NEIWPCC

Hudson River Estuary Program

A Program of the New York State Department of Environmental Conservation

Tighe&Bond

Engineers | Environmental Specialists

Services provided in New York by T&B Engineering, P.C.

Road-Stream Crossing Joint Municipal Management Plan

Town of Esopus, NY

County of Ulster, NY

January 2020

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Section 5 Future Planning

Appendices

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Section 1 Introduction

1.1 Background

The Town of Esopus is located within the Lower Hudson River Basin, one of the largest drainage areas on the eastern seaboard of the United States, and one of the most diverse drainage basins in the State of New York. The Town is bordered by water on three sides, being bounded by the Hudson River to the east, Rondout Creek to the north, Wallkill River to the west, and the Town of Lloyd to the south. Removal of impediments to aquatic connectivity resulting from the road-stream crossings is important from a biological perspective because of the well-documented presence of American Eel, a catadromous freshwater eel and an important prey species, and river herring, anadromous and ecologically, recreationally, and economically important fish. The Black Creek, a tributary to the Hudson River in the Town of Esopus, is a known river herring spawning run, and has been sampled by the New York Department of Environmental Conservation (NYSDEC) for river herring since 2013. Populations of the American Eel in the Hudson River Estuary are on the decline and have been monitored since 2008 by the NYSDEC Hudson River Eel Project. The Black Creek has been a Hudson River Eel Project sampling site since 2010.

1.2 Stream Crossing Inventory

In the Summer of 2017, Tighe & Bond staff performed an inventory assessment of 89 road-stream crossings in the Town of Esopus, funded by the New England Interstate Water Pollution Control Commission (NEIWPCC) and in cooperation with the NYSDEC Hudson River Estuary Program. We examined the conditions of these stream crossings and provided the Town and County with a catalog of crossing structures. In addition to the crossings assessed by Tighe & Bond in 2017, 26 crossings were assessed by other stake holders for a total of 115 crossings observed within the Town of Esopus in 2017. Since this initial inventory, 20 more crossings were inventoried by Tighe & Bond and other stakeholders bringing the current total up to 135. The majority of the road-stream crossing are for Town and Ulster County roads. These last 20 crossings were inventoried after the initial inventory because they existed on roads with private access and required permission be obtained before they could be observed.

An interactive map of the culvert assessments completed within the Town can be accessed at https://naacc.org/naacc_search_crossing.cfm. By entering the State and Town and querying the search engine the user will be provided with all of data assessed within the Town boundaries. Here the user may view the interactive map which provides the location, passability rating, and other relevant data of each culvert. By clicking on a crossing, the user can view photos and data taken at each of the culverts.

1.3 Project Goals

The overall objective of this project was to develop a Town/County Joint Municipal Management Plan inclusive of all inventoried locations where a public road crosses a stream in the Swarte Kill-Wallkill River, Black Creek, and Twaalfskill Brook-Rondout Creek HUC12 subwatersheds within the limits of the Town of Esopus. By using this comprehensive approach, the improvements in watersheds with crossings under multiple jurisdictions can be considered holistically. The Town and County are committed to improving culverts within the Town of Esopus, and this Municipal Management Plan is a tool to advance the Hudson River Estuary Program 2015 – 2020 Action Agenda. The development of a Joint Municipal Management Plan began with the inventory of culverts within the Town limit and continues with the prioritization and selection of the culverts in need of repair or replacement, the conceptual design of improvements using hydrologic and hydraulic modelling, and the production of "Shovel-Ready" designs complete with stamped engineering drawings, probable costs, and permitting requirements. This Joint Municipal Management Plan will serve as a guide for the Town/County to implement future crossing improvements.

Figure 1 shows the crossings inventoried within the Town of Esopus.

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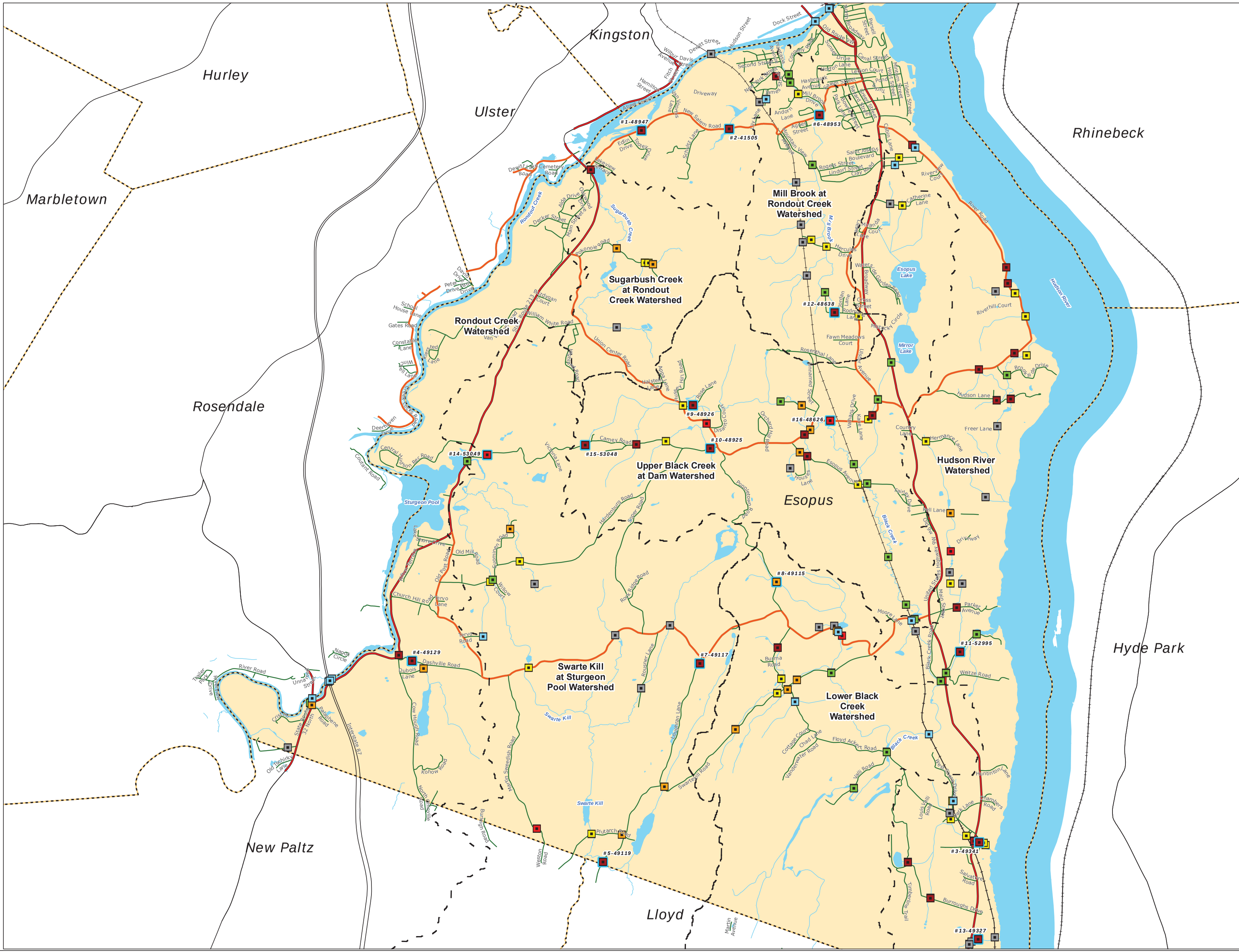

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LOCUS MAP

Top 16 Priority Culverts

- Severe Barrier
- Significant Barrier
- Moderate Barrier

Culvert Passibility

- Severe barrier
- Significant barrier
- Moderate barrier
- Minor barrier
- Insignificant barrier
- No barrier
- Private/Other

Streets

- State Route
- County Road
- Town Road
- River/Stream
- Railroad
- Watershed Boundary
- Town Boundary

0 2,500 5,000
Feet
1 " = 2,500 '

NOTES

1. Streets and Town Boundary layers were accessed from the online NYS GIS data clearinghouse on June 23, 2017.
2. NAACC Road Stream Crossing Points were accessed from the NAACC online database for the Town of Esopus.
3. Culvert Passibility rating was determined from field work performed by Tighe & Bond in Summer 2017.
4. Horizontal Datum is New York State Plane (Central) NAD83.

Road-Stream Crossing Map

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FIGURE
1

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Section 2
Culvert Prioritization

With 135 total crossings inventoried within the Town Boundary of Esopus, it was necessary to prioritize which crossing should be considered as candidates for repair/replacement first, and in doing so, create a ranked list of all crossing structures in need of repair. While all stakeholders (NEIWPCC, Esopus, and Ulster County) are interested in the removal of impediments to aquatic connectivity, other priorities related to flooding issues, maintenance issues, and the structure's overall condition are also of interest. Perspectives for all three entities were taken into consideration when creating the prioritization matrix described in this section. The following criteria were used to prioritize replacement of the inventoried crossings and generally relates to three overall priority metrics.

1. Aquatic Passability
2. Structural Condition
3. Town/County Maintenance and Flooding Priority

2.1 Aquatic Passability

Aquatic passability refers to a culvert's ability for fish and wildlife to pass through it. Additionally, a culvert that has aquatic passability is a culvert that is successfully performing its function. Such a culvert allows for the unimpeded flow of water and does not drastically alter the stream itself. The 135 Esopus stream crossings that were inventoried were assessed for their ability for aquatic passage based on the following predictors of passability:

- Inlet Grade – The position of the invert relative to the stream bottom at the inlet
- Outlet Drop – The vertical distance between the outlet and the water surface or the distance between the outlet and the stream bottom if the crossing is dry
- Physical Barriers – Any obstruction that presents a physical obstacle to aquatic passage
- Constriction – The relative width of the crossing compared to the width of the stream
- Water Depth – The depth of the water in the structure compared to the depth of the stream
- Water Velocity – The water velocity in the structure compared to the water velocity in the stream
- Scour Pool – The presence of a scour pool at the outlet is noted as it is an indicator of velocity issues at high flows
- Substrate – The comparison between substrate in the structure and in the stream channel
- Substrate Coverage – Degree to which a structure invert is covered by substrate
- Openness – The cross-sectional area of the structure opening divided by the structure length

- Height – The maximum height of the crossing structure. This predictor is only necessary for rating very small structures
- Outlet Armoring – The presence or absence of streambed armoring such as riprap, asphalt, or concrete
- Internal Structures – The presence of absence of structures inside a culvert or bridge such as weirs, baffles, or supports

The North Atlantic Aquatic Connectivity Collaborative (NAACC) determined scores for each of these predictors within each culvert based on the conditions observed and measurements taken during the inventory. NAACC then computed a composite value, known as the Aquatic Barrier Rating, for each crossing using a numeric scoring algorithm based on the opinions of specialists who decided both the relative importance of all the available predictors of successful aquatic passage as well as how to score each predictor. These Aquatic Barrier ratings were developed to create an overall qualitative label for each structure and to quantify the condition of stream crossings. See Appendix F for the NAACC Numeric Scoring System.

Including the Aquatic Barrier Rating, four priority metrics were considered that focus on Aquatic Passability:

- **Aquatic Barrier Rating** - The aquatic barrier ratings used are Severe, Significant, Moderate, Minor, and Insignificant. The barrier severity scores for field-surveyed road-stream crossings are calculated in the NAACC database using the scoring algorithm described in the NAACC Numeric Scoring System.
- **Aquatic Organism Passage (AOP)** – Culverts are labeled Full AOP, Reduced AOP, or No AOP based on easily observable characteristics (e.g. If the outlet drop to water surface is 1 foot or greater, the culvert has no AOP). See Appendix F for the full AOP classification NAACC Coarse Screen criteria.
- **Habitat Connectivity** – ArcGIS network analysis was used to calculate the distance between the culvert of concern and the next closest upstream barrier. Culverts with greater distances were regarded as higher priority because there would be a greater positive impact by restoring the stream at that crossing location.
- **Perennial Flow Condition** – Culverts that were known to have permanent flow were prioritized over culverts with no flow because improving the flow of these consistent streams would achieve a greater impact.

2.2 Structural Condition

In conjunction with the metrics focusing on aquatic passability, it was important to incorporate metrics included in the NAACC databased, but not related directly to aquatic passability. The next group of metrics are related to structural condition or limitations of the culverts. The metrics considered were:

- **Hydraulic Capacity** – Cornell University’s New York State Water Resources Institute used data collected by the NEIWPCC inventory to calculate each culvert’s Maximum Future Flood Return Period, measured in years. This return period represents the chance, on an annual basis, that the most intense flood that can be hydraulically passed by the culvert will occur.

- **Flow Alignment** – Culverts that are flow aligned mimic the stream better and create fewer issues within their surrounding environments. This information was collected from the NEIWPCC inventory.
- **Crossing Condition** – During the inventory, culverts were given condition ratings of either Poor, OK, or New. These ratings were based on the culvert's overall appearance, considering any apparent cracks, holes, deformities, or deteriorations.

2.3 Town/County Maintenance and Flooding Priority

The final metric used to prioritize culverts consisted of input from the Town/County on crossings they considered to be maintenance and/or flooding issues. Ten culverts were designated as being a flooding/maintenance concern to the Town/County.

- **Town/County Priority** – The culverts were prioritized by the Town/County if they were known to cause flooding to residents or required routine maintenance.

2.4 Prioritization System

A numeric score value was developed for each of the prioritization metrics described above. This prioritization system enabled the metrics reported in separate units or in qualitative descriptions to be translated into simple numbers that could be summed to provide an overall score for each culvert. Table 2-1 summarizes the culvert replacement prioritization system used.

TABLE 2-1

Culvert Replacement Prioritization System

	Priority Metric	Dataset	Methodology	Scoring
Aquatic Passability	**Aquatic Barrier Rating**	NAACC dataset	The aquatic barrier ratings used are Severe, Significant, Moderate, Minor, and Insignificant. The barrier severity scores for field-surveyed road-stream crossings are calculated in the NAACC database using the scoring algorithm described in the NAACC Numeric Scoring System.	Aquatic Barrier Scoring (Severe barrier = 5, Significant barrier = 4, Moderate barrier = 3, Otherwise = 0)
	AOP Rating	NAACC dataset	Aquatic Organism Passage ranking classes are Full AOP, Reduced AOP and No AOP.	AOP Scoring (No AOP = 5, Otherwise = 0)
	Habitat Connectivity	NAACC dataset and AOP ranking	Use ArcGIS network analysis to calculate distance from barrier of concern upstream to the next closest Severe, Significant, or Moderate barrier; upstream crossings with no information were assumed to not be barriers	Connectivity Scoring (≥2 miles = 4, ≥1 mile = 3, >0.5 miles = 1, Otherwise = 0)
	Perennial Flow Condition	NAACC dataset	Culverts that are known to have stream flow	Flow Scoring (Typical Low Flow =5, No Flow=0)
Structural Condition	**Hydraulic Capacity**	Cornell Water Resources modeling results from NAACC survey data	Maximum Future Flood Return Period (yr) that culvert has capacity to hydraulically pass	Capacity Scoring (≤2yr = 5, ≤10yr = 4, ≤25yr = 3, ≤50yr = 2, ≤100yr = 0, N/A=5)
	Flow Alignment	NAACC dataset	Survey data results in either flow aligned or flow skewed	Alignment Scoring (Flow Aligned = 0, Skewed = 1)
	Crossing Condition	NAACC dataset	Survey data results on the condition of the culvert	Crossing Condition Scoring (Poor = 5, Ok = 3, New = 0)
	Town/County Priority	Input from Town/County	Culverts that are know to cause flooding to residents or are habitual maintenance issues	Town Priority Scoring (High =5, Low=0)

2.5 Prioritization Results

The higher the overall score, the higher the priority ranking. For example, if a culvert were to obtain the maximum ranking in each metric, it would receive an overall score of 35 and have a final ranking of 1, being the highest priority for repair or replacement.

In total, 135 crossings were assessed, scored, and ranked. Below is a table of the Top 15 highest priority culverts based on this assessment. The full results table of the prioritization can be seen in Appendix A.

TABLE 2-2

Top 15 Highest Priority Culverts

Crossing Survey ID #	Road	Road Owner	Total Score	Rank
48953	Salem St	County	32	1
49119	Swartekill Rd	Esopus	31	2
48947	New Salem Rd	County	30	3
41505	New Salem Rd	County	30	4
49341	Floyd Ackert Rd	Esopus	30	5
49129	Dashville Rd	Esopus	29	6
49117	Loughran Rd	Esopus	28	7
49115	Poppletown Rd	Esopus	28	8
48925	Hardenburgh Rd	Esopus	25	9
52995	Winding Brook Rd	Esopus	25	10
48638	Rodmans Ln	Esopus	25	11
49327	Barry Dr	Esopus	25	12
53049	Carney Rd	Esopus	24	13
53048	Carney Rd	Esopus	24	14
48626	Union Center Rd	County	24	15

Figure 2 shows the Top 16 priority crossings within the Town of Esopus. One privately owned crossing on Rose Lane (ID #48926) is shown in Figure 2 because it ranked in the Top 16 highest scoring crossings but is not included in Table 2-2 as a Top 15 because it was determined that Rose Lane is a privately-owned roadway. See Appendix A for inventory summaries of the Top 15 priority crossings. This summary format can be used by the Town or County as a simple way to document each crossing's overall condition.

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LOCUS MAP

Top 16 Priority Culverts

- Severe Barrier
- Significant Barrier
- Moderate Barrier

Streets

- State Route
- County Road
- Town Road
- River/Stream
- Railroad
- Watershed Boundary
- Town Boundary

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Feet
1 " = 2,500 '

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4. Horizontal Datum is New York State Plane (Central) NAD83.

Culvert Priority Map

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FIGURE
2

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This prioritization system and 15 priority crossings were presented to the Town, County, and NEIWPCC to jointly select the top six crossing replacements (3 Ulster County-owned and 3 Town of Esopus-owned) that met the stakeholders' collective goals. A conceptual design was prepared for the top six priority crossings selected. The six crossings included:

Town of Esopus

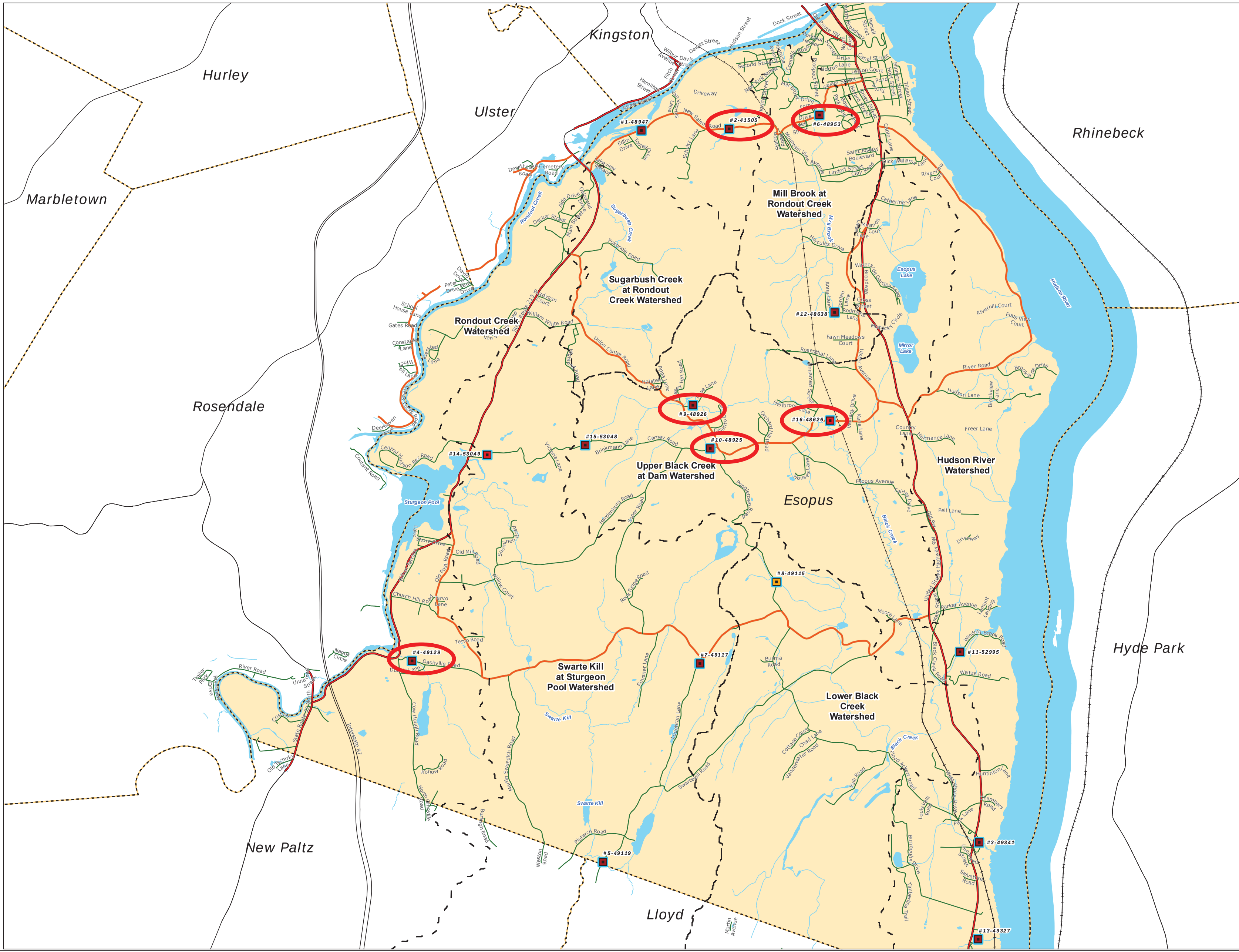
1. 48925 – Hardenburgh Road
2. 48926 – Rose Lane
3. 49129 – Dashville Road

Ulster County

4. 41505 – New Salem Road
5. 48626 – Union Center Road
6. 48953 – Salem Street

Rose Lane does not appear in the Top 15 priority crossings because it is a privately-owned road. Originally thought to be Town-owned, the Rose Lane crossing (ID #48926) had a rank of 9 with a total score of 27. The private ownership of this suspected Town owned road was learned after the conceptual designs were completed.

Figure 3 shows the top six crossings, circled in red, selected by the stakeholders for conceptual design.



ESOPUS

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LOCUS MAP

Top 16 Priority Culverts

- Severe Barrier
- Significant Barrier
- Moderate Barrier

Streets

- State Route
- County Road
- Town Road
- River/Stream
- Railroad
- Watershed Boundary
- Town BoundarytT

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Top 6 - Culvert Priority Map

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FIGURE
3

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Section 3
Best Management Practices for Road-Stream Crossing Designs

Most of the culverts in the Town of Esopus, including those at the six priority crossings in this study, consist of pipes placed with their inverts (or bottoms) at stream grade. While low in cost, this type of culvert easily becomes a barrier to aquatic passability. The NYSDEC recommends that bridges, natural channel box culverts, and bottomless arches be the preference for new stream crossings and should be used whenever possible.

3.1 Design Goals

The key goal when designing a suitable stream crossing should be to mimic the stream's natural conditions as best as possible. This goal can be accomplished by taking specific elements of the stream into consideration when designing an effective crossing. Elements to consider include stream width, flow alignment, substrate, and capacity at the 100-year design storm. Maintaining the natural width of the stream will prevent constriction, a common cause of scouring, erosion, and ponding. Following the alignment of the flow of water through stream will prevent sediment deposition upstream as well as erosion of the downstream banks. Matching the slope of the stream will help maintain the stream velocity and prevent erosion and ponding. Using a substrate consistent with the existing streambed will allow aquatic organisms to easily move through the structure. Lastly, making the crossing passable at the 100-year design storm will mitigate potential flooding issues during major rainfall events.

3.2 Culvert Standards

The NYSDEC has set forth measurable guidelines to aid in the design process and to ensure all new crossings are designed to be compatible with the existing stream. See Appendix B for NYSDEC Stream Crossing Guidelines. Some key guidelines are as follows:

- **Crossing Width** – The crossing opening should be at least 1.25 times the width of the stream channel bed. Stream width is defined as the distance from bank to bank at ordinary high-water level or between the edges of terrestrial, rooted vegetation.
- **Depth and Velocity** – At low flows, water depths and velocities should be the same as they are in the natural areas upstream and downstream of the crossing
- **Substrate** – Substrate should match the streambed and resist displacement during floods. Additionally, four-sided box culverts used as stream crossings must be embedded into the stream to at least 20 percent of the height at the downstream invert

3.3 Culvert Types

3.3.1 Culvert Shapes

Figure 3-1 below shows six examples of the various culvert shapes and the dimensions relating to them.

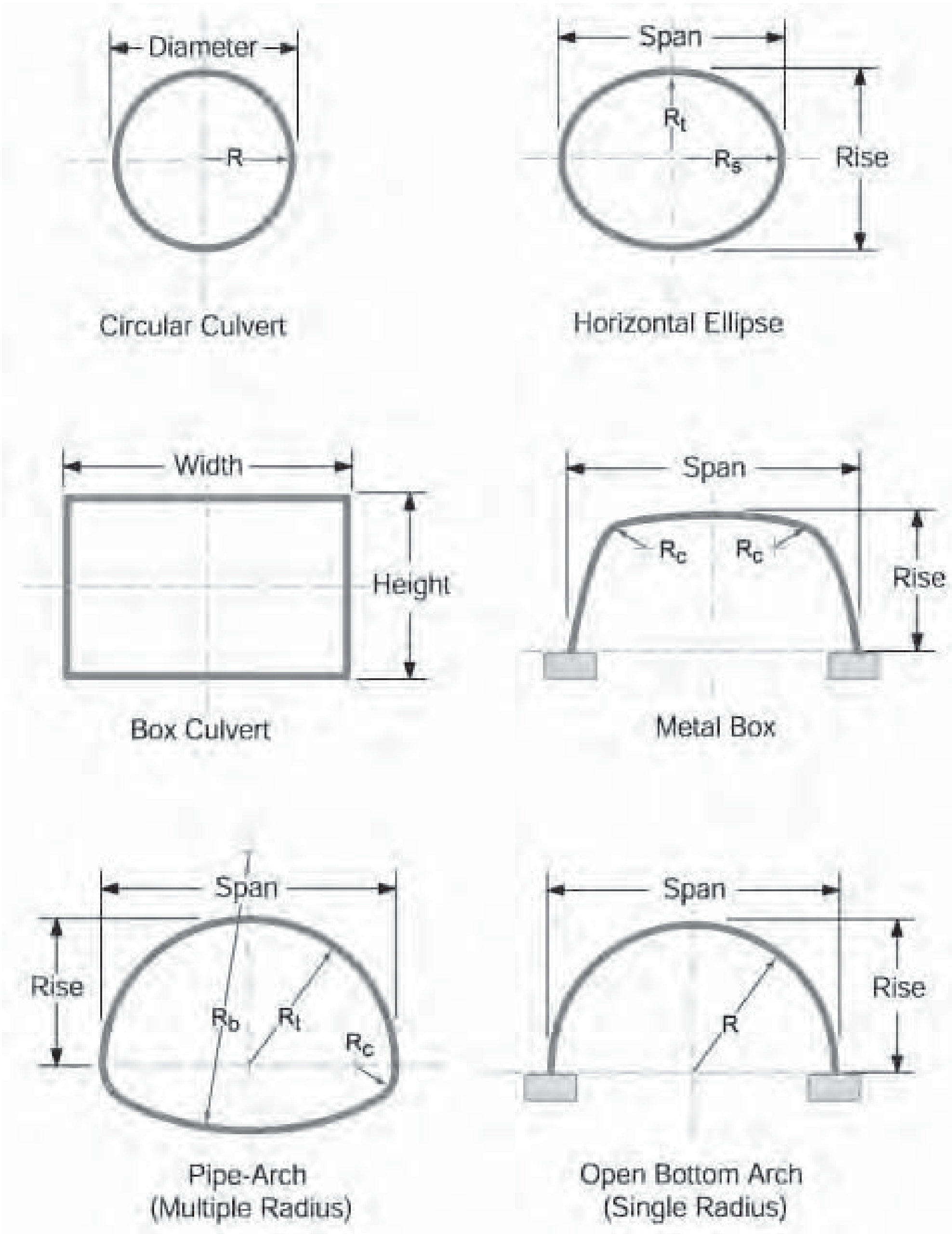


FIGURE 3-1
Culvert Shapes and Dimensions
Source: http://www.fsl.orst.edu/geowater/FX3/help/FX3_Help.html

3.3.2 Recommended Culvert Types

Below are five recommended types of culverts for future replacement efforts:

TABLE 3-1
Three-Sided Box Concrete Culvert

	**Material:**
	Steel-reinforced concrete
	Anticipated Service Life[1]:
	70 years
	Advantages:
	• ≥1′ road fill required above required • Maximum flow area for span/width • Resilient/low maintenance costs
	Disadvantages:
	• Weight of concrete may limit installation options • Larger equipment may be needed to install • Higher Construction Cost • Requires installation of footings which adds construction/road closure time

TABLE 3-2
Four-Sided Box Concrete Culvert

	**Material:**
	Steel-reinforced concrete
	Anticipated Service Life[1]:
	70 years
	Advantages:
	• ≥1′ road fill above required • No footings, reduces construction/road closure time • Maximum flow area for span/width • Resilient/low maintenance costs
	Disadvantages:
	• Larger equipment may be needed to install • Higher construction cost

TABLE 3-3
Aluminum Box

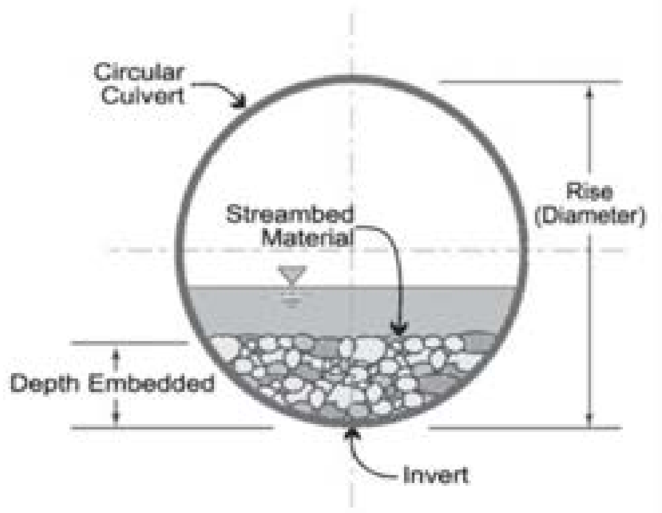
Material:	Aluminum
Anticipated Service Life[1]:	50 Years
Advantages:	• ≥1.5′ of cover for HS25 vehicle load rating • Corrosion resistant metal • Low section profile • Moderate construction cost
Disadvantages:	• Strict cover requirements • Potential for extended road closure during footing installation • Less flow area per span/width compared to concrete box

TABLE 3-4
Structural Plate (ALSP) Single Radius Arch

Material:	Galvanized Steel or Aluminum
Anticipated Service Life[1]:	50 Years
Advantages:	• Wide span, low profile • Wide range of sizing options • Moderate construction cost
Disadvantages:	• Strict cover requirements • ≥2.5′ of cover for HS25 vehicle load rating • Potential for extended road closure during footing installation • Higher maintenance cost

TABLE 3-5

Round/Elliptical Culvert



Material:

Metal, Plastic, or Concrete

Anticipated Service Life[1]:

20-70 Years (material based)

Advantages:

- Quick installation
- Useful for small intermittent streams
- Low construction cost

Disadvantages:

- Typically requires ≥3' of cover for HS25 vehicle load rating
- Can be difficult to embed depending on size
- Limited bankfull widths can be achieved and can be difficult to provide natural bottom

[1]Anticipated service life presented is based on the *NYSDOT Highway Design Manual, Chapter 8 – Highway Drainage* and will vary based on velocities of the stream, potentially abrasive stream bed loads, corrosive soils or water, and coating/gauge thickness of metal.

3.4 Culvert Design Life

The design life for a culvert replacement should be considered when selecting the culvert type for each crossing based on the type of crossing location. The design life is defined as the number of years in-service performance which the culvert is desired to provide. According to the *NYSDOT Highway Design Manual, Chapter 8 – Highway Drainage* the following culvert design lives should be considered based on type of crossing, summarized in Table 3-6.

TABLE 3-6

Crossing Type Replacement Culvert Design Lives

Crossing Type	Design Life (Years)
Driveways	20
Significant Locations[1]	70
Other Locations	50

[1]Significant locations are defined as follows:

- Natural watercourses, or channels, such as perennial streams
- Highways functionally classified as interstates and other freeways
- Under fills ≥15 feet
- Locations with high traffic volumes
- Locations where long detours would be required if the culvert failed

Section 4
Priority Culvert Conceptual Designs

Conceptual designs were developed for the six top priority crossing for replacement. The first task to develop the conceptual designs was a Hydrologic and Hydraulic (H&H) analysis of six stream crossings. The hydrologic portion of the analysis determines the amount of runoff and the hydraulic analysis determines the ability of the culvert and contributing watercourse to convey the runoff through the crossing. The goal of this H&H analysis was to evaluate the amount of runoff anticipated at the crossing and size the conceptual design crossing to accommodate the 100-year design storm event and meet the NYSDEC Stream Crossing Guidelines, included in Appendix B.

4.1 Hydrology Methodology and Input Parameters

HydroCAD is a computer model software based on USDA-SCS Technical Release No. 20 (TR-20). TR-20 is a single event watershed scale runoff and routing model. HydroCAD computes direct runoff and develops hydrographs resulting from a synthetic or natural rainstorm.

The data input requirements for the HydroCAD model are summarized in the following categories:

1. Watershed Area
2. Weighted Runoff Curve Number
3. Time of Concentration
4. Precipitation Depth and Frequency
5. Pond Volumes

HydroCAD was used to model the peak flows to each culvert from its watershed during the 2-Year, 5-Year, 10-Year, 25-Year, 50-Year, and 100-Year Design Storm events. The storage of ponds contributing to the culverts was considered where it was applicable.

4.1.1 Watershed Area

Each stream crossing has its own unique watershed that contributes flow to the culvert. The watershed extents were determined using shapefiles from the USGS Stream Stats web application and an elevation dataset, derived from available Ulster County LiDAR elevation data. Each watershed was further subdivided and refined into multiple subwatersheds based on orthographic imagery and LiDAR elevation data. Refer to Appendix D for watershed maps.

4.1.2 Weighted Runoff Curve Number

Runoff curve numbers (CN) are empirical parameters used to evaluate runoff from rainfall events that were originally developed by the Natural Resources Conservation Service's (NRCS) predecessor agency, the Soil Conservation Service (SCS). The CN is a function of land use and soil type, and the CN values were estimated for each land use following the NRCS Urban Hydrology for Small Watersheds TR-55 methodology, Ulster County Land Cover dataset, and orthographic imagery. Each combination of land use cover and hydrologic soil group has a different CN value. Table C-1, in Appendix D, shows the land use identification, hydrologic soil group, area, and CN value used to develop weighted CN values for each watershed.

4.1.3 Time of Concentration

The time of concentration (Tc) is the time required for runoff to travel from the hydraulically most distant point in the watershed to the outlet. The hydraulically most distant point is the point with the longest travel time to the watershed outlet, which is not necessarily the point with the longest flow distance within a defined channel to the outlet.

The NRCS Urban Hydrology for Small Watersheds TR-55 Method was used to determine the time of concentration for each subwatershed. Each Tc travel path is divided into a minimum of three segments: sheet flow, shallow concentrated flow, and open channel flow. The times of concentration for sheet flow and open channel flow were determined using the TR-55 Method. The times of concentration for shallow concentrated flow were determined using the NRCS Part 630 National Engineering Handbook Method. Input parameters used in the HydroCAD model to develop the hydrologic model can be found in Table 4-1.

TABLE 4-1
Hydrology Input Parameters

Watershed ID	Watershed Name	Area (acres)	CN	Tc (min.)
WS-01	Crossing #49129, Dashville Road	125.89	77	141.5
WS-02	Crossing #49129, Dashville Road	157.77	74	106.8
WS-03	Crossing #49129, Dashville Road	129.07	80	124.7
WS-04	Crossing #49129, Dashville Road	119.66	76	100.1
WS-11	Crossing #41505, New Salem Road	128.29	77	125.5
WS-12	Crossing #41505, New Salem Road	175.16	70	105
WS-21	Crossing #48953, Salem Street	555.7	76	187.5
WS-22	Crossing #48953, Salem Street	517.47	79	93.5
WS-23	Crossing #48953, Salem Street	319.72	71	111.1
WS-31	Crossing #48926, Rose Lane	272.49	77	158.8
WS-32	Crossing #48926, Rose Lane	552.39	76	343.9
WS-41	Crossing #48626, Union Center Road	18.93	59	44.8
WS-51	Crossing #48925, Hardenburgh Road	249.1	80	122
WS-52	Crossing #48925, Hardenburgh Road	22.62	73	45.4

4.1.4 Precipitation Depth and Frequency

Precipitation depth and frequency was used to develop the rainfall data that is input into the model to transform the unit hydrograph to a runoff value for a given storm frequency. The model was run for a range of design storms based on the precipitation as estimated from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14, and a Soil Conservation Service Type III 24-hour synthetic storm was used to provide a rainfall distribution. For reference the 100-year rainfall event at the site equates to 7.94 inches of rain over a 24-hour period. See Appendix D for the NOAA Atlas 14 precipitation frequency estimates.

4.1.5 Pond Volume

The storage volume of the applicable ponds in the culvert watersheds was estimated using HydroCAD with Ulster County LiDAR Digital Elevation Model and ArcGIS area tools. Hydrologic analysis was performed assuming a starting water surface elevation was at the outlet elevation of the ponds. Subwatersheds upstream of significant ponds were routed through the ponds to simulate, as reasonably practical, the detention effect of ponds on runoff within the watershed.

4.2 Hydrologic Analysis Results

The HydroCAD models developed for each crossing, using the inputs described above, estimated the peak flow rates at the culverts under existing conditions. Results from the hydrologic analysis are shown in Table 4-2.

TABLE 4-2
Hydrologic Model Analyses Results – Peak Flows

Crossing ID#	Peak Flow (cfs) by Storm Return Frequency					
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
49129 - Dashville Rd	152.17	238.92	326.06	474.51	617.65	793.00
41505 - New Salem Rd	47.45	120.35	181.24	256.30	318.98	434.44
48953 - Salem St	298.05	473.69	651.89	957.28	1248.57	1601.19
48926 - Rose Lane	118.10	179.35	240.51	344.63	446.25	570.96
48626 - Union Center Rd	2.52	5.85	9.77	17.16	24.82	34.74
48925 - Hardenburgh Rd	57.19	95.62	134.42	198.74	258.87	331.13

4.3 Hydraulic Methodology and Input Parameters

Hydraulic analysis for the six stream crossings was developed using HEC-RAS, a hydraulic modeling program available from the U.S. Army Corps of Engineers. Steady state models were developed for each location from approximately 500 feet upstream and downstream of each crossing or to a separate waterbody less than 500 feet upstream or downstream from the culvert.

4.3.1 Cross Sections

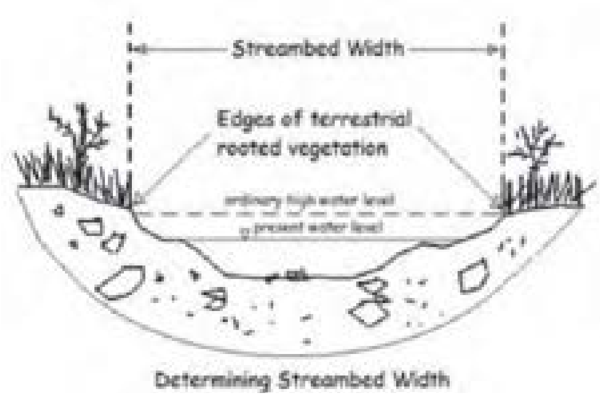
To create the models, Tighe & Bond first created Triangular Irregular Network (TIN) elevation surfaces using LIDAR topographic data for overbank areas beyond the extent of the assumed cross sections. Geometric representations of the channel, banks, and cross-sections were created using the AutoCAD to extract cross-sections from the TIN. Cross sections were extracted at the culvert openings and every 50 feet along the channel. Each crossing model had between 15 and 24 cross-sections depending on how long the channel ran uninterrupted by a separate waterbody. The Manning's roughness coefficients (Manning's n) were estimated to range from 0.03 to 0.035 in the channel, and 0.1 (forest cover) in the overbank areas. In some instances, a stream would be abutted by a roadway. When this occurred a Manning's n value of 0.013 was assigned to that segment of the cross section. Road widths were estimated based on LiDAR and orthographic imagery. The overbank and roadway Manning's n values were constant horizontally along the cross sections and were assumed using orthographic imagery.

4.3.2 Inflow Hydrograph

Peak flows from the hydrologic analysis for the 50-Year and 100-Year Design Storms were used as inflow hydrographs to the hydraulic model.

4.3.3 Stream Channel Bed Width

Field measurement of the top six crossing priorities were taken at three cross sections upstream and downstream of the existing culverts and averaged to determine existing stream channel width. The stream channel width is defined as the width of the channel at the ordinary high-water level and generally coincides with the edge of terrestrial rooted vegetation. The NYS Stream Crossing Guidelines and Standards state that stream crossing openings should be atleast 1.25 times the width of the stream channel bed. Conceptual culvert designs were sized to pass the 100-Year Design Storm and have a minimum width of 1.25 times the stream channel bed width.



Source: NYSDEC Stream Crossing Guidelines and Standards

4.4 Existing Hydraulic Analysis Results

Hydraulic crossing models for the top six crossing priorities were developed and run for the 50-Year and 100-Year Design Storms. The model for all of the existing crossings indicated the roadway would be overtopped during the 50-Year and 100-Year Design Storms.

4.5 Conceptual Design Hydraulic Analysis Results

The existing hydraulic crossing models for the top six crossing priorities were modified with several conceptual box culvert alternative sizes to safely pass the 100-Year Design Storm and meet the 1.25 times stream channel bed width criteria. Culvert heights were generally maintained to match existing conditions, to minimize the stream channel grading and provide adequate cover over the conceptual design culverts. Results from the conceptual design hydraulic analysis are shown in Table 4-3. All dimensions are in feet.

TABLE 4-3

Conceptual Crossing Design Hydraulic Analysis Results

Crossing ID#	SCB Width[1]	1.25 × SCB Width[1]	Concept Culvert Size	100-Year WSEL[2]	Freeboard to Low Chord	Freeboard to Road Surface
49129 - Dashville Rd	15.0	18.8	26 x 4	235.9	0.9	2.2
48925 - Hardenburgh Rd	12.0	15.0	15 x 3	295.8	-1.8	0.2
41505 - New Salem Rd	13.0	16.3	16.5 x 5	171.5	1.5	3.5
48926 - Rose Lane	12.0	15.0	20 x 4	222.9	1.1	3.0
48953 - Salem St	14.5	18.1	18.5 x 8	137.5	-1.8	0.0
48626 - Union Center Rd	15.0	18.8	19 x 3	130.1	2.4	3.9

[1] SCB Width = Stream Channel Bed Width

[2] WSEL = Maximum Water Surface Elevation

Freeboard is defined as the distance from the maximum water surface elevation upstream of a culvert to the top of the culvert opening (referred to as the low chord) or the road surface elevation. Negative freeboard indicates the maximum water surface elevation exceeding the low chord. Conceptual design culvert sizes were selected to have a freeboard to the road surface greater than or equal to zero, meaning that the road would not overtop during the 100-Year Design Storm.

4.6 Conceptual Culvert Design Drawings

Using the results from the H&H analysis, conceptual culvert design drawings were developed. Precast concrete, four-sided box culverts are proposed with 20 percent of the culvert open height buried at the downstream invert in accordance with the NYSDEC Stream Crossing Guidelines. Riprap and natural channel materials are proposed to line the bottom of the culvert. Rectangular concrete box culverts are the most efficient shape to achieve the project goals for aquatic and terrestrial passability, 100-Year Design Storm, and 1.25 times stream channel bed width. Other aluminum box or arch shaped culverts would require additional width to pass the 100-Year Design Storm, and in several situations the culverts evaluated were near or exceeding the width which would result in being considered a bridge rather than a culvert, which requires additional long term costs to comply with New York regulations. The concept culvert widths resulting from the H&H analysis are significantly wide enough utilizing a rectangular box shape.

Open bottom precast concrete box culverts were also evaluated; however, the top slab of these style culverts would need to be thicker than a four-sided box culvert causing issues with roadway cover. In addition, while the material cost for this style culvert is slightly less than a four-sided box culvert, the installation cost is greater due to the need to install footings prior to installing the open bottom box structures. An open bottom box culvert would likely result in a longer road closure to install than a four-sided box culvert.

See Appendix C for proposed concept culvert design drawings for the top six priority crossings. See Appendix E for figures showing the natural resources at the location of the top six priority crossings that may affect permitting requirements.

4.7 Conceptual Culvert Design Opinion of Probable Cost

Opinions of probable costs were developed for each of the conceptual culvert designs. The opinions of probable costs are based on Class 3 level construction cost estimates, as defined by the Association for the Advancement of Cost Engineering (AACE) International Recommended Practices and Standards. According to AACE International Recommended Practices and Standards, the estimate class designators are labeled Class 1, 2, 3, 4, and 5, where a Class 5 estimate is based on the lowest level of project definition and a Class 1 estimate is closest to full project definition and maturity. The end usage for a Class 3 estimate is for planning projects and preliminary design purposes. The expected accuracy range of a Class 3 estimate is between +30% to -20%.

The total project cost includes the cost to construct the project; 7.5% to cover mobilization, demobilization, and related expenses; 10% general conditions to cover costs such as bonds, insurance, project management, etc.; 10% engineering and permitting cost to cover engineering fees through construction; 3% for temporary construction and permeant easement costs; and 20% contingency for scope items that may not have been fully developed during this conceptual design level. The costs are based upon recently completed project bids and RSMeans Construction Cost Data.

This is an engineer's opinion of probable cost. Tighe & Bond has no control over the cost or availability of labor, equipment or materials, or over market conditions or the Contractor's method of pricing, and that the estimates of probable construction costs are made on the basis of the Tighe & Bond's professional judgment and experience. Tighe & Bond makes no guarantee nor warranty, expressed or implied, that the bids or the negotiated cost of the Work will not vary from this estimate of the Opinion Probable Cost. See Appendix C for detailed conceptual culvert design opinions of probable cost.

A summary of conceptual culvert design opinions of probable cost as shown in Table 4-4.

TABLE 4-4
Summary of Conceptual Culvert Design Opinions of Probable Cost

Crossing ID#	Opinion of Probable Cost
49129 - Dashville Road	$435,300
48925 - Hardenburgh Road	$301,700
41505 - New Salem Road	$431,700
48926 - Rose Lane	$330,800
48953 - Salem Street	$658,200
48626 - Union Center Road	$251,400

4.8 Conceptual Culvert Sizing for Those Not Selected as Priorities

The conceptual design work performed in development of this municipal management plan only focused on 6 out of 135 stream crossings in the Town of Esopus. The remaining 129 culverts will need to be addressed at some point in their lifespan. To aide in this process, the New York State Water Resources Institute at Cornell University has developed their own method of hydraulic and hydrologic analysis for stream crossings. This procedure is included in this document in Appendix F. While this method is not a replacement for a hydraulic and hydrologic analysis performed by a Professional Engineer, it can be a useful tool determining conceptual culvert replacement sizing.

Section 5
Future Planning

5.1 Funding and Permitting

5.1.1 Potential Funding Opportunities

There are some grant funding opportunities that exist to offset portions of the planning and construction costs that municipalities face for culvert replacement projects. The current available grant opportunities focus on flood prevention, wetlands restoration, and stream re-connectivity. Below in Table 5-1 is a list of potential grants the Town and County should consider pursing to fund future culvert related projects. The level of project development required to apply varies by funding opportunity. Some funding opportunities require only planning level engineering assessments and some require full permitting and shovel-ready designs. Check with the Grant Agency/Organization for the requirements to apply for each of the opportunities listed below, as they may change over time.

TABLE 5-1
Funding Opportunities

Grant Agency /Organization	Grant Program	Description
Federal Emergency Management Agency (FEMA)	Pre-Disaster Mitigation	Projects with the goal of reducing overall risk to people and structures from future events and decreasing reliance on Federal funding to repair damage done by future disasters. Apply in conjunction with the New York State Department of Homeland Security and Emergency Services.
NYSDEC	Climate Smart Communities Grant	Projects for climate change adaptation and mitigation. Resizing of culverts to prevent flooding qualify for this program.
NYSDEC	Non-Agricultural Nonpoint Source Planning Grant	Projects for the initial planning of non-agricultural nonpoint source water quality improvement projects. Culvert repair/replacement planning and streambank stabilization planning qualify for this program.
NYSDEC	Water Quality Improvement Plan Culvert Repair and Replacement	Projects to address erosion and erosion risks caused by failing or inadequately sized culverts through culvert repair or replacement.

Hudson River Estuary Program, NYSDEC	Hudson River Estuary Program Tributary Restoration and Resiliency	Projects for the restoration of free-flowing waters to benefit water quality, conserve and restore habitat, and help communities with existing and projected impacts of localized flooding.
U.S. Fish & Wildlife Service	North American Wetlands Conservation Act Small Grant	Projects aimed at wetland restoration or rehabilitation with the overall goal of returning natural/historic function to the degraded wetland.

5.1.2 Potential Permitting Requirements

A roadwork permit may be required for a culvert replacement project by New York State, Ulster County, or the Town of Esopus, depending on which entity owns the road-stream crossing, but may be waived depending on the requirements of that municipality. In addition, these types of projects are required under 6 NYCRR Part 617 to perform a State Environmental Quality Review (SEQR). Culvert replacement projects are generally considered Unlisted Actions under SEQR and require completion of Part 1 of a Short Environmental Assessment Form.

Besides the permitting requirements of the owner of the roadway being crossed, NYSDEC and/or Army Corps of Engineers (ACOE) may also require permitting for a culvert replacement project. There are four types of permits that may potentially be required depending on the as described below.

Freshwater Wetlands General Permit (NYSDEC)

A Freshwater Wetland Disturbance Permit may be required as per Article 24 of the Environmental Conservation Law and is implemented by 6 NYCRR Part 663, 664, and Part 665. The purpose of this permit is to allow the NYSDEC to comment on, and, prohibit any construction activity (including culvert replacement work) that may adversely impact the natural values of a state-regulated wetland, and its adjacent areas.

Typically, NYSDEC regulated wetlands are at least 12.4 acres in size; however smaller wetland areas may be regulated by the state if they are considered to be of unusual local importance. Culvert replacement work that will occur within a State-regulated wetland and/or its adjacent areas (100-ft buffer) will require an Article 24 Freshwater Wetland Disturbance Permit.

Protection of Waters/Stream Disturbance Permit (NYSDEC)

Per Title 5, Article 15 of the Environmental Conservation Law, NYSDEC has the authority and responsibility to preserve and protect the lakes, rivers, streams and ponds within New York State from activities that can adversely affect or destroy the delicate ecological balance of these important areas.

The state provides designated water classifications for bodies of water that range from AA to D (AA being assigned to water used as a source of drinking water and D being the lowest classification standard). Bodies of water which are classified as A through C may also have the designation (T) which stands for trout population or (TS) which stands for trout spawning.

Culvert replacement work that will disturb the bed or banks of a protected stream or other water course with an AA, A, B or C(T) or C(TS) designation will require an Article 15 Stream Disturbance Permit.

Esopus is home to multiple Classification B streams, notably sections of the Black Creek north of Esopus Lake. Culvert Replacement work disturbing a water course with a Class C or D designation do not fall under the jurisdiction of this permit.

Section 404 General Permit (ACOE)

Under Section 404 of the Clean Water Act, ACOE is responsible for regulating the discharge of dredge or fill material into the waters of the United States (including wetlands). For most culvert replacement projects that will have minimal adverse impact, coverage under a general nationwide permit is appropriate. Generally, culvert replacement work is anticipated to be covered under the ACEOE Nationwide Permit (NWP) #3 – Maintenance. NWP #3 is intended for projects including:

- Repair, rehabilitation, or replacement of any previously authorized, currently serviceable structure, provided the structure is not to be put to uses differing from those uses specified in the original permit or most recently authorized modification.

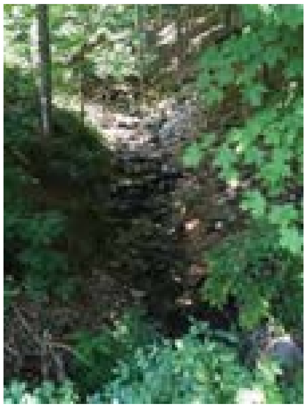
Section 401 Water Quality Certification (NYSDEC)

Under Section 401 of the Clean Water Act, the NYSDEC is responsible for issuing or denying a Water Quality Certification (WQC) for ACOE Section 404 NWPs. NWP #3 is granted blanket WQC coverage under Section 401 in New York State provided that the project complies with all the NWPs General Conditions.

Additional permitting considerations may also be required based on the location of the road-stream crossing. These considerations are generally addressed as part of the SEQR process. A large portion of the land in Esopus is within the habitat of plants or animals that New York State considers to be endangered or threatened. When projects take place in these areas the project must receive screening from the NYS Natural Heritage program. Screening for sites listed on the National or State Register of Historic Places is also generally required.

APPENDIX A
Culvert Priority Ranking and Inventory Summary Sheets

Priority Culvert Inventory Summary Sheets



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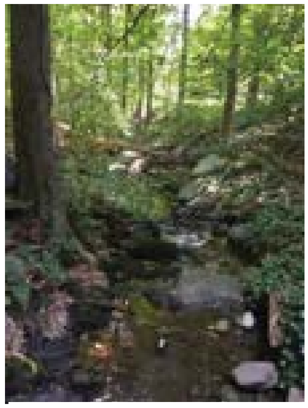

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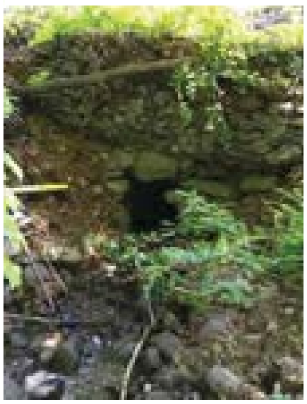

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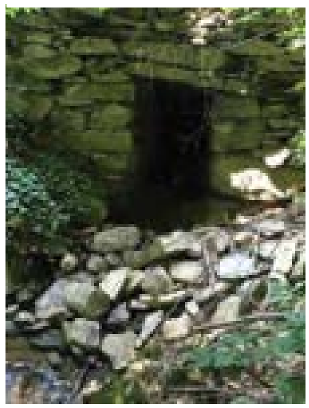
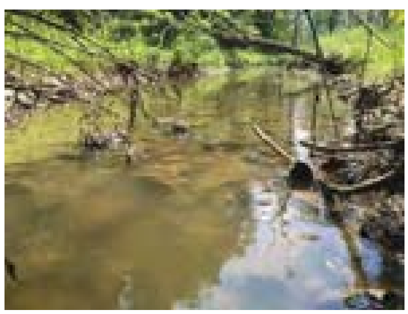


OUTLET

Survey ID: 49327
Road Owner: Esopus
Road Name: Barry Drive
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow-Aligned
Owner Priority: Low
Future Max Return Period (yr): Unknown
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.07

Comments:

UPSTREAM



DOWNSTREAM

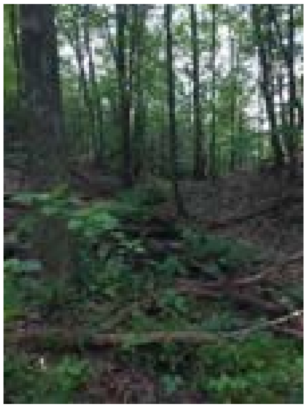
INLET

OUTLET

Survey ID: 53049
Road Owner: Esopus
Road Name: Carney Road
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow-Aligned
Owner Priority: Low
Future Max Return Period (yr): 0
Aquatic Barrier Rating: Significant Barrier
Habitat Connectivity (miles): 0.29

Comments:
Deformation includes large hole in pipe and offset pipe joints allowing water to run under pipe.

Priority Culvert Inventory Summary Sheets



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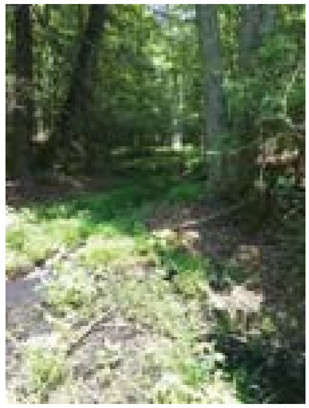


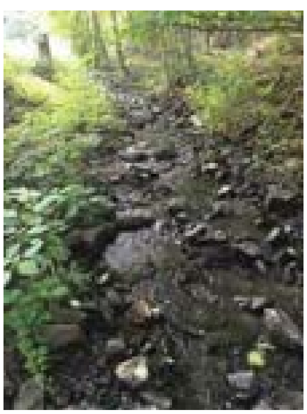
DOWNSTREAM

INLET

OUTLET

Survey ID: 53048
Road Owner: Esopus
Road Name: Carney Road
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow-Aligned
Owner Priority: High
Future Max Return Period (yr): 5
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.05

Comments:
Rotted invert.



UPSTREAM

DOWNSTREAM

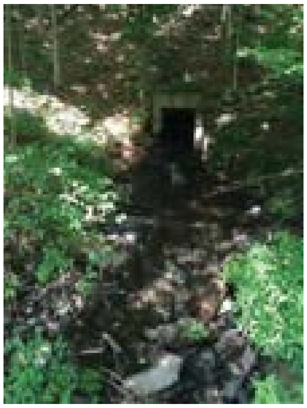
INLET

OUTLET

Survey ID: 49129
Road Owner: Esopus
Road Name: Dashville Road
Number of Culverts: 1
Crossing Condition: OK
Alignment: Skewed (>45^{O})
Owner Priority: High
Future Max Return Period (yr): 0
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.13

Comments:
Invert is rusted.

Priority Culvert Inventory Summary Sheets



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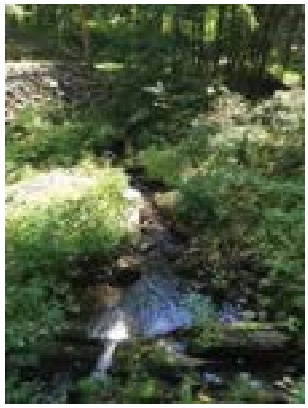


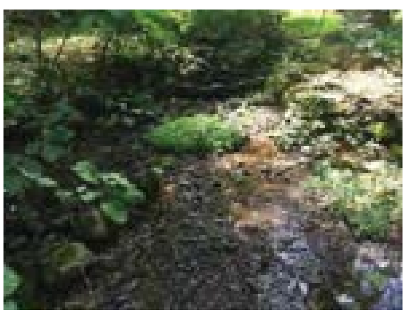
DOWNSTREAM

INLET

OUTLET

Survey ID: 49341
Road Owner: Esopus
Road Name: Floyd Ackert Road
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow-Aligned
Owner Priority: High
Future Max Return Period (yr): Unknown
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.04

Comments:



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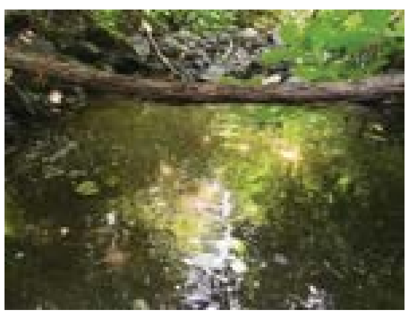


DOWNSTREAM

INLET

OUTLET

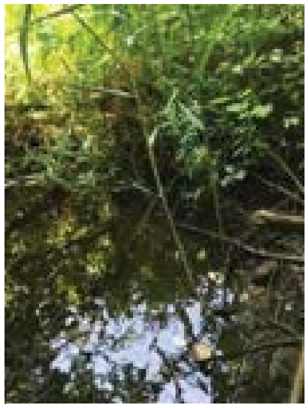
Survey ID: 48925
Road Owner: Esopus
Road Name: Hardenburgh Road
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow-Aligned
Owner Priority: Low
Future Max Return Period (yr): 1
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.45

Comments:

Rusted invert. Dam downstream.

Priority Culvert Inventory Summary Sheets

UPSTREAM



DOWNSTREAM

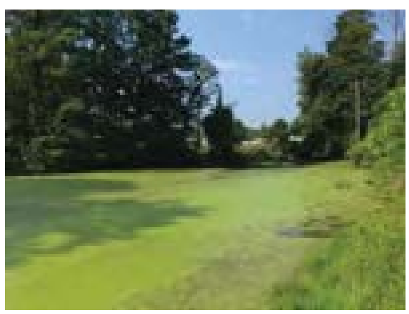
INLET

OUTLET

Survey ID: 49117
Road Owner: Esopus
Road Name: Loughran Road
Number of Culverts: 1
Crossing Condition: OK
Alignment: Flow-Aligned
Owner Priority: High
Future Max Return Period (yr): Unknown
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.45

Comments:

DOWNSTREAM 1

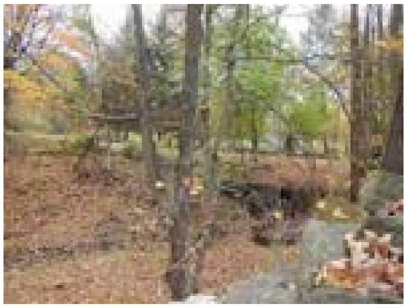


DOWNSTREAM 2

Survey ID: 48947
Road Owner: County
Road Name: New Salem Road
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow-Aligned
Owner Priority: High
Future Max Return Period (yr): 0
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.00

Comments:
Crossing is completely submerged and/or full of debris and woody vegetation at inlet. Outlet could not be located.

Priority Culvert Inventory Summary Sheets



UPSTREAM

DOWNSTREAM

INLET

OUTLET

Survey ID: 41505
Road Owner: County
Road Name: New Salem Road
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow Aligned
Owner Priority: High
Future Max Return Period (yr): Unknown
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.28

Comments:
Lots of knotweed on downstream side. Bottom of pipe rotted out

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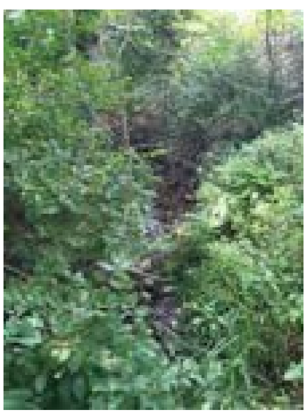


UPSTREAM

DOWNSTREAM

INLET

OUTLET

Survey ID: 49115
Road Owner: Esopus
Road Name: Poppletown Rd
Number of Culverts: 1
Crossing Condition: Poor
Alignment: No AOP
Owner Priority: High
Future Max Return Period (yr): 1
Aquatic Barrier Rating: Moderate Barrier
Habitat Connectivity (miles): 0.31

Comments:
Culvert invert is rotted out. No water flowing in the pipe

Priority Culvert Inventory Summary Sheets

UPSTREAM

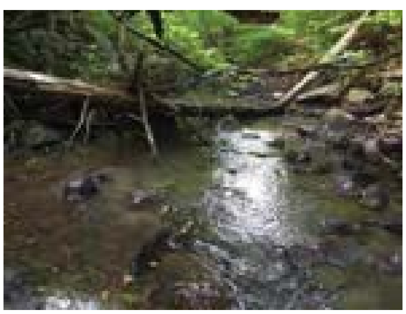
DOWNSTREAM

INLET

OUTLET

Survey ID: 48638
Road Owner: Esopus
Road Name: Rodmans Lane
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow-Aligned
Owner Priority: Low
Future Max Return Period (yr): Unknown
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.08

Comments:



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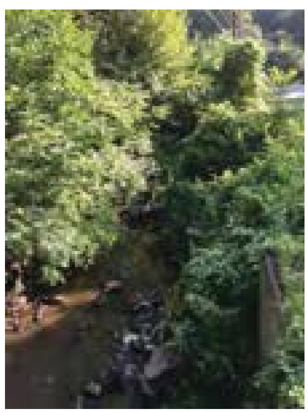

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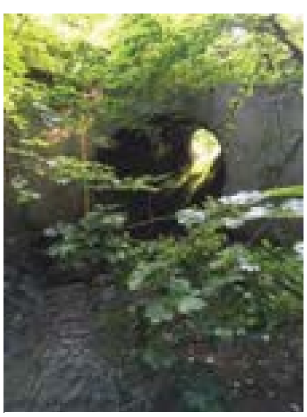

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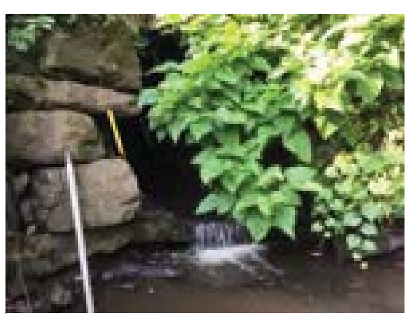
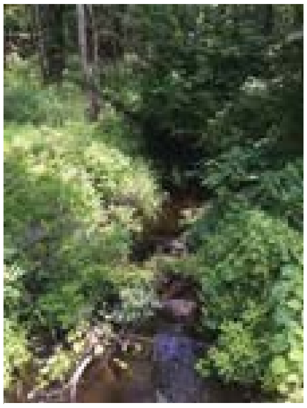


OUTLET

Survey ID: 48953
Road Owner: County
Road Name: Salem Street
Number of Culverts: 1
Crossing Condition: OK
Alignment: Flow-Aligned
Owner Priority: High
Future Max Return Period (yr): Unknown
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 2.23

Comments:

Priority Culvert Inventory Summary Sheets



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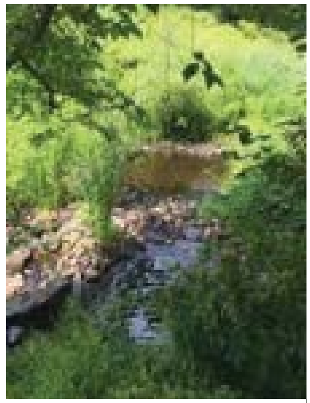


DOWNSTREAM

INLET

OUTLET

Survey ID: 49119
Road Owner: Esopus
Road Name: Swartekill Road
Number of Culverts: 2
Crossing Condition: OK
Alignment: Flow-Aligned
Owner Priority: High
Future Max Return Period (yr): 2
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 1.35

Comments:

UPSTREAM

DOWNSTREAM

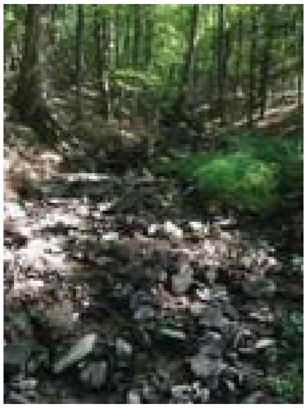
INLET

OUTLET

Survey ID: 48626
Road Owner: County
Road Name: Union Center Road
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow-Aligned
Owner Priority: Low
Future Max Return Period (yr): 0
Aquatic Barrier Rating: Significant Barrier
Habitat Connectivity (miles): 0.10

Comments:

Priority Culvert Inventory Summary Sheets



UPSTREAM

DOWNSTREAM

INLET

OUTLET

Survey ID: 52995
Road Owner: Esopus
Road Name: Winding Brook Road
Number of Culverts: 1
Crossing Condition: Poor
Alignment: Flow Aligned
Owner Priority: Low
Future Max Return Period (yr): 0
Aquatic Barrier Rating: Severe Barrier
Habitat Connectivity (miles): 0.47

Comments:

Crossing was originally stacked stone and concrete. Concrete pipes were added later to inlet side.

Water flowing under structure. Fish in outlet scour pond.

Town of Esopus / Ulster County Culvert Replacement Priortization

Survey_Id	Alignment	AOP Rating	Crossing Condition	Aquatic Barrier Rating	Flow Condition	Number Of Culverts	Road Owner	Road	Stream_Name	Material	Town/County Priority	Habitat Connectivity Total Length (Miles)	Future Max Return Period (yr)	AOP Ranking	Aquatic Barrier Ranking	Hydraulic Capacity	Flow Alignment	Crossing Condition	Town/County Priority	Perennial Flow Condition	Habitat Connectivity	Total	Ranking
48953	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	Salem street	Unknown	Metal	High	2.23		5	5	5	0	3	5	5	4	32	1
49119	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	2	Esopus	Swarterkill road	Unknown	Metal	High	1.35	2	5	5	5	0	3	5	5	3	31	2
48947	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	County	New Salem Rd.	Rondout creek	Metal	High	0.00	0	5	5	5	0	5	5	5	0	30	3
41505	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	County	New Salem Rd.	unknown	Metal	High	0.28		5	5	5	0	5	5	5	0	30	4
49341	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Floyd Ackert Road	Unknown	Concrete	High	0.04		5	5	5	0	5	5	5	0	30	5
49129	Skewed (>45°)	No AOP	OK	Severe barrier	Typical low-flow	1	Esopus	Dashville Road	Unknown	Metal	High	0.13	0	5	5	5	1	3	5	5	0	29	6
49117	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	Esopus	Loughran Road	Unknown	Plastic	High	0.45		5	5	5	0	3	5	5	0	28	7
49115	Flow-Aligned	No AOP	Poor	Moderate barrier	Typical low-flow	1	Esopus	Poppletown Road	Unknown	Metal	High	0.31	1	5	3	5	0	5	5	5	0	28	8
48926	Skewed (>45°)	No AOP	Poor	Severe barrier	Typical low-flow	1	Private	Rose Lane	Unknown	Combination	Low	0.98		5	5	5	1	5	0	5	1	27	9
48925	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Hardenburg Road	Unknown	Metal	Low	0.45	1	5	5	5	0	5	0	5	0	25	10
52995	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Winding Brook Road	Unknown	Combination	Low	0.47	0	5	5	5	0	5	0	5	0	25	11
48638	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Rodmans Lane	Unknown	Metal	Low	0.08		5	5	5	0	5	0	5	0	25	12
49327	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Barry Drive	Unknown	Combination	Low	0.07		5	5	5	0	5	0	5	0	25	13
53049	Flow-Aligned	No AOP	Poor	Significant barrier	Typical low-flow	1	Esopus	Carney Road	Unknown	Concrete	Low	0.29	0	5	4	5	0	5	0	5	0	24	14
53048	Flow-Aligned	No AOP	Poor	Severe barrier	No Flow	1	Esopus	Carney Road	Unknown	Metal	High	0.05	5	5	5	4	0	5	5	0	0	24	15
48626	Flow-Aligned	No AOP	Poor	Significant barrier	Typical low-flow	1	County	Union Center Rd.	Unknown	Metal	Low	0.10	0	5	4	5	0	5	0	5	0	24	16
48448	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	Union Center Rd.	tributary to Black Creek	Metal	Low	0.23	0	5	5	5	0	3	0	5	0	23	17
48450	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	Union Center Rd.	unnamed	Metal	Low	0.22	1	5	5	5	0	3	0	5	0	23	18
48945	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	New Salem Rd.	Unknown	Combination	Low	0.00	0	5	5	5	0	3	0	5	0	23	19
49113	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	2	Esopus	Floyd Ackert Road	Unknown	Plastic	Low	0.24	1	5	5	5	0	3	0	5	0	23	20
49326	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	Esopus	Burroughs Drive	Unknown	Plastic	Low	0.12	2	5	5	5	0	3	0	5	0	23	21
49349	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	Esopus	Pareker Avenue	Unknown	Metal	Low	0.27	0	5	5	5	0	3	0	5	0	23	22
41492	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	River Rd.	trib to Hudson River	Metal	Low	0.36		5	5	5	0	3	0	5	0	23	23
41504	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	New Salem Rd.	trib to Rondout Creek	Metal	Low	0.00		5	5	5	0	3	0	5	0	23	24
48618	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	2	Esopus	Esopus Avenue	Unknown	Plastic	Low	0.36		5	5	5	0	3	0	5	0	23	25
48695	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	Union Center Rd.	unnamed	Combination	Low	0.00		5	5	5	0	3	0	5	0	23	26
48921	Flow-Aligned	No AOP	OK	Severe barrier	No Flow	1	Esopus	Carney Road	Unknown	Metal	High	0.53		5	5	5	0	3	5	0	0	23	27
49578	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	New Salem Rd.	Sugarbush Creek	Concrete	Low	0.00		5	5	5	0	3	0	5	0	23	28
49132	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	James Street	Unknown	Metal	Low	0.55	25	5	5	3	0	5	0	5	0	23	29
49128	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	State	Route 213	Unknown	Concrete	Low	0.13	10	5	5	4	0	3	0	5	0	22	30
49335	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	2	Esopus	Hudson Lane	Unkown	Metal	Low	0.33	10	5	5	4	0	3	0	5	0	22	31
49340	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	State	Route 9w	Unknown	Concrete	Low	0.08	10	5	5	4	0	3	0	5	0	22	32
49130	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	2	Esopus	Dubois lane	Unknown	Plastic	Low	0.71		5	3	5	0	3	0	5	1	22	33
52992	Flow-Aligned	No AOP	OK	Significant barrier	Typical low-flow	1	Esopus	Martin Swedish Road	Unknown	Plastic	Low	0.57	0	5	4	5	0	3	0	5	0	22	34
48451	Flow-Aligned	No AOP	OK	Significant barrier	Typical low-flow	1	County	Union Center Rd.	unnamed	Concrete	Low	0.31		5	4	5	0	3	0	5	0	22	35
48878	Flow-Aligned	No AOP	OK	Significant barrier	Typical low-flow	1	County	Old Post Rd.	tributary to Black Creek	Metal	Low	0.06		5	4	5	0	3	0	5	0	22	36
48620	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	2	Esopus	Esopus Avenue	Unknown	Plastic	Low	0.21	0	5	3	5	0	3	0	5	0	21	37
48880	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	2	County	Old Post Rd.	tributary to Black Creek	Metal	Low	0.07	0	5	3	5	0	3	0	5	0	21	38
49124	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	1	State	Route 32	Unknown	Concrete	Low	0.21	0	5	3	5	0	3	0	5	0	21	39
53043	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	2	Esopus	Hellbrook	Unknown	Plastic	Low	0.25	2	5	3	5	0	3	0	5	0	21	40
49112	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	1	Esopus	Swartekill Road	Unknown	Plastic	Low	0.57		5	3	5	0	3	0	5	0	21	41
65292	Flow-Aligned	No AOP	Poor	Moderate barrier	Moderate	1	Esopus	Old post road	Unknown	Metal	Low	1.28		5	3	5	0	5	0	0	3	21	42
49118	Flow-Aligned	Reduced AOF	Poor	Moderate barrier	Typical low-flow	1	Esopus	Swartekill Road	Unknown	Combination	Low	1.27		0	3	5	0	5	0	5	3	21	43
49325	Flow-Aligned	no score - mis	Poor	Severe barrier	Typical low-flow	0	Esopus	Burroughs Drive	Unknown		Low	0.26	2	0	5	5	0	5	0	5	0	20	44
48942	Flow-Aligned	No AOP	Poor	Minor barrier	Typical low-flow	2	Esopus	Pokonoie road	Unknown	Metal	Low	0.04		5	0	5	0	5	0	5	0	20	45
48437	Skewed (>45°)	No AOP	OK	Severe barrier	No Flow	1	County	River Rd.	unnamed	Metal	Low	0.10	0	5	5	5	1	3	0	0	0	19	46
48944	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	2	Esopus	Pokonoie Road	Unknown	Concrete	Low	1.03		0	3	5	0	3	0	5	3	19	47
48941	Skewed (>45°)	No AOP	OK	Minor barrier	Typical low-flow	1	Esopus	Pokonoie road	Unknown	Rock/Stone	Low	0.08		5	0	5	1	3	0	5	0	19	48
48952	Skewed (>45°)	No AOP	OK	Minor barrier	Typical low-flow	1	Esopus	Andorn Lane	Unknown	Metal	Low	0.35		5	0	5	1	3	0	5	0	19	49
53044	Flow-Aligned	Reduced AOF	Poor	Insignificant barrier	Typical low-flow	1	Esopus	Ulster Avenue	Unknown	Concrete	Low	2.30	0	0	0	5	0	5	0	5	4	19	50
49111	Flow-Aligned	Full AOP	Poor	Insignificant barrier	Typical low-flow	1	Esopus	Floyd Ackert Road	Black Creak	Combination	Low	2.55		0	0	5	0	5	0	5	4	19	51
41503	Flow-Aligned	No AOP	OK	Severe barrier	No Flow	1	County	River Rd.	trib to Hudson River	Metal	Low	0.20		5	5	5	0	3	0	0	0	18	52
49316	Flow-Aligned	No AOP	OK	Severe barrier	No Flow	1	Esopus	Hudson Lane	Unknown	Metal	Low	0.20		5	5	5	0	3	0	0	0	18	53
49110	Flow-Aligned	Full AOP	Poor	Insignificant barrier	Typical low-flow	1	Esopus	Valli Road	Black creek	Combination	Low	1.80		0	0	5	0	5	0	5	3	18	54
48442	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Ulster Ave.	unnamed	Concrete	Low	2.30	0	0	0	5	0	3	0	5	4	17	55
48693	Flow-Aligned	No AOP	OK	Severe barrier	No Flow	1	County	River Rd.	unnamed	Metal	Low	0.02	10	5	5	4	0	3	0	0	0	17	56
48605	Skewed (>45°)	Reduced AOF	OK	Moderate barrier	Typical low-flow	2	Esopus	Swartekill Road	Unknown	Plastic	Low	0.12	1	0	3	5	1	3	0	5	0	17	57
65300	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	1	Esopus	Private	Unkown	Plastic	Low	0.85		0	3	5	0	3	0	5	1	17	58
63597	Skewed (>45°)	Full AOP	OK	Insignificant barrier	Typical low-flow	1	Esopus	CSX railroad	Hell Brook	Combination	Low	1.48		0	0	5	1	3	0	5	3	17	59
53047	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	2	Esopus	Floyd Ackert Road	Unknown	Plastic	Low	0.68		0	3	5	0	3	0	5	1	17	60
65299	Flow-Aligned	No AOP	OK	Significant barrier	Moderate	1	Esopus	Private	Unknown	Combination	Low	0.45		5	4	5	0	3	0	0	0	17	61
49131	Flow-Aligned	Reduced AOF	Poor	Moderate barrier	Typical low-flow	2	Esopus	Souminen road	Unknown	Metal	Low	0.72	25	0	3	3	0	5	0	5	1	17	62
49116	Flow-Aligned	no score - mis	OK	no score - missing dat	Typical low-flow	2	Esopus	Rousner Road	Unknown	Plastic	Low	2.00	1	0	0	5	0	3	0	5	3	16	63
63599	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	1	Esopus	railroad	Black Creek	No data	Low	2.00		0	0	5	0	3	0	5	3	16	64
48449	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	2	County	Union Center Rd.	tributary to Black Creek	Metal	Low	0.09	1	0	3	5	0	3	0	5	0	16	65
48633	Flow-Aligned	No AOP	OK	Moderate barrier	No Flow	1	Esopus	Union Center Road	Unknown	Metal	Low	0.00	0	5	3	5	0	3	0	0	0	16	66
48899	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	County	Old Post Rd.	Swarte Kill	Metal	Low	1.94	0	0	0	5	0	3	0	5	3	16	67
49120	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	1	Esopus	Plutarch Road	Unknown	Plastic	Low	0.57	1	0	3	5	0	3	0	5	0	16	68
49313	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	State	Route 9W	Unknown	Concrete	Low	1.89	0	0	0	5	0	3	0	5	3	16	69
48943	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	1	Esopus	Pokonoie	Unknown	Concrete	Low	0.34		0	3	5	0	3	0	5	0	16	70
63596	Skewed (>45°)	Full AOP	OK	Insignificant barrier	Typical low-flow	1	Esopus	CSX railway	Hell Brook	Combination	Low	0.67		0	0	5	1	3	0	5	1	15	71
48616	Flow-Aligned	no score - mis	Poor	Minor barrier	Typical low-flow	1	Esopus	Esopus Avenue	Unknown	Metal	Low	0.24		0	0	5	0	5	0	5	0	15	72

Town of Esopus / Ulster County Culvert Replacement Priortization

Survey_Id	Alignment	AOP Rating	Crossing Condition	Aquatic Barrier Rating	Flow Condition	Number Of Culverts	Road Owner	Road	Stream_Name	Material	Town/County Priority	Habitat Connectivity Total Length (Miles)	Future Max Return Period (yr)	AOP Ranking	Aquatic Barrier Ranking	Hydraulic Capacity	Flow Alignment	Crossing Condition	Town/County Priority	Perennial Flow Condition	Habitat Connectivity	Total	Ranking
48923	Flow-Aligned	Reduced AOF	Poor	Minor barrier	Typical low-flow	1	Esopus	Carney Road	Unknown	Metal	Low	0.54		0	0	5	0	5	0	5	0	15	73
52994	No data	Full AOP	OK	No barrier	Typical low-flow	1	Interstate	I 87	Walkill River	No data	Low	0.28	0	0	0	5	1	3	0	5	0	14	74
41502	Flow-Aligned	no score - mis	OK	no score - missing dat	Typical low-flow	1	County	River Rd.	trib to Hudson River	Metal	Low	0.62		0	0	5	0	3	0	5	1	14	75
50525	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	-1	Esopus	Old US Route 9W	Rondout Creek		Low	0.73		0	0	5	0	3	0	5	1	14	76
48454	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	2	County	Union Center Rd.	tributary to Black Creek	Metal	Low	0.72	2	0	0	5	0	3	0	5	1	14	77
48907	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Hardenburg Road	Unknown	Combination	Low	0.64	0	0	0	5	0	3	0	5	1	14	78
49315	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	County	River Rd.	Unknown	Metal	Low	0.62	0	0	0	5	0	3	0	5	1	14	79
48950	Skewed (>45°)	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Millbrook road	Unknown	Concrete	Low	0.48	0	0	0	5	1	3	0	5	0	14	80
49346	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	State	Route 9w	Black Creek	Combination	Low	0.71		0	0	5	0	3	0	5	1	14	81
49347	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Black Creek Road	Black Creek	Combination	Low	0.61		0	0	5	0	3	0	5	1	14	82
48602	Skewed (>45°)	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Floyd Ackert	Unknown	Plastic	Low	0.38		0	0	5	1	3	0	5	0	14	83
49064	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	-1	Interstate	I 87	Walkill River		Low	0.27	0	0	0	5	0	3	0	5	0	13	84
49125	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	1	State	Route 32	Wallkill River	Combination	Low	0.14	0	0	0	5	0	3	0	5	0	13	85
49127	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	1	Esopus	Walkway	Walkill river	No data	Low	0.31	0	0	0	5	0	3	0	5	0	13	86
49328	Flow-Aligned	no score - mis	OK	no score - missing dat	Typical low-flow	1	State	Route 9w	Unknown	No data	Low	0.33	0	0	0	5	0	3	0	5	0	13	87
49343	Flow-Aligned	no score - mis	OK	no score - missing dat	Typical low-flow	1	Esopus	Floyd Ackert Road	Unknown	Plastic	Low	0.38		0	0	5	0	3	0	5	0	13	88
49350	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	1	Esopus	Railroad	Unknown	No data	Low	0.28		0	0	5	0	3	0	5	0	13	89
48444	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Ulster Ave.	unnamed	Metal	Low	0.03	0	0	0	5	0	3	0	5	0	13	90
48601	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Swartekill Road	Unknown	Plastic	Low	0.56	2	0	0	5	0	3	0	5	0	13	91
48608	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Hermance Lane	Unknown	Concrete	Low	0.07	0	0	0	5	0	3	0	5	0	13	92
48614	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	2	Esopus	Esopus Avenue	Unknown	Metal	Low	0.29	0	0	0	5	0	3	0	5	0	13	93
48655	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	2	Esopus	Mountain View Road	Unknown	Metal	Low	0.33	0	0	0	5	0	3	0	5	0	13	94
48660	Flow-Aligned	No AOP	OK	Minor barrier	No Flow	1	Esopus	Dick Williams Lane	Unknown	Plastic	Low	0.00	0	5	0	5	0	3	0	0	0	13	95
48905	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	2	Esopus	Hardenburg road	Unknown	Plastic	Low	0.32	0	0	0	5	0	3	0	5	0	13	96
48906	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Hardenburg	Unknown	Plastic	Low	0.60	0	0	0	5	0	3	0	5	0	13	97
48909	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	State	Route 213	Unkown	Concrete	Low	0.09	0	0	0	5	0	3	0	5	0	13	98
48949	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Connelly	Unknown	Concrete	Low	0.02	0	0	0	5	0	3	0	5	0	13	99
49121	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Plutarch Road	Unknown	Metal	Low	0.44	1	0	0	5	0	3	0	5	0	13	100
49123	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	Esopus	Old route 32	Unknown	Concrete	Low	0.03	1	0	0	5	0	3	0	5	0	13	101
65288	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	2	Esopus	Hercules Drive	Unknown	Metal	Low	0.07		0	0	5	0	3	0	5	0	13	102
65289	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Hercules	Unknown	Concrete	Low	0.37		0	0	5	0	3	0	5	0	13	103
41501	Flow-Aligned	Reduced AOF	OK	Severe barrier	No Flow	1	County	River Rd.	trib to Hudson	Metal	Low	0.23		0	5	5	0	3	0	0	0	13	104
49342	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	2	Esopus	West shore drive	Unknown	Concrete	Low	0.24		0	0	5	0	3	0	5	0	13	105
49344	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	Esopus	Winding Brook Road	Black Creek	Combination	Low	0.25		0	0	5	0	3	0	5	0	13	106
53046	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Swarte Kill Road	Unknown	Metal	Low	0.38		0	0	5	0	3	0	5	0	13	107
65293	Skewed (>45°)	Reduced AOF	OK	Minor barrier	Moderate	2	Esopus	Rosner lane	Unknown	Plastic	Low	1.28		0	0	5	1	3	0	0	3	12	108
48884	Flow-Aligned	no score - mis	OK	no score - missing dat	No Flow	1	County	Old Post Rd.	Swarte Kill	Metal	Low	1.28		0	0	5	0	3	0	0	3	11	109
48866	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	County	Old Post Rd.	Black Creek	Concrete	Low	0.25	50	0	0	2	0	3	0	5	0	10	110
65294	Flow-Aligned	Reduced AOF	Poor	Minor barrier	Moderate	1	Esopus	Floy Ackert road	Unknown	Plastic	Low	0.38		0	0	5	0	5	0	0	0	10	111
65295	Flow-Aligned	Reduced AOF	Poor	Insignificant barrier	Moderate	2	Esopus	Private drive	Unknown	Metal	Low	0.45		0	0	5	0	5	0	0	0	10	112
48643	Flow-Aligned	Reduced AOF	Poor	Minor barrier	No Flow	1	Esopus	Catherine Lane	Unknown	Metal	Low	0.06		0	0	5	0	5	0	0	0	10	113
65290	Flow-Aligned	Full AOP	OK	Insignificant barrier	Moderate	1	Esopus	Driveway	Unknown	Combination	Low	0.65		0	0	5	0	3	0	0	1	9	114
65291	Flow-Aligned	Full AOP	OK	Insignificant barrier	Moderate	1	Esopus	Railroad	Unknown	Combination	Low	0.69		0	0	5	0	3	0	0	1	9	115
48694	Skewed (>45°)	Reduced AOF	OK	Minor barrier	No Flow	1	County	River Rd.	unnamed	Combination	Low	0.18		0	0	5	1	3	0	0	0	9	116
65296	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Private drive	Unknown	Metal	Low	0.03		0	0	5	0	3	0	0	0	8	117
65297	Flow-Aligned	Reduced AOF	OK	Minor barrier	No Flow	1	Esopus	Private drive	Unknown	Plastic	Low	0.04		0	0	5	0	3	0	0	0	8	118
65298	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Railroad	Unknown	Concrete	Low	0.23		0	0	5	0	3	0	0	0	8	119
65301	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Private	Unknowm	Metal	Low	0.12		0	0	5	0	3	0	0	0	8	120
65310	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Public park path	Unknown	Combination	Low	0.10		0	0	5	0	3	0	0	0	8	121
65346	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Private	Unkown	Metal	Low	0.12		0	0	5	0	3	0	0	0	8	122
48447	Flow-Aligned	Reduced AOF	OK	Minor barrier	No Flow	1	County	Union Center Rd.	unnamed	Metal	Low	0.03		0	0	5	0	3	0	0	0	8	123
48641	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	No Flow	1	Esopus	Anna Lane	Unknown	Plastic	Low	0.23		0	0	5	0	3	0	0	0	8	124
48886	No data	Full AOP	No data	No barrier	No data	-1	County	Old Post Rd.			Low	0.86	0	0	0	5	1	0	0	0	1	7	125
50527	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Unkown	Rondout Creek		Low	0.90	2	0	0	5	1	0	0	0	1	7	126
50487	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Frank Koenig Blvd/ Rc	Rondout Creek		Low	0.91		0	0	5	1	0	0	0	1	7	127
48696	No data	Full AOP	No data	No barrier	No data	-1	Esopus				Low	0.00	0	0	0	5	1	0	0	0	0	6	128
50481	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Hilterbrant Lane	Unknown		Low	0.05		0	0	5	1	0	0	0	0	6	129
50482	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Floridia Street	Unkown		Low	0.00		0	0	5	1	0	0	0	0	6	130
50483	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Tervo Road	Unkown		Low	0.00		0	0	5	1	0	0	0	0	6	131
50532	No data	Full AOP	No data	No barrier	No data	-1	Esopus				Low	0.23		0	0	5	1	0	0	0	0	6	132
54846	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Floyd Ackert Road	Unkown		Low	0.47		0	0	5	1	0	0	0	0	6	133
48645	Flow-Aligned	no score - mis	Unknown	no score - missing dat	No data	-1	Esopus	Catherine Lane			Low	0.24	2	0	0	5	0	0	0	0	0	5	134
65320	Flow-Aligned	Reduced AOF	New	Insignificant barrier	Moderate	1	Esopus	Private	Unknown	Concrete	Low	0.29		0	0	5	0	0	0	0	0	5	135

Town of Esopus / Ulster County Culvert Replacement Priortization

Survey_Id	Alignment	AOP Rating	Crossing Condition	Aquatic Barrier Rating	Flow Condition	Number Of Culverts	Road Owner	Road	Stream_Name	Material	Town/County Priority	Habitat Connectivity Total Length (Miles)	Future Max Return Period (yr)	Total	Ranking
48953	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	Salem street	Unknown	Metal	High	2.23		32	1
49119	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	2	Esopus	Swarterkill road	Unknown	Metal	High	1.35	2	31	2
48947	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	County	New Salem Rd.	Rondout creek	Metal	High	0.00	0	30	3
41505	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	County	New Salem Rd.	unknown	Metal	High	0.28		30	4
49341	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Floyd Ackert Road	Unknown	Concrete	High	0.04		30	5
49129	Skewed (>45°)	No AOP	OK	Severe barrier	Typical low-flow	1	Esopus	Dashville Road	Unknown	Metal	High	0.13	0	29	6
49117	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	Esopus	Loughran Road	Unknown	Plastic	High	0.45		28	7
49115	Flow-Aligned	No AOP	Poor	Moderate barrier	Typical low-flow	1	Esopus	Poppletown Road	Unknown	Metal	High	0.31	1	28	8
48926	Skewed (>45°)	No AOP	Poor	Severe barrier	Typical low-flow	1	Private	Rose Lane	Unknown	Combination	Low	0.98		27	9
48925	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Hardenburg Road	Unknown	Metal	Low	0.45	1	25	10
52995	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Winding Brook Road	Unknown	Combination	Low	0.47	0	25	11
48638	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Rodmans Lane	Unknown	Metal	Low	0.08		25	12
49327	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	Barry Drive	Unknown	Combination	Low	0.07		25	13
53049	Flow-Aligned	No AOP	Poor	Significant barrier	Typical low-flow	1	Esopus	Carney Road	Unknown	Concrete	Low	0.29	0	24	14
53048	Flow-Aligned	No AOP	Poor	Severe barrier	No Flow	1	Esopus	Carney Road	Unknown	Metal	High	0.05	5	24	15
48626	Flow-Aligned	No AOP	Poor	Significant barrier	Typical low-flow	1	County	Union Center Rd.	Unknown	Metal	Low	0.10	0	24	16
48448	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	Union Center Rd.	tributary to Black Creek	Metal	Low	0.23	0	23	17
48450	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	Union Center Rd.	unnamed	Metal	Low	0.22	1	23	18
48945	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	New Salem Rd.	Unknown	Combination	Low	0.00	0	23	19
49113	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	2	Esopus	Floyd Ackert Road	Unknown	Plastic	Low	0.24	1	23	20
49326	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	Esopus	Burroughs Drive	Unknown	Plastic	Low	0.12	2	23	21
49349	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	Esopus	Pareker Avenue	Unknown	Metal	Low	0.27	0	23	22
41492	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	River Rd.	trib to Hudson River	Metal	Low	0.36		23	23
41504	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	New Salem Rd.	trib to Rondout Creek	Metal	Low	0.00		23	24
48618	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	2	Esopus	Esopus Avenue	Unknown	Plastic	Low	0.36		23	25
48695	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	Union Center Rd.	unnamed	Combination	Low	0.00		23	26
48921	Flow-Aligned	No AOP	OK	Severe barrier	No Flow	1	Esopus	Carney Road	Unknown	Metal	High	0.53		23	27
49578	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	County	New Salem Rd.	Sugarbush Creek	Concrete	Low	0.00		23	28
49132	Flow-Aligned	No AOP	Poor	Severe barrier	Typical low-flow	1	Esopus	James Street	Unknown	Metal	Low	0.55	25	23	29
49128	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	State	Route 213	Unknown	Concrete	Low	0.13	10	22	30
49335	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	2	Esopus	Hudson Lane	Unkown	Metal	Low	0.33	10	22	31
49340	Flow-Aligned	No AOP	OK	Severe barrier	Typical low-flow	1	State	Route 9w	Unknown	Concrete	Low	0.08	10	22	32
49130	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	2	Esopus	Dubois lane	Unknown	Plastic	Low	0.71		22	33
52992	Flow-Aligned	No AOP	OK	Significant barrier	Typical low-flow	1	Esopus	Martin Swedish Road	Unknown	Plastic	Low	0.57	0	22	34
48451	Flow-Aligned	No AOP	OK	Significant barrier	Typical low-flow	1	County	Union Center Rd.	unnamed	Concrete	Low	0.31		22	35
48878	Flow-Aligned	No AOP	OK	Significant barrier	Typical low-flow	1	County	Old Post Rd.	tributary to Black Creek	Metal	Low	0.06		22	36
48620	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	2	Esopus	Esopus Avenue	Unknown	Plastic	Low	0.21	0	21	37
48880	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	2	County	Old Post Rd.	tributary to Black Creek	Metal	Low	0.07	0	21	38
49124	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	1	State	Route 32	Unknown	Concrete	Low	0.21	0	21	39
53043	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	2	Esopus	Hellbrook	Unknown	Plastic	Low	0.25	2	21	40
49112	Flow-Aligned	No AOP	OK	Moderate barrier	Typical low-flow	1	Esopus	Swartekill Road	Unknown	Plastic	Low	0.57		21	41
65292	Flow-Aligned	No AOP	Poor	Moderate barrier	Moderate	1	Esopus	Old post road	Unknown	Metal	Low	1.28		21	42
49118	Flow-Aligned	Reduced AOF	Poor	Moderate barrier	Typical low-flow	1	Esopus	Swartekill Road	Unknown	Combination	Low	1.27		21	43
49325	Flow-Aligned	no score - mis	Poor	Severe barrier	Typical low-flow	0	Esopus	Burroughs Drive	Unknown		Low	0.26	2	20	44
48942	Flow-Aligned	No AOP	Poor	Minor barrier	Typical low-flow	2	Esopus	Pokonoie road	Unknown	Metal	Low	0.04		20	45
48437	Skewed (>45°)	No AOP	OK	Severe barrier	No Flow	1	County	River Rd.	unnamed	Metal	Low	0.10	0	19	46
48944	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	2	Esopus	Pokonoie Road	Unknown	Concrete	Low	1.03		19	47
48941	Skewed (>45°)	No AOP	OK	Minor barrier	Typical low-flow	1	Esopus	Pokonoie road	Unknown	Rock/Stone	Low	0.08		19	48
48952	Skewed (>45°)	No AOP	OK	Minor barrier	Typical low-flow	1	Esopus	Andorn Lane	Unknown	Metal	Low	0.35		19	49
53044	Flow-Aligned	Reduced AOF	Poor	Insignificant barrier	Typical low-flow	1	Esopus	Ulster Avenue	Unknown	Concrete	Low	2.30	0	19	50
49111	Flow-Aligned	Full AOP	Poor	Insignificant barrier	Typical low-flow	1	Esopus	Floyd Ackert Road	Black Creak	Combination	Low	2.55		19	51
41503	Flow-Aligned	No AOP	OK	Severe barrier	No Flow	1	County	River Rd.	trib to Hudson River	Metal	Low	0.20		18	52
49316	Flow-Aligned	No AOP	OK	Severe barrier	No Flow	1	Esopus	Hudson Lane	Unknown	Metal	Low	0.20		18	53

Town of Esopus / Ulster County Culvert Replacement Priortization

Survey_Id	Alignment	AOP Rating	Crossing Condition	Aquatic Barrier Rating	Flow Condition	Number Of Culverts	Road Owner	Road	Stream_Name	Material	Town/County Priority	Habitat Connectivity Total Length (Miles)	Future Max Return Period (yr)	Total	Ranking
49110	Flow-Aligned	Full AOP	Poor	Insignificant barrier	Typical low-flow	1	Esopus	Valli Road	Black creek	Combination	Low	1.80		18	54
48442	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Ulster Ave.	unnamed	Concrete	Low	2.30	0	17	55
48693	Flow-Aligned	No AOP	OK	Severe barrier	No Flow	1	County	River Rd.	unnamed	Metal	Low	0.02	10	17	56
48605	Skewed (>45°)	Reduced AOF	OK	Moderate barrier	Typical low-flow	2	Esopus	Swartekill Road	Unknown	Plastic	Low	0.12	1	17	57
65300	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	1	Esopus	Private	Unkown	Plastic	Low	0.85		17	58
63597	Skewed (>45°)	Full AOP	OK	Insignificant barrier	Typical low-flow	1	Esopus	CSX railroad	Hell Brook	Combination	Low	1.48		17	59
53047	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	2	Esopus	Floyd Ackert Road	Unknown	Plastic	Low	0.68		17	60
65299	Flow-Aligned	No AOP	OK	Significant barrier	Moderate	1	Esopus	Private	Unknown	Combination	Low	0.45		17	61
49131	Flow-Aligned	Reduced AOF	Poor	Moderate barrier	Typical low-flow	2	Esopus	Souminen road	Unknown	Metal	Low	0.72	25	17	62
49116	Flow-Aligned	no score - mis	OK	no score - missing da	Typical low-flow	2	Esopus	Rousner Road	Unknown	Plastic	Low	2.00	1	16	63
63599	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	1	Esopus	railroad	Black Creek	No data	Low	2.00		16	64
48449	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	2	County	Union Center Rd.	tributary to Black Creek	Metal	Low	0.09	1	16	65
48633	Flow-Aligned	No AOP	OK	Moderate barrier	No Flow	1	Esopus	Union Center Road	Unknown	Metal	Low	0.00	0	16	66
48899	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	County	Old Post Rd.	Swarte Kill	Metal	Low	1.94	0	16	67
49120	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	1	Esopus	Plutarch Road	Unknown	Plastic	Low	0.57	1	16	68
49313	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	State	Route 9W	Unknown	Concrete	Low	1.89	0	16	69
48943	Flow-Aligned	Reduced AOF	OK	Moderate barrier	Typical low-flow	1	Esopus	Pokonoie	Unknown	Concrete	Low	0.34		16	70
63596	Skewed (>45°)	Full AOP	OK	Insignificant barrier	Typical low-flow	1	Esopus	CSX railway	Hell Brook	Combination	Low	0.67		15	71
48616	Flow-Aligned	no score - mis	Poor	Minor barrier	Typical low-flow	1	Esopus	Esopus Avenue	Unknown	Metal	Low	0.24		15	72
48923	Flow-Aligned	Reduced AOF	Poor	Minor barrier	Typical low-flow	1	Esopus	Carney Road	Unknown	Metal	Low	0.54		15	73
52994	No data	Full AOP	OK	No barrier	Typical low-flow	1	Interstate	I 87	Walkill River	No data	Low	0.28	0	14	74
41502	Flow-Aligned	no score - mis	OK	no score - missing da	Typical low-flow	1	County	River Rd.	trib to Hudson River	Metal	Low	0.62		14	75
50525	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	-1	Esopus	Old US Route 9W	Rondout Creek		Low	0.73		14	76
48454	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	2	County	Union Center Rd.	tributary to Black Creek	Metal	Low	0.72	2	14	77
48907	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Hardenburg Road	Unknown	Combination	Low	0.64	0	14	78
49315	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	County	River Rd.	Unknown	Metal	Low	0.62	0	14	79
48950	Skewed (>45°)	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Millbrook road	Unknown	Concrete	Low	0.48	0	14	80
49346	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	State	Route 9w	Black Creek	Combination	Low	0.71		14	81
49347	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Black Creek Road	Black Creek	Combination	Low	0.61		14	82
48602	Skewed (>45°)	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Floyd Ackert	Unknown	Plastic	Low	0.38		14	83
49064	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	-1	Interstate	I 87	Walkill River		Low	0.27	0	13	84
49125	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	1	State	Route 32	Wallkill River	Combination	Low	0.14	0	13	85
49127	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	1	Esopus	Walkway	Walkill river	No data	Low	0.31	0	13	86
49328	Flow-Aligned	no score - mis	OK	no score - missing da	Typical low-flow	1	State	Route 9w	Unknown	No data	Low	0.33	0	13	87
49343	Flow-Aligned	no score - mis	OK	no score - missing da	Typical low-flow	1	Esopus	Floyd Ackert Road	Unknown	Plastic	Low	0.38		13	88
49350	Flow-Aligned	Full AOP	OK	No barrier	Typical low-flow	1	Esopus	Railroad	Unknown	No data	Low	0.28		13	89
48444	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Ulster Ave.	unnamed	Metal	Low	0.03	0	13	90
48601	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Swartekill Road	Unknown	Plastic	Low	0.56	2	13	91
48608	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Hermance Lane	Unknown	Concrete	Low	0.07	0	13	92
48614	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	2	Esopus	Esopus Avenue	Unknown	Metal	Low	0.29	0	13	93
48655	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	2	Esopus	Mountain View Road	Unknown	Metal	Low	0.33	0	13	94
48660	Flow-Aligned	No AOP	OK	Minor barrier	No Flow	1	Esopus	Dick Williams Lane	Unknown	Plastic	Low	0.00	0	13	95
48905	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	2	Esopus	Hardenburg road	Unknown	Plastic	Low	0.32	0	13	96
48906	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Hardenburg	Unknown	Plastic	Low	0.60	0	13	97
48909	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	State	Route 213	Unkown	Concrete	Low	0.09	0	13	98
48949	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Connelly	Unknown	Concrete	Low	0.02	0	13	99
49121	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Plutarch Road	Unknown	Metal	Low	0.44	1	13	100
49123	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	Esopus	Old route 32	Unknown	Concrete	Low	0.03	1	13	101
65288	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	2	Esopus	Hercules Drive	Unknown	Metal	Low	0.07		13	102
65289	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	1	Esopus	Hercules	Unknown	Concrete	Low	0.37		13	103
41501	Flow-Aligned	Reduced AOF	OK	Severe barrier	No Flow	1	County	River Rd.	trib to Hudson	Metal	Low	0.23		13	104
49342	Flow-Aligned	Reduced AOF	OK	Minor barrier	Typical low-flow	2	Esopus	West shore drive	Unknown	Concrete	Low	0.24		13	105
49344	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	Esopus	Winding Brook Road	Black Creek	Combination	Low	0.25		13	106

Town of Esopus / Ulster County Culvert Replacement Priortization

Survey_Id	Alignment	AOP Rating	Crossing Condition	Aquatic Barrier Rating	Flow Condition	Number Of Culverts	Road Owner	Road	Stream_Name	Material	Town/County Priority	Habitat Connectivity Total Length (Miles)	Future Max Return Period (yr)	Total	Ranking
53046	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	Typical low-flow	1	Esopus	Swarte Kill Road	Unknown	Metal	Low	0.38		13	107
65293	Skewed (>45°)	Reduced AOF	OK	Minor barrier	Moderate	2	Esopus	Rosner lane	Unknown	Plastic	Low	1.28		12	108
48884	Flow-Aligned	no score - mis	OK	no score - missing da	No Flow	1	County	Old Post Rd.	Swarte Kill	Metal	Low	1.28		11	109
48866	Flow-Aligned	Full AOP	OK	Insignificant barrier	Typical low-flow	1	County	Old Post Rd.	Black Creek	Concrete	Low	0.25	50	10	110
65294	Flow-Aligned	Reduced AOF	Poor	Minor barrier	Moderate	1	Esopus	Floy Ackert road	Unknown	Plastic	Low	0.38		10	111
65295	Flow-Aligned	Reduced AOF	Poor	Insignificant barrier	Moderate	2	Esopus	Private drive	Unknown	Metal	Low	0.45		10	112
48643	Flow-Aligned	Reduced AOF	Poor	Minor barrier	No Flow	1	Esopus	Catherine Lane	Unknown	Metal	Low	0.06		10	113
65290	Flow-Aligned	Full AOP	OK	Insignificant barrier	Moderate	1	Esopus	Driveway	Unknown	Combination	Low	0.65		9	114
65291	Flow-Aligned	Full AOP	OK	Insignificant barrier	Moderate	1	Esopus	Railroad	Unknown	Combination	Low	0.69		9	115
48694	Skewed (>45°)	Reduced AOF	OK	Minor barrier	No Flow	1	County	River Rd.	unnamed	Combination	Low	0.18		9	116
65296	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Private drive	Unknown	Metal	Low	0.03		8	117
65297	Flow-Aligned	Reduced AOF	OK	Minor barrier	No Flow	1	Esopus	Private drive	Unknown	Plastic	Low	0.04		8	118
65298	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Railroad	Unknown	Concrete	Low	0.23		8	119
65301	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Private	Unknowm	Metal	Low	0.12		8	120
65310	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Public park path	Unknown	Combination	Low	0.10		8	121
65346	Flow-Aligned	Reduced AOF	OK	Minor barrier	Moderate	1	Esopus	Private	Unkown	Metal	Low	0.12		8	122
48447	Flow-Aligned	Reduced AOF	OK	Minor barrier	No Flow	1	County	Union Center Rd.	unnamed	Metal	Low	0.03		8	123
48641	Flow-Aligned	Reduced AOF	OK	Insignificant barrier	No Flow	1	Esopus	Anna Lane	Unknown	Plastic	Low	0.23		8	124
48886	No data	Full AOP	No data	No barrier	No data	-1	County	Old Post Rd.			Low	0.86	0	7	125
50527	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Unkown	Rondout Creek		Low	0.90	2	7	126
50487	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Frank Koenig Blvd/ Rc	Rondout Creek		Low	0.91		7	127
48696	No data	Full AOP	No data	No barrier	No data	-1	Esopus				Low	0.00	0	6	128
50481	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Hilterbrant Lane	Unknown		Low	0.05		6	129
50482	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Floridia Street	Unkown		Low	0.00		6	130
50483	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Tervo Road	Unkown		Low	0.00		6	131
50532	No data	Full AOP	No data	No barrier	No data	-1	Esopus				Low	0.23		6	132
54846	No data	Full AOP	No data	No barrier	No data	-1	Esopus	Floyd Ackert Road	Unkown		Low	0.47		6	133
48645	Flow-Aligned	no score - mis	Unknown	no score - missing da	No data	-1	Esopus	Catherine Lane			Low	0.24	2	5	134
65320	Flow-Aligned	Reduced AOF	New	Insignificant barrier	Moderate	1	Esopus	Private	Unknown	Concrete	Low	0.29		5	135

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APPENDIX B

NYS DEC Stream Crossing Guidelines

Stream Crossings - Protecting and Restoring Stream Continuity

This information was developed for those involved in designing and constructing stream crossings – with an eye toward protecting and restoring stream continuity.

The guidelines and standards presented here describe minimum criteria to avoid fragmentation of streams. The objective is to maintain natural conditions that do not restrict the movement of fish and wildlife through the stream system. Although these guidelines meet this objective, additional engineering design may be necessary to ensure structural integrity and appropriate hydraulic capacity.

Introduction

Photo by Scott Jackson

New York State is rich with many miles of high quality, productive streams. This valuable resource sustains natural communities by nourishing vegetation and providing food sources, shelter and spawning areas for fish and wildlife. It also provides innumerable additional benefits to us, such as recreation and aesthetic enjoyment and economic support.

Streams are long, linear ecosystems. The processes that nourish these ecosystems are interrelated and dependent on "continuity" of the stream corridor. Our transportation and access needs often result in fragmentation of streams. Many stream crossings, such as bridges and culverts, act as barriers to fish and wildlife. Awareness of the effects of stream crossings plays an important role in maintaining stream continuity.

The design and condition of stream crossings determines whether a stream can function naturally and whether animals can move unimpeded along the stream corridor. These are key elements in assuring the overall health of the system. This web page describes stream crossing designs that promote natural stream conditions and allow unrestricted movement within stream corridors while maintaining our access and transportation needs.

Stream Continuity and Natural Communities

The continuity of streams, as well as their connection to riparian and upland areas, is necessary to the well being of all species that inhabit or are associated with stream ecosystems. When designing and installing stream crossings, the needs of invertebrates, fish, amphibians, reptiles, and mammals must be taken into account. These animals rely on being able to move unimpeded, both daily and seasonally, through the stream and adjacent areas. Finding shelter, escaping danger, searching for food, and maintaining genetic diversity are some of the many activities that require stream continuity and connection to the watershed.

Continuity for Healthy Stream Ecosystems

As organisms move through their various life stages, they need access to a variety of habitat areas. Their needs may change as they grow and develop; however, in general they rely on adequate spawning and nursery areas; optimal temperatures and oxygen levels; natural substrates; good cover and food supplies; and optimal hydrologic conditions such as water depth and velocity. Disrupting the continuity of a stream can affect these conditions as well as an animal's ability to access prime areas.

Access to coldwater habitats

During the summer, species such as brook trout travel to and congregate in cold water sections of streams and tributaries. If fish are prevented from reaching these areas, they can become susceptible to heat stress and mortality. Also, if travel is limited, they may become overcrowded and vulnerable to disease and predators.

Access to feeding areas

Different habitats provide various feeding opportunities throughout a day or season, and species regularly travel to take advantage of these resources. Restricting access to prime feeding areas can affect a variety of species.

Access to breeding, spawning, and nursery areas

Some species need to travel to reach spawning areas in streams. Barriers and restrictions can prevent adult fish from traveling to spawning areas, and offspring from dispersing into juvenile and eventually adult habitat.

Natural dispersal

Natural dispersal is important, especially when streams are damaged by major events such as pollution, flooding, or severe drought. Dispersal is a critical aspect in returning a stream to a healthy, productive environment. When animals are impeded from traveling in and along stream corridors, they may be subject to increased predation and mortalities, reducing the ability to repopulate an area.

Other

Streams nourish nearby habitats. Poor crossing design and installation can result in degradation of these areas and adversely affect native plants and animals.

Recognizing Problems

The following three common stream crossing problems can create barriers to fish and wildlife and lead to several consequences. Recognizing poor crossing structures and installations is an important step in evaluating whether they should be fixed or replaced.

Undersized Crossings: Undersized crossings can result in restrictions of natural flow, scouring and erosion, high flow velocities, clogging and ponding.

Shallow Crossings: Water depths are too low for many organisms to move through, and the bottom may lack appropriate stream bed material.

Double Culverts: Restriction of natural flow, clogging with debris, ponding and flooding.

Perched Crossings: Low flow, unnatural bed material, scouring and erosion, ponding.

Consequences of Poor Crossings

Low Flow

Species movement within the stream is restricted during low flow. Fish and other aquatic organisms need sufficient water depth to move through a stream crossing. Low flows may also lead to stagnant conditions within the crossing.

Unnatural Bed Materials

Metal and concrete are not appropriate materials for species that travel along the streambed. The substrate in or under a crossing should match the natural substrate of the surrounding stream in order to maintain natural conditions.

Scouring and Erosion

In undersized crossings, high water velocities may scour natural substrates in and downstream of the crossing, degrading habitat for fish and other wildlife. High water velocities and related flow alterations may also erode stream banks. In perched culverts, scour pools often develop downstream of the culvert and eventually undercut the culvert and impede upstream passage.

High Flow

Water velocity is higher in a constricted crossing than it is upstream or downstream. This high flow degrades wildlife habitat and weakens the structural integrity of a crossing. During floods, undersized crossings may be filled with fast-moving water, exacerbating the problems associated with poorly designed crossings.

Clogging

Some crossings – especially under-sized ones – can become clogged by woody debris, leaves, and other material. This may intensify the effect of floods and make a crossing impassable to wildlife. In addition, costly, routine maintenance is often required.

Ponding

Under-sized crossings can cause water to backup in areas upstream of the crossing. It may occur year-round, during seasonal high water or floods, or when crossings become clogged. Ponding can lead to property damage, road and bank erosion, and severe changes in upstream habitat.

Solutions

Stream crossings should be properly sized, placed and installed. They should be large enough to allow fish, wildlife, and floods to pass, and so that stream flows and velocities are not altered. They should also have either an open bottom or be imbedded into the stream bed so that substrate and water depth are similar to the surrounding stream.

Stream Crossing Guidelines

A goal of this information is to provide practical, effective, long-term solutions for protecting and restoring stream continuity. Crossings that meet this goal are those that are “invisible” to fish and wildlife. They should be designed and installed so that natural stream flow and substrate are mimicked throughout the crossing and so that they do not constrict or fragment the stream.

Good crossings that create no noticeable change in the stream include bridges and open-bottom arches and culverts that sufficiently span the stream channel bed, and box and pipe culverts that sufficiently span and are adequately sunk into the stream channel bed.

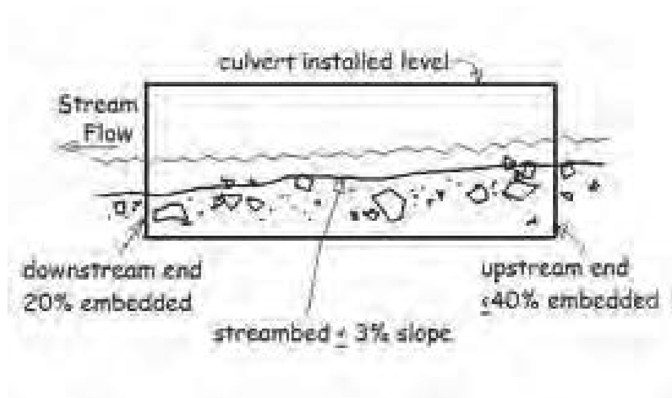
Stream Crossing Standards

The following recommended standards are effective for reducing stream barriers and impediments to fish and wildlife.

I. TYPE

A. Bridges and bottomless arches are preferred and should be used whenever possible.

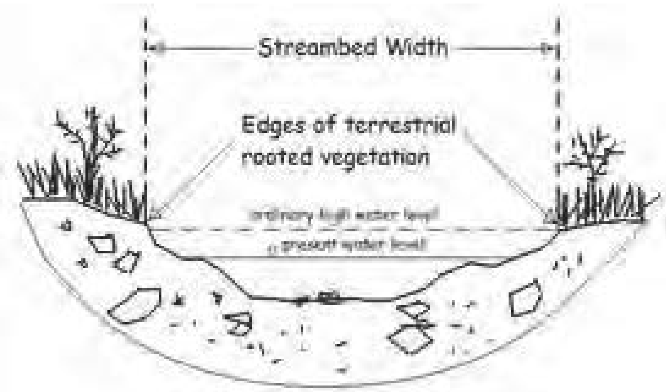
B. Box and Pipe culverts, if used, must be:



- Embedded into the streambed to at least 20 percent of the culvert height at the downstream invert
- Used only on “flat” streambeds (slopes no steeper than 3 percent)
- Installed level

II. WIDTH

The crossing opening (whether open arch, bridge, or culvert) should be at least 1.25 times the width of the stream channel bed. This width is measured bank to bank at the ordinary high-water level (ohwl) or edges of terrestrial, rooted vegetation.



Determining Streambed Width

An average of three measurements, (project location and straight sections of the stream upstream and downstream) should be used to determine the channel bed width.

III. DEPTH AND VELOCITY

At low flows, water depths and velocities should be the same as they are in natural areas upstream and down stream of the crossing.

IV. SUBSTRATE

Natural substrate should be used within the crossing, and it should match the upstream and downstream substrates. It should resist displacement during floods and should be designed so that appropriate material is maintained during normal flows.

Conclusion

Awareness of the benefits of maintaining stream continuity is essential to protecting this valuable resource. The stream crossing designed standards presented here promote stream continuity, allowing unrestricted movement of fish and wildlife within the stream corridor while maintaining our access and transportation needs.

This information should be used as a supplement to sound engineering designs that provide appropriate structural integrity and hydraulic capacity.

Required DEC Permits

DEC permits are required for projects involving:

- All streams classified as C(T) or higher
- All navigable waters
- NYSDEC regulated freshwater wetlands outside the Adirondack Park. (NOTE: Wetlands in the Adirondack Park are regulated by the Adirondack Park Agency.)

Other Potential Permits

Permits may also be required from other government agencies, such as but not limited to:

Adirondack Park Agency (518-891-4050) – If your proposal involves stream crossing work in the Adirondack Park, please contact the Adirondack Park Agency before finalizing plans. This will help to eliminate unnecessary delays and assure that your project design satisfies both agencies.

U.S. Army Corps of Engineers (NY District: 518-266-6350, Buffalo District: 716-879-4330) – The Corps of Engineers regulates activities involving dredging, excavation, placement of fill, or construction of certain structures in waterways and wetlands of the United States.

Further Information and Jurisdictional Inquiries

Contact the appropriate regional DEC Environmental Permits office, based on the county where the project is located.

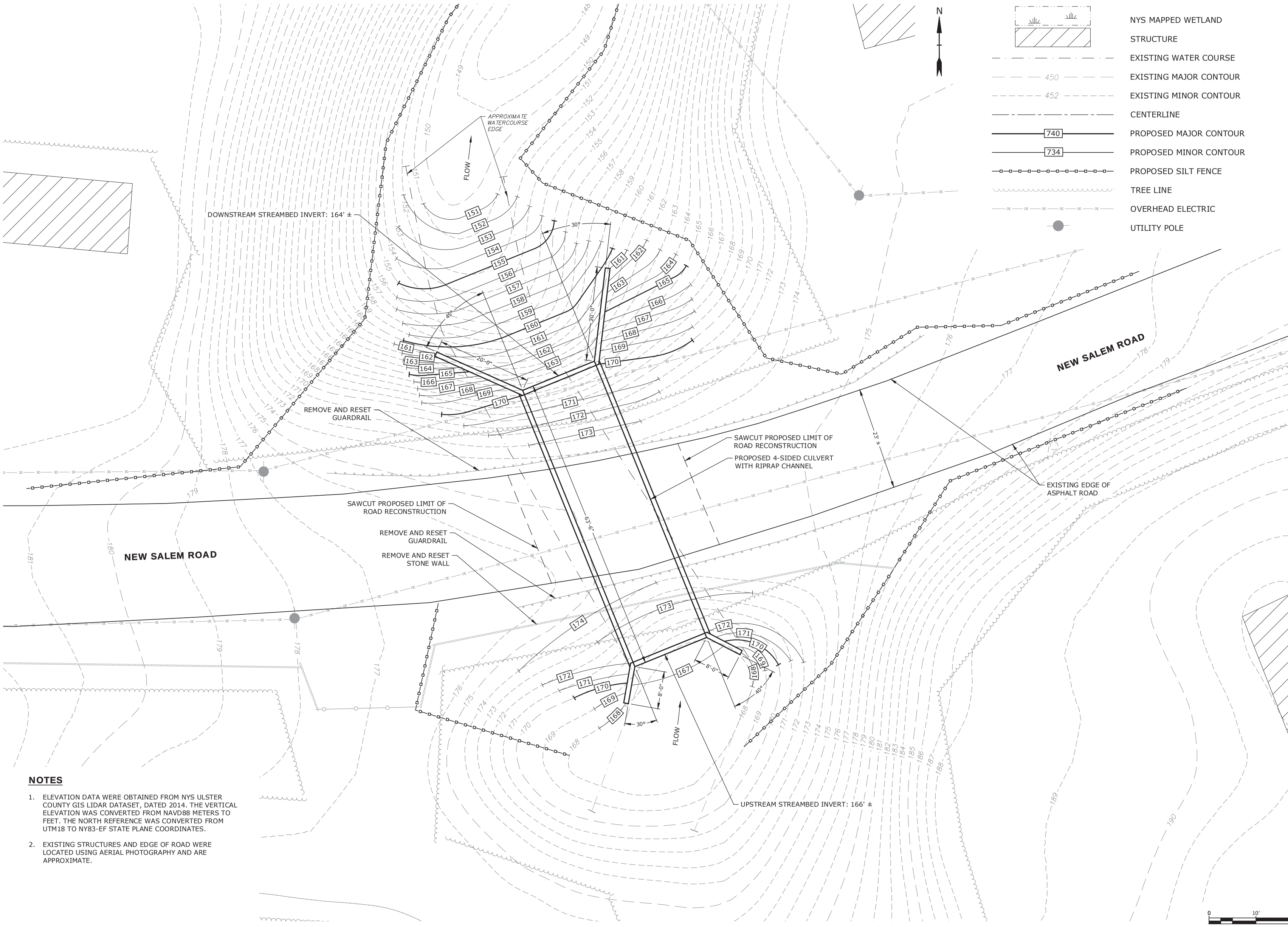
References

Singler, A. and Graber, B., 2005. Massachusetts Stream Crossings Handbook. Massachusetts Riverways Program, Massachusetts Department of Fish and Game

Bates, K. P.E., 2003. Design of Road Culverts for Fish Passage. Washington Department of Fish and Wildlife

River and Stream Continuity Project, 2004. River and Stream Continuity Project Web Page (see link in right column). University of Massachusetts Amherst.

APPENDIX C
Concept Culvert Replacement Drawings and OPCCs



LEGEND:

	NYS MAPPED WETLAND
	STRUCTURE
	EXISTING WATER COURSE
450	EXISTING MAJOR CONTOUR
452	EXISTING MINOR CONTOUR
	CENTERLINE
740	PROPOSED MAJOR CONTOUR
734	PROPOSED MINOR CONTOUR
	PROPOSED SILT FENCE
	TREE LINE
	OVERHEAD ELECTRIC
	UTILITY POLE

NOTES

1. ELEVATION DATA WERE OBTAINED FROM NYS ULSTER COUNTY GIS LIDAR DATASET, DATED 2014. THE VERTICAL ELEVATION WAS CONVERTED FROM NAVD88 METERS TO FEET. THE NORTH REFERENCE WAS CONVERTED FROM UTM18 TO NY83-EF STATE PLANE COORDINATES.
2. EXISTING STRUCTURES AND EDGE OF ROAD WERE LOCATED USING AERIAL PHOTOGRAPHY AND ARE APPROXIMATE.

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Esopus Town and County Road Concept

NEIWPCC

Esopus, NY

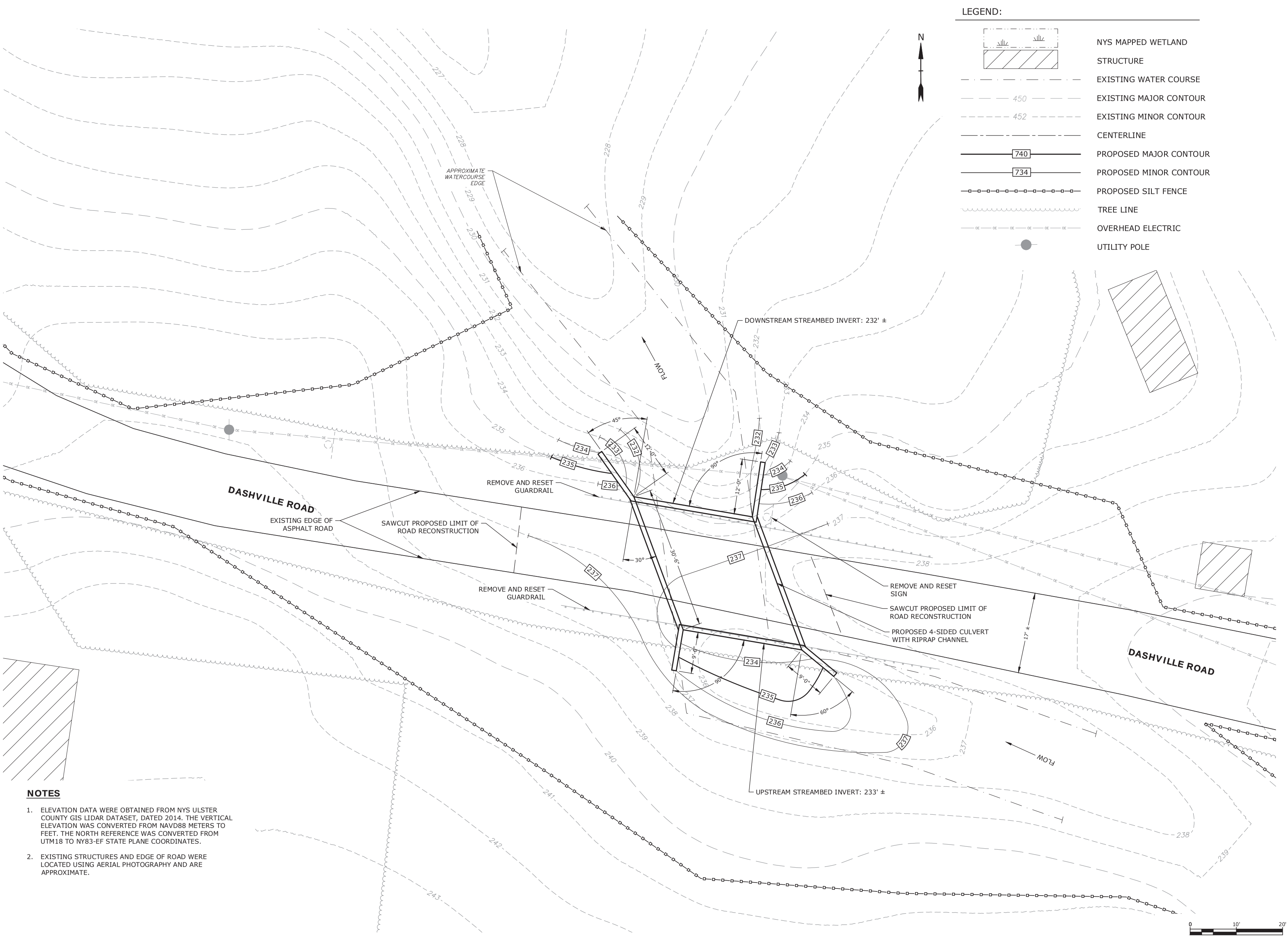
MARK	DATE	DESCRIPTION

PROJECT NO:	N5008-002
DATE:	09/16/2019
FILE:	N5008-02-C-101-NSAL.dwg
DRAWN BY:	RM, RRB
CHECKED:	DFV
APPROVED:	DH

CULVERT PLAN
41505 - NEW SALEM ROAD

SCALE: 1" = 10'

C-101
SHEET 3 OF 9



NOTES

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2. EXISTING STRUCTURES AND EDGE OF ROAD WERE LOCATED USING AERIAL PHOTOGRAPHY AND ARE APPROXIMATE.

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DRAWN BY:	RM, RRB
CHECKED:	DFV
APPROVED:	DH

CULVERT PLAN
49129 - DASHVILLE ROAD

SCALE: 1" = 10'

C-102
SHEET 4 OF 9

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LEGEND:

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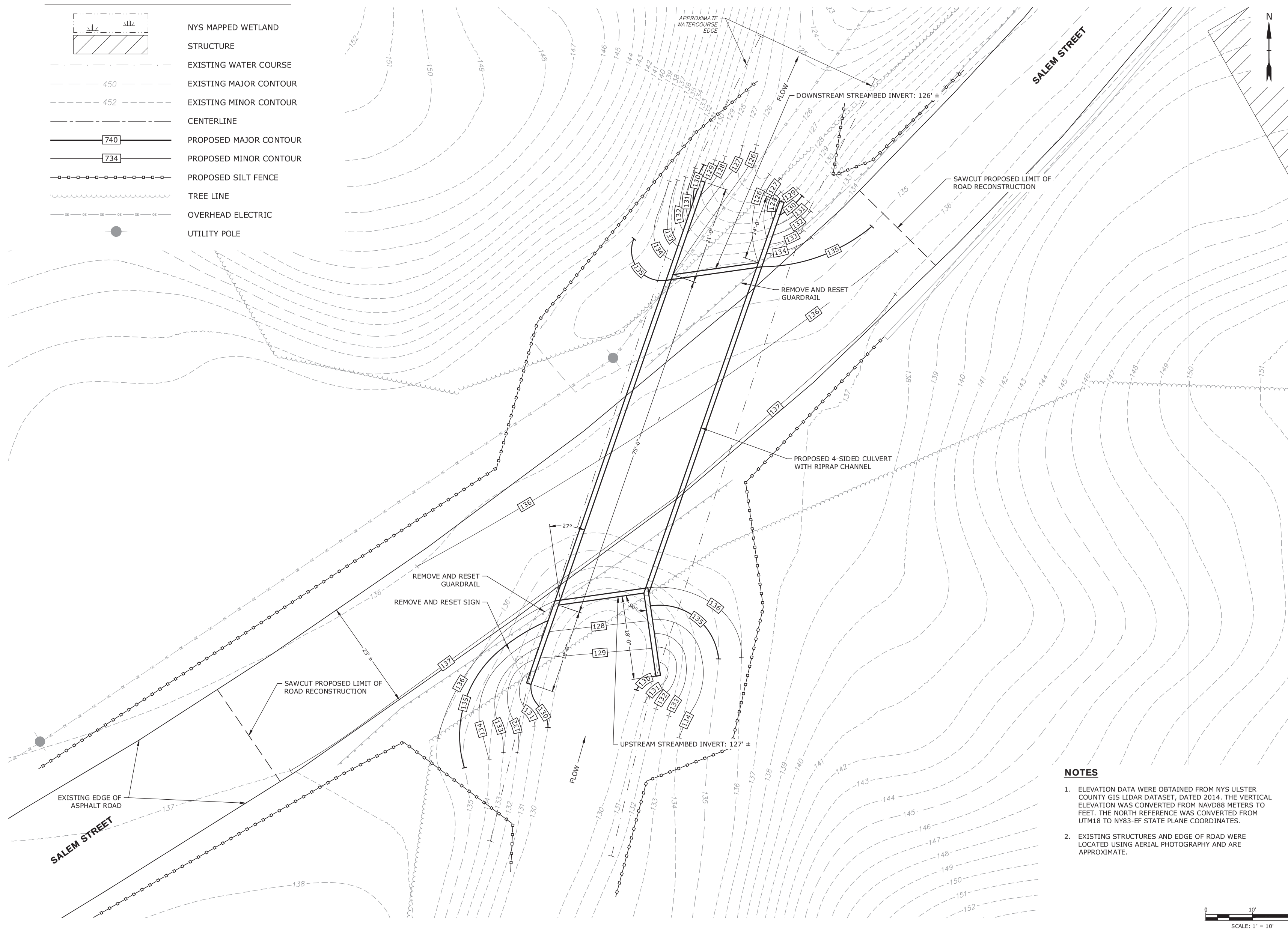
	STRUCTURE
	EXISTING WATER COURSE
450	EXISTING MAJOR CONTOUR
452	EXISTING MINOR CONTOUR
	CENTERLINE
740	PROPOSED MAJOR CONTOUR
734	PROPOSED MINOR CONTOUR
	PROPOSED SILT FENCE
	TREE LINE
	OVERHEAD ELECTRIC
	UTILITY POLE



NOTES

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2. EXISTING STRUCTURES AND EDGE OF ROAD WERE LOCATED USING AERIAL PHOTOGRAPHY AND ARE APPROXIMATE.

0 10' 20'
SCALE: 1" = 10'

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FILE:	N5008-02-C-103-SALM.dwg
DRAWN BY:	RM, RRB
CHECKED:	DFV
APPROVED:	DH

CULVERT PLAN
48953 - SALEM STREET

SCALE: 1" = 10'

C-103
SHEET 5 OF 9

Last Saved: 9/26/2019
Plotted On:Sep 26, 2019-3:28pm By: RRB
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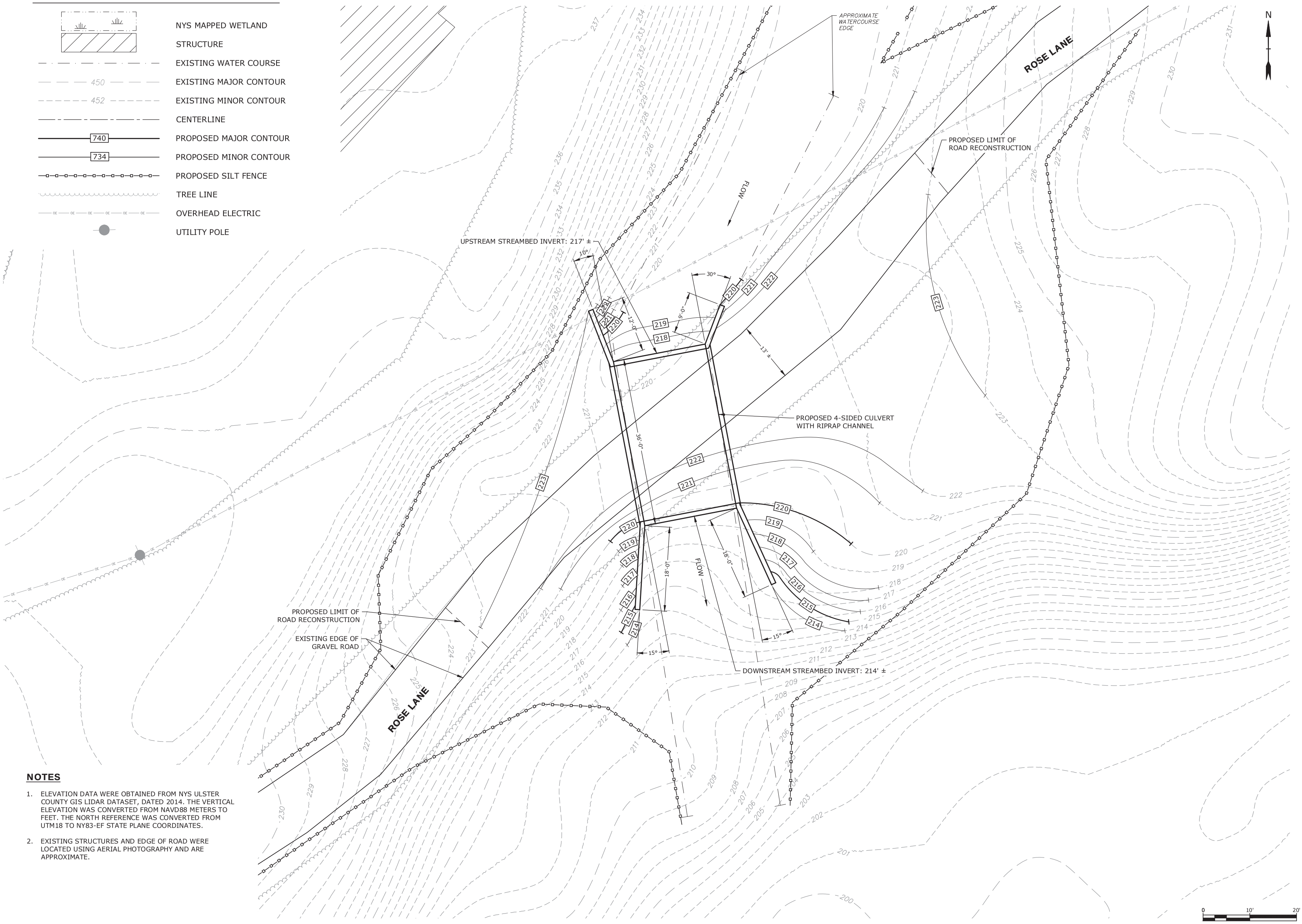

NOTES

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FILE:	N5008-02-C-104-ROSE.dwg
DRAWN BY:	RM, RRB
CHECKED:	DFV
APPROVED:	DH

CULVERT PLAN
48926 - ROSE LANE

SCALE: 1" = 10'

C-104
SHEET 6 OF 9

Last Saved: 9/25/2019
Plotted On:Sep 26, 2019-3:33pm By: RRB
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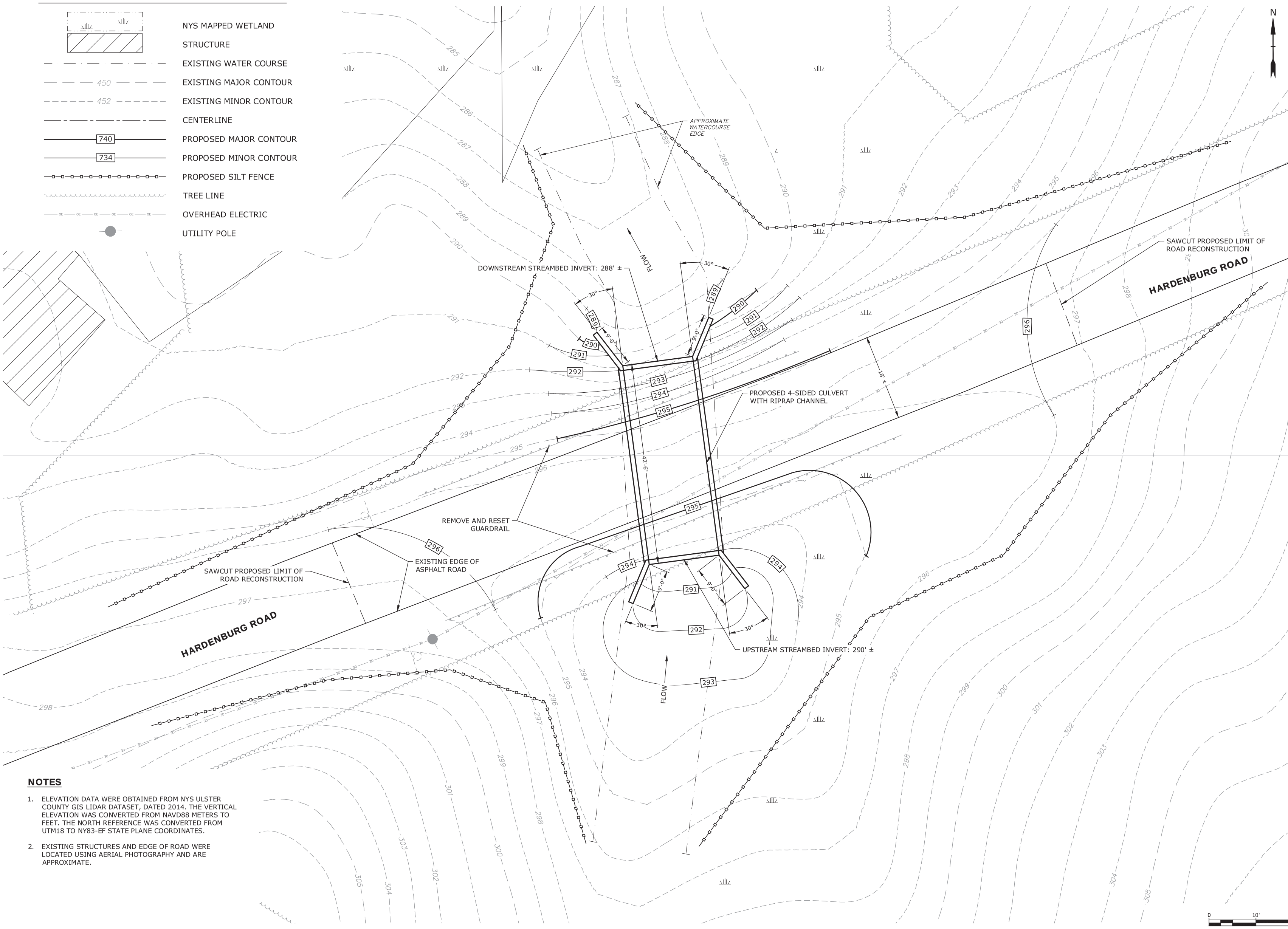

LEGEND:

- NYS MAPPED WETLAND
- STRUCTURE
- EXISTING WATER COURSE
- 450 EXISTING MAJOR CONTOUR
- 452 EXISTING MINOR CONTOUR
- CENTERLINE
- 740 PROPOSED MAJOR CONTOUR
- 734 PROPOSED MINOR CONTOUR
- PROPOSED SILT FENCE
- TREE LINE
- OVERHEAD ELECTRIC
- UTILITY POLE

NOTES

1. ELEVATION DATA WERE OBTAINED FROM NYS ULSTER COUNTY GIS LIDAR DATASET, DATED 2014. THE VERTICAL ELEVATION WAS CONVERTED FROM NAVD88 METERS TO FEET. THE NORTH REFERENCE WAS CONVERTED FROM UTM18 TO NY83-EF STATE PLANE COORDINATES.
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PROJECT NO:	N5008-002
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FILE:	N5008-02-C-105-HARD.dwg
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APPROVED:	DH

CULVERT PLAN
48925 - HARDENBURG ROAD

SCALE: 1" = 10'

C-105
SHEET 7 OF 9

Last Saved: 9/25/2019
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LEGEND:

- NYS MAPPED WETLAND
- STRUCTURE
- EXISTING WATER COURSE
- 450 EXISTING MAJOR CONTOUR
- 452 EXISTING MINOR CONTOUR
- CENTERLINE
- 740 PROPOSED MAJOR CONTOUR
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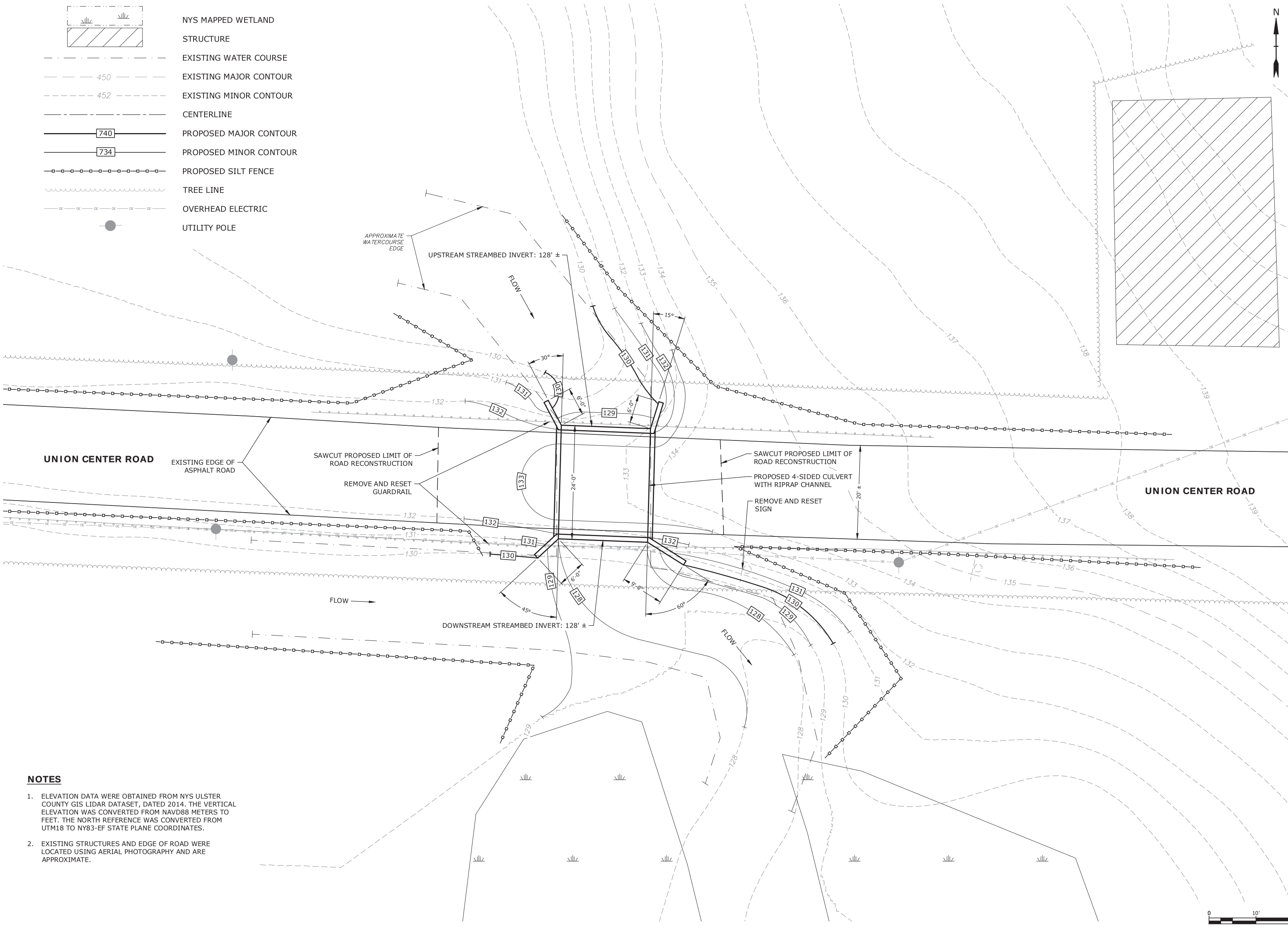
- PROPOSED SILT FENCE
- TREE LINE
- OVERHEAD ELECTRIC
- UTILITY POLE



NOTES

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PROJECT NO:	N5008-002
DATE:	09/16/2019
FILE:	N5008-02-C-106-UCEN.dwg
DRAWN BY:	RM, RRB
CHECKED:	DFV
APPROVED:	DH

CULVERT PLAN
48626 - UNION CENTER ROAD

SCALE: 1" = 10'

C-106
SHEET 8 OF 9

Last Saved: 9/25/2019
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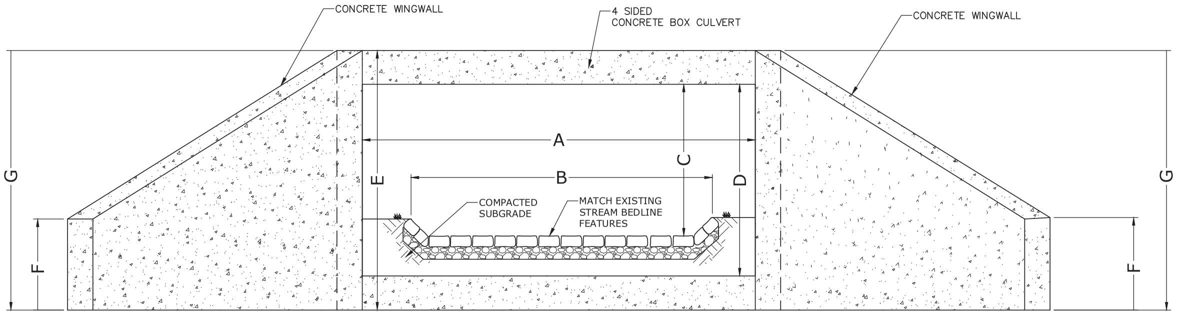

4 SIDED CULVERT SECTION
NO SCALE

CULVERT AND WINGWALLS							
LOCATION	DIMENSIONS						
	A	B	C	D	E	F	G
41505 - NEW SALEM ROAD (UPSTREAM)	16'-6"	13'-0"	5'-0"	6'-4"	8'-6"	4'-6"	8'-6"
41505 - NEW SALEM ROAD (DOWNSTREAM)	16'-6"	13'-0"	5'-0"	6'-4"	8'-6"	2'-0"	11'-0"
49129 - DASHVILLE ROAD (UPSTREAM)	26'-0"	15'-0"	4'-0"	5'-0"	7'-6"	5'-6"	7'-6"
49129 - DASHVILLE ROAD (DOWNSTREAM)	26'-0"	15'-0"	4'-0"	5'-0"	7'-6"	4'-6"	7'-6"
48953 - SALEM STREET (UPSTREAM)	18'-6"	14'-6"	8'-0"	10'-0"	12'-2"	6'-2"	12'-2"
48953 - SALEM STREET (DOWNSTREAM)	18'-6"	14'-6"	8'-0"	10'-0"	12'-2"	6'-2"	12'-2"
48926 - ROSE LANE (UPSTREAM)	20'-0"	12'-0"	4'-0"	5'-0"	7'-2"	L: 3'-2" R: 7'-2"	7'-2"
48926 - ROSE LANE (DOWNSTREAM)	20'-0"	12'-0"	4'-0"	5'-0"	7'-2"	2'-0"	8'-0"
48925 - HARDENBURG ROAD (UPSTREAM)	15'-0"	12'-0"	3'-0"	4'-0"	6'-0"	4'-0"	6'-0"
48925 - HARDENBURG ROAD (DOWNSTREAM)	15'-0"	12'-0"	3'-0"	4'-0"	6'-0"	3'-0"	6'-0"
48626 - UNION CENTER ROAD (UPSTREAM)	19'-0"	15'-0"	3'-0"	4'-0"	6'-2"	4'-2"	6'-2"
48626 - UNION CENTER ROAD (DOWNSTREAM)	19'-0"	15'-0"	3'-0"	4'-0"	6'-2"	4'-2"	6'-2"

NOTE

1. "L" & "R" REPRESENT THE "LEFT" AND "RIGHT" WINGWALL FACING DOWNSTREAM.

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Esopus Town and County Road Concept

NEIWPCC

Esopus, NY

MARK	DATE	DESCRIPTION

PROJECT NO:	N5008-002
DATE:	09/16/2019
FILE:	N5008-02-C-107-CULV.dwg
DRAWN BY:	RRB
CHECKED:	DFV
APPROVED:	DH

CULVERT DETAILS

SCALE: NO SCALE

C-501
SHEET 9 OF 9

Last Saved: 9/16/2019
Plotted On:Sep 26, 2019-3:43pm By: RRB
Tighe & Bond:J:\N\N5008 NEIWPCC\02 - Restoration Connectivity\Drawings_Figures\AutoCAD\Sheet\Conceptual Design\Sheet\N5008-02-C-107-CULV.dwg

TABLE D-1

ENGINEER'S OPINION OF PROBABLE COST Tighe&Bond

Project: NEIWPCC Esopus Town and County Road Concept - New Salem Road #41505
Location: Esopus, NY

Estimate Type:
- [x] Conceptual
- [ ] Preliminary Design
- [ ] Design Development
- [ ] Construction
- [ ] Change Order

Prepared By: RRB
Date Prepared: 9/26/2019
Updated by:
Date Updated:
T&B Project No.: N5008-004-02

Bid Item Number	Item No.	Description	Quantity	Units	Material/Installed Cost $/Unit	Material/Installed Cost Total	Installation $/Unit	Installation Total	Total
1		**MOBILIZATION , DEMOBILIZATION AND RELATED EXPENSES**							
	1	Mob., Demob. & Related Exp. (7.5% Total Const.)	1	LS	$23,900	$23,900	$0	$0	$23,900
						$23,900		**$0**	**$23,900**
2		**GENERAL REQUIREMENTS**							
	1	General Requirements (10% Total Const.)	1	LS	$31,500	$31,500	$0	$0	$31,500
	2	Temporary Controls/Water Handling	1	LS	$20,000.00	$20,000	$0	$0	$20,000
	3	Silt Fence	530	LF	$4.00	$2,120	$0	$0	$2,120
	4	Traffic Control	1	LS	$6,500.00	$6,500	$0	$0	$6,500
						$60,120		**$0**	**$60,120**
3		**GENERAL CONSTRUCTION**							
		Division 2 - Site Work							
	1	Site Preparation (Tree and Shrub Removal)	1	LS	$10,000.00	$10,000	$0	$0	$10,000
	2	Existing Culvert Demolition	1	LS	$5,000.00	$5,000	$0	$0	$5,000
	3	Excavation/Backfill/Compaction/Grading	900	CY	$25.00	$22,500	$0	$0	$22,500
	4	Borrow Materials	45	CY	$40.00	$1,800	$0	$0	$1,800
	5	Riprap Stone Material	165	CY	$100.00	$16,500	$0	$0	$16,500
	6	4-Sided Concrete Box Culvert	1	LS	$112,500.00	$112,500	$28,125	$28,125	$140,625
	7	Concrete Wingwalls (Assumed 1' thick)	13.5	CY	$1,200.00	$16,200	$300	$4,050	$20,250
	8	Bituminous Concrete Pavement (Assumed 4" thick)	23	TON	$120.00	$2,760	$0	$0	$2,760
	9	Process Gravel Base (Assumed 8" thick)	22	CY	$42.00	$924	$0	$0	$924
	10	Remove and Reset Guardrail	100	LF	$15.00	$1,500	$0	$0	$1,500
	11	Remove and Reset Stone Wall	50	LF	$100.00	$5,000	$0	$0	$5,000
	12	Pavement Markings (4" Wide)	200	LF	$0.60	$120	$0	$0	$120
	13	Loam and Seed	300	SY	$7.50	$2,250	$0	$0	$2,250
	14	Landscaping/Restoration	1	LS	$5,000.00	$5,000	$0	$0	$5,000
						$202,054.00		**$32,175.00**	**$234,229.00**

Construction Subtotal Cost	**$318,300**
Contingency - 20% of Construction Cost	**$63,700**
Total Construction Cost	**$382,000**
Engineering & Permitting Services (10%)	**$38,200**
Construction/Permanent Easements (3%)	**$11,500**
Total Opinion of Probable Cost	**$431,700**

TABLE D-2

ENGINEER'S OPINION OF PROBABLE COST Tighe&Bond

Project: NEIWPCC Esopus Town and County Road Concept - Dashville Road #49129
Location: Esopus, NY

Estimate Type:
- ☑ Conceptual
- ☐ Preliminary Design
- ☐ Design Development
- ☐ Construction
- ☐ Change Order

Prepared By: RRB
Date Prepared: 9/26/2019
Updated by:
Date Updated:
T&B Project No.: N5008-004-02

Bid Item Number	Item No.	Description	Quantity	Units	Material/Installed Cost $/Unit	Material/Installed Cost Total	Installation $/Unit	Installation Total	Total
1	**MOBILIZATION , DEMOBILIZATION AND RELATED EXPENSES**								
	1	Mob., Demob. & Related Exp. (7.5% Total Const.)	1	LS	$24,100	$24,100	$0	$0	$24,100
						$24,100		**$0**	**$24,100**
2	**GENERAL REQUIREMENTS**								
	1	General Requirements (10% Total Const.)	1	LS	$31,800	$31,800	$0	$0	$31,800
	2	Temporary Controls/Water Handling	1	LS	$20,000.00	$20,000	$0	$0	$20,000
	3	Silt Fence	620	LF	$4.00	$2,480	$0	$0	$2,480
	4	Traffic Control	1	LS	$6,500.00	$6,500	$0	$0	$6,500
						$60,780		**$0**	**$60,780**
3	**GENERAL CONSTRUCTION**								
	Division 2 - Site Work								
	1	Site Preparation (Tree and Shrub Removal)	1	LS	$5,000.00	$5,000	$0	$0	$5,000
	2	Existing Culvert Demolition	1	LS	$2,500.00	$2,500	$0	$0	$2,500
	3	Excavation/Backfill/Compaction/Grading	600	CY	$25.00	$15,000	$0	$0	$15,000
	4	Borrow Materials	32	CY	$40.00	$1,280	$0	$0	$1,280
	5	Riprap Stone Material	120	CY	$100.00	$12,000	$0	$0	$12,000
	6	4-Sided Concrete Box Culvert	1	LS	$139,000.00	$139,000	$34,750	$34,750	$173,750
	7	Concrete Wingwalls (Assumed 1' thick)	9.5	CY	$1,200.00	$11,400	$300	$2,850	$14,250
	8	Bituminous Concrete Pavement (Assumed 4" thick)	25	TON	$120.00	$3,000	$0	$0	$3,000
	9	Process Gravel Base (Assumed 8" thick)	25	CY	$42.00	$1,050	$0	$0	$1,050
	10	Remove and Reset Guardrail	100	LF	$15.00	$1,500	$0	$0	$1,500
	11	Remove and Reset Street Sign	1	EA	$100.00	$100	$0	$0	$100
	12	Pavement Markings (4" Wide)	950	LF	$0.60	$570	$0	$0	$570
	13	Loam and Seed	134	SY	$7.50	$1,005	$0	$0	$1,005
	14	Landscaping/Restoration	1	LS	$5,000.00	$5,000	$0	$0	$5,000
						$198,405.00		**$37,600.00**	**$236,005.00**

Construction Subtotal Cost	**$320,900**
Contingency - 20% of Construction Cost	**$64,200**
Total Construction Cost	**$385,100**
Engineering & Permitting Services (10%)	**$38,600**
Construction/Permanent Easements (3%)	**$11,600**
Total Opinion of Probable Cost	**$435,300**

TABLE D-3

ENGINEER'S OPINION OF PROBABLE COST Tighe&Bond

Project: NEIWPCC Esopus Town and County Road Concept - Salem Street #48953
Location: Esopus, NY

Estimate Type: ☑ Conceptual ☐ Preliminary Design ☐ Design Development ☐ Construction ☐ Change Order

Prepared By: RRB
Date Prepared: 9/26/2019
Updated by:
Date Updated:
T&B Project No.: N5008-004-02

Bid Item Number	Item No.	Description	Quantity	Units	Material/Installed Cost $/Unit	Material/Installed Cost Total	Installation $/Unit	Installation Total	Total
1	**MOBILIZATION , DEMOBILIZATION AND RELATED EXPENSES**								
	1	Mob., Demob. & Related Exp. (7.5% Total Const.)	1	LS	$35,600	$35,600	$0	$0	$35,600
						$35,600		**$0**	**$35,600**
2	**GENERAL REQUIREMENTS**								
	1	General Requirements (10% Total Const.)	1	LS	$48,100	$48,100	$0	$0	$48,100
	2	Temporary Controls/Water Handling	1	LS	$20,000.00	$20,000	$0	$0	$20,000
	3	Silt Fence	540	LF	$4.00	$2,160	$0	$0	$2,160
	4	Traffic Control	1	LS	$6,500.00	$6,500	$0	$0	$6,500
						$76,760		**$0**	**$76,760**
3	**GENERAL CONSTRUCTION**								
	Division 2 - Site Work								
	1	Site Preparation (Tree and Shrub Removal)	1	LS	$8,000.00	$8,000	$0	$0	$8,000
	2	Existing Culvert Demolition	1	LS	$2,000.00	$2,000	$0	$0	$2,000
	3	Excavation/Backfill/Compaction/Grading	1,575	CY	$25.00	$39,375	$0	$0	$39,375
	4	Borrow Materials	57	CY	$40.00	$2,280	$0	$0	$2,280
	5	Riprap Stone Material	137	CY	$100.00	$13,700	$0	$0	$13,700
	6	4-Sided Concrete Box Culvert	1	LS	$195,000.00	$195,000	$48,750	$48,750	$243,750
	7	Concrete Wingwalls (Assumed 1' thick)	24	CY	$1,200.00	$28,800	$300	$7,200	$36,000
	8	Bituminous Concrete Pavement (Assumed 4" thick)	105	TON	$120.00	$12,600	$0	$0	$12,600
	9	Process Gravel Base (Assumed 8" thick)	105	CY	$42.00	$4,410	$0	$0	$4,410
	10	Remove and Reset Guardrail	150	LF	$15.00	$2,250	$0	$0	$2,250
	11	Remove and Reset Street Sign	1	EA	$100.00	$100	$0	$0	$100
	12	Pavement Markings (4" Wide)	700	LF	$0.60	$420	$0	$0	$420
	13	Loam and Seed	406	SY	$7.50	$3,045	$0	$0	$3,045
	14	Landscaping/Restoration	1	LS	$5,000.00	$5,000	$0	$0	$5,000
						$316,980.00		**$55,950.00**	**$372,930.00**

Construction Subtotal Cost	**$485,300**
Contingency - 20% of Construction Cost	**$97,100**
Total Construction Cost	**$582,400**
Engineering & Permitting Services (10%)	**$58,300**
Construction/Permanent Easements (3%)	**$17,500**
Total Opinion of Probable Cost	**$658,200**

TABLE D-4

ENGINEER'S OPINION OF PROBABLE COST Tighe&Bond

Project: NEIWPCC Esopus Town and County Road Concept - Rose Lane #48926
Location: Esopus, NY

Estimate Type: ☑ Conceptual ☐ Preliminary Design ☐ Design Development ☐ Construction ☐ Change Order

Prepared By: RRB
Date Prepared: 9/26/2019
Updated by:
Date Updated:
T&B Project No.: N5008-004-02

Bid Item Number	Item No.	Description	Quantity	Units	Material/Installed Cost $/Unit	Material/Installed Cost Total	Installation $/Unit	Installation Total	Total
1		**MOBILIZATION , DEMOBILIZATION AND RELATED EXPENSES**							
	1	Mob., Demob. & Related Exp. (7.5% Total Const.)	1	LS	$17,900	$17,900	$0	$0	$17,900
						$17,900		**$0**	**$17,900**
2		**GENERAL REQUIREMENTS**							
	1	General Requirements (10% Total Const.)	1	LS	$24,200	$24,200	$0	$0	$24,200
	2	Temporary Controls/Water Handling	1	LS	$20,000.00	$20,000	$0	$0	$20,000
	3	Silt Fence	440	LF	$4.00	$1,760	$0	$0	$1,760
	4	Traffic Control	1	LS	$6,500.00	$6,500	$0	$0	$6,500
						$52,460		**$0**	**$52,460**
3		**GENERAL CONSTRUCTION**							
	Division 2 - Site Work								
	1	Site Preparation (Tree and Shrub Removal)	1	LS	$8,000.00	$8,000	$0	$0	$8,000
	2	Existing Culvert Demolition	1	LS	$2,000.00	$2,000	$0	$0	$2,000
	3	Excavation/Backfill/Compaction/Grading	700	CY	$25.00	$17,500	$0	$0	$17,500
	4	Borrow Materials	30	CY	$40.00	$1,200	$0	$0	$1,200
	5	Riprap Stone Material	105	CY	$100.00	$10,500	$0	$0	$10,500
	6	4-Sided Concrete Box Culvert	1	LS	$85,000.00	$85,000	$21,250	$21,250	$106,250
	7	Concrete Wingwalls (Assumed 1' thick)	11.5	CY	$1,200.00	$13,800	$300	$3,450	$17,250
	8	Process Gravel Base (Assumed 8" thick)	44	CY	$42.00	$1,848	$0	$0	$1,848
	9	Loam and Seed	525	SY	$7.50	$3,938	$0	$0	$3,938
	10	Landscaping/Restoration	1	LS	$5,000.00	$5,000	$0	$0	$5,000
						$148,785.50		**$24,700.00**	**$173,485.50**

Construction Subtotal Cost	**$243,900**
Contingency - 20% of Construction Cost	**$48,800**
Total Construction Cost	**$292,700**
Engineering & Permitting Services (10%)	**$29,300**
Construction/Permanent Easements (3%)	**$8,800**
Total Opinion of Probable Cost	**$330,800**

TABLE D-5

ENGINEER'S OPINION OF PROBABLE COST Tighe&Bond

Project: NEIWPCC Esopus Town and County Road Concept - Hardenburg Road #48925
Location: Esopus, NY

Estimate Type:
- [x] Conceptual
- [ ] Preliminary Design
- [ ] Design Development
- [ ] Construction
- [ ] Change Order

Prepared By: RRB
Date Prepared: 9/26/2019
Updated by:
Date Updated:
T&B Project No.: N5008-004-02

Bid Item Number	Item No.	Description	Quantity	Units	Material/Installed Cost $/Unit	Material/Installed Cost Total	Installation $/Unit	Installation Total	Total
1	**MOBILIZATION , DEMOBILIZATION AND RELATED EXPENSES**								
	1	Mob., Demob. & Related Exp. (7.5% Total Cosnt.)	1	LS	$16,300	$16,300	$0	$0	$16,300
						$16,300		**$0**	**$16,300**
2	**GENERAL REQUIREMENTS**								
	1	General Requirements (10% Total Const.)	1	LS	$22,100	$22,100	$0	$0	$22,100
	2	Temporary Controls/Water Handling	1	LS	$20,000.00	$20,000	$0	$0	$20,000
	3	Silt Fence	575	LF	$4.00	$2,300	$0	$0	$2,300
	4	Traffic Control	1	LS	$6,500.00	$6,500	$0	$0	$6,500
						$50,900		**$0**	**$50,900**
3	**GENERAL CONSTRUCTION**								
	Division 2 - Site Work								
	1	Site Preparation (Tree and Shrub Removal)	1	LS	$8,000.00	$8,000	$0	$0	$8,000
	2	Existing Culvert Demolition	1	LS	$2,000.00	$2,000	$0	$0	$2,000
	3	Excavation/Backfill/Compaction/Grading	600	CY	$25.00	$15,000	$0	$0	$15,000
	4	Borrow Materials	27	CY	$40.00	$1,080	$0	$0	$1,080
	5	Riprap Stone Material	100	CY	$100.00	$10,000	$0	$0	$10,000
	6	4-Sided Concrete Box Culvert	1	LS	$70,000.00	$70,000	$17,500	$17,500	$87,500
	7	Concrete Wingwalls (Assumed 1' thick)	6.5	CY	$1,200.00	$7,800	$300	$1,950	$9,750
	8	Bituminous Concrete Pavement (Assumed 4" thick)	75	TON	$120.00	$9,000	$0	$0	$9,000
	9	Process Gravel Base (Assumed 8" thick)	75	CY	$42.00	$3,150	$0	$0	$3,150
	10	Remove and Reset Guardrail	50	LF	$15.00	$750	$0	$0	$750
	11	Loam and Seed	520	SY	$7.50	$3,900	$0	$0	$3,900
	12	Landscaping	1	LS	$5,000.00	$5,000	$0	$0	$5,000
						$135,680.00		**$19,450.00**	**$155,130.00**

Construction Subtotal Cost	**$222,400**
Contingency - 20% of Construction Cost	**$44,500**
Total Construction Cost	**$266,900**
Engineering & Permitting Services (10%)	**$26,700**
Construction/Permanent Easements (3%)	**$8,100**
Total Opinion of Probable Cost	**$301,700**

TABLE D-6

ENGINEER'S OPINION OF PROBABLE COST Tighe&Bond

Project: NEIWPCC Esopus Town and County Road Concept - Union Center Road #48626

Location: Esopus, NY

Estimate Type:
- [x] Conceptual
- [ ] Preliminary Design
- [ ] Design Development
- [ ] Construction
- [ ] Change Order

Prepared By: RRB
Date Prepared: 9/26/2019
Updated by:
Date Updated:
T&B Project No.: N5008-004-02

Bid Item Number	Item No.	Description	Quantity	Units	Material/Installed Cost $/Unit	Material/Installed Cost Total	Installation $/Unit	Installation Total	Total
1	**MOBILIZATION , DEMOBILIZATION AND RELATED EXPENSES**								
	1	Mob., Demob. & Related Exp. (7.5% Total Const.)	1	LS	$13,600	$13,600	$0	$0	$13,600
						$13,600		**$0**	**$13,600**
2	**GENERAL REQUIREMENTS**								
	1	General Requirements (10% Total Const.)	1	LS	$18,400	$18,400	$0	$0	$18,400
	2	Temporary Controls/Water Handling	1	LS	$20,000.00	$20,000	$0	$0	$20,000
	3	Silt Fence	640	LF	$4.00	$2,560	$0	$0	$2,560
	4	Traffic Control	1	LS	$6,500.00	$6,500	$0	$0	$6,500
						$47,460		**$0**	**$47,460**
3	**GENERAL CONSTRUCTION**								
	Division 2 - Site Work								
	1	Site Preparation (Tree and Shrub Removal)	1	LS	$7,000.00	$7,000	$0	$0	$7,000
	2	Existing Culvert Demolition	1	LS	$3,000.00	$3,000	$0	$0	$3,000
	3	Excavation/Backfill/Compaction/Grading	450	CY	$25.00	$11,250	$0	$0	$11,250
	4	Borrow Materials	20	CY	$40.00	$800	$0	$0	$800
	5	Riprap Stone Material	128	CY	$100.00	$12,800	$0	$0	$12,800
	6	4-Sided Concrete Box Culvert	1	LS	$55,000.00	$55,000	$13,750	$13,750	$68,750
	7	Concrete Wingwalls (Assumed 1' thick)	5	CY	$1,200.00	$6,000	$300	$1,500	$7,500
	8	Bituminous Concrete Pavement (Assumed 4" thick)	31	TON	$120.00	$3,720	$0	$0	$3,720
	9	Process Gravel Base (Assumed 8" thick)	31	CY	$42.00	$1,302	$0	$0	$1,302
	10	Remove and Reset Guardrail	100	LF	$15.00	$1,500	$0	$0	$1,500
	11	Remove and Reset Street Sign	1	EA	$100.00	$100	$0	$0	$100
	12	Pavement Markings (4" Wide)	250	LF	$0.60	$150	$0	$0	$150
	13	Loam and Seed	175	SY	$7.50	$1,313	$0	$0	$1,313
	14	Landscaping/Restoration	1	LS	$5,000.00	$5,000	$0	$0	$5,000
						$108,934.50		**$15,250.00**	**$124,184.50**

Construction Subtotal Cost	**$185,300**
Contingency - 20% of Construction Cost	**$37,100**
Total Construction Cost	**$222,400**
Engineering Services (10%)	**$22,300**
Construction/Permanent Easements (3%)	**$6,700**
Total Opinion of Probable Cost	**$251,400**

APPENDIX D
Hydrologic and Hydraulic Analysis
Supporting Information

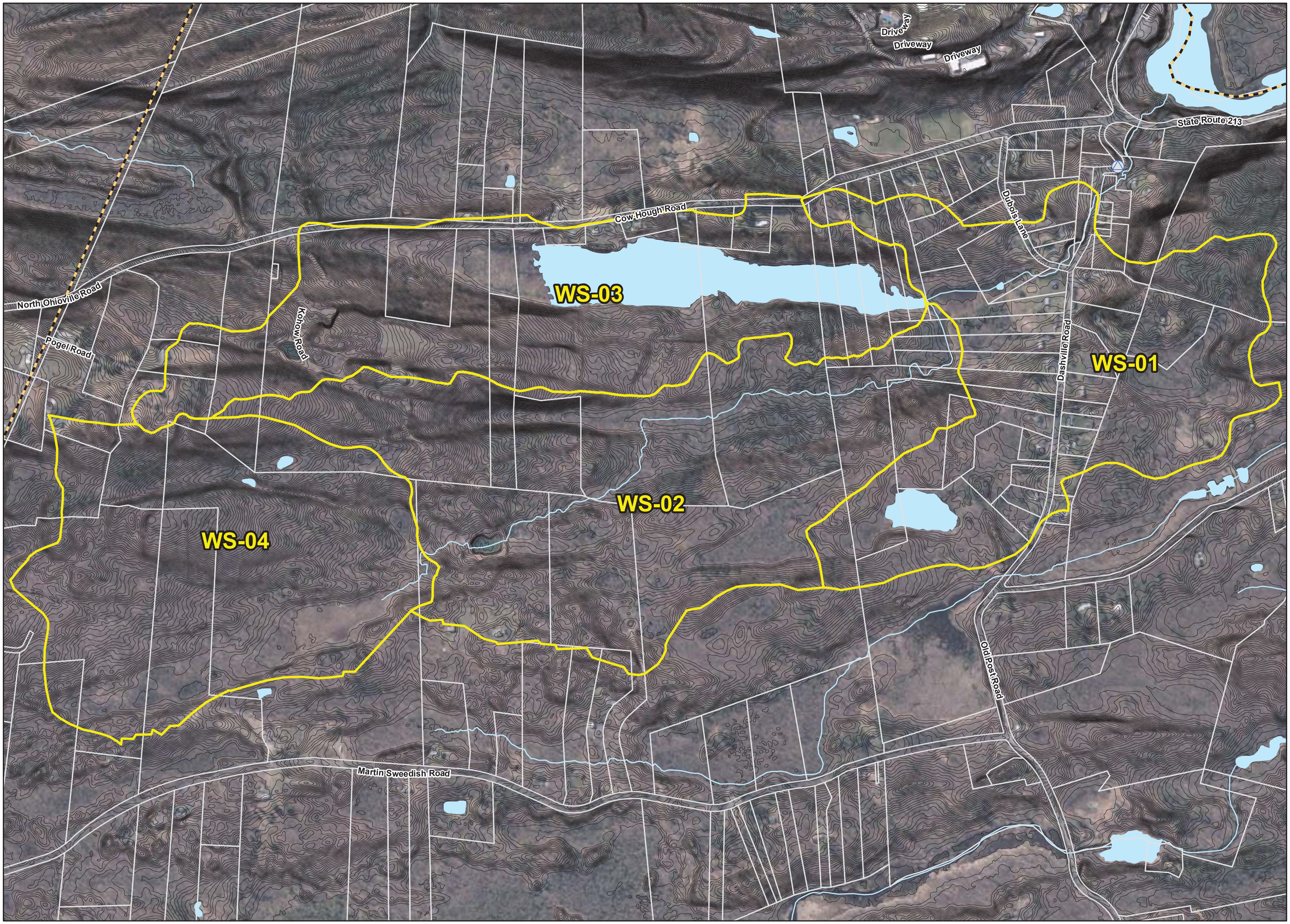

FIGURE 2
WATERSHED MAP

LEGEND

- Culvert
- 2-foot Contour
- Stream
- Waterbody
- Parcel Boundary
- Culvert Watershed

LOCUS MAP

0 325 650
Feet
1:7,800

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Dashville Road Watershed
Esopus, New York
Culvert #49129

April 2019

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Services provided in New York by T&B Engineering, P.C.

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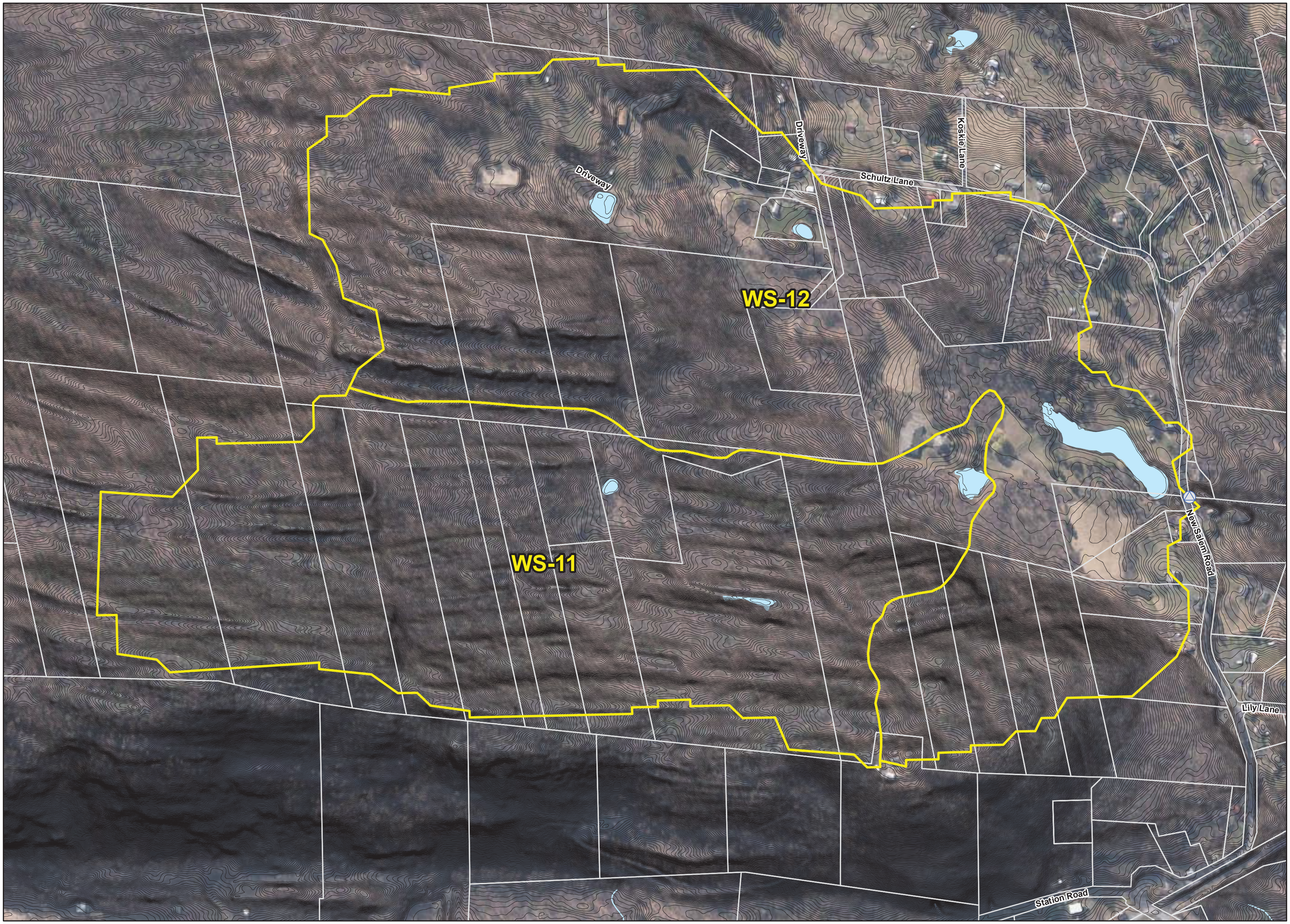

FIGURE 2
WATERSHED MAP

LEGEND

- Culvert
- 2-foot Contours
- Stream
- Waterbody
- Parcel Boundary
- Culvert Watershed

LOCUS MAP

0 225 450
Feet
1:5,400

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

New Salem Road Watershed
Esopus, New York
Culvert #41505

April 2019

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FIGURE 2
WATERSHED MAP

LEGEND

- Culvert
- 2-foot Contour
- Stream
- Waterbody
- Parcel Boundary
- Culvert Watershed

LOCUS MAP

0 550 1,100
Feet
1:13,200

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Salem Street Watershed
Esopus, New York
Culvert #48953

April 2019

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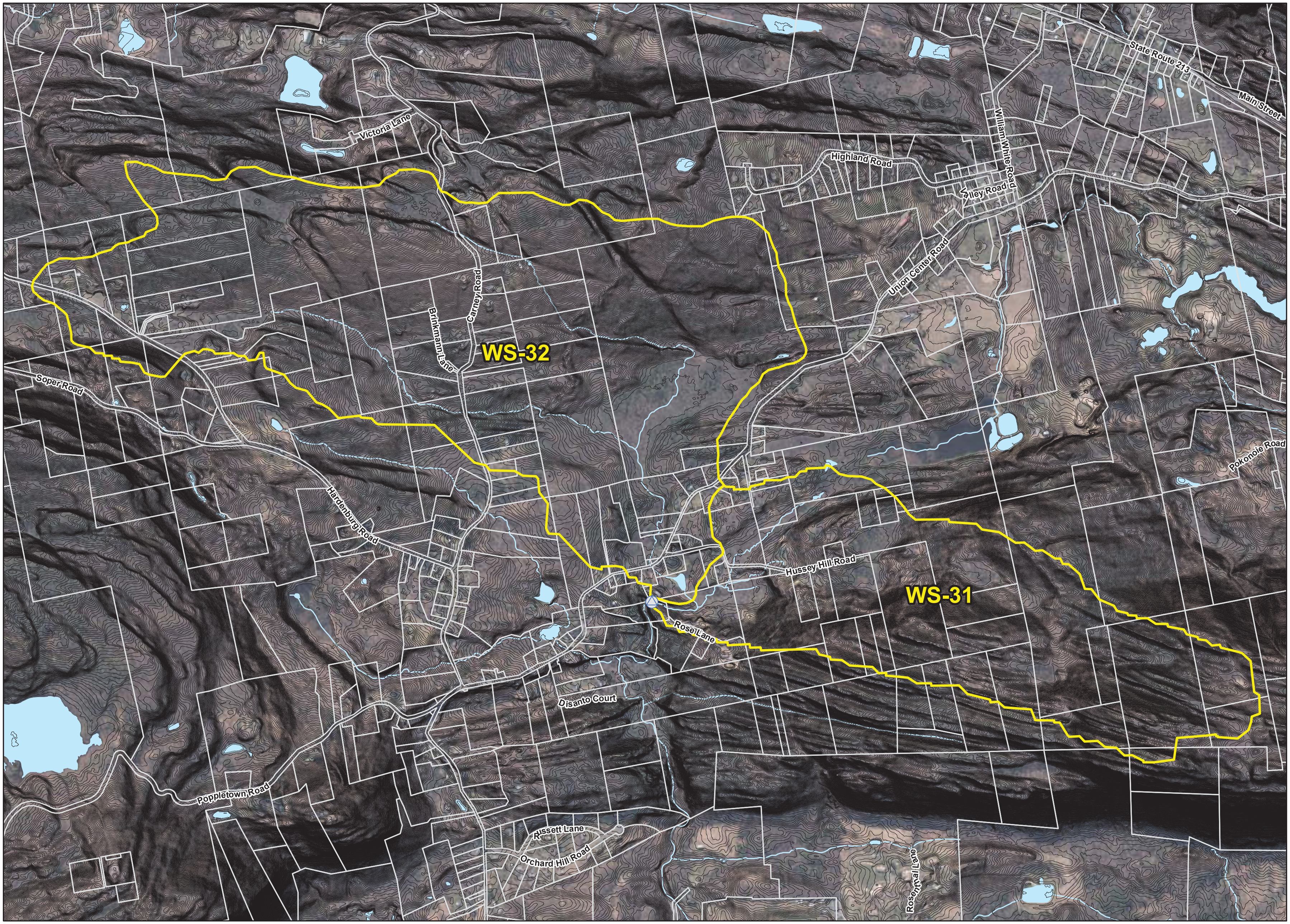

FIGURE 2
WATERSHED MAP

LEGEND

- Culvert
- 2-foot Contour
- Stream
- Waterbody
- Parcel Boundary
- Culvert Watershed

LOCUS MAP

0 525 1,050
Feet
1:12,600

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Rose Lane Watershed
Esopus, New York
Culvert #48926

April 2019

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FIGURE 2
WATERSHED MAP

LEGEND

- Culvert
- 2-foot Contour
- Culvert Watershed
- Stream
- Waterbody
- Parcel Boundary

LOCUS MAP

0 100 200
Feet
1:2,400

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Union Center Watershed
Esopus, New York
Culvert #48626

April 2019

Tighe&Bond
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Services provided in New York by T&B Engineering, P.C.

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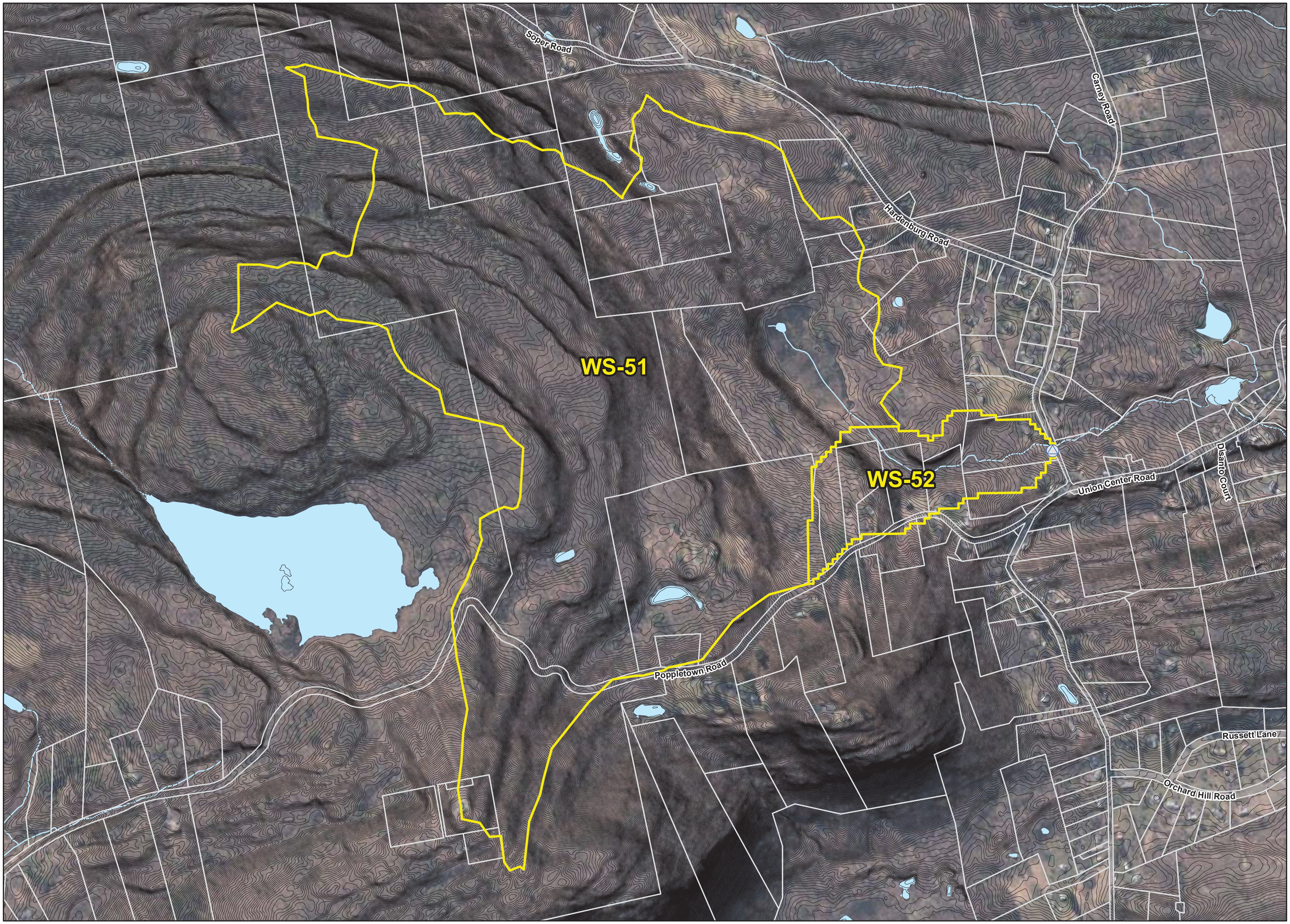

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FIGURE 2
WATERSHED MAP

LEGEND

- Culvert
- 2-foot Contour
- Stream
- Waterbody
- Parcel Boundary
- Culvert Watershed

LOCUS MAP

0 300 600
Feet
1:7,200

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Hardenburg Road Watershed
Esopus, New York
Culvert #48925

April 2019

Tighe&Bond
Engineers | Environmental Specialists
Services provided in New York by T&B Engineering, P.C.

N-5008

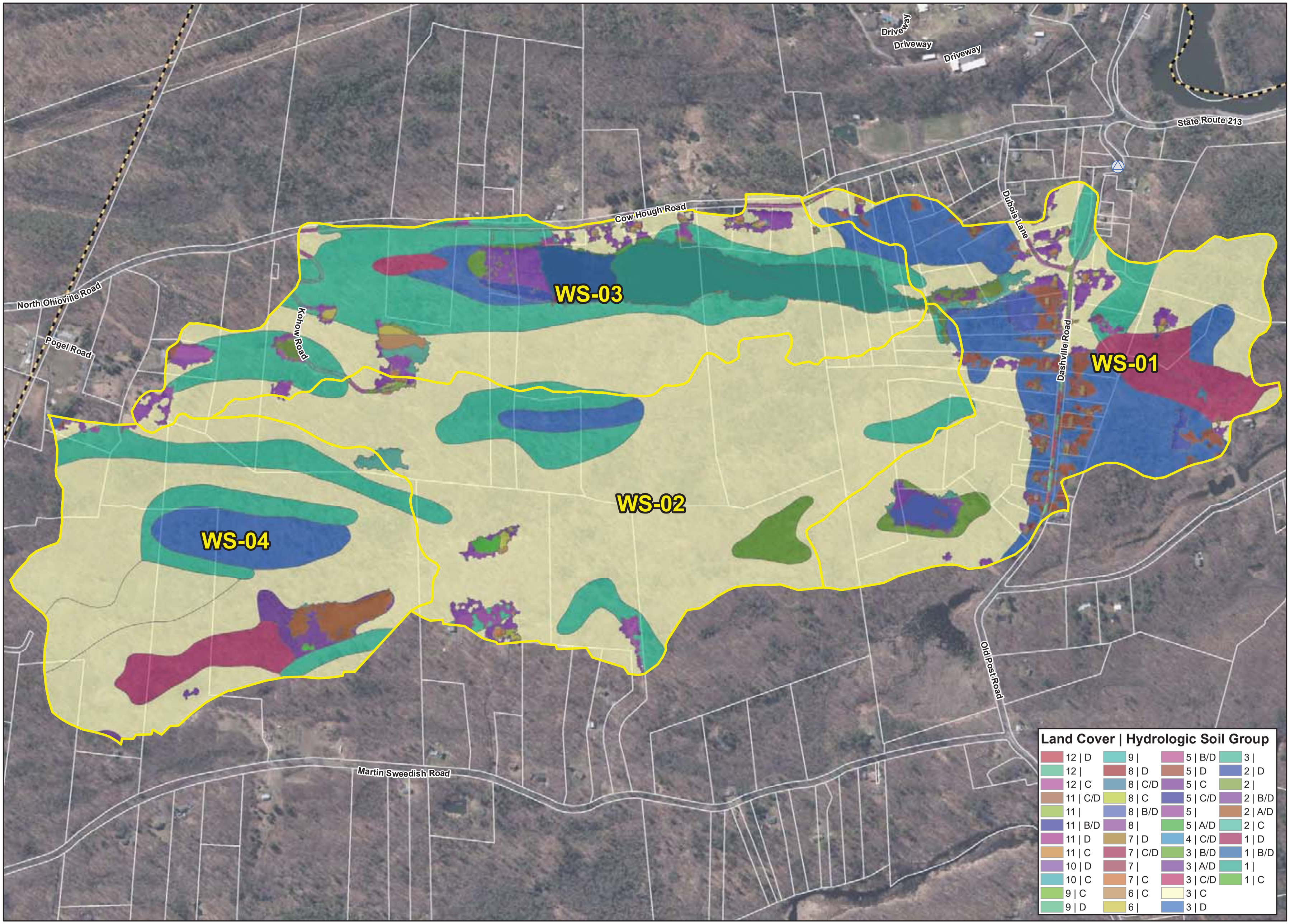

FIGURE 2
SOIL AND LAND COVER MAP

LEGEND

- Culvert
- Culvert Watershed
- Parcel Boundary

LOCUS MAP

0 325 650
Feet
1:7,800

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Dashville Road Watershed
Esopus, New York
Culvert #49129

April 2019

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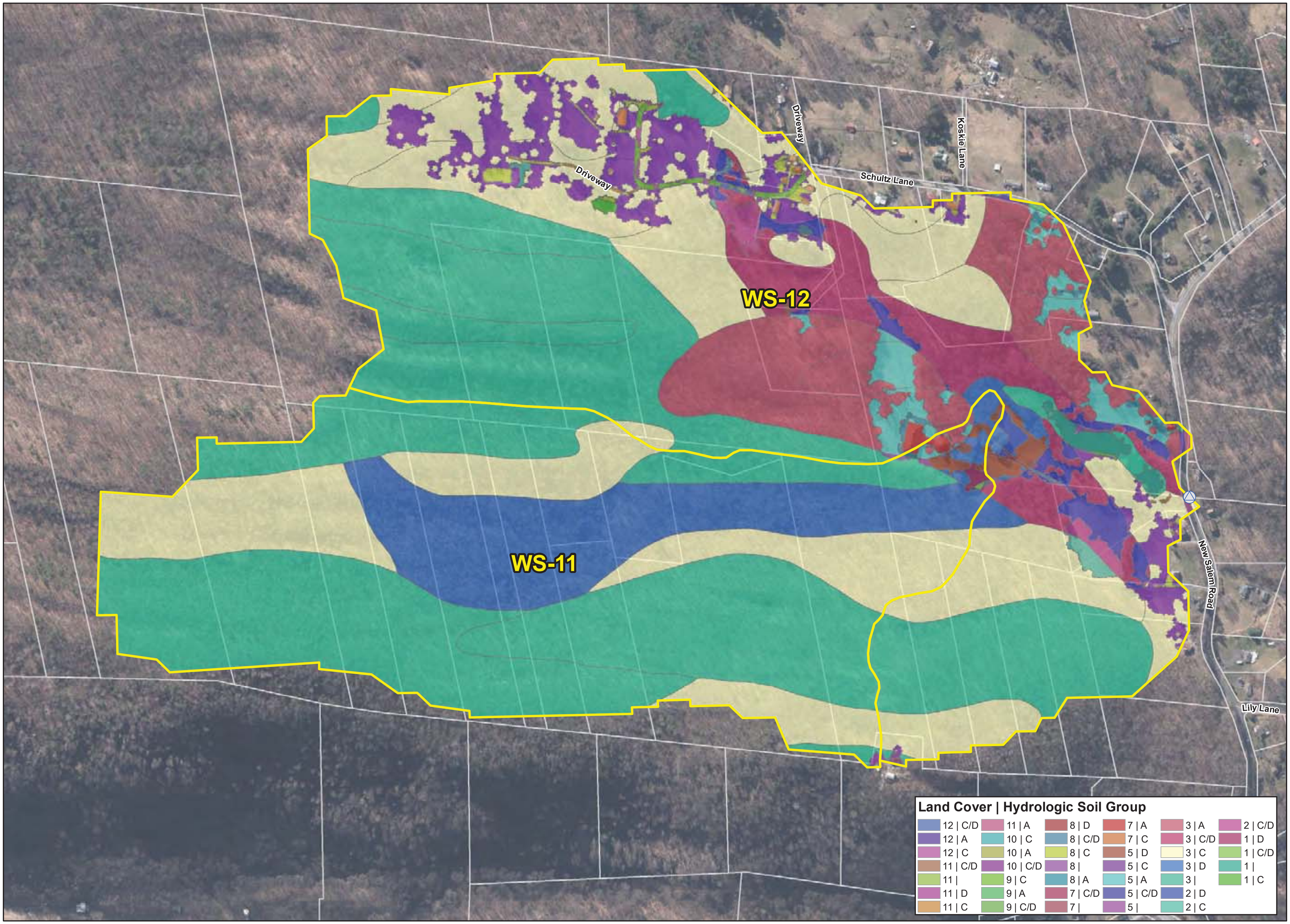
N-5008

FIGURE 2
SOIL AND LAND COVER MAP



LEGEND

- Culvert
- Culvert Watershed
- Parcel Boundary

LOCUS MAP

0 225 450
Feet
1:5,400

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

New Salem Road Watershed
Esopus, New York
Culvert #41505

April 2019

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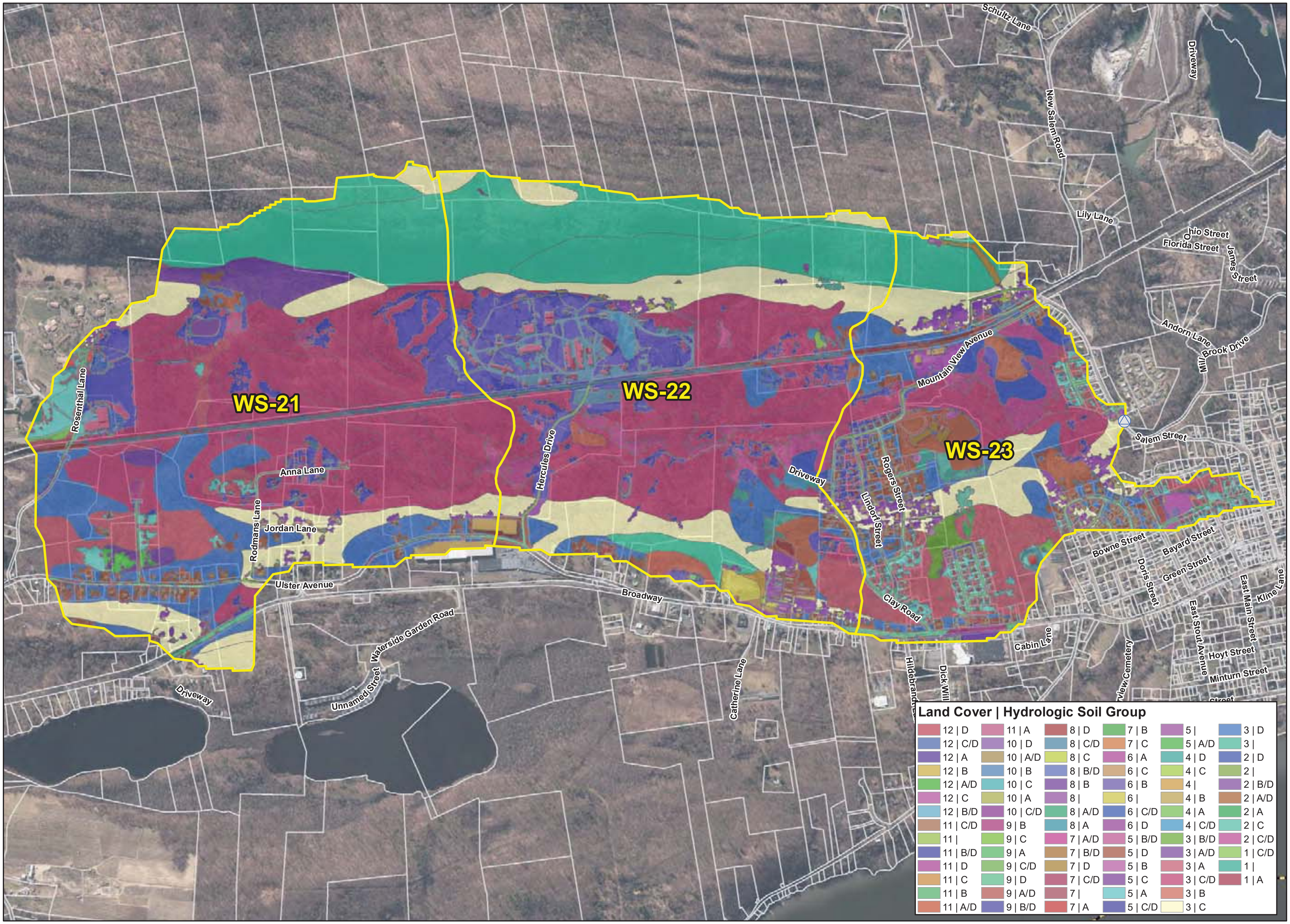

FIGURE 2
SOIL AND LAND COVER MAP

LEGEND

- Culvert
- Culvert Watershed
- Parcel Boundary

LOCUS MAP

0 550 1,100
Feet
1:13,200

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Salem Street Watershed
Esopus, New York
Culvert #48953

April 2019

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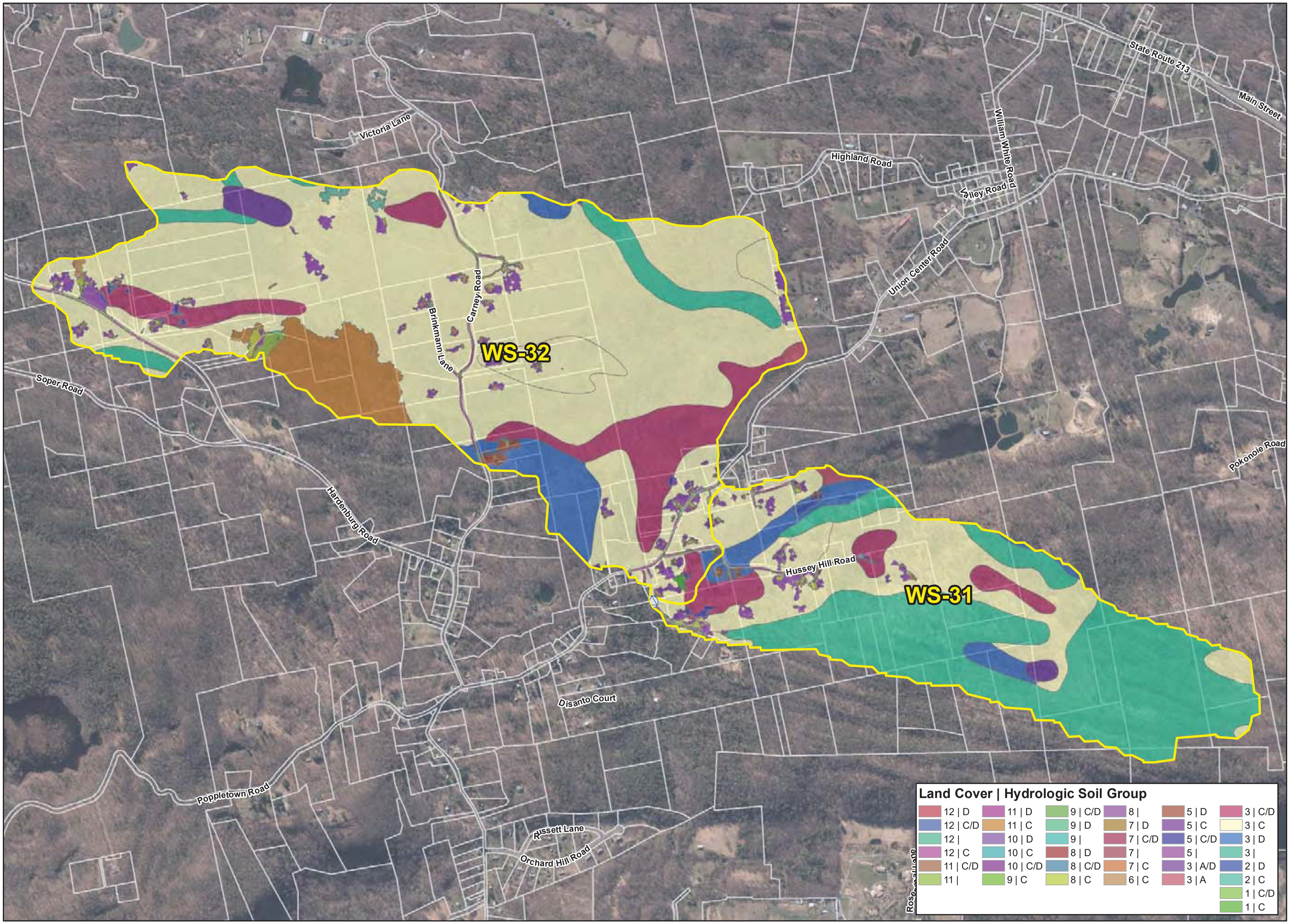

FIGURE 2
SOIL AND LAND COVER MAP

LEGEND

- Culvert
- Culvert Watershed
- Parcel Boundary

LOCUS MAP

0 525 1,050
Feet
1:12,600

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Rose Lane Watershed
Esopus, New York
Culvert #48926

April 2019

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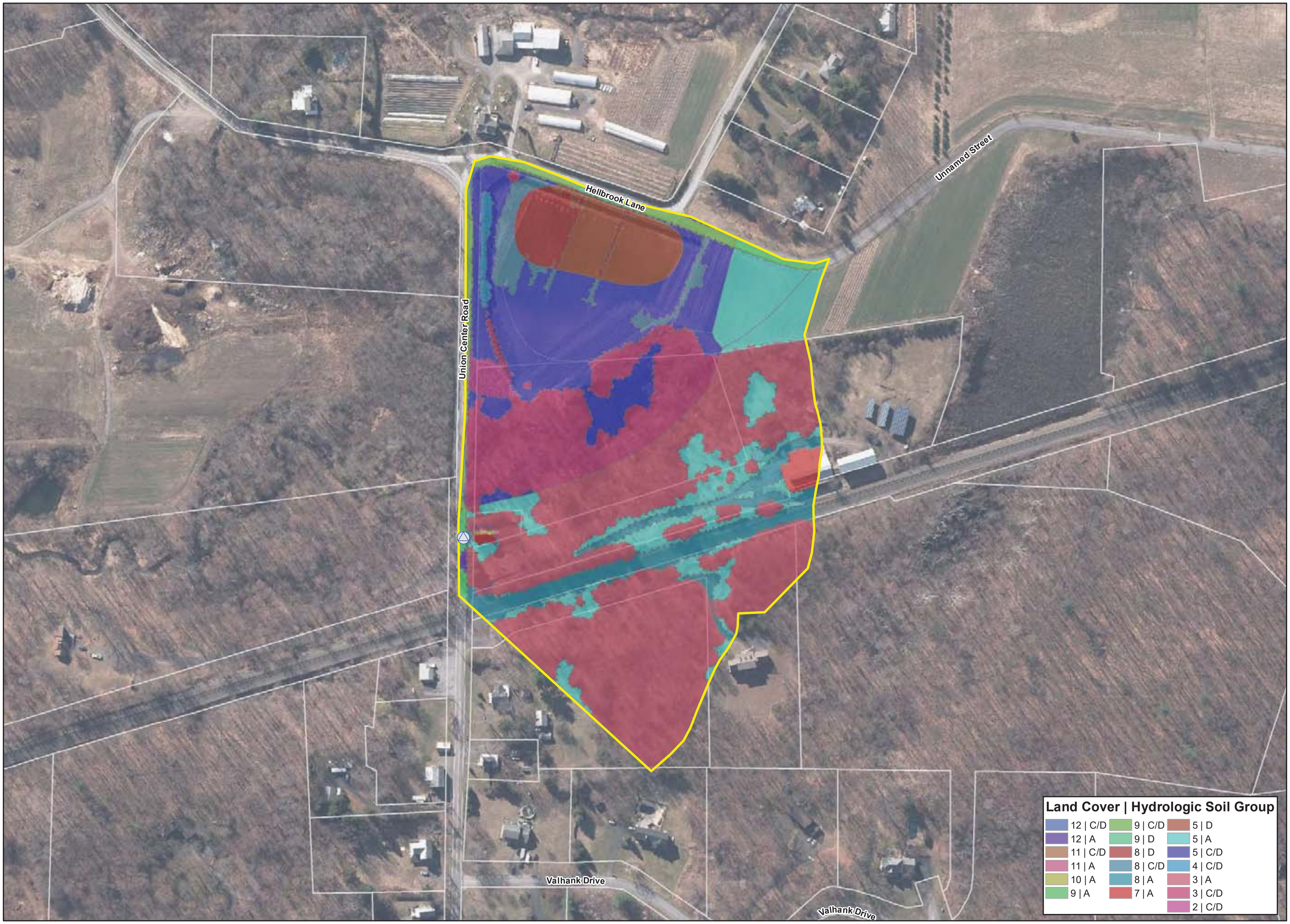

FIGURE 2
SOIL AND LAND COVER MAP

LEGEND

- Culvert
- Culvert Watershed
- Parcel Boundary

LOCUS MAP

0 100 200
Feet
1:2,400

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Union Center Watershed
Esopus, New York
Culvert #48626

April 2019

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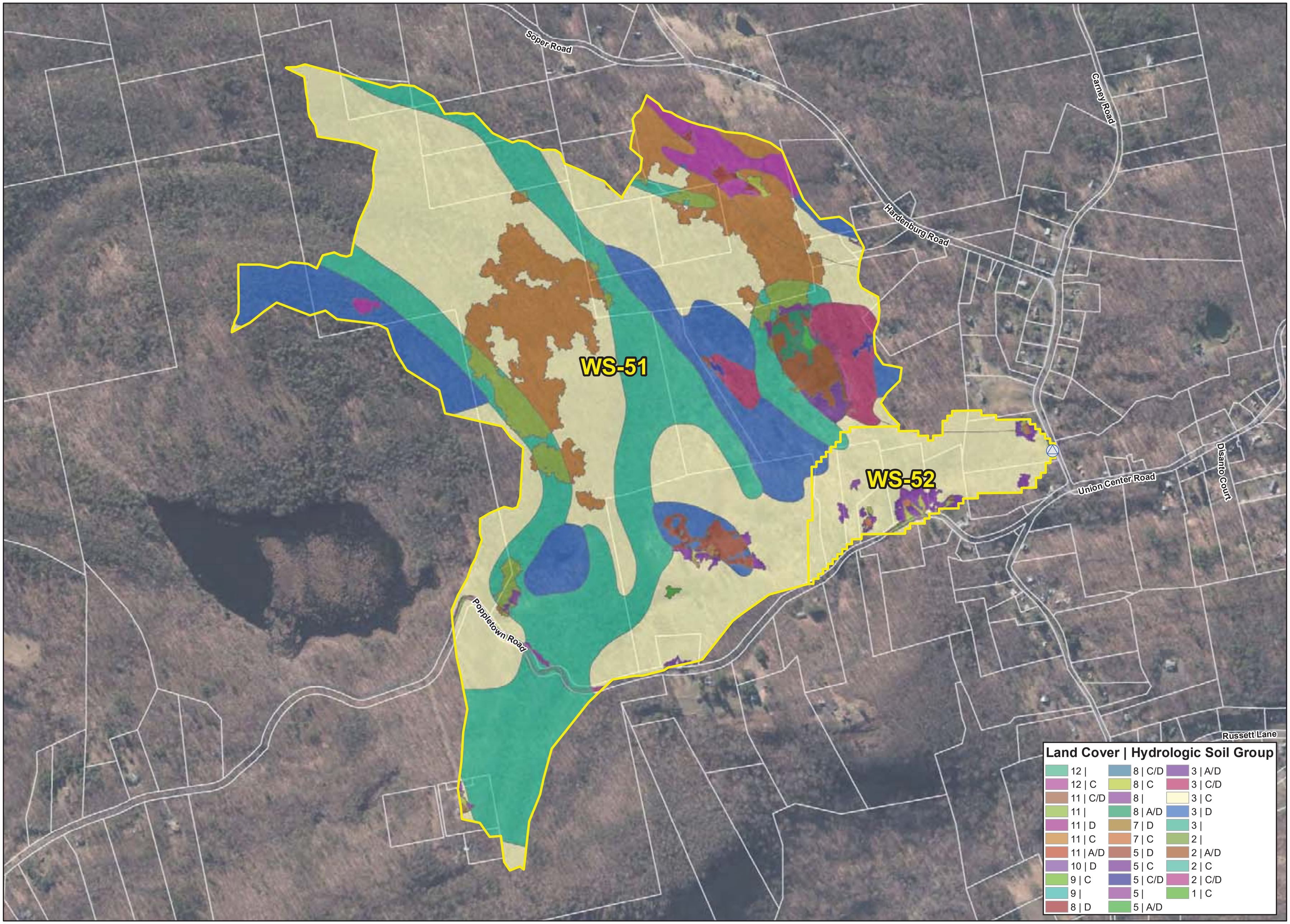

FIGURE 2
SOIL AND LAND COVER MAP

LEGEND

Culvert
Culvert Watershed
Parcel Boundary

LOCUS MAP

0 300 600
Feet
1:7,200

NOTES

1. Ortho provided by New York State (2016).
2. Data provided by Ulster County.gov.

Hardenburg Road Watershed
Esopus, New York
Culvert #48925

April 2019

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N-5008

Ulster County Land Cover approximate equivalent land cover for TR-55

Ulster County Land Use ID		TR-55 Equivalent CN Value				
LU_ID	**Land Cover Description**	**CN Description**	**A Soils**	**B Soils**	**C Soils**	**D Soils**
1	Water	Water	98	98	98	98
2	Wetlands (emergent)	Water	98	98	98	98
3	Tree Canopy	Woods (Fair)	36	60	73	79
4	Scrub-Shrub	Brush (Fair)	35	56	70	77
5	Low Vegetation	Brush (Good)	30	48	65	73
6	Barren	Open Space (Poor)	68	79	86	89
7	Structures	Roofs	98	98	98	98
8	Other Impervious Surfaces	Impervious	98	98	98	98
9	Roads	Streets and roads (paved)	98	98	98	98
10	Tree Canopy Over Structures	Roofs	98	98	98	98
11	Tree Canopy Over Other Impervious Surfaces	Impervious	98	98	98	98
12	Tree Canopy Over Roads	Streets and roads (paved)	98	98	98	98

Weighted CN Value

Subwatershed	Area (acres)	Weighted CN
WS-01	125.89	77
WS-02	157.77	74
WS-03	129.07	80
WS-04	119.66	76
WS-11	128.29	77
WS-12	175.16	70
WS-21	555.7	76
WS-22	517.47	79
WS-23	319.72	71
WS-31	272.49	77
WS-32	552.39	76
WS-41	18.93	59
WS-51	249.1	80
WS-52	22.62	73

NOAA Atlas 14, Volume 10, Version 3 ROSENDALE 2 E
Station ID: 30-7274
Location name: Tillson, New York, USA*
Latitude: 41.85°, Longitude: -74.05°
Elevation:
Elevation (station metadata): 40 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.336 (0.261-0.419)	0.402 (0.312-0.501)	0.510 (0.394-0.638)	0.599 (0.461-0.754)	0.721 (0.537-0.945)	0.815 (0.594-1.09)	0.910 (0.642-1.26)	1.01 (0.682-1.44)	1.15 (0.745-1.69)	1.26 (0.797-1.89)
10-min	0.476 (0.370-0.593)	0.569 (0.442-0.710)	0.721 (0.558-0.903)	0.847 (0.653-1.07)	1.02 (0.760-1.34)	1.15 (0.841-1.54)	1.29 (0.910-1.78)	1.43 (0.965-2.04)	1.63 (1.06-2.40)	1.78 (1.13-2.68)
15-min	0.560 (0.435-0.698)	0.669 (0.520-0.835)	0.848 (0.657-1.06)	0.996 (0.767-1.25)	1.20 (0.894-1.58)	1.36 (0.989-1.82)	1.52 (1.07-2.10)	1.69 (1.14-2.40)	1.92 (1.24-2.83)	2.10 (1.33-3.16)
30-min	0.754 (0.587-0.940)	0.901 (0.700-1.13)	1.14 (0.885-1.43)	1.34 (1.03-1.69)	1.62 (1.20-2.12)	1.83 (1.33-2.44)	2.04 (1.44-2.82)	2.27 (1.53-3.23)	2.58 (1.67-3.80)	2.82 (1.79-4.24)
60-min	0.949 (0.738-1.18)	1.13 (0.881-1.42)	1.44 (1.11-1.80)	1.69 (1.30-2.12)	2.03 (1.51-2.66)	2.30 (1.67-3.07)	2.56 (1.81-3.54)	2.85 (1.92-4.06)	3.24 (2.10-4.77)	3.55 (2.24-5.33)
2-hr	1.23 (0.963-1.52)	1.47 (1.15-1.82)	1.86 (1.45-2.32)	2.19 (1.70-2.74)	2.64 (1.98-3.44)	2.98 (2.19-3.96)	3.33 (2.37-4.59)	3.72 (2.51-5.26)	4.27 (2.77-6.25)	4.71 (2.99-7.04)
3-hr	1.42 (1.12-1.75)	1.70 (1.34-2.10)	2.16 (1.69-2.68)	2.55 (1.98-3.17)	3.07 (2.32-4.00)	3.47 (2.56-4.61)	3.89 (2.79-5.36)	4.36 (2.95-6.14)	5.04 (3.28-7.35)	5.60 (3.56-8.33)
6-hr	1.79 (1.42-2.19)	2.16 (1.72-2.66)	2.78 (2.19-3.42)	3.29 (2.58-4.07)	3.99 (3.04-5.18)	4.51 (3.36-5.99)	5.08 (3.68-7.00)	5.73 (3.90-8.03)	6.71 (4.39-9.73)	7.54 (4.81-11.1)
12-hr	2.21 (1.76-2.68)	2.70 (2.16-3.29)	3.52 (2.80-4.30)	4.19 (3.32-5.15)	5.12 (3.92-6.61)	5.81 (4.36-7.68)	6.55 (4.79-9.03)	7.45 (5.09-10.4)	8.82 (5.78-12.7)	9.99 (6.39-14.7)
24-hr	2.64 (2.12-3.19)	3.25 (2.62-3.94)	4.26 (3.42-5.18)	5.10 (4.07-6.23)	6.26 (4.83-8.04)	7.11 (5.38-9.35)	8.04 (5.92-11.0)	9.17 (6.29-12.7)	10.9 (7.18-15.6)	12.4 (7.97-18.1)
2-day	3.07 (2.49-3.69)	3.78 (3.07-4.54)	4.94 (3.99-5.96)	5.90 (4.74-7.16)	7.23 (5.62-9.22)	8.21 (6.25-10.7)	9.27 (6.86-12.6)	10.6 (7.28-14.5)	12.6 (8.30-17.9)	14.3 (9.20-20.7)
3-day	3.37 (2.75-4.03)	4.12 (3.36-4.93)	5.35 (4.34-6.42)	6.36 (5.14-7.69)	7.77 (6.06-9.86)	8.80 (6.72-11.4)	9.93 (7.37-13.4)	11.3 (7.80-15.5)	13.4 (8.86-19.0)	15.2 (9.80-21.9)
4-day	3.62 (2.97-4.32)	4.40 (3.60-5.25)	5.67 (4.62-6.80)	6.73 (5.45-8.11)	8.18 (6.40-10.4)	9.26 (7.09-12.0)	10.4 (7.75-14.1)	11.8 (8.19-16.2)	14.0 (9.27-19.8)	15.8 (10.2-22.8)
7-day	4.29 (3.53-5.09)	5.13 (4.23-6.10)	6.52 (5.34-7.76)	7.66 (6.24-9.18)	9.24 (7.26-11.6)	10.4 (8.00-13.4)	11.7 (8.69-15.6)	13.2 (9.15-17.9)	15.4 (10.2-21.6)	17.3 (11.2-24.8)
10-day	4.94 (4.09-5.84)	5.83 (4.82-6.90)	7.30 (6.01-8.66)	8.51 (6.96-10.2)	10.2 (8.03-12.7)	11.4 (8.80-14.6)	12.8 (9.50-16.9)	14.3 (9.97-19.3)	16.6 (11.0-23.2)	18.5 (12.0-26.3)
20-day	6.97 (5.82-8.18)	7.98 (6.65-9.38)	9.64 (8.00-11.4)	11.0 (9.08-13.1)	12.9 (10.2-15.9)	14.3 (11.1-18.1)	15.8 (11.8-20.6)	17.4 (12.2-23.3)	19.7 (13.2-27.3)	21.5 (14.0-30.4)
30-day	8.69 (7.29-10.2)	9.79 (8.20-11.5)	11.6 (9.67-13.6)	13.1 (10.8-15.5)	15.1 (12.0-18.6)	16.7 (12.9-20.9)	18.3 (13.6-23.6)	20.0 (14.1-26.6)	22.2 (14.9-30.6)	23.9 (15.6-33.7)
45-day	10.8 (9.14-12.6)	12.1 (10.1-14.1)	14.0 (11.8-16.4)	15.7 (13.0-18.4)	17.9 (14.3-21.8)	19.7 (15.3-24.4)	21.4 (15.9-27.4)	23.1 (16.3-30.7)	25.3 (17.1-34.8)	27.0 (17.6-37.9)
60-day	12.7 (10.7-14.7)	14.0 (11.8-16.2)	16.1 (13.5-18.8)	17.8 (14.9-20.9)	20.3 (16.2-24.6)	22.2 (17.2-27.4)	24.0 (17.9-30.5)	25.8 (18.3-34.1)	28.0 (18.9-38.3)	29.6 (19.3-41.4)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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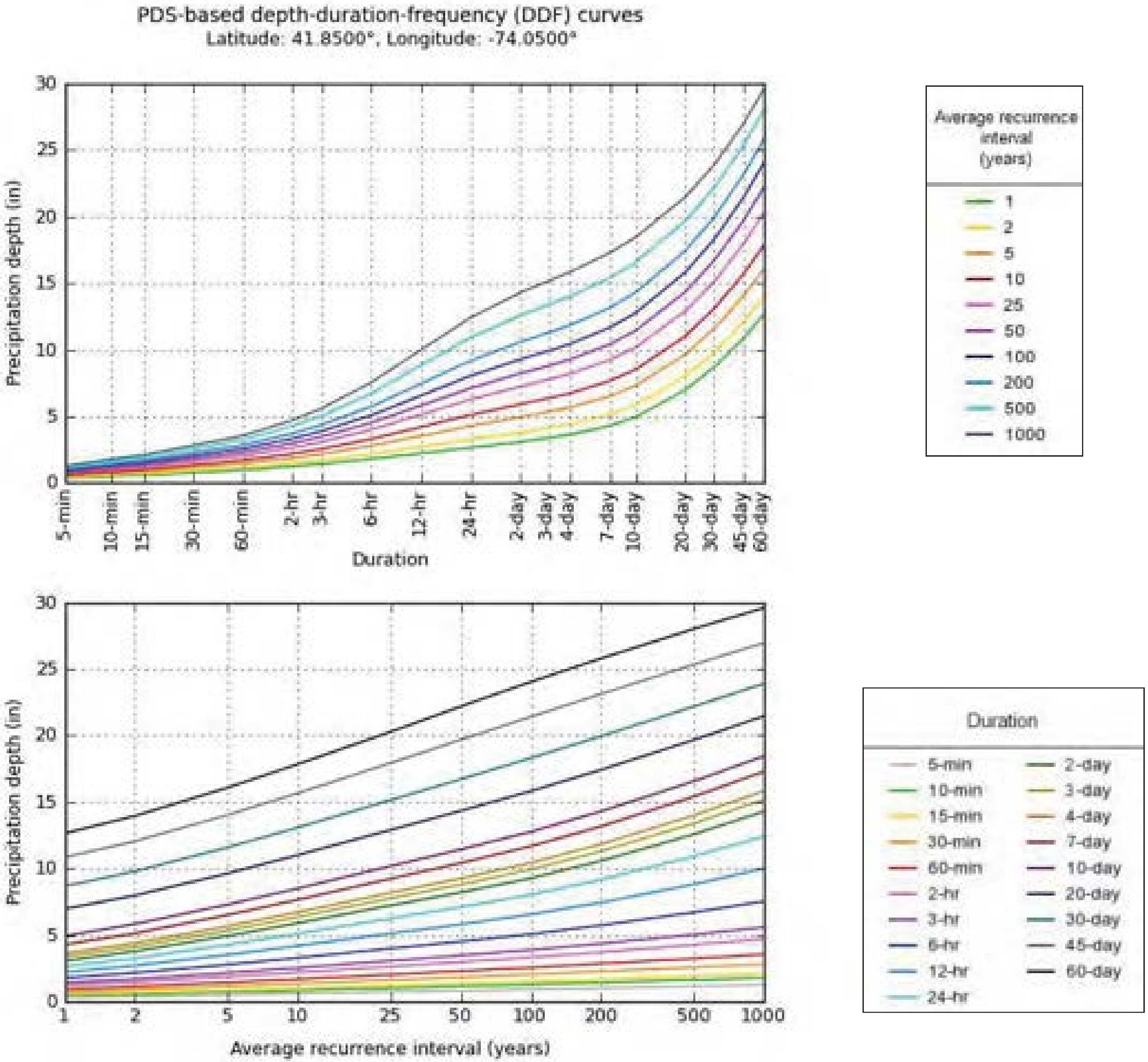
PF graphical



NOAA Atlas 14, Volume 10, Version 3

Created (GMT): Wed May 29 17:50:44 2019

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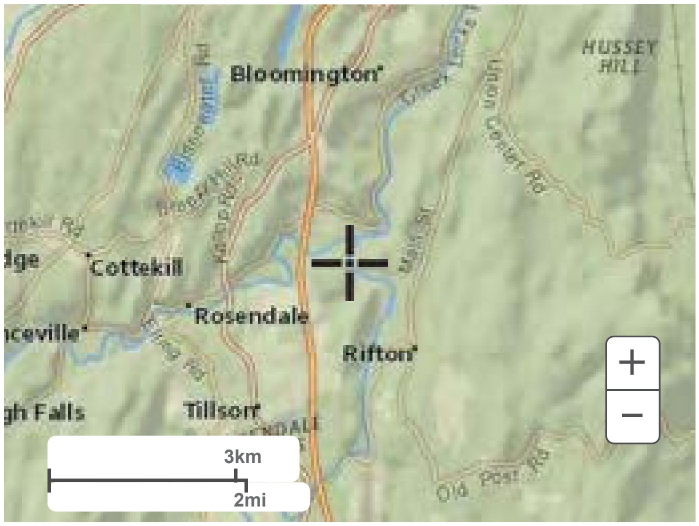
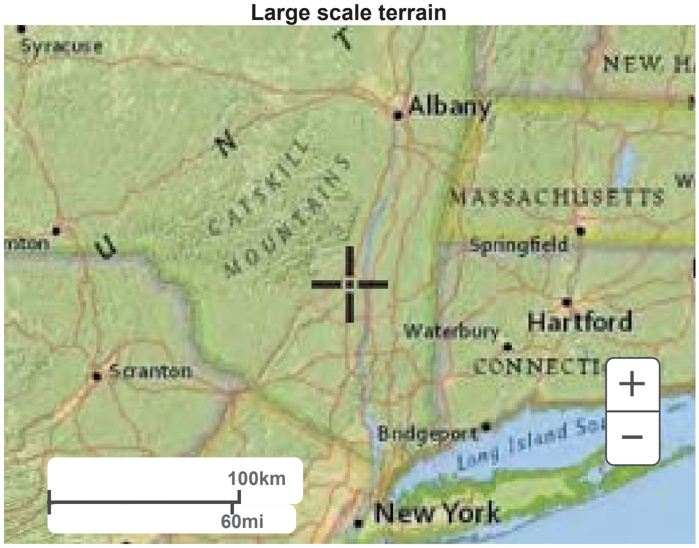
Maps & aerials

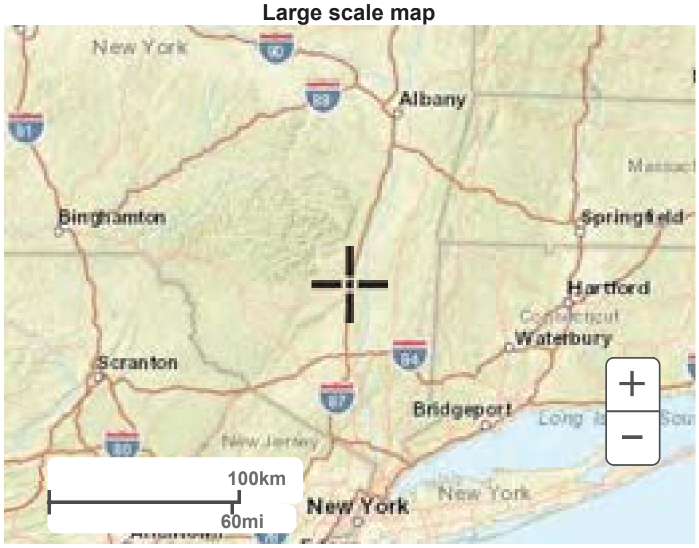
Small scale terrain



Large scale terrain



Large scale map



Large scale aerial

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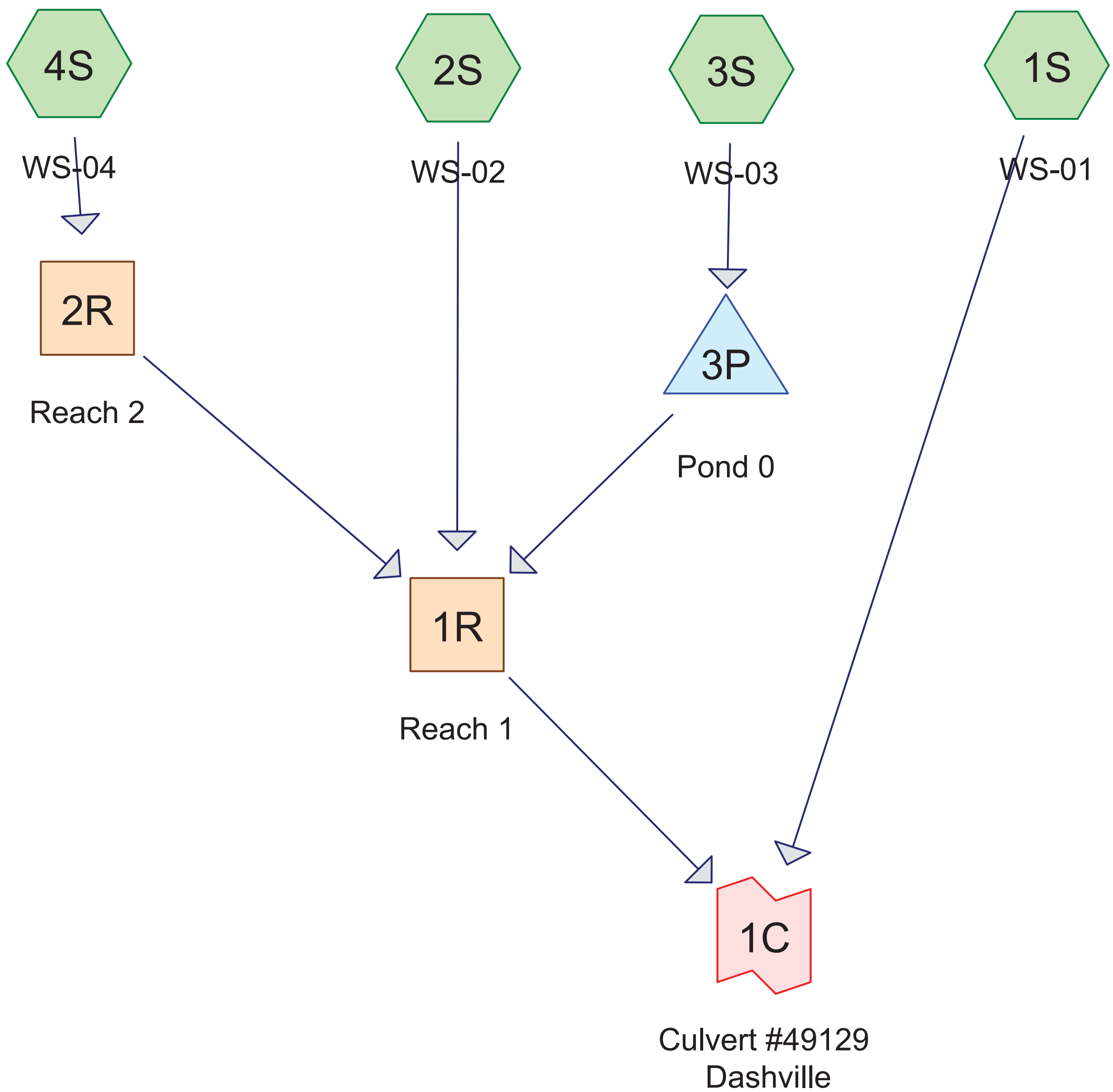
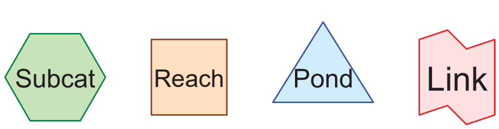
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer





Routing Diagram for Culvert #49129
Prepared by Tighe & Bond, Printed 6/17/2019
HydroCAD® 10.00-20 s/n 03436 © 2017 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
245.550	76	(1S, 4S)
157.770	74	(2S)
129.070	80	(3S)
532.390	**76**	**TOTAL AREA**

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-01 Runoff Area=125.890 ac 0.00% Impervious Runoff Depth>1.13"
Tc=141.5 min CN=76 Runoff=37.02 cfs 11.867 af

Subcatchment 2S: WS-02 Runoff Area=157.770 ac 0.00% Impervious Runoff Depth>1.03"
Tc=106.8 min CN=74 Runoff=49.52 cfs 13.549 af

Subcatchment 3S: WS-03 Runoff Area=129.070 ac 0.00% Impervious Runoff Depth>1.39"
Tc=124.7 min CN=80 Runoff=51.88 cfs 14.910 af

Subcatchment 4S: WS-04 Runoff Area=119.660 ac 0.00% Impervious Runoff Depth>1.15"
Tc=100.1 min CN=76 Runoff=44.55 cfs 11.438 af

Reach 1R: Reach 1 Inflow=115.27 cfs 38.703 af
Outflow=115.27 cfs 38.703 af

Reach 2R: Reach 2 Avg. Flow Depth=0.81' Max Vel=4.18 fps Inflow=44.55 cfs 11.438 af
n=0.040 L=4,960.0' S=0.0218 '/' Capacity=220.87 cfs Outflow=42.07 cfs 11.153 af

Pond 3P: Pond 0 Peak Elev=272.14' Storage=47.138 af Inflow=51.88 cfs 14.910 af
Outflow=36.40 cfs 14.001 af

Link 1C: Culvert #49129 Dashville Inflow=152.17 cfs 50.570 af
Primary=152.17 cfs 50.570 af

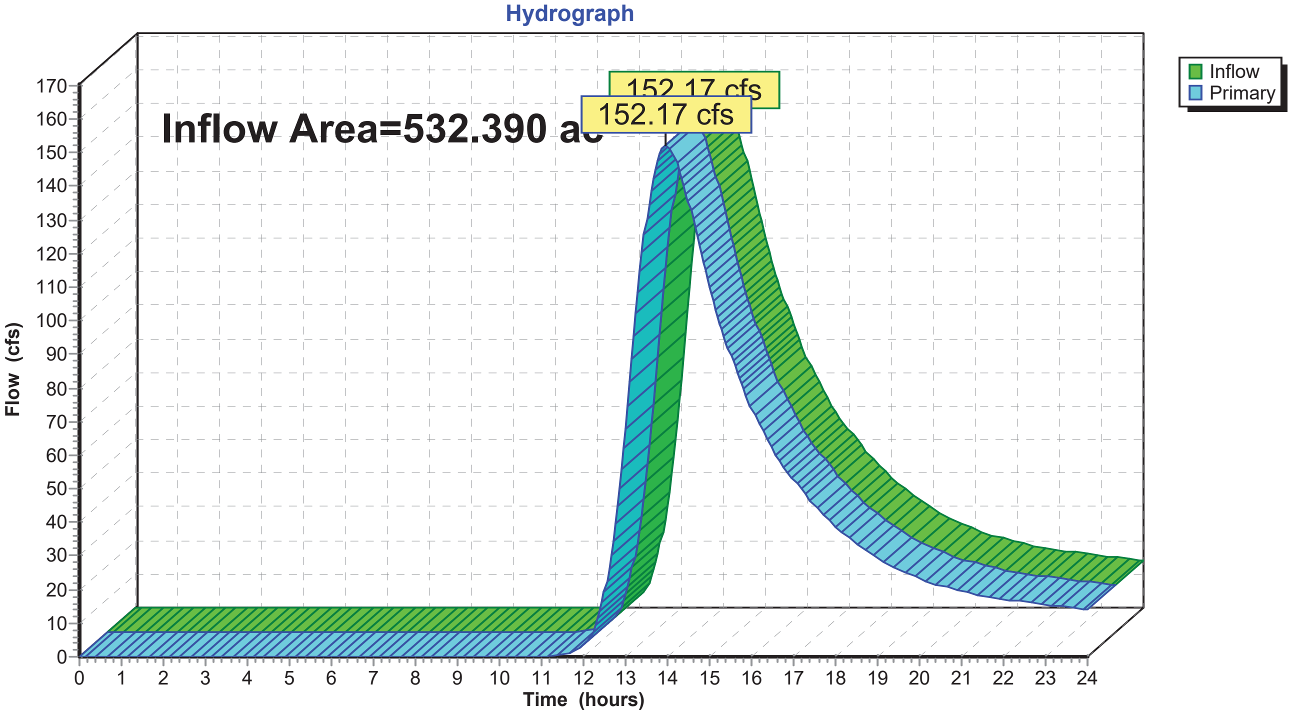
Total Runoff Area = 532.390 ac Runoff Volume = 51.764 af Average Runoff Depth = 1.17"
100.00% Pervious = 532.390 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #49129 Dashville

Inflow Area = 532.390 ac, 0.00% Impervious, Inflow Depth > 1.14" for 2-Year event
Inflow = 152.17 cfs @ 13.97 hrs, Volume= 50.570 af
Primary = 152.17 cfs @ 13.97 hrs, Volume= 50.570 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #49129 Dashville



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-01 Runoff Area=125.890 ac 0.00% Impervious Runoff Depth>1.69"
Tc=141.5 min CN=76 Runoff=56.76 cfs 17.781 af

Subcatchment 2S: WS-02 Runoff Area=157.770 ac 0.00% Impervious Runoff Depth>1.57"
Tc=106.8 min CN=74 Runoff=78.25 cfs 20.669 af

Subcatchment 3S: WS-03 Runoff Area=129.070 ac 0.00% Impervious Runoff Depth>2.00"
Tc=124.7 min CN=80 Runoff=75.92 cfs 21.558 af

Subcatchment 4S: WS-04 Runoff Area=119.660 ac 0.00% Impervious Runoff Depth>1.72"
Tc=100.1 min CN=76 Runoff=68.25 cfs 17.118 af

Reach 1R: Reach 1 Inflow=182.58 cfs 57.905 af
Outflow=182.58 cfs 57.905 af

Reach 2R: Reach 2 Avg. Flow Depth=1.04' Max Vel=4.81 fps Inflow=68.25 cfs 17.118 af
n=0.040 L=4,960.0' S=0.0218 '/' Capacity=220.87 cfs Outflow=65.41 cfs 16.775 af

Pond 3P: Pond 0 Peak Elev=272.19' Storage=48.513 af Inflow=75.92 cfs 21.558 af
Outflow=56.85 cfs 20.461 af

Link 1C: Culvert #49129 Dashville Inflow=238.92 cfs 75.686 af
Primary=238.92 cfs 75.686 af

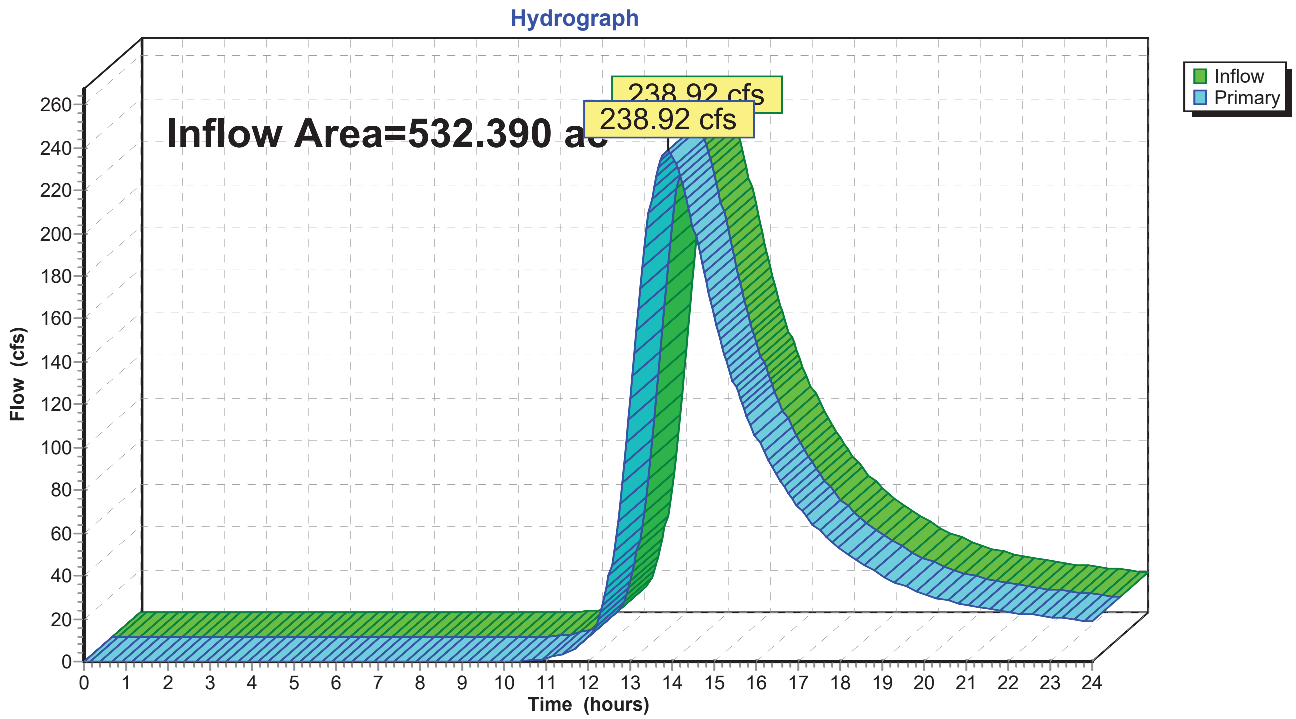
Total Runoff Area = 532.390 ac Runoff Volume = 77.127 af Average Runoff Depth = 1.74"
100.00% Pervious = 532.390 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #49129 Dashville

Inflow Area = 532.390 ac, 0.00% Impervious, Inflow Depth > 1.71" for 5-Year event
Inflow = 238.92 cfs @ 13.88 hrs, Volume= 75.686 af
Primary = 238.92 cfs @ 13.88 hrs, Volume= 75.686 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #49129 Dashville



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-01 Runoff Area=125.890 ac 0.00% Impervious Runoff Depth>2.26"
Tc=141.5 min CN=76 Runoff=76.25 cfs 23.666 af

Subcatchment 2S: WS-02 Runoff Area=157.770 ac 0.00% Impervious Runoff Depth>2.12"
Tc=106.8 min CN=74 Runoff=107.05 cfs 27.821 af

Subcatchment 3S: WS-03 Runoff Area=129.070 ac 0.00% Impervious Runoff Depth>2.61"
Tc=124.7 min CN=80 Runoff=99.14 cfs 28.051 af

Subcatchment 4S: WS-04 Runoff Area=119.660 ac 0.00% Impervious Runoff Depth>2.28"
Tc=100.1 min CN=76 Runoff=91.75 cfs 22.766 af

Reach 1R: Reach 1 Inflow=250.60 cfs 77.018 af
Outflow=250.60 cfs 77.018 af

Reach 2R: Reach 2 Avg. Flow Depth=1.23' Max Vel=5.28 fps Inflow=91.75 cfs 22.766 af
n=0.040 L=4,960.0' S=0.0218 '/' Capacity=220.87 cfs Outflow=88.53 cfs 22.373 af

Pond 3P: Pond 0 Peak Elev=272.24' Storage=49.737 af Inflow=99.14 cfs 28.051 af
Outflow=77.30 cfs 26.824 af

Link 1C: Culvert #49129 Dashville Inflow=326.06 cfs 100.683 af
Primary=326.06 cfs 100.683 af

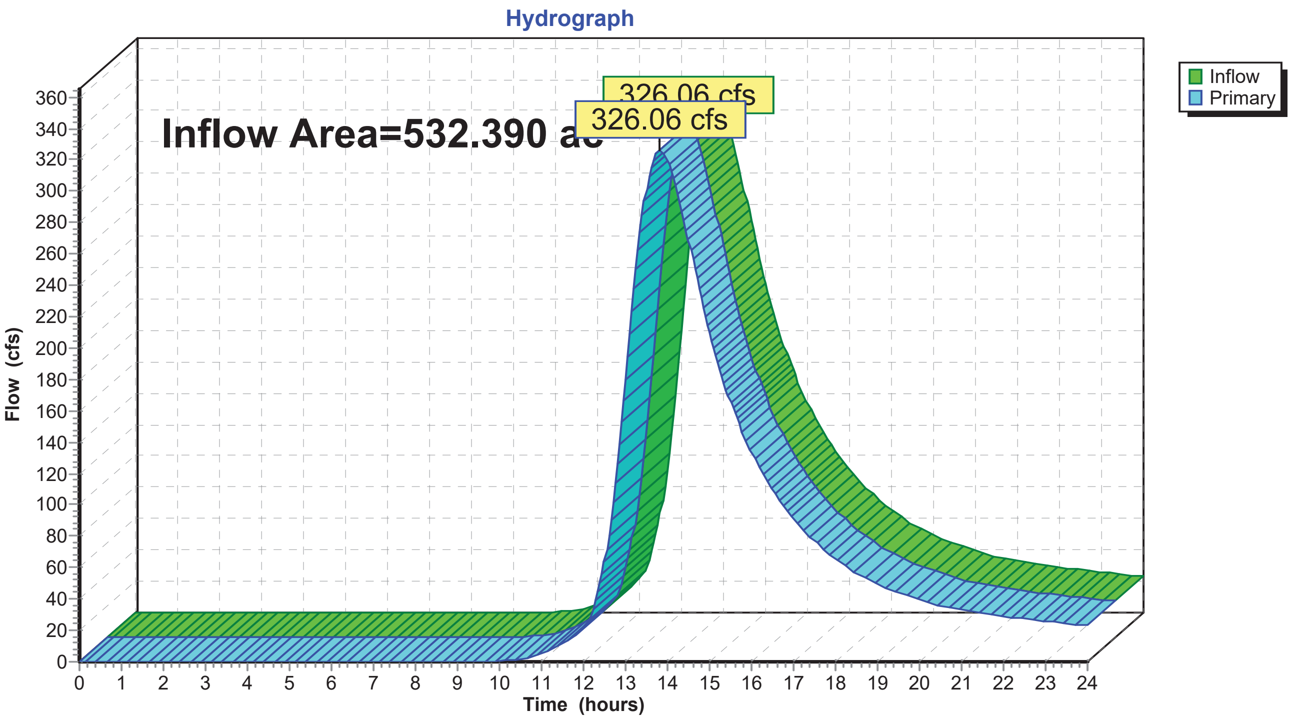
Total Runoff Area = 532.390 ac Runoff Volume = 102.304 af Average Runoff Depth = 2.31"
100.00% Pervious = 532.390 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #49129 Dashville

Inflow Area =	532.390 ac,	0.00% Impervious,	Inflow Depth > 2.27"	for 10-Year event
Inflow =	326.06 cfs @	13.83 hrs, Volume=	100.683 af	
Primary =	326.06 cfs @	13.83 hrs, Volume=	100.683 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #49129 Dashville



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-01 Runoff Area=125.890 ac 0.00% Impervious Runoff Depth>3.21"
Tc=141.5 min CN=76 Runoff=108.98 cfs 33.672 af

Subcatchment 2S: WS-02 Runoff Area=157.770 ac 0.00% Impervious Runoff Depth>3.05"
Tc=106.8 min CN=74 Runoff=156.18 cfs 40.080 af

Subcatchment 3S: WS-03 Runoff Area=129.070 ac 0.00% Impervious Runoff Depth>3.62"
Tc=124.7 min CN=80 Runoff=137.50 cfs 38.920 af

Subcatchment 4S: WS-04 Runoff Area=119.660 ac 0.00% Impervious Runoff Depth>3.25"
Tc=100.1 min CN=76 Runoff=131.30 cfs 32.365 af

Reach 1R: Reach 1 Inflow=366.88 cfs 109.464 af
Outflow=366.88 cfs 109.464 af

Reach 2R: Reach 2 Avg. Flow Depth=1.50' Max Vel=5.89 fps Inflow=131.30 cfs 32.365 af
n=0.040 L=4,960.0' S=0.0218 '/' Capacity=220.87 cfs Outflow=127.52 cfs 31.898 af

Pond 3P: Pond 0 Peak Elev=272.30' Storage=51.575 af Inflow=137.50 cfs 38.920 af
Outflow=112.07 cfs 37.486 af

Link 1C: Culvert #49129 Dashville Inflow=474.51 cfs 143.137 af
Primary=474.51 cfs 143.137 af

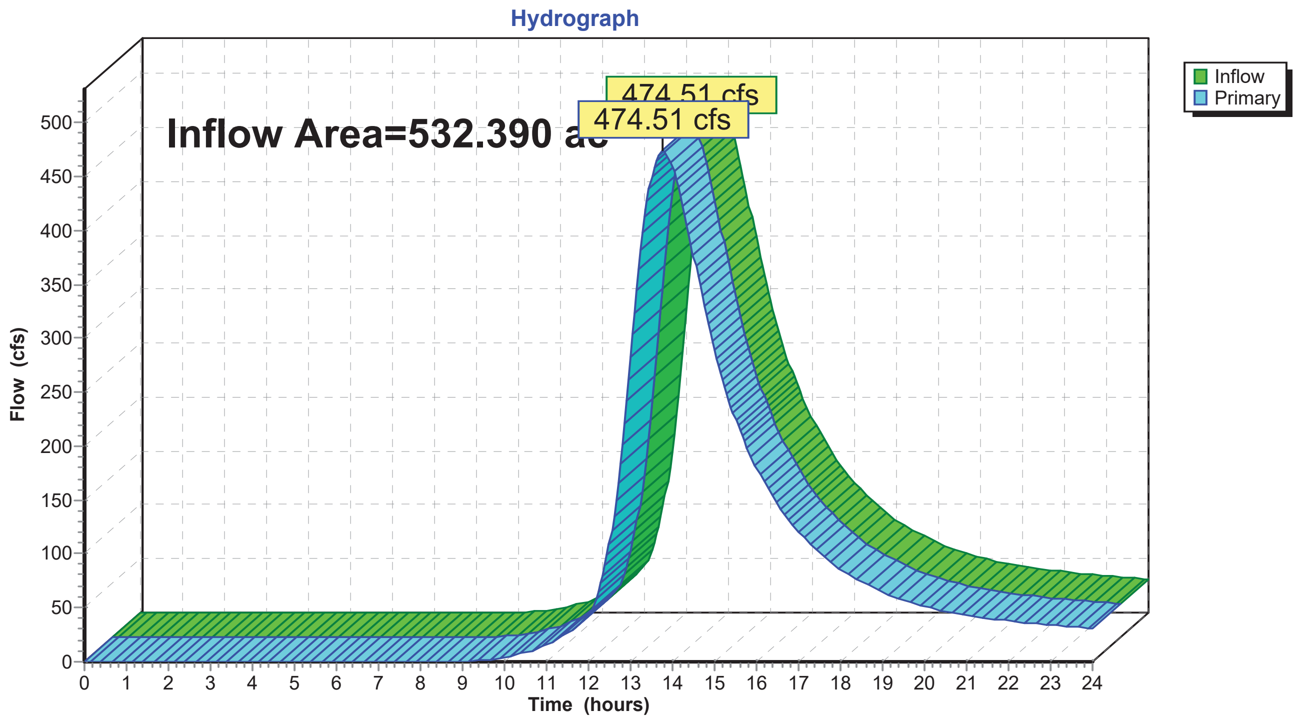
Total Runoff Area = 532.390 ac Runoff Volume = 145.037 af Average Runoff Depth = 3.27"
100.00% Pervious = 532.390 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #49129 Dashville

Inflow Area = 532.390 ac, 0.00% Impervious, Inflow Depth > 3.23" for 25-Year event
Inflow = 474.51 cfs @ 13.77 hrs, Volume= 143.137 af
Primary = 474.51 cfs @ 13.77 hrs, Volume= 143.137 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #49129 Dashville



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-01 Runoff Area=125.890 ac 0.00% Impervious Runoff Depth>4.13"
Tc=141.5 min CN=76 Runoff=140.27 cfs 43.343 af

Subcatchment 2S: WS-02 Runoff Area=157.770 ac 0.00% Impervious Runoff Depth>3.96"
Tc=106.8 min CN=74 Runoff=203.35 cfs 52.002 af

Subcatchment 3S: WS-03 Runoff Area=129.070 ac 0.00% Impervious Runoff Depth>4.58"
Tc=124.7 min CN=80 Runoff=173.59 cfs 49.293 af

Subcatchment 4S: WS-04 Runoff Area=119.660 ac 0.00% Impervious Runoff Depth>4.18"
Tc=100.1 min CN=76 Runoff=169.05 cfs 41.638 af

Reach 1R: Reach 1 Inflow=479.09 cfs 140.781 af
Outflow=479.09 cfs 140.781 af

Reach 2R: Reach 2 Avg. Flow Depth=1.72' Max Vel=6.35 fps Inflow=169.05 cfs 41.638 af
n=0.040 L=4,960.0' S=0.0218 '/' Capacity=220.87 cfs Outflow=164.81 cfs 41.108 af

Pond 3P: Pond 0 Peak Elev=272.36' Storage=53.166 af Inflow=173.59 cfs 49.293 af
Outflow=145.33 cfs 47.670 af

Link 1C: Culvert #49129 Dashville Inflow=617.65 cfs 184.123 af
Primary=617.65 cfs 184.123 af

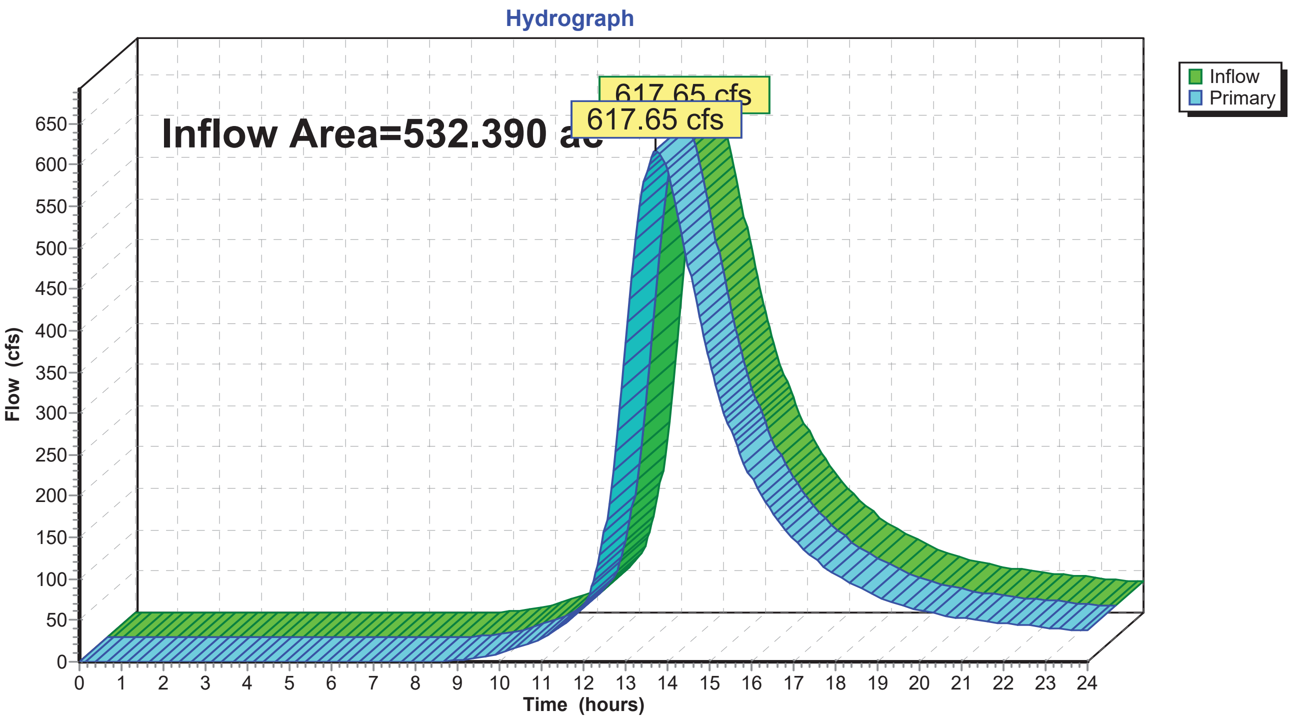
Total Runoff Area = 532.390 ac Runoff Volume = 186.276 af Average Runoff Depth = 4.20"
100.00% Pervious = 532.390 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #49129 Dashville

Inflow Area = 532.390 ac, 0.00% Impervious, Inflow Depth > 4.15" for 50-Year event
Inflow = 617.65 cfs @ 13.73 hrs, Volume= 184.123 af
Primary = 617.65 cfs @ 13.73 hrs, Volume= 184.123 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #49129 Dashville



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-01 Runoff Area=125.890 ac 0.00% Impervious Runoff Depth>5.27"
Tc=141.5 min CN=76 Runoff=178.62 cfs 55.262 af

Subcatchment 2S: WS-02 Runoff Area=157.770 ac 0.00% Impervious Runoff Depth>5.08"
Tc=106.8 min CN=74 Runoff=261.08 cfs 66.764 af

Subcatchment 3S: WS-03 Runoff Area=129.070 ac 0.00% Impervious Runoff Depth>5.76"
Tc=124.7 min CN=80 Runoff=216.89 cfs 61.964 af

Subcatchment 4S: WS-04 Runoff Area=119.660 ac 0.00% Impervious Runoff Depth>5.32"
Tc=100.1 min CN=76 Runoff=214.96 cfs 53.062 af

Reach 1R: Reach 1 Inflow=617.02 cfs 179.346 af
Outflow=617.02 cfs 179.346 af

Reach 2R: Reach 2 Avg. Flow Depth=1.95' Max Vel=6.81 fps Inflow=214.96 cfs 53.062 af
n=0.040 L=4,960.0' S=0.0218 '/' Capacity=220.87 cfs Outflow=210.35 cfs 52.463 af

Pond 3P: Pond 0 Peak Elev=272.42' Storage=54.952 af Inflow=216.89 cfs 61.964 af
Outflow=185.82 cfs 60.120 af

Link 1C: Culvert #49129 Dashville Inflow=793.00 cfs 234.608 af
Primary=793.00 cfs 234.608 af

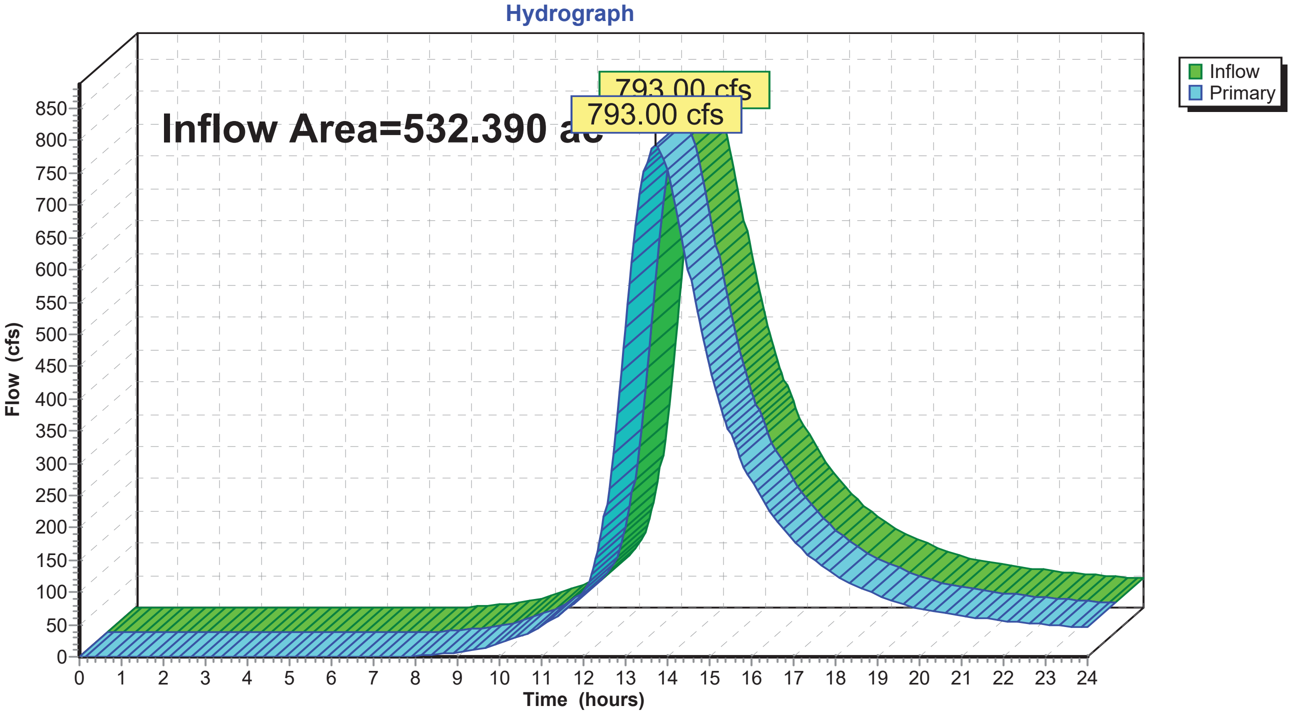
Total Runoff Area = 532.390 ac Runoff Volume = 237.052 af Average Runoff Depth = 5.34"
100.00% Pervious = 532.390 ac 0.00% Impervious = 0.000 ac

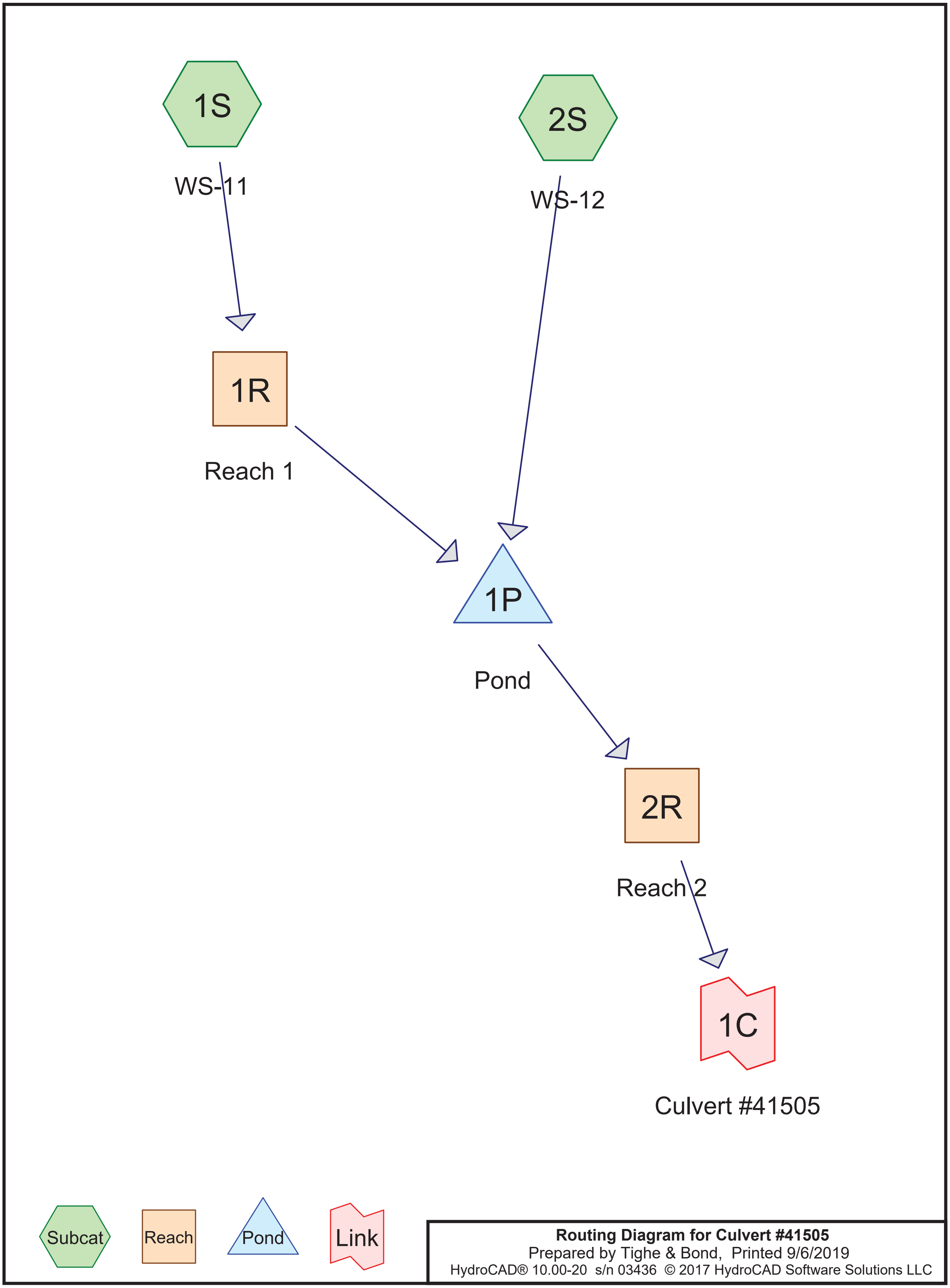
Summary for Link 1C: Culvert #49129 Dashville

Inflow Area = 532.390 ac, 0.00% Impervious, Inflow Depth > 5.29" for 100-Year event
Inflow = 793.00 cfs @ 13.70 hrs, Volume= 234.608 af
Primary = 793.00 cfs @ 13.70 hrs, Volume= 234.608 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #49129 Dashville





Routing Diagram for Culvert #41505
Prepared by Tighe & Bond, Printed 9/6/2019
HydroCAD® 10.00-20 s/n 03436 © 2017 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
128.290	77	(1S)
175.160	70	(2S)
303.450	**73**	**TOTAL AREA**

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

Subcatchment1S: WS-11 Runoff Area=128.290 ac 0.00% Impervious Runoff Depth>1.08"
Tc=125.5 min CN=77 Runoff=43.33 cfs 11.495 af

Subcatchment2S: WS-12 Runoff Area=175.160 ac 0.00% Impervious Runoff Depth>0.73"
Tc=105.0 min CN=70 Runoff=42.25 cfs 10.627 af

Reach 1R: Reach 1 Avg. Flow Depth=7.45' Max Vel=0.36 fps Inflow=43.33 cfs 11.495 af
n=0.450 L=370.0' S=0.0054 '/' Capacity=6.19 cfs Outflow=41.33 cfs 11.202 af

Reach 2R: Reach 2 Avg. Flow Depth=1.09' Max Vel=5.24 fps Inflow=47.45 cfs 20.348 af
n=0.045 L=55.0' S=0.0364 '/' Capacity=160.46 cfs Outflow=47.45 cfs 20.339 af

Pond 1P: Pond Peak Elev=174.62' Storage=6.016 af Inflow=75.33 cfs 21.829 af
36.0" Round Culvert n=0.025 L=40.0' S=0.0500 '/' Outflow=47.45 cfs 20.348 af

Link 1C: Culvert #41505 Inflow=47.45 cfs 20.339 af
Primary=47.45 cfs 20.339 af

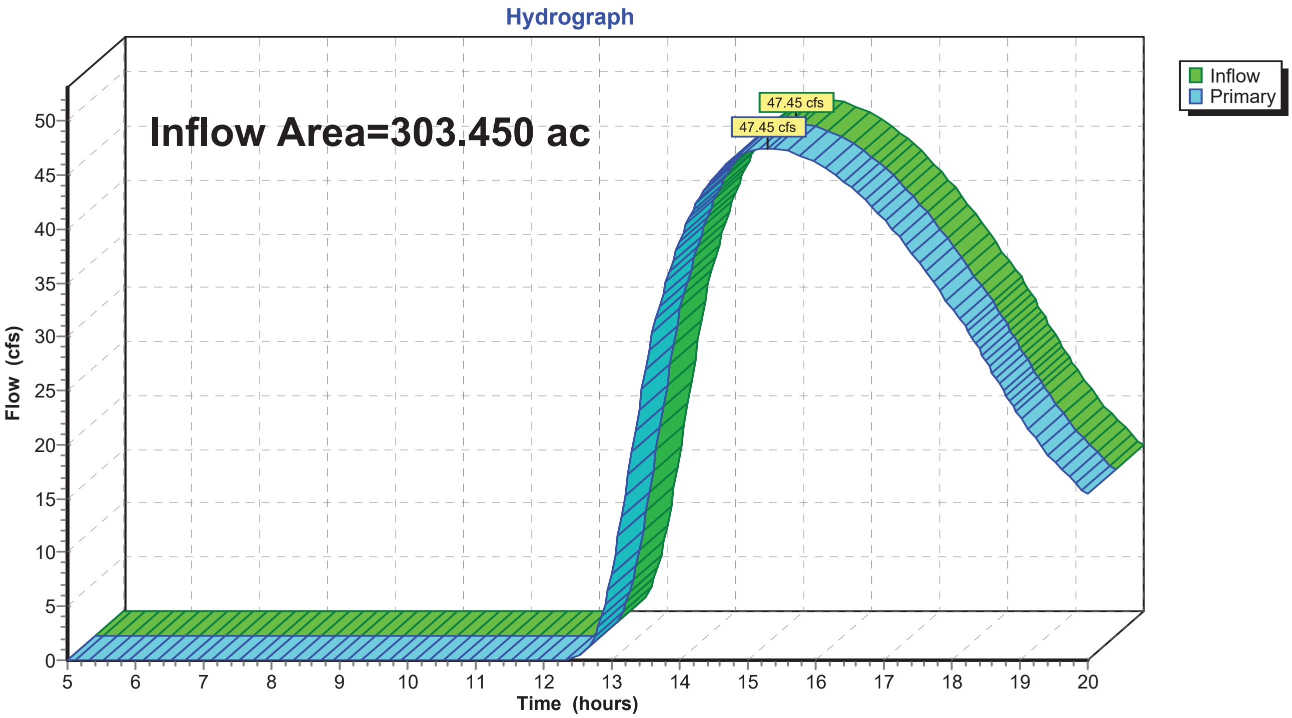
Total Runoff Area = 303.450 ac Runoff Volume = 22.122 af Average Runoff Depth = 0.87"
100.00% Pervious = 303.450 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #41505

Inflow Area = 303.450 ac, 0.00% Impervious, Inflow Depth > 0.80" for 2-Year event
Inflow = 47.45 cfs @ 15.31 hrs, Volume= 20.339 af
Primary = 47.45 cfs @ 15.31 hrs, Volume= 20.339 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #41505



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

Subcatchment 1S: WS-11 Runoff Area=128.290 ac 0.00% Impervious Runoff Depth>1.61"
Tc=125.5 min CN=77 Runoff=65.48 cfs 17.216 af

Subcatchment 2S: WS-12 Runoff Area=175.160 ac 0.00% Impervious Runoff Depth>1.17"
Tc=105.0 min CN=70 Runoff=71.15 cfs 17.130 af

Reach 1R: Reach 1 Avg. Flow Depth=10.75' Max Vel=0.37 fps Inflow=65.48 cfs 17.216 af
n=0.450 L=370.0' S=0.0054 '/' Capacity=6.19 cfs Outflow=62.62 cfs 16.836 af

Reach 2R: Reach 2 Avg. Flow Depth=1.76' Max Vel=6.80 fps Inflow=127.70 cfs 30.899 af
n=0.045 L=55.0' S=0.0364 '/' Capacity=160.46 cfs Outflow=120.35 cfs 30.884 af

Pond 1P: Pond Peak Elev=194.07' Storage=10.133 af Inflow=120.04 cfs 33.966 af
36.0" Round Culvert n=0.025 L=40.0' S=0.0500 '/' Outflow=127.70 cfs 30.899 af

Link 1C: Culvert #41505 Inflow=120.35 cfs 30.884 af
Primary=120.35 cfs 30.884 af

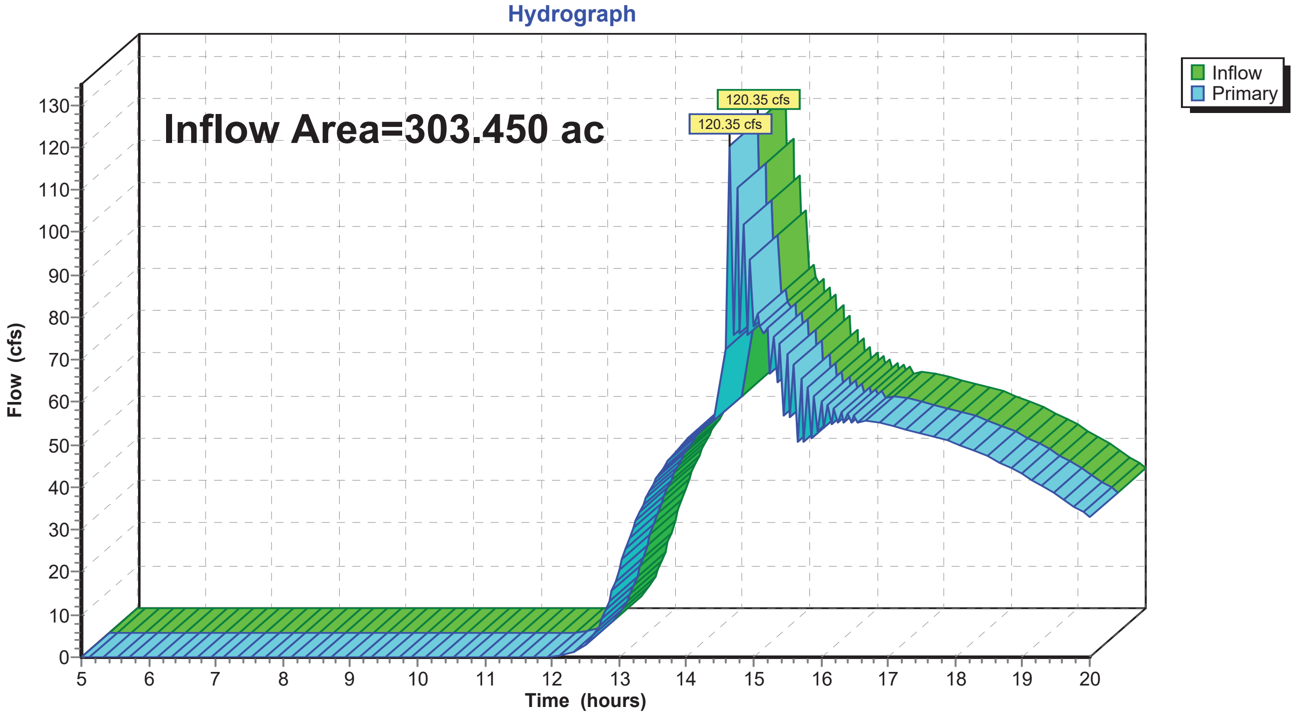
Total Runoff Area = 303.450 ac Runoff Volume = 34.346 af Average Runoff Depth = 1.36"
100.00% Pervious = 303.450 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #41505

Inflow Area =	303.450 ac,	0.00% Impervious,	Inflow Depth > 1.22"	for 5-Year event	
Inflow =	120.35 cfs @	14.65 hrs,	Volume=	30.884 af	
Primary =	120.35 cfs @	14.65 hrs,	Volume=	30.884 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #41505



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

Subcatchment 1S: WS-11 Runoff Area=128.290 ac 0.00% Impervious Runoff Depth>2.14"
Tc=125.5 min CN=77 Runoff=87.35 cfs 22.907 af

Subcatchment 2S: WS-12 Runoff Area=175.160 ac 0.00% Impervious Runoff Depth>1.63"
Tc=105.0 min CN=70 Runoff=100.97 cfs 23.849 af

Reach 1R: Reach 1 Avg. Flow Depth=14.00' Max Vel=0.37 fps Inflow=87.35 cfs 22.907 af
n=0.450 L=370.0' S=0.0054 '/' Capacity=6.19 cfs Outflow=83.57 cfs 22.446 af

Reach 2R: Reach 2 Avg. Flow Depth=2.13' Max Vel=7.53 fps Inflow=179.24 cfs 41.925 af
n=0.045 L=55.0' S=0.0364 '/' Capacity=160.46 cfs Outflow=181.24 cfs 41.908 af

Pond 1P: Pond Peak Elev=216.00' Storage=10.133 af Inflow=165.20 cfs 46.295 af
36.0" Round Culvert n=0.025 L=40.0' S=0.0500 '/' Outflow=179.24 cfs 41.925 af

Link 1C: Culvert #41505 Inflow=181.24 cfs 41.908 af
Primary=181.24 cfs 41.908 af

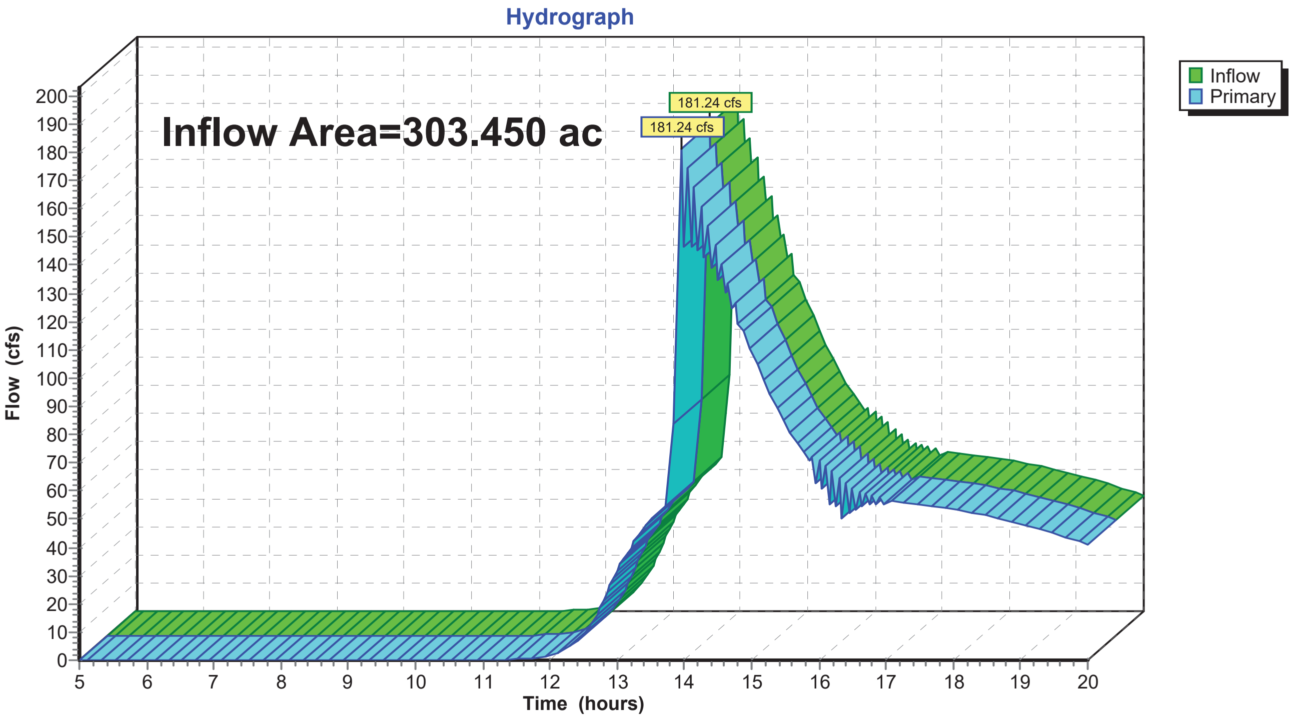
Total Runoff Area = 303.450 ac Runoff Volume = 46.756 af Average Runoff Depth = 1.85"
100.00% Pervious = 303.450 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #41505

Inflow Area = 303.450 ac, 0.00% Impervious, Inflow Depth > 1.66" for 10-Year event
Inflow = 181.24 cfs @ 13.95 hrs, Volume= 41.908 af
Primary = 181.24 cfs @ 13.95 hrs, Volume= 41.908 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #41505



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

Subcatchment1S: WS-11 Runoff Area=128.290 ac 0.00% Impervious Runoff Depth>3.05"
Tc=125.5 min CN=77 Runoff=124.10 cfs 32.583 af

Subcatchment2S: WS-12 Runoff Area=175.160 ac 0.00% Impervious Runoff Depth>2.44"
Tc=105.0 min CN=70 Runoff=152.87 cfs 35.641 af

Reach 1R: Reach 1 Avg. Flow Depth=19.45' Max Vel=0.37 fps Inflow=124.10 cfs 32.583 af
n=0.450 L=370.0' S=0.0054 '/' Capacity=6.19 cfs Outflow=118.71 cfs 31.990 af

Reach 2R: Reach 2 Avg. Flow Depth=2.58' Max Vel=8.09 fps Inflow=282.96 cfs 61.320 af
n=0.045 L=55.0' S=0.0364 '/' Capacity=160.46 cfs Outflow=256.30 cfs 61.301 af

Pond 1P: Pond Peak Elev=282.40' Storage=10.133 af Inflow=242.79 cfs 67.632 af
36.0" Round Culvert n=0.025 L=40.0' S=0.0500 '/' Outflow=282.96 cfs 61.320 af

Link 1C: Culvert #41505 Inflow=256.30 cfs 61.301 af
Primary=256.30 cfs 61.301 af

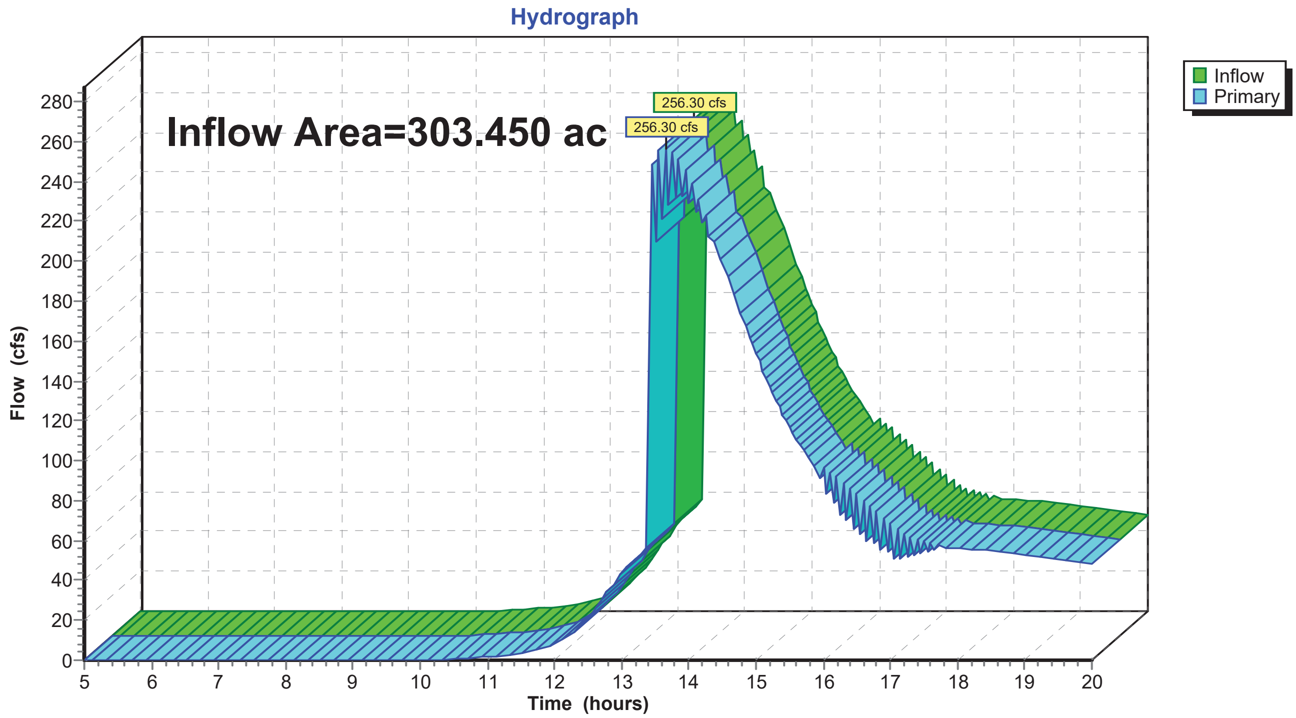
Total Runoff Area = 303.450 ac Runoff Volume = 68.225 af Average Runoff Depth = 2.70"
100.00% Pervious = 303.450 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #41505

Inflow Area = 303.450 ac, 0.00% Impervious, Inflow Depth > 2.42" for 25-Year event
Inflow = 256.30 cfs @ 13.65 hrs, Volume= 61.301 af
Primary = 256.30 cfs @ 13.65 hrs, Volume= 61.301 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #41505



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

Subcatchment1S: WS-11 Runoff Area=128.290 ac 0.00% Impervious Runoff Depth>3.92"
Tc=125.5 min CN=77 Runoff=159.08 cfs 41.933 af

Subcatchment2S: WS-12 Runoff Area=175.160 ac 0.00% Impervious Runoff Depth>3.24"
Tc=105.0 min CN=70 Runoff=203.62 cfs 47.333 af

Reach 1R: Reach 1 Avg. Flow Depth=24.64' Max Vel=0.38 fps Inflow=159.08 cfs 41.933 af
n=0.450 L=370.0' S=0.0054 '/' Capacity=6.19 cfs Outflow=152.17 cfs 41.219 af

Reach 2R: Reach 2 Avg. Flow Depth=2.95' Max Vel=8.38 fps Inflow=326.62 cfs 80.839 af
n=0.045 L=55.0' S=0.0364 '/' Capacity=160.46 cfs Outflow=318.98 cfs 80.819 af

Pond 1P: Pond Peak Elev=319.26' Storage=10.133 af Inflow=318.04 cfs 88.552 af
36.0" Round Culvert n=0.025 L=40.0' S=0.0500 '/' Outflow=326.62 cfs 80.839 af

Link 1C: Culvert #41505 Inflow=318.98 cfs 80.819 af
Primary=318.98 cfs 80.819 af

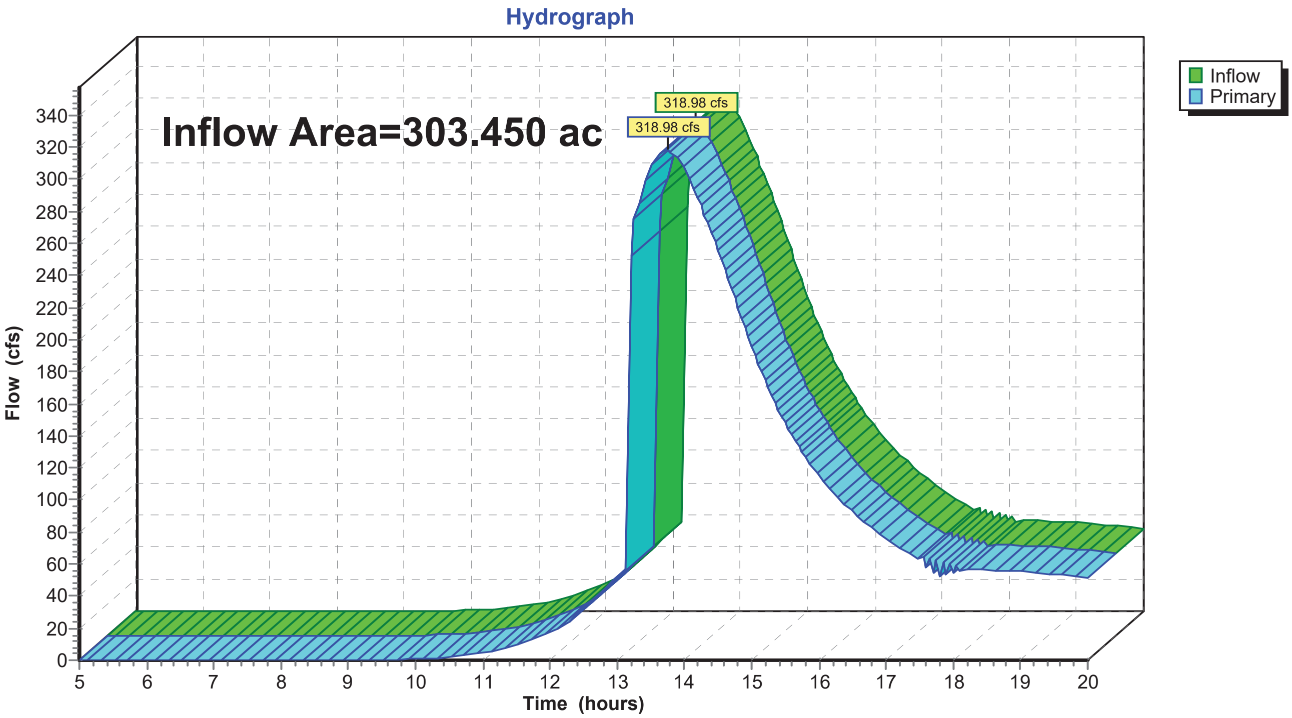
Total Runoff Area = 303.450 ac Runoff Volume = 89.266 af Average Runoff Depth = 3.53"
100.00% Pervious = 303.450 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #41505

Inflow Area =	303.450 ac,	0.00% Impervious,	Inflow Depth > 3.20"	for 50-Year event
Inflow =	318.98 cfs @	13.75 hrs, Volume=	80.819 af	
Primary =	318.98 cfs @	13.75 hrs, Volume=	80.819 af, Atten= 0%, Lag= 0.0 min	

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #41505



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

Subcatchment 1S: WS-11 Runoff Area=128.290 ac 0.00% Impervious Runoff Depth>5.00"
Tc=125.5 min CN=77 Runoff=201.58 cfs 53.454 af

Subcatchment 2S: WS-12 Runoff Area=175.160 ac 0.00% Impervious Runoff Depth>4.25"
Tc=105.0 min CN=70 Runoff=266.51 cfs 62.013 af

Reach 1R: Reach 1 Avg. Flow Depth=30.95' Max Vel=0.38 fps Inflow=201.58 cfs 53.454 af
n=0.450 L=370.0' S=0.0054 '/' Capacity=6.19 cfs Outflow=192.84 cfs 52.596 af

Reach 2R: Reach 2 Avg. Flow Depth=3.65' Max Vel=8.74 fps Inflow=561.61 cfs 105.646 af
n=0.045 L=55.0' S=0.0364 '/' Capacity=160.46 cfs Outflow=434.44 cfs 105.625 af

Pond 1P: Pond Peak Elev=608.36' Storage=10.133 af Inflow=410.71 cfs 114.609 af
36.0" Round Culvert n=0.025 L=40.0' S=0.0500 '/' Outflow=561.61 cfs 105.646 af

Link 1C: Culvert #41505 Inflow=434.44 cfs 105.625 af
Primary=434.44 cfs 105.625 af

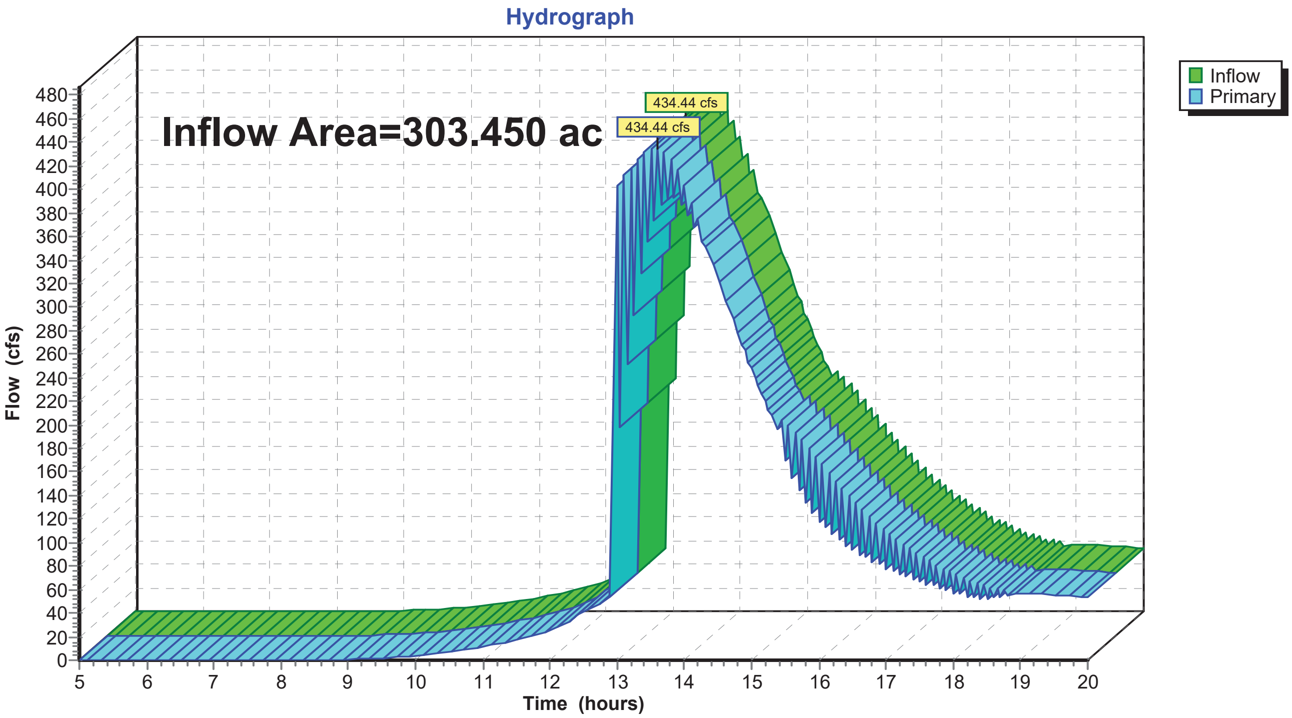
Total Runoff Area = 303.450 ac Runoff Volume = 115.467 af Average Runoff Depth = 4.57"
100.00% Pervious = 303.450 ac 0.00% Impervious = 0.000 ac

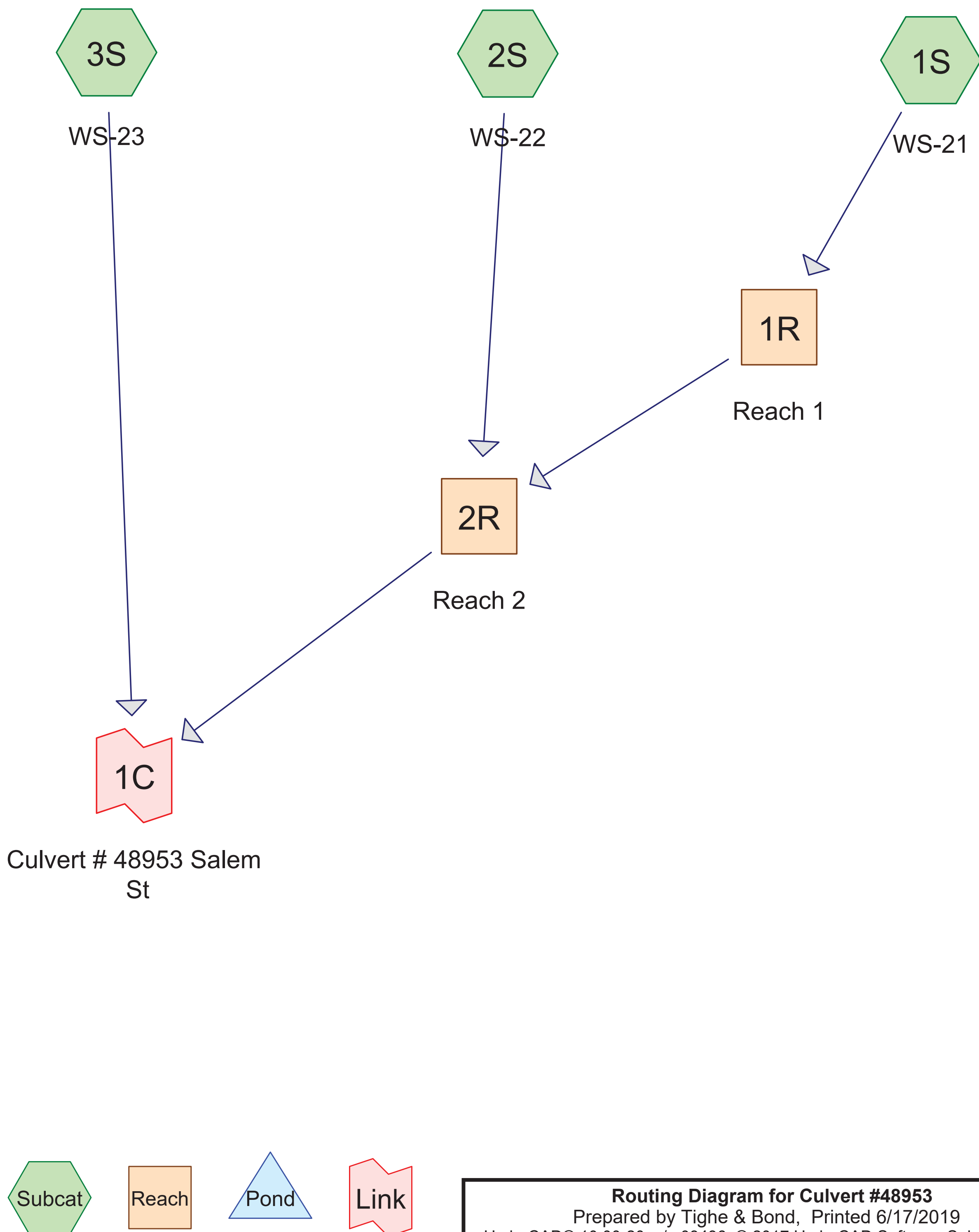
Summary for Link 1C: Culvert #41505

Inflow Area = 303.450 ac, 0.00% Impervious, Inflow Depth > 4.18" for 100-Year event
Inflow = 434.44 cfs @ 13.60 hrs, Volume= 105.625 af
Primary = 434.44 cfs @ 13.60 hrs, Volume= 105.625 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #41505





Routing Diagram for Culvert #48953
Prepared by Tighe & Bond, Printed 6/17/2019
HydroCAD® 10.00-20 s/n 03436 © 2017 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
555.700	76	(1S)
517.470	79	(2S)
319.720	71	(3S)
1,392.890	**76**	**TOTAL AREA**

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-21 Runoff Area=555.700 ac 0.00% Impervious Runoff Depth>1.11"
Tc=187.5 min CN=76 Runoff=131.93 cfs 51.481 af

Subcatchment 2S: WS-22 Runoff Area=517.470 ac 0.00% Impervious Runoff Depth>1.33"
Tc=93.5 min CN=79 Runoff=238.72 cfs 57.525 af

Subcatchment 3S: WS-23 Runoff Area=319.720 ac 0.00% Impervious Runoff Depth>0.87"
Tc=111.1 min CN=71 Runoff=79.52 cfs 23.188 af

Reach 1R: Reach 1 Avg. Flow Depth=2.32' Max Vel=2.94 fps Inflow=131.93 cfs 51.481 af
n=0.030 L=4,305.0' S=0.0019 '/' Capacity=98.95 cfs Outflow=128.48 cfs 49.925 af

Reach 2R: Reach 2 Avg. Flow Depth=3.40' Max Vel=2.58 fps Inflow=249.26 cfs 107.450 af
n=0.040 L=3,930.0' S=0.0015 '/' Capacity=718.75 cfs Outflow=229.89 cfs 104.323 af

Link 1C: Culvert # 48953 Salem St Inflow=298.05 cfs 127.511 af
Primary=298.05 cfs 127.511 af

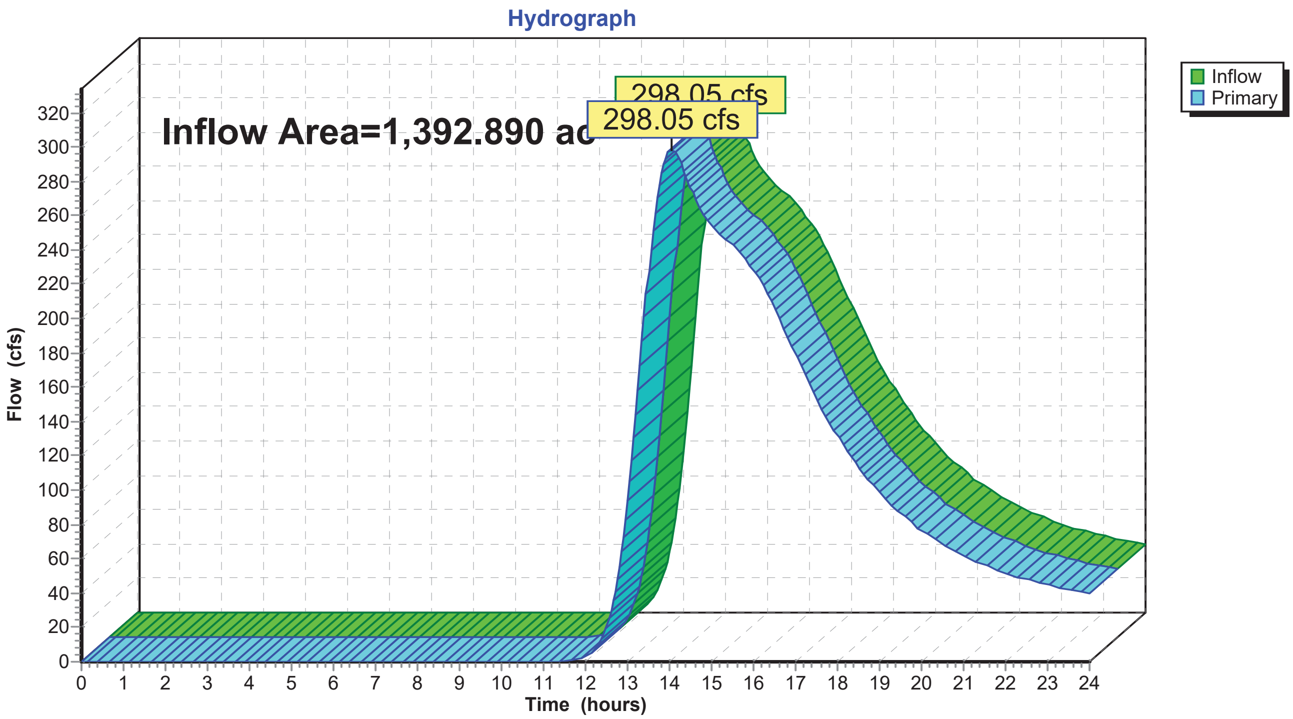
Total Runoff Area = 1,392.890 ac Runoff Volume = 132.194 af Average Runoff Depth = 1.14"
100.00% Pervious = 1,392.890 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert # 48953 Salem St

Inflow Area = 1,392.890 ac, 0.00% Impervious, Inflow Depth > 1.10" for 2-Year event
Inflow = 298.05 cfs @ 14.05 hrs, Volume= 127.511 af
Primary = 298.05 cfs @ 14.05 hrs, Volume= 127.511 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert # 48953 Salem St



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-21 Runoff Area=555.700 ac 0.00% Impervious Runoff Depth>1.67"
Tc=187.5 min CN=76 Runoff=202.49 cfs 77.253 af

Subcatchment 2S: WS-22 Runoff Area=517.470 ac 0.00% Impervious Runoff Depth>1.94"
Tc=93.5 min CN=79 Runoff=353.20 cfs 83.822 af

Subcatchment 3S: WS-23 Runoff Area=319.720 ac 0.00% Impervious Runoff Depth>1.37"
Tc=111.1 min CN=71 Runoff=131.50 cfs 36.492 af

Reach 1R: Reach 1 Avg. Flow Depth=3.06' Max Vel=3.21 fps Inflow=202.49 cfs 77.253 af
n=0.030 L=4,305.0' S=0.0019 '/' Capacity=98.95 cfs Outflow=197.16 cfs 75.329 af

Reach 2R: Reach 2 Avg. Flow Depth=4.26' Max Vel=2.92 fps Inflow=381.31 cfs 159.150 af
n=0.040 L=3,930.0' S=0.0015 '/' Capacity=718.75 cfs Outflow=358.53 cfs 155.371 af

Link 1C: Culvert # 48953 Salem St Inflow=473.69 cfs 191.863 af
Primary=473.69 cfs 191.863 af

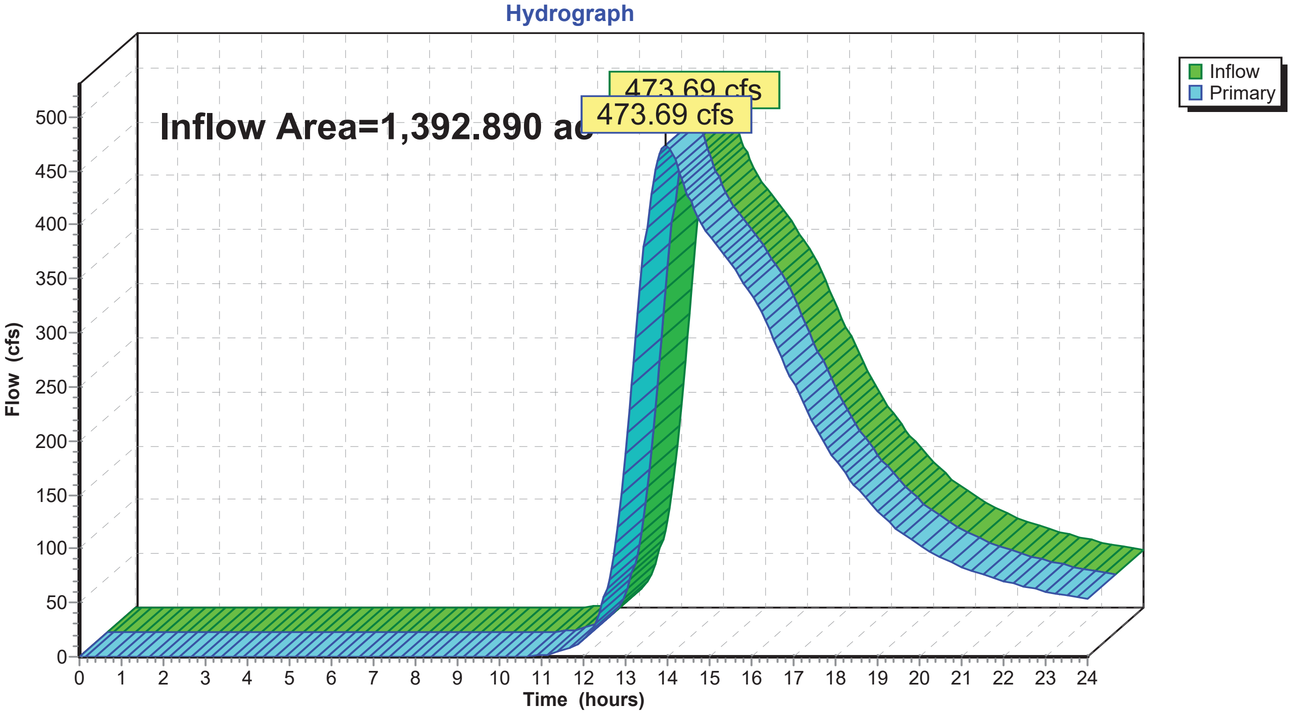
Total Runoff Area = 1,392.890 ac Runoff Volume = 197.567 af Average Runoff Depth = 1.70"
100.00% Pervious = 1,392.890 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert # 48953 Salem St

Inflow Area =	1,392.890 ac,	0.00% Impervious,	Inflow Depth > 1.65"	for 5-Year event	
Inflow =	473.69 cfs @	13.95 hrs,	Volume=	191.863 af	
Primary =	473.69 cfs @	13.95 hrs,	Volume=	191.863 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert # 48953 Salem St



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-21 Runoff Area=555.700 ac 0.00% Impervious Runoff Depth>2.22"
Tc=187.5 min CN=76 Runoff=272.48 cfs 102.917 af

Subcatchment 2S: WS-22 Runoff Area=517.470 ac 0.00% Impervious Runoff Depth>2.54"
Tc=93.5 min CN=79 Runoff=465.44 cfs 109.606 af

Subcatchment 3S: WS-23 Runoff Area=319.720 ac 0.00% Impervious Runoff Depth>1.88"
Tc=111.1 min CN=71 Runoff=184.80 cfs 50.071 af

Reach 1R: Reach 1 Avg. Flow Depth=3.80' Max Vel=3.36 fps Inflow=272.48 cfs 102.917 af
n=0.030 L=4,305.0' S=0.0019 '/' Capacity=98.95 cfs Outflow=265.36 cfs 100.660 af

Reach 2R: Reach 2 Avg. Flow Depth=4.97' Max Vel=3.18 fps Inflow=513.58 cfs 210.266 af
n=0.040 L=3,930.0' S=0.0015 '/' Capacity=718.75 cfs Outflow=488.00 cfs 205.922 af

Link 1C: Culvert # 48953 Salem St Inflow=651.89 cfs 255.993 af
Primary=651.89 cfs 255.993 af

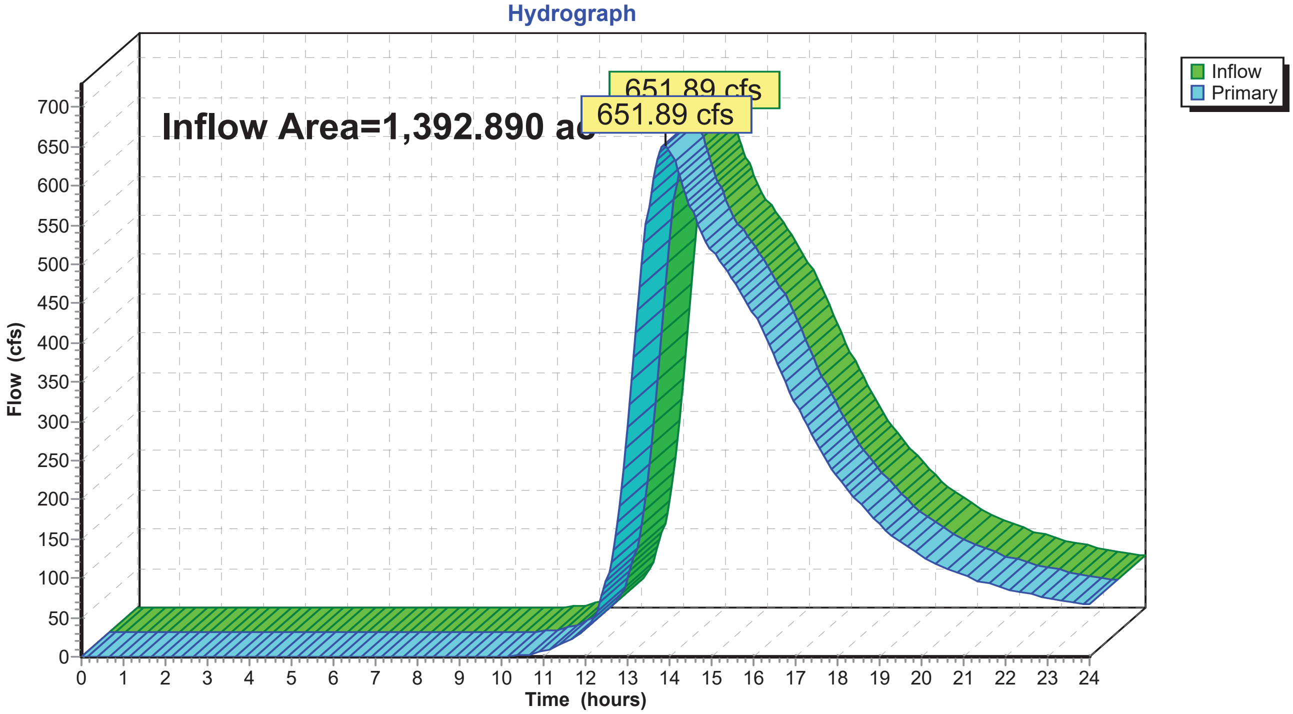
Total Runoff Area = 1,392.890 ac Runoff Volume = 262.594 af Average Runoff Depth = 2.26"
100.00% Pervious = 1,392.890 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert # 48953 Salem St

Inflow Area = 1,392.890 ac, 0.00% Impervious, Inflow Depth > 2.21" for 10-Year event
Inflow = 651.89 cfs @ 13.90 hrs, Volume= 255.993 af
Primary = 651.89 cfs @ 13.90 hrs, Volume= 255.993 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert # 48953 Salem St



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-21 Runoff Area=555.700 ac 0.00% Impervious Runoff Depth>3.17"
Tc=187.5 min CN=76 Runoff=391.87 cfs 146.587 af

Subcatchment 2S: WS-22 Runoff Area=517.470 ac 0.00% Impervious Runoff Depth>3.55"
Tc=93.5 min CN=79 Runoff=650.98 cfs 152.917 af

Subcatchment 3S: WS-23 Runoff Area=319.720 ac 0.00% Impervious Runoff Depth>2.76"
Tc=111.1 min CN=71 Runoff=277.47 cfs 73.662 af

Reach 1R: Reach 1 Avg. Flow Depth=5.04' Max Vel=3.50 fps Inflow=391.87 cfs 146.587 af
n=0.030 L=4,305.0' S=0.0019 '/' Capacity=98.95 cfs Outflow=380.52 cfs 143.816 af

Reach 2R: Reach 2 Avg. Flow Depth=5.95' Max Vel=3.51 fps Inflow=737.19 cfs 296.732 af
n=0.040 L=3,930.0' S=0.0015 '/' Capacity=718.75 cfs Outflow=706.67 cfs 291.540 af

Link 1C: Culvert # 48953 Salem St Inflow=957.28 cfs 365.202 af
Primary=957.28 cfs 365.202 af

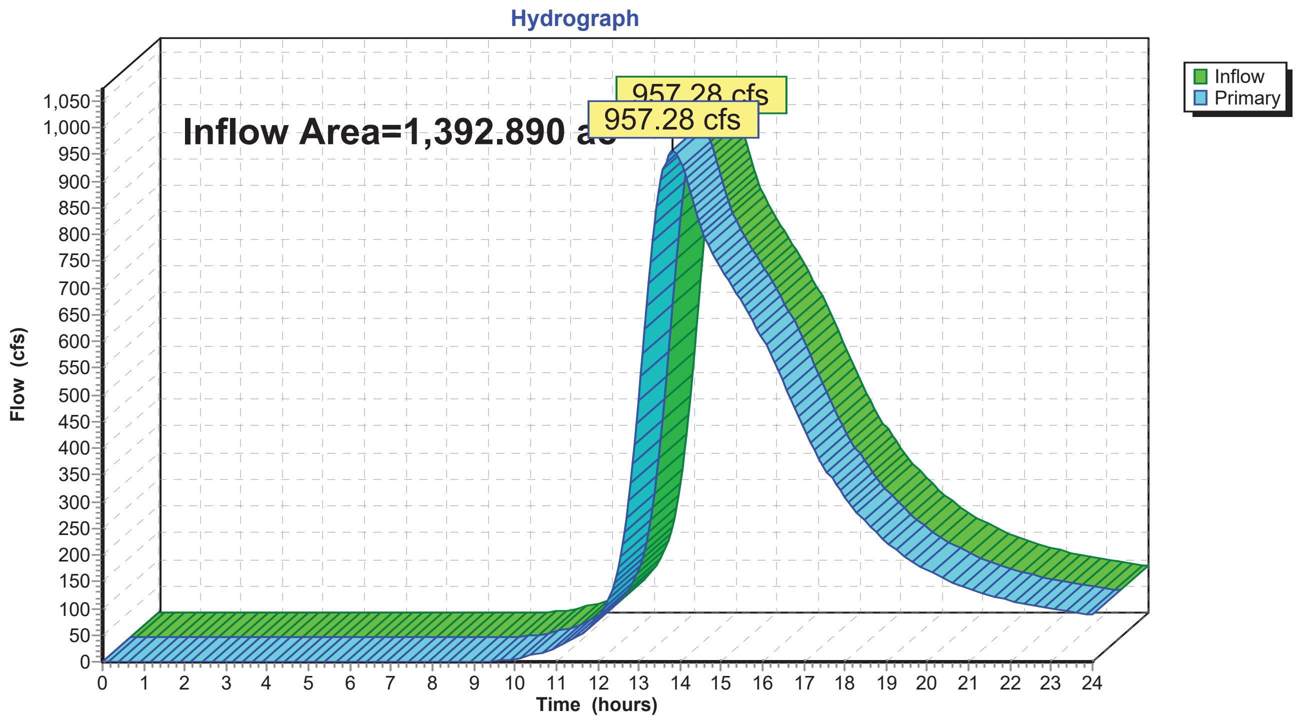
Total Runoff Area = 1,392.890 ac Runoff Volume = 373.166 af Average Runoff Depth = 3.21"
100.00% Pervious = 1,392.890 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert # 48953 Salem St

Inflow Area =	1,392.890 ac,	0.00% Impervious,	Inflow Depth > 3.15"	for 25-Year event	
Inflow =	957.28 cfs @	13.83 hrs,	Volume=	365.202 af	
Primary =	957.28 cfs @	13.83 hrs,	Volume=	365.202 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert # 48953 Salem St



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-21 Runoff Area=555.700 ac 0.00% Impervious Runoff Depth>4.08"
Tc=187.5 min CN=76 Runoff=506.14 cfs 188.812 af

Subcatchment 2S: WS-22 Runoff Area=517.470 ac 0.00% Impervious Runoff Depth>4.51"
Tc=93.5 min CN=79 Runoff=826.06 cfs 194.360 af

Subcatchment 3S: WS-23 Runoff Area=319.720 ac 0.00% Impervious Runoff Depth>3.64"
Tc=111.1 min CN=71 Runoff=367.71 cfs 96.860 af

Reach 1R: Reach 1 Avg. Flow Depth=6.23' Max Vel=3.57 fps Inflow=506.14 cfs 188.812 af
n=0.030 L=4,305.0' S=0.0019 '/' Capacity=98.95 cfs Outflow=490.84 cfs 185.582 af

Reach 2R: Reach 2 Avg. Flow Depth=6.78' Max Vel=3.73 fps Inflow=949.19 cfs 379.942 af
n=0.040 L=3,930.0' S=0.0015 '/' Capacity=718.75 cfs Outflow=912.88 cfs 374.005 af

Link 1C: Culvert # 48953 Salem St Inflow=1,248.57 cfs 470.865 af
Primary=1,248.57 cfs 470.865 af

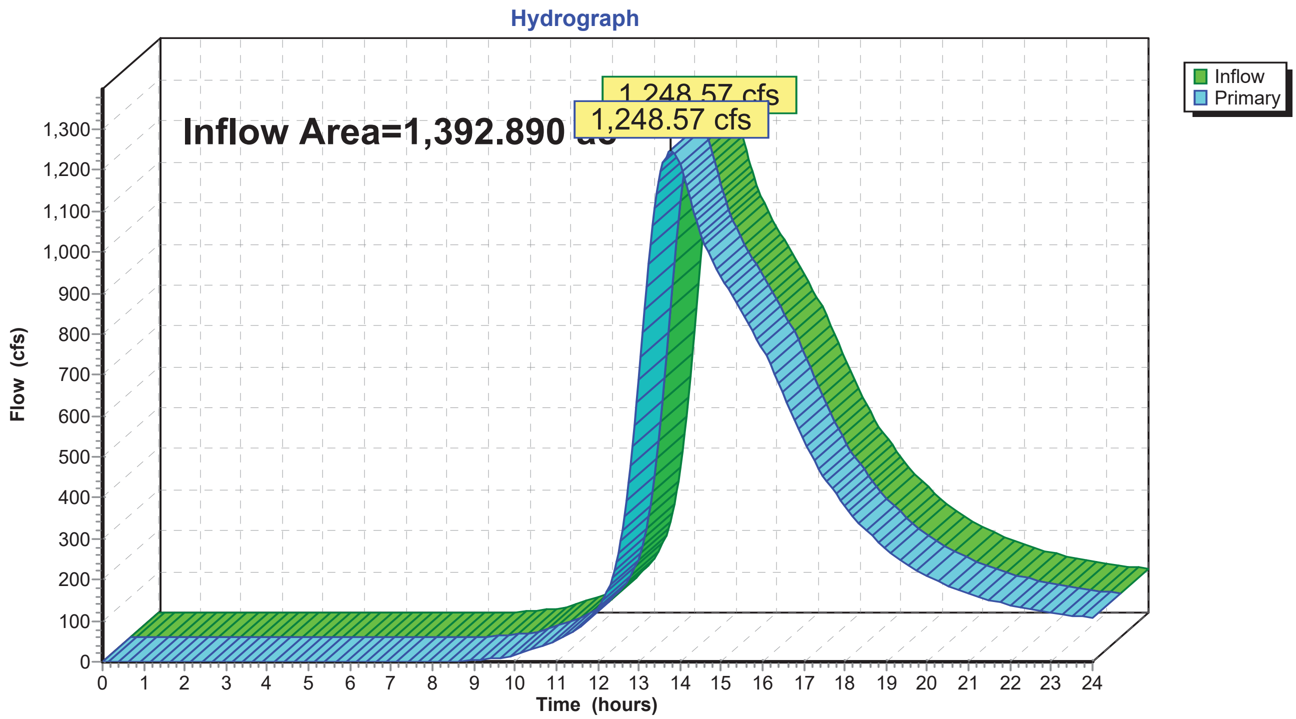
Total Runoff Area = 1,392.890 ac Runoff Volume = 480.033 af Average Runoff Depth = 4.14"
100.00% Pervious = 1,392.890 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert # 48953 Salem St

Inflow Area = 1,392.890 ac, 0.00% Impervious, Inflow Depth > 4.06" for 50-Year event
Inflow = 1,248.57 cfs @ 13.78 hrs, Volume= 470.865 af
Primary = 1,248.57 cfs @ 13.78 hrs, Volume= 470.865 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert # 48953 Salem St



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-21 Runoff Area=555.700 ac 0.00% Impervious Runoff Depth>5.20"
Tc=187.5 min CN=76 Runoff=645.63 cfs 240.875 af

Subcatchment 2S: WS-22 Runoff Area=517.470 ac 0.00% Impervious Runoff Depth>5.68"
Tc=93.5 min CN=79 Runoff=1,037.46 cfs 245.081 af

Subcatchment 3S: WS-23 Runoff Area=319.720 ac 0.00% Impervious Runoff Depth>4.72"
Tc=111.1 min CN=71 Runoff=479.22 cfs 125.813 af

Reach 1R: Reach 1 Avg. Flow Depth=7.69' Max Vel=3.63 fps Inflow=645.63 cfs 240.875 af
n=0.030 L=4,305.0' S=0.0019 '/' Capacity=98.95 cfs Outflow=625.56 cfs 237.115 af

Reach 2R: Reach 2 Avg. Flow Depth=7.79' Max Vel=3.92 fps Inflow=1,205.03 cfs 482.196 af
n=0.040 L=3,930.0' S=0.0015 '/' Capacity=718.75 cfs Outflow=1,161.36 cfs 475.392 af

Link 1C: Culvert # 48953 Salem St Inflow=1,601.19 cfs 601.205 af
Primary=1,601.19 cfs 601.205 af

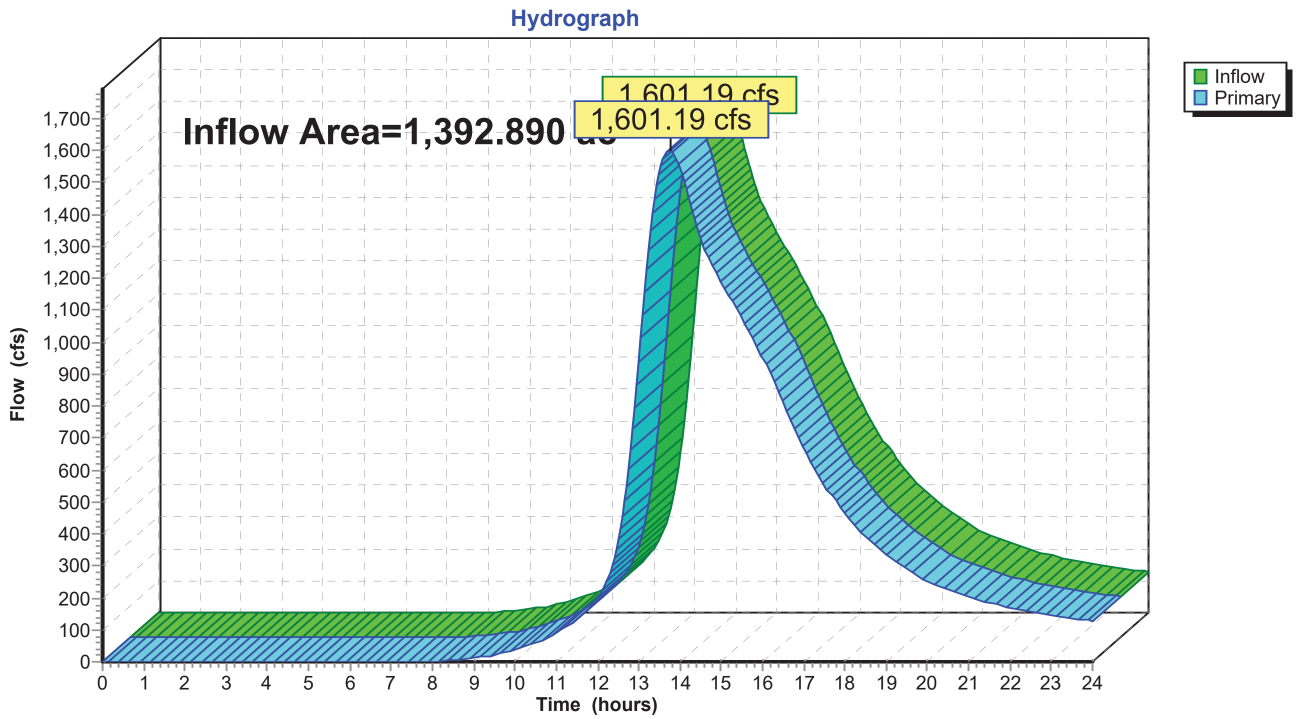
Total Runoff Area = 1,392.890 ac Runoff Volume = 611.768 af Average Runoff Depth = 5.27"
100.00% Pervious = 1,392.890 ac 0.00% Impervious = 0.000 ac

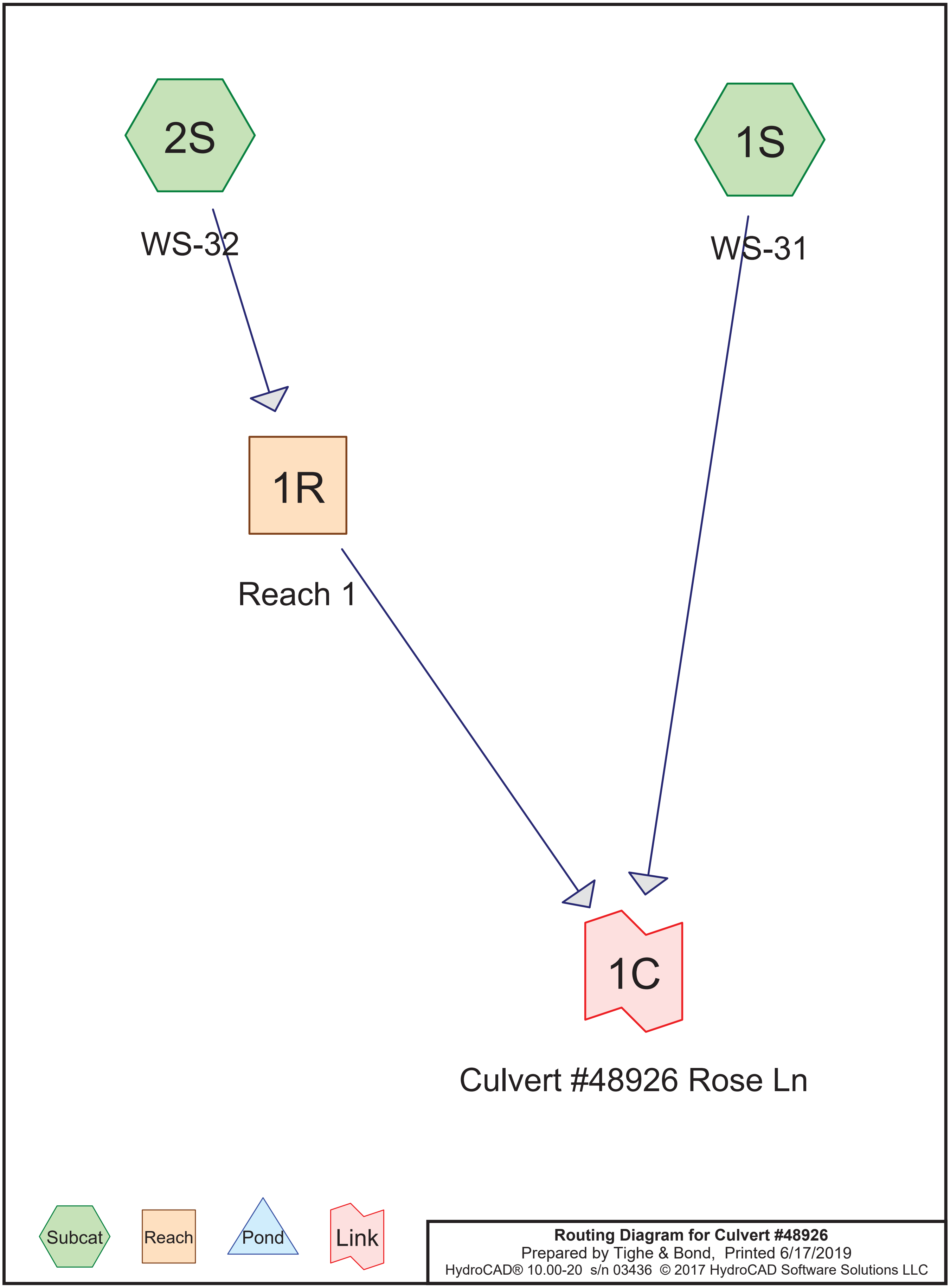
Summary for Link 1C: Culvert # 48953 Salem St

Inflow Area = 1,392.890 ac, 0.00% Impervious, Inflow Depth > 5.18" for 100-Year event
Inflow = 1,601.19 cfs @ 13.75 hrs, Volume= 601.205 af
Primary = 1,601.19 cfs @ 13.75 hrs, Volume= 601.205 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert # 48953 Salem St





Routing Diagram for Culvert #48926
Prepared by Tighe & Bond, Printed 6/17/2019

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
272.490	77	(1S)
552.390	76	(2S)
824.880	**76**	**TOTAL AREA**

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-31 Runoff Area=272.490 ac 0.00% Impervious Runoff Depth>1.18"
Tc=158.8 min CN=77 Runoff=77.81 cfs 26.866 af

Subcatchment 2S: WS-32 Runoff Area=552.390 ac 0.00% Impervious Runoff Depth>1.01"
Tc=343.9 min CN=76 Runoff=84.86 cfs 46.562 af

Reach 1R: Reach 1 Avg. Flow Depth=2.63' Max Vel=2.24 fps Inflow=84.86 cfs 46.562 af
n=0.045 L=790.0' S=0.0025 '/' Capacity=52.07 cfs Outflow=84.81 cfs 46.092 af

Link 1C: Culvert #48926 Rose Ln Inflow=118.10 cfs 72.959 af
Primary=118.10 cfs 72.959 af

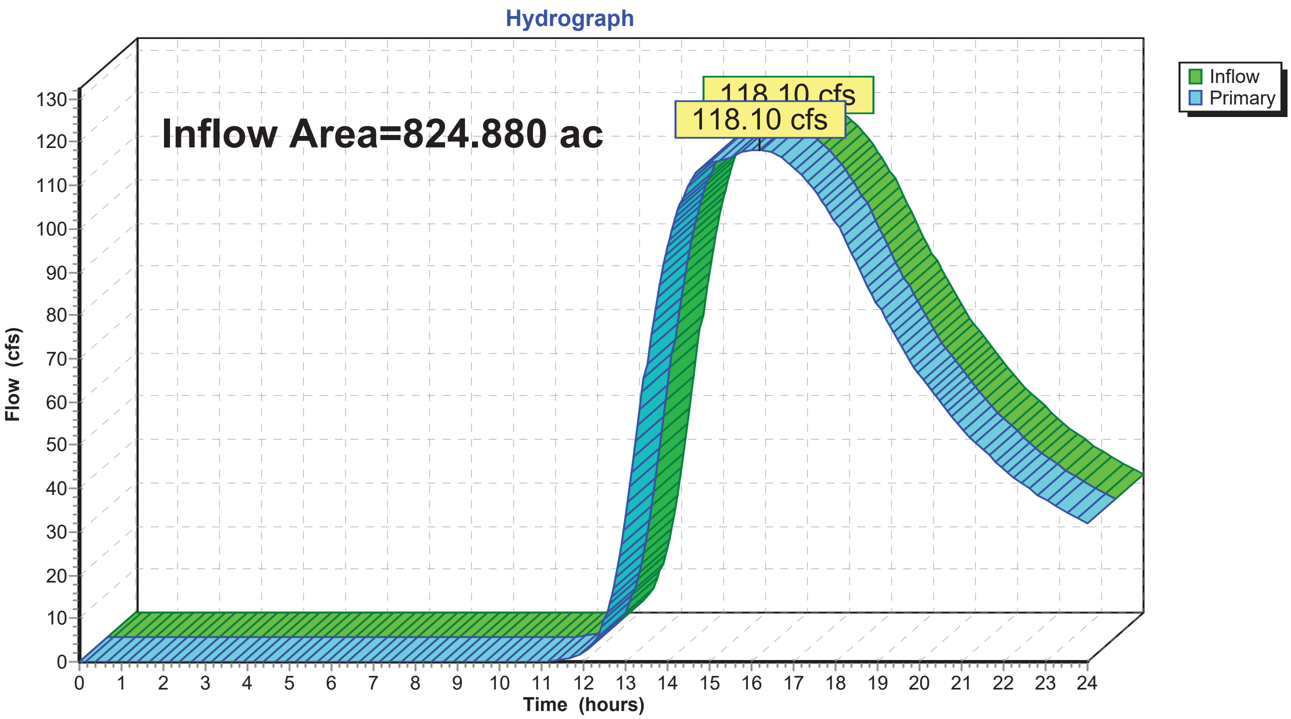
Total Runoff Area = 824.880 ac Runoff Volume = 73.428 af Average Runoff Depth = 1.07"
100.00% Pervious = 824.880 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48926 Rose Ln

Inflow Area =	824.880 ac,	0.00% Impervious, Inflow Depth > 1.06"	for 2-Year event	
Inflow =	118.10 cfs @	16.17 hrs, Volume=	72.959 af	
Primary =	118.10 cfs @	16.17 hrs, Volume=	72.959 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48926 Rose Ln



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-31 Runoff Area=272.490 ac 0.00% Impervious Runoff Depth>1.76"
Tc=158.8 min CN=77 Runoff=117.58 cfs 39.910 af

Subcatchment 2S: WS-32 Runoff Area=552.390 ac 0.00% Impervious Runoff Depth>1.53"
Tc=343.9 min CN=76 Runoff=129.53 cfs 70.321 af

Reach 1R: Reach 1 Avg. Flow Depth=3.49' Max Vel=2.39 fps Inflow=129.53 cfs 70.321 af
n=0.045 L=790.0' S=0.0025 '/' Capacity=52.07 cfs Outflow=129.43 cfs 69.715 af

Link 1C: Culvert #48926 Rose Ln Inflow=179.35 cfs 109.624 af
Primary=179.35 cfs 109.624 af

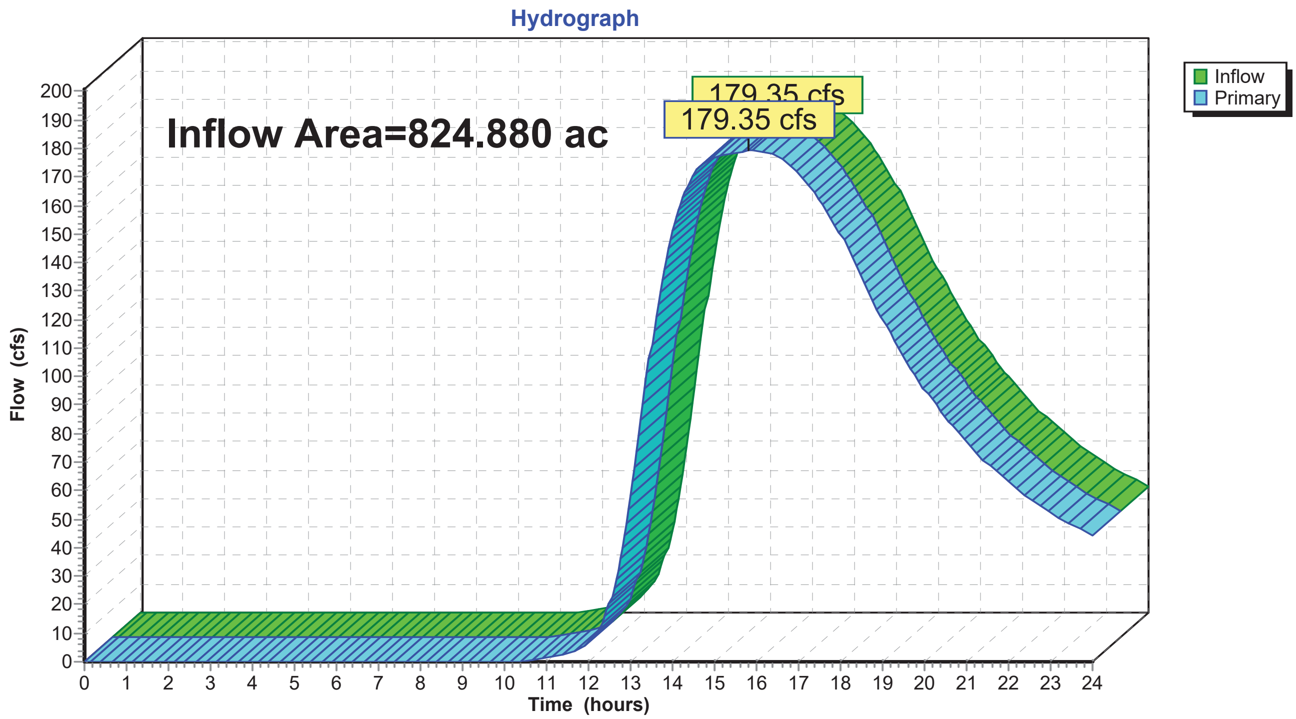
Total Runoff Area = 824.880 ac Runoff Volume = 110.231 af Average Runoff Depth = 1.60"
100.00% Pervious = 824.880 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48926 Rose Ln

Inflow Area =	824.880 ac,	0.00% Impervious,	Inflow Depth > 1.59"	for 5-Year event	
Inflow =	179.35 cfs @	15.82 hrs,	Volume=	109.624 af	
Primary =	179.35 cfs @	15.82 hrs,	Volume=	109.624 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48926 Rose Ln



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-31 Runoff Area=272.490 ac 0.00% Impervious Runoff Depth>2.33"
Tc=158.8 min CN=77 Runoff=156.89 cfs 52.829 af

Subcatchment 2S: WS-32 Runoff Area=552.390 ac 0.00% Impervious Runoff Depth>2.04"
Tc=343.9 min CN=76 Runoff=173.90 cfs 94.070 af

Reach 1R: Reach 1 Avg. Flow Depth=4.35' Max Vel=2.47 fps Inflow=173.90 cfs 94.070 af
n=0.045 L=790.0' S=0.0025 '/' Capacity=52.07 cfs Outflow=173.87 cfs 93.337 af

Link 1C: Culvert #48926 Rose Ln Inflow=240.51 cfs 146.166 af
Primary=240.51 cfs 146.166 af

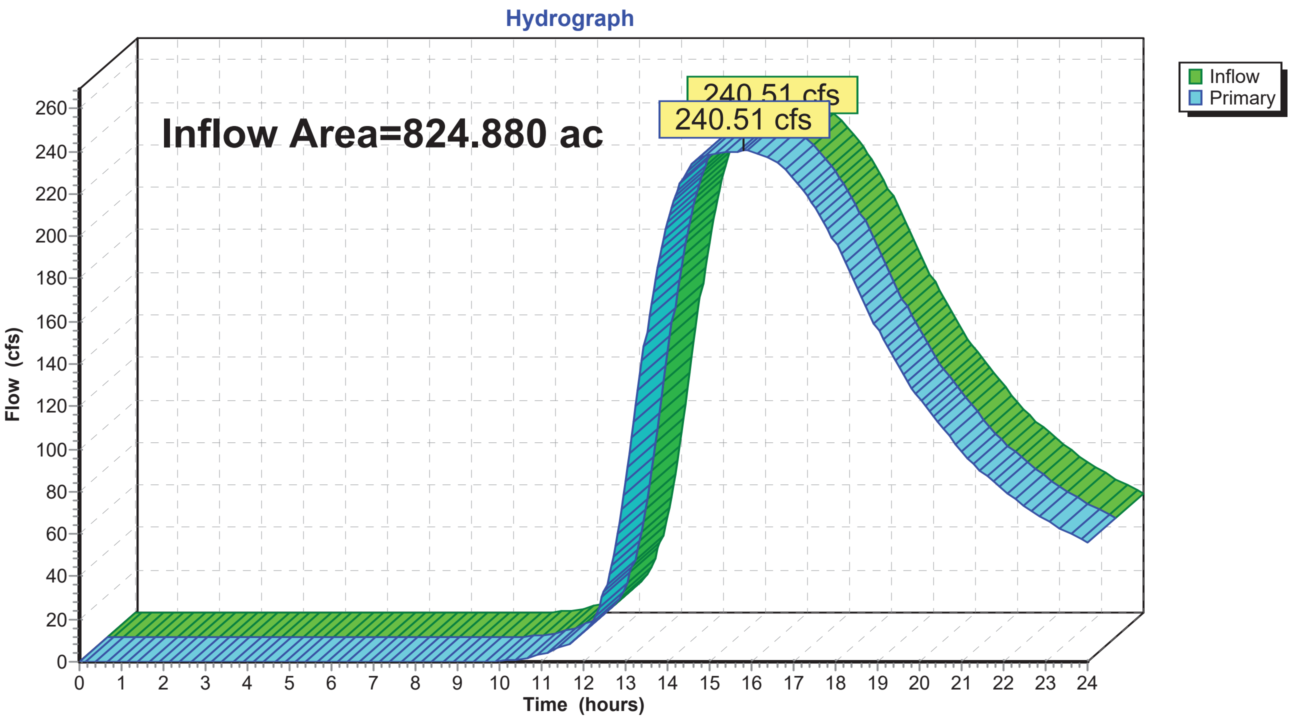
Total Runoff Area = 824.880 ac Runoff Volume = 146.899 af Average Runoff Depth = 2.14"
100.00% Pervious = 824.880 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48926 Rose Ln

Inflow Area = 824.880 ac, 0.00% Impervious, Inflow Depth > 2.13" for 10-Year event
Inflow = 240.51 cfs @ 15.80 hrs, Volume= 146.166 af
Primary = 240.51 cfs @ 15.80 hrs, Volume= 146.166 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48926 Rose Ln



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-31 Runoff Area=272.490 ac 0.00% Impervious Runoff Depth>3.29"
Tc=158.8 min CN=77 Runoff=223.11 cfs 74.715 af

Subcatchment 2S: WS-32 Runoff Area=552.390 ac 0.00% Impervious Runoff Depth>2.92"
Tc=343.9 min CN=76 Runoff=250.11 cfs 134.612 af

Reach 1R: Reach 1 Avg. Flow Depth=5.80' Max Vel=2.55 fps Inflow=250.11 cfs 134.612 af
n=0.045 L=790.0' S=0.0025 '/' Capacity=52.07 cfs Outflow=249.60 cfs 133.679 af

Link 1C: Culvert #48926 Rose Ln Inflow=344.63 cfs 208.394 af
Primary=344.63 cfs 208.394 af

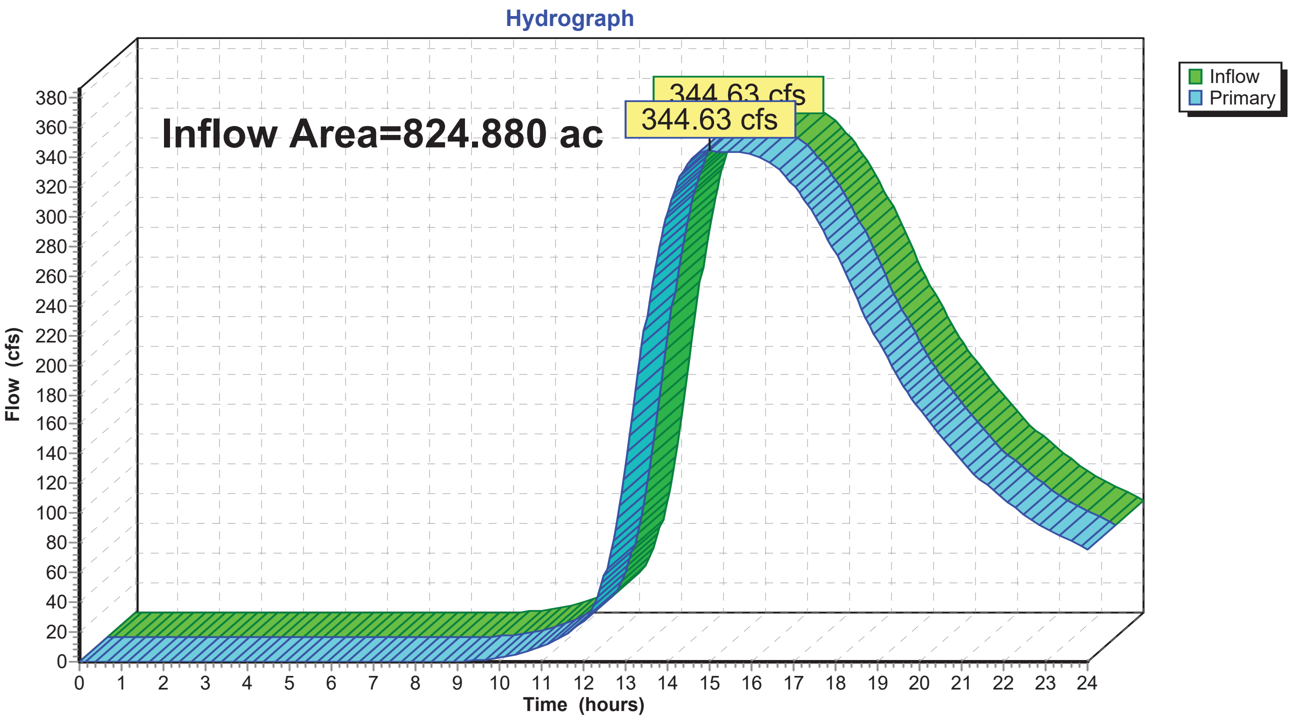
Total Runoff Area = 824.880 ac Runoff Volume = 209.327 af Average Runoff Depth = 3.05"
100.00% Pervious = 824.880 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48926 Rose Ln

Inflow Area = 824.880 ac, 0.00% Impervious, Inflow Depth > 3.03" for 25-Year event
Inflow = 344.63 cfs @ 15.01 hrs, Volume= 208.394 af
Primary = 344.63 cfs @ 15.01 hrs, Volume= 208.394 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48926 Rose Ln



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-31 Runoff Area=272.490 ac 0.00% Impervious Runoff Depth>4.22"
Tc=158.8 min CN=77 Runoff=286.19 cfs 95.800 af

Subcatchment 2S: WS-32 Runoff Area=552.390 ac 0.00% Impervious Runoff Depth>3.78"
Tc=343.9 min CN=76 Runoff=323.33 cfs 173.917 af

Reach 1R: Reach 1 Avg. Flow Depth=7.21' Max Vel=2.59 fps Inflow=323.33 cfs 173.917 af
n=0.045 L=790.0' S=0.0025 '/' Capacity=52.07 cfs Outflow=322.57 cfs 172.798 af

Link 1C: Culvert #48926 Rose Ln Inflow=446.25 cfs 268.599 af
Primary=446.25 cfs 268.599 af

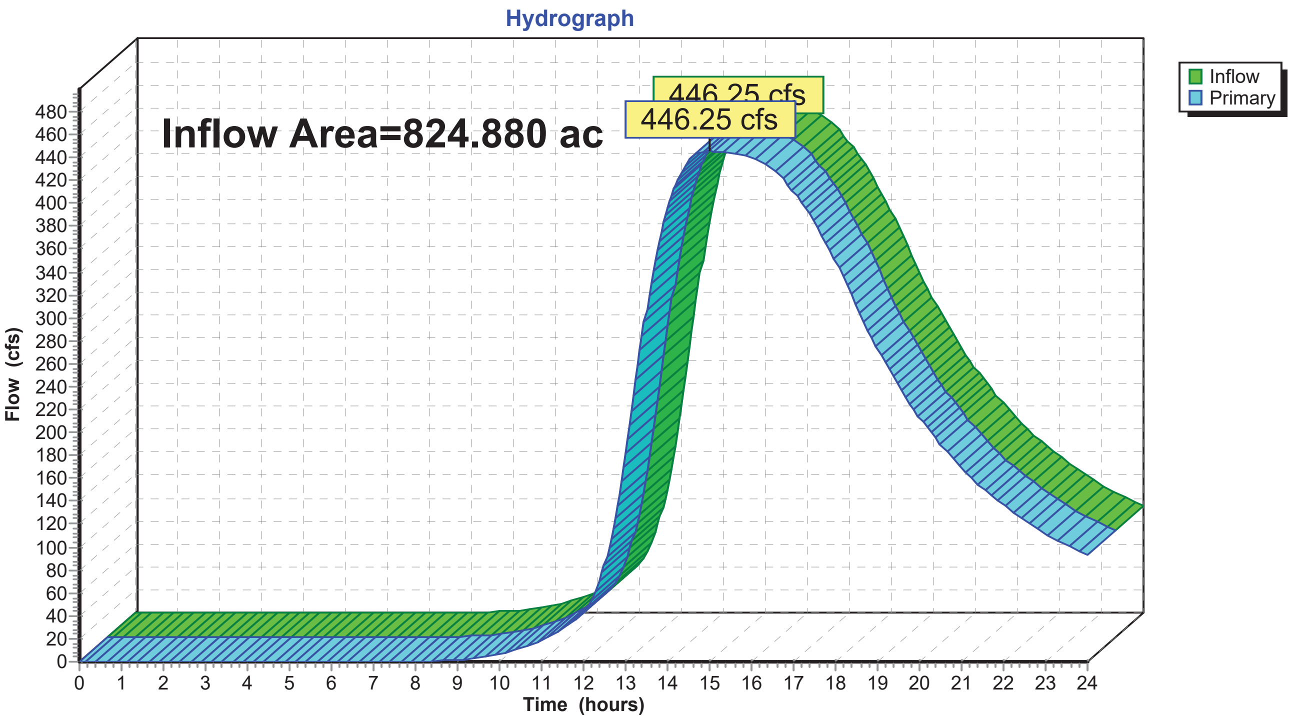
Total Runoff Area = 824.880 ac Runoff Volume = 269.718 af Average Runoff Depth = 3.92"
100.00% Pervious = 824.880 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48926 Rose Ln

Inflow Area =	824.880 ac,	0.00% Impervious, Inflow Depth > 3.91"	for 50-Year event	
Inflow =	446.25 cfs @	15.00 hrs, Volume=	268.599 af	
Primary =	446.25 cfs @	15.00 hrs, Volume=	268.599 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48926 Rose Ln



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-31 Runoff Area=272.490 ac 0.00% Impervious Runoff Depth>5.36"
Tc=158.8 min CN=77 Runoff=362.90 cfs 121.731 af

Subcatchment 2S: WS-32 Runoff Area=552.390 ac 0.00% Impervious Runoff Depth>4.83"
Tc=343.9 min CN=76 Runoff=412.98 cfs 222.477 af

Reach 1R: Reach 1 Avg. Flow Depth=8.93' Max Vel=2.62 fps Inflow=412.98 cfs 222.477 af
n=0.045 L=790.0' S=0.0025 '/' Capacity=52.07 cfs Outflow=412.01 cfs 221.134 af

Link 1C: Culvert #48926 Rose Ln Inflow=570.96 cfs 342.865 af
Primary=570.96 cfs 342.865 af

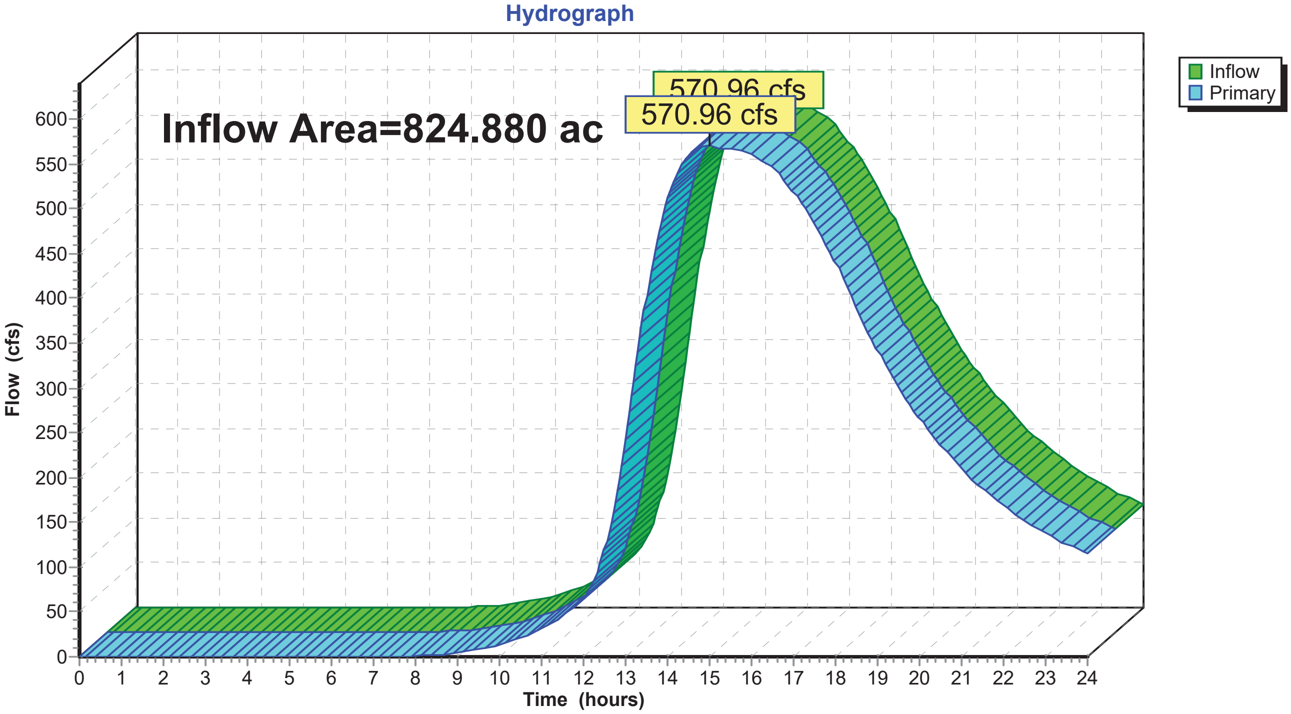
Total Runoff Area = 824.880 ac Runoff Volume = 344.208 af Average Runoff Depth = 5.01"
100.00% Pervious = 824.880 ac 0.00% Impervious = 0.000 ac

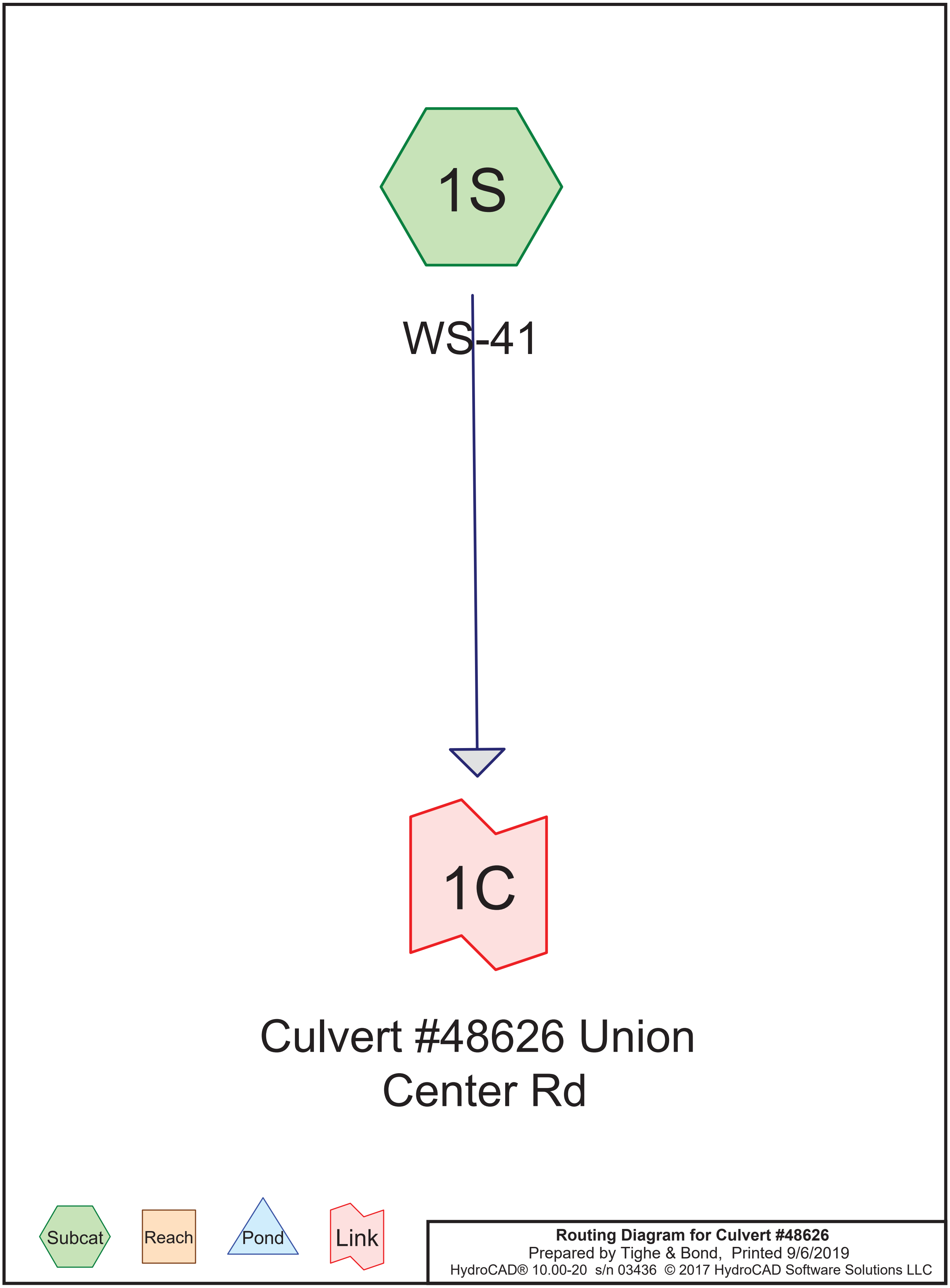
Summary for Link 1C: Culvert #48926 Rose Ln

Inflow Area = 824.880 ac, 0.00% Impervious, Inflow Depth > 4.99" for 100-Year event
Inflow = 570.96 cfs @ 14.98 hrs, Volume= 342.865 af
Primary = 570.96 cfs @ 14.98 hrs, Volume= 342.865 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48926 Rose Ln





Routing Diagram for Culvert #48626
Prepared by Tighe & Bond, Printed 9/6/2019
HydroCAD® 10.00-20 s/n 03436 © 2017 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
18.930	59	(1S)
18.930	**59**	**TOTAL AREA**

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1S: WS-41 Runoff Area=18.930 ac 0.00% Impervious Runoff Depth>0.38"
Tc=44.8 min CN=59 Runoff=2.52 cfs 0.602 af

Link 1C: Culvert #48626 Union Center Rd Inflow=2.52 cfs 0.602 af
Primary=2.52 cfs 0.602 af

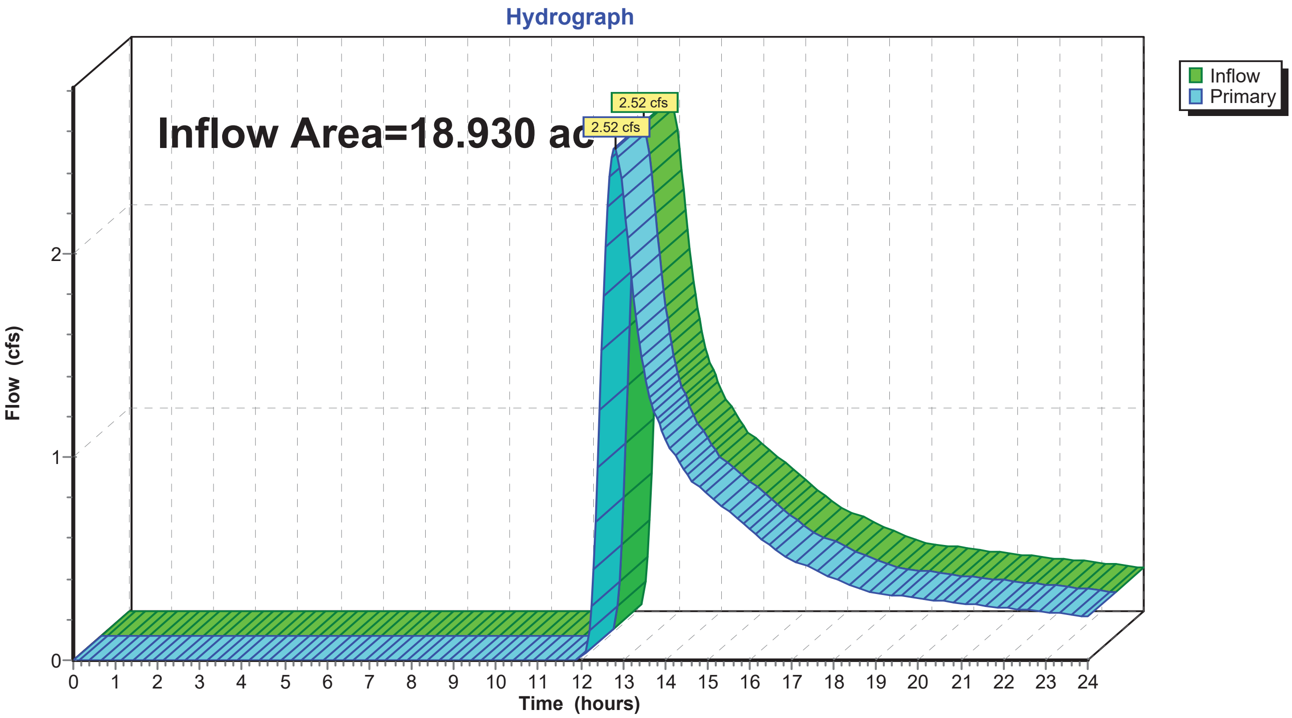
Total Runoff Area = 18.930 ac Runoff Volume = 0.602 af Average Runoff Depth = 0.38"
100.00% Pervious = 18.930 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48626 Union Center Rd

Inflow Area = 18.930 ac, 0.00% Impervious, Inflow Depth > 0.38" for 2-Year event
Inflow = 2.52 cfs @ 12.81 hrs, Volume= 0.602 af
Primary = 2.52 cfs @ 12.81 hrs, Volume= 0.602 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48626 Union Center Rd



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-41 Runoff Area=18.930 ac 0.00% Impervious Runoff Depth>0.72"
Tc=44.8 min CN=59 Runoff=5.85 cfs 1.129 af

Link 1C: Culvert #48626 Union Center Rd Inflow=5.85 cfs 1.129 af
Primary=5.85 cfs 1.129 af

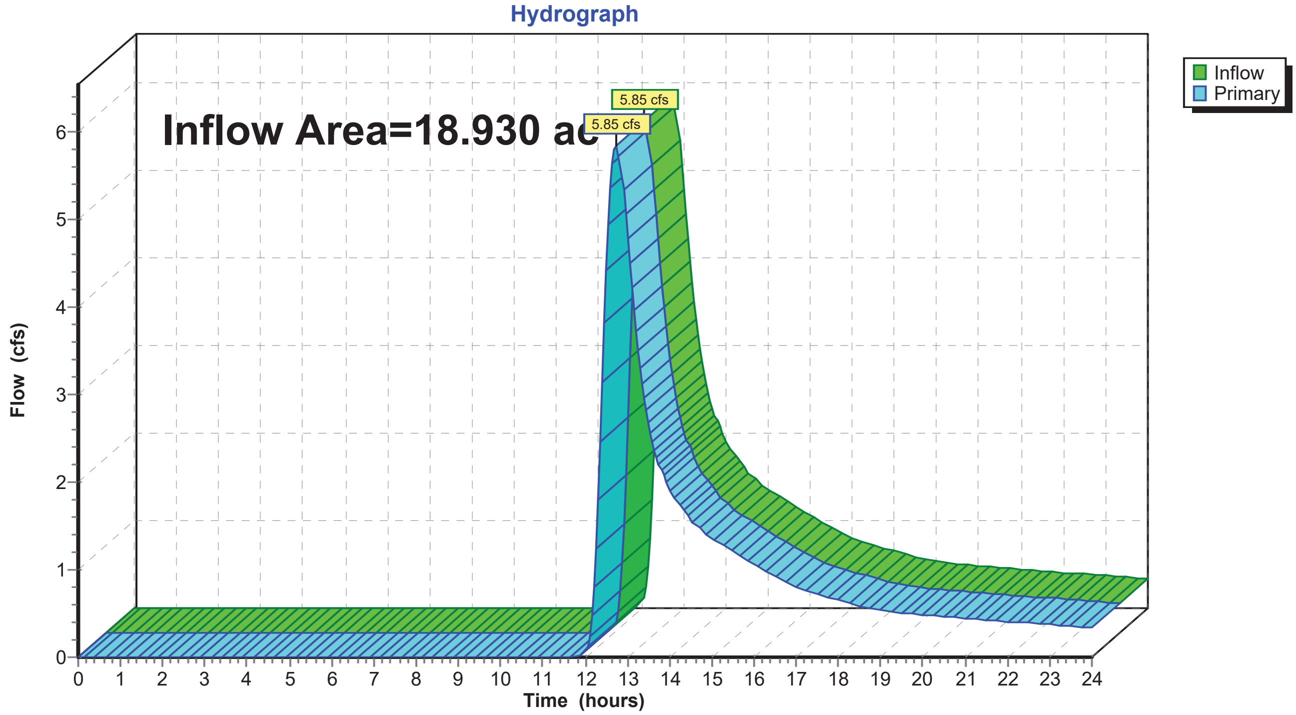
Total Runoff Area = 18.930 ac Runoff Volume = 1.129 af Average Runoff Depth = 0.72"
100.00% Pervious = 18.930 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48626 Union Center Rd

Inflow Area =	18.930 ac,	0.00% Impervious,	Inflow Depth > 0.72"	for 5-Year event	
Inflow =	5.85 cfs @	12.74 hrs,	Volume=	1.129 af	
Primary =	5.85 cfs @	12.74 hrs,	Volume=	1.129 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48626 Union Center Rd



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1S: WS-41 Runoff Area=18.930 ac 0.00% Impervious Runoff Depth>1.09"
Tc=44.8 min CN=59 Runoff=9.77 cfs 1.712 af

Link 1C: Culvert #48626 Union Center Rd Inflow=9.77 cfs 1.712 af
Primary=9.77 cfs 1.712 af

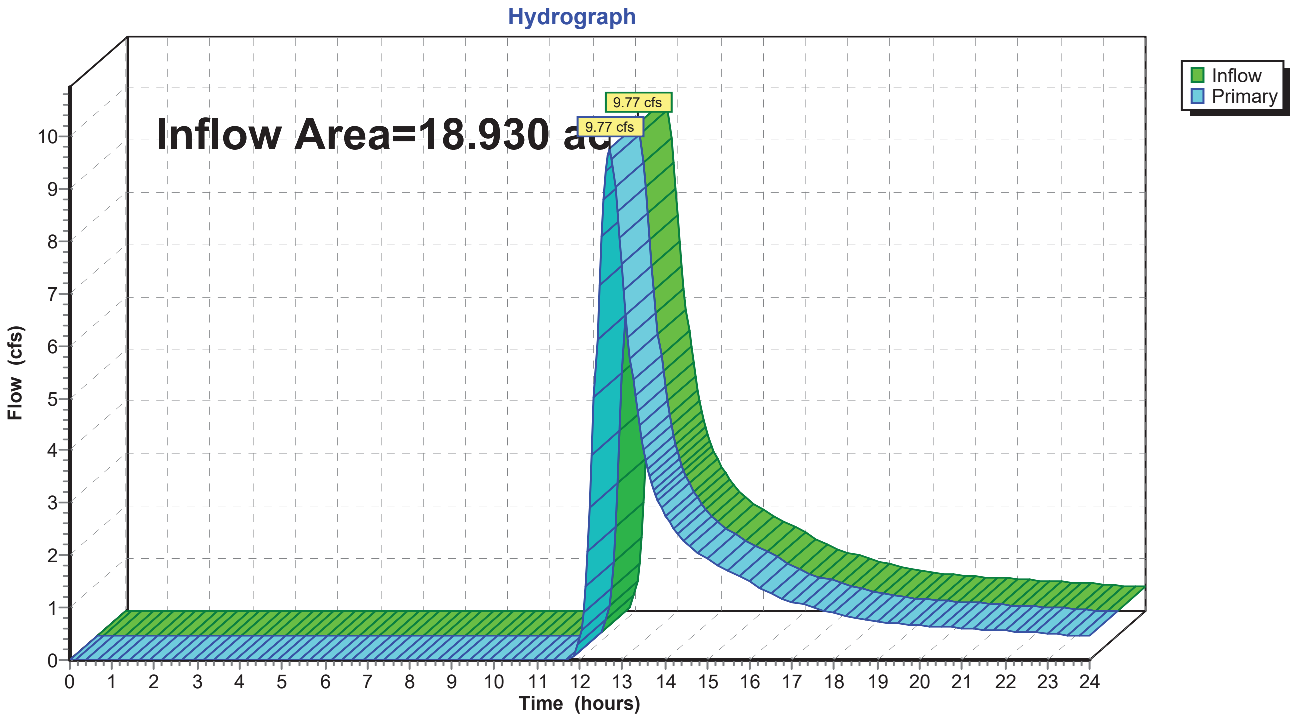
Total Runoff Area = 18.930 ac Runoff Volume = 1.712 af Average Runoff Depth = 1.09"
100.00% Pervious = 18.930 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48626 Union Center Rd

Inflow Area =	18.930 ac,	0.00% Impervious, Inflow Depth >	1.09"	for 10-Year event
Inflow =	9.77 cfs @	12.70 hrs, Volume=	1.712 af	
Primary =	9.77 cfs @	12.70 hrs, Volume=	1.712 af,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48626 Union Center Rd



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-41 Runoff Area=18.930 ac 0.00% Impervious Runoff Depth>1.77"
Tc=44.8 min CN=59 Runoff=17.16 cfs 2.795 af

Link 1C: Culvert #48626 Union Center Rd Inflow=17.16 cfs 2.795 af
Primary=17.16 cfs 2.795 af

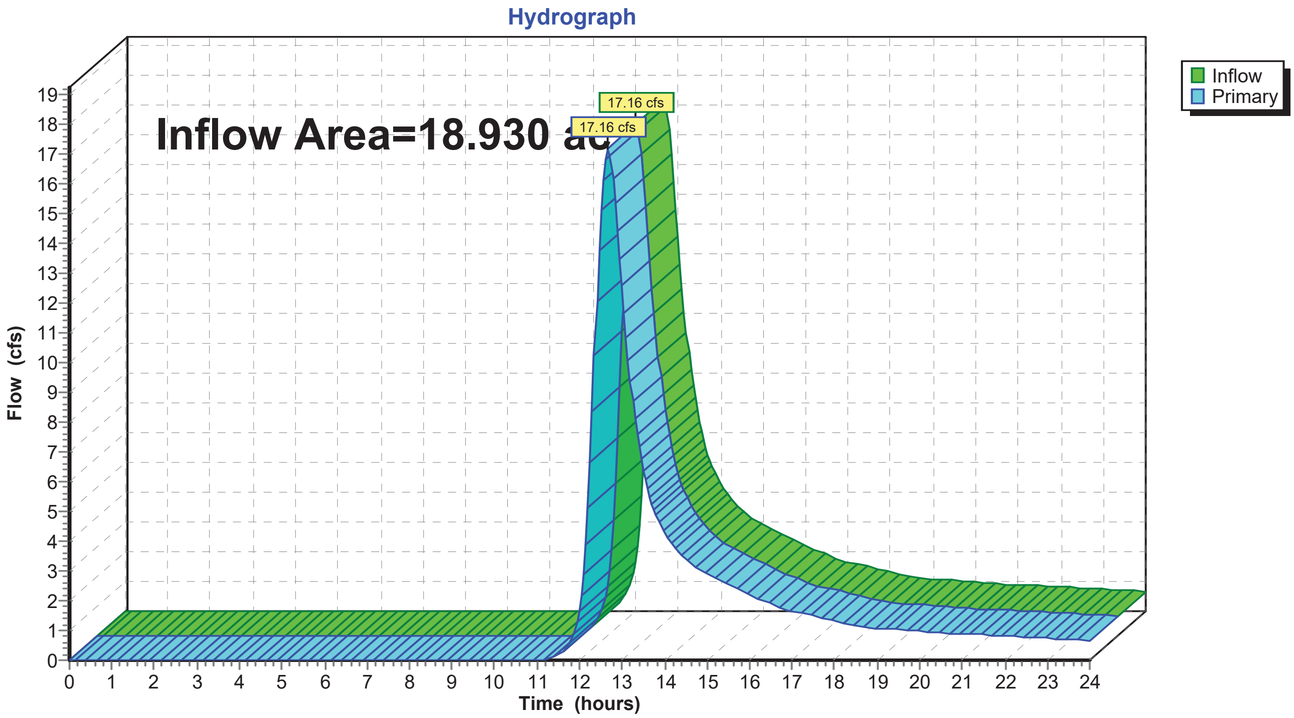
Total Runoff Area = 18.930 ac Runoff Volume = 2.795 af Average Runoff Depth = 1.77"
100.00% Pervious = 18.930 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48626 Union Center Rd

Inflow Area = 18.930 ac, 0.00% Impervious, Inflow Depth > 1.77" for 25-Year event
Inflow = 17.16 cfs @ 12.68 hrs, Volume= 2.795 af
Primary = 17.16 cfs @ 12.68 hrs, Volume= 2.795 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48626 Union Center Rd



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1S: WS-41 Runoff Area=18.930 ac 0.00% Impervious Runoff Depth>2.48"
Tc=44.8 min CN=59 Runoff=24.82 cfs 3.918 af

Link 1C: Culvert #48626 Union Center Rd Inflow=24.82 cfs 3.918 af
Primary=24.82 cfs 3.918 af

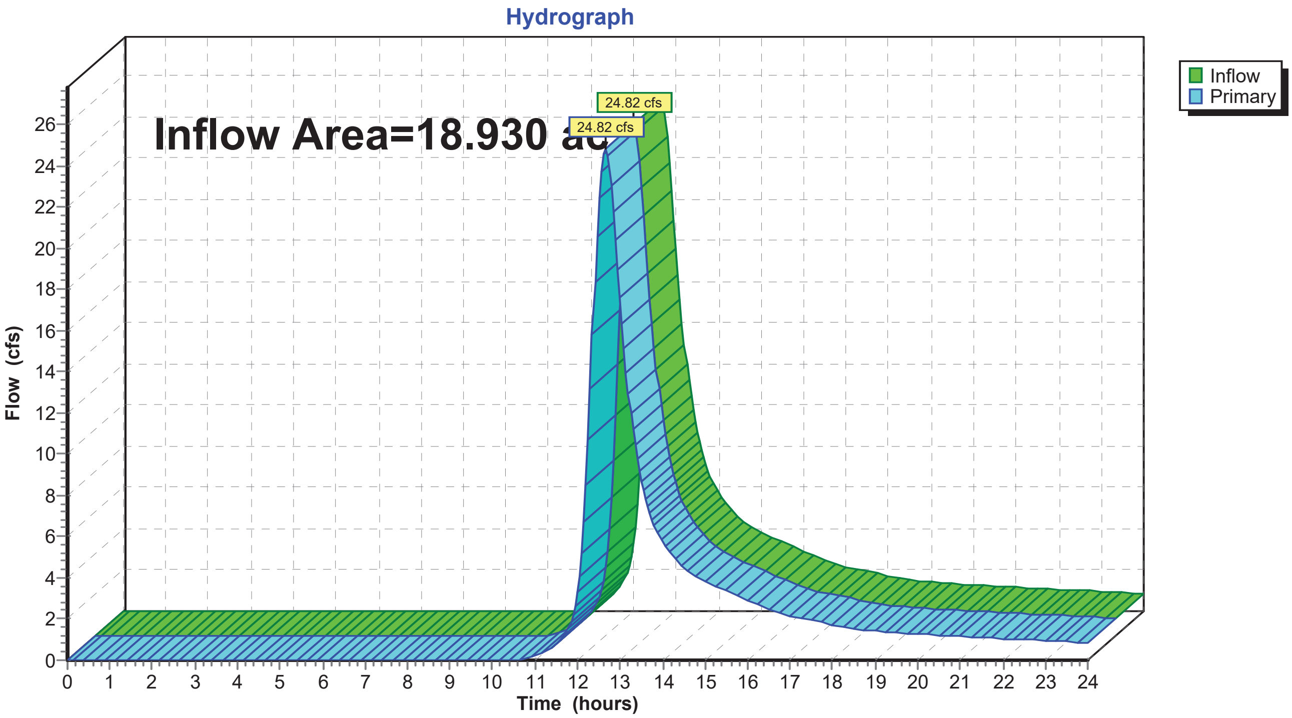
Total Runoff Area = 18.930 ac Runoff Volume = 3.918 af Average Runoff Depth = 2.48"
100.00% Pervious = 18.930 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48626 Union Center Rd

Inflow Area = 18.930 ac, 0.00% Impervious, Inflow Depth > 2.48" for 50-Year event
Inflow = 24.82 cfs @ 12.66 hrs, Volume= 3.918 af
Primary = 24.82 cfs @ 12.66 hrs, Volume= 3.918 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48626 Union Center Rd



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: WS-41 Runoff Area=18.930 ac 0.00% Impervious Runoff Depth>3.41"
Tc=44.8 min CN=59 Runoff=34.74 cfs 5.376 af

Link 1C: Culvert #48626 Union Center Rd Inflow=34.74 cfs 5.376 af
Primary=34.74 cfs 5.376 af

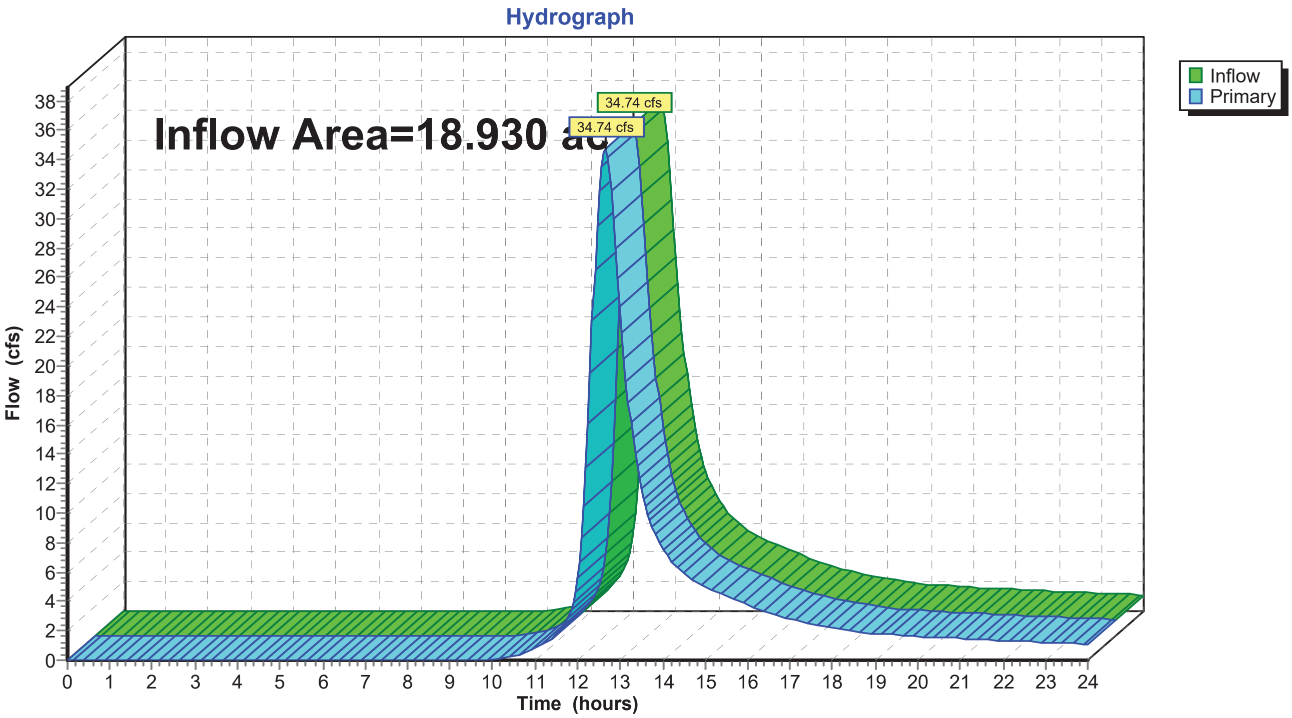
Total Runoff Area = 18.930 ac Runoff Volume = 5.376 af Average Runoff Depth = 3.41"
100.00% Pervious = 18.930 ac 0.00% Impervious = 0.000 ac

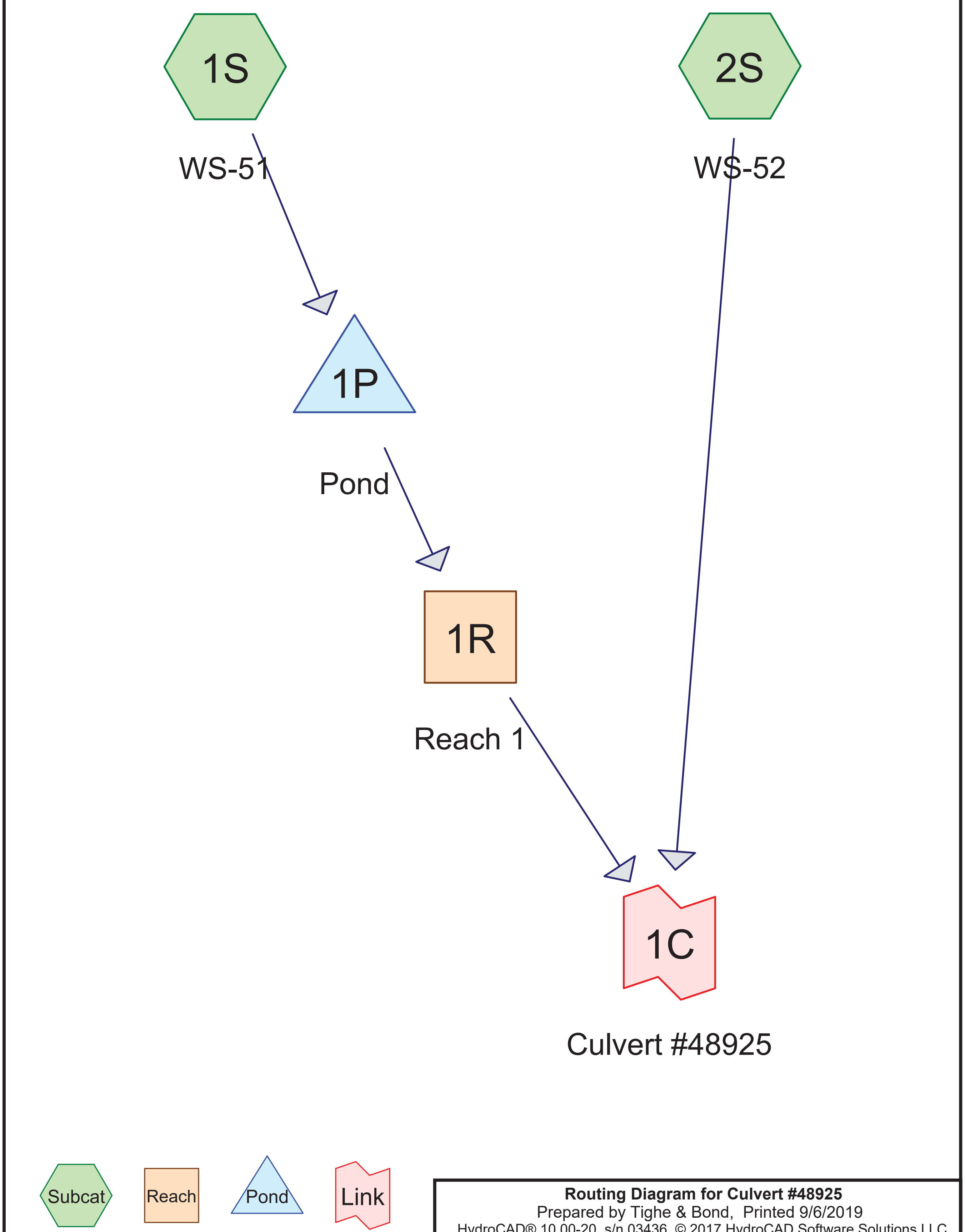
Summary for Link 1C: Culvert #48626 Union Center Rd

Inflow Area = 18.930 ac, 0.00% Impervious, Inflow Depth > 3.41" for 100-Year event
Inflow = 34.74 cfs @ 12.64 hrs, Volume= 5.376 af
Primary = 34.74 cfs @ 12.64 hrs, Volume= 5.376 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48626 Union Center Rd





Routing Diagram for Culvert #48925
Prepared by Tighe & Bond, Printed 9/6/2019

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
249.100	80	(1S)
22.620	73	(2S)
271.720	**79**	**TOTAL AREA**

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

Subcatchment1S: WS-51 Runoff Area=249.100 ac 0.00% Impervious Runoff Depth>1.26"
Tc=122.0 min CN=80 Runoff=101.71 cfs 26.093 af

Subcatchment2S: WS-52 Runoff Area=22.620 ac 0.00% Impervious Runoff Depth>0.90"
Tc=45.4 min CN=73 Runoff=11.52 cfs 1.699 af

Reach 1R: Reach 1 Avg. Flow Depth=0.93' Max Vel=5.53 fps Inflow=55.30 cfs 18.773 af
n=0.045 L=1,105.0' S=0.0434 '/' Capacity=536.71 cfs Outflow=55.28 cfs 18.590 af

Pond 1P: Pond Peak Elev=346.37' Storage=11.403 af Inflow=101.71 cfs 26.093 af
Outflow=55.30 cfs 18.773 af

Link 1C: Culvert #48925 Inflow=57.19 cfs 20.288 af
Primary=57.19 cfs 20.288 af

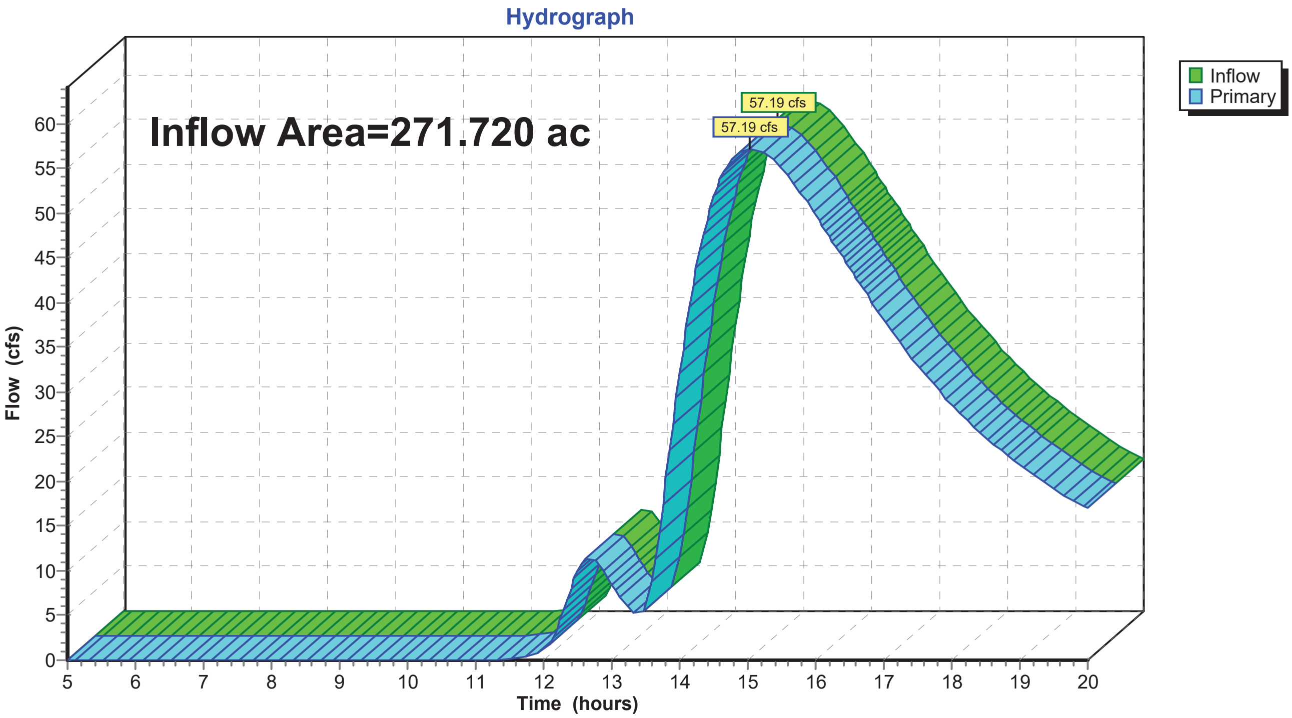
Total Runoff Area = 271.720 ac Runoff Volume = 27.792 af Average Runoff Depth = 1.23"
100.00% Pervious = 271.720 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48925

Inflow Area = 271.720 ac, 0.00% Impervious, Inflow Depth > 0.90" for 2-Year event
Inflow = 57.19 cfs @ 15.04 hrs, Volume= 20.288 af
Primary = 57.19 cfs @ 15.04 hrs, Volume= 20.288 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48925



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

Subcatchment 1S: WS-51 Runoff Area=249.100 ac 0.00% Impervious Runoff Depth>1.83"
Tc=122.0 min CN=80 Runoff=148.72 cfs 38.014 af

Subcatchment 2S: WS-52 Runoff Area=22.620 ac 0.00% Impervious Runoff Depth>1.40"
Tc=45.4 min CN=73 Runoff=18.37 cfs 2.638 af

Reach 1R: Reach 1 Avg. Flow Depth=1.23' Max Vel=6.46 fps Inflow=92.67 cfs 30.088 af
n=0.045 L=1,105.0' S=0.0434 '/' Capacity=536.71 cfs Outflow=92.63 cfs 29.872 af

Pond 1P: Pond Peak Elev=346.94' Storage=14.691 af Inflow=148.72 cfs 38.014 af
Outflow=92.67 cfs 30.088 af

Link 1C: Culvert #48925 Inflow=95.62 cfs 32.510 af
Primary=95.62 cfs 32.510 af

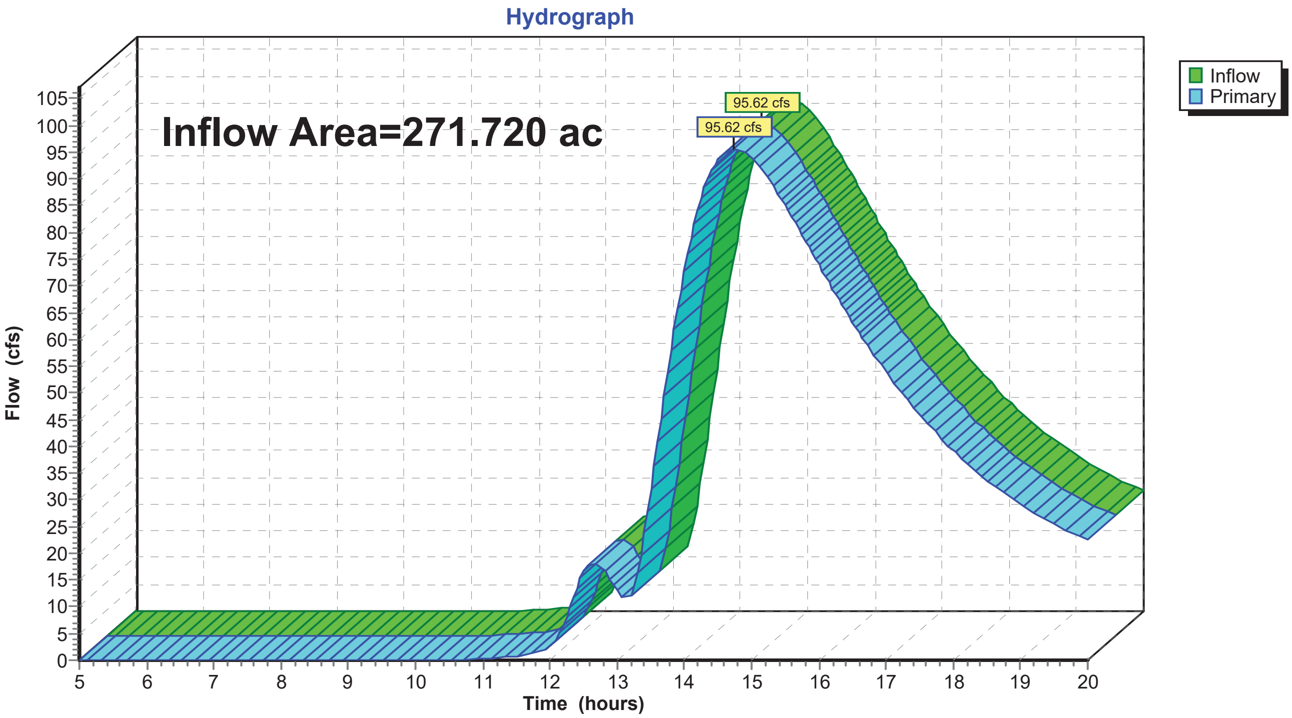
Total Runoff Area = 271.720 ac Runoff Volume = 40.652 af Average Runoff Depth = 1.80"
100.00% Pervious = 271.720 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48925

Inflow Area = 271.720 ac, 0.00% Impervious, Inflow Depth > 1.44" for 5-Year event
Inflow = 95.62 cfs @ 14.74 hrs, Volume= 32.510 af
Primary = 95.62 cfs @ 14.74 hrs, Volume= 32.510 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48925



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

Subcatchment1S: WS-51 Runoff Area=249.100 ac 0.00% Impervious Runoff Depth>2.39"
Tc=122.0 min CN=80 Runoff=193.99 cfs 49.702 af

Subcatchment2S: WS-52 Runoff Area=22.620 ac 0.00% Impervious Runoff Depth>1.90"
Tc=45.4 min CN=73 Runoff=25.23 cfs 3.590 af

Reach 1R: Reach 1 Avg. Flow Depth=1.47' Max Vel=7.14 fps Inflow=130.42 cfs 41.262 af
n=0.045 L=1,105.0' S=0.0434 '/' Capacity=536.71 cfs Outflow=130.36 cfs 41.019 af

Pond 1P: Pond Peak Elev=347.43' Storage=17.712 af Inflow=193.99 cfs 49.702 af
Outflow=130.42 cfs 41.262 af

Link 1C: Culvert #48925 Inflow=134.42 cfs 44.609 af
Primary=134.42 cfs 44.609 af

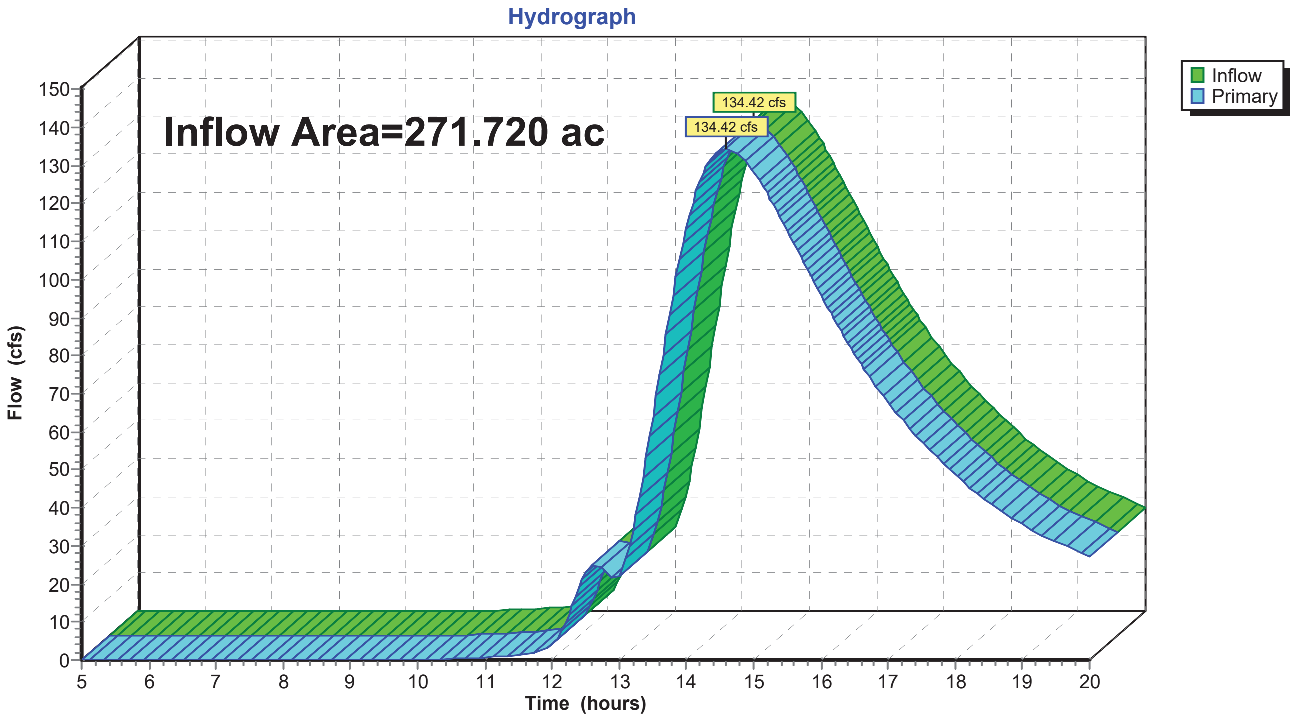
Total Runoff Area = 271.720 ac Runoff Volume = 53.292 af Average Runoff Depth = 2.35"
100.00% Pervious = 271.720 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48925

Inflow Area = 271.720 ac, 0.00% Impervious, Inflow Depth > 1.97" for 10-Year event
Inflow = 134.42 cfs @ 14.59 hrs, Volume= 44.609 af
Primary = 134.42 cfs @ 14.59 hrs, Volume= 44.609 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48925



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

Subcatchment 1S: WS-51 Runoff Area=249.100 ac 0.00% Impervious Runoff Depth>3.34"
Tc=122.0 min CN=80 Runoff=269.00 cfs 69.334 af

Subcatchment 2S: WS-52 Runoff Area=22.620 ac 0.00% Impervious Runoff Depth>2.78"
Tc=45.4 min CN=73 Runoff=36.91 cfs 5.234 af

Reach 1R: Reach 1 Avg. Flow Depth=1.80' Max Vel=7.97 fps Inflow=192.97 cfs 60.134 af
n=0.045 L=1,105.0' S=0.0434 '/' Capacity=536.71 cfs Outflow=192.88 cfs 59.851 af

Pond 1P: Pond Peak Elev=348.15' Storage=22.510 af Inflow=269.00 cfs 69.334 af
Outflow=192.97 cfs 60.134 af

Link 1C: Culvert #48925 Inflow=198.74 cfs 65.085 af
Primary=198.74 cfs 65.085 af

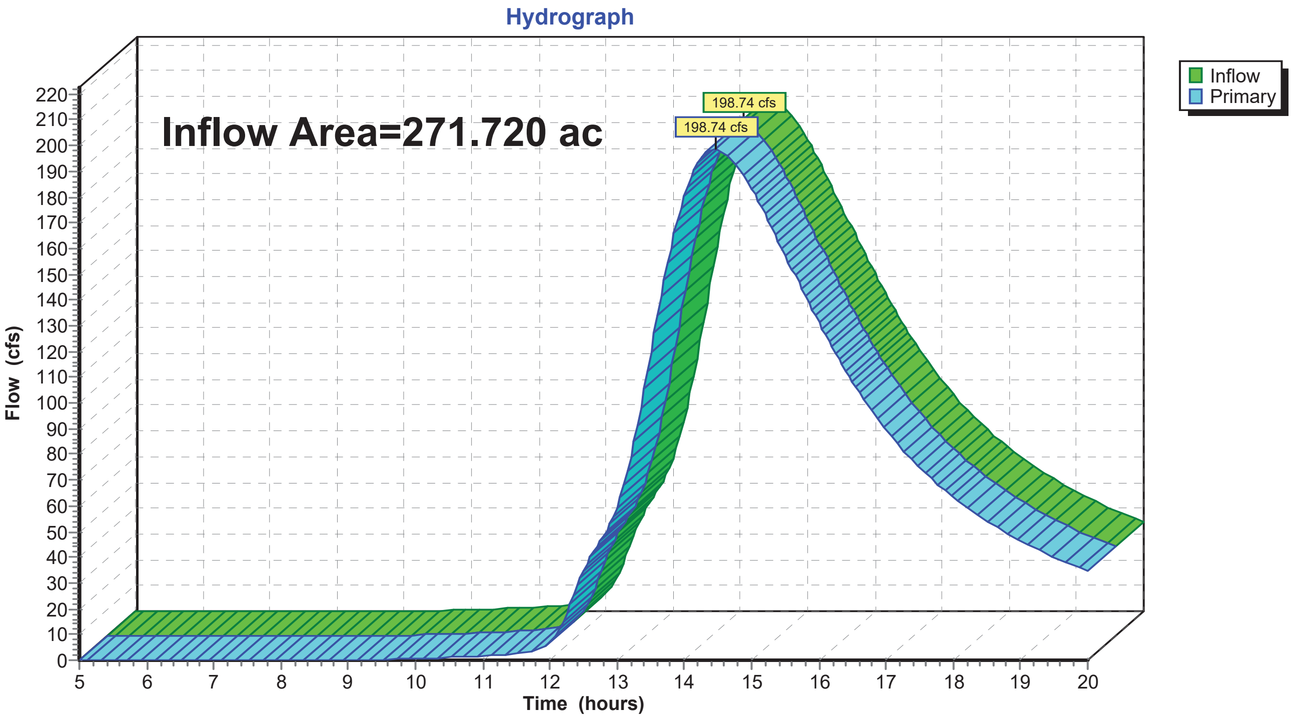
Total Runoff Area = 271.720 ac Runoff Volume = 74.567 af Average Runoff Depth = 3.29"
100.00% Pervious = 271.720 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48925

Inflow Area = 271.720 ac, 0.00% Impervious, Inflow Depth > 2.87" for 25-Year event
Inflow = 198.74 cfs @ 14.46 hrs, Volume= 65.085 af
Primary = 198.74 cfs @ 14.46 hrs, Volume= 65.085 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48925



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

Subcatchment1S: WS-51 Runoff Area=249.100 ac 0.00% Impervious Runoff Depth>4.24"
Tc=122.0 min CN=80 Runoff=339.62 cfs 88.118 af

Subcatchment2S: WS-52 Runoff Area=22.620 ac 0.00% Impervious Runoff Depth>3.63"
Tc=45.4 min CN=73 Runoff=48.16 cfs 6.843 af

Reach 1R: Reach 1 Avg. Flow Depth=2.06' Max Vel=8.58 fps Inflow=251.41 cfs 78.266 af
n=0.045 L=1,105.0' S=0.0434 '/' Capacity=536.71 cfs Outflow=251.30 cfs 77.947 af

Pond 1P: Pond Peak Elev=348.75' Storage=26.843 af Inflow=339.62 cfs 88.118 af
Outflow=251.41 cfs 78.266 af

Link 1C: Culvert #48925 Inflow=258.87 cfs 84.790 af
Primary=258.87 cfs 84.790 af

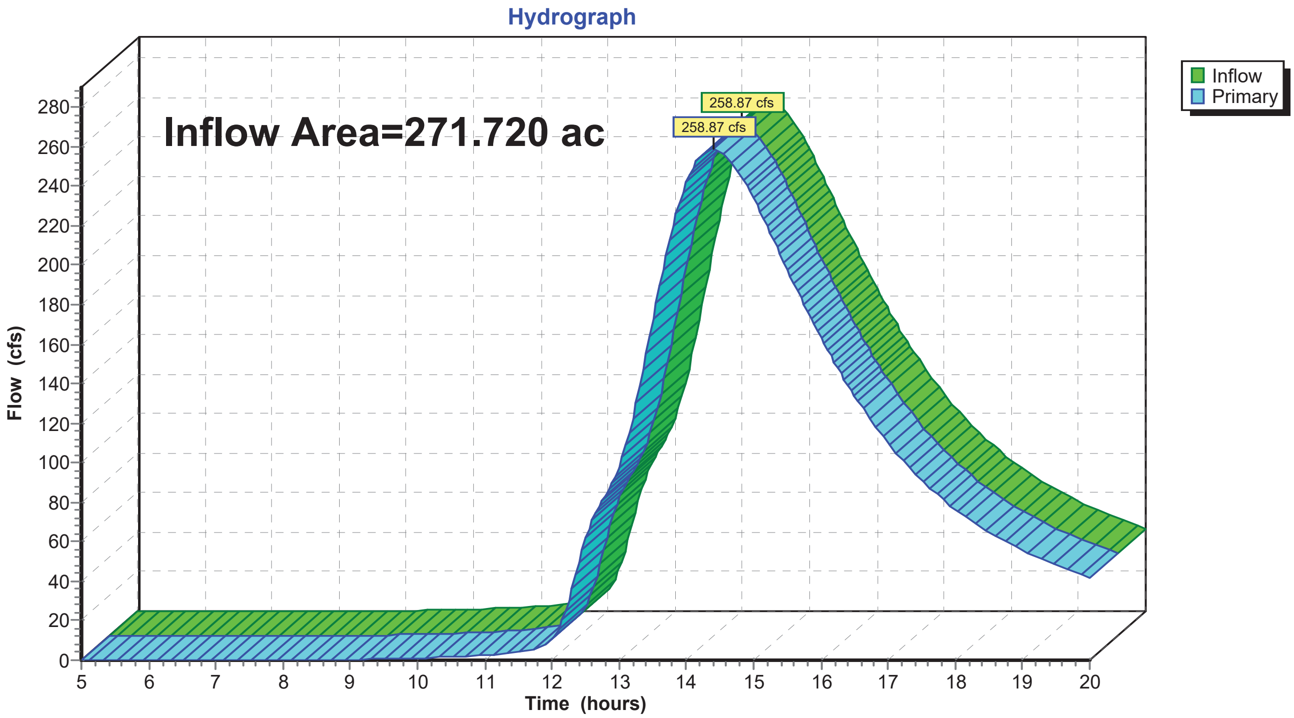
Total Runoff Area = 271.720 ac Runoff Volume = 94.960 af Average Runoff Depth = 4.19"
100.00% Pervious = 271.720 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48925

Inflow Area = 271.720 ac, 0.00% Impervious, Inflow Depth > 3.74" for 50-Year event
Inflow = 258.87 cfs @ 14.39 hrs, Volume= 84.790 af
Primary = 258.87 cfs @ 14.39 hrs, Volume= 84.790 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

Link 1C: Culvert #48925



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

Subcatchment 1S: WS-51 Runoff Area=249.100 ac 0.00% Impervious Runoff Depth>5.35"
Tc=122.0 min CN=80 Runoff=424.71 cfs 111.106 af

Subcatchment 2S: WS-52 Runoff Area=22.620 ac 0.00% Impervious Runoff Depth>4.69"
Tc=45.4 min CN=73 Runoff=61.92 cfs 8.844 af

Reach 1R: Reach 1 Avg. Flow Depth=2.34' Max Vel=9.17 fps Inflow=321.66 cfs 100.511 af
n=0.045 L=1,105.0' S=0.0434 '/' Capacity=536.71 cfs Outflow=321.50 cfs 100.152 af

Pond 1P: Pond Peak Elev=349.41' Storage=31.901 af Inflow=424.71 cfs 111.106 af
Outflow=321.66 cfs 100.511 af

Link 1C: Culvert #48925 Inflow=331.13 cfs 108.996 af
Primary=331.13 cfs 108.996 af

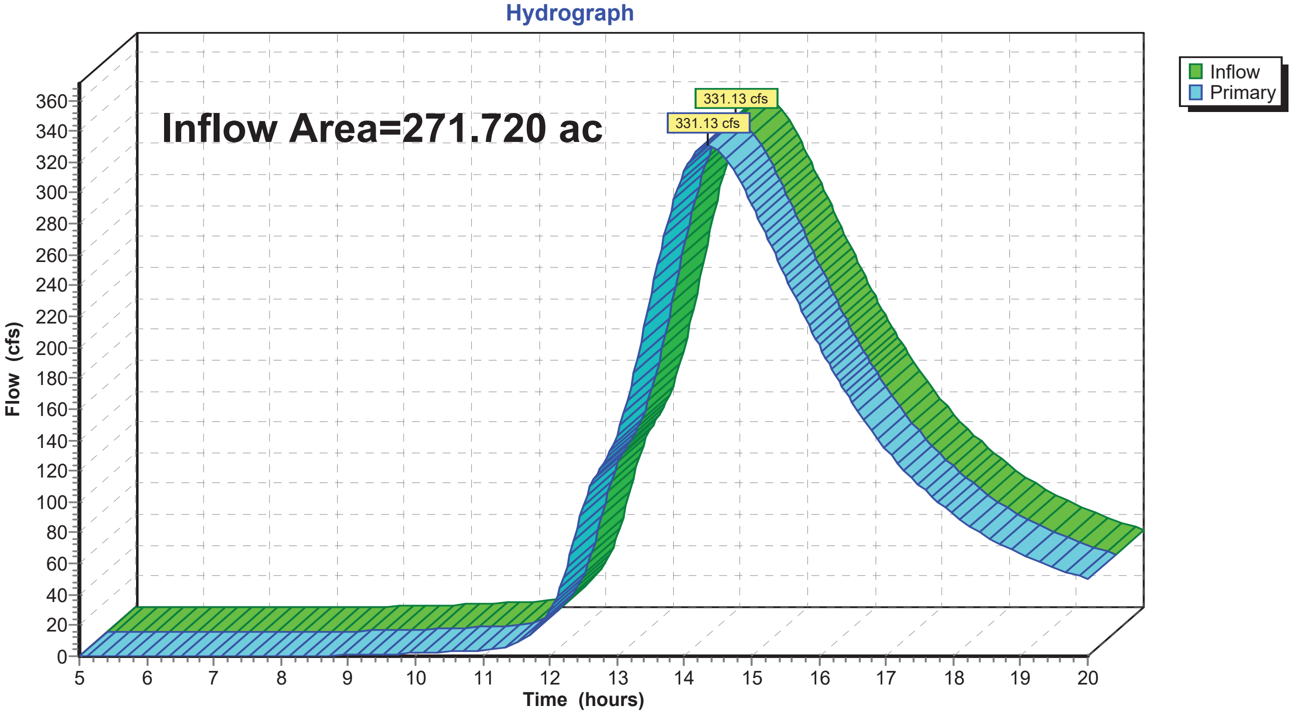
Total Runoff Area = 271.720 ac Runoff Volume = 119.950 af Average Runoff Depth = 5.30"
100.00% Pervious = 271.720 ac 0.00% Impervious = 0.000 ac

Summary for Link 1C: Culvert #48925

Inflow Area = 271.720 ac, 0.00% Impervious, Inflow Depth > 4.81" for 100-Year event
Inflow = 331.13 cfs @ 14.35 hrs, Volume= 108.996 af
Primary = 331.13 cfs @ 14.35 hrs, Volume= 108.996 af, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs

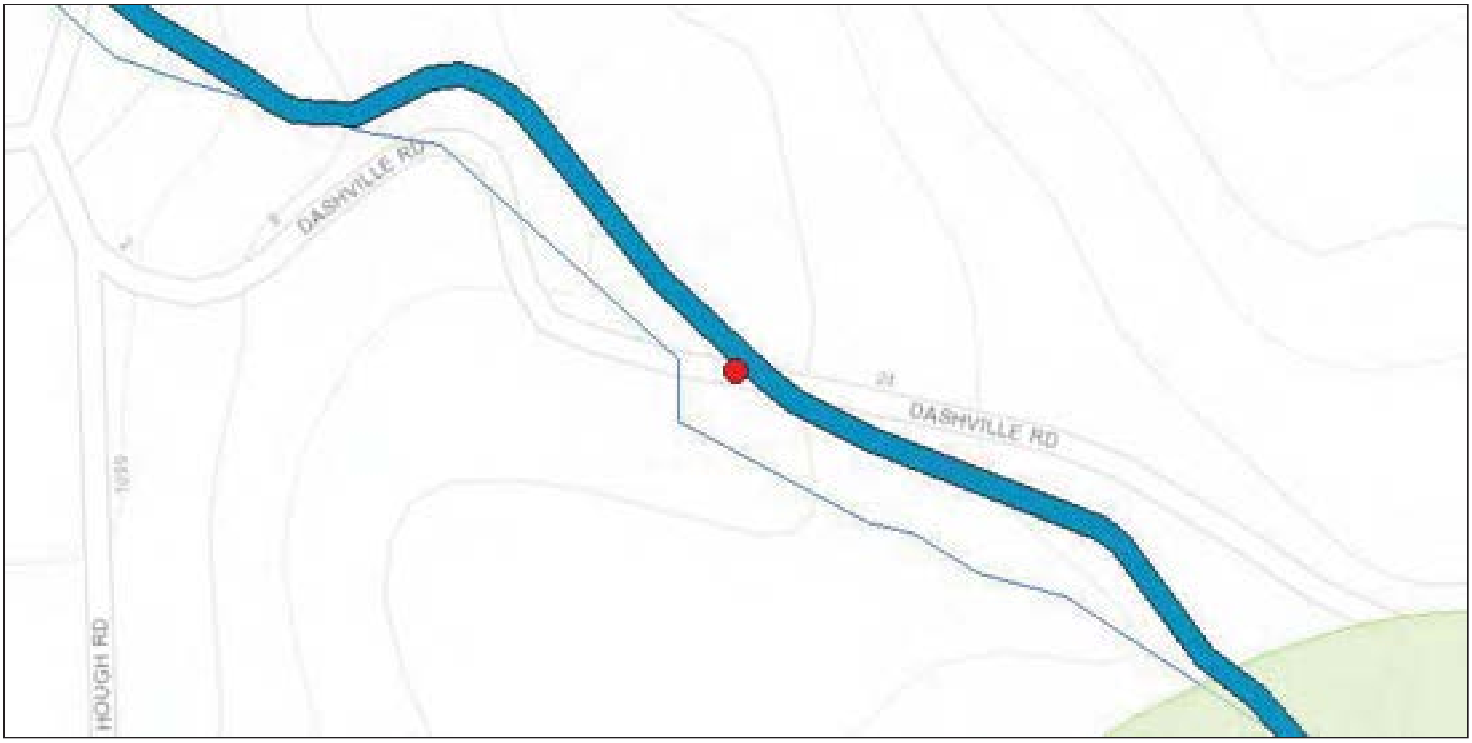
Link 1C: Culvert #48925



APPENDIX E

Concept Culvert Replacement Natural Resource Figures

Environmental Resource Mapper



The coordinates of the point you clicked on are:

UTM 18	**Easng:**	579404.745	**Northing:**	4630276.603
Longitude/Latude	**Longitude:**	-74.044	**Latude:**	41.820

The approximate address of the point you clicked on is:
31-31 Dashville Rd, New Paltz, New York, 12561

County: Ulster
Town: Esopus
USGS Quad: ROSENDALE

DEC Region

Region 3:
(Lower Hudson Valley) Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster and Westchester counes. F or more informaon visit **hp://w ww.dec.ny.gov/about/607.html**.

Rare Plants and Rare Animals

This locaon is in the vicinity of Bats Listed as Endangered or Threatened -- Contact NYSDEC Regional Office

Naonal W etands Inventory

Aribut e: undefined
Type: undefined

Acres: undefined

For more informaon about the Na onal W etands Inventory wetlands visit **hp://w ww.fws.gov/wetlands/**

If your project or acon is within or near an ar ea with a rare animal, a permit may be required if the species is listed as endangered or threatened and the department determines the acon ma y be harmful to the species or its habitat.

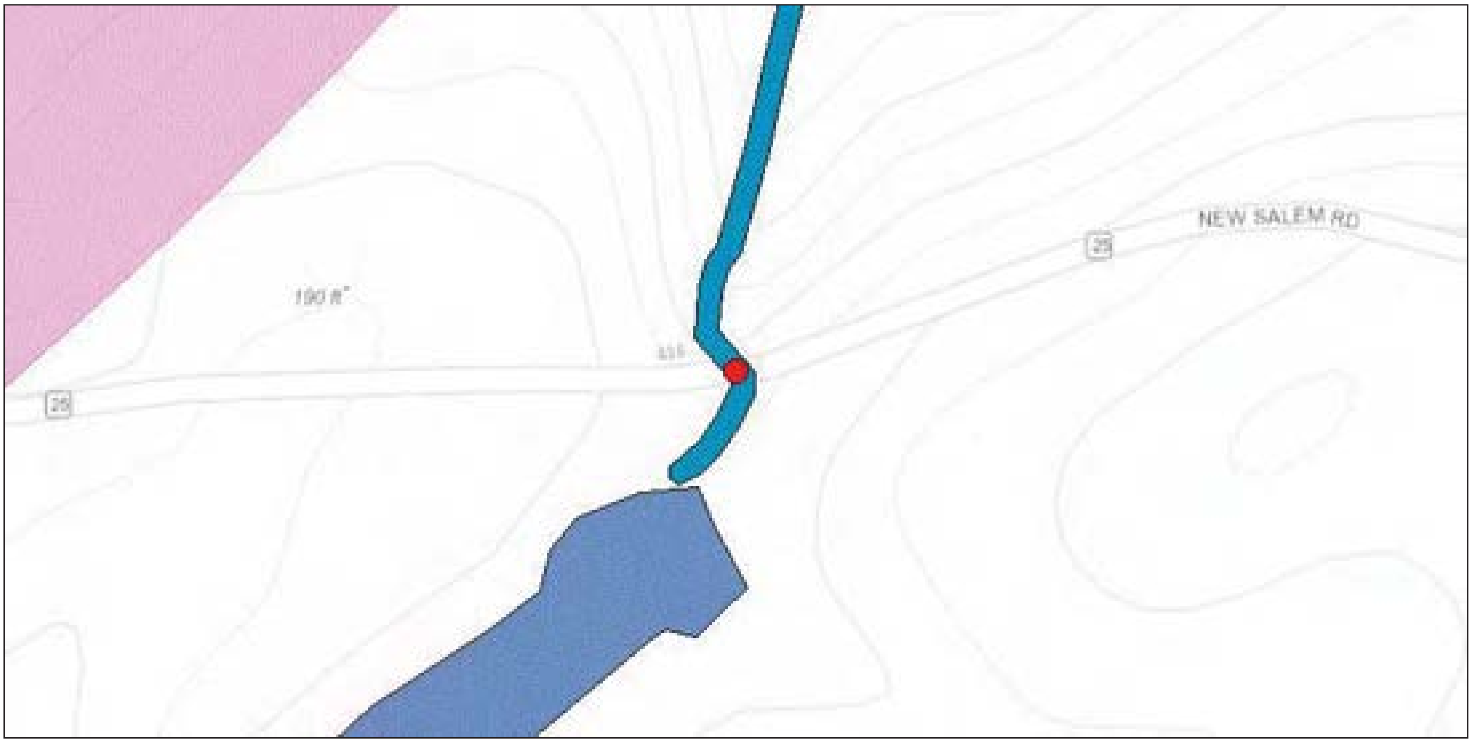
If your project or acon is within or near an ar ea with rare plants and/or significant natural communies, the environmental impacts may need to be addressed.

The presence of a unique geological feature or landform near a project, unto itself, does not trigger a requirement for a NYS DEC permit. Readers are advised, however, that there is the chance that a unique feature may also show in another data layer (ie. a wetland) and thus be subject to permit jurisdicon.

Please refer to the "Need a Permit?" tab for permit informaon or other authoriz aons r egarding these natural resources.

Disclaimer: If you are considering a project or acon in, or near , a wetland or a stream, a NYS DEC permit may be required. The Environmental Resources Mapper does not show all natural resources which are regulated by NYS DEC, and for which permits from NYS DEC are required. For example, Regulated Tidal Wetlands, and Wild, Scenic, and Recreaonal Riv ers, are currently not included on the maps.

Environmental Resource Mapper



The coordinates of the point you clicked on are:

UTM 18	**Easng:**	583238.600	**Northing:**	4639114.914
Longitude/Latude	**Longitude:**	-73.996	**Latude:**	41.900

The approximate address of the point you clicked on is:
374-428 New Salem Rd, Kingston, New York, 12401

County: Ulster
Town: Esopus
USGS Quad: KINGSTON EAST

DEC Region

Region 3:
(Lower Hudson Valley) Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster and Westchester counes. F or more informaon visit **hp://w ww.dec.ny.gov/about/607.html**.

Rare Plants and Rare Animals

This locaon is in the vicinity of Animals Listed as Endangered or Threatened - Contact NYSDEC Regional Office

This locaon is in the vicinity of Bats Listed as Endangered or Threatened -- Contact NYSDEC Regional Office

Naonal W etands Inventory

Aribut e: undefined
Type: undefined
Acres: undefined

For more informaon about the Na onal W etands Inventory wetlands visit **hp://w ww.fws.gov/wetlands/**

If your project or acon is within or near an ar ea with a rare animal, a permit may be required if the species is listed as endangered or threatened and the department determines the acon ma y be harmful to the species or its habitat.

If your project or acon is within or near an ar ea with rare plants and/or significant natural communities, the environmental impacts may need to be addressed.

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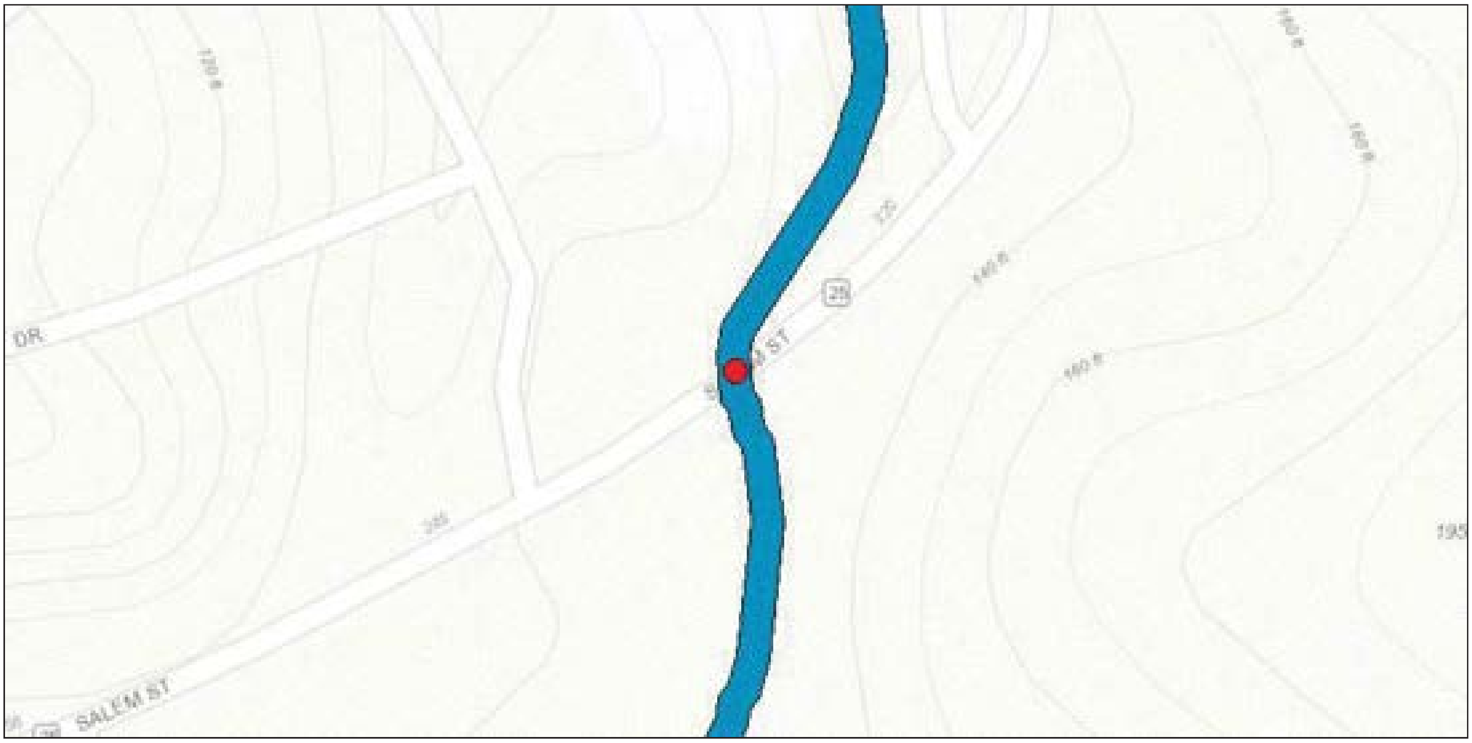
Environmental Resource Mapper



The coordinates of the point you clicked on are:

UTM 18	**Easng:**	584347.353	**Northing:**	4639361.164
Longitude/Latude	**Longitude:**	-73.983	**Latude:**	41.902

The approximate address of the point you clicked on is:
220-244 Salem St, Port Ewen, New York, 12466

County: Ulster
Town: Esopus
USGS Quad: KINGSTON EAST

DEC Region

Region 3:
(Lower Hudson Valley) Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster and Westchester counes. F or more informaon visit **hp://w ww.dec.ny.gov/about/607.html**.

Waterbody Classificaons f or Rivers/Streams

Regulaon: 855.4-3
Standard: C
Classificaon: C

Rare Plants and Rare Animals

This locaon is in the vicinity of Bats Listed as Endangered or Threatened -- Contact NYSDEC Regional Office

Naonal W etands Inventory

Aribut e: undefined
Type: undefined
Acres: undefined

For more informaon about the Na onal W etands Inventory wetlands visit **hp://w ww.fws.gov/wetlands/**

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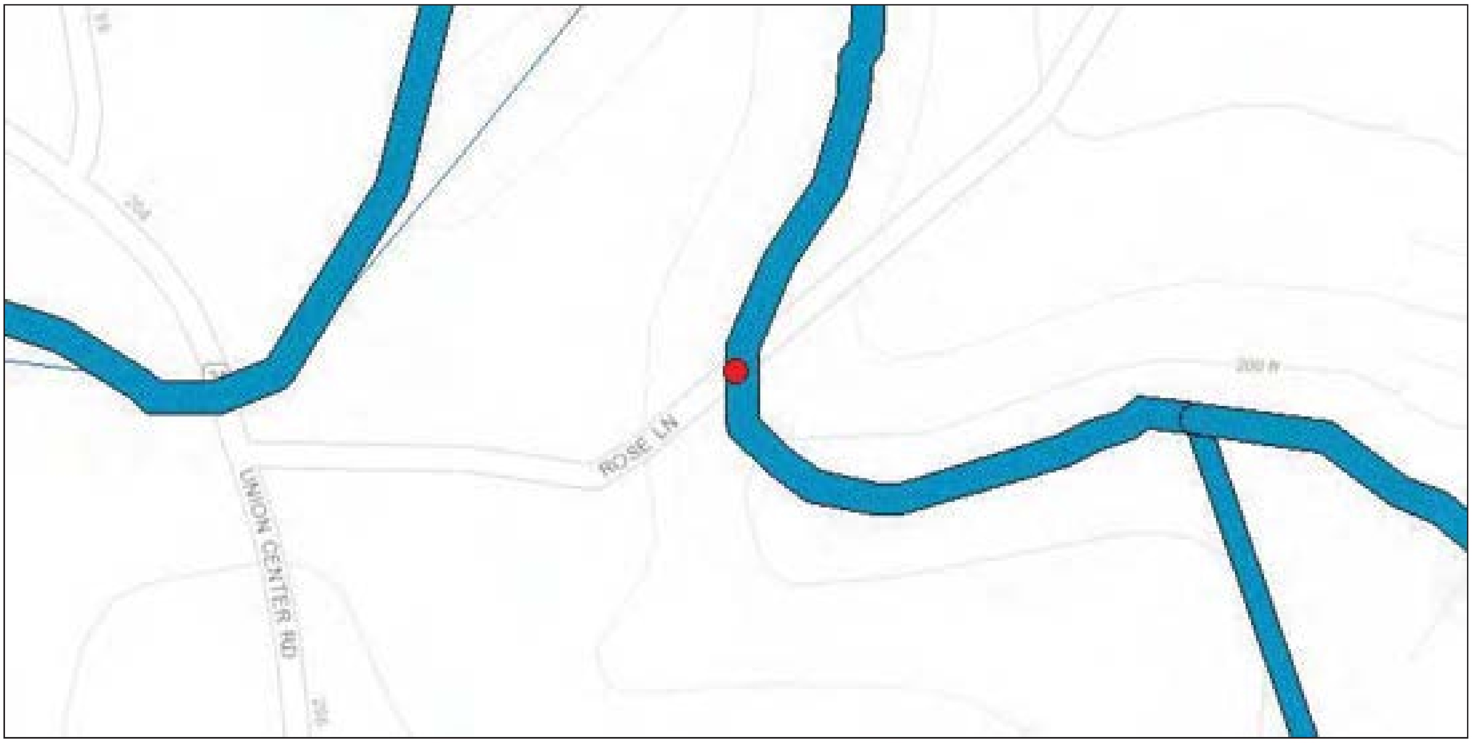
Environmental Resource Mapper



The coordinates of the point you clicked on are:

UTM 18	**Easng:**	582835.575	**Northing:**	4634535.224
Longitude/Latude	**Longitude:**	-74.002	**Latude:**	41.858

The approximate address of the point you clicked on is:
2-98 Rose Ln, Ulster Park, New York, 12487

County: Ulster
Town: Esopus
USGS Quad: ROSENDALE

DEC Region

Region 3:
(Lower Hudson Valley) Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster and Westchester counes. F or more informaon visit **hp://w ww.dec.ny.gov/about/607.html**.

Waterbody Classificaons f or Rivers/Streams

Regulaon: 862-423
Standard: C
Classificaon: C

Rare Plants and Rare Animals

This locaon is in the vicinity of Animals Listed as Endangered or Threatened - Contact NYSDEC Regional Office

This locaon is in the vicinity of Bats Listed as Endangered or Threatened -- Contact NYSDEC Regional Office

Naonal W etands Inventory

Aribut e: undefined
Type: undefined
Acres: undefined

For more informaon about the Na onal W etands Inventory wetlands visit **hp://w ww.fws.gov/wetlands/**

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If your project or acon is within or near an ar ea with rare plants and/or significant natural communies, the environmental impacts may need to be addressed.

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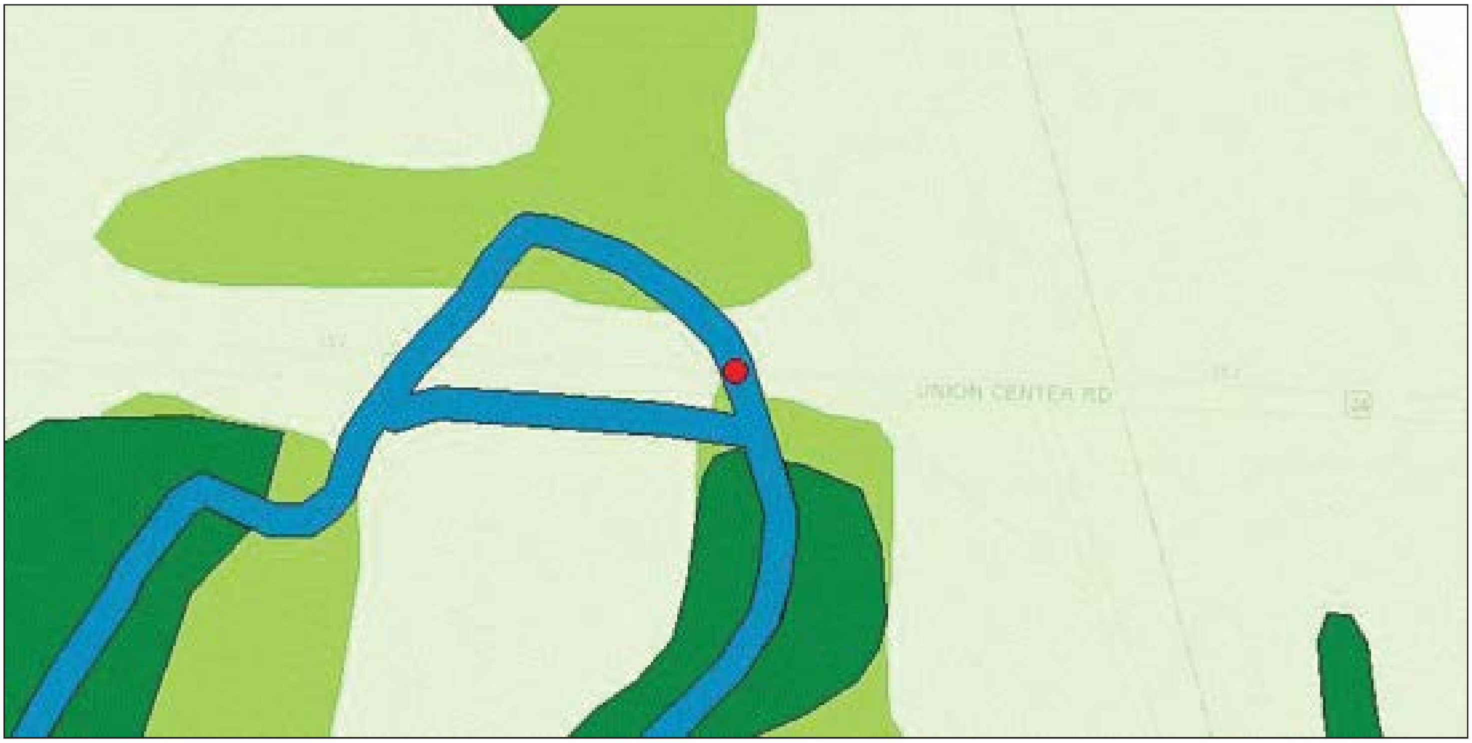
Environmental Resource Mapper



The coordinates of the point you clicked on are:

UTM 18	**Easng:**	584548.322	**Northing:**	4634311.043
Longitude/Latude	**Longitude:**	-73.981	**Latude:**	41.856

The approximate address of the point you clicked on is:
361 Union Center Rd, Ulster Park, New York, 12487

County: Ulster
Town: Esopus
USGS Quad: HYDE PARK

DEC Region

Region 3:
(Lower Hudson Valley) Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster and Westchester counes. F or more informaon visit hp://w ww.dec.ny.gov/about/607.html.

[Old or Potenal R ecords (Not displayed on the map)]()

Common Name: Angled Spikerush
Scienfic Name: Eleocharis quadrangulata
Date Last Documented: 1936-09-06
Locaon: Esopus Lake
NYS Protected: Endangered

Waterbody Classificaons f or Rivers/Streams

Regulaon: 862-423
Standard: C
Classificaon: C

Freshwater Wetlands Checkzone

This locaon is in the vicinity of one or mor e Regulated Freshwater Wetlands.

Rare Plants and Rare Animals

This locaon is in the vicinity of Animals Listed as Endangered or Threatened - Contact NYSDEC Regional Office

This locaon is in the vicinity of Kentucky Warbler -- Not Listed by NYS

This locaon is in the vicinity of Bats Listed as Endangered or Threatened -- Contact NYSDEC Regional Office

Naonal W etands Inventory

Aribut e: undefined
Type: undefined
Acres: undefined

For more informaon about the Na onal W etands Inventory wetlands visit **hp://w ww.fws.gov/wetlands/**

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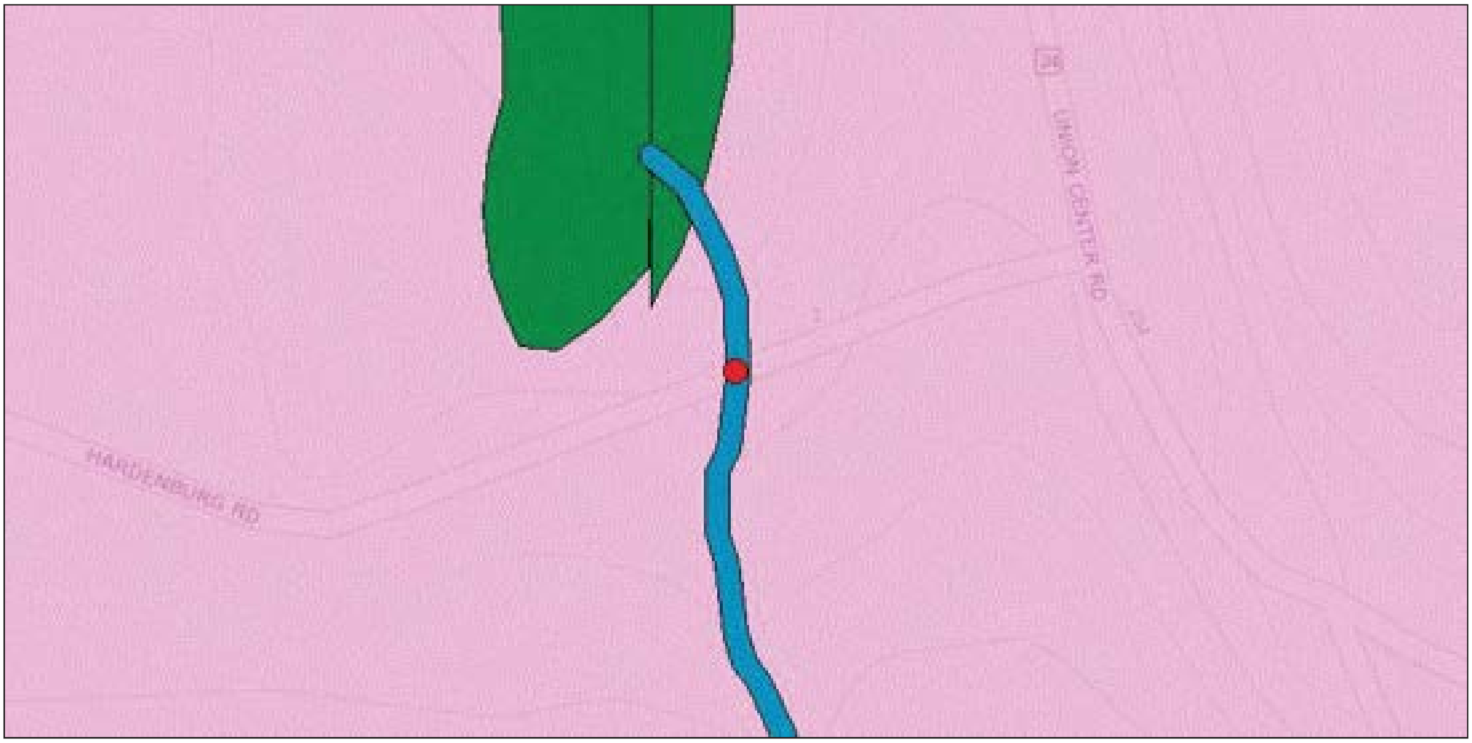
Environmental Resource Mapper



The coordinates of the point you clicked on are:

UTM 18	**Easng:**	583067.963	**Northing:**	4633827.254
Longitude/Latude	**Longitude:**	-73.999	**Latude:**	41.852

The approximate address of the point you clicked on is:
2-22 Hardenburg Rd, Ulster Park, New York, 12487

County: Ulster
Town: Esopus
USGS Quad: HYDE PARK

DEC Region

Region 3:
(Lower Hudson Valley) Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster and Westchester counes. F or more informaon visit hp://w ww.dec.ny.gov/about/607.html.

Waterbody Classificaons f or Rivers/Streams

Regulaon: 862-423
Standard: C
Classificaon: C

Natural Communies in the Vicinity

Natural Community Name: Hemlock-northern hardwood forest
Locaon: Shaupeneak Mountain
Ecological System: Uplands

Rare Plants and Rare Animals

This locaon is in the vicinity of Animals Listed as Endangered or Threatened - Contact NYSDEC Regional Office

This locaon is in the vicinity of Bats Listed as Endangered or Threatened -- Contact NYSDEC Regional Office

Naonal W etands Inventory

Aribut e: undefined
Type: undefined
Acres: undefined

For more informaon about the Na onal W etands Inventory wetlands visit **hp://w ww.fws.gov/wetlands/**

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APPENDIX F
NAACC Road-Stream Crossing Scoring System

Scoring Road-Stream Crossings as Part of the North Atlantic Aquatic Connectivity Collaborative (NAACC)

Adopted by the NAACC Steering Committee
November 10, 2015

INTRODUCTION

The North Atlantic Aquatic Connectivity Collaborative (NAACC) was launched in 2015 with a rapid assessment protocol for evaluating aquatic passability at road-stream crossings and an online database (https://www.streamcontinuity.org/cdb2) for storing and scoring data collected using this protocol. Two scoring systems are proposed to evaluate aquatic passability at road-stream crossings. The first is a coarse screen for use in classifying crossings into one of three categories: "Full AOP" (Aquatic Organism Passage), "Partial AOP," and "No AOP." The second system is an algorithm for computing an aquatic passability score, ranging from 0 (low) to 1 (high), for each road-stream crossing. These two scoring systems are not particular to any taxonomic or functional group but instead seek to evaluate passability for the full range of aquatic organisms likely to be found in rivers and streams.

NAACC COARSE SCREEN

Table 1 below identifies characteristics and conditions that allow crossings to be classified as providing "Full AOP," "Reduced AOP," or "No AOP."

Table 1. NAACC Coarse Screen

Metric	Flow Condition	Crossing Classification Full AOP	Reduced AOP	No AOP
		If all are true	*If any are true*	*If any are true*
Inlet Grade		At Stream Grade	Inlet Drop or Perched	
Outlet Grade		At Stream Grade		Cascade, Free Fall onto Cascade
Outlet Drop to Water Surface		= 0		≥ 1 ft
Outlet Drop to Water Surface/ Outlet Drop to Stream Bottom				> 0.5
Inlet or Outlet Water Depth	Typical-Low	> 0.3 ft		< 0.3 ft w/Outlet Drop to Water Surface > 0
	Moderate	> 0.4 ft		< 0.4 ft w/Outlet Drop to Water Surface > 0
Structure Substrate Matches Stream		Comparable or Contrasting		
Structure Substrate Coverage		100%	< 100%	
Physical Barrier Severity		None	Minor or Moderate	Severe

The primary objective of the coarse screen is to identify those crossings that are likely to be a barrier to most or all species and those that are likely to provide something close to full aquatic organism passage. If it is necessary to get a better feel for how bad those crossing are that are labeled as "reduced AOP" one can use the numeric scoring system.

NAACC Numeric Scoring System

The numeric scoring algorithm is based on the opinions of experts who decided both the relative importance of all the available predictors of passability as well as a way to score each predictor. Scoring involves three steps: (1) generating a component score for each predictor variable, (2) combining these predictions with a weighted average to generate a composite score for the crossing, and (3) assigning a final score based on the minimum of the composite score or the component score for the *outlet drop* variable.

Variables Used

Crossing assessments are generally done during "typical low-flow conditions." Some variables are important for assessing conditions at the time of the survey; others provide indirect evidence of likely conditions at higher flows.

<u>Inlet Grade</u>: The position of the structure invert relative to the stream bottom at the inlet.

<u>Outlet Drop</u>: Outlet drop is based on the variable *Outlet Drop to Water Surface* unless the value for *Water Depth Matches Stream* = "Dry" in which case outlet drop is based on the variable *Outlet Drop to Stream Bottom*.

<u>Physical Barriers</u>: This variable covers a wide variety of circumstances ranging from obstructions to dewatered culverts or bridge cells that represent physical barriers to aquatic organism passage.

<u>Constriction</u>: The relative width of the crossing compared to the width of the stream. "Severe" = <50%, "Moderate" = 50-100%; other options include "Spans Only Bankfull/Active Channel" and "Spans Full Channel & Banks." *Constriction* is an indirect indicator of potential velocity issues at higher flows.

<u>Water Depth</u>: Water depth in the structure relative to water depths found in the natural channel at the time of survey.

<u>Water Velocity</u>: Water velocity in the structure relative to water velocities found in the natural channel at the time of survey.

<u>Scour Pool</u>: Presence/absence of a scour pool at the crossing outlet and size relative to the natural stream channel. *Scour Pool* is an indirect indicator of potential velocity issues at higher flows. *Scour pool* is included solely as an indicator of velocities at higher flows. It is not based on the effects of the pool itself which can actually be positive for fish passage.

<u>Substrate Matches Stream</u>: An assessment of whether the substrate in the structure matches the substrate in the natural stream channel. *Substrate Matches Stream* is used to evaluate how a discontinuity in substrate might inhibit passage for species that either use substrate as the medium for travel (e.g., mussels) or require certain types of substrate for cover during movements (e.g., crayfish, salamanders, juvenile fish).

Substrate Coverage: Degree to which a crossing structure is covered by substrate. *Substrate Coverage* is directly related to passability for some aquatic species that require substrate or that tend to avoid areas that lack cover. It is also an important element of roughness that can create areas of low-velocity water (boundary layers) utilized by weak-swimming organisms. *Substrate Coverage* is also an indirect indicator of potential velocity issues at higher flows.

Openness: Cross-sectional area of the structure opening divided by the structure length (distance between inlet and outlet) measured in feet. *Openness* is calculated for both the inlet and outlet and the lower value is assigned to the structure. If there are multiple structures at a crossing the value for the structure with the highest *Openness* is assigned to the crossing as a whole. Turtles are believed to be affected by the *Openness* of a crossing structure; other species may be affected as well.

Height: Maximum height of the crossing structure. This variable is parameterized so that it only comes into play for very small structures.

Outlet Armoring: Presence/absence of streambed armoring (e.g., riprap, asphalt, concrete) at the outlet and the relative amount of armoring. Armoring is considered "extensive" if the length (upstream to downstream) of the streambed that is armored is greater or equal to half the bankfull width of the natural stream channel. *Outlet Armoring* is an indirect indicator of potential velocity issues at higher flows.

Internal Structures: Presence/absence of structures inside a culvert or bridge (e.g. weirs, baffles, supports). The *Internal Structures* variable is used in the scoring algorithm as it relates to the potential for creating turbulence within a crossing structure. To the extent that *Internal Structures* physically block the movement of aquatic organisms it is covered by the *Physical Barriers* variable.

Step 1: Component Scores

The component scores are not meant to equate to passability. In each case the component score is intended the cover the full range of problems (assessable by our protocol) associated with that variable: from 0 (worst case) to 1 (best case). For *inlet grade*, having an inlet drop or perched inlet is the worst case among the options, thus they score "0." This is not meant to say that all structures with inlet drops are impassible. The effect of *inlet grade* on passability scores is controlled by the weight it is given in computing the composite score (see Step 2 below).

Scoring categorical predictors is simply a matter of assigning a score for each possible category. Table 2 lists all of the categorical predictors and the scores associated with each category.

Scoring continuous predictors requires a function to convert the predictor to a score. There are three continuous predictors and three associated functions. The functional forms used were chosen because they have shapes desired by the expert team or because they fit the series of points specified by the expert team. Appendix A includes the r code defining each of these functions ("x" is the measured value for each variable).

The scoring equation for *Openness* is:

(1) $s_o = a(1 - e^{-kx(1-d)})^{1/(1-d)}$

Where S_o is the score for openness, a=1, k=15, and d = 0.62 when openness is recorded in feet.

The equation for Height is:

(2) $s_h = \min(\frac{ax^2}{b^2 + x^2}, 1)$

Where S_h is the component score for height, a = 1.1, and b=2.2 when height is recorded in feet.

The equation for Outlet Drop is:

(3) $s_{od} = 1 - \frac{ax^2}{b^2 + x^2}$

Where S_{od} is the Outlet Drop component score, a=1.029412, and b=0.51449575 when outlet drop is recorded in feet.

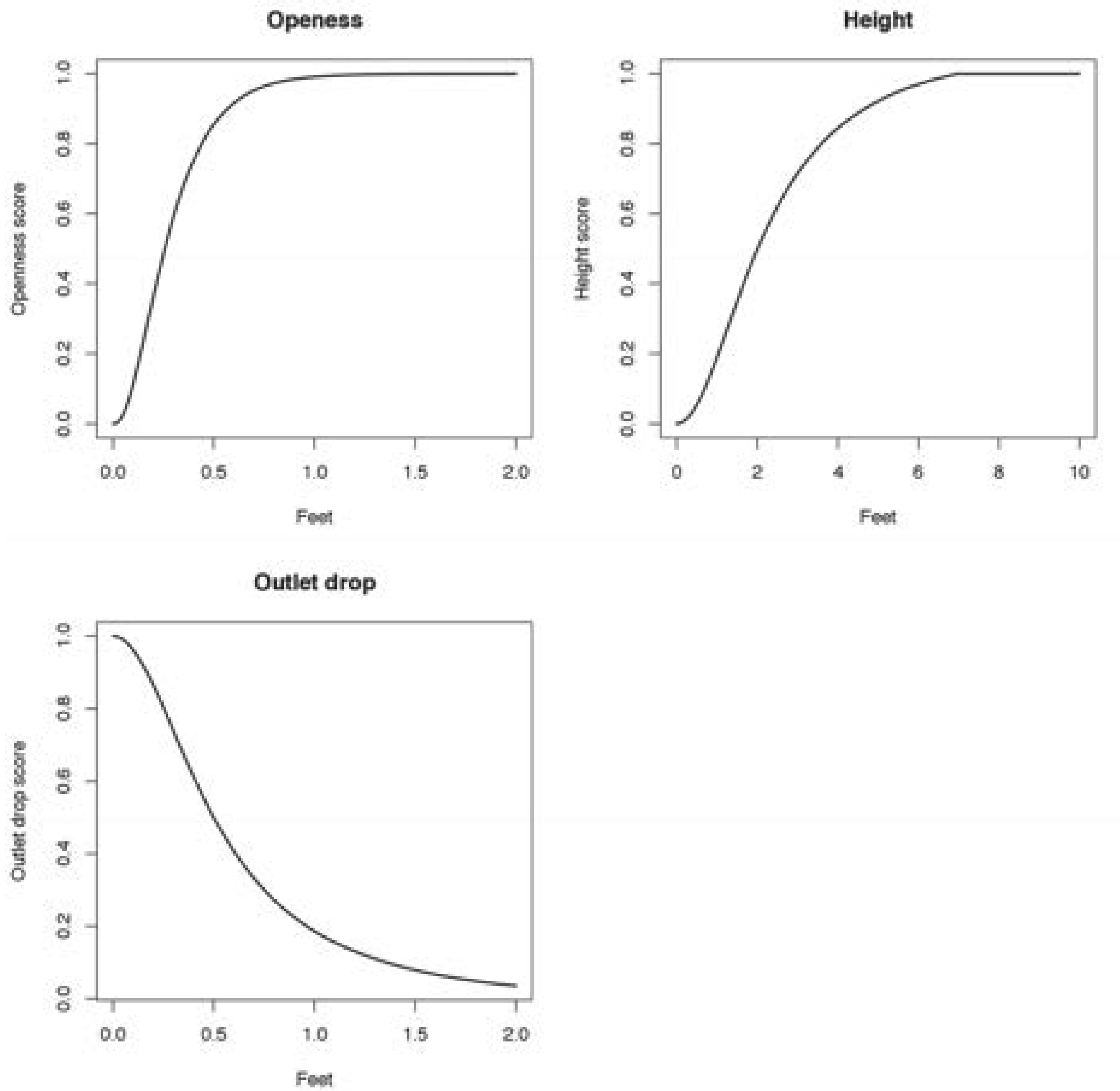


Figure 1. Continuous predictor variables

Table 2. Component scores for categorical variables used in calculating the crossing score

parameter	level	score
Constriction	severe	0
Constriction	moderate	0.5
Constriction	spans only bankfull/active channel	0.9
Constriction	spans full channel and banks	1
Inlet grade	at stream grade	1
Inlet grade	inlet drop	0
Inlet grade	perched	0
Inlet grade	clogged/collapsed/submerged	1
Inlet grade	unknown	1
Internal structures	none	1
Internal structures	baffles/weirs	0
Internal structures	supports	0.8
Internal structures	other	1
Outlet armoring	extensive	0
Outlet armoring	not extensive	0.5
Outlet armoring	none	1
Physical barriers	none	1
Physical barriers	minor	0.8
Physical barriers	moderate	0.5
Physical barriers	severe	0
Scour pool	large	0
Scour pool	small	0.8
Scour pool	none	1
Substrate coverage	none	0
Substrate coverage	25%	0.3
Substrate coverage	50%	0.5
Substrate coverage	75%	0.7
Substrate coverage	100%	1
Substrate matches stream	none	0
Substrate matches stream	not appropriate	0.25
Substrate matches stream	contrasting	0.75
Substrate matches stream	comparable	1
Water depth	no (significantly deeper)	0.5
Water depth	no (significantly shallower)	0
Water depth	yes (comparable)	1
Water depth	dry (stream also dry)	1
Water velocity	no (significantly faster)	0
Water velocity	no (significantly slower)	0.5
Water velocity	yes (comparable)	1
Water velocity	dry (stream also dry)	1

Some notes about the component scores

1. The option "clogged/collapsed/submerged" for *inlet grade* is an option surveyors use to indicate that it was not possible to measure the structure's dimensions. If the inlet is clogged or collapsed enough to affect passability it will be covered under *physical barriers*. This is why it receives a "1" instead of a "0", because problems associated with this option are covered by the *physical barriers* variable.

2. The rationale for giving a component score of "1" to "unknown" for *inlet grade* is similar to that for "clogged/collapsed/submerged." It is hard to know how to interpret "unknown." However, if conditions at the inlet are creating a physical barrier to passage it will be covered under *physical barriers*.

3. We included *inlet grade* as a variable in addition to *physical barriers* because inlet drops create both velocity and physical barrier (jump barrier) issues. The physical barrier issues are covered by the *physical barriers* variable. The *inlet grade* variable captures the velocity issues at the inlet. Perched inlets can create depth issues at low flows (if water can't get into the structure inlet). These may not be apparent at the time of the survey. Thus, the presence of a perched inlet is a concern even if it doesn't represent a physical barrier ("dry") at the time when the survey is conducted.

4. The variable *internal structures* is included to account for turbulence issues. There is likely to be turbulence associated with weirs and baffles when these are included inside crossing structures. If they also create physical barriers they will be covered by the *physical barriers* variable. They are often included in structures to help aquatic organism passage but they sometimes do more harm than good and may be good for some species while creating problems for others. The inclusion of well-designed weirs or baffles is likely to improve the component scores for water depth and water velocity. They get docked a little in our scoring system for introducing turbulence.

5. It is difficult to know how to score the "other" option under *internal structures* because it is difficult to know what, if any, impact these other structures will have on turbulence. If, however, they represent a physical barrier they will be covered under the *physical barriers* variable.

Step 2: Weighted Composite Scores

An expert team of nine people provided input on how the variables should be weighted based on best professional judgement. The weights used with the component scores are listed in table 3. The weights are simply the means of the nine weights for each variable provided by the experts. We display the weights out to three decimal places not to suggest that we know the weights to this level of precision but to reduce overall error in the model by not introducing an additional source of error (rounding error). The composite score is the sum of the products of each component score and its weight.

Table 3. Weights associated with each parameter in the scoring algorithm.

parameter	weight
Outlet drop	0.161
Physical barriers	0.135
Constriction	0.090
Inlet grade	0.088
Water depth	0.082
Water velocity	0.080
Scour pool	0.071
Substrate matches stream	0.070
Substrate coverage	0.057
Openness	0.052
Height	0.045
Outlet armoring	0.037
Internal structures	0.032

Step 3: Final Aquatic Passability Score

The final Aquatic Passability Score is the lower of either the composite score or the *Outlet Drop* component score. The rationale for this is that although many factors can affect aquatic organism passage, when an outlet drop is above a certain size it becomes the predominant factor that determines passability.

Aquatic Passability Score = Min[Composite Score, *Outlet Drop* score]

Mapping Aquatic Passability Scores

For mapping purposes, we assigned narrative descriptors for different ranges of aquatic passability as follows.

Descriptor	Aquatic Passability Score(s)
No barrier	1.0
Insignificant barrier	0.80 – 0.99
Minor barrier	0.60 – 0.79
Moderate barrier	0.40 – 0.59
Significant barrier	0.20 – 0.39
Severe barrier	0.00 – 0.19

People often ask about the relationship between these categories and actual passability for fish and other aquatic organisms. At this point the relationship is unknown and we regard it as a fruitful area for future research. The concept of aquatic passability is complicated and includes: variation in the swimming and leaping abilities of individuals within a species (what proportion of the population can pass), variability in passage requirements for a broad diversity of species that inhabit rivers and streams (what proportion of species can pass), and the timing of passability (for what proportion of the year is the structure passable).

For now, the best way to consider the aquatic passability scores is that they represent the degree to which crossings deviate from an ideal. We assume that those crossings that are very close to the ideal (scores > 0.6) will present only a minor or insignificant barrier to aquatic organisms. Those structures that are farthest from the ideal (scores < 0.4) are likely to be either significant or severe barriers. These are, however, arbitrary distinctions imposed on a continuous scoring system and should be used with that in mind.

APPENDIX G

New York State Water Resources Institute - Cornell Culverts Model

The Cornell Culverts Model

Last Updated: 8/29/18 by Allison Truhlar
Created by David Gold
Soil and Water Lab
Cornell University

Objective: To identify undersized culverts for both current and future precipitation estimates in order to facilitate investment in climate resilient communities.

Model Description: The Cornell culvert model uses culvert data collected in the field in conjunction with publicly available topography, precipitation, land use and soil data to delineate the watershed of individual culverts, compute the peak discharge generated over each culvert watershed for a range of storm events, and evaluate the hydraulic capacity of each culvert.

This model consists of four main components: 1. watershed delineation, 2. peak discharge calculation, 3. capacity calculation, and 4. return period assignment. The watershed component of the model is conducted using ArcGIS, while the peak discharge calculation, capacity calculation and return period assignment are executed using Python scripts.

1. The watershed delineation component of the model is conducted on ArcGIS using custom tools created by Rebecca Marjerison for her PhD dissertation. The tools first delineate the watershed of each culvert. Next, all culvert watersheds being evaluated are aggregated into a single shapefile. Finally, the area, weighted Curve Number (CN) and Time of Concentration (T_c) are computed for each watershed.

2. The second component of the model is the peak discharge calculation. The watershed data compiled in the initial phase of the model is used as the input for this component. The procedure set in the USDA Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) graphical method is used to determine peak discharge for various return period storms for each delineated watershed.

3. The third component of the model is the calculation of culvert capacity. Using field data, the capacity of each culvert is modeled using the inlet control equation set forth by the Federal Highway Administration Hydraulic Design Series 5. In this model, the headwater ponding height was assumed to be the height of the road surface above the culvert invert.

4. In the final component of the model, the assigned capacity of each culvert is compared against the peak discharges calculated for the culvert in order to determine the maximum return period storm that the culvert can safely pass.

Model Inputs:

1. Culvert data collected by field data teams using either the NAACC protocol or the Tompkins county storm water data collection protocol.

2. The precipitation depths from the 1, 2, 5, 10, 25, 50, 100, 200 and 500 year 24-hour return period storm events in the watershed of interest.

3. DEM tiles covering the entire watershed of interest (accuracy of the model output is dependent on accuracy of the DEM used, therefore the highest resolution DEM available for the watershed of interest should be used).

4. New York state curve number raster constructed by Rebecca Marjerison.

Model Outputs:

1. current_runoff.csv: Contains the runoff from the 1, 2, 5, 10, 25, 50, 100, 200 and 500 year return period 24-hour storm events under current precipitation.

2. future_runoff.csv: Contains the runoff from the 1, 2, 5, 10, 25, 50, 100, 200 and 500 year return period 24-hour storm events under projected 2050 precipitation.

3. culv_geom.csv: Contains calculated geometry values of each culvert including area and necessary constants used in the capacity equations.

4. capacity_output.csv: Contains the capacity of each culvert in m^3/s.

5. return_periods.csv: Contains the maximum return period storm event that each culvert can safely pass under current and projected 2050 precipitation estimates.

6. model_output.csv: Contains a summary of the model output including the maximum return period that each culvert can pass for current and future precipitation, the capacity of each culvert, the culvert GPS coordinates, the cross sectional area of each culvert, and the computed watershed area, time of concentration and curve number for each culvert.

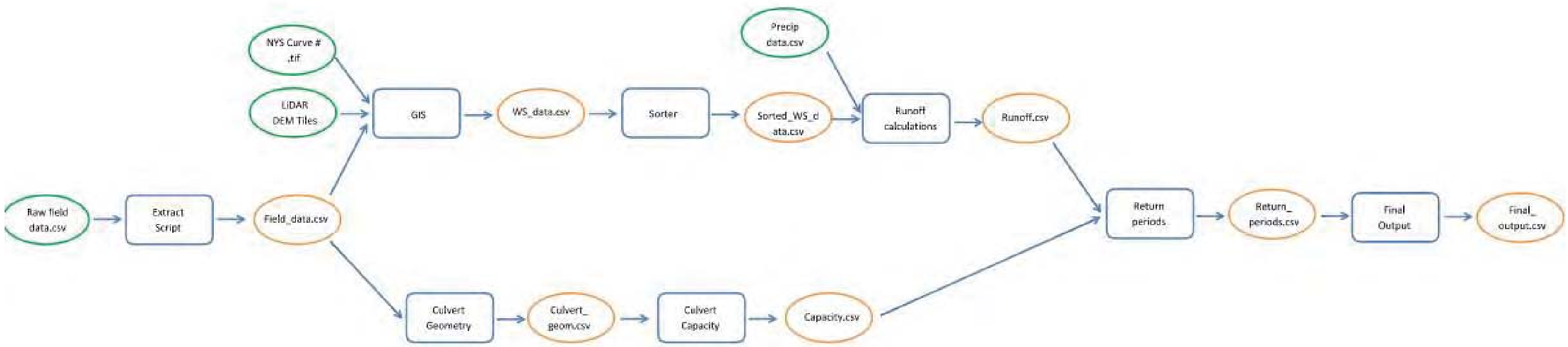
Required Software:

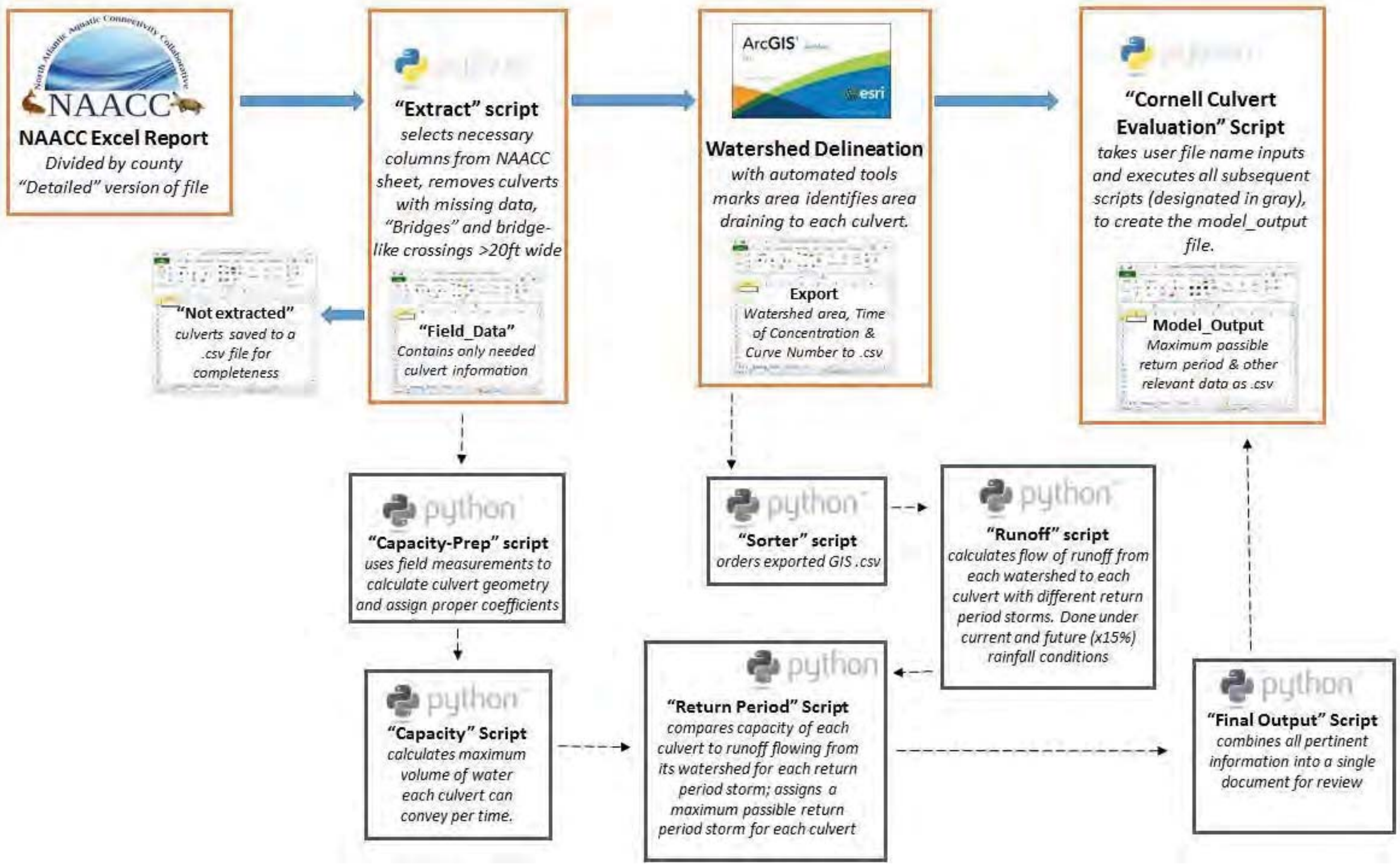
This model was developed and tested using:

1. ESRI ArcMap 10.3.1
2. Python 2.7 (comes with the ArcMap 10.3.1 installation)

   a. NumPy 1.7.1 package (comes with the ArcMap 10.3.1 installation, also available at https://pypi.python.org/pypi/numpy)
3. IDLE, a Python editor (comes with the ArcMap 10.3.1 installation)
4. Microsoft Excel
5. (Optional) R version 3.4.3

Flow Charts of Model:

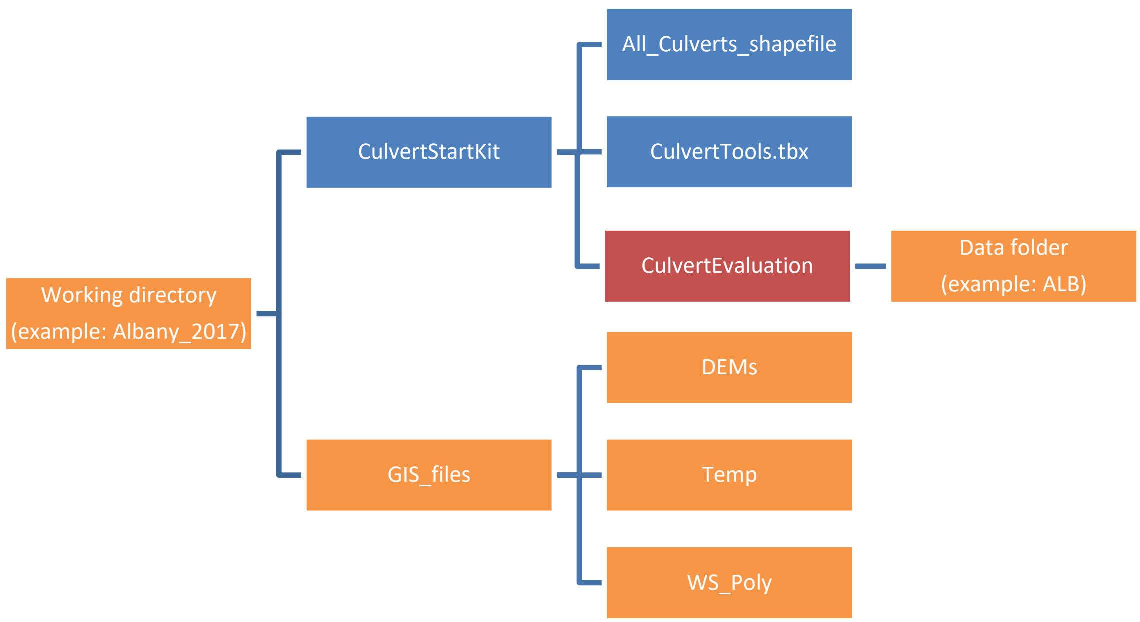



NAACC
NAACC Excel Report
Divided by county
"Detailed" version of file
"Extract" script
selects necessary columns from NAACC sheet, removes culverts with missing data, "Bridges" and bridge-like crossings >20ft wide
"Field_Data"
Contains only needed culvert information
"Not extracted"
culverts saved to a .csv file for completeness
ArcGIS
esri
Watershed Delineation
with automated tools marks area identifies area draining to each culvert.
Export
Watershed area, Time of Concentration & Curve Number to .csv
"Cornell Culvert Evaluation" Script
takes user file name inputs and executes all subsequent scripts (designated in gray), to create the model_output file.
Model_Output
Maximum possible return period & other relevant data as .csv
python
"Capacity-Prep" script
uses field measurements to calculate culvert geometry and assign proper coefficients
python
"Sorter" script
orders exported GIS .csv
python
"Runoff" script
calculates flow of runoff from each watershed to each culvert with different return period storms. Done under current and future (x15%) rainfall conditions
python
"Capacity" Script
calculates maximum volume of water each culvert can convey per time.
python
"Return Period" Script
compares capacity of each culvert to runoff flowing from its watershed for each return period storm; assigns a maximum possible return period storm for each culvert
python
"Final Output" Script
combines all pertinent information into a single document for review

Procedure:

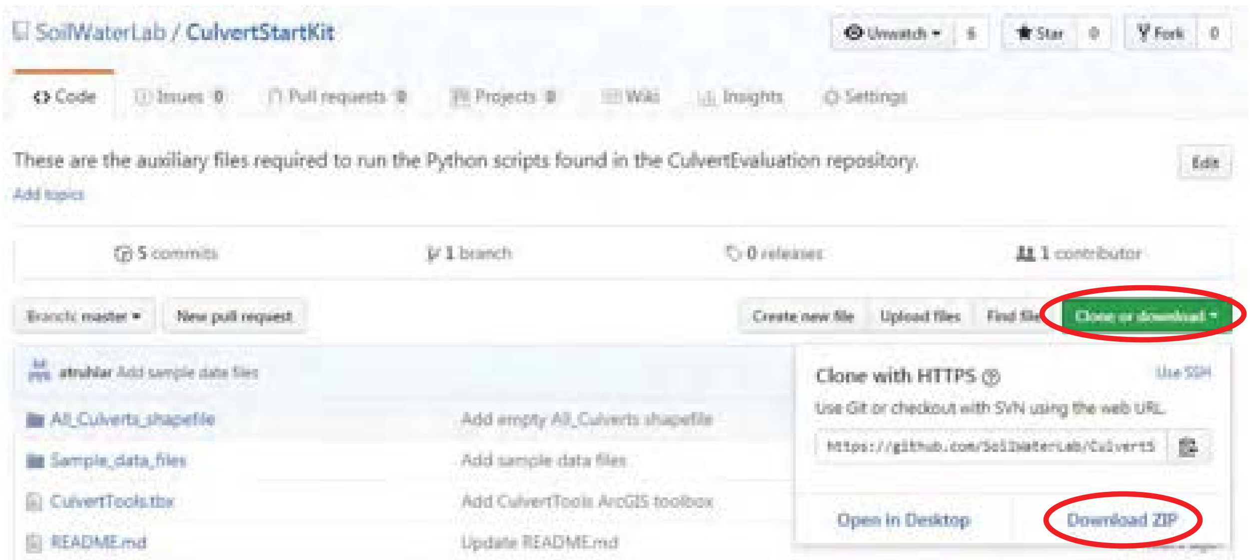
Part 0: Set up your file structure

The suggested file structure is shown below. Each rectangle represents a folder (or in the case of CulvertTools.tbx, an Arc Toolbox). **Blue rectangles** correspond to the CulvertStartKit folder that can be downloaded from the Cornell Soil & Water Github repository (https://github.com/SoilWaterLab/CulvertStartKit). The **red rectangle** corresponds to the CulvertEvaluation folder, that can be downloaded from the Cornell Soil & Water Github repository (https://github.com/SoilWaterLab/CulvertEvaluation). **Orange rectangles** are user-created folders:



To download the CulvertStartKit or CulvertEvaluation folder from Github, first navigate to the links above. Then, click on the green button on the right side of the webpage that reads "Clone or Download." A drop-down menu will appear, select "Download ZIP." (see image on next page).

After unzipping the Github downloads, be sure to next the CulvertEvaluation folder within the CulvertStartKit folder, as shown above.



The current naming convention for the data folder is a three-letter acronym. For example, if analyzing culverts in Albany county, the data folder would be named ALB. The working directory can have any descriptive name.

Part 1: Download data and prepare GIS file

Step 1: Export Data

If using NAACC data:

I. Download the NAACC spreadsheet.
II. Save the data in .csv format into your "data" folder within Culvert_Beta_scripts. For the file name, use the same three-letter acronym as the folder name (e.g., ALB.csv).
III. See note below about the column order required for NAACC data.

Note: To input data using the NAACC formatting, even if not sourced from NAACC, ensure these data are in the correct column for proper interpretation by the model. Only the bolded columns are required. All other columns can be empty. See Sample_NAACC_data.csv in CulvertModel_StartKit.

A. Survey_Id
L. Crossing Type (using the same word descriptors as is used in NAACC protocol, i.e. "Bridge", "culvert")
T. GPS_X_Coordinate (if corrected GPS coordinates are available, ensure they are in these columns)
U. GPS_Y_Coordinate (if corrected GPS coordinates are available, ensure they are in these columns)
W. Inlet_Type (using the same word descriptors as is used in NAACC protocol, i.e. "projecting", "wingwall")
Y. Number_Of_Culverts
AB. Road_Fill_Height
AJ. NAACC_CulvertID
AN. Crossing_Structure_Length
AR. Inlet_Height
AS. Inlet_Structure
AT. Inlet_Substrate_Water_Width
AU. Inlet_Water_Depth
AV. Inlet_Width
AX. Material ["Dual-Walled HDPE", "Plastic", "Corrugated HDPE", "Smooth Metal", "Corrugated Metal", "Metal", "Concrete", "Stone"]
BC. Outlet_Height (not currently used because of Inlet Control assumption)
BD. Outlet_Structure (not currently used because of Inlet Control assumption)
BE. Outlet_Substrate_Water_Width (not currently used because of Inlet Control assumption)
BF. Outlet_Water_Depth (not currently used because of Inlet Control assumption)
BG. Outlet_Width (not currently used because of Inlet Control assumption)
BJ. Slope_Percent

If using Fulcrum data:

I. Log onto fulcrum
II. Click on the “Stormwater culvert data collection” app
III. Click on “export data” (lower left hand side of page)
IV. Ensure file type is CSV
V. Choose “Mobile Device Created Time ”, “Eastern Time”
VI. Check “Include GPS data”
VII. Set the date range that you’d like data from
VIII. Hit next then hit finish on the next page
IX. Wait for the data to finish exporting, then click download and save the zip file to your project folder.
X. Extract the zip file to the “data” folder within the subfolder you’ve created for your county or watershed.

Explanation: This model has been constructed to accept data in two different formats, the method of data collection will dictate which format the data has been collected in. If the data was collected following the North Atlantic Aquatic Connectivity Collaborative (NAACC) protocol, follow the NAACC data procedure. If the data was collected for the Tompkins county stormwater project, follow the Fulcrum procedure.

Step 2: Data extraction

I. Ensure the downloaded .csv field data file is in the “Scripts” folder
II. Run the “extract” python script
  a. Right click on “Extract” Python file in the Scripts folder
  b. Select “Edit” or “Edit with IDLE”
  c. F5 on your keyboard will activate the user interface. Alternatively, from the “Run” dropdown menu, select “Run Module”.
  d. Type the ***full path*** of the file containing your culvert field measurements
  e. When asked for Watershed abbreviation, type the three letter abbreviation you used to name your data folder within Culvert_Beta_scripts.
    i. *For example: If modeling all culverts in Albany county, enter “ALB.”*
  f. If data is from fulcrum, type “F” when prompted, if the data is from NAACC, type “N”.
  g. Your data will output to the Culvert_Beta_scripts folder as two csv files, starting with the three-letter watershed abbreviation. Move these to the data folder.
    i. *For example: The extract script outputs ALB_field_data.csv and ALB_not_extracted.csv to the Culvert_Beta_scripts folder. Move both of these files to the data folder “ALB.”*
    ii. *See sample_field_data.csv and sample_not_extracted.csv files in the CulvertModel_StartKit*

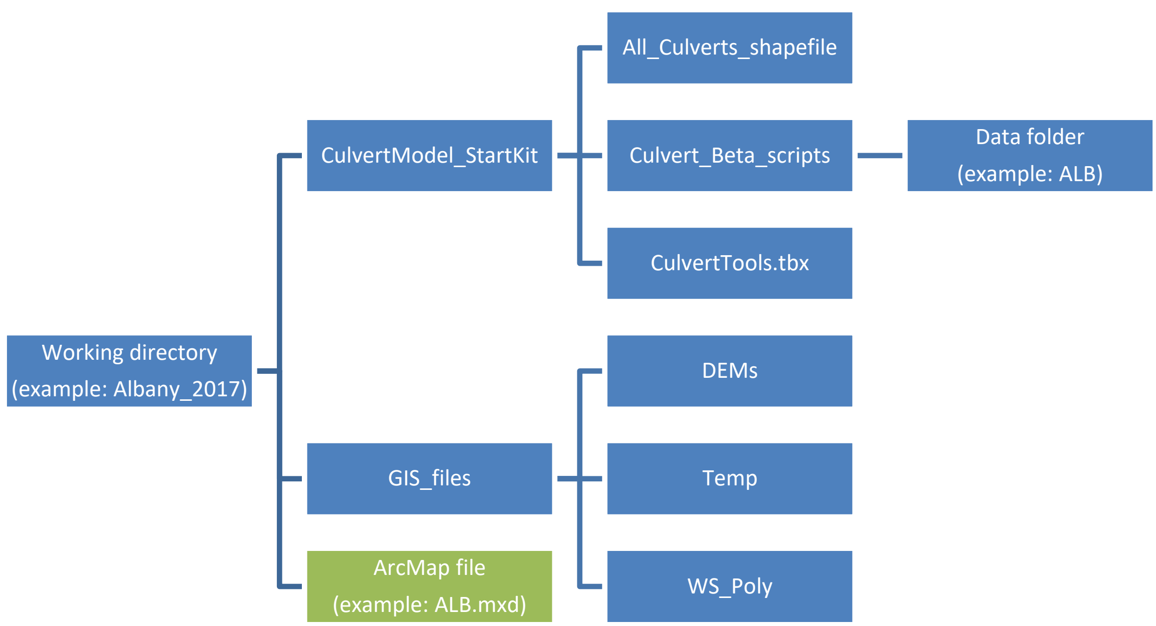
What is in the field_data.csv and not_extracted.csv files?

- Field_data.csv is your culvert crossing data, ready to be used in the ArcGIS part of the model.
- Not_extracted.csv contains culvert crossing data that was rejected for modeling. Reasons for rejection, in the order evaluated within the extract.py script, are:
  - Negative measurement values for inlet width, inlet height, HW, or culvert length.
  - If the crossing type is marked as bridge, **and** the inlet shape **is not** Box/Bridge with Abutments **or** Open Bottom Arch Bridge/Culvert.
  - If the crossing type is marked as bridge, the inlet shape is Box/Bridge with Abutments **or** Open Bottom Arch Bridge/Culvert, **and** the inlet width **is** more than 20 ft.

Explanation: The raw field data spreadsheet, whether from Fulcrum or NAACC, contains extraneous information that crowds the data sheet and makes it difficult to find the relevant culvert information. The extract script creates a new spreadsheet that contains only the information relevant to culvert evaluation. A second new spreadsheet is also created that captures all of the data points that did not meet the modeling criteria because of missing information or dimensions unacceptable to the current model. Also: To run Python script on a given file, it must be located in the same folder as the script.

Step 3: Create and save the GIS file

I. Open a new GIS file and save it to your working directory (see **green** rectangle below).



II. Set the coordinate system to: "Projected Coordinate System: UTM-NAD 83 Zone 18N" for culverts located in the Eastern majority of New York State.

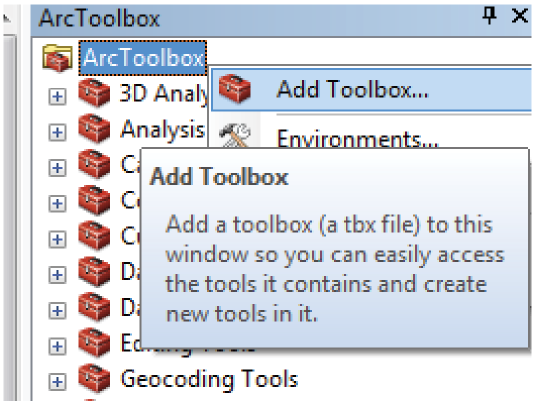
   a. In the table of contents, <u>right click</u> on "Layers" and select "Properties"

b. Select the “Coordinate System” tab

i. Navigate to Projected Coordinate System: “UTM-NAD 83 Zone 18N”

III. Load the Culverts Toolbox into ArcToolbox

a. Right click within the ArcToolbox window and select “Add Toolbox.” Then navigate to the location of the CulvertTools file.



Step 4: Load culvert and elevation data into GIS map

I. In ArcCatalog, locate extracted culvert field data file in the scripts folder, right click and select “Create Feature Class” and then “From XY Table”. In the dialog box:

a. Ensure that the X field is set to “Longitude” and the Y field is set to “Latitude”

b. Select “Coordinate System of Input Coordinates”

c. Select: Geographic Coordinate system-> World-> WGS 1984

d. Specify your working directory as the location for new shapefile to be saved

II. Project new shapefile to UTM coordinates

a. Arctoolbox→ Data Management Tools→Projections and Transformations→Project (or just search “project”)

b. Choose the newly created shape file as your target file

c. Select Projected Coordinate System: “UTM-NAD83 Zone18N” (or whatever coordinate system is appropriate for your culverts’ location. This should be the same as what you set in Step 3) as new coordinate system

d. Remove unprojected shapefile from the GIS file

Explanation: This step converts the field data from a .csv file to a shapefile that can be used in ArcGIS. The GPS points collected are in the WGS84 coordinate system, so we need to first make sure that GIS imports the points in the appropriate location as WGS84, then projects the newly created shapefile to UTM coordinates.

Step 5: Download DEMs

Note: If at Cornell, do not follow the below steps. Instead, use the stitched 10m DEM of NYS available on the WRI server (WRI Interns > Culvert Project > GIS_Data > NYS_10m_DEM_mosaic). You can optionally clip this DEM to the extent of your county of interest. County boundaries are available from the NYS GIS Clearinghouse or CUGIR. If necessary, first merge together counties. To clip a raster (DEM) with a polygon (the county boundaries), you can use Data Management > Raster > Raster Processing > Clip.

I. Add a basemap to better visualize culvert locations:
   a. Select the add layer icon, , then choose "Add Basemap" and select the one titled "streets" (or another of your choice that includes street locations)

II. Download the highest resolution DEM available (often 1m, 2m or 10m resolution)
   For culverts located in New York State:
   a. Go to the NYS GIS clearinghouse (gis.ny.gov)
   b. Click on the "Data" tab on the left of the gray bar (as of April 2016)
   c. Click on "Elevation" in the Data tab dropdown
   d. From the top of the list of options on the left-hand side of the window, select "Statewide Interactive DEM Download"
   e. Selecting an option from the Download button, , from the right-hand menu of symbols, encircle the area of your desired DEM coverage, referencing the locations of culvert points on your ArcMap to determine which LiDAR tiles are needed.
   f. From the download results menu that appears on the left-hand side of the window, select available LiDAR tiles with the highest resolution from the "DEM Results" dropdown. Click on each tile name to download.

III. Create a new folder in your working directory called "DEMs" and copy the downloaded DEMs to that folder.

IV. Add LiDAR tiles to the GIS file

Explanation: The NY state GIS clearinghouse is a repository for publically available GIS data in the state. This includes 10-m data statewide, 2-m LiDAR DEMs in Tompkins County and 1-m and 2-m LiDAR DEMs in the Hudson Valley. The LiDAR data can be downloaded in tiles, which can be found on the NYS Orthoimagery app. Each LiDAR tile has a unique number. The basemap may be helpful in identifying the rough location of the DEM tiles.

Part 2: Watershed delineation, T_c and aggregated CN calculation using ArcGIS

Step 6: Mosaic DEMs

I. **Note:** This step is not required if you have county-wide LiDAR data available, or if you are using the state-wide 10m DEM file from Cornell.

II. Use the mosaic tool to combine all DEMs

   a. Arctoolbox→ Data Management→ Raster→ Raster Dataset→ Mosaic to New Raster (or search "mosaic to new raster")

      i. (If working with two sets of DEM tiles at different resolutions, first mosaic tiles of the same resolution. Then, resample the lower resolution mosaic to the cell size of the higher resolution mosaic before proceeding).
      ii. Choose all DEM tiles as input rasters
      iii. Select the DEM folder as output location
      iv. Name your new raster as "yourwatershedname_DEM.img"
      v. Check if the Coordinate System of the DEMs are UTM-NAD 83 Zone 18N (or whatever you set in Step 3).
         1. If not, first mosaic to their current coordinate system using the "mosaic to new raster" tool, then using the "project raster" tool, project the mosaiced DEM to "UTM-NAD 83 Zone 18N" (or whatever you set in Step 3).
         2. If so, choose "Projected Coordinate System: UTM-NAD 83 Zone 18N" (or whatever you set in Step 3) as special reference for raster
      vi. Pixel Type: 32 bit float (or check the property of your DEM file)
      vii. Set Number of bands equal to 1
      viii. Hit "ok"

Explanation: This tool aggregates all DEM Lidar tiles into a single tile. For a tutorial on the procedure, see this video: https://www.youtube.com/watch?v=MxoaylTyNKg

Step 7: Burn Streams

I. **Note:** This step is not necessary if working with 1m DEM data.
II. Ensure that the Spatial Analyst extension is activated.
III. Add a layer of national hydrography dataset (NHD) flowlines specific to your state or region, projected to UTM coordinates as assigned in Step 3. *Hereafter called NHDFlowline_p.shp*
   a. The NHD Flowlines can be downloaded from the USGS and then clipped to the extent of your county of interest.
IV. Create a new shapefile for clipping that encompass all the culvert points as well as sufficient additional area to include contributing flowlines. Alternatively, use the county boundaries.

V. Using the Clip (analysis) tool, clip NHDFlowline_p.shp by the clip shapefile (Step 7, III.) to create "flow_clip.shp"

VI. Conversion Tools → To Raster → Feature to Raster to convert the clipped flowline "flow_clip.shp" to raster "flow_ras"

   a. Output cell size should be the same as the DEM. To do this, click on Environments > Output Coordinates. Under the Output Coordinate System drop-down menu, select "Same as Layer 'yourDEM'". Then go to Environments > Processing Extent. Under the Extent drop-down menu, select "Same as layer yourDEM." Under the Snap Raster drop-down menu, also select your DEM file. Save these changes by clicking okay. Your Output cell size should now be set to the same size as your DEM cell size (you can check the DEM cell size by right clicking on the DEM, navigating to Properties > Source, and looking at Cell Size under Raster Information.

VII. Spatial Analyst → Reclass → Reclassify

   a. Set the input raster to flow_ras.
   b. Reclassify the old values of NODATA as new values of 0.
   c. Reclassify all other values as new values of 1.
   d. Save the output raster flow_burn.

VIII. Spatial Analyst → Map Algebra → Raster Calculator

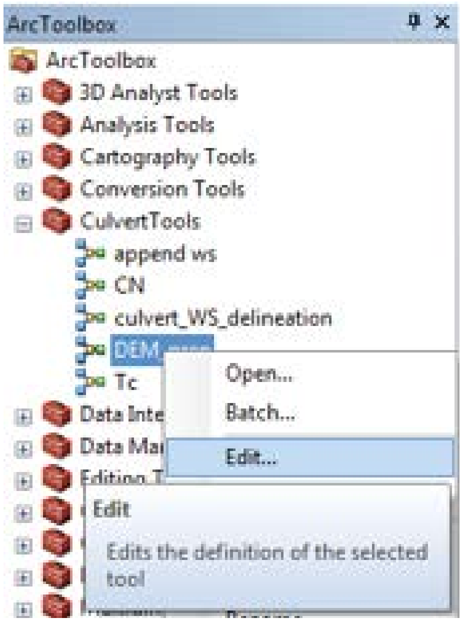
   a. Enter the following expression:
   CON("flow_burn" == 1, "yourwatershedname_DEM", "yourwatershedname_DEM" + maximum elevation of yourwatershedname_DEM).
   b. Save as yourwatershedname_DEMburn

Explanation: "The first step in creating a hydrologically correct DEM is to 'burn streams'. Stream burning ensures that flow is forced to those cells that correspond to the true locations of streams. Stream burning is somewhat of a misnomer since it actually involves raising the elevation of all cells in the DEM that do not fall along the stream network. The general rule for stream burning is that all non-stream cells in the DEM should be raised by an amount greater than the DEM's highest elevation. You will do this by converting the stream vector data to raster then building an equation that raises all cells in the DEM that do not fall along streams by 1300 (the max elevation of the DEM)." (Hydrologic Modeling Using GIS, http://www.oberlin.edu/OCTET/HowTo/GIS/Tutorial/SpatialAnalysist-Hydrology/Hydrologic%20Modeling%20Using%20GIS.doc)

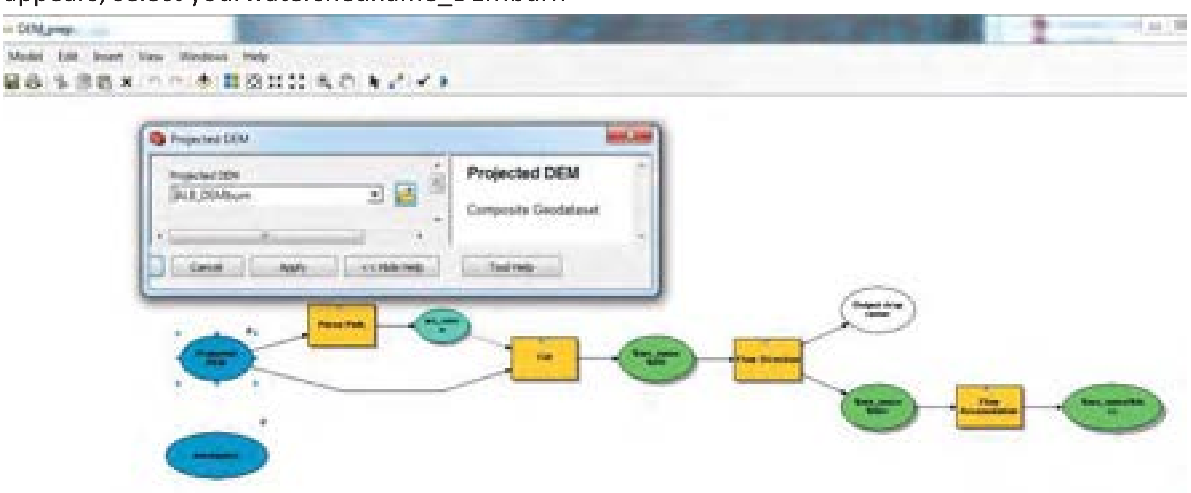
Step 8: Run the DEM_prep tool

I. *Be aware that this tool and others may be small and hard to notice in a corner of your screen when it is first opened.*

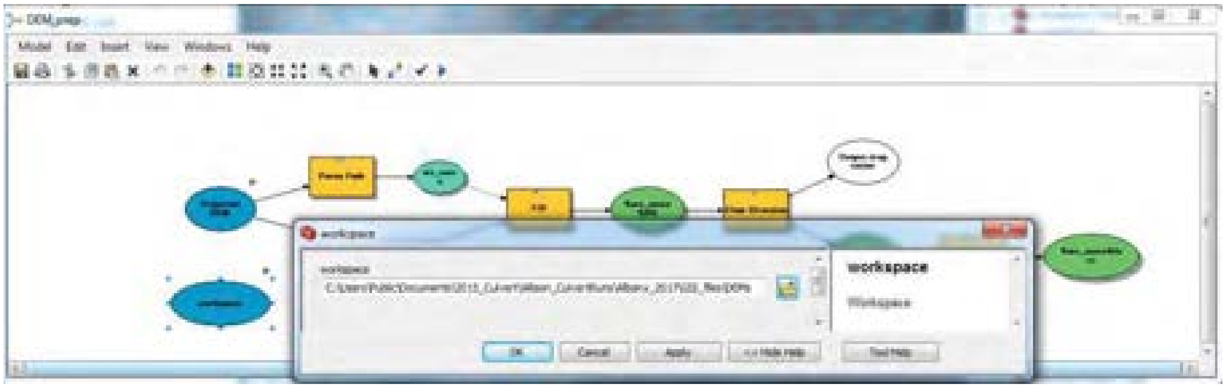
II. In the Culvert_Tools toolbox, right click on DEM_prep and select "edit".



III. Double click on the blue circle that says "Projected DEM." In the drop-down dialogue that appears, select yourwatershedname_DEMburn



IV. Double click on the Blue Circle that says “Workspace”. In the dialogue that appears, navigate to your DEM folder.



V. Hit the check mark to validate that all inputs are in properly 

VI. Run the model by clicking the blue arrow: 

Explanation: This tool will create two new rasters from your mosaiced DEM. First, it will create a flow direction[1] raster, then it will create a flow accumulation[2] raster. These rasters will be used in the delineation of culvert watersheds.

Note: As a quick check for whether the tool is working correctly, the flow direction file it creates should have 8 distinct values (1,2, 4, 8, 16, 32, 64, and 128), which indicate the relative elevation of a given cell to its eight adjacent neighbor cells. Flow travels towards lower cell values.[3]

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[1] http://help.arcgis.com/EN/arcgisdesktop/10.0/help/index.html#//009z00000063000000.htm
[2] http://help.arcgis.com/EN/arcgisdesktop/10.0/help/index.html#/How_Flow_Accumulation_works/009z00000062000000/
[3] http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/flow-direction.htm

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Optional steps: Step 9 and 10

Step 9: Create flow paths from flow accumulation raster (Optional)

I. Use Raster calculator to extract largest flow paths from layer
   a. Arctoolbox→spatial analyst→ map algebra→ raster calculator (or just search "raster calculator")
   b. Enter the equation SetNull("watershedabbreviation_DEMfacc.tif"<5000,1)
      i. Double click on "SetNull" in the conditional box
      ii. Double click on your flow accumulation layer in the layers and variables box to add it into the set_null calculation before the comma
      iii. Set all values of the flow accumulation less than 5000 to be equal to 1
   c. Set your output location and name the new raster
   d. Hit ok

II. Convert your new raster layer into a shapefile using the "raster to polyline" tool
   a. Arctoolbox→conversion tools→ from raster→ raster to polyline (or just search "raster to polyline")
   b. Choose your newly created raster as the input raster
   c. Name the shapefile you will be creating "watershedabbreviation_flowpaths" and save it to a desired location
   d. Hit "ok"

Explanation: This step will create a flow network from the flow accumulation layer. This will give you a rough idea of where the areas of highest flow accumulation are, as predicted by the DEM. This is a useful step for visualizing where GIS will likely delineate the culvert watersheds and assessing the accuracy of culvert GPS points.

Step 10: Asses point locations, move points that seem to be inaccurate to the closest flow paths (Optional)

I. Search through each point to ensure that it accurately reflects the true location of the culvert.

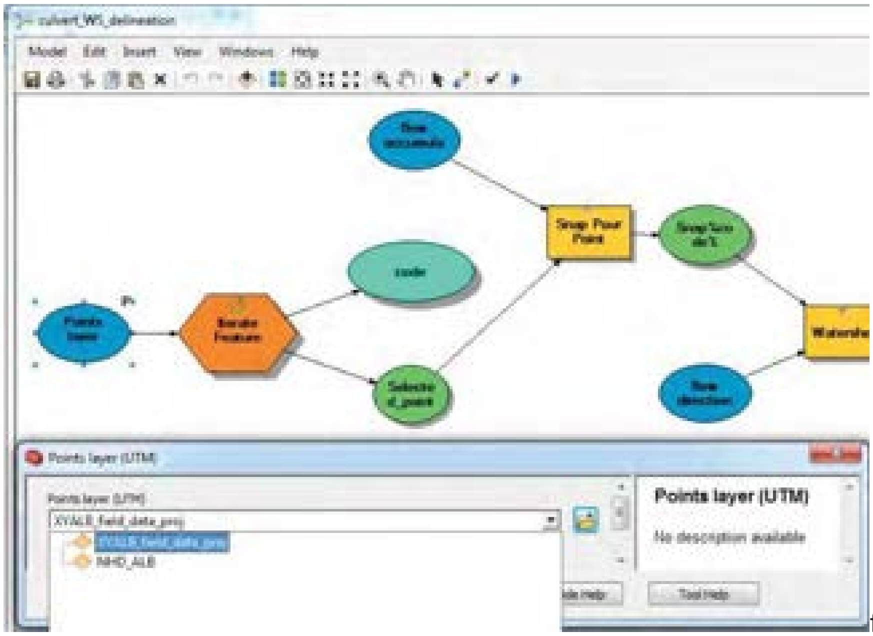
II. To move a culvert (see note), right click on the culvert point layer, and select "Edit Layer"
   a. Document which culverts have been moved manually

Note: The Satellite Imagery basemap is helpful for this step. Be very careful here, unless the proper location is obvious and a clear GPS error is apparent, do not manually manipulate the culvert's location. Many culverts are not on major waterways and the resolution of the DEM can influence flow accumulation lines (visualized in Step 8).

Step 11: Culvert Watershed Delineation

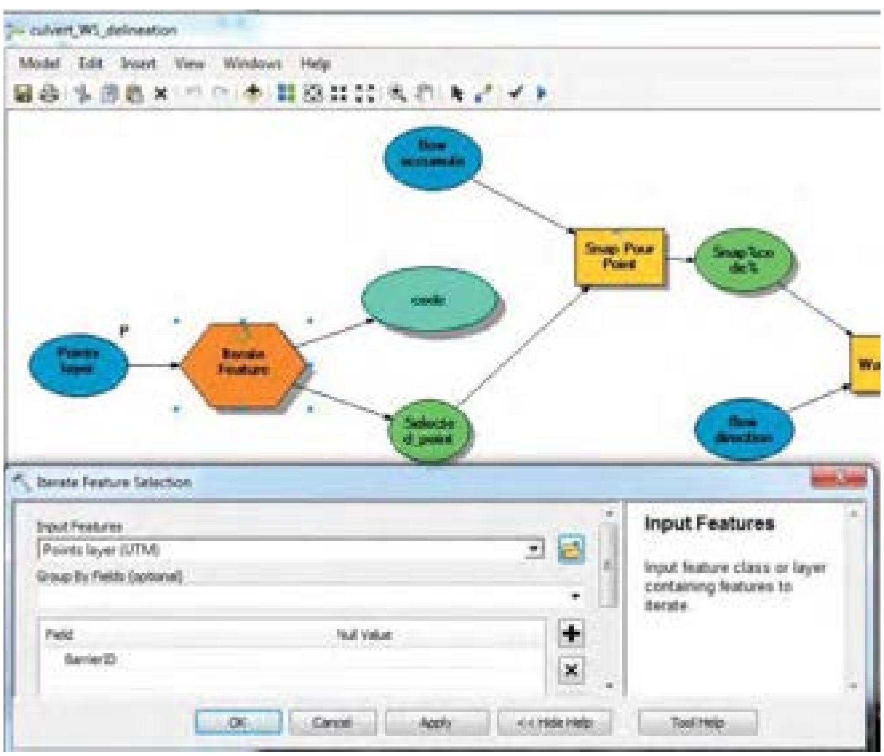
I. In the Culvert Toolbox, <u>right click</u> on the Culvert_ws_delineation tool and select "edit"

II. <u>Double click</u> on the blue circle furthest to the left, and select your projected culverts point layer

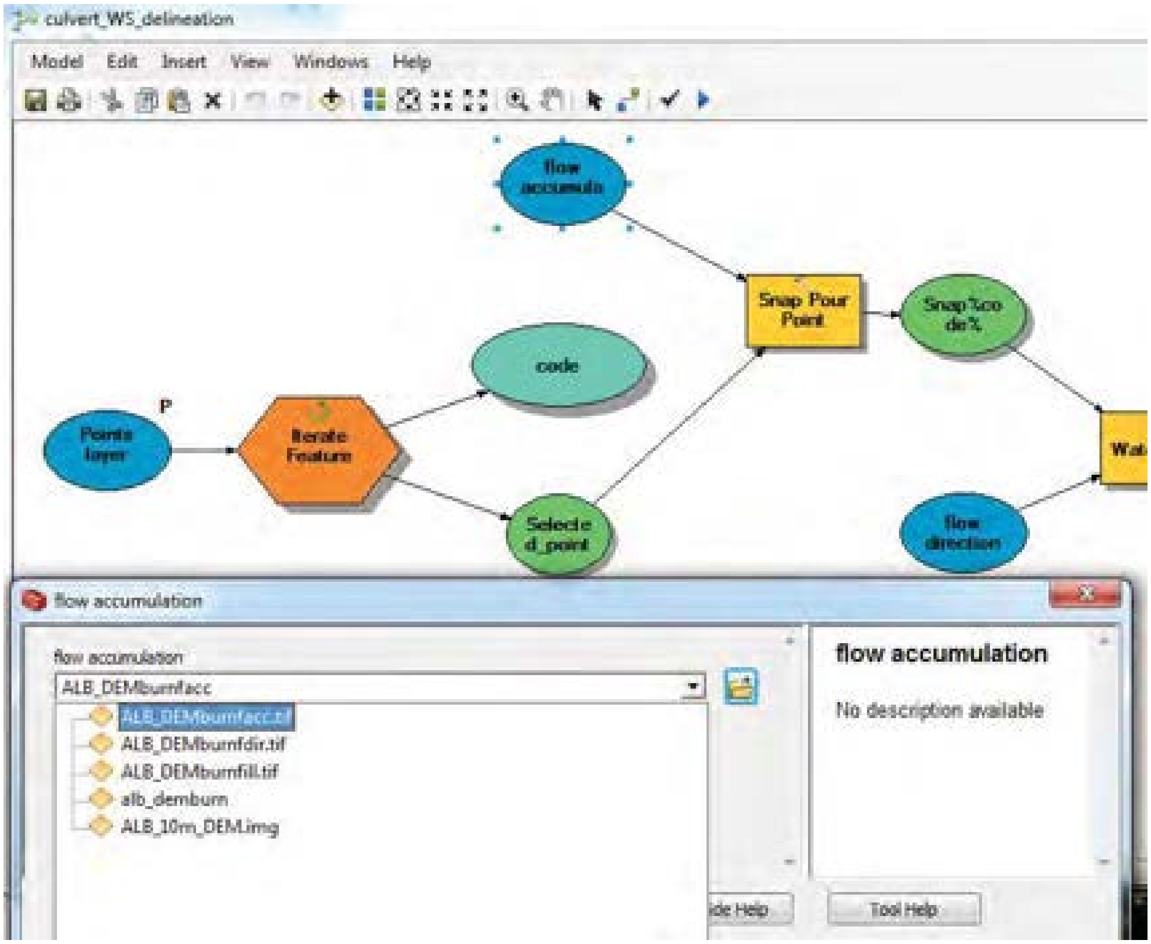


flow l

III. <u>Double click</u> on the Iterate Feature selection. Input Features = Points Layer UTM. Field = BarrierID.



IV. Double click on the flow accumulation bubble. Select your flow accumulation raster.



V. Double click on the snap pour point rectangle.

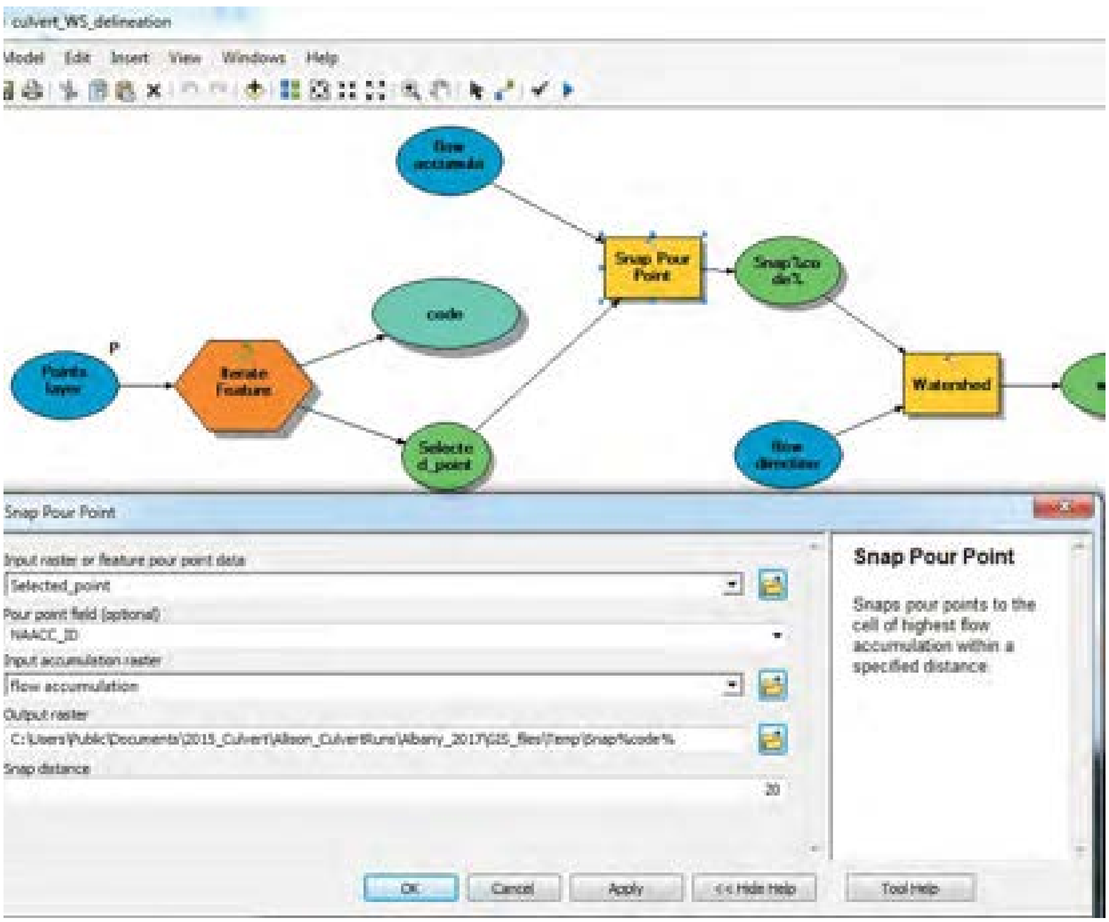
a. Input raster or feature pour point data = Selected_point

b. Ensure that the pour point field exists for the layer (e.g. FID or NAACC_ID)

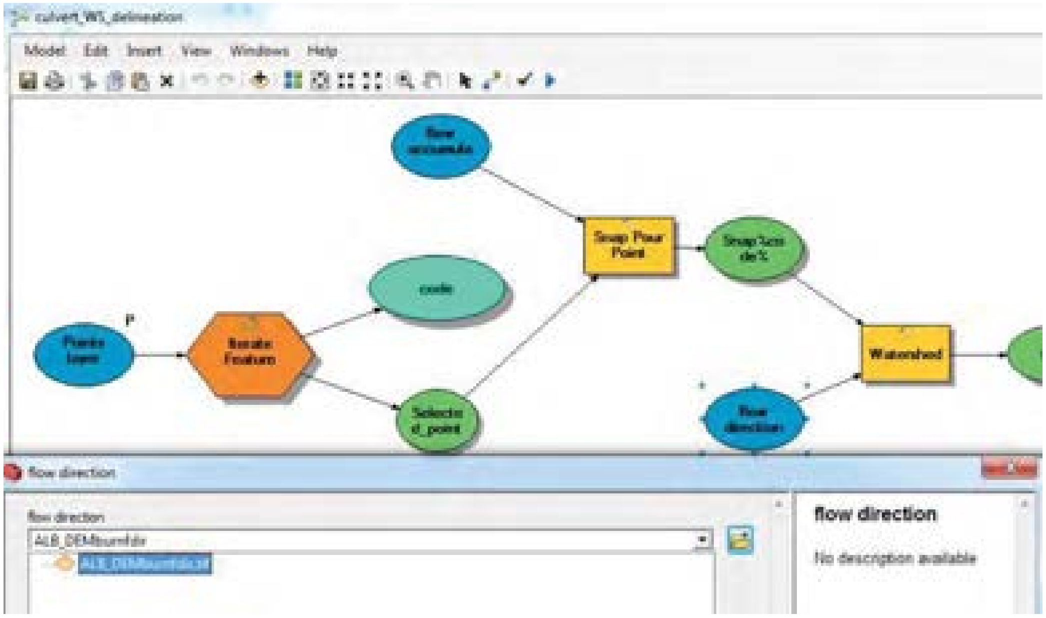
c. Input accumulation raster = flow accumulation

d. Ensure the "output raster" file path exists in your system. Keep Snap%code% as the file name.

e. Ensure that the snap distance at the bottom is set to 20 m (or desired snap distance).

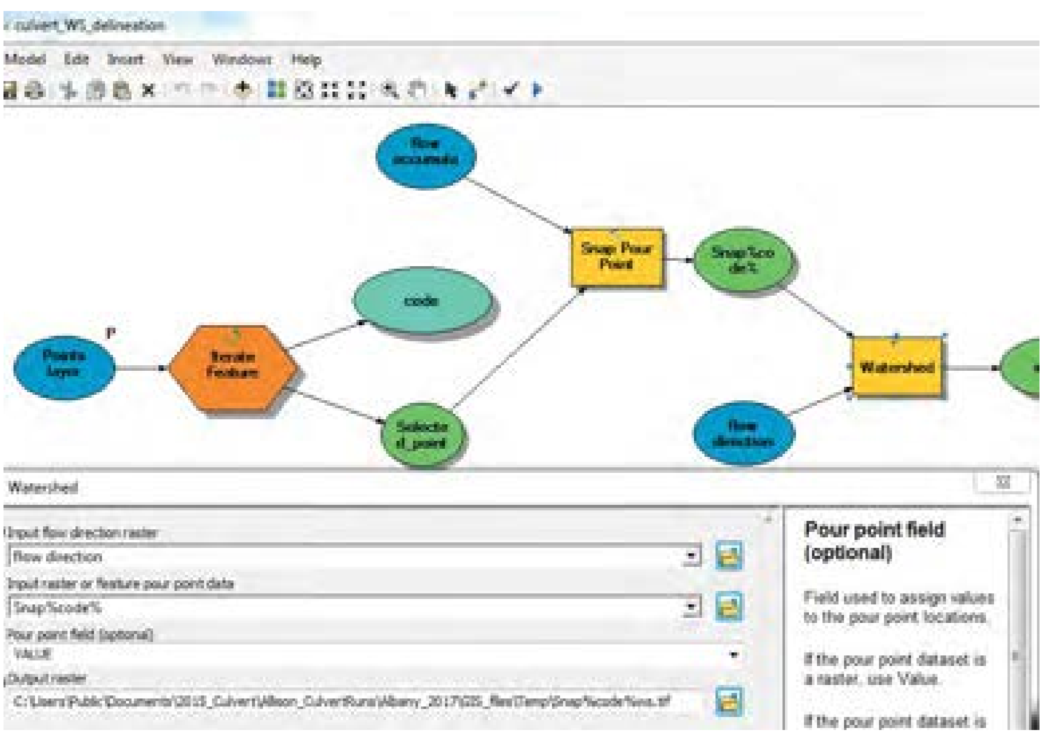


VI. <u>Double click</u> on the flow direction bubble and select your flow direction raster



VII. Double click on the yellow Watershed square.

a. Input flow direction raster = flow direction
b. Input raster or feature pour point data = Snap%code%
c. Pour point field (optional) = VALUE
d. Ensure the output raster path <u>exists in your system</u>, keeping the default file name (Snap%code%ws.tif)



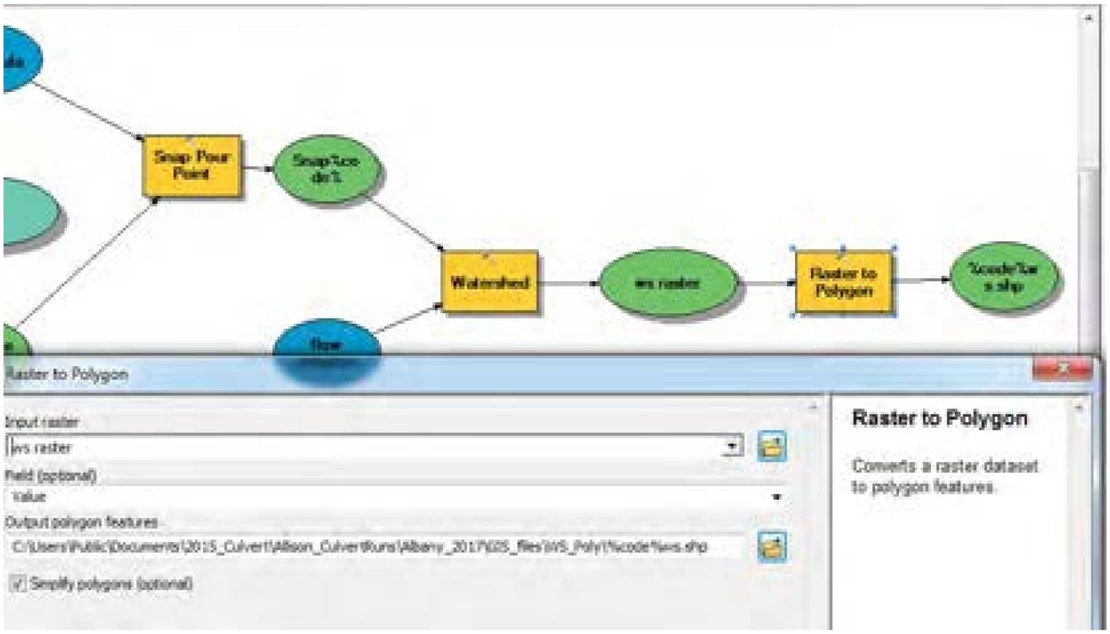
VIII. Ensure you have an empty folder named WS_Poly in your working directory (see Step 3.I.)

IX. <u>Double click</u> on the Raster to Polygon yellow rectangle

a. Input raster = ws raster

b. Field (optional) = Value

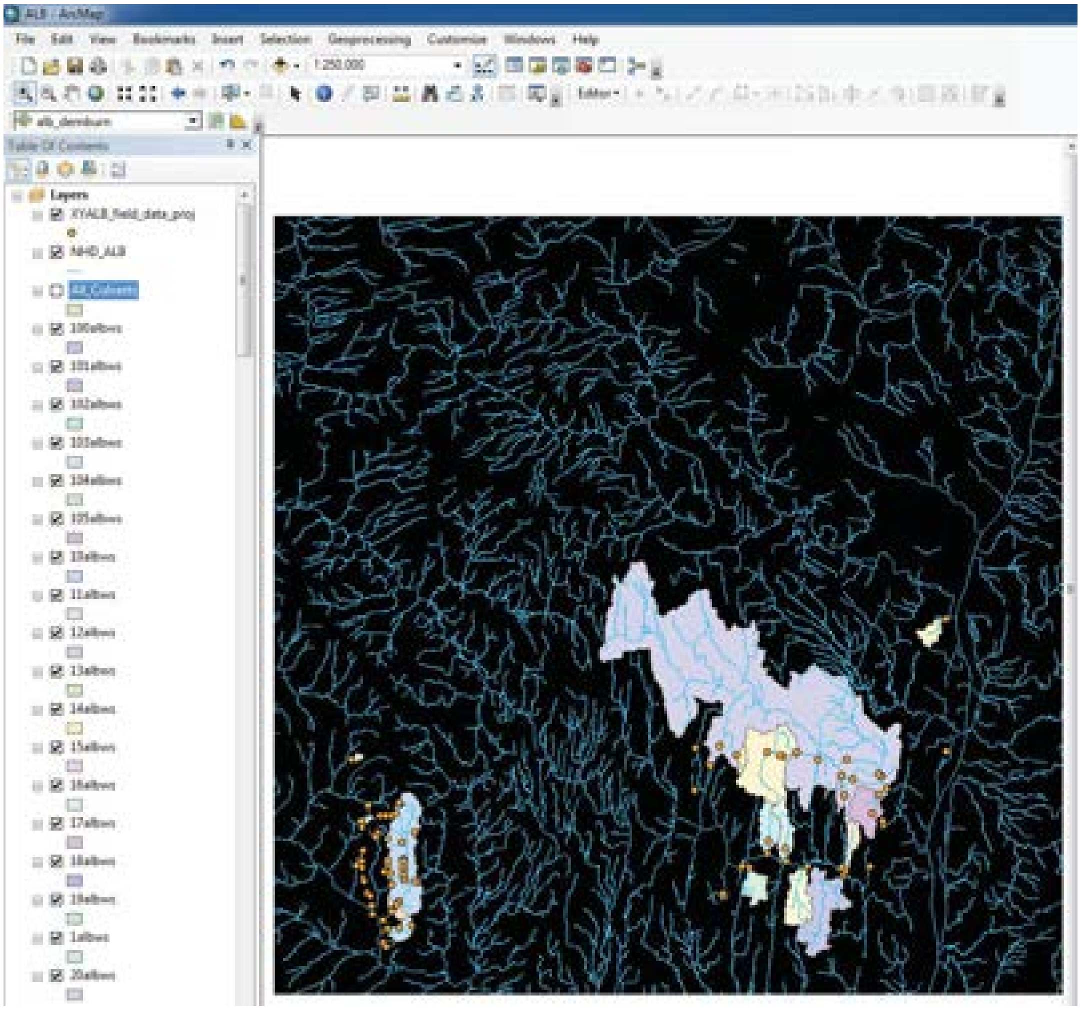
c. Output polygon features = Navigate to your WS_Poly folder and then add %code%ws.shp



X. Hit the check mark to validate that all inputs are entered properly: 

XI. Run the model by clicking the blue arrow: 

XII. Your map should looking something like the below picture after the tool finishes. Note that it is common for 1/3 to ½ of culverts to have a very small delineated watershed area (< 1 ha). This is something that we are actively working on fixing in the model. These small watersheds will not be processed in later steps of the model.



Explanation: This tool will delineate the watershed[4] of each culvert using the flow direction and flow accumulation rasters. Each culvert's watershed will save to the WS_Poly folder and will take the same name as its culvert point.

[4] https://developers.arcgis.com/rest/elevation/api-reference/watershed.htm

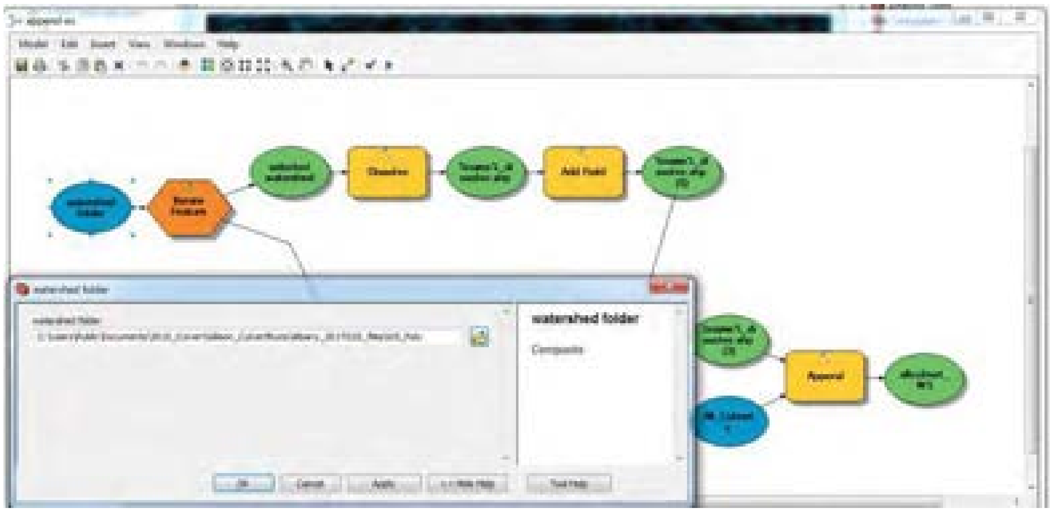
Step 11: Append WS

I. Copy the All_Culverts shapefile from Model Start Kit to your working directory

  a. Ensure its attribute table is empty by right clicking on the layer in the Table of Contents and selecting “open attribute table”

II. In the Culvert Toolbox, <u>right click</u> on the append_ws tool and select “edit”

III. <u>Double click</u> on the blue ellipse that says “watershed folder” and select your WS_Poly folder

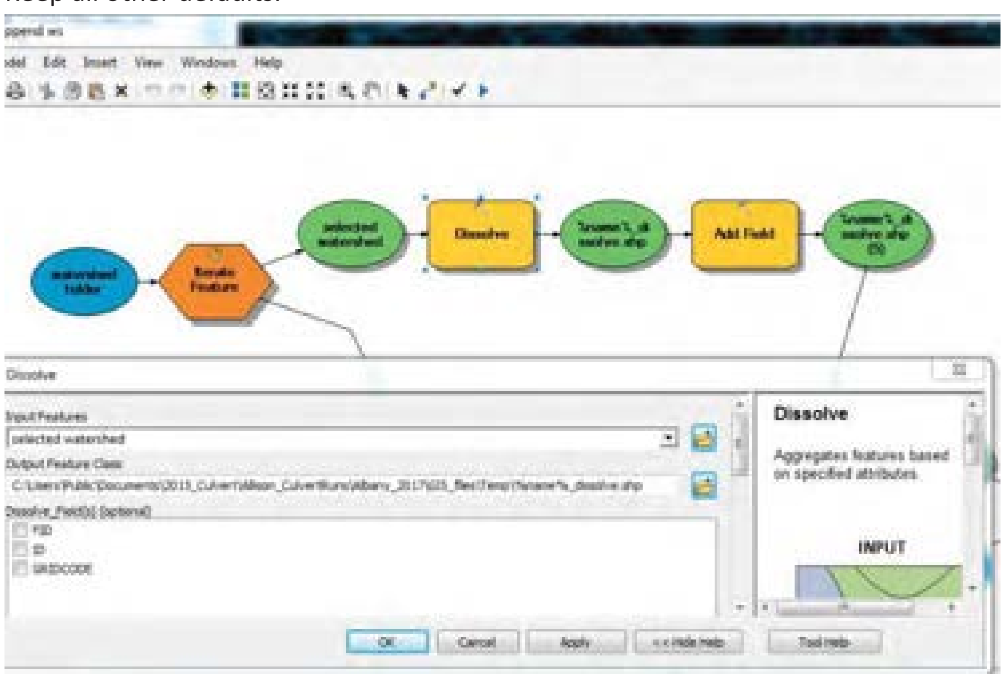


IV. <u>Double click</u> on the yellow rectangle that says “Dissolve.”

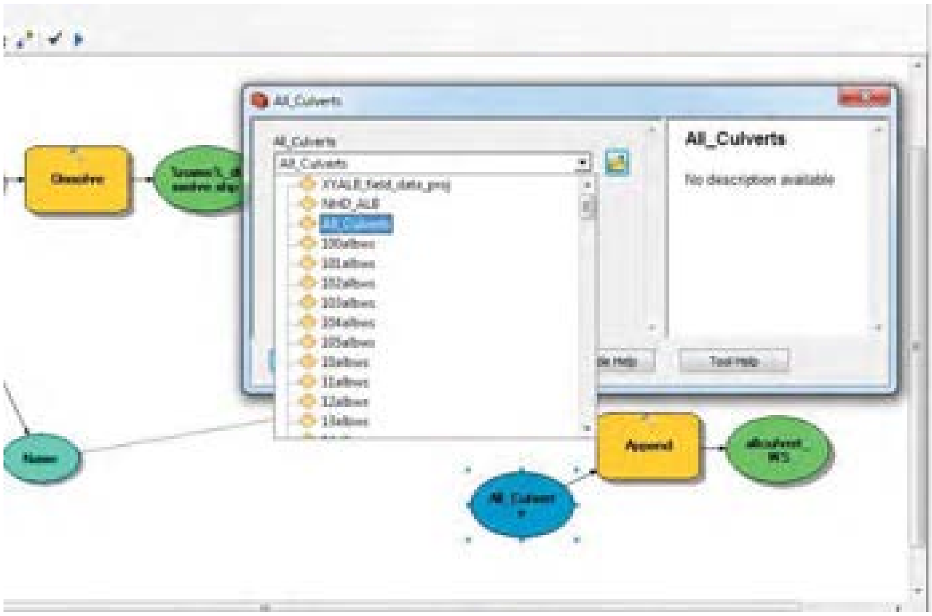
  a. Input features = selected watershed

  b. For the Output Feature Class, verify that the Temp path is correct for your system. Keep the file name %name%dissolve.shp

  c. Keep all other defaults.



V. Double click on the blue ellipse on the right hand side of the model that says “All_Culverts.” Select the All_Culverts shapefile.



VI. Validate and run append ws. 

VII. Your map should look just like your delineated culvert watershed map, but all the watersheds will be the same color.

Explanation: The append_ws tool amalgamates all the culvert watersheds into a single shapefile. Each individual watershed then becomes an attribute in this new “All_Culverts” shapefile.

Step 12: Prepare the All_Culverts shapefile for export

I. Add empty columns to the All_Culverts file for Area, Time of Concentration and Curve Number
   a. In the table of contents, right click on the All_Culverts and select “open attribute table”
   b. Click on the drop down in the top left corner of the attribute table and select “Add Field”
      i. Title the new field “Area_sqkm” and select “float” as the type. Leave the defaults for precision and scale.
   c. Add another field titled “Tc_hr” with type “float”
   d. Add a third field titled “CN” with type “float”
   e. Right click on the heading of the Area_sqkm field and select “Calculate Geometry” and hit “yes” when the dialogue box pops up
      i. Ensure that “area” is listed in the property field
      ii. Select square kilometers for the units
      iii. Hit “ok”

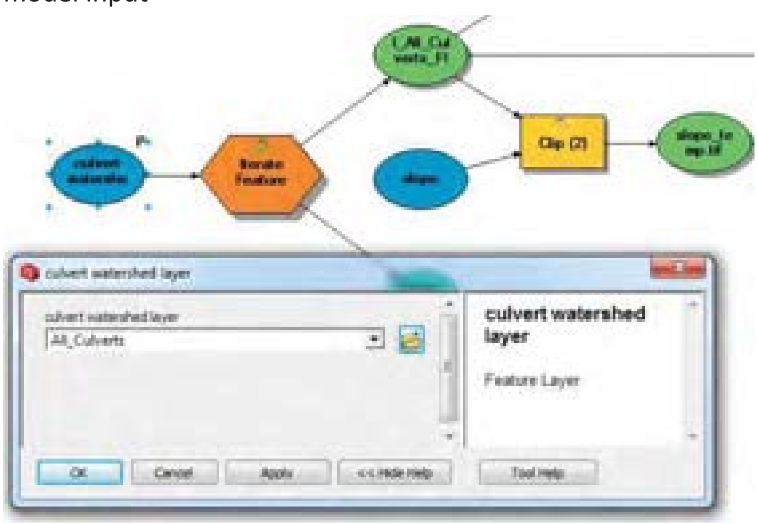
Explanation: In this step we are setting up our watershed data file to be exported. In order to calculate the peak discharge, we will need the area, time of concentration (Tc) and Curve Number (CN) for each culvert watershed. The area is calculated in this step. Tc and CN will be calculated in the next two steps. The python code to be run later on relies on column order to track inputs, so following the order above when you add fields is important.

Step 13: Calculate the T_c for each culvert watershed

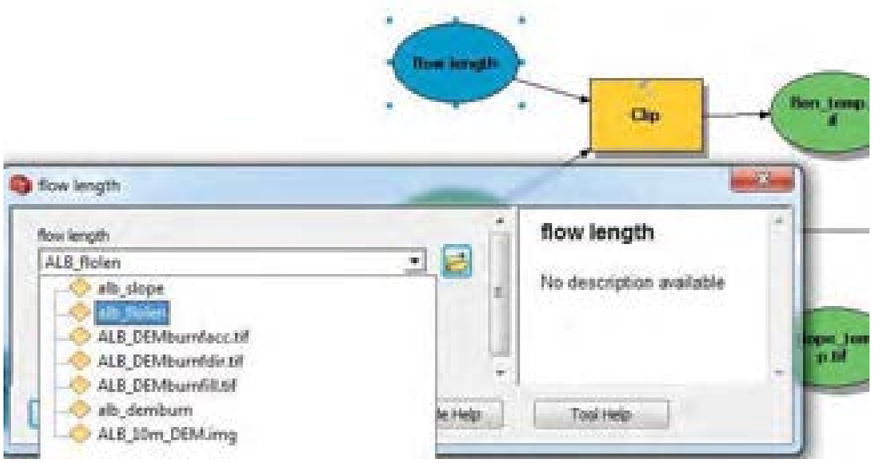
I. Calculate the watershed slope using the Slope tool
   a. Create a filled version of the NYS DEM (or clipped county DEM). Use the Fill tool under Spatial Analyst.
   b. Arctoolbox→ Spacial Analyst→Surface→Slope
   c. Select the filled DEM you just created. NOT the filled *burned* DEM created in Step 7.
   d. Select percent rise for type
   e. Save the new raster to your DEM folder

II. Calculate the watershed flow lengths (For a county, on the new computer, this step takes about 5 min)
   a. Arctoolbox→ Spacial Analyst→Hydrology→Flow length
   b. Select the flow direction. This can be the burned flow direction raster from Step 7.
   c. Ensure that method is set to "UPSTREAM"
   d. Save the new raster to your DEM folder

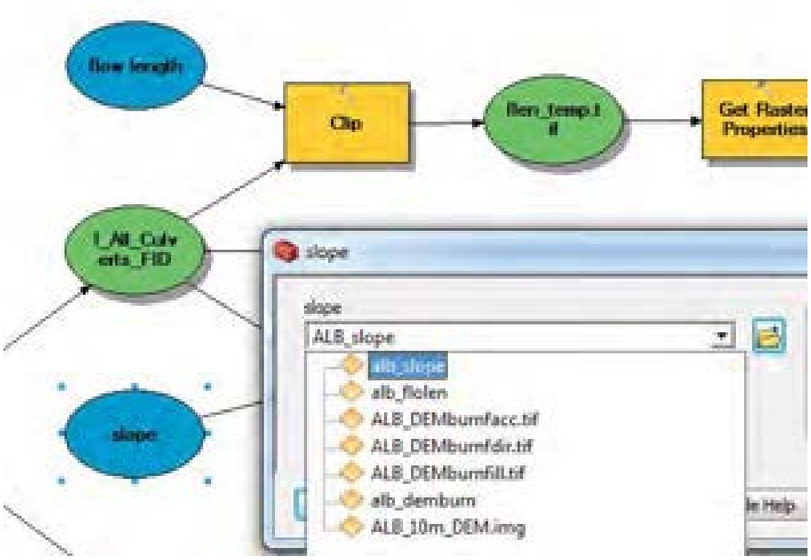
III. In the Culvert Toolbox, <u>right click</u> on the T_c tool and select "edit"
   a. <u>Double click</u> on the blue ellipse furthest to the left and select the "All_Culverts" file as model input



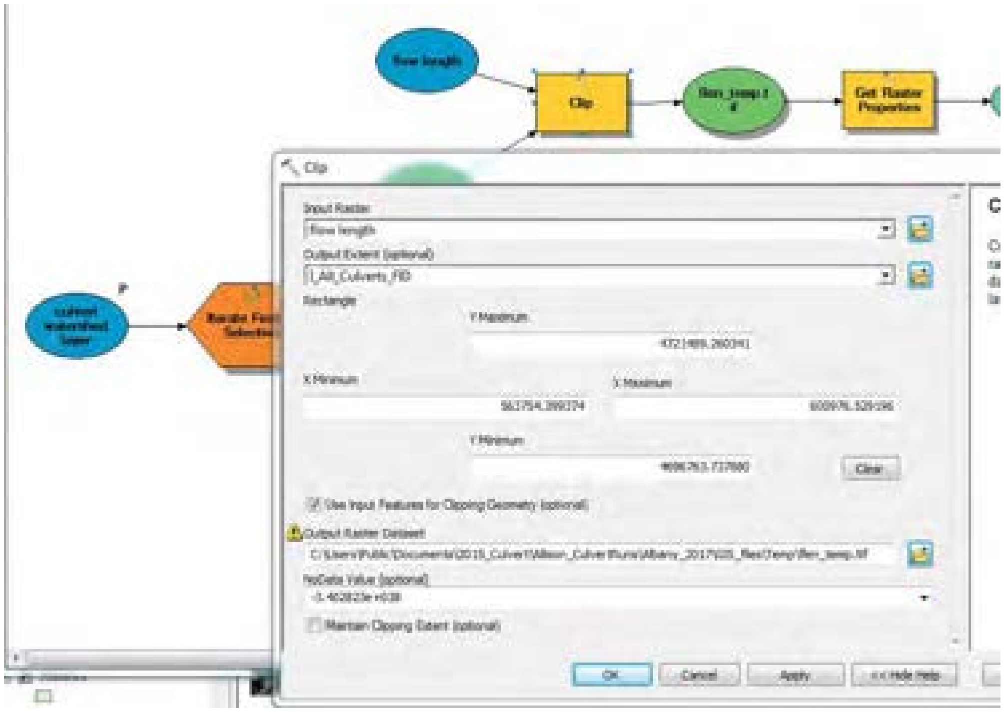
b. Double click on the flow length ellipse and select the newly created flow length raster



c. Double click on the slope ellipse and select the newly created slope raster



d. Double click on both yellow Clip squares and ensure the path to your Temp folder is correct. Keep the default file name (flen_temp.tif for the flow length clip, and slope_temp.tif for the slope clip).



IV. Validate and run the model . No new files will be created. The Tc field in All_Culverts will be filled in.

Explanation: This tool uses the Kripitch equation to calculate time of concentration for each culvert watershed. The slope of each watershed is taken by clipping the slope raster for the entire watershed to the boundaries of each culvert watershed, then calculating the average slope for each watershed. The flow length is taken by clipping the flow length raster of the entire watershed to each culvert watershed and selecting the longest flow path inside each culvert watershed.

Step 14: Calculate the weighted CN for each culvert watershed

I. Add a raster of curve numbers for your area of interest to the table of contents
   a. A curve number raster has been created for NY by Rebecca Marjerison for use in this model. It is based on 2006 landuse and 2010 soils data from New York State. It is available from the Cornell Soil and Water Lab.

II. Project Curve Number raster (Project Raster (Data Management)) to your UTM coordinate system from Step 3 (NAD_1983_UTM_Zone_18N for Eastern NY)
   a. Save as "CN_UTM.tif"

III. Clip(Data Management) “CN_UTM.tif” by “All_culverts” to get “CN_UTMclip”

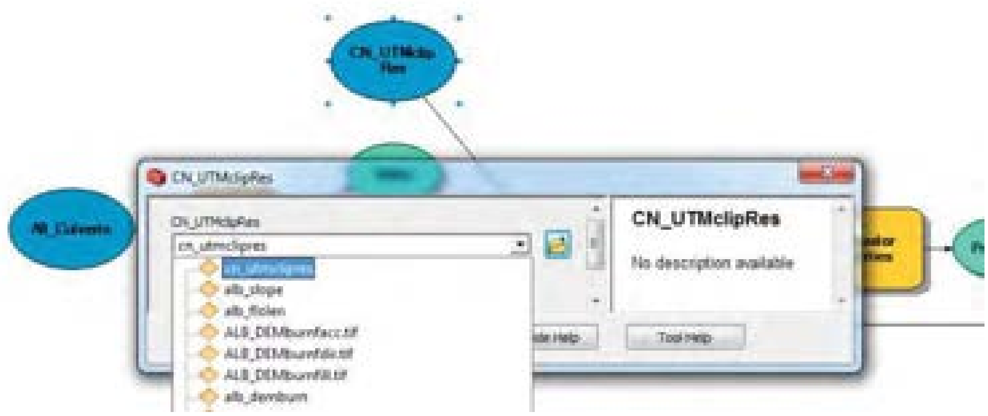
a. Check “Use Input Features for Clipping Geometry”

IV. Resample (Tools/Data Management Tools/Raster/Raster Processing/Resample) “CN_UTMclip” to the size of the DEM

V. In the Culvert Toolbox, <u>right click</u> on the CN tool and select “edit”

a. <u>Double click</u> on the blue ellipse farthest to the left and select the “All_culverts” layer

b. <u>Double click</u> on the blue ellipse that has an arrow going to the yellow “clip” ellipse and select the resampled CN_UTMclip.tif as the input file

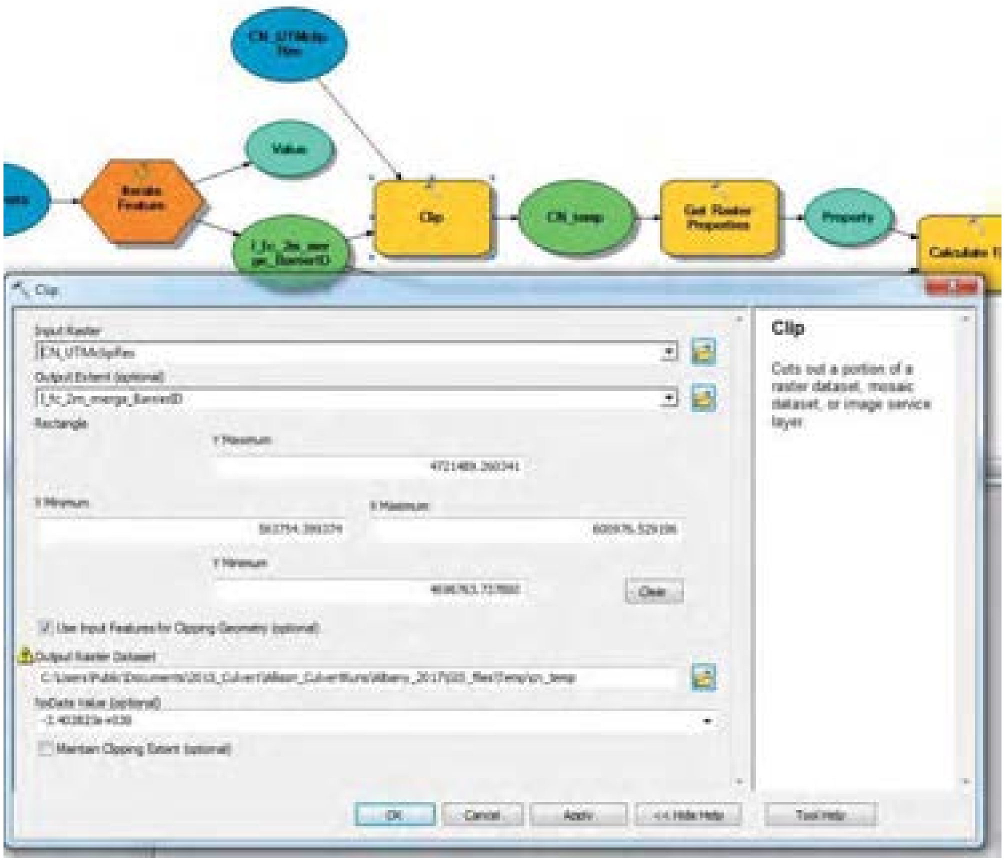


c. <u>Double click</u> on the yellow rectangle labeled “Clip”

   a. Input raster = CN_UTMclipRes (the resampled CN raster)

   b. Output extent = l_fc_2m_merge_BarrierID

   c. Ensure the Output Raster Dataset path exists in your system. Keep the default file name (cn_temp)



d. Verify and run the model *(If error results, see note below)*

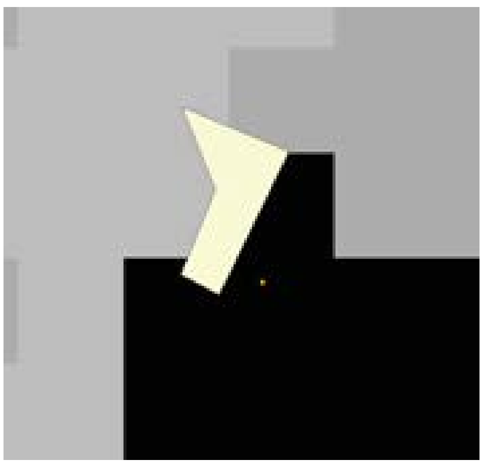
e. Ensure that the temporary files are being saved to a proper location on your machine

Explanation: The NY_Curve_Number.tif file is a raster image created by Rebecca Marjerison that combines 2006 landuse and 2010 soils data from New York State into a single Curve Number raster file. Each pixel value in the raster represents a curve number, the CN tool clips the raster to each individual culvert watershed and then finds a weighted average of the curve number of that watershed and adds it to the attribute table.

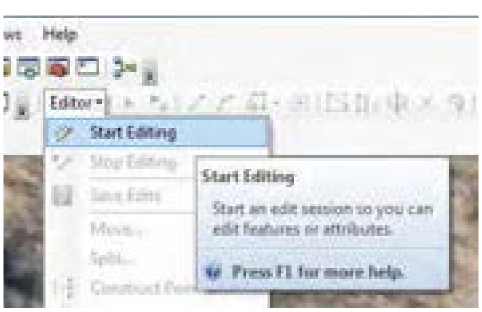
Note: This step has trouble on small watersheds. Occasionally, in the middle of a run, the script will stop, with an error message. If this happens, exit the model, open the attribute table of the All_Culverts layer and, skipping the entry with the area that was too small, select all of the remaining culverts that haven’t been analyzed. Do this each time the script has an error. If possible, next, go back through the layer at the end, zoom to each culvert that wasn’t analyzed and use the “identify” cursor to determine the value of the CN raster beneath the culvert watershed:

1. Example culvert watershed that could not be analyzed using the CN tool:

2. Turn back on the statewide CN raster:



3. Use the identify cursor  to determine the CN value(s) under the watershed, and estimate an average.
4. Right click on the All_Culverts shapefile and open the attribute table.
5. Start an editing session, and change the value of the CN field for the watershed to the estimated average.



Step 15: Export watershed data from ArcGIS

I. Export data as text file from ArcGIS
  a. Right click on the All_culverts shapefile and select "open attribute table"
  b. In the Table Options drop down in the top left corner of the attribute table, selected "Export"
  c. Ensure that the Export is set to "all data"
  d. Save the script as a .txt file into the "Scripts" folder

II. Open the text file in Excel
  a. First open excel, then load the file, ensuring that "all files" is selected in the "open" window
  b. Once opened, a Text Import Wizard should open automatically in Excel.
    i. In step one of the Text Import Wizard dialogue box, ensure that the bubble for "Delimited" is selected as the file type
    ii. Hit "Next"
    iii. In step two of the Text Import Wizard dialogue box, select "Comma" as the delimiter and ensure that no other boxes are selected.
    iv. Hit "finish"

III. Save the file in yourwatershedname subfolder within the "Scripts" folder as a .csv

Explanation: Once all of the relevant data has been added to the All_Culverts attribute table, it is ready to be exported for use in the Cornell Culverts Evaluation Python script. This script will use this data in conjunction with NRCC precipitation data (downloaded in the next step) to determine the peak discharge from various storm events for each culvert. In order for the data to be accepted by Python, it must be saved in CSV format in the same folder as the Python script.

Step 16: Download NRCC precipitation data

I. Go to: http://precip.eas.cornell.edu/

II. Select the "Data and Products" tab

III. In the "Select Product" column on the left hand side, select "Extreme Precipitation Tables- Text/CSV"

IV. Type the name of the county that contains the study watershed.

V. Click the "Submit" Box in the center of the screen below the map, a text file called "output" will then download automatically

VI. Follow the procedure in step 15.II to open and save the output text file in excel as a CSV file.

Explanation: The North Eastern Regional Climate Center (NRCC) provides estimates of the precipitation values for a range of return period storms of varying durations. This step locates the data for the study watershed and exports it to a .csv file that will be used in the peak discharge calculations in the next step.

Part 3: Use the python script to compute the peak discharge, capacity and max return periods

Step 17: Run Cornell_Culverts_Evaluation python script

I. Ensure that the "data" folder within yourwatershedname subfolder contains the exported data from the GIS in step 15, the precipitation CSV file exported from NRCC in step 16 and the exacted culvert data file from step 2.

II. Open "county_list.csv", located within the "Scripts" folder, and include the names of all input files, ensuring ".csv" follows each file name you enter.
   a. Help with this and instructions on using the code is available in the "README.txt" found within the "Scripts" folder.

III. Right click on the Cornell_Culverts_Evaluation.py file in your "scripts" folder
   i. Select "Edit with IDLE"
   ii. Once the script is open, hit F5 (This will open the python shell)

IV. Follow the script's instructions, entering "county_list.csv" when prompted.

This script will perform the following operations:

1. Calculate peak discharge for both current and future storm events. Events evaluated include the 1, 2, 5, 10, 25, 50, 200 and 500 year storms.
2. Calculate the cross sectional area of each culvert and assign each culvert minor loss coefficients based on culvert material and geometry.
3. Calculate the capacity of each culvert
4. Compare the capacity and peak discharges for each culvert and assign each culvert a maximum return period storm that it can safely pass
5. Summarize the data output in a single .csv file titled "model_output"

Script inputs:

1. Watershed data CSV file (final output from steps 2-15)
2. Field data collection file (product of the extraction in step 2)
3. Precipitation file (product of step 16)

Script Outputs (same as model outputs!):

1. culv_geometry: a csv file containing the areas of each culvert and assigned coefficients used in the capacity calculations
2. capacity_output: a CSV file containing the maximum capacity of each culvert before the headwater overtops the road surface
3. current_runoff: a CSV file containing the calculated runoff of each culvert watershed under the 1, 2, 5, 10, 25, 50, 100, 200 and 500 year storm events with current precipitation data
4. future_runoff: a CSV file containing the calculated runoff of each culvert watershed under the 1, 2, 5, 10, 25, 50, 100, 200 and 500 year storm events with projected 2050 precipitation data

5. return_periods: a CSV file containing the maximum return period storm that each culvert can safely pass for the current and projected 2050 precipitation data.
6. model_output: a CSV file containing a summary of the above 5 outputs. The file contains the maximum return period that each culvert can safely pass, the capacity of each culvert and information about culvert geometry. This file can be viewed as the final output of this model.

Explanation: The Cornell_Culvert_Evaluation script does not actually perform any calculations by itself; instead, it serves as a command center to call on various functions that each performs a certain task.

Optional Step 18: Use R script to append Survey_ID numbers

1. This step was created to append Survey_ID numbers onto the model_output file created by the Cornell_Culvert_Evaluation python script. It requires the R script survey_id_v2.R, available from Allison Truhlar.
2. The R script requires the yourwatershedname.csv file, yourwatershedname_field_data.csv, yourwatershedname_not_extracted.csv, yourwatershedname_export.csv, and yourwatershedname_model_output.csv.

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