City of South Burlington Comprehensive Culvert Assessment Final Report

South Burlington, VT

CVT0737 (Marshall Avenue)

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1.0 Introduction and Background

Under a task order with the Chittenden County Regional Planning Commission (CCRPC), Fitzgerald Environmental Associates (FEA) has been contracted to conduct a comprehensive assessment of 150 mapped conveyance culverts within the City of South Burlington. We identified 28 culverts during our desktop and field assessments that were not included in the comprehensive assessment. See **Appendix A** for a summary of unassessed culverts. The following report and appendices detail the assessment.

The goal of this project is to conduct a comprehensive city-wide culvert assessment and replacement prioritization for conveyance culverts within the City of South Burlington. This project builds off previous assessments conducted of culverts in the Bartlett Brook (FEA, 2009) and Potash Brook (FEA, 2011) watersheds. These previous assessments did not include all culverts within CSB and are over a decade old. Given the statewide impacts of recent large flooding events and the fact that these events will happen more frequently because of climate change, it is critical to conduct an updated assessment to allow CSB to address problematic culverts before they cause significant issues.

For this assessment, FEA performed the following tasks:

- Buildout Analysis
- Field Assessment
    - Culvert Condition
    - Geomorphic Compatibility and Aquatic Organism Passage Scoring
    - Hydraulic Modeling Data
- Hydrologic Modeling
- Existing Condition Hydraulic Modeling
- Culvert Prioritization
- Proposed Condition Hydraulic Modeling and Conceptual Designs for Select High-Priority Culverts

The prioritized list of culverts to be replaced can be used by CSB to efficiently implement culvert upgrades. These culvert upgrades will not only improve public safety, by allowing for safe travel during flooding events and reducing the risk of catastrophic culvert failure but also improve aquatic habitat along streams within CSB. A summary of assessed culverts can be found in **Table 1**.

Table 1: Summary of Assessed Culverts

Structure ID	Location	Structure Ownership	Stream Name
A	Parallel to Railroad	Railway	Potash Brook
B	Railroad	Railway	Potash Brook
CVT	East of Kennedy Drive	Private	n/a (Drainage)
CVT0001	Kennedy Drive	South Burlington	Tributary to Potash Brook
CVT0002	Kennedy Drive	South Burlington	Centennial Brook
CVT0003	Ethan Allen Drive	South Burlington	n/a (Drainage)
CVT0004	Hinesburg Road	VTRANS	Tributary to Lake Champlain
CVT0005	South Burlington Recreation Path	South Burlington	Tributary to Lake Champlain
CVT0008	Farm Access Road	Private	Potash Brook
CVT0009	Hinesburg Road	VTRANS	Potash Brook
CVT0010	End of Oak Hill Drive	Private	Potash Brook
CVT0013	Railroad	Railway	Tributary to Winooski River
CVT0021	Harbor View Road	South Burlington	Potash Brook
CVT0572A	Shelburne Road	VTRANS	Potash Brook Tributary 2
CVT0572B	Shelburne Road	VTRANS	Potash Brook Tributary 2
CVT0589	Trail	Private	Tributary to Potash Brook
CVT0599	Trail	Tributary to Potash Brook Tributary 1	Potash Brook Sub-Tributary
CVT0600	Railroad	Bartlett Brook	Bartlett Brook
CVT0607	Harbor View Road	Bartlett Brook Tributary 1	Bartlett Brook Tributary 1
CVT0609	Shelburne Road	Bartlett Brook Tributary 1	Bartlett Brook Tributary 1
CVT0619	Shelburne Road	Bartlett Brook	Bartlett Brook
CVT0622	Trail	Bartlett Brook	Bartlett Brook
CVT0623	UVM Hort Farm	Private	Bartlett Brook
CVT0632	UVM Hort Farm	Private	Tributary to Bartlett Brook
CVT0634	Chittenden Regional Correctional Facility	Private	Potash Brook Tributary 2
CVT0647	UVM Miller Farm	Private	Potash Brook Tributary 3
CVT0653	Patchen Road	South Burlington	Centennial Brook
CVT0656	Airport Parkway	South Burlington	Centennial Brook
CVT0664	Hinesburg Road	VTRANS	Muddy Brook
CVT0677	Hinesburg Road	VTRANS	Tributary to Muddy Brook
CVT0678	Midland Avenue	South Burlington	Tributary to Muddy Brook
CVT0679	Midland Avenue	South Burlington	Tributary to Muddy Brook
CVT0680	Midland Avenue	South Burlington	Tributary to Muddy Brook
CVT0712	Dorset Street	South Burlington	Muddy Brook
CVT0724	Hinesburg Road	VTRANS	n/a (Drainage)
CVT0725	Van Sicklen Road	South Burlington	n/a (Drainage)
CVT0729	Nowland Farm Road	South Burlington	Muddy Brook
CVT0731	Nowland Farm Road	South Burlington	Tributary to Muddy Brook
CVT0735	Interstate 89	VTRANS	Tributary to Muddy Brook
CVT0735B	Interstate 89	VTRANS	Muddy Brook
CVT0737	Marshall Avenue	South Burlington	Muddy Brook
CVT0738	Williston Road	VTRANS	Muddy Brook
CVT0739	National Guard Avenue	South Burlington	Muddy Brook
CVT0740	River Cove Road	South Burlington	Muddy Brook
CVT0758	Bartlett Bay Road	South Burlington	Tributary to Lake Champlain
CVT0768	Fayette Road	South Burlington	Tributary to Lake Champlain
CVT0769	National Guard Avenue	South Burlington	Tributary to Muddy Brook
CVT0779	Butler Drive	South Burlington	Potash Brook Tributary 7
CVT0780	Butler Drive	South Burlington	Potash Brook Tributary 7
CVT0781	Butler Drive	South Burlington	Potash Brook Tributary 7
CVT0782	Butler Drive	South Burlington	Potash Brook Tributary 7
CVT0798	Moss Glen Lane	South Burlington	Potash Brook Tributary 7
CVT0799	Stonehedge Drive	South Burlington	n/a (Drainage)
CVT0800	Meadowland Drive	Private	n/a (Drainage)
CVT0802	Moss Glen Lane	South Burlington	Potash Brook Tributary 7
CVT0811	Park Road	South Burlington	Potash Brook Sub-Tributary
CVT0813	Meadowland Drive	Private	Tributary to Potash Brook
CVT0814	South Burlington Recreation Path	South Burlington	Potash Brook Sub-Tributary
CVT0821	Brewer Parkway	South Burlington	Potash Brook Sub-Tributary
CVT0829	Farrell Street Park Path	South Burlington	Potash Brook Tributary 2
CVT0835	Swift Street	South Burlington	Potash Brook Tributary 2
CVT0837	Queen City Park Road	South Burlington	Potash Brook
CVT0838	Farrell Street	South Burlington	Potash Brook
CVT0841	Interstate 189	VTRANS	Potash Brook
CVT0847	Interstate 89	VTRANS	Potash Brook Tributary 7
CVT0848	Interstate 89	VTRANS	Potash Brook Tributary 7

Structure ID	Location	Structure Ownership	Stream Name
CVT0849	Interstate 189	VTRANS	Potash Brook Tributary 3
CVT0852	Interstate 189	VTRANS	Potash Brook
CVT0856	Dorset Street	South Burlington	Potash Brook Tributary 7
CVT0857	Interstate 89	VTRANS	Potash Brook
CVT0859	Interstate 189	VTRANS	Potash Brook
CVT0861	Spear Street	South Burlington	Potash Brook
CVT0868	Dorset Street	South Burlington	Potash Brook
CVT0869	Parallel to Spear Street	South Burlington	n/a (Drainage)
CVT0883	Kennedy Drive	South Burlington	Potash Brook
CVT0890	Kennedy Drive	South Burlington	Tributary to Potash Brook
CVT0893	Kimball Avenue	South Burlington	Potash Brook
CVT0896	Winding Brook Drive	Private	Tributary to Potash Brook
CVT0907	Kimball Avenue	South Burlington	Tributary to Potash Brook
CVT0911	Spear Street Recreation Path	South Burlington	Potash Brook Sub-Tributary
CVT0914	Spear Street Recreation Path	South Burlington	Potash Brook Tributary 3
CVT0916	Spear Street	South Burlington	Potash Brook Tributary 3
CVT0922	Interstate 89	VTRANS	Potash Brook Tributary 3
CVT0928	Williston Road	South Burlington	Tributary to Potash Brook

Structure ID	Location	Structure Ownership	Stream Name
CVT0939	Railroad	Railway	Tributary to Lake Champlain
CVT0940	Railroad	Railway	Tributary to Lake Champlain
CVT0944	UVM Hort Farm	Private	n/a (Drainage)
CVT0945	Dorset Street	South Burlington	Tributary to Muddy Brook
CVT0947	Aviation Avenue	Private	Tributary to Potash Brook
CVT0954	Old Cross Road	South Burlington	n/a (Drainage)
CVT0960	Swift Street	South Burlington	Tributary to Potash Brook
CVT0962	Kennedy Drive	South Burlington	Tributary to Potash Brook
CVT0963	Kennedy Drive	South Burlington	Tributary to Potash Brook
CVT0964	Railroad	Railway	Tributary to Potash Brook
CVT0965	Kennedy Drive	South Burlington	n/a (Drainage)
CVT0966	Songbird Road	South Burlington	Tributary to Potash Brook
CVT0970	Queen City Park Road	South Burlington	Tributary to Potash Brook
CVT0973	Airport Parkway	South Burlington	Tributary to Winooski River
CVT0974	Airport Parkway	South Burlington	Tributary to Winooski River
CVT0976	Kennedy Drive	South Burlington	n/a (Drainage)
CVT0986	Spear Street	South Burlington	Potash Brook Tributary 2
CVT0990	Dorset Street	South Burlington	Potash Brook Tributary 3

Structure ID	Location	Structure Ownership	Stream Name
CVT0991	Haves Avenue	South Burlington	n/a (Drainage)
CVT0996	End of Iby Street	Private	n/a (Drainage)
CVT1004	Market Street	South Burlington	Potash Brook Tributary 3
L03409	Kennedy Drive	South Burlington	n/a (Drainage)
L03765	Meadowland Drive	Private	Potash Brook
L04018	Indian Creek	Private	Tributary to Potash Brook
L04032	Indian Creek	Private	Tributary to Potash Brook
L04297	Railroad	Railway	Potash Brook
L04442	National Guard Avenue	South Burlington	n/a (Drainage)
L05931	Nowland Farm Road	South Burlington	Munroe Brook Tributary 1
L06115	Interstate 189	VTRANS	Tributary to Potash Brook
L07232	Interstate 89	VTRANS	Tributary to Centennial Brook
L07461	Harbor Heights	Private	Tributary to Bartlett Brook
L07547	Driveway	Private	n/a (Drainage)
L08216	Saturn Way	Private	Tributary to Lake Champlain
L08694	Interstate 89	VTRANS	Tributary to Potash Brook
L08714	Interstate 189	VTRANS	Tributary to Potash Brook
L08718	Spear Street	South Burlington	Tributary to Potash Brook
L09905	Windswept Lane	South Burlington	Tributary to Muddy Brook

1.1 Study Area

The City of South Burlington is located primarily within the Munroe Brook-Shelburne Bay watershed, with some land area in the Muddy Brook and Winooski River watersheds (HUC-12). See **Figure 1** for a map of streams and watersheds within the City and **Table 2** for the number of assessed culverts on each stream.

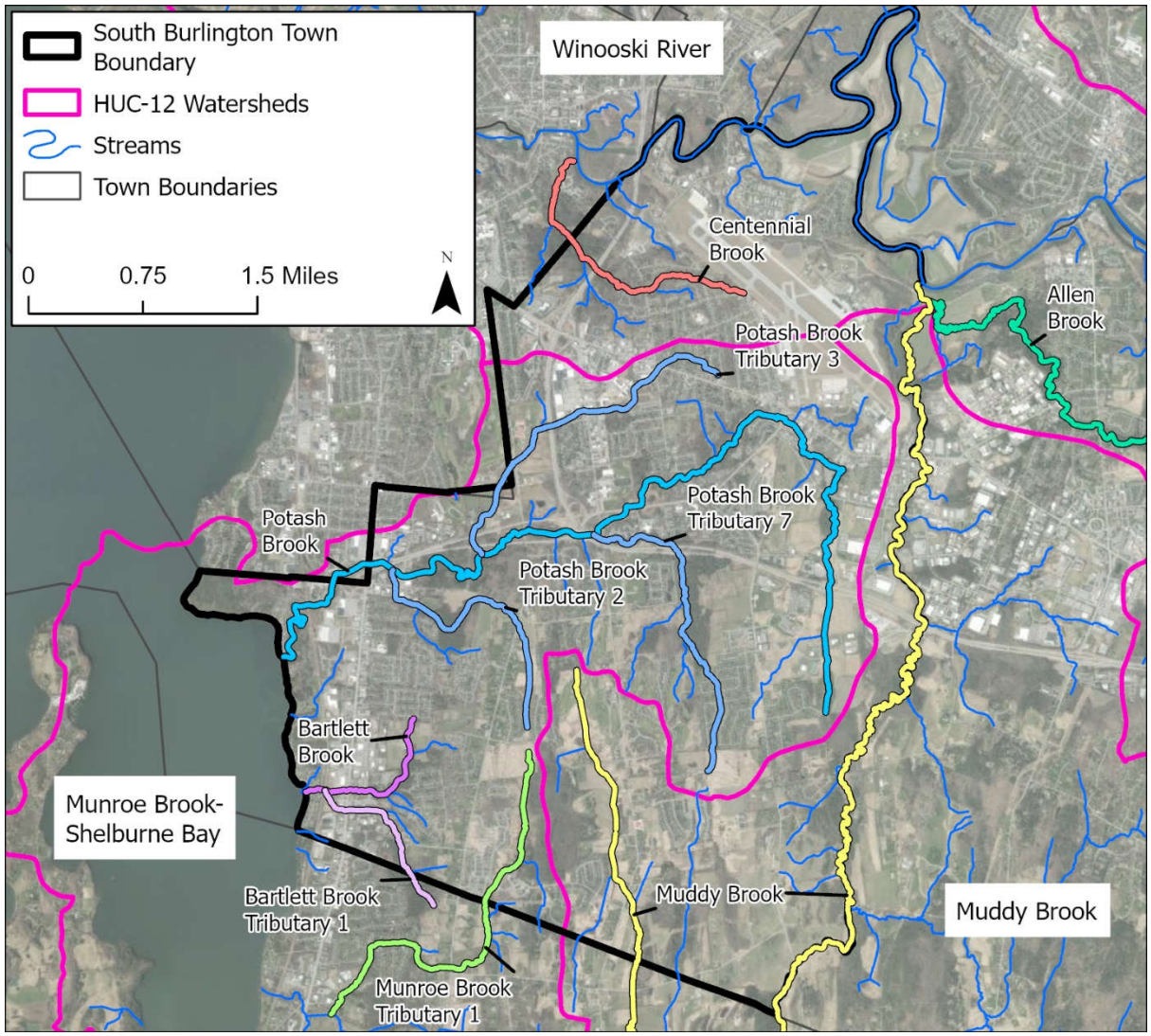

Figure 1. Study Area Streams.

The Munroe Brook-Shelburne Bay watershed (HUC-12) drains an area of 20.4 square miles within the municipalities of Burlington, Shelburne, and South Burlington. Major streams in the watershed include Potash Brook and Munroe Brook. The streams in the South Burlington portion of the watershed are Potash Brook and Munroe Brook Tributary 1.

The Muddy Brook watershed (HUC-12) drains an area of 21.2 square miles within the municipalities of Saint George, Shelburne, South Burlington, and Williston. Major streams in the watershed include Muddy Brook and Sucker Brook. Shelburne Pond is also located within the watershed. The streams in the South Burlington portion of the watershed are Muddy Brook and its tributaries.

The Winooski River watershed (HUC-12) drains an area of 49.3 square miles within the municipalities of Burlington, Colchester, Essex, Essex Junction, Richmond, South Burlington, Westford, Williston, Winooski. Major streams in the watershed include Allen Brook, Alder Brook, and the Winooski River. The streams in the South Burlington portion of the watershed are Allen Brook and its tributaries.

Table 2: Culvert Count by Stream

Watershed (HUC-12)	Stream	Culvert Count
Munroe Brook – Shelburne Bay (93 culverts)	Bartlett Brook	4
	Tributary to Bartlett Brook	4
	Munroe Brook Tributary 1	1
	Potash Brook	18
	Potash Brook Tributary 2	6
	Potash Brook Tributary 3	7
	Potash Brook Tributary 7	9
	Tributary to Potash Brook (Other)	25
	Tributary to Lake Champlain	7
	Drainage (Non-stream)	12
Muddy Brook (20 culverts)	Muddy Brook	8
	Tributary to Muddy Brook	9
	Drainage (Non-stream)	3
Winooski River (9 culverts)	Allen Brook	1
	Centennial Brook	3
	Tributary to Centennial Brook	1
	Tributary to Winooski River	3
	Drainage (Non-stream)	1

2.0 Buildout Analysis

A buildout analysis was conducted to estimate the maximum future impervious area for 121 conveyance culvert watersheds within CSB. Twenty-nine (29) culverts were excluded from this analysis. See **Appendix A** for a summary of culverts not included in the buildout analysis.

The analysis accounted for existing impervious surfaces, natural resource constraints, existing dwellings, CSB land development regulations, and a preliminary buildout analysis conducted by the Chittenden County Regional Planning Commission (CCRPC). The preliminary CCRPC buildout results were only available within CSB, so the maximum future impervious area was only calculated for portions of the watersheds within CSB. The buildout analysis was extended to portions of the watersheds outside of CSB by assuming equivalent percent increases to those calculated within CSB.

The buildout analysis for each watershed summarizes the maximum potential increase in impervious surfaces if all undeveloped areas were built out to the maximum extent permissible under CSB zoning regulations (CSB, 2024). Buildout analysis parcels created by CCRPC (2022), which contain the maximum number of allowed dwellings on each parcel, were used for this analysis. The most current impervious cover dataset created by the University of Vermont Spatial Analysis Lab (UVM SAL) (2022) was used to determine existing impervious cover. The most current dwelling unit data created by CCRPC (2023) was used to determine the existing number of dwelling units. Buildout analysis for commercial and industrial parcels was conducted using the maximum allowable impervious cover.

2.1 Residential and Mixed-Use Areas

The preliminary buildout analysis conducted by CCRPC in 2022 did not account for natural resource constraints; therefore, FEA adjusted the maximum allowed dwelling units per parcel to account for all constraint areas defined in the South Burlington Land Development Regulations (CSB, 2024) as hazards or designated habitat blocks. The following areas are considered hazards:

- Class I and II Wetlands and Their Associated 100- or 50-Foot Buffers
- B2: 500-Year Floodplain (0.2% Annual Chance of Flood)
- Special Flood Hazard Area: 100-Year Floodplain (1% Annual Chance of Flood)
- Very Steep Slopes (> 25%)
- River Corridor

Some encroachments into these regulated areas may be permissible through local and state permitting processes. The level of permissible encroachment would depend on many factors and negotiations during the permitting process. To simplify the buildout analysis, it was assumed that no future development will occur in areas with mapped natural resource constraints. To adjust the allowed dwelling units per parcel to account for natural resource constraints, the percentage of each parcel without natural resource constraints (buildable percentage) was multiplied by the number of allowed dwellings calculated during the CCRPC analysis. The existing number of dwellings present on the parcel was then subtracted from this value to determine the new dwelling unit potential. For example, if a parcel with 50% of its area occupied by natural resource constraints and 20 existing dwelling units was determined to have a maximum dwelling capacity of 100 units, the maximum allowable dwellings after adjusting for natural resource constraints would be 50 units. The new dwelling unit potential for the parcel would be 30 units.

The lot size of these new dwelling units was determined by dividing the buildable area of the parcel by the new dwelling unit potential. Lot percent impervious was calculated by fitting an exponential curve (**Figure 2**) to the estimated percent impervious cover by dwelling density values in the Soil Conservation Service (SCS) TR-55 urban hydrology user manual (1986). The new impervious area was calculated using the following equation:

*New impervious area = lot size * new dwelling unit potential * (lot percent impervious / 100)*

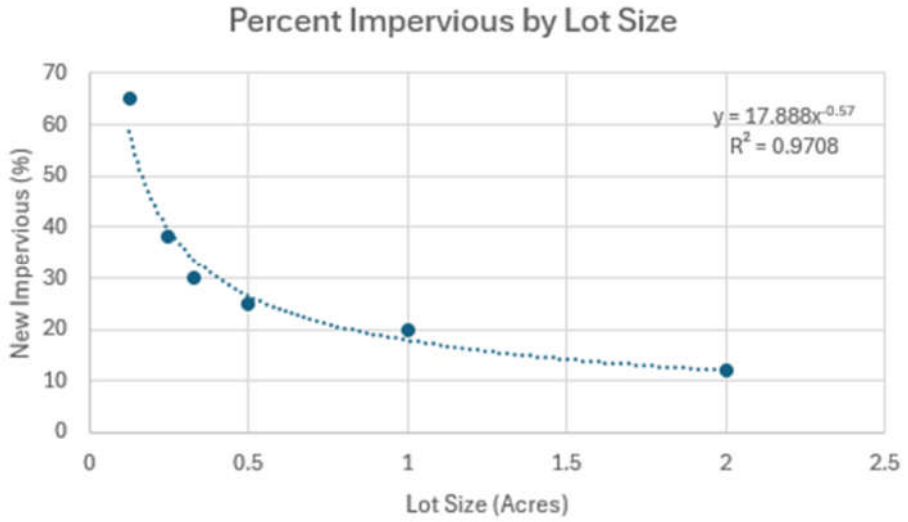

Figure 2: Exponential curve showing estimated percent impervious based on lot size.

For example, if a 1.2-acre parcel had 0.2 acres of natural resource constraints, it would have 1 acre of buildable area. If the new dwelling potential of this parcel was 2 units, the lot size would be 0.5 acres, resulting in a lot percent impervious value of 26.6%. The new impervious area on this parcel would be 0.266 acres. Parcels were then intersected with existing impervious surface data to determine the existing amount of impervious cover.

2.2 Industrial and Commercial Areas

Parcels zoned as industrial and commercial properties were assumed to already have the maximum impervious cover allowed by the City of South Burlington (70%). These parcels were intersected with existing impervious surface data, which was used to calculate the existing impervious percent. If the existing impervious percentage was found to be less than the assumed maximum percentage impervious cover, the new impervious area was calculated by multiplying the difference between the existing impervious percent and maximum impervious percentage by the total parcel area. For example, if a 1-acre commercial parcel was found to have an existing impervious cover of 50%, the new impervious cover would be 20%, resulting in a new impervious area of 0.2 acres and a total impervious area of 0.7 acres.

2.3 Watershed Analysis

To calculate the existing, new, and total percentage of impervious land area within each culvert watershed, the parcels were intersected with the culvert watershed areas. The existing, new, and total impervious areas were determined for each watershed using an area-weighted averaging approach and converted to percentages.

Due to the spatial limitations of the preliminary buildout analysis conducted by CCRPC, this analysis could only be conducted for the portions of each watershed within CSB. To extend the results outside of CSB, the percent increase in impervious area for portions of the watershed outside of CSB was assumed to be equivalent to the calculated percent increase within CSB.

2.4 Buildout Analysis Results

See **Appendix B** for a map of the buildout analysis results at the subwatershed level within CSB and **Appendix C** for a table of full watershed buildout analysis results. **Appendix C** also contains information about the percentage of each watershed that is within CSB. A summary of watershed buildout results can be found below in **Table 3.**

Table 3: Watershed Buildout Summary

Percent Impervious Increase Under Full Buildout	Watershed Count
0-2%	7
2%-5%	4
5%-10%	32
10%-20%	40
20%-40%	31
>40%	7

3.0 Field Data Collection

During the spring, summer, and fall of 2025, FEA personnel documented the existing condition of each assessed culvert and associated headwalls, recorded the location of the culvert inlet and outlet using a submeter GPS, and collected data for hydraulic modeling. For culverts conveying intermittent or perennial streams, additional data were collected to evaluate geomorphic compatibility and aquatic organism passage.

FEA visited a total of 150 culverts identified by CSB and CCRPC, 31 of which were not assessed due to not existing (21) or being difficult to locate (10). In addition, four of the stream crossing structures visited were assessed as bridges rather than culverts. See **Table 4** for a summary of the 150 culverts visited by FEA. See **Appendix A** for a description of culverts that were not assessed and **Appendix D** for a map of all culverts visited by FEA.

Table 4: Culverts Visited by FEA

Field Determination	Count
Not Assessed	31
Drainage Culvert	16
Intermittent Stream Culvert	56
Perennial Stream Culvert	43
Perennial Stream Bridge	4

3.1 General Culvert Characteristics

Information about the condition and material of each culvert and the associated inlet and outlet headwalls (if present) was collected for all culverts. Pipe and headwall conditions were classified as “poor”, “fair”, or “good” based on specific criteria relevant to the material. See **Appendix E** for descriptions of the criteria considered for condition assessment. Additionally, the span, rise, and length of each culvert were documented. Span and rise dimensions were measured with an extendable stadia rod. Lengths were determined from submeter GPS locations of culvert inlets and outlets. Photographs looking at the culvert inlet and outlet, as well as the upstream and downstream channel or ditch were also taken.

3.2 Geomorphic Compatibility (GC) and Aquatic Organism Passage (AOP) Data

GC and AOP data were collected for all intermittent and perennial stream culverts following the VTANR Stream Geomorphic Assessment (SGA) Culvert Assessment Field Form protocol (2009). The GC data includes information about bed material, deposition/erosion, channel width, and culvert configuration relative to the stream and associated roadway. The AOP data includes information about culvert outlet perch, water depth in the culvert and outlet pool, and whether the culvert bottom is naturalized. Similar data were collected for perennial stream bridges following the VTANR SGA Bridge & Arch Assessment Form (2009).

Appendix F contains blank culvert and bridge assessment forms which display the data collected at each culvert. Data were collected digitally using the ArcGIS Survey123 app rather than with paper assessment forms. Perennial and intermittent stream crossing data were used to determine GC, AOP, and AOP retrofit scores using the methods described in the Vermont Culvert Geomorphic Compatibility Screening Tool (MMI, 2008) and the Vermont Culvert Aquatic Organism Passage Screening Tool (MMI, 2009). See **Appendix G** for GC and AOP results. A summary of geomorphic compatibility and aquatic organism passage results can be viewed below in **Table 5** and **Table 6**.

Table 5: AOP Results by Culvert Ownership

AOP Coarse Score	Count by Culvert Ownership			
	CSB (56)	VTRANS (24)	Private (16)	Railway (7)
No AOP	7	4	2	1
Reduced AOP	34	9	8	4
Full AOP	15	11	6	2

Table 6: Geomorphic Compatibility Results by Culvert Ownership

Geomorphic Compatibility	Count by Culvert Ownership			
	CSB (56)	VTRANS (24)	Private (16)	Railway (7)
Mostly Incompatible	1	0	0	0
Partially Compatible	18	7	7	3
Mostly Compatible	25	9	5	2
Fully Compatible	12	8	4	2

3.3 Hydraulic Modeling Data

The following supplemental data were collected for all assessed culverts to support hydraulic modeling:

- Culvert Dimensions (span, rise, and length)
- Channel Slope (% within 50 feet of outlet)
- Overflow Pipe Presence/Absence
- Road Elevation (relative to inlet)
- Number of Culverts at Crossing
- Inlet Headwall Configuration
- Culvert Material
- Channel Width
- Culvert Slope
- Road Type

The methods for culvert slope data collection varied depending on site conditions. See **Table 7** for a summary of the methods used to measure culvert slope. Early in the assessment process, a centimeter-grade GPS (Trimble Geo 7X or Emlid Reach RS3) was used to collect the location and elevation of the culvert inlet and outlet and the road surface. When reviewed, the elevation data collected using this method was determined to be generally unreliable due to factors including overhead utility lines, tree cover, and culverts with high roadway embankments that limit the ability of the GPS to receive location data from satellites.

Most culvert slope data were collected using a rotating laser level or a four-foot-long digital level. The laser level was the preferred method, allowing for the collection of relative elevation data to the nearest 0.1 foot. The laser level was typically set up on the road or within the culvert, and a 25-foot stadia rod was used to measure the elevation of the culvert inlet and outlet relative to the laser level. This method was found to be effective for culverts with bottoms located 10-15 feet below the elevation of the laser level or for culverts with sufficient height to laser level through.

For culverts not suitable for laser level use, a four-foot-long digital level was used to determine culvert slope. The level was placed in the pipe flush to the pipe bottom, and a slope was recorded at the inlet and outlet to the nearest 0.1%. For culverts large enough to walk into, additional measurements were taken inside the culvert. All slope measurements were averaged to determine the final culvert slope. For culverts assessed with this method, the elevation of the road relative to the culvert inlet was determined by comparing the LiDAR elevation of the inlet to the LiDAR elevation of the road surface (VCGI, 2023). The LiDAR used has a resolution of 0.35 meters.

For culverts where the inlet and outlet were too far apart to be measured with the laser level and where the inlet and outlet slopes measured by the digital level differed significantly, final slopes were determined by comparing the LiDAR elevations of the inlet and outlet (VCGI, 2023). The elevation of the road relative to the culvert inlet was determined in the same way as for culverts measured with the digital level.

After all culvert slopes had been collected, a LiDAR-determined slope was calculated for each culvert. Field-determined culvert slopes greater than 5 percent or less than 1 percent were compared to the LiDAR-determined slope for the culvert. If the field-determined slope was significantly different than the LiDAR-determined slope, the field-determined slope was compared to the approximate culvert slope visible in the inlet and outlet pictures. If the field-determined slope was found to be different than the culvert slope in the inlet and outlet pictures, the culvert was revisited and the culvert slope was remeasured.

Table 7: Culvert Slope Assessment Methods

Assessment Method	Count
Centimeter GPS	9
Digital Level	53
Laser Level	52
LiDAR	5

4.0 Hydrologic Modeling

Hydrologic modeling was conducted for 122 culverts. Twenty-eight (28) culverts were excluded from this analysis. See **Appendix A** for a summary of culverts not included in the hydrologic analysis.

4.1 Watershed Delineation

Watersheds delineated by FEA as part of the Bartlett Brook Culvert Assessment and Prioritization (2009) and Potash Brook Culvert Assessment and Prioritization (2010) projects were verified against LiDAR-derived contours and stormwater mapping provided by CSB. The watersheds for all culverts on perennial streams mapped by StreamStats (USGS, 2016) were delineated using the StreamStats online tool and were also verified against LiDAR-derived contours and stormwater mapping provided by CSB. High-resolution stormwater mapping data was not available for areas outside of CSB, so watersheds in these areas could only be verified using LiDAR data.

All other culvert watersheds not previously delineated by FEA or delineated by StreamStats were delineated manually using LiDAR-derived contours and stormwater mapping provided by the City of South Burlington. Culvert watersheds that were difficult to delineate remotely were visited in the field to confirm drainage areas. Additionally, throughout the culvert assessment process, the channel characteristics in the vicinity of each culvert were compared to the theoretical characteristics of a typical channel with the same watershed area. Culvert watersheds with major discrepancies between actual and theoretical channel characteristics received additional review and were updated as necessary. Watershed maps for each culvert are included in **Appendix H**.

4.2 Hydrology Calculations

Culvert hydrology was calculated using various regression methods based on watershed characteristics. FEA utilized multiple regression analyses to get the most accurate estimate of peak flows to each culvert. All culverts were assessed for hydrology using either the Rational Method (for smaller watersheds), or the USGS Method (for larger watersheds). Additional information about the methods used can be found below. Peak flows were calculated for both existing and full buildout conditions.

Rational Method

The Rational Method, as described in section 4.6 of the VTrans Hydraulics Manual (2016) was used to calculate peak flows for all watersheds smaller than 200 acres (0.31 mi^2). Peak flows were calculated for the 1-, 2-, 5-, 10-, 25-, 50- and 100-year storms using the following equation:

$Q = C * I * A$

Where:

Q = The peak runoff rate in cubic feet per second (cfs).

C = The dimensionless runoff coefficient for the underlying land cover.

I = The average rainfall intensity in inches per hour (in/hr) for a duration equal to the time of concentration for a selected storm event.

A = The area of the contributing drainage basin in acres.

Landcover for each watershed was determined using data from the University of Vermont Spatial Analysis Lab (UVM SAL) (2016). To calculate peak flow under buildout conditions, it was assumed that new impervious areas were converted from tree canopy to impervious. If the area of new impervious surfaces was greater than the tree canopy area, it was assumed that the difference would be converted from the area of grass/shrub. An area-weighted runoff coefficient (C) was determined for each watershed using the values shown in **Table 8**.

Table 8: C Values by Landcover

Land Cover	Runoff Coefficient (C)
Tree	0.3
Grass/Shrub	0.4
Bare Soil	0.6
Impervious	0.8
Water	0.9

The average rainfall intensity for each modeled storm event was calculated using the regional 2-year 30-minute rainfall intensity, a recurrence interval factor, and a duration factor derived from the time of concentration. Rainfall intensity for the regional 2-year 30-minute storm was determined to be 0.79 inches per hour (NRCC, 2022).

To calculate peak flows using the rational method, a time of concentration for each watershed was determined. Initially, time of concentration was calculated using the lag equation as described on page 2.20 of the Part 650 Engineering Field Handbook (USDA NRCS, 2021). However, this method was found to overestimate the time of concentration as it does not account for the increased runoff velocities associated with flow through piped stormwater infrastructure.

Instead, time of concentration was calculated by determining a travel time for each segment of the flow path having a uniform slope landcover, and flow type. These segments were identified visually using land cover data (UVM SAL, 2016) and LiDAR-derived contours (VCGI, 2023). Segments within the first 150 feet of the flow path outside of channelized areas were assumed to be sheet flow.

United States Geological Survey (USGS) Regression Equation Method for Unaged Sites

The USGS regression equation method for ungaged sites, as described in Estimating Flood Discharges at Selected Annual Exceedance Probabilities for Unregulated Rural Streams in Vermont (Olson, 2025) was used to calculate peak flows for all watersheds with areas greater than or equal to 200 acres. For watersheds with areas between 128 and 200 acres, values were calculated using both the USGS and rational methods. The rational method was found to produce more accurate discharge estimates and was used to calculate the final peak flows for these watersheds. For all watersheds with an area greater than 200 acres, peak flows were calculated with the USGS method for the 2-, 5-, 10-, 25-, 50-, and 100-year storms.

Each storm recurrence interval has a unique regression equation, but the inputs to these equations are the same. The inputs are the drainage area of the watershed (mi^2), the percentage of the watershed covered by open water and wetlands, and the average annual precipitation in the watershed (in). The percentage of the watershed covered by open water and wetlands was determined using land cover data from the University of Vermont Spatial Analysis Lab (2016). A single average annual precipitation value of 35.23 inches was used for all watersheds (PRISM Group, 2014), as the geographic scale of the project is limited to the City of South Burlington and elevation does not differ significantly throughout the study area.

Due to the high level of development within the City of South Burlington, as evidenced by the average percent imperviousness of approximately 20% across the study watersheds, the USGS regression method described above, developed for rural watersheds, was found to underestimate peak flows. To account for this, an urban adjustment factor, as described in Methods for Adjusting U.S. Geological Survey Rural Regression Peak Discharges in an Urban Settings (Moglen and Shivers, 2006) was used to adjust the peak flows. The simple imperviousness method, which adjusts the rural peak flows based on the percent impervious surface within the watershed, was used to determine the urban adjustment factor. On average, the calculated urban peak flows were approximately twice as high as the corresponding rural peak flows.

4.3 Hydrology Results

A summary of the calculated peak flow results is included in **Appendix I**. The USGS Urban method was used for 43 culverts, and the Rational Method was used for 79 culverts. A table summarizing the average percentage increase in peak flow under buildout conditions for each storm event and hydrology method can be found below in **Table 9.**

Table 9: Buildout Average Peak Flow Increase

Storm	Hydrology Method	Buildout Average % Peak Flow Increase	Buildout Average Absolute Peak Flow Increase (cfs)
Q1	USGS Urban	N/A	N/A
	Rational Method	35%	5.5
Q2	USGS Urban	11%	16.4
	Rational Method	35%	7.4
Q5	USGS Urban	10%	21.2
	Rational Method	34%	9.6
Q10	USGS Urban	8%	21.8
	Rational Method	34%	11.8
Q25	USGS Urban	7%	22.0
	Rational Method	34%	14.1
Q50	USGS Urban	5%	20.8
	Rational Method	34%	16.3
Q100	USGS Urban	4%	18.4
	Rational Method	34%	18.5

5.0 Hydraulic Modeling

Hydraulic modeling was conducted for all field-assessed culverts conveying an intermittent or perennial stream. This resulted in the creation of hydraulic models for 103 individual culverts at 97 stream crossings. Five of these stream crossings have multiple (2-3) culverts, and four of these stream crossings are bridges that can be reasonably modeled as concrete box culverts.

5.1 Hydraulic Modeling Input Data

FEA used HY-8 version 8.0.1.2 (FHWA, 2025) to evaluate the hydraulic capacity of each culvert. While detailed topographic data was not collected for each site, FEA's site observations were sufficient to characterize how culvert hydraulics interact with the downstream channel (tailwater) and roadway elevation. Tailwater equations were used to evaluate the hydraulic capacity of each culvert. As a result, factors such as headwater storage upstream of the embankment were not considered by the model.

HY-8 requires five categories of user-input data to model a crossing: discharge data, tailwater data, roadway data, culvert data, and site data. Descriptions of these data are included below, alongside documentation of all assumptions made to simplify models for generalizability between crossings. Overall, a conservative modeling approach was taken. Uncertainty about culvert parameters was resolved by selecting options that resulted in the highest headwater elevation for each modeled culvert.

Discharge Data

Watershed areas were previously determined for each crossing. The Rational and USGS urban-adjusted regression equation methods were applied to calculate peak flows for crossings with watersheds smaller and larger than 200 acres, respectively. Additional information on this methodology can be found in Section 4. Discharge data for each modeled crossing was entered in HY-8 through the *Recurrence* option, which enables specification of peak flows by recurrence interval.

The minimum design frequency peak flow for each crossing was considered for evaluation of culvert compatibility. The Vermont Agency of Transportation (VTrans) defines minimum design frequencies for culverts by roadway classification: the 100-year storm (Q100) for freeways; the 50-year storm (Q50) for railroads, principal arterial, minor arterial, and collector roads; and the 25-year storm (Q25) for local roads (VTrans, 2015). Trails were assumed to have the same design storm as local roads (25-year). **Appendix J** and **Table 10** summarize the minimum design frequency and corresponding peak flow for each modeled culvert utilizing the VTrans classifications.

Table 10: Roadway Classification Summary

Design Storm	Roadway Classification	Count
Q25	Local Road	36
	Trail	11
Q50	Railroad	7
	Principal Arterial	16
	Minor Arterial	12
	Collector	4
Q100	Freeway	17

Tailwater Data

Modeling the tailwater of a crossing in HY-8 requires definition of the channel type, bottom width, channel slope, channel Manning's roughness coefficient (n), and channel invert elevation. For all crossings, the channel type was described as trapezoidal. To standardize the approach for deriving channel bottom width, a 1:1 (H:V) side slope was assumed (i.e., a 3-foot bankfull channel corresponds to a bottom width of 1 foot). In cases where a 1:1 side slope resulted in unreasonably high tailwater elevations where model tailwater control would not be expected, the side slope grade was adjusted based on field photographs and overall channel observations (e.g., incised channel geometries, large wetland valley complexes, etc.).

Tailwater channel slopes were visually assessed and binned during the field data collection process. For the most conservative modeling approach, the lowest slope for each bin was selected. Channel Manning's roughness coefficients were set to 0.025 for silt and sand, 0.035 for gravel, 0.040 for cobble, and 0.050 for boulder substrate (Arcement and Schneider, 1989).

Roadway Data

HY-8 requires six parameters to define the roadway associated with a modeled crossing – roadway profile, roadway station, crest length, crest elevation, roadway surface, and top width. For consistency across all modeled crossings, roadway crest elevation was assumed to be constant, and the crest length was entered as 100 feet. Unpaved roadway surfaces (i.e., railroad, trail, grass) were modeled as gravel. Roadway elevation data was either collected in the field in relation to the culvert inverts utilizing a laser level or estimated remotely from LiDAR data for taller and less accessible embankments.

Culvert Data

Culvert shape, size, material, profile and taper type, inlet depression, and inlet configuration are required culvert data in HY-8. Most modeled culverts could be represented by simple shapes with preset or user-defined span and rise dimensions (e.g., circular pipe, box, pipe-arch). The four assessed bridges were modeled as concrete box culverts. Two culverts with nonstandard dimensions required the creation of user-defined shapes. For pipes composed of multiple sections with varying dimensions, the most constraining dimension was modeled. For mixed material pipes, the material at the culvert outlet was modeled. A straight culvert type with no inlet depression was assumed for all culverts. For open-bottom culverts, an embedment depth of 0.1 inches and a Manning's roughness coefficient corresponding to the channel substrate rather than the culvert material were specified.

Site Data

To model the position and length of each culvert, site data were entered into HY-8 using the Culvert Invert Data option. Culvert length, inlet, and outlet invert elevations were collected following the methods described in Section 3. HY-8 computed the slope of each culvert using the provided elevation and station data. Culvert slopes were assumed to be consistent between the inlet and the outlet.

5.2 Model Quality Assurance

Data collected during field assessments were cross-checked with photographs of culvert inlets, outlets, and upstream and downstream channels to ensure accurate modeling of each stream crossing. Preliminary modeling of each culvert and subsequent review of entered parameters was completed by different individuals to eliminate data entry errors that might influence model results. Additionally, visual outputs in HY-8 were examined to assess whether headwater, tailwater, and roadway elevations were reasonable for each crossing.

5.3 Hydraulic Modeling Results

See **Attachment K** for hydraulic modeling results organized by culvert ID. The total discharge, culvert discharge, roadway discharge, and headwater depth ratio (HW/D) for each culvert are presented for the Q2, Q5, Q10, Q25, Q50, and Q100 storm events, with the culvert design storm highlighted in blue. Roadway discharge represents how much flow is overtopping the roadway, while culvert discharge represents the volume of flow moving through the culvert.

HW/D is a standard hydraulic result comparing water depth at the culvert inlet to the diameter (or rise) of the culvert. For example, a HW/D value greater than one indicates that the culvert is flowing full and the headwater elevation is above the top of the culvert; a value less than one indicates that the headwater elevation at the inlet is below the top of the culvert.

Additionally, the hydraulic modeling results include the overtopping event for each culvert, which indicates the total discharge required to exceed culvert and roadway capacity, leading to floodwaters overtopping the roadway. This is an important parameter to consider when prioritizing culvert replacement. The roadway may not overtop during large storm events if there is a high embankment, even if a culvert has a high HW/D value. In **Attachment K,** storm events that result in overtopping are shown in bold and storm events that result in overtopping before the design storm are highlighted in red. **Table 10** summarizes the number of culverts overtopping above and below their design storms by culvert ownership. Any event that results in a road discharge greater than 0 cfs is considered to be an overtopping event.

Table 11: Hydraulic Results by Culvert Ownership

Owner	Overtopping Culverts	Culverts Overtopping Below Design Storm
CSB	18	11
VTRANS	2	1
Private	9	5
Railway	3	2

6.0 Culvert Prioritization

Prioritization was conducted for all field-assessed culverts conveying an intermittent or perennial stream (103). The prioritization process involved assigning each culvert a score between 0 and 38. Scores considered hydraulic capacity, roadway overtopping risk, overall culvert condition, geomorphic compatibility, and erosion level.

6.1 Prioritization Criteria

The following prioritization criteria were used to calculate culvert sub-scores.

Hydraulic Capacity

Score based on headwater-to-depth ratio (HW/D) during the design storm.

- **0:** Less than 0.5
- **2:** 0.5 to 1.0
- **5:** 1.0-2.0
- **10:** Greater than 2

Roadway Overtopping Risk

- **0:** Culvert does not overtop during the design storm.
- **10:** Culvert overtops during the design storm.

Overall Culvert Condition

Score based on pipe and headwall condition. Use the headwall in the worst condition for scoring. If no headwall is present, it is assumed to be in the same condition as the pipe.

- **0:**
  - Pipe and headwall in good condition.
- **2:**
  - Pipe in good condition and headwall in fair condition.
  - Pipe in fair condition and headwall in good condition.
- **4:**
  - Pipe and headwall in fair condition
  - Pipe in good condition and headwall in poor condition.
- **6:**
  - Pipe in poor condition and headwall in good or fair condition.
  - Pipe in fair condition and headwall in poor condition.
- **8:**
  - Pipe and headwall in poor condition.

Geomorphic Compatibility

Score based on geomorphic compatibility screening.

- **0:** Fully compatible.
- **1:** Mostly compatible.
- **2:** Partially compatible.
- **3:** Mostly incompatible.
- **4:** Fully incompatible.

Erosion Level

- **0:** No erosion present.
- **3:** Low erosion present.
- **6:** High erosion present.

6.2 Prioritization Results

Prioritization scores were generated by summing the sub-scores from each category. Culverts that received a higher score are higher priority for replacement. Culvert replacement priorities were assigned based on the score ranges shown in **Table 12.** See **Table 13** for a full breakdown of culvert prioritization. A summary sheet containing detailed information for each field-assessed culvert conveying a perennial or intermittent stream can be found in **Appendix L**.

Table 12: Replacement Priorities by Prioritization Score

Prioritization Score	Replacement Priority	Culvert Count
0-15	Low	70
15-25	Medium	18
26-38	High	15

Table 13: Replacement Priorities by Prioritization Score

Structure ID	Location	Prioritization Criteria													Additional Criteria		Prioritization Scoring	
		Hydraulic Capacity		Roadway Overtopping Risk				Overall Structure Condtion			Geomorphic Compatability (GC)		Erosion Level					
		HW/D (Design Storm)	Subscore	Design Storm Discharge (cfs)	Roadway Overtopping Discharge (cfs)*	Road Type	Subscore	Headwall Condition	Pipe Condition	Subscore	GC Score	Subscore	Erosion Level	Subscore	AOP Coarse Score	Buildout % Impervious Cover Increase	Overall Prioritization Score**	Overall Priority
CVT0821	Brewer Parkway	10.33	10	85.8	34.1	Municipal Road	10	Poor	Poor	8	Partially Compatible	2	High	6	No AOP	19.5%	36	High
CVT0964	Railroad	22.07	10	47.7	6.6	Railway	10	Poor	Poor	8	Partially Compatible	2	High	6	Reduced AOP	29.3%	36	High
CVT0928	Williston Road	3.92	10	85.8	13.7	Municipal Road	10	Poor	Poor	8	Mostly Compatible	1	High	6	Reduced AOP	13.1%	35	High
CVT0758	Bartlett Bay Road	4.51	10	93.6	47.1	Municipal Road	10	Fair	Fair	4	Partially Compatible	2	High	6	Reduced AOP	9.2%	32	High
CVT0769	National Guard Avenue	3.85	10	43.2	30.4	Municipal Road	10	Poor	Poor	8	Mostly Compatible	1	Low	3	Reduced AOP	24.4%	32	High
CVT0572B	Farm Access Road	1.42	5	33.1	15.6	Trail	10	Poor	Poor	8	Partially Compatible	2	High	6	Reduced AOP	15.2%	31	High
CVT0647	UVM Miller Farm	1.37	5	143.7	86.3	Trail	10	Poor	Poor	8	Partially Compatible	2	High	6	Reduced AOP	8.6%	31	High
CVT0835	Swift Street	2.78	10	106.5	19.5	Municipal Road	10	Fair	Poor	6	Partially Compatible	2	Low	3	No AOP	12.5%	31	High
CVT0829	Farrell Street Park Path	3.60	10	80.3	17.9	Trail	10	Poor	Fair	6	Mostly Compatible	1	Low	3	Reduced AOP	13.2%	30	High
CVT0986	Spear Street	2.42	10	29.4	12.2	Municipal Road	10	Poor	Poor	8	Mostly Compatible	1	None	0	Reduced AOP	14.9%	29	High
L08216	Saturn Way	1.11	5	17.2	13.6	Private Road	10	Poor	Fair	6	Partially Compatible	2	High	6	Reduced AOP	5.3%	29	High
CVT0001	Winding Brook Drive	3.05	10	36.1	30.9	Private Road	10	Fair	Fair	4	Mostly Compatible	1	Low	3	Reduced AOP	40.4%	28	High
CVT0013	Ethan Allen Drive	6.22	10	70.7	33.1	Municipal Road	10	Good	Good	0	Partially Compatible	2	High	6	Reduced AOP	29.7%	28	High
CVT0008	East of Kennedy Drive	1.11	5	142.0	115.0	Trail	10	Fair	Fair	4	Partially Compatible	2	High	6	Reduced AOP	25.3%	27	High
CVT0960	Swift Street	2.35	10	25.2	36.2	Municipal Road	0	Poor	Poor	8	Partially Compatible	2	High	6	Reduced AOP	22.0%	26	High
CVT0589	Hinesburg Road	2.04	10	49.3	28.9	State Highway	10	Poor	Good	4	Mostly Compatible	1	None	0	Reduced AOP	18.6%	25	Moderate
CVT0813	Meadowland Drive	4.28	10	71.6	19.0	Private Road	10	Poor	Good	4	Fully Compatible	0	None	0	Full AOP	21.0%	24	Moderate
CVT0916	Spear Street	1.70	5	212.3	115.3	Municipal Road	10	Fair	Fair	4	Partially Compatible	2	Low	3	Full AOP	8.6%	24	Moderate
CVT0659	Hinesburg Road	1.09	5	439.5	372.9	State Highway	10	Poor	Fair	6	Mostly Compatible	1	None	0	Full AOP	7.5%	22	Moderate
CVT0914	Spear Street Recreation Path	1.38	5	182.8	56.9	Trail	10	Good	Good	0	Mostly Incompatible	3	Low	3	Reduced AOP	8.6%	21	Moderate
CVT0962	Kennedy Drive	9.12	10	39.8	32.7	Municipal Road	10	Good	Good	0	Mostly Compatible	1	None	0	Full AOP	41.4%	21	Moderate
L05931	Nowland Farm Road	5.82	10	13.5	13.2	Municipal Road	10	Good	Good	0	Mostly Compatible	1	None	0	Full AOP	6.0%	21	Moderate
CVT0004	Parallel to Railroad	3.56	10	108.5	88.6	Railway	10	Good	Good	0	Fully Compatible	0	None	0	Full AOP	9.4%	20	Moderate
CVT0623	UVM Hort Farm	1.55	5	71.0	43.1	Private Road	10	Fair	Fair	4	Mostly Compatible	1	None	0	Full AOP	9.2%	20	Moderate
CVT0002	Interstate 89	0.64	2	107.7	782.2	Interstate	0	Poor	Poor	8	Partially Compatible	2	High	6	Reduced AOP	7.4%	18	Moderate
CVT0779	Butler Drive	1.18	5	43.7	60.8	Municipal Road	0	Poor	Poor	8	Partially Compatible	2	Low	3	Reduced AOP	24.7%	18	Moderate
CVT0780	Butler Drive	1.28	5	43.7	60.8	Municipal Road	0	Poor	Poor	8	Partially Compatible	2	Low	3	Reduced AOP	24.7%	18	Moderate
CVT0781	Butler Drive	1.12	5	66.2	85.9	Municipal Road	0	Poor	Poor	8	Partially Compatible	2	Low	3	Reduced AOP	17.7%	18	Moderate
CVT0782	Butler Drive	1.12	5	66.2	85.9	Municipal Road	0	Poor	Poor	8	Partially Compatible	2	Low	3	No AOP	17.7%	18	Moderate
CVT0005	Railroad	1.63	5	108.5	115.4	Railway	0	Fair	Fair	4	Partially Compatible	2	High	6	Reduced AOP	9.4%	17	Moderate
CVT0009	Kennedy Drive	0.88	2	213.1	555.2	Municipal Road	0	Fair	Poor	6	Partially Compatible	2	High	6	Reduced AOP	23.0%	16	Moderate
CVT0725	Nowland Farm Road	1.94	5	47.1	36.3	Municipal Road	10	Good	Good	0	Mostly Compatible	1	None	0	Reduced AOP	2.6%	16	Moderate

*discharge at which flow crests roadway

**higher scores = higher priority for structure replacement

Structure ID	Location	Prioritization Criteria													Additional Criteria		Prioritization Scoring	
		Hydraulic Capacity		Roadway Overtopping Risk				Overall Structure Condtion			Geomorphic Compatability (GC)		Erosion Level					
		HW/D (Design Storm)	Subscore	Design Storm Discharge (cfs)	Roadway Overtopping Discharge (cfs)*	Road Type	Subscore	Headwall Condition	Pipe Condition	Subscore	GC Score	Subscore	Erosion Level	Subscore	AOP Coarse Score	Buildout % Impervious Cover Increase	Overall Prioritization Score**	Overall Priority
CVT0893	Kimball Avenue	0.90	2	138.6	421.1	Municipal Road	0	Fair	Poor	6	Partially Compatible	2	High	6	Reduced AOP	25.3%	16	Moderate
CVT0010	Kennedy Drive	1.22	5	213.1	551.2	Municipal Road	0	Fair	Good	2	Partially Compatible	2	High	6	No AOP	23.0%	15	Low
CVT0599	End of Oak Hill Drive	0.81	2	50.3	129.4	Trail	0	Poor	Good	4	Partially Compatible	2	High	6	Reduced AOP	26.7%	14	Low
CVT0622	Trail	0.95	2	106.0	287.4	Trail	0	Poor	Poor	8	Mostly Compatible	1	Low	3	Reduced AOP	20.7%	14	Low
CVT0634	Chittenden Regional Correctional Facility	1.28	5	89.8	129.2	Trail	0	Poor	Good	4	Partially Compatible	2	Low	3	Full AOP	12.5%	14	Low
CVT0896	Winding Brook Drive	0.66	2	32.7	93.6	Private Road	0	Fair	Fair	4	Partially Compatible	2	High	6	No AOP	30.5%	14	Low
CVT0940	Railroad	0.68	2	40.5	126.6	Railway	0	Poor	Good	4	Partially Compatible	2	High	6	Reduced AOP	5.9%	14	Low
L04018	Indian Creek	3.00	10	44.1	46.9	Private Road	0	Good	Good	0	Mostly Compatible	1	Low	3	No AOP	6.4%	14	Low
CVT0656	Airport Parkway	0.74	2	18.2	66.5	Municipal Road	0	Poor	Fair	6	Partially Compatible	2	Low	3	Reduced AOP	21.9%	13	Low
CVT0907	Kimball Avenue	0.95	2	26.7	41.4	Municipal Road	0	Poor	Fair	6	Partially Compatible	2	Low	3	No AOP	57.3%	13	Low
CVT0945	Dorset Street	1.79	5	45.0	68.3	Municipal Road	0	Poor	Poor	8	Fully Compatible	0	None	0	Reduced AOP	22.7%	13	Low
L07232	Interstate 89	0.78	2	155.9	670.5	Interstate	0	Good	Poor	6	Partially Compatible	2	Low	3	No AOP	9.6%	13	Low
L08718	Spear Street	1.25	5	18.7	53.2	Municipal Road	0	Poor	Good	4	Mostly Compatible	1	Low	3	Reduced AOP	24.8%	13	Low
CVT0619	Shelburne Road	1.08	5	143.6	370.2	US Highway	0	Good	Fair	2	Partially Compatible	2	Low	3	Reduced AOP	14.7%	12	Low
CVT0849	Interstate 189	1.24	5	270.2	571.2	Interstate	0	Fair	Good	2	Partially Compatible	2	Low	3	No AOP	8.4%	12	Low
CVT0890	Kennedy Drive	0.60	2	30.5	156.8	Municipal Road	0	Good	Fair	2	Partially Compatible	2	High	6	Full AOP	29.2%	12	Low
CVT0970	Queen City Park Road	0.66	2	19.5	66.8	Municipal Road	0	Good	Poor	6	Mostly Compatible	1	Low	3	Reduced AOP	17.5%	12	Low
CVT0572A	South Burlington Recreation Path	0.95	2	33.7	70.9	Trail	0	Fair	Good	2	Mostly Compatible	1	High	6	Reduced AOP	14.9%	11	Low
CVT0632	UVM Hort Farm	1.77	5	42.2	44.6	Trail	0	Fair	Good	2	Mostly Compatible	1	Low	3	Reduced AOP	21.8%	11	Low
CVT0841	Interstate 189	0.91	2	712.1	1,706.6	Interstate	0	Poor	Good	4	Partially Compatible	2	Low	3	Reduced AOP	14.3%	11	Low
CVT0868	Dorset Street	0.86	2	303.4	480.9	Municipal Road	0	Good	Fair	2	Mostly Compatible	1	High	6	Full AOP	19.8%	11	Low
CVT0677	Midland Avenue	1.33	5	105.6	126.4	Municipal Road	0	Fair	Fair	4	Mostly Compatible	1	None	0	Reduced AOP	6.6%	10	Low
CVT0678	Midland Avenue	1.33	5	105.6	126.4	Municipal Road	0	Fair	Fair	4	Mostly Compatible	1	None	0	Reduced AOP	6.6%	10	Low
CVT0679	Midland Avenue	1.33	5	105.6	126.4	Municipal Road	0	Fair	Fair	4	Mostly Compatible	1	None	0	Reduced AOP	6.6%	10	Low
CVT0852	Interstate 189	0.71	2	520.9	1,743.4	Interstate	0	Fair	Fair	4	Mostly Compatible	1	Low	3	Full AOP	16.3%	10	Low
CVT0861	Spear Street	1.38	5	447.2	544.4	Municipal Road	0	Good	Good	0	Partially Compatible	2	Low	3	Reduced AOP	16.4%	10	Low
CVT0963	Kennedy Drive	0.93	2	10.6	22.0	Municipal Road	0	Fair	Fair	4	Mostly Compatible	1	Low	3	No AOP	46.1%	10	Low
CVT0990	Dorset Street	0.90	2	97.7	143.2	Municipal Road	0	Poor	Poor	8	Fully Compatible	0	None	0	Full AOP	10.1%	10	Low
L04032	Indian Creek	0.97	2	30.6	46.3	Private Road	0	Poor	Poor	8	Fully Compatible	0	None	0	Full AOP	24.6%	10	Low
CVT0837	Queen City Park Road	0.78	2	640.3	2,117.5	Municipal Road	0	Fair	Good	2	Partially Compatible	2	Low	3	Full AOP	14.2%	9	Low
CVT0883	Kennedy Drive	1.28	5	297.3	455.1	Municipal Road	0	Fair	Fair	4	Fully Compatible	0	None	0	Reduced AOP	20.2%	9	Low

*discharge at which flow crests roadway

**higher scores = higher priority for structure replacement

Structure ID	Location	Prioritization Criteria													Additional Criteria		Prioritization Scoring	
		Hydraulic Capacity		Roadway Overtopping Risk				Overall Structure Condtion			Geomorphic Compatability (GC)		Erosion Level					
		HW/D (Design Storm)	Subscore	Design Storm Discharge (cfs)	Roadway Overtopping Discharge (cfs)*	Road Type	Subscore	Headwall Condition	Pipe Condition	Subscore	GC Score	Subscore	Erosion Level	Subscore	AOP Coarse Score	Buildout % Impervious Cover Increase	Overall Prioritization Score**	Overall Priority
B	Shelburne Street	0.67	2	622.4	3,349.9	State Highway	0	Fair	Good	2	Mostly Compatible	1	Low	3	Reduced AOP	14.2%	8	Low
CVT0653	Patchen Road	0.90	2	84.2	339.4	Municipal Road	0	Fair	Poor	6	Fully Compatible	0	None	0	Reduced AOP	8.6%	8	Low
CVT0814	South Burlington Recreation Path	0.84	2	28.4	55.7	Trail	0	Poor	Good	4	Mostly Compatible	1	None	0	Reduced AOP	4.8%	7	Low
L06115	Interstate 189	0.71	2	30.4	116.9	Interstate	0	Good	Good	0	Partially Compatible	2	Low	3	No AOP	9.1%	7	Low
CVT0607	Harbor View Road	0.83	2	66.0	147.5	Municipal Road	0	Good	Good	0	Mostly Compatible	1	Low	3	Reduced AOP	21.4%	6	Low
CVT0740	River Cove Road	0.59	2	638.3	1,635.6	Municipal Road	0	Good	Good	0	Mostly Compatible	1	Low	3	Full AOP		6	Low
CVT0811	Park Road	0.76	2	23.9	83.5	Municipal Road	0	Poor	Good	4	Fully Compatible	0	None	0	Reduced AOP	5.9%	6	Low
CVT0838	Farrell Street	0.70	2	491.6	1,310.7	Municipal Road	0	Good	Good	0	Mostly Compatible	1	Low	3	Full AOP	14.3%	6	Low
CVT0911	Spear Street Recreation Path	1.66	5	9.8	17.0	Trail	0	Good	Good	0	Mostly Compatible	1	None	0	No AOP	2.4%	6	Low
CVT0922	Interstate 89	0.83	2	156.2	521.7	Interstate	0	Good	Good	0	Mostly Compatible	1	Low	3	Full AOP	8.6%	6	Low
L04297	Railroad	0.60	2	642.7	3,949.3	Railway	0	Good	Good	0	Mostly Compatible	1	Low	3	No AOP	14.3%	6	Low
L08714	Interstate 189	0.63	2	78.9	360.3	Interstate	0	Fair	Fair	4	Fully Compatible	0	None	0	Reduced AOP	5.8%	6	Low
A	Champlain Parkway	0.76	2	718.8	2,312.1	State Highway	0	Fair	Good	2	Mostly Compatible	1	None	0	Full AOP	14.2%	5	Low
CVT0021	Hinesburg Road	0.55	2	273.4	1,322.8	State Highway	0	Good	Good	0	Fully Compatible	0	Low	3	Full AOP	21.6%	5	Low
CVT0738	Williston Road	0.78	2	1,129.1	3,328.1	US Highway	0	Good	Fair	2	Mostly Compatible	1	None	0	No AOP	7.1%	5	Low
CVT0739	National Guard Avenue	0.52	2	969.6	2,781.5	Municipal Road	0	Good	Good	0	Fully Compatible	0	Low	3	Full AOP	7.6%	5	Low
CVT0847	Interstate 89	0.57	2	175.7	853.0	Interstate	0	Good	Good	0	Fully Compatible	0	Low	3	Full AOP	11.6%	5	Low
CVT0609	Shelburne Road	0.54	2	114.7	581.1	US Highway	0	Good	Good	0	Partially Compatible	2	None	0	Reduced AOP	19.8%	4	Low
CVT0600	Railroad	0.56	2	168.7	1,000.4	Railway	0	Good	Good	0	Mostly Compatible	1	None	0	Reduced AOP	16.0%	3	Low
CVT0664	Hinesburg Road	0.67	2	17.5	46.2	State Highway	0	Good	Good	0	Mostly Compatible	1	None	0	Reduced AOP	3.4%	3	Low
CVT0729	Nowland Farm Road	0.66	2	21.0	109.8	Municipal Road	0	Good	Good	0	Mostly Compatible	1	None	0	Reduced AOP	0.1%	3	Low
CVT0731	Nowland Farm Road	0.66	2	21.0	109.8	Municipal Road	0	Good	Good	0	Mostly Compatible	1	None	0	Reduced AOP	0.1%	3	Low
CVT0768	Fayette Road	0.61	2	44.2	117.6	Municipal Road	0	Good	Good	0	Mostly Compatible	1	None	0	Reduced AOP	5.3%	3	Low
CVT0856	Dorset Street	0.54	2	181.6	826.8	Municipal Road	0	Good	Good	0	Mostly Compatible	1	None	0	Reduced AOP	10.9%	3	Low
CVT0859	Interstate 189	0.95	2	481.6	1,228.2	Interstate	0	Good	Good	0	Mostly Compatible	1	None	0	Full AOP	16.3%	3	Low
CVT0680	Dorset Street	0.92	2	137.5	248.9	Municipal Road	0	Good	Good	0	Fully Compatible	0	None	0	Reduced AOP	7.7%	2	Low
CVT0735	Interstate 89	0.72	2	1,082.5	2,494.6	Interstate	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	6.5%	2	Low
CVT0735B	Interstate 89	0.52	2	1,082.5	4,550.5	Interstate	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	6.5%	2	Low
CVT0848	Interstate 89	0.54	2	177.6	839.0	Interstate	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	11.5%	2	Low
CVT0857	Interstate 89	0.83	2	466.6	2,703.7	Interstate	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	16.8%	2	Low
CVT0939	Railroad	0.71	2	40.5	151.0	Railway	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	5.9%	2	Low
CVT0966	Songbird Road	0.57	2	48.8	176.5	Municipal Road	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	25.0%	2	Low

*discharge at which flow crests roadway

**higher scores = higher priority for structure replacement

Structure ID	Location	Prioritization Criteria													Additional Criteria		Prioritization Scoring	
		Hydraulic Capacity		Roadway Overtopping Risk				Overall Structure Condtion			Geomorphic Compatability (GC)		Erosion Level					
		HW/D (Design Storm)	Subscore	Design Storm Discharge (cfs)	Roadway Overtopping Discharge (cfs)*	Road Type	Subscore	Headwall Condition	Pipe Condition	Subscore	GC Score	Subscore	Erosion Level	Subscore	AOP Coarse Score	Buildout % Impervious Cover Increase	Overall Prioritization Score**	Overall Priority
L03765	Meadowland Drive	0.81	2	62.5	155.4	Private Road	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	18.2%	2	Low
L08694	Interstate 89	0.58	2	39.0	255.2	Interstate	0	Good	Good	0	Fully Compatible	0	None	0	Reduced AOP	32.3%	2	Low
L09905	Windswept Lane	0.46	0	29.3	160.0	Municipal Road	0	Fair	Good	2	Fully Compatible	0	None	0	Reduced AOP	18.3%	2	Low
CVT0737	Marshall Avenue	0.24	0	1064.5	15228.7	Municipal Road	0	Good	Good	0	Mostly Compatible	1	None	0	Full AOP	7.0%	1	Low
CVT0798	Moss Glen Lane	0.36	0	72.5	481.7	Municipal Road	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	17.0%	0	Low
CVT0802	Moss Glen Lane	0.48	0	76.4	525.5	Municipal Road	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	16.7%	0	Low
CVT1004	Market Street	0.45	0	105.6	889.7	Municipal Road	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	9.4%	0	Low
L07461	Harbor Heights	0.36	0	6.5	67.8	Private Road	0	Good	Good	0	Fully Compatible	0	None	0	Full AOP	13.6%	0	Low

*discharge at which flow crests roadway
**higher scores = higher priority for structure replacement

6.3 Proposed Condition Hydraulic Modeling and Conceptual Designs

Proposed condition hydraulic models and conceptual designs were completed for six high-priority culverts. Factors considered for conceptual design included culvert ownership, watershed size, and culvert condition. Proposed culvert dimensions were selected based on the field-observed bankfull width of the stream. All proposed culverts pass the design storm without overtopping. Conceptual designs showing a plan and profile view of both the existing and proposed culverts were created for each selected high-priority culvert. See **Table 14** for a summary of the proposed conditions hydraulic modeling and **Attachment M** for the conceptual designs.

Table 14: Conceptual Design Existing and Proposed Conditions

Structure ID	Location	Observed Bankfull Width	Existing Conditions		Proposed Conditions	
			Structure	Overtopping Flow	Structure	Overtopping Flow (Storm)
CVT0013	Ethan Allen Drive	8’	24” CPP	33.1 cfs (5-year storm)	8’ x 6’ Concrete Box Culvert	560.1 cfs (>100-year storm)
CVT0758	Bartlett Bay Road	9’	24” RCP	47.1 cfs (2-year storm)	9’ x 6’ Concrete Box Culvert	417.4 (>100-year storm)
CVT0769	National Guard Avenue	3.8’	24” CMP	30.4 cfs (10-year storm)	48” CMP	88.9 cfs (>100-year storm)
CVT0821	Brewer Parkway	7’	24” CMP	34.1 cfs (2-year storm)	7’ x 6’ Concrete Box Culvert	737.5 cfs (>100-year storm)
CVT0835	Swift Street	6’	36” CMP	19.5 cfs (2-year storm)	6’ x 6’ Concrete Box Culvert	251 cfs (>100-year storm)
CVT0928	Williston Road	5’	18” RCP	13.7 cfs (2-year storm)	60” x 46” CMPA	147.0 cfs (>100-year storm)

7.0 Conclusions and Next Steps

This comprehensive culvert assessment represents an extensive effort to assess the condition, hydraulic capacity, and replacement prioritization of stream culverts within the City of South Burlington. The City-wide nature of this assessment far exceeds the geographic scales of previous culvert assessments within CSB, which took place over a decade ago. The culvert inlet and outlet location data, as well as information about pipe size, material, and condition, provide opportunities to improve existing stream crossing data in the City's asset management system.

This assessment provides a roadmap for the City to address problematic and deficient crossing culverts. The prioritization conducted during this assessment represents a first step and we expect that the City will consider factors not included in this report, including road rehabilitation priorities, nearby utility upgrades, and projected project costs in their final prioritization of crossing structure replacements. The conceptual plans provided for priority City stream crossings provide a starting point for the design process. Additional final design and permitting efforts will be required to prepare these projects for implementation.

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