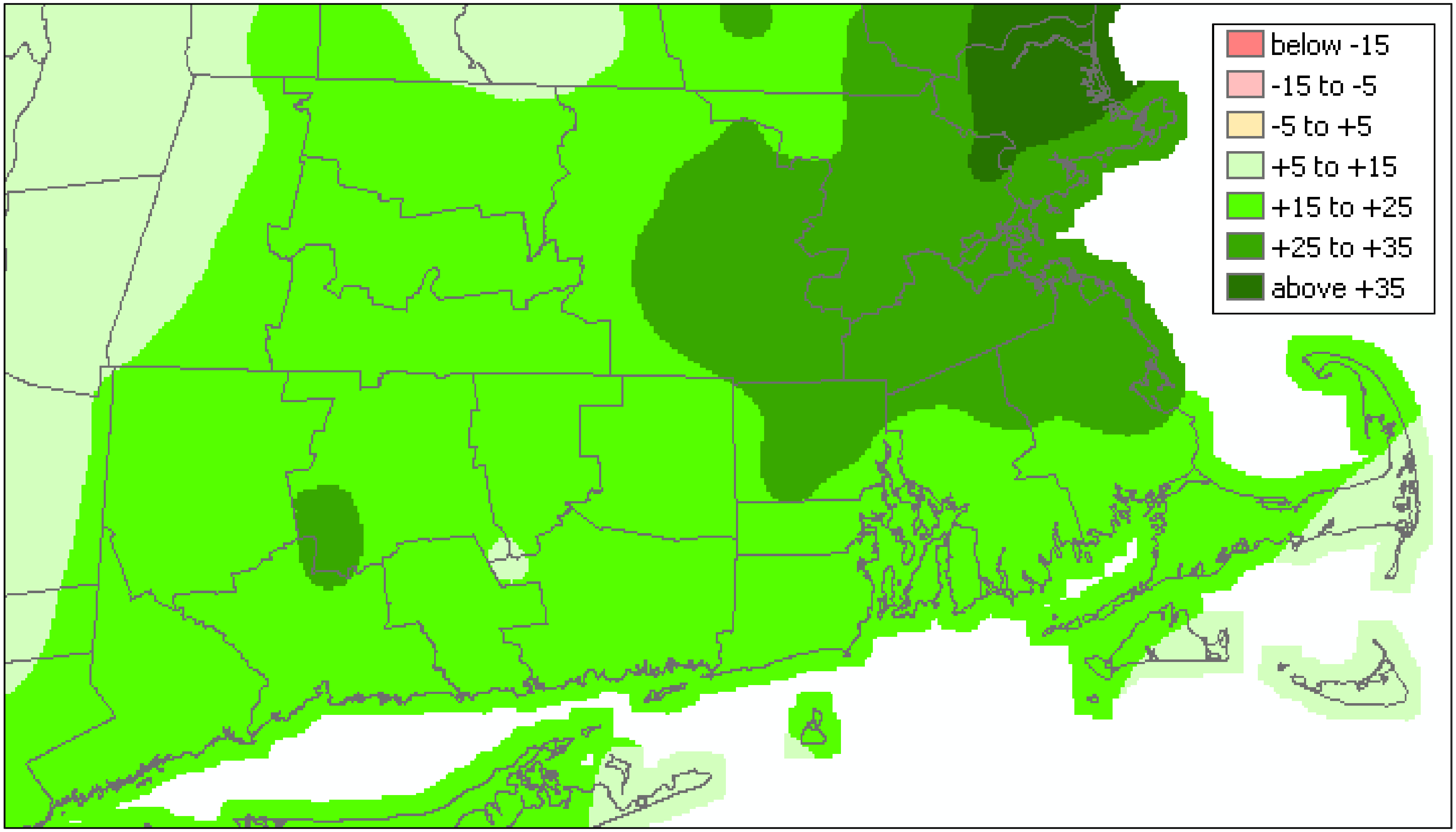

Figure C-9 Difference in 100-Year, 24-Hour Precipitation in Percent NRCC (Precip.net) vs. TP-40

Appendix D

Flood Frequency Curves

Appendix D of this report includes a plot of the Annual Peak Discharge (Streamflow) and an example of the set of three flood frequency curves that were computed at USGS stream gaging station number 01188000, Bunnell (Burlington) Brook near Burlington, CT, which is within the project limits. The period of record for the gage extends from 1932-present and the drainage area at the gage is approximately 4.2 square miles.

Figure D-1 is a plot of the Annual Peak Discharges for the stream gage, which shows that data broken down based on the full period of record 1932 – 2013, the period 1932 – 1970 and the period 1971 – 2013. Trend lines have also been shown for the same time periods. A positive or increasing trend is shown for the annual peak discharges for the full period of record 1932 – 2013 and the time period 1971 – 2013, with the later period showing a steeper trend. The time period 1932 – 1970 shows a negative or decreasing trend. The drought period in the 1960s can be seen in the plot.

Figure D-2 is the flood frequency curve that includes the full period of record to date, 1932 – 2013 (82 years), Figure D-3 is the flood frequency curve that includes the period of record from 1932 – 1970 (39 years) and Figure D-4 is the flood frequency curve that includes the period of record from 1971 – 2013 (43 years). The "dots" on these plots represents the annual peak discharges for the record period and the blue line represents the peak discharge estimate for a given flood exceedance probability or recurrence interval (frequency). The following table presents a comparison of the peak discharge (flow) estimates at the stream gage based on the set of three flood frequency curves described above.

Comparison of Flood Frequency Curves at USGS Stream Gage 01188000

Exceedance Probability	Frequency (Year)	Peak Discharge (Flow) Estimates (cfs)		
		1932 - 2013	1932 - 1970	1971 - 2013
0.002	500	2,254	1,920	2,731
0.005	200	1,812	1,531	2,146
0.01	100	1,514	1,272	1,766
0.02	50	1,246	1,039	1,435
0.04	25	1,003	831	1,144
0.1	10	719	590	816
0.2	5	527	429	601
0.5	2	292	235	346

Reviewing the results of the 100-year frequency flood, the peak discharge estimate using the 1971–2013 data is approximately 17 % higher than if the full period of records is used for this particular sample gage.

Appendix D

Confidence Limits

Examples of the upper and lower confidence limits computed with flood frequency-peak discharge estimates at a USGS stream gaging station are shown in Appendix D, Figures D-2, D-3 and D-4. The confidence limits are graphically represented by the dashed red lines in these figures. The following table shows the peak discharge estimates and the upper and lower confidence limits computed at USGS stream gaging station number 01188000, Bunnell (Burlington) Brook near Burlington, CT for the period of record, 1932 – 2013.

Confidence Limits for Peak Discharge Estimates at USGS Stream Gage 01188000 (1932 – 2013 Period of Record)

Exceedance Probability	Frequency (Year)	Peak Discharge (Flow) Estimates				
		Lower Confidence Limit		Estimate (cfs)	Upper Confidence Limit	
		% Difference	(cfs)		(cfs)	% Difference
0.002	500	-23	1,734	2,254	3,140	39
0.005	200	-21	1,425	1,812	2,451	35
0.01	100	-20	1,212	1,514	2,001	32
0.02	50	-19	1,015	1,246	1,605	29
0.04	25	-17	834	1,003	1,259	26
0.1	10	-15	613	719	868	21
0.2	5	-13	458	527	618	17
0.5	2	-12	257	292	332	14

For the 100-year frequency flood, the table shows that the predicted peak discharge is 1,514-cfs, but there 90 % probability that the true estimate of the 100-year peak discharge would lie between 2,001-cfs and 1,212-cfs, which are approximately 32% and 20% higher and lower, respectively, than the predicted value.

Peak discharge estimates were also determined at the USGS stream gaging station using the USGS regression equations (StreamStats). The estimates are shown on the following tables.

The first table shows the estimates along with the standard error of prediction. The standard error of prediction is a measure of the accuracy of the regression equations when predicting values for basins not used in the regression analysis. The USGS publication for the regression equations states that there is a 67-percent probability that the true value at a site is within the range of the standard error of prediction.

The second table shows the estimates along with the upper and lower confidence limits (90% confidence interval).

Standard Error of Prediction for Peak Discharge Estimates Using USGS Regression Equations at USGS Stream Gage 01188000

Frequency (Year)	SEP - Standard Error of Prediction (%)			Peak Discharge (Flow) Estimates (cfs)		
	Average	minus (-)	plus (+)	(-) SEP	Estimate	(+) SEP
500	45	35.4	54.7	866	1,340	2,073
100	37.6	30.8	44.4	789	1,140	1,646
50	35.9	29.6	42.1	695	987	1,403
10	32.7	27.5	37.9	460	634	874

Confidence Limits for Peak Discharge Estimates at USGS Stream Gage 01188000 Using USGS Regression Equations

Exceedance Probability	Frequency (Year)	Peak Discharge (Flow) Estimates				
		Lower Confidence Limit		Estimate (cfs)	Upper Confidence Limit	
		% Difference	(cfs)		(cfs)	% Difference
0.002	500	-71	391	1,340	2,546	90
0.01	100	-62	438	1,140	1,997	75
0.02	50	-59	403	987	1,696	72
0.1	10	-55	285	634	1,049	65

The regression equations underestimated the peak discharges in comparison to the results obtained from the statistical analysis of the annual peak discharges at the gage. For the 100-year frequency flood, the regression equation predicted a peak discharge of 1,140-cfs while the gage analysis predicted a value of 1,514-cfs. The standard error of prediction for the regression equation indicated at a 67-percent probability that the true 100-year discharge estimate would lie between 1,646-cfs and 789-cfs, which are approximately 44% and 31% higher and lower, respectively, than the predicted value. The confidence limits indicate that there is a 90 % probability that the true estimate of the 100-year peak discharge would lie between 1,997-cfs and 438-cfs, which are approximately 75% and 62% higher and lower, respectively, than the predicted value.

An example of upper and lower confidence limits provided with precipitation estimates can be found in Appendix C, Table C-2, which is a data product from the NRCC Precip.net web tool showing the point precipitation estimates for the various storm frequencies-durations taken near Burlington, CT (Latitude 41.775, Longitude 72.991) along with the associated confidence limits. Note that this location is the approximate centroid of the drainage area tributary to USGS Stream Gage 01188000 on Bunnell Brook referenced above.

The following table shows the precipitation estimates and the upper and lower confidence limits for the 24-hour duration and various storm frequencies extracted from the NRCC Precip.net tables.

Confidence Limits for NRCC (Precip.net) 24-Hour Precipitation Estimates

Exceedance Probability	Frequency (Year)	24-Hour Precipitation Estimates				
		Lower Confidence Limit		Estimate (in.)	Upper Confidence Limit	
		% Difference	(in.)		(in.)	% Difference
0.002	500	-31	9.25	13.43	18.84	40
0.005	200	-27	7.76	10.63	14.19	33
0.01	100	-24	6.8	8.91	11.45	29
0.02	50	-20	5.95	7.48	9.24	24
0.04	25	-17	5.2	6.27	7.46	19
0.1	10	-12	4.38	4.98	5.63	13
0.2	5	-8	3.83	4.18	4.56	9
0.5	2	-3	3.21	3.32	3.46	4

For the 100-year frequency storm, the table shows that the predicted precipitation depth is 8.91-inches, but there 90 % probability that the true estimate of the 100-year precipitation depth would lie between 11.45-inches and 6.8-inches, which are approximately 29% and 24% higher and lower, respectively, than the predicted value.

As can be seen from the examples provided above, a significant level of uncertainty in the accuracy of the estimates of the extreme events (low probability) needed for hydrologic analysis and hydraulic design currently exists. Recent discussions challenging the underlying assumption of stationarity in frequency analysis, in particular as related to climate change, adds another level of uncertainty.

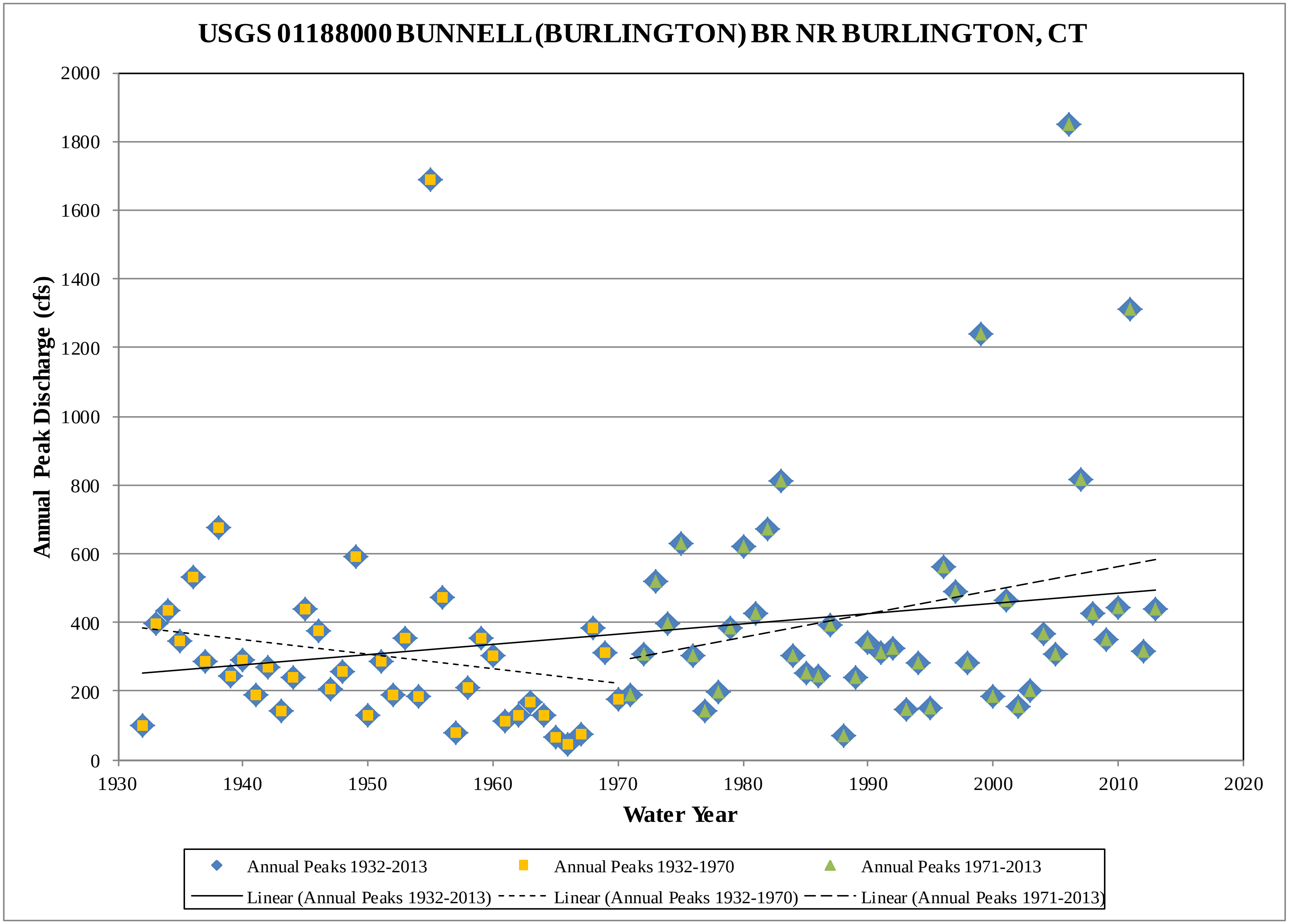

Figure D-1 Annual Peak Discharge at USGS Stream Gaging Station No. 01188000 (1932 – 2013)

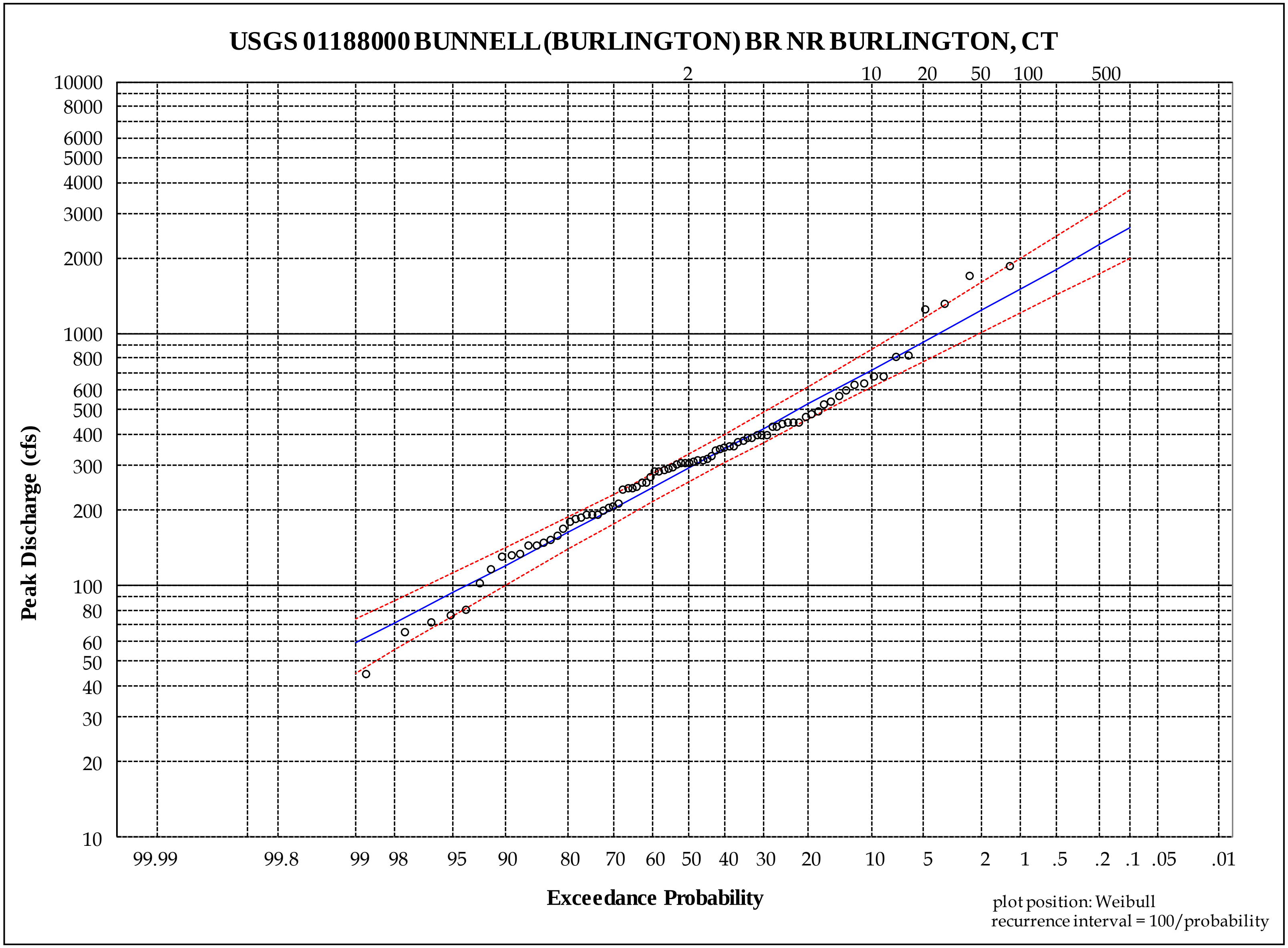

Figure D-2 Flood Frequency Curve for USGS Stream Gaging Station No. 01188000 (1932 – 2013)

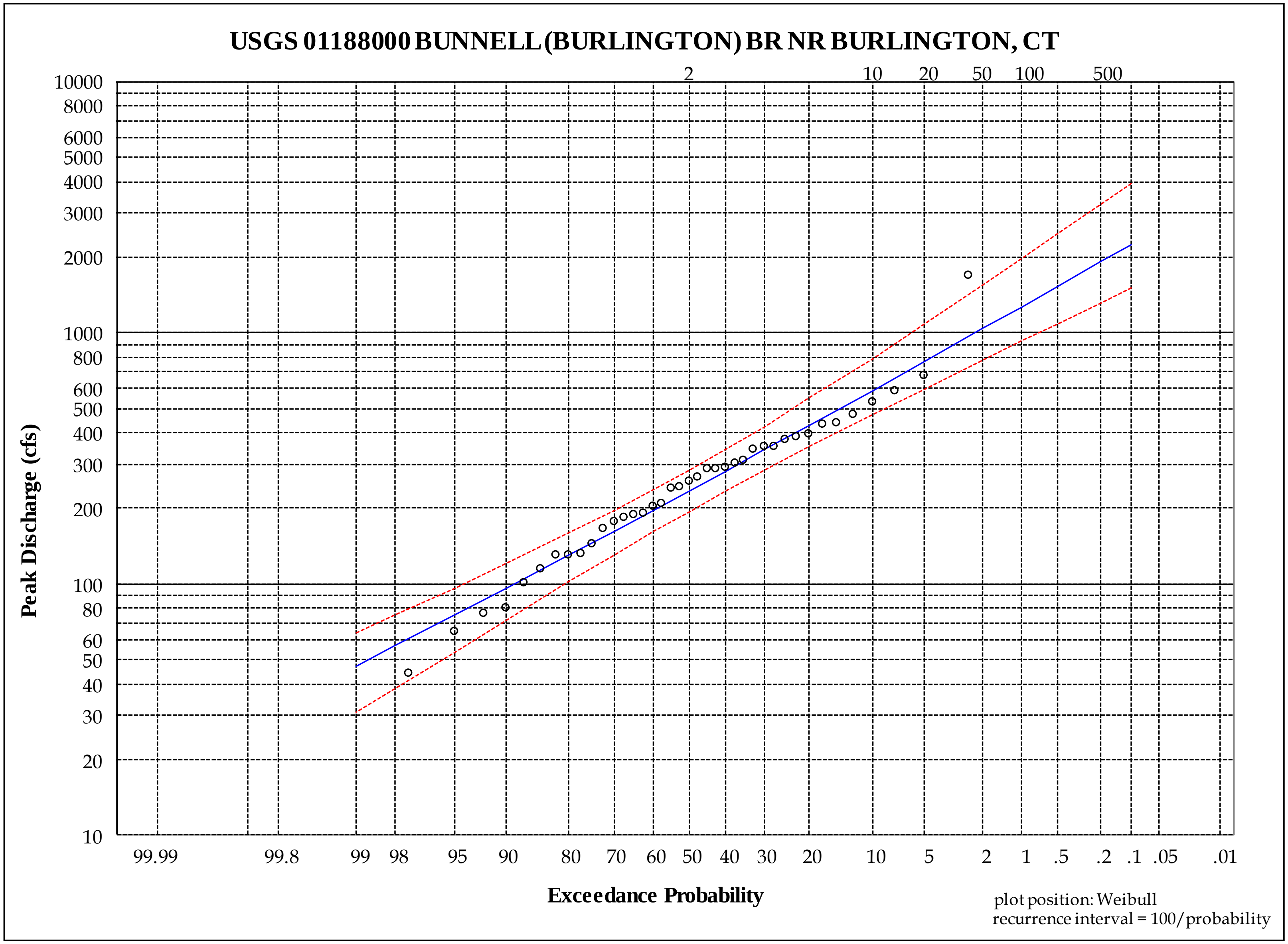

Figure D-3 Flood Frequency Curve for USGS Stream Gaging Station No. 01188000 (1932 – 1970)

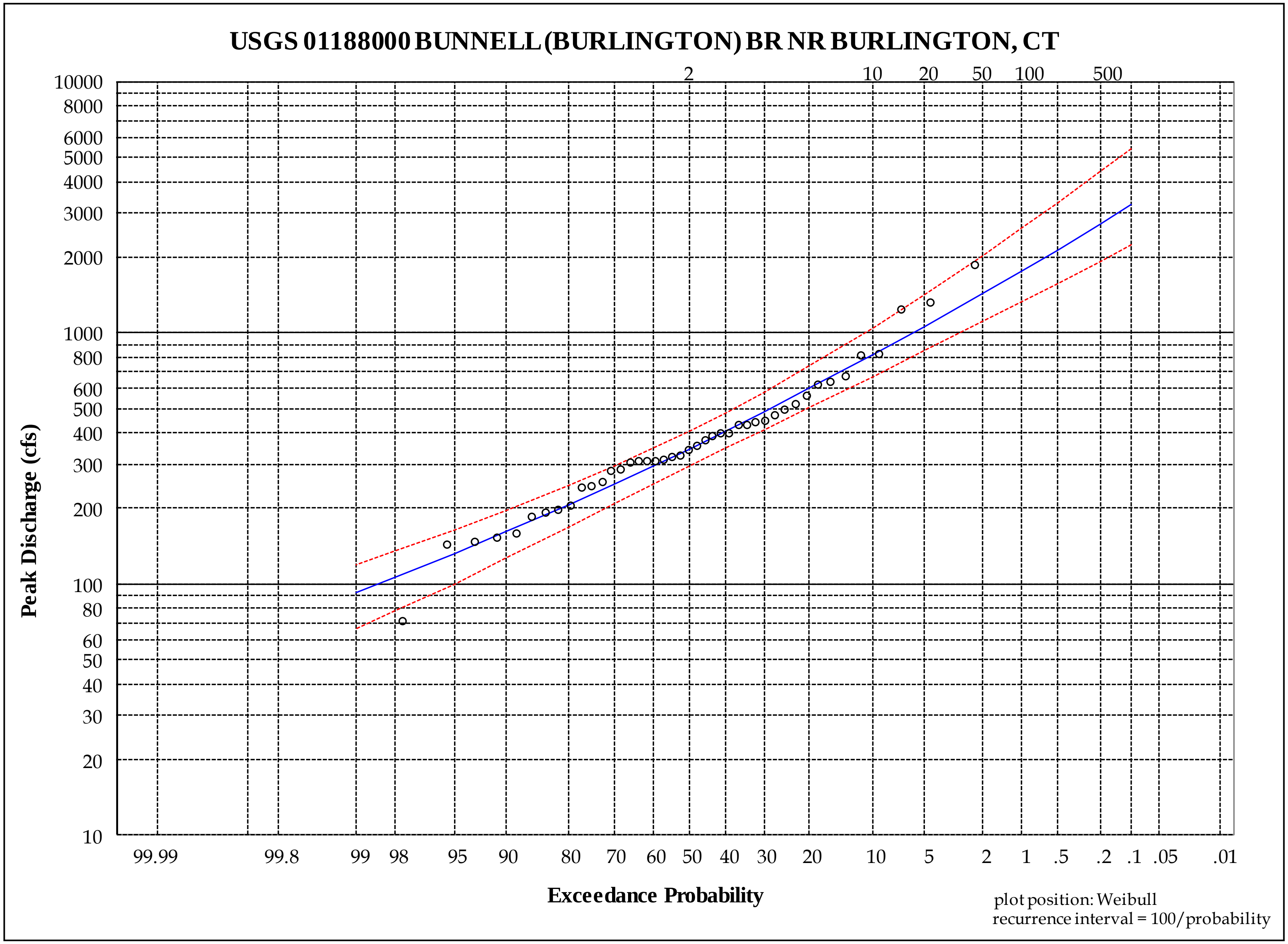

Figure D-4 Flood Frequency Curve for USGS Stream Gaging Station No. 01188000 (1971 – 2013)

Table E-1 – Results of Hydraulic Evaluations – Hydraulic Adequacy and Adaptive Capacity Determinations

Structure No.	Feature Carried	Features Intersected	Town Name	Structure Type	Hydraulic Opening (W x H) or (Diameter)	Open Bottom (Y/N)	Drainage Area (mi^2)	Hydrologic Method (RM,SCS,SS)[*1]	Estimated Discharge Rate (cfs)[*2]			Design Discharge[*2]					Check Discharge[*2]					Hydraulically Adequate (Y/N)	Hyd. Adequate w/TP-40 (Y/N)	Adaptive Capacity (Y/N)
									50-Yr[*2]	100-Yr[*2]	500-Yr[*2]	Inlet Submerged (Y/N)	HW/D > 1.5 (Y/N)	Freeboard < 1-Ft (Y/N)	Overtopping (Y/N)	Velocity > 14 fps (Y/N)	Inlet Submerged (Y/N)	HW/D > 1.5 (Y/N)	Freeboard < 1-Ft (Y/N)	Overtopping (Y/N)	Velocity > 14 fps (Y/N)			
01930	Route 4	Guinea Brook	Sharon	CIP Slab	8' x 14'	Y	4.09	SS	646	779	1120	N	N	N	N	Y	N	N	N	N	Y	Y	*6	N
01937	Route 4	Birdseye Brook	Cornwall	CIP Slab	6' x 7.5'	Y	1.27	SCS	-	308	533	N	*4	N	N	N	Y	*4	Y	N	N	Y	Y	N
01945	Route 4	Catlin Brook	Harwinton	Conc Deck	10' x 10'	Y	1.27	SCS	-	1024	2151	Y	*4	Y	Y	*3	Y	Y	Y	Y	*3	N	Y	N
01946	Route 4	Rock Brook	Harwinton	Conc Deck	14' x 10'	Y	2.50	SS	663	765	1043	N	N	N	N	N	N	N	N	N	N	Y	*6	Y
01947	Route 4	Brook	Harwinton	CIP Slab	12' x4'	Y	0.83	SCS	420	586	-	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	*5	N
01948	Route 4	North Branch Bunnell Bk	Burlington	Conc Box	8' x 6'	N	0.52	SCS	445	587	-	Y	N	N	N	Y	Y	Y	N	N	Y	Y	Y	Y
01949	Route 4	Misery Brook	Burlington	Conc Deck	8' x 8'	Y	1.62	SS	433	509	604	N	N	N	N	Y	Y	N	N	N	Y	Y	*6	Y
01985	U.S. Route 6	Todd Hollow Brook	Plymouth	CIP Slab	6' x 7'	Y	0.36	SCS	344	457	-	Y	N	N	N	N	Y	Y	N	N	N	Y	Y	Y
01987	U.S. Route 6	Cuss Gutter Brook	Bristol	Conc Slab	8' x 7'	Y	0.55	SCS	636	840	-	Y	*4	Y	Y	*3	Y	*4	Y	Y	*3	N	Y	N
02048	U.S. Route 7	Cobble Brook	Kent	CIP Slab	15.5' x 8'	Y	3.38	SS	533	638	900	N	N	N	N	N	N	N	N	N	Y	Y	*6	Y
02050	U.S. Route 7	Kent Falls Brook	Kent	Conc Deck	16' x 15'	Y	5.77	SS	858	1030	1460	N	N	N	N	Y	N	N	N	N	Y	Y	*6	N
02051	U.S. Route 7	Deep Brook	Cornwall	CIP Arch	12' x 10.5'	Y	0.89	SCS	762	1013	-	N	N	N	N	N	Y	N	N	N	N	Y	Y	Y
02078	Route 848	Brook	Thomaston	CIP Deck	8' x 6'	Y	0.24	RM	97	118	-	N	N	N	N	N	N	N	N	N	N	Y	Y	N
02079	Route 848	Nibbling Brook	Thomaston	CIP Slab	12' x 7.9'	Y	2.18	SS	390	454	644	N	N	N	N	N	N	N	N	N	N	Y	*6	Y
02082	SR 800	Brook	Torrington	CIP Slab	8' x 4'	Y	0.56	SCS	646	959	-	Y	Y	Y	Y	*3	Y	Y	Y	Y	*3	N	N	N
02089	Route 8	Brook	Colebrook	CIP Slab	6' x 4'	Y	0.40	SCS	289	504	-	Y	*4	Y	Y	*3	Y	*4	Y	Y	*3	N	N	N
02200	Route 20	Brook	Winchester	CIP Deck	4.6' x 6'	Y	0.31	RM	192	198	-	Y	N	N	N	N	Y	N	N	N	N	Y	Y	Y
02204	Route 20	Falls Brook	Hartland	CIP Box	6' x 6'	N	0.33	RM	222	270	-	N	N	N	N	Y	Y	N	N	N	Y	Y	Y	N
02205	Route 20	Falls Brook	Hartland	CIP Box	8' x 6'	N	0.44	SCS	331	359	-	Y	N	N	N	Y	Y	N	N	N	Y	Y	Y	N
02230	U.S. Route 202	Hill Brook	Litchfield	CIP Slab	10' x 4'	Y	0.92	SCS	-	910	1742	Y	Y	Y	Y	*3	Y	Y	Y	Y	*3	N	N	N
02231	U.S. Route 202	Still Brook	Litchfield	CIP Slab w/floor	12' x 8.5'	N	2.33	SS	458	540	850	N	N	N	N	Y	N	N	N	N	Y	Y	*6	N
02238	Us Route 202	Gulf Stream	Torrington	Conc Slab	17' x 20'	Y	3.84	SS	825	954	1303	N	N	N	N	Y	N	N	N	N	Y	Y	*6	N
02297	Route 41	Ball Brook	Salisbury	Conc Slab	8' x 4'	Y	2.41	SS	-	543	802	Y	*4	Y	Y	N	Y	*4	Y	Y	N	N	*6	N
02305	U.S. Route 44	Burton Brook	Salisbury	CIP Arch	8' X 7.1'	Y	3.51	SS	557	676	1240	Y	*4	Y	Y	N	Y	*4	Y	Y	N	N	*6	N
02306	U.S. Route 44	Garnet Brook	Salisbury	Conc Slab	7' x 5.5'	Y	0.80	SCS	713	1010	-	Y	*4	Y	Y	*3	Y	*4	Y	Y	*3	N	N	N
02313	U.S. Route 44	Mallory Brook	Barkhamsted	Conc Box	10' x 9'	N	1.40	SCS		1426	2857	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N
02314	U.S. Route 44	Mallory Brook	Barkhamsted	Conc Box	16- x 10'	N	3.00	SS	787	930	1314	N	N	N	N	N	Y	N	N	N	Y	Y	*6	Y
02315	U.S. Route 44	Brook	Barkhamsted	Conc Box	7.5' x 8'	N	1.48	SCS	-	895	1620	Y	*4	Y	Y	*3	Y	*4	Y	Y	*3	N	Y	N
02316	U.S. Route 44	Brook	Barkhamsted	Conc Box	6' x 6'	N	0.48	SCS	587	732	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	*3	N	Y	N
02317	U.S. Route 44	Brook	New Hartford	Conc Box	12' x 7.5'	N	0.70	SCS	591	855	-	N	N	N	N	N	Y	N	N	N	N	Y	Y	Y

Table E-1 – Results of Hydraulic Evaluations – Hydraulic Adequacy and Adaptive Capacity Determinations

Structure No.	Feature Carried	Features Intersected	Town Name	Structure Type	Hydraulic Opening (W x H) or (Diameter)	Open Bottom (Y/N)	Drainage Area (mi^2)	Hydrologic Method (RM,SCS,SS)*1	Estimated Discharge Rate (cfs)*2			Design Discharge*2					Check Discharge*2					Hydraulically Adequate (Y/N)	Hyd. Adequate w/TP-40 (Y/N)	Adaptive Capacity (Y/N)
									50-Yr*2	100-Yr*2	500-Yr*2	Inlet Submerged (Y/N)	HW/D > 1.5 (Y/N)	Freeboard < 1-Ft (Y/N)	Overtopping (Y/N)	Velocity > 14 fps (Y/N)	Inlet Submerged (Y/N)	HW/D > 1.5 (Y/N)	Freeboard < 1-Ft (Y/N)	Overtopping (Y/N)	Velocity > 14 fps (Y/N)			
02414	Route 63	Wattles Brook	Watertown	Conc Box	10' x 8'	N	2.27	SS	360	412	559	N	N	N	N	Y	N	N	N	N	Y	Y	*6	N
02420	Route 63	Brook	Morris	CIP Deck	10' x 9'	Y	0.63	SCS	377	494	-	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N
02423	Route 63	Brook	Cornwall	CIP Box	18' X 8'	N	3.62	SS	740	880	1221	N	N	N	N	Y	N	N	N	N	Y	Y	*6	N
02467	Route 72	Poland River	Plymouth	Conc Deck	10' x 5.6'	Y	5.56	SS	1130	1320	1818	Y	*4	Y	Y	N	Y	*4	Y	Y	*3	N	*6	N
02471	Route 72	Poland River	Harwinton	Conc Deck	12' x 5.4'	Y	2.42	SS	604	697	967	Y	*4	Y	Y	N	Y	*4	Y	Y	N	N	*6	N
02613	Route 109	Mallory Brook	Washington	CIP Arch	11' x 5.7'	Y	1.91	SS	340	394	707	Y	N	N	N	N	Y	*4	Y	Y	N	Y	*6	N
02615	Route 109	East Morris Brook	Morris	Conc Deck	12' x 4.5'	Y	0.78	SCS	405	550	-	Y	N	N	N	N	Y	Y	Y	N	N	Y	Y	N
02616	Route 109	Beaver Brook	Morris	Conc Deck	6' x 3'	Y	0.25	RM	130	159	-	Y	*4	Y	Y	N	Y	*4	Y	Y	*3	N	N	N
02617	Route 109	Brook	Morris	Double Box	2 - 9' x 7'	N	4.59	SS	736	867	1165	Y	N	N	N	Y	Y	N	N	N	Y	Y	*6	N
02770	Route 183	Colebrook Brook	Winchester	CIP Slab	11' x 6'	Y	2.33	SS	602	713	847	Y	*4	Y	Y	Y	Y	*4	Y	Y	Y	N	*6	N
02771	Route 183	Colebrook Brook	Winchester	CIP Slab	12' x 4'	Y	1.72	SS	498	598	847	Y	Y	Y	Y	N	Y	Y	Y	Y	N	N	*6	N
02965	Route 47	Brook	Washington	Conc Deck	6' x 5.5'	Y	0.17	RM	120	145	-	N	N	N	N	N	N	N	N	N	N	Y	Y	N
02966	Route 47	Kirbys Brook	Washington	CIP Deck	8' x 14'	Y	0.87	SCS	381	447	-	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N
03260	Route 4	Brook	Torrington	CIP Deck	4' X 6'	Y	0.11	RM	40	48	-	N	N	N	N	N	N	N	N	N	N	Y	Y	Y
03300	U.S. Route 44	Brook	Salisbury	Conc Deck	6' x 6.7'	Y	0.31	RM	200	244	-	N	N	N	N	Y	N	N	N	N	Y	Y	Y	N
03333	Route 8 & Ramp	Pickett Brook	Harwinton	Conc Box	11' x 7'	N	1.48	SCS	-	1618	3210	Y	Y	Y	Y	*3	Y	Y	Y	Y	Y	N	N	N
05408	Route 4	Punch Brook	Burlington	CMA	12.7' x 8.1'	N	1.66	SS	431	507	684	Y	N	N	N	N	Y	*4	Y	Y	*3	Y	Y	Y
05417	Route 109	Brook	Morris	Metal Arch	11.4' x 7.25'	N	2.01	SS	376	442	600	Y	N	N	N	N	Y	N	Y	N	N	Y	*6	Y
05418	Route 128	Mill Brook	Cornwall	CIP Slab	12' x 9.5'	Y	4.50	SS	762	914	1480	Y	N	N	N	N	Y	*4	Y	Y	Y	Y	*6	N
05896	U.S. Route 202	Bee Brook	Washington	Conc Deck	14' x 9'	Y	3.49	SS	570	674	958	N	N	N	N	N	N	N	N	N	N	Y	*6	Y
06668	Route 179	Brook	Burlington	CMA	7.25' X 5.25'	N	0.11	RM	93	113	-	N	N	N	N	N	N	N	N	N	N	Y	Y	Y
06712	Route 63	Brook	Watertown	CMP	84"	N	0.82	SCS	815	1064	-	Y	N	N	N	N	Y	Y	N	N	N	Y	Y	Y

*1 RM = Rational Method/ SCS = SCS Unit Hydrograph/ SS = StreamStats.
*2 RM and SCS discharges based on "Precip.net" precipitation.
*3 Overtops prior to design or check discharge
*4 The headwater depth is less than 1.5 times the hydraulic opening height at a stage when overtopping would initiate.
*5 The culvert allows the 50 year event to pass without roadway overtopping, but has less than 1-ft of freeboard during the event.
*6 Hydrologic study used Regression Equations (StreamStats) and therefore TP-40 precipitation rates were not considered
CIP = Cast In Place/ CMP = Corrugated Metal Pipe/ CMA = Corrugated Metal Arch

Table E-2 - Results of Hydraulic Evaluations – Discharge Comparison

Structure No.	Feature Carried	Features Intersected	Town Name	Drainage Area (mi^2)	Hydrologic Method (RM,SCS,SS)*1	Estimated Peak Discharge (cfs)			Culvert Discharge (cfs) at Specified HW Stage				Design Discharge (cfs) Estimate Based on Increase in Precipitation*4								Open Bottom (Y/N)	Velocity > 14 fps (Y/N)	Scour Critical (113)	Hydraulically Adequate (Y/N)	Adaptive Capacity (Y/N)	Notes
						50-Yr*2	100-Yr*2	500-Yr*2	Inlet Submerged	1.5 HW/D	1-Ft Freeboard	Overtopping	0.5-in (SCS, SS) - 10% (RM)	1.0-in (SCS, SS) - 20% (RM)	1.5-in (SCS, SS) - 30% (RM)	2.0-in (SCS, SS) - 40% (RM)	2.5-in (SCS, SS) - 50% (RM)	3.0-in (SCS, SS) - 60% (RM)	3.5-in (SCS, SS) - 70% (RM)	4.0-in (SCS, SS) - 80% (RM)						
01930	Route 4	Guinea Brook	Sharon	4.09	SS	646	779	1120	1,180	-	1,360	1,449	867	958	1,052	1,150	1,251	1,356	1,464	1,574	Y	Y	6	Y	N	Embankment erosion along inlet east wingwall. Stream flows favor this side of the wingwall creating scour pocket.
01937	Route 4	Birdseye Brook	Cornwall	1.27	SCS	-	308	533	358	-	522	580	339	365	390	423	450	478	503	530	Y	N	3	Y	N	Scour critical bridge rating.
01945	Route 4	Catlin Brook	Harwinton	1.27	SCS	-	1024	2151	900	-	900	1,024	1,140	1,260	1,370	1,500	1,610	-	-	-	Y	*3	6	N	N	Bridge inspection reports do not cite a degree of erosion or scour sufficient to raise concerns.
01946	Route 4	Rock Brook	Harwinton	2.50	SS	663	765	1043	1,100	-	1,640	1,798	830	898	967	1038	1111	1187	1264	1342	Y	N	8	Y	Y	Channel around the culvert is heavily armored.
01947	Route 4	Brook	Harwinton	0.83	SCS	420	586	-	196	305	262	333	470	520	580	645	700	-	-	-	Y	N	6	N	N	The velocity of the structure is in the low to normal range where erosion does not appear to be an issue.
01948	Route 4	North Branch Bunnell Bk	Burlington	0.52	SCS	445	587	-	300	480	700	750	495	546	600	653	705	757	813	-	N	Y	8	Y	Y	Increases in outlet velocities may result in some additional erosion downstream but heavily armored streambed appears sufficient.
01949	Route 4	Misery Brook	Burlington	1.62	SS	433	509	604	545	-	604	669	553	597	643	691	740	790	841	893	Y	Y	6	Y	Y	Streambed naturally armored. Inspection reports do not cite a current degree of erosion or scour.
01985	U.S. Route 6	Todd Hollow Brook	Plymouth	0.36	SCS	344	457	-	150	370	513	558	385	425	468	510	555	598	640	-	Y	N	6	Y	Y	Heavily armored streambed.
01987	U.S. Route 6	Cuss Gutter Brook	Bristol	0.55	SCS	636	840	-	370	-	490	561	636	703	771	839	908	977	1047	1116	Y	*3	6	N	N	Bridge Inspection Report indicated that there are exposed footings along the northwest wingwall and the east abutment.
02048	U.S. Route 7	Cobble Brook	Kent	3.38	SS	533	638	900	980	-	1,220	1,342	709	782	859	938	1020	1104	1191	1280	Y	N	6	Y	Y	Scour along the full length of the southwest wingwall.
02050	U.S. Route 7	Kent Falls Brook	Kent	5.77	SS	858	1030	1460	2,450	3,900	3,800	4,015	1145	1264	1387	1514	1646	1782	1923	2067	Y	Y	6	Y	N	Previous scour and undermining at abutments.
02051	U.S. Route 7	Deep Brook	Cornwall	0.89	SCS	762	1013	-	1,000	1,640	2,000	2,103	858	956	1,055	1,155	1,256	1,357	-	-	Y	N	6	Y	Y	Footings through structure are exposed but no undermining. Countermeasures could be sufficient to provide adaptive capacity.
02078	Route 848	Brook	Thomaston	0.24	RM	97	118	-	290	460	570	629	107	116	126	136	146	155	-	-	Y	N	6	Y	N	Existing 3-ft drop at outlet.
02079	Route 848	Nibbling Brook	Thomaston	2.18	SS	390	454	644	700	-	700	821	502	551	602	656	710	767	825	884	Y	N	6	Y	Y	Some adaptive capacity to convey flows greater than these discharges without the velocity becoming an issue.
02082	SR 800	Brook	Torrington	0.56	SCS	646	959	-	170	270	300	424	780	879	980	1082	1187	1295	-	-	Y	*3	6	N	N	Scour conditions and undermining conditions along the abutments have been reported and repaired at this structure.
02089	Route 8	Brook	Colebrook	0.40	SCS	330	505	-	120	-	125	174	404	459	516	573	633	695			Y	*3	6	N	N	Scour conditions and undermining conditions along the abutments have been reported and repaired at this structure.
02200	Route 20	Brook	Winchester	0.31	RM	166	198	-	154	245	304	339	183	199	216	232	249	266	-	-	Y	N	6	Y	Y	Scour at the outlet and undermining at the northwest wingwall footing.
02204	Route 20	Falls Brook	Hartland	0.33	RM	222	270	-	235	380	700	740	244	266	289	311	333	355	-	-	N	Y	8	Y	N	Minor erosion condition at outlet; however, there appears to be a significant amount of ledge at both the inlet and the outlet.
02205	Route 20	Falls Brook	Hartland	0.44	SCS	306	441	-	315	505	950	970	362	405	450	494	540	-	-	-	N	Y	8	Y	N	Scour hole at outlet.

Table E-2 - Results of Hydraulic Evaluations – Discharge Comparison

Structure No.	Feature Carried	Features Intersected	Town Name	Drainage Area (mi^2)	Hydrologic Method (RM,SCS,SS)*1	Estimated Peak Discharge (cfs)			Culvert Discharge (cfs) at Specified HW Stage				Design Discharge (cfs) Estimate Based on Increase in Precipitation*4								Open Bottom (Y/N)	Velocity > 14 fps (Y/N)	Scour Critical (113)	Hydraulically Adequate (Y/N)	Adaptive Capacity (Y/N)	Notes
						50-Yr*2	100-Yr*2	500-Yr*2	Inlet Submerged	1.5 HW/D	1-Ft Freeboard	Overtopping	0.5-in (SCS, SS) - 10% (RM)	1.0-in (SCS, SS) - 20% (RM)	1.5-in (SCS, SS) - 30% (RM)	2.0-in (SCS, SS) - 40% (RM)	2.5-in (SCS, SS) - 50% (RM)	3.0-in (SCS, SS) - 60% (RM)	3.5-in (SCS, SS) - 70% (RM)	4.0-in (SCS, SS) - 80% (RM)						
02230	U.S. Route 202	Hill Brook	Litchfield	0.92	SCS	-	910	1742	140	255	380	424	1,014	1,119	1,220	1,328	1,438	-	-	-	Y	*3	6	N	N	Outlet velocities 10-yr frequency and greater events appear to adversely impact the downstream channel rather than the structure.
02231	U.S. Route 202	Still Brook	Litchfield	2.33	SS	458	540	850	875	-	969	1,048	596	652	712	774	837	902	969	1038	N	Y	6	Y	N	Residential structure slightly below road elev. Downstream channel erosion.
02238	U.S. Route 202	Gulf Stream	Torrington	3.84	SS	825	954	1303	4,220	-	4,450	4,735	1043	1135	1230	1327	1428	1531	1637	1746	Y	Y	6	Y	N	Abutment footings exposed up to 40".
02297	Route 41	Ball Brook	Salisbury	2.41	SS	452	543	802	150	-	203	266	603	667	733	801	871	944	1019	1096	Y	N	6	N	N	Inspection Reports indicate exposed footing along both abutments. Increases in velocity could result in further erosion.
02305	U.S. Route 44	Burton Brook	Salisbury	3.51	SS	557	676	1240	275	-	290	356	752	833	916	1002	1091	1183	1278	1376	Y	N	6	N	N	Undermining at base of masonry footings recently repaired. Some stream bank erosion reported upstream of the structure.
02306	U.S. Route 44	Garnet Brook	Salisbury	0.80	SCS	713	1010	-	230	580	283	346	814	921	1030	1141	1254	1368	1483	1600	Y	*3	6	N	N	Outlet velocities prior to overtopping are in the 10-ft/s to 11.5-ft/s range.
02313	U.S. Route 44	Mallory Brook	Barkhamsted	1.40	SCS	-	1567	2857	690	-	1,000	1,100	1,728	1,891	2,055	2,222	-	-	-	-	N	Y	8	N	N	Velocity at overtopping is 15.2 ft/s .
02314	U.S. Route 44	Mallory Brook	Barkhamsted	3.00	SS	787	930	1314	1,310	2,050	2,640	2,788	1006	1084	1165	1248	1333	1420	1510	1601	N	N	8	Y	Y	Increases in outlet velocities may result in larger scour hole at , but would not necessarily be detrimental to the structure.
02315	U.S. Route 44	Brook	Barkhamsted	1.48	SCS	-	895	1620	450		542	614	997	1,098	1,201	1,305	-	-	-	-	N	*3	8	N	N	Velocity at overtopping is 22.7 ft/s . Field review indicated there was a 4' drop at the outlet creating a scour hole.
02316	U.S. Route 44	Brook	Barkhamsted	0.48	SCS	476	673	-	230	380	520	552	544	615	687	763	839	916	994	-	N	Y	8	N	N	Velocity at overtopping is 23.7 ft/s . Field review indicated there was a scour hole at outlet.
02317	U.S. Route 44	Brook	New Hartford	0.70	SCS	591	855	-	600	1,000	1,020	1,144	955	1,057	1,162	1,271	-	-	-	-	N	N	8	Y	Y	Backwater from the downstream Farmington River overtops the roadway.
02414	Route 63	Wattles Brook	Watertown	2.27	SS	360	412	559	580	880	1,510	1,584	459	508	559	611	666	722	780	839	N	Y	8	Y	N	Debris noted.
02420	Route 63	Brook	Morris	0.63	SCS	377	494	-	705	-	785	886	422	466	512	559	605	653	-	-	Y	Y	6	Y	N	Tops of abutment footings exposed. Stream flow undercutting channel banks up- and downstream of structure.
02423	Route 63	Brook	Cornwall	3.62	SS	740	880	1221	1,450	2,370	2,700	2,893	967	1,057	1,151	1,247	1,346	1,448	1,552	1,660	N	Y	8	Y	N	Scour hole and erosion at outlet.
02467	Route 72	Poland River	Plymouth	5.56	SS	1130	1320	1818	320	540	540	633	1438	1560	1687	1817	1951	2088	2230	2374	Y	N	6	N	N	Large boulders placed upstream creating a dam which could detain flow. Routing of storage was not analyzed.
02471	Route 72	Poland River	Harwinton	2.42	SS	604	697	967	370	635	560	640	759	823	889	957	1027	1098	1172	1248	Y	N	6	N	N	Velocity at overtopping is 12 ft/s .
02613	Route 109	Mallory Brook	Washington	1.91	SS	340	394	707	345	-	430	488	438	483	531	579	630	682	735	791	Y	N	3	Y	N	Scour critical bridge rating.
02615	Route 109	East Morris Brook	Morris	0.78	SCS	405	550	-	270	460	405	469	460	516	575	631	692	750	-	-	Y	N	6	Y	N	East abutment footing exposed.
02616	Route 109	Beaver Brook	Morris	0.25	RM	130	159	-	69	-	69	107	143	156	169	182	195	208	-	-	Y	N	6	N	N	Velocities are in the low range, consistent with the flat swampy location. Inspection Reports indicate there is silt and sand built up.

Table E-2 - Results of Hydraulic Evaluations – Discharge Comparison

						Estimated Peak Discharge (cfs)			Culvert Discharge (cfs) at Specified HW Stage				Design Discharge (cfs) Estimate Based on Increase in Precipitation*4													
Structure No.	Feature Carried	Features Intersected	Town Name	Drainage Area (mi^2)	Hydrologic Method (RM,SCS,SS)*1	50-Yr*2	100-Yr*2	500-Yr*2	Inlet Submerged	1.5 HW/D	1-Ft Freeboard	Overtopping	0.5-in (SCS, SS) - 10% (RM)	1.0-in (SCS, SS) - 20% (RM)	1.5-in (SCS, SS) - 30% (RM)	2.0-in (SCS, SS) - 40% (RM)	2.5-in (SCS, SS) - 50% (RM)	3.0-in (SCS, SS) - 60% (RM)	3.5-in (SCS, SS) - 70% (RM)	4.0-in (SCS, SS) - 80% (RM)	Open Bottom (Y/N)	Velocity > 14 fps (Y/N)	Scour Critical (113)	Hydraulically Adequate (Y/N)	Adaptive Capacity (Y/N)	Notes
02617	Route 109	Brook	Morris	4.59	SS	736	867	1165	867	1,400	1,700	1,832	959	1055	1154	1256	1362	1472	1584	1700	N	Y	8	Y	N	Erosion at inlet.
02770	Route 183	Colebrook Brook	Winchester	2.33	SS	602	713	847	420	-	520	615	775	838	903	971	1040	1110	1183	1257	Y	Y	6	N	N	Channel within structure is somewhat lower than up/downstream channel. Scour walls within structure suggest past scour.
02771	Route 183	Colebrook Brook	Winchester	1.72	SS	498	598	847	300	-	445	503	640	693	746	802	859	918	977	1039	Y	N	6	N	N	Outlet velocity is 13.2-ft/s at overtopping. Channel bed is composed of large cobbles/angular rocks. No reported scour issues.
02965	Route 47	Brook	Washington	0.17	RM	120	145	-	205	326	285	331	132	144	156	168	180	192	-	-	Y	N	6	Y	N	Existing undermining of bagged concrete countermeasure.
02966	Route 47	Kirbys Brook	Washington	0.87	SCS	381	559	-	1,095	-	1,205	1,315	447	516	588	662	738	815	-	-	Y	Y	6	Y	N	Inlet wing wall is shifting and repairs will be required.
03260	Route 4	Brook	Torrington	0.11	RM	38	50	-	150	-	160	195	42	46	49	53	57	61	-	-	Y	N	6	Y	Y	Existing stream bank erosion may be exacerbated by increased discharge/frequency; however, structure considered adaptive.
03300	U.S. Route 44	Brook	Salisbury	0.31	RM	200	244	-	290	460	610	664	220	240	260	280	300	320	-	-	Y	Y	6	Y	N	Exposed outlet wingwall footings.
03333	Route 8 & Ramp	Pickett Brook	Harwinton	1.48	SCS	-	1618	3210	520	865	1,385	1,460	1,796	1,976	2,159	2,346	-	-	-	-	N	*3	8	N	N	Outlet velocities of the structure are in the high range and erosion is likely to occur at the outlet that will require maintenance.
05408	Route 4	Punch Brook	Burlington	1.66	SS	431	507	684	625	-	839	936	550	595	641	688	737	787	838	890	N	N	8	Y	Y	Possible obstruction from debris could result in erosion of the embankment slope requiring more frequent maintenance.
05417	Route 109	Brook	Morris	2.01	SS	376	442	600	420	-	585	668	490	540	591	644	699	756	814	874	N	N	8	Y	Y	Inspection Reports indicate no notable streambed movement. Outlet velocity is in normal range.
05418	Route 128	Mill Brook	Cornwall	4.50	SS	762	914	1480	805	-	920	1,066	1011	1214	1320	1430	1544	1661	1782	1905	Y	N	5	Y	N	Scour hole at outlet. Scour within structure attributed to poor alignment of the bridge and the stream channel.
05896	U.S. Route 202	Bee Brook	Washington	3.49	SS	570	674	958	958	-	1,030	1,200	746	822	900	981	1065	1151	1240	1331	Y	N	6	Y	Y	Increases in outlet velocities may result in slight erosion downstream, which could require routine maintenance.
06668	Route 179	Brook	Burlington	0.11	RM	93	113	-	195	240	430	460	102	112	121	130	140	149	-	-	N	N	8	Y	Y	Slight obstruction to channel upstream from debris thrown along NW embankment. Channel flow favors SW bank due to debris.
06712	Route 63	Brook	Watertown	0.82	SCS	808	1064	-	535	830	1,320	1,384	898	989	1,082	1,175	1,268	1,363	1,457	-	N	N	8	Y	Y	Some debris at inlet. Channel would likely remain stable since it is heavily armored.

*1 RM = Rational Method/ SCS = SCS Unit Hydrograph/ SS = StreamStats.

*2 RM and SCS discharges based on "Precip.net" precipitation.

*3 Overtops prior to design or check discharge.

*4 Increase in design precipitation in 0.5 inch increments for SCS Unit Hydrograph and StreamStats methods and 10 percent increments in precipitation intensity (in/hr) for Rational Method.

Color Code: **Purple** indicates the discharge at the controlling hydraulic design criteria headwater stage. **Orange** indicates design discharge exceeds the discharge at the controlling hydraulic design criteria headwater stage; therefore hydraulic inadequacy. **Red** indicates the range the precipitation/discharge would need to increase to exceed the controlling hydraulic design criteria headwater stage. **Green** indicates that the range the precipitation/discharge would need to increase to exceed the controlling hydraulic design criteria headwater stage is less or more than the values shown in the table.

Table E-3 - Results of Hydraulic Evaluations – Velocity Comparison

Structure No.	Feature Carried	Features Intersected	Town Name	Drainage Area (mi^2)	Hydrologic Method (RM,SCS,SS)[*1]	Velocity (ft/s) Based on Specified Discharge Frequency or Headwater Stage							Design Velocity (ft/s) Based on Increase in Precipitation[*3]							
						50-Yr[*2]	100-Yr[*2]	500-Yr[*2]	Inlet Submerged	1.5 HW/D	1-Ft Freeboard	Overtopping	0.5-in (SCS, SS) - 10% (RM)	1.0-in (SCS, SS) - 20% (RM)	1.5-in (SCS, SS) - 30% (RM)	2.0-in (SCS, SS) - 40% (RM)	2.5-in (SCS, SS) - 50% (RM)	3.0-in (SCS, SS) - 60% (RM)	3.5-in (SCS, SS) - 70% (RM)	4.0-in (SCS, SS) - 80% (RM)
01930	Route 4	Guinea Brook	Sharon	4.09	SS	16.4	17.4	19.3	19.7	o	20.6	21	17.9	18.5	19	19.5	20	20.6	21	-
01937	Route 4	Birdseye Brook	Cornwall	1.27	SCS	-	10.2	11.9	10.6	o	11.6	12.8	10.5	10.6	10.7	11	11.2	11.4	11.5	11.6
01945	Route 4	Catlin Brook	Harwinton	1.27	SCS	-	14.9		14.2	o	14.2	14.9	15.1	15.3	15.5	15.6	15.7	-	-	-
01946	Route 4	Rock Brook	Harwinton	2.50	SS	-	12.1	13.4	13.6	o	15.5	16.1	12.4	12.7	13.1	13.4	13.6	13.9	14.2	14.5
01947	Route 4	Brook	Harwinton	0.83	SCS	o	o	o	4.4	6.1	5.4	6.5	o	o	o	o	o	o	o	o
01948	Route 4	North Branch Bunnell Bk	Burlington	0.52	SCS	14.4	15.6	-	13	14.7	16.5	16.9	14.9	15.2	15.7	16.1	16.5	16.9	-	-
01949	Route 4	Misery Brook	Burlington	1.62	SS	13.5	14.3	15.2	14.6	-	15.2	15.6	14.7	15.1	15.5	15.7	15.8	15.9	16	16.1
01985	U.S. Route 6	Todd Hollow Brook	Plymouth	0.36	SCS	8.1	10.7	-	3.8	11.2	12.2	13.3	9.2	10.1	11.1	12.1	13.3	o	o	o
01987	U.S. Route 6	Cuss Gutter Brook	Bristol	0.55	SCS	o	o	o	11.4	-	12.5	13.1	o	o	o	o	o	o	o	o
02048	U.S. Route 7	Cobble Brook	Kent	3.38	SS	12.2	13	14.5	14.8	-	15.9	16.5	13.4	13.8	14.2	14.6	15	15.4	15.8	16.1
02050	U.S. Route 7	Kent Falls Brook	Kent	5.77	SS	13.8	14.7	16.6	18.1	22.7	22.5	23.1	15.4	15.9	16.3	16.7	17.1	17.4	17.7	18.1
02051	U.S. Route 7	Deep Brook	Cornwall	0.89	SCS	12.7	13.9	-	14	16.9	18.6	19.4	13.2	13.7	14.1	14.6	15	15.4	-	-
02078	Route 848	Brook	Thomaston	0.24	RM	9.9	10.4	-	12.8	15.2	16.7	17.6	10.2	10.4	10.5	10.7	10.8	11	-	-
02079	Route 848	Nibbling Brook	Thomaston	2.18	SS	11.7	12.1	13.4	13.7	-	13.7	14.4	12.5	12.8	13.1	13.5	13.8	14.1	14.4	o
02082	SR 800	Brook	Torrington	0.56	SCS	o	o	o	6.1	9	10.9	11.4	o	o	o	o	o	o	o	o
02089	Route 8	Brook	Colebrook	0.40	SCS	o	o	-	6.8	-	7.3	7.4	o	o	o	o	o	o	o	o
02200	Route 20	Brook	Winchester	0.31	RM	13.2	13.6	-	12.9	14.4	15.3	15.7	13.6	13.7	14	14.2	14.5	14.7	-	-
02204	Route 20	Falls Brook	Hartland	0.33	RM	20	20.6	-	20.2	22.7	-	-	20.7	21.1	21.5	21.7	22	22.2	-	-
02205	Route 20	Falls Brook	Hartland	0.44	SCS	20.9	22.4	-	21	23	26.4	26.8	21.6	22.1	22.5	22.9	23.4	-	-	-
02230	U.S. Route 202	Hill Brook	Litchfield	0.92	SCS	o	o	o	7.7	9.2	10.4	11	o	o	o	o	o	o	o	o
02231	U.S. Route 202	Still Brook	Litchfield	2.33	SS	15.1	15.7	17.6	17.7	-	18.2	18.6	15.6	16.5	16.8	17.2	17.5	17.8	18.2	18.5
02238	U.S. Route 202	Gulf Stream	Torrington	3.84	SS	13.5	14.2	15.7	22.5	-	23	23.7	14.7	15.2	15.6	15.8	16	16.3	16.6	16.8
02297	Route 41	Ball Brook	Salisbury	2.41	SS	o	o	o	8.6	-	9.5	10.2	o	o	o	o	o	o	o	o
02305	U.S. Route 44	Burton Brook	Salisbury	3.51	SS	o	o	o	11.3	-	11.5	11.7	o	o	o	o	o	o	o	o
02306	U.S. Route 44	Garnet Brook	Salisbury	0.80	SCS	o	o	o	10.2	o	11	11.6	o	o	o	o	o	o	o	o
02313	U.S. Route 44	Mallory Brook	Barkhamsted	1.40	SCS	o	o	o	13.2	o	14.7	15.2	o	o	o	o	o	o	o	o
02314	U.S. Route 44	Mallory Brook	Barkhamsted	3.00	SS	12.6	13.2	14.7	14.7	16.3	17.5	17.8	13.6	13.9	14.2	14.5	14.8	15	15.2	15.4
02315	U.S. Route 44	Brook	Barkhamsted	1.48	SCS	o	o	o	21	o	21.7	22.2	o	o	o	o	o	o	o	o

Table E-3 - Results of Hydraulic Evaluations – Velocity Comparison

Structure No.	Feature Carried	Features Intersected	Town Name	Drainage Area (mi^2)	Hydrologic Method (RM,SCS,SS)*1	Velocity (ft/s) Based on Specified Discharge Frequency or Headwater Stage							Design Velocity (ft/s) Based on Increase in Precipitation*3							
						50-Yr*2	100-Yr*2	500-Yr*2	Inlet Submerged	1.5 HW/D	1-Ft Freeboard	Overtopping	0.5-in (SCS, SS) - 10% (RM)	1.0-in (SCS, SS) - 20% (RM)	1.5-in (SCS, SS) - 30% (RM)	2.0-in (SCS, SS) - 40% (RM)	2.5-in (SCS, SS) - 50% (RM)	3.0-in (SCS, SS) - 60% (RM)	3.5-in (SCS, SS) - 70% (RM)	4.0-in (SCS, SS) - 80% (RM)
02316	U.S. Route 44	Brook	Barkhamsted	0.48	SCS	23	o	o	20.2	22.1	23.5	23.7	o	o	o	o	o	o	o	o
02317	U.S. Route 44	Brook	New Hartford	0.70	SCS	11.5	13.1	-	11.6	13.8	14	14.6	13.5	14.1	o	o	o	o	o	o
02414	Route 63	Wattles Brook	Watertown	2.27	SS	18.1	18.7	19.9	20	21.6	24.7	25.2	19.2	19.6	19.9	20.2	20.5	20.8	21.1	21.4
02420	Route 63	Brook	Morris	0.63	SCS	14.6	15.5	-	16.9	-	17.4	18.1	15	15.2	15.6	15.9	16.2	16.5	-	-
02423	Route 63	Brook	Cornwall	3.62	SS	18.1	18.8	20.1	20.7	23	23.7	24.3	19.2	19.6	19.9	20.2	20.4	20.6	21	21.2
02467	Route 72	Poland River	Plymouth	5.56	SS	o	o	o	10	12.2	12.2	12.7	o	o	o	o	o	o	o	o
02471	Route 72	Poland River	Harwinton	2.42	SS	o	o	o	10	12	11.4	12	o	o	o	o	o	o	o	o
02613	Route 109	Mallory Brook	Washington	1.91	SS	10.5	11.2	o	11	-	11.7	12.4	11.8	12.4	o	o	o	o	o	o
02615	Route 109	East Morris Brook	Morris	0.78	SCS	8	o	o	7	9.3	8	9.5	9.3	o	o	o	o	o	o	o
02616	Route 109	Beaver Brook	Morris	0.25	RM	7.4	o	-	6.1	-	6.1	7.8	o	o	o	o	o	o	o	o
02617	Route 109	Brook	Morris	4.59	SS	17.6	18.2	19.4	18.2	20.1	21	21.4	18.6	19.1	19.3	19.6	20	20.2	20.6	21
02770	Route 183	Colebrook Brook	Winchester	2.33	SS	15.5	o	o	14	-	14.8	15.5	o	o	o	o	o	o	o	o
02771	Route 183	Colebrook Brook	Winchester	1.72	SS	13.2	o	o	11	-	12.6	13.2	o	o	o	o	o	o	o	o
02965	Route 47	Brook	Washington	0.17	RM	9.5	10	-	11.4	13.5	12.8	13.5	9.7	10	10.2	10.4	10.7	10.9	-	-
02966	Route 47	Kirbys Brook	Washington	0.87	SCS	16.1	17.1	-	20.5	-	21	21.8	16.4	16.8	17.2	17.7	18.2	18.7	-	-
03260	Route 4	Brook	Torrington	0.11	RM	6.7	7.4	-	10.7	-	10.9	11.7	6.9	7.2	7.4	7.5	7.7	7.8	-	-
03300	U.S. Route 44	Brook	Salisbury	0.31	RM	14.7	15	-	15.7	17.4	19	19.5	15	15.2	15.4	15.6	15.8	16	-	-
03333	Route 8 & Ramp	Pickett Brook	Harwinton	1.48	SCS	-	o	o	18.3	20.1	23	23.4	o	o	o	o	o	o	o	o
05408	Route 4	Punch Brook	Burlington	1.66	SS	10.5	11.1	12.5	12.1	-	13.7	14.5	11.5	11.8	12.2	12.6	12.9	13.4	13.7	14.1
05417	Route 109	Brook	Morris	2.01	SS	8.8	10.4	12.8	10	-	12.5	13.5	10.2	11.9	12.2	13.2	o	o	o	o
05418	Route 128	Mill Brook	Cornwall	4.50	SS	12.7	13.7	o	13	-	13.7	14.1	14	o	o	o	o	o	o	o
05896	U.S. Route 202	Bee Brook	Washington	3.49	SS	10.9	11.6	13	13	-	13.3	14	12	12.4	12.7	13.1	13.5	13.8	o	o
06668	Route 179	Brook	Burlington	0.11	RM	7.4	7.9	-	9.8	10.8	15	15.8	7.7	7.9	8.1	8.3	8.5	8.7	-	-
06712	Route 63	Brook	Watertown	0.82	SCS	10.2	11.2	-	9.2	10.3	12	12.3	10.6	10.9	11.2	11.6	11.8	12.2	o	o

*1 RM = Rational Method/ SCS = SCS Unit Hydrograph/ SS = StreamStats.

"o " indicates structure overtops before specified discharge frequency, headwater stage or precipitation increase.

*2 RM and SCS discharges based on "Precip.net" precipitation.

*3 Increase in design precipitation in 0.5 inch increments for SCS Unit Hydrograph and StreamStats methods and 10 percent increments in precipitation intensity (in/hr) for Rational Method.