Vermont Statewide Historic Stone Culvert Inventory

National Register of Historic Places
Multiple Property Documentation Form

Stone Highway Culverts in Vermont
1750 to 1930

Building a stone culvert on Parrish Road, Williamsville, Vermont. Photograph by Porter C. Thayer, 1909, courtesy of Porter Thayer Photograph Collection, University of Vermont, and the William Thayer Family.

Prepared for:
Vermont Agency of Transportation, Environmental Section, Montpelier, VT

Prepared by:
Historic Documentation Company, Inc., Portsmouth, RI

August, 2017

NPS Form 10-900-a OMB No. 1024-0018
(March 1992)

United States Department of the Interior
National Park Service

National Register of Historic Places
Multiple Property Documentation Form

This form is used for documenting multiple property groups relating to one or several historic contexts. See instructions in How to Complete the Multiple Property Documentation Form (National Register Bulletin 16B). Complete each item by entering the requested information. For additional space, use continuation sheets (Form 10-900-a). Use a typewriter, word processor, or computer to complete all items.

__X_ New Submission ____ Amended Submission

A. Name of Multiple Property Listing

Stone Highway Culverts in Vermont

B. Associated Historic Contexts

(Name each associated historic context, identifying theme, geographical area and chronological period for each.)

Stone Highway Culverts in Vermont 1750 to 1930.

C. Form Prepared by

name/title Richard M. Casella, Suzanne Jamele, Jessica Goerold, Architectural Historians

organization Historic Documentation Company, Inc. **date** August 2017

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city or town Portsmouth **state** RI **zip code** 02871-4229

D. Certification

As the designated authority under the National Historic Preservation Act of 1966, as amended, I hereby certify that this documentation form meets the National Register documentation standards and sets forth requirements for the listing of related properties consistent with the National Register criteria. This submission meets the procedural and professional requirements set forth in 36 CFR Part 60 and the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation. (See continuation sheet for additional comments.)

_______________________________________ _______________
Signature and title of certifying official Date

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State or Federal agency and bureau

I hereby certify that this multiple property documentation form has been approved by the National Register as a basis for evaluating related properties for listing in the National Register.

_______________________________________ _______________
Signature of the Keeper Date of Action

Stone Highway Culverts in Vermont
Name of Multiple Property Listing)

Vermont
State

Table of Contents for Written Narrative

Provide the following information on continuation sheets. Cite the letter and the title before each section of the narrative. Assign page numbers according to the instructions for continuation sheets in How to Complete the Multiple Property Documentation Form (National Register Bulletin 16B). Fill in page numbers for each section in the space below.

Page Numbers

E. STATEMENT OF HISTORIC CONTEXTS

Introduction

Stone highway culverts, being small structures located beneath the roadway and out of sight of the motoring public, have received scant attention from the historic preservation community. This inventory and study of Vermont's stone highway culverts is a direct outgrowth of a project conducted in the neighboring state of New Hampshire in 2008 and is believed to be the second statewide survey of the resource type.[1] That study was conceived, designed and funded in 2007 by the New Hampshire Department of Transportation with technical assistance from the New Hampshire Division of Historical Resources. The New Hampshire project prompted students in the University of Vermont's (UVM) Historic Preservation Program to undertake a study of stone culverts in four Vermont towns to fulfill the Community Project requirement of their graduate program. The UVM study was completed in 2013, with assistance from the Environmental Section of the Vermont Agency of Transportation (VTrans).[2] The interest generated by the UVM study and the need to manage proposed work involving stone culverts, prompted VTrans to develop this project to inventory stone highway culverts in the 237 towns in Vermont. Funding was obtained from Federal Highway Administration (FHWA) and research and fieldwork commenced in late 2014. [3]

Due to similarities of geology, topography, history and development of Vermont and New Hampshire, the characteristics of the historic stone highway culverts found in the two states are alike. Much of the historic contexts developed for New Hampshire's stone culverts, including types, periods of construction, materials, design and methods of construction are included in this report. Up until the last decade of the 19th century when state highway departments were forming, the building of stone highway culverts was entirely a local undertaking. The actual builders were sometimes masons by trade, but more often farmers and road builders adept at moving and stacking fieldstone for walls and foundations, and splitting and trimming slabs of rock taken from outcrops or boulders too big to move. It is rarely possible to attribute a stone highway culvert to a particular person and therefore the context associated with their design and workmanship can be considered generic and vernacular and applicable across wide a geographic area, in this case New England.

Culvert Origins

Culverts are believed to have originated over two millennia ago with man's desire to drain away surface water to claim swampy land for cultivation. Archaeological remains indicate the Romans drained their arable lands in Europe and England with both open and covered drains.

[1] National Register of Historic Places Multiple Property Documentation Form. "Stone Highway Culverts in New Hampshire." Prepared by Richard M. Casella, Historic Documentation Company, Inc., Portsmouth RI, for NHDOT, Concord NH, August 2008.
[2] "Identifying Historic Stone Culverts in Vermont." Prepared by Samantha Ford, Jessica Goerold & Elissa Portman for the University of Vermont Historic Preservation Program Community Project, Fall 2013, Professor Robert McCullough. Project coordination and assistance provided by Jeannine Russell and Brennan Gauthier, Vermont Agency of Transportation Environmental Section.
[3] The project was managed by the Vermont Agency of Transportation Environmental Section, with direct supervision by Jeannine Russell, Archaeology Officer, and Brennan Gauthier, Archaeologist.

About 600 BC Etruscan engineers built a narrow open channel with masonry walls through Rome to drain a low-lying swampy area into the Tiber and claim the land for what would become Forum Romanum. Less than ten feet wide, it was covered with stone and brick arches by Marcus Agrippa about 33 BC to run under roads and buildings. It became known as *Cloaca Maxima* – literally Greatest Sewer. Parts of it survive today and serve as an example of early stone arch culvert design.

When low swampy areas are crossed with roads on earthen causeways, culverts provided a means of equalizing the level of the water on either side, thereby preventing the causeway from acting as a dam and becoming saturated, soft and unstable. Early American roads typically skirted wetlands due to the cost of building a filled road. Turnpikes and other roads built by subscription or otherwise well-funded were an exception and usually followed as straight a line as economically possible. Railroads on the other hand, typically crossed wetlands since maintaining a flat grade and straight course reduced operating costs and justified the expense of a filled causeway. Surviving stone culverts on abandoned turnpikes and railroad lines provide the earliest examples in New England.

The basic design of stone box and stone arch culverts developed from the ancient practices of stone slab and stone-arch bridge construction and remained unchanged for highway applications right up to their demise in the early 20th century. The design and sizing of stone culverts based on engineering principles, i.e., the mathematical analysis of the structural and hydraulic requirements of a culvert for a particular application, was developed by railroad engineers in the mid-19th century. Stone highway culverts on the other hand, were built intuitively by local road builders and were very rarely the product of calculations. It was not until the early 20th century and the introductions of concrete and steel highway culverts that the hydraulic engineering principles developed by railroad engineers were applied to highway culverts.

Defining Culverts

The term *culvert* has been given varying general and technical definitions over the last century:

- *Webster's Unabridged Dictionary*, 1903: "A passage under a road or canal, covered with a bridge; an arched drain for the passage of water." In this case, a road is considered either a highway or a railroad.
- *Encyclopaedia Britannica, 14th Edition*, 1928: "It is frequently necessary to make a passage for water under roads, railways, banks, canals, etc. The drain made to carry the water in such cases is called a culvert. It may be either flat or arched, and is usually built strongly of stone or brickwork. The introduction of ferro-concrete affords a ready means of constructing culverts strongly and economically. The derivation of the word is apparently from the French *couloir*, a water-way."[4]
- *Oxford English Dictionary*, 1989: "A channel, conduit, or tunneled drain of masonry or brick-work conveying a stream of water across beneath a canal, railway embankment, or road; also applied to an arched or barrel-shaped drain or sewer. In connexion with railways and highways, it is sometimes disputed whether a particular structure is a 'culvert' or a 'bridge.' The essential purpose of a *bridge*, however, is to carry a road at a desired height over a river and its channel, a chasm, or the like; that of a *culvert* to afford a passage for a small crossing stream under the embankment of a railway or highway, or beneath a road where the configuration of the surface does not require a bridge."[5]

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[4] "Culvert," *Encyclopaedia Britannica* [14th ed.] (New York: Encyclopaedia Britannica, Inc, 1928): 858.
[5] Oxford English Dictionary, 1989.

- Walter Webb, railroad engineer, 1900: "Although a variable percentage of the rain falling on any section of country soaks into the ground and does not immediately reappear, yet a very large percentage flows over the surface, always seeking and following the lowest channels. The roadbed of a railroad is constantly intersecting these channels, which frequently are normally dry. In order to prevent injury to railroad embankments by the impounding of such rainfall, it is necessary to construct waterways through the embankment through which such rain flow may freely pass. Such waterways, called culverts, are also applicable for the bridging of very small although perennial streams, and therefore in this work the term culvert will be applied to all water channels passing through the railroad embankment which are not of sufficient magnitude to require a special structural design, such as is necessary for a large masonry arch or a truss bridge."[6]
- Solomon Hollister, structural engineer, 1924: "A culvert is a conduit constructed through embankments for the purpose of conducting small streams or surface water. Culverts may range in size from sectional pipe up to structures, which are in themselves practically small bridges. Culverts having spans in excess of 25 to 30 feet are usually considered bridges."[7]
- John Bateman, highway engineer, 1947: "A culvert is a drain for carrying surface water under roadways as opposed to a bridge, which carries a roadway over a watercourse or ravine. Bridges also are defined as structures having separate superstructures and substructures whereas the two are combined in a culvert. Some highway organizations differentiate between culverts and bridges on the basis of the span length, 6 to 12 feet being commonly taken as the dividing line."[8]
- Federal Highway Administration, 2002: "A structure designed hydraulically to take advantage of submergence to increase hydraulic capacity. Culverts, as distinguished from bridges, are usually covered with embankment and are composed of structural material around the entire perimeter, although some are supported on spread footings with the streambed serving as the bottom of the culvert. Culverts may qualify to be considered “bridge” length."[9]

The distinction between bridges and culverts by engineers charged with inspecting and maintaining their safety has been mostly based on span length. The Federal Highway Administration's *Bridge Inspector's Training Manual* considers structures beneath highways less than 20 feet in span to be culverts. This classification is partly based on the 1968 Federal Highway Act mandating each state to institute a bridge inspection program for bridges 20 feet and longer on federal highways. But calling all structures less than 20 feet culverts ignores bona-fide bridges under 20 feet and sows confusion. Numerous states, including New Hampshire, define culverts as structures with spans less than 10 feet, and bridges as structures with spans 10 feet or greater, but this miscategorizes drainage structures over 10 feet span buried in highway embankments that are technically culverts. Vermont does not simply classify under-road structures as either bridges or culverts, but instead calls them Long Structures – bridges with a span greater than 20 feet; Short Structures – bridges and culverts with a span between 6 and 20 feet; and Ultra-Short Structures – less than 6 feet in span or diameter. To further confuse matters, VTrans keeps a list known as the Small Culvert Inventory, of all structures under 6 feet that it maintains on state roads. Since the parameters of *what is a culvert* continues to vary depending on the circumstances of who is using the term and why, those studying culverts need to understand how information and data pertaining to their structures is classified.

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6 Walter L. Webb. *Railroad Construction, Theory and Practice* (New York: John Wiley & Sons, 1900): 202-203.
7 Solomon C. Hollister, "Culverts," in Hool, George A. and Kinne, W. S., Editors, *Reinforced Concrete and Masonry Structures* (New York: McGraw-Hill Book Co., 1924): 579.
8 John H. Bateman, *Introduction to Highway Engineering.* (New York: John Wiley & Sons, Inc., 1947): 48-49.
9 U.S. Department of Transportation, Federal Highway Administration. *Bridge Inspector's Reference Manual.* (2002).

Highway Culverts

"The progress of civilization has everywhere been marked by good roads. It may even be said to be largely due to them."[10] The story of the evolution of the stone highway culvert in Vermont naturally follows the progress of road and highway development, beginning in the late 18th century, advancing through the 19th century and into the early 20th century. James Garvin, former NH State Architectural Historian was one of the first preservation professionals to recognize the historical importance of stone highway culverts:

> "Stone highway culverts are among the earliest and potentially most enduring of highway structures, being built from the era of first settlement down to the late nineteenth and early twentieth centuries, when vitrified clay, concrete, and corrugated metal culverts became available to supplant them. Constructed to prevent the erosion of early roads during times of high water and to avoid the need to ford small streams, stone culverts introduced several of the methods and materials of early bridge building on a small scale. Although often overlooked in the history of transportation, stone culverts represent some of the earliest examples of vernacular engineering in the New England landscape."[11]

Although the widespread use of stone culverts ended with the introduction of manufactured pipe culverts, in rocky environs like New England, where abundant fieldstone, granite outcrops and able stone workers abound, the building of stone culverts persisted into the early 20th century as a practical alternative to the other less permanent types.

Stone highway culverts have received very little scholarly attention. The engineering literature of the 19th century pertaining to road engineering contains sparse mention of culverts and only in general terms. In some cases the terms "typical" or "standard" are used in conjunction with "stone culvert," giving the impression that their features of design should be common knowledge. This makes tracing the introduction and development of stone highway culverts difficult. Much has been written on Roman roads but none of the sources examined discuss the building of culverts under them. Perhaps historians ignored them due to their commonness and apparent insignificance.

The term culvert came into use in France about 1770 in connection with canal construction and later with railways, highways, and town-drainage. "It has been conjectured to be a corruption of the French words *couloir*, a waterway, or *coulouëre*, a channel, gutter, or any such hollow, along which melted things are to run', or *couler*, to flow. On the other hand some think 'culvert' an English dialect word, taken into technical use at the epoch of canal-making."[12]

The works of the two early 19th century Englishmen usually credited with the development of modern road design, engineer Thomas Telford and road-builder John L. Macadam, are well treated in the literature. The principal of paving the road with small clean angular stone that unites into a solid mass under traffic is often attributed to Macadam, while Telford advanced the idea of using a foundation layer of larger stones under the pavement to promote drainage and

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[10] Francis V. Greene. "Roads and Road-Making," *Harpers Weekly* 33 (August 10, 1889):633.
[11] "Proposal and Scope of Work for Statewide Planning and Research Project: Asset Management for Stone Highway Culverts, New Hampshire, Dating to 17th to 20th Centuries." Prepared by NHDOT by James Garvin, Joyce McKay and Nadine Peterson. February, 2007.
[12] Oxford English Dictionary, 1989.

prevent the smaller paving stone, called road metal, from sinking into soft ground. Although Telford and Macadam deserve the credit for modernizing England's road system, their ideas were employed much earlier by the French engineer Pierre-Marie-Jerome Tresaguet. In 1764 Tresaguet proposed roads of a layered-stone design with a heavy stone under-course and a smaller-stone top course. Tresaguet roads were built throughout France beginning about 1775.[13] Although the design principals of all three men largely hinged on the importance of proper road drainage, their writings apparently do not discuss the proper design and use of culverts.

In America, even the best early roads built by subscription were constructed by "plowing two furrows, about twenty feet apart, and then scraping the loose earth into the middle to form the road; the surface of marshes was covered with a layer of tree trunks, placed close together affording a foundation passable but disagreeable to travel. In the spring and during wet periods even the best roads were mere quagmires."[14]

In 1802 the U.S. Congress enacted legislation to build roads with funds raised from the sale of land in Ohio and in 1806 construction of the Cumberland Road was begun following the methods of Macadam and Telford. The purpose of the road, which extended from Cumberland, Maryland through southwestern Pennsylvania, to Wheeling, West Virginia, was to "cement the bond of union between the coast states and the interior," and provide a road suitable for "moving heavy ordnance." [15] The Cumberland Road, also called the National Road, was later continued on to Illinois. By 1856 the federal government had transferred all ownership and jurisdiction of the road to each of the states it passed through. Presumably small stone bridges and culverts would have been built along the way where stone was cheaply available, but whether any have been described or survive was not determined.

Vermont Road Development

In Vermont in the mid-to-late 18th century, early roads were laid out in some areas of the interior along property lines coinciding with the edges of a range of square or rectangular parcels of land.[16] Known as range roads and cross range roads, they were typically two to four rods wide (a rod equals 16.5 feet) but occasionally up to ten rods wide.[17] Like other early New England roads, range roads were undoubtedly equipped with rudimentary bridges and culverts of timber construction with the occasional use of dry-laid stone abutments where conditions warranted it and field and rubble stone were readily available. The road system of Vermont as it existed in at the end of the 18th century is depicted on a map created by J. Reid in 1796.[18]

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13 R. J. Forbes, "Roads to c.1900." In *A History of Technology, Volume IV.* Charles Singer, E. J. Holmyard, A. R. Hall and T. I. Williams, Editors. (New York: Oxford University Press, 1958): 526-527.
14 Charles L. Whittle, "Ancient and Modern Highways." *New England Magazine* 17 (February 1898):763.
15 *Ibid.*
16 James L. Garvin, "Range Roads." In *Old Stone Wall* (Newsletter of the New Hampshire Division of Historical Resources, Concord, NH), Spring 2002. Christopher J. Lenney. *Sightseeking. Clues to the Landscape of New England.* Durham, NH: University of New Hampshire Press, 2005.
17 J. W. Goldthwait, "Old Range Roads in New Hampshire," *New Hampshire Highways* (December, 1930):4.
18 J. Reid "Vermont from the latest Authorities." New York: J. Reid, 1796. In Vermont State Highway Department [& US Bureau of Public Roads], *Report of a Survey of Transportation on the State Highways of Vermont.* Washington: U.S. Government Printing Office, 1927.

Following the Revolution, the newly established state governments granted privileges to private enterprises for the construction of toll roads known as turnpikes. Virginia passed the first turnpike act in 1785; the earliest turnpikes in Vermont were in the Champlain Valley and chartered beginning in 1800. Turnpikes were generally located and built as entirely new roads, but in some cases existing roads were acquired and utilized.[19] Covered bridges built by the turnpike companies have been noted, but there is no mention of culverts in the literature reviewed. Turnpike construction was usually pushed hard at least expense to open the road and collect revenue; the first bridges and culverts along the turnpikes would have almost exclusively of timber construction.[20]

By the mid-19th century most of Vermont's private toll roads were returned to the jurisdiction of the towns they passed through due to the failure of their owners to properly maintain them as required by their charters. Up until the end of the 19th century, towns acted independently of each other in the management and maintenance of their roads, resulting in great variance in their passability. This condition became increasingly recognized by the State as a detriment to the economic advancement of its people.

During the late 19th century there was an effort throughout the United States to improve highways of the country which called attention to the defects of the roadway systems. Known as the Good Roads Movement, it created interest in immediate reform of the methods of constructing and maintaining roads. The Legislatures of nearly every state considered one or more bills designed to improve roadways.

Good Roads Movement

The origins of the Good Roads Movement movement in America begins shortly after the Civil War with calls for better roads by engineers. In 1870 Clemens Herschel of Boston wrote an essay entitled "The Science of Road Making." [21] Considered one of the earliest and most important discussions on proper road building, it won first prize in a competition for papers on good roads sponsored by the Massachusetts State Board of Agriculture. Herschel provided the following advice on culverts:

> It is very bad policy to make culverts of wood, unless indeed they are so situated as to be constantly under water; the cost of replacing them after the embankment and road has been built over them is disproportionately great. They should be made of stone, or brick; lately of vitrified stone-ware, or cement drain-pipe, oval or egg-shaped, has been used to advantage in their construction.

Other engineers soon joined the discussion, often mentioning culverts and their opinions on the merits of stone versus pipe culverts:

- The basis of all road improvement is drainage, both surface and subsoil. The road surface may possess different degrees of excellence but it is always better with an underdrained base than without one. The road should be crowned 8" with wide ditches on each side to carry the runoff

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[19] Frederick J. Wood. *The Turnpikes of New England* (Boston: Marshall Jones Company, 1919.): 215-216, 247-248.
[20] See: J. W. Goldthwait, “Six Old New Hampshire Turnpikes,” *New Hampshire Highways* (July-December 1932).
[21] Clemens Herschel, "The Science of Road Making," *Engineering News* 4 (June 2, 1877): 148. The essay was later expanded and printed in book form under the same title in 1890.

to the nearest watercourse. An improvement over the small box culvert is the pipe; the ends are often secured with light stone walls – a better method is to extend pipe and protect with riprap at a slope of one to one.[22]

- A point too often neglected in constructing a gravel road is the consideration of the proper size and position of the culverts. Stone culverts must be built of good-sized, well-shaped quarry stone, 6-8" thick, 2 feet wide with parallel beds, laid dry, making walls 2 feet thick. No space in joints not to exceed 1 inch, and exposed stones at ends of culverts to be squared and pitch-faced.[23]
- Stone culverts are too bulky for many of the occasions for cross-drainage beneath highways. The low, rough broad conduit is much more liable to choke with silt, rubbish and ice in a frosty country than the cheaper smooth iron pipe would be, near the surface, where it can feel the warmth of every thaw as snow and ice does.[24]
- In some localities good stone is plentiful and cheap, and this fact, with perhaps other local considerations, will sometimes make it seem best to reject the use of pipe and to construct a stone culvert. In nearly every case rough rubble masonry will answer every purpose.[25]

The movement for better roads gained momentum during the last two decades of the 19th century. In 1889 alone dozens of articles appeared, not just in the technical publications like *Municipal Engineering, Journal of the Franklin Institute*, and *Engineering News*, but in popular magazines such as *The American, Harper's Weekly, Scribner's Magazine,* and *Scientific American.* Many of the technical papers stressed the importance of drainage in road design and the need for proper culverts but few mentioned specific designs of culverts for highway use.[26]

Periodicals devoted to highway improvement sprung up: the League of American Wheelmen, a national bicycling organization, began publishing a *Bulletin* in 1885 which was renamed *Good Roads* in 1895. Another organization called "The Good Roads Movement" published *Highways* magazine about the same time.

According to Professor Emory Johnson of the University of Pennsylvania, "The marked inferiority of the highways in America as compared with those of European countries has led to an earnest attempt by several states to inaugurate a reform."[27] Among the earliest "reformers" were the progressive states of Massachusetts and Vermont who passed road legislation in 1892 followed by New York in 1893.

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22 C.G. Elliott, "Road Improvement," *Engineering News and American Contract Journal* 15 (March 13, 1886): 161.
23 Charles C. Brown, "Gravel Roads," *Engineering News and American Contract Journal* 15 (April 24, 1886): 262.
24 James B. Olcott, "Road Making and Maintenance," in Haupt, Lewis M., *Essays on Roadmaking and Maintenance and Road Laws* (Philadelphia: University of Pennsylvania Press, 1891): 128.
25 Ontario Legislative Assembly. "Stone Culverts," Sessional Papers (No. 36) Legislature of the Province of Ontario, (1894): 51.
26 In 1890 C. Frank Allen, a member of the Boston Society of Civil Engineers published a comprehensive paper entitled "Roads and Road Building" that elicited wide ranging discussion on the specifics of the road bed design but little comment on culverts. The California Roads Convention of 1892 included numerous papers on the need for good roads including one by W.E. McClintock of the Massachusetts Highway Commission. See "Good Country Roads" *Engineering Record* 29 (December 23, 1893): 58.
27 E. R. Johnson, "The Improvement of Country Roads in Massachusetts and New York," *Annals of the American Academy of Political and Social Sciences* 5 (September 1894): 269.

Vermont Highway Commission & State Funding for Better Roads & Culverts

In 1892 the Vermont General Assembly passed "the first legislation providing for State participation in highway improvement and established the principle of State aid in the improvement of Vermont highways."[28] The law provided for the election of a road commissioner in each town in order to place responsibility for the roads in one man instead of several and the collection of a state tax to be used to provide State Aid to towns for road improvement and maintenance. A state Highway Commission was created to examine the state's highway system and make recommendations to the legislature for its improvement.

It was found that until the late 19th century the state's roads were unpaved and with the exception of the gravel, none of the natural soils were fit to be used alone in road construction. The soils were too light and unstable to withstand the traffic over them and the disintegrating effect of water and frost. The roads required continued attention and repair. The 1894 Vermont Highway Commission's Biennial Report (Report) stated that it was chiefly for this reason that the money then expended on the highways of Vermont was almost all spent on repairs, and that little new or permanent work was accomplished. As a result, Vermont had a system of highways that was difficult and expensive to maintain and the poor condition of the roads put a severe strain on all traffic that used them. A large proportion of the highway funds were expended in repairing the damage done to the hill roads by storm waters.

The 1894 Report included standards for construction and maintenance of roadways and encouraged the use of crushed stone or macadam wherever possible to improve road surfaces and durability. The state encouraged towns to establish the most commonly used roads as "permanent roads" and to reconstruct them with more longlasting materials, thus decreasing the on-going need for costly repairs. In regards to culverts, the Report encouraged new ones be constructed of stone and when replacing old wood culverts they too should be stone and enlarged where necessary.

> Wherever it is necessary to carry the water across the road a culvert is needed. This should be of durable material, ample size and well constructed. Stone is the best material to use in Vermont. The foundations should be safe from frost, the side walls well laid up and the top covered with flat stones or an arch. Above the top of the culvert should be filled sufficient material to protect it from injury—a precaution often neglected. Other materials which answer well for culvert work, especially for the smaller sizes, are iron pipe and tile. These need to be well laid, protected at the ends from undermining by the water, and above from crushing by the traffic.[29]

The 1894 Report included a portion of the the 1893 Brattleboro Selectmen's Report on the state of roadwork in their town:

> Another important factor concerning practical economy in road management are the bridges. The policy of a town in Vermont the last four years has been to replace wooden culverts and bridges, as fast as they wear out, with stone bridges, built entirely of stone, roading and all. Where one opening cannot be made large enough for the stream with stone covers, two or more openings are

[28] Vermont State Highway Department [& US Bureau of Public Roads], *Report of a Survey of Transportation on the State Highways of Vermont.* Washington: U.S. Government Printing Office, 1927, p. 9.
[29] Vermont Highway Commission, *Report of the Vermont Highway Commission.* Burlington VT: Free Press Association, 1894, p. 40.

> made. It has been demonstrated many times that stone bridges can be built, where stone is close by, for less money than to renew with wood.[30]
>
> If culverts are necessary, build them deep down under the roadway. For a common box drainage culvert, dig a trench four feet deep, six feet wide, build two side walls, two feet high, two feet thick, and two feet apart. Cover the opening with strong flat stones, not less than four feet long; fill the space at each end of these cover-stones with small stones, never with earth; then cover 18 inches with gravel. This makes a culvert two feet square, and being deep under the road will not be marred by the shock of travel or the action of frost. Make the outlet free and ample.[31]

The 1896 Vermont Highway Commission Report continued advocating for roads to be improved with better surfaces of gravel, stone or macadam. It noted the interest in suitable roads had been raised all over the State, due in part to the spread of information in regard to good roads, to the increase of summer travel upon the roads, and last, but not least, to the very large number of bicycle riders using the roads.[32]

Town road commissioners were reminded that the state tax money could be used for construction of culverts of stone, iron pipe or vitrified tile built in a substantial and workmanlike manner and examples of work recently undertaken as reported by road commissioners were provided:[33]

- I used for culverts split granite for the walls, and limestone ledge for covers about 3 by 4 feet and 6 inches thick.
- Thirteen culverts were built of stone, from 3 to 4 feet in width and from 16 to 18 feet in length. They cost about six dollars apiece, where the wooden ones cost from two to three dollars. I think the stone ones much the cheaper, and would advise everybody to use stone and tile in most places in Vermont.

In 1898 the Legislature passed *An Act to Improve the Public Roads, and Establish the Vermont Highway Commission* and among its provisions were standards for the construction of culverts.

> Every section of road that is rebuilt must be properly drained. Wherever it is necessary for water to cross the road to reach a lower level substantial conduits must be built of stone or tile large enough to take all the water that will come to that place in times of floods or violent storms. Conduits of stone that are two feet span or more, and those of tile that are ten inches or more in diameter, will be considered culverts. Stone culverts must be not less than two feet span, with substantial side walls on good foundation. The covering stones to be well chinked upon the walls to give even bearings. Cracks between covering stones to be covered with flat stones. The whole should be covered with broken stone and finished with gravel. Culverts may be built on any of the main public roads where those made of wood need repairing. Conduits and culverts are often made too small, not large enough to take the water -large enough for ordinary conditions, but should be made for the extraordinary occasions. The heaviest storm ever known will be repeated and should be provided for, or the road will surely be destroyed. Since the law defines culverts as not exceeding four feet in span, I have learned that it has been the policy of selectmen of some towns to insist that small bridges, on being repaired, be reduced to culverts, that they may hereafter be maintained out of the highway fund. This is the reverse of good management. Most

[30] Ibid., p. 52.
[31] Ibid., p. 54.
[32] *Report of the Vermont Highway Commission,* 1896, p. 13.
[33] Ibid., pp. 34, 38.

> of the culverts and small bridges should be enlarged rather than diminished in size. The damage done to roads by every summer storm inconsequence of insufficient drainage is great, and in large measure is preventable. The main thing in maintaining an earth road is to get rid of the water as quickly as possible.

The Third Biennial Report of the Vermont Highway Commissioner, issued in 1904, reported on the progress of culvert improvements throughout the state:[34]

> At the beginning of State aid there was no part of the highways in worse condition than the small bridges called culverts. They were made of wood and in all degrees of decay and dilapidation. Who cannot remember when riding along the country roads of the frequent holdups to a slow walk to get safely over an old dilapidated plank culvert. The planks were loose, helterskelter or broken, generally the old log sides were displaced or decayed, the culvert doing little or no service except to annoy the traveler. We have encouraged and advised the town commissioners to extend the work of building permanent culverts. There is a sense in which this is the foundation of all good country road work. The durability and welfare of roads depends upon them. We have been pleased to note that a few towns have used their entire apportionment some years in building culverts. In the past four years there have been built in the State 4,555 culverts of stone or tile, at a cost of $49,538.52. These make but little show, nevertheless they are there, in every town in the State and no money has been better invested than that used for their building. There has been an inclination to do culvert work too cheaply, in such a way that it has to be done over again, insufficient walls, cracks left uncovered between covering stones. Regulations have been changed to correct this defective work and limiting the size to nothing less than two feet for stone and ten inches for tile. The use of vitrified tile for culverts has increased and proves satisfactory when used under right conditions and the Work properly done.

In 1906 the Highway Commissioner continued the discussion of culvert improvements made using state funds:

> The old plank culverts have very largely disappeared having been replaced by the more substantial ones of stone, or tile, or steel, and in this line of work, as in road building the material at hand is first considered. Towns in Orleans, Washington, and other counties are building fine split granite culverts from native stone. Towns in Rutland County are using marble for the same purpose and other towns are using slate and other stone, while still others in the absence of proper stone are using tile, and steel with a few experimenting with concrete with good success. Cut No. 14 represents a culvert built at East Montpelier with common field stone care being taken to cut out or select proper blocks for sides and cover to give it strength and the balance were used as illustrated (Figure 1). Cut No. 15 represents one of the split granite culverts as built in Orleans County with native stone (Figure 2). These cuts of roads and culverts illustrate the variety of work that has been and is being done with State money on our highways and with two exceptions they illustrate what can be done in towns with limited means with common materials used in a common sense way.

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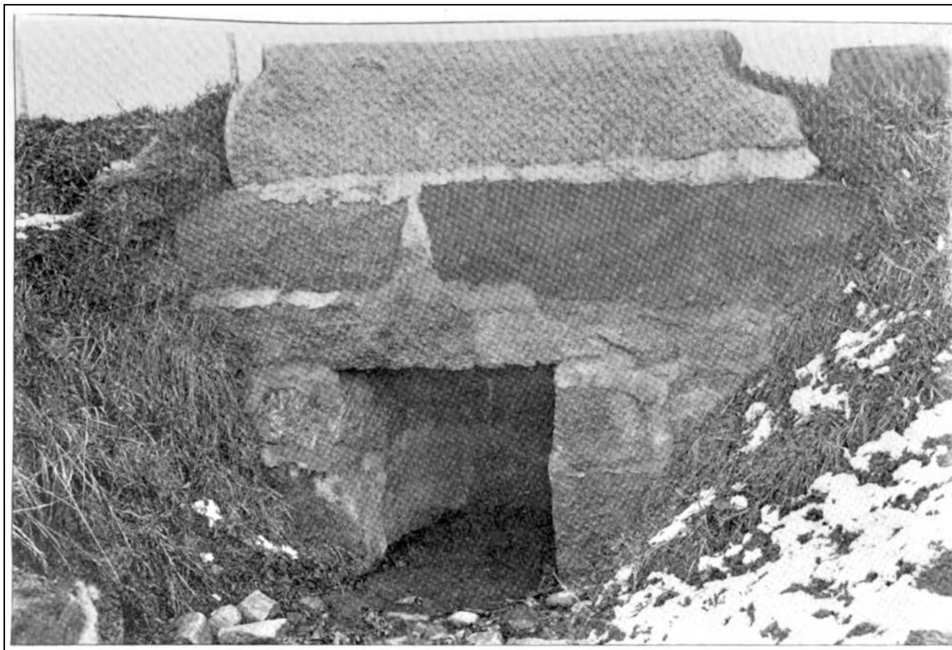
[34] *Third Biennial Report of the Vermont Highway Commissioner*, 1904, pp. 7, 18, 19.

Cut No. 14—Stone culvert built in East Montpelier in 1897. 3½x3½x30 with 18 foot fill.

FIGURE 1: Stone culvert built in East Montpelier, c. 1905 (Vermont Highway Commissioner, 1906).



Cut No. 15—Stone culvert built in Glover in 1905.

FIGURE 2: Stone culvert built Glover, c. 1905 (Vermont Highway Commissioner, 1906).

In 1906 the Vermont Legislature passed Act No. 111 that required the Highway Commissioner to prepare a manual of rules and regulations for the expenditure of state funds on highways. In March 1907 the Commissioner published *Bulletin No. 1: State Aid Laws and General Directions for Building Improved Highways*, which included detailed instructions for the construction of stone, tile, concrete and steel pipe culverts for which towns could seek state funding. The guidelines noted that "the use of concrete is increasing rapidly and culverts properly built of this material are proving, in many respects, superior to all others and are recommended wherever conditions would seem to warrant their use."[35] The following instructions were given for building stone culverts:

> Claims may be made for stone culverts of from two (2) to four (4) feet span built on any of the main highways. Wherever the foundation is defective an excavation should be made from four to six (4 to 6) inches deeper than the bottom of the proposed culvert and at least two (2) feet wider than the walls to be built. The bottom of the excavation should be paved with even sized stones, placed carefully by hand, leaning toward the mouth of the culvert. This pavement should be well rammed down and the walls of the culvert built on this foundation of good substantial stone well laid. The covering stones should reach well over on each wall and should be well chinked to give an even bearing, and all joint cracks carefully covered with flat stones. The walls should be backed up with small and broken stones, and the whole covered with broken stone and finished with gravel. In very soft soils flagging stones for the bottom are preferable if long enough to receive the Side walls. In hard or gravelly soils, where the conditions do not call for a special foundation, the paving of the bottom may be omitted, but the other specifications followed as given. Wing walls are often necessary to protect the heads of culverts and should be substantially built where needed. Special care should be taken to provide a free inlet and outlets to all culverts so that water may find its way quickly and freely through them.

Stone Highway Culvert Types

Stone highway culverts in Vermont as in other New England states are of two main types: box culverts and arched culverts. Box culverts have vertical stone walls that carry stone slabs spanning the opening. Arch culverts are essentially small versions of stone arch bridges and consist of stones arranged to form an arched opening by wedging against one another. Usually the arch stones are wedge-shaped, sometimes naturally occurring but usually shaped with hammer and chisel. Both box and arch culverts take various forms that are considered as sub-types. A more detailed description of the culvert types studied is presented in "Section F: Associated Property Types."

Stone box culverts with natural slabs or quarried lintels spanning the opening were seldom if ever the product of design by a structural engineer. [Note: the difference between slabs and lintels is in their width, lintels being narrower]. When the span of a box culvert reaches bridge length, 10 feet in states including New Hampshire and Massachusetts, or 6 feet in Vermont, they are typically called stone slab bridges. The great variability in the strength of stone, especially when acting as a beam in the case of slabs and lintels spanning an opening, along with the inability to see internal flaws or fine cracks, has limited the use of stone by engineers to only very short spans in which a large factor of safety can be assumed. In stone arches on the other

[35] Vermont Highway Commissioner. "Bulletin No. 1: State Aid Laws and General Directions for Building Improved Highways," In *Fifth Biennial Report of the Vermont Highway Commissioner*, 1907-1908, p. 32.

hand, the stones are in compression and spans can be safely designed to reach beyond 200 feet. Spans greater than about 30 feet, especially segmental or elliptical arches of low rise – so-called flat arches – impose huge forces on the arch stones and abutments and have usually been the product of an engineer's calculations.

Culverts typically differ from bridges in their structural and hydraulic characteristics. Since culverts are usually in highway or railroad embankments and covered by earth fill, they must carry a large dead load depending on the type and depth of the cover material. In bridge design, dead loads are to be minimized, but in the case of stone culverts the cover fill plays beneficial structural role by distributing a portion of the vertically imposed live loads laterally away from the roof stones of the culvert. The roadway embankment can also act as a dam. During flood events that exceed the hydraulic capacity of the culvert, the culvert becomes submerged and operates under hydraulic pressure which can damage the culvert and embankment if they are not designed for submergence.

Stone Box Culverts

A stone box culvert consists of a series of stone slabs laid adjacent to one another the length of the culvert, spanning between two stone channel walls. Structurally, the slab functions as a simple beam, one of the oldest forms of construction. In architecture, a beam supported at each end to create a opening in a wall and carry a section of wall or roof members is known as a lintel. Known as post and lintel, post and beam, or column and beam construction, early forms in wood or bound papyrus reeds may date back several hundred thousand years. The oldest stone examples that have been accurately dated are nearly 6000 years old, Stonehenge in England, built 3800 years ago, being a well-known example. The Greeks elevated column and beam construction to an art form, exemplified by the Parthenon, built c. 448 BC.

The idea of using stone slabs resting on stone walls (abutments) and piers to bridge a watercourse must also be many thousands of years old, but surviving examples are difficult to date. Where slabs of stone were readily available, early man undoubtedly muscled them into a resting place atop other stones to bridge streams. The earliest of England's famous "clapper" bridges are dated to the late Bronze Age. They consist of massive granite slabs resting on piers of roughly stacked stones. The name clapper derives from the Anglo-Saxon word 'cleaca' meaning, "bridging the stepping stones." The most famous is Post Bridge in Dartmoor, England built about 1000 BC which has four granite slabs 15' long and 6' wide, each weighing in excess of eight tons.[36]

The extent to which Native Americans manipulated stone for building in the Northeast, other than forming piles or mounds of stones known as cairns, remains open to speculation. Stones were undoubtedly rearranged in streambeds to provide stepping-stones for crossing, but methodically built stone bridges of arch or slab design have not been attributed to Native Americans. The English and other early immigrants with stone masonry skills apparently introduced the first stone slab bridges and box culverts to America.

[36] Eric deMare'. *The Bridges of Britain.* (London: B.T. Batsford Ltd., 1954): 36-37.

Stonemasons built box culverts intuitively. They assessed the character and strength of the available stone and judged the thickness needed to span a given opening on the basis of experience and perhaps testing. Precise calculation of the strength of stone in tension is seldom possible: it is a natural substance of varying composition with unknown internal imperfections. Invisible hairline cracks, inherent or induced during quarrying, transporting, prying or lifting, are the most serious and beyond the control of the engineer. Stone has great strength in compression but little in tension and a beam must have great tensile strength in its lower half to span wide openings. Reinforced concrete beams and slabs with lines of steel rods placed near the bottom to resist tensional forces were introduced to bridge building at the end of the 19th century and soon eliminated further use of stone slabs for large culverts and bridge spans. Stone box culverts survive by the hundreds in the New England states with 120 inventoried as part of this study in Vermont alone.

Stone Arch Culverts

Arched stone culverts are either semi-circular or segmental arches. The span and rise of a semi-circular arch is equal, meaning its span and its rise increases in direct proportion. The simplicity of semi-circular arches makes them suitable for short-span culverts in high embankments. Representing only a segment of a circle, the segmental arch has a span greater than its rise and provides a larger opening with less material and labor than a semi-circular arch. The advantage of a larger opening, however, comes with the cost of heavier abutments to withstand the greater thrust of a segmental arch. The segmental arch occurs very rarely in culvert spans under ten feet, but are fairly common in spans between ten and twenty feet where their use is typically associated with the need for a wide waterway opening in a low embankment.

The oldest known so-called true arch, or voussoir arch, as distinguished from pointed and corbelled arches, was discovered in Iraq in the 1930s and dates to roughly 3500 BC. The Romans were the first to employ the voussoir arch in bridge building, using only semi-circular arches from about 241 BC to about 200 AD.[37] The first use of the segmental arch for a bridge is credited to Li Ch'un, a Chinese engineer who designed the Great Stone Bridge over the Chiao River in the 5th century AD.[38] The segmental arch bridge was introduced in Europe, during the Renaissance. French engineer Phillippe de la Hire was the first to develop methods for analyzing the forces acting on arches.[39]

Hundreds of notable stone arch bridges were built throughout the world during the first half of the 19th century. In the United States monumental examples were built mostly by the railroads,

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[37] Rudyard A. Jones, "The Origin of the Voussoir Arch." *Civil Engineering* (April 1941): 259: Jean-Pierre Adam, *Roman Building Materials and Techniques.* Translated by Anthony Mathews. (Bloomington, Indiana: Indiana University Press, 1994): 162.
[38] Roland Turner and Steven L. Goulden, Editors. *Great Engineers and Pioneers in Technology* (New York: St. Martin's Press, 1981): 118.
[39] la Hire described his graphical method of analyzing forces acting on bodies in equilibrium, known as graphic statics today in his 1695 *Traite de Macanique*. For arches, la Hire proposed his smooth voussoir theory, which ignored friction between stones and employed force diagrams using polygons, later called the line of force method. Turner and Goulden, 1981, pp. 227-228.

all semi-circular arches.[40] By the mid-19th century the use of the stone arch was in rapid decline due to the advent of truss bridges of wood and iron, all iron, and finally all steel construction. For large culverts however, the stone arch remained the first choice of railroads into the early 20th century for its ability to carry high dead loads and withstand high water flows.[41] It is estimated that many dozens of stone arch highway culverts survive in the New England states, however only one was inventoried as part of this study in Vermont.

Field and Ledge Stone – Worked and Unworked

The types of stonework found in Vermont's stone culverts is dependent on the source of the stone and the degree to which the stone has been worked. Unworked stone is loose stone found in fields or at ledge outcrops small enough to be moved and stacked as-is, by one or two men, to form the walls and roof of a culvert. Pry bars and a stone boat pulled by ox or horse – the same tools used to clear fields of rocks for crops and build fieldstone walls – were all that was needed to build small culverts. Worked stone is stone that has been split, chipped or cut using iron tools to alter its size or shape so it can be moved or better utilized for the purpose. Splitting large fieldstones or mining rock from ledge outcrops or quarries was done using simple iron hand tools in use for centuries including hammer, chisel, drill and wedge of various types. Once split into large but movable pieces, often with just one or two split faces, the stone might take the form of a flat slab suitable for the roof of the culvert or the base of the culvert wall. Split stone was often further worked with a hammer, or hammer and chisel, to shape or "square-up" the stones to stack more tightly together in a wall.

Splitting and Quarrying Stone

From about 1780 on, stone was split in New England by hand using the flat wedge method or the plug and feather method. The flat wedge method uses a hammer and cape chisel with a flat and pointed cutting edge that creates narrow rectangular slot into which a flat wedge is inserted between two flat shims. A series of holes about 2" deep and spaced about 4" apart were cut along the desired split line and the shims and wedges inserted. The wedges are then sequentially tapped with a hammer until the rock splits. Stone split with that flat wedge method are identified by the shallow flat slots along the split edge of the stones.

The plug & feather uses a hammer and a plug drill that creates a round hole into which two shims called feathers are inserted with a wedge called a plug between them. The holes are generally about 1" in diameter and 3" deep and spaced every six inches or so apart in a line. This

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[40] Important early monumental stone arch bridges in the US include the Carrollton Viaduct (1829) on the B&O Railroad, High Bridge (1839-1848) part of the Croton Aqueduct in New York City and Starrucca Viaduct (1847) in Susquehanna, Pennsylvania. See: Albert W. Buel, "The Merits and Permanency of the Masonry Arch Bridge." *Engineering Magazine*, 17 (April, 1899): 31; Ted Ruddock, *Arch Bridges and Their Builders, 1735-1835.* (London: Cambridge University Press, 1979): 175-178; H. G. Tyrrell, *Concrete Bridges and Culverts, For Both Railroads and Highways.* (Chicago: The M.C. Clark Pub. Co., 1909): 83-85; Charles S. Whitney, *Bridges: A Study in Their Art, Science, and Evolution.* (New York: W. E. Rudge, 1929): 183,186.

[41] *Ibid*., p. 639.

method came into use in New England about 1820 and allowed easier quarrying of granite from ledges. Prior to that time, the plug and feather method entailed the drilling of only three holes, which produced more erratic pieces and was usually limited to use on glacial boulders.[42] Stone split with the plug and feather method are identified by the evenly-spaced half-round holes along the split edge of the stones.

Stone for culverts often came from commercial quarries when they were near enough to the culvert site to justify the cost of transportation. In quarries large sections of rock were broken using explosives and then split into smaller pieces by men using the plug and feather method. Quarry rubble stone consisting of pieces of odd size and shape known as quarry waste or spoil was sold cheap. In the 1860s machine rock drills powered directly by steam or compressed air were introduced that could bore holes at ten-times the speed of hand drilling and greatly lowered the cost of cut stone. Lintels used in building construction, particularly "seconds" that were left unfinished due to some defects, were also bought at quarries and used for the culvert roof or "cover" stones. At the end of the 19th century Vermont developed a state highway commission that provided funds for the improvement of highways and specifically the building of stone culverts. With a source of funds for reimbursement of the costs, town road builders probably obtained more uniform stone from local quarries when they could.

Stone Masonry Types

The patterns and styles of stone masonry wall construction take many forms depending on the degree to which the stone has been worked or finished, the amount of labor expended in constructing the wall and the purpose of the wall. Stone masonry is often divided into two broad categories, rubble masonry and ashlar masonry, each with several subtypes can lead to confusion. Ashlar typically consists of carefully cut and squared stone of uniform size laid in courses. Rubble masonry utilizes unworked or minimally worked stone of uneven size laid without coursing.

In general, culverts may be constructed of fieldstone or rubble, split stone, or cut stone squared and smoothed to varying degrees of finish. The terms fieldstone and rubble implies local loose stone gathered and laid-up as-is with little if any cutting or trimming to improve the fit. Coursed rubble or coursed fieldstone walls exhibit an effort by the mason to periodically level-off the work to keep the forces in vertical alignment to the greatest degree possible. A chipping hammer is used to roughly shape the more irregular stones. Uncoursed rubble work is randomly laid with no attempt at horizontal coursing and with a large amount of "chinking" – using small stones to fill the irregularly shaped gaps between the larger stones.

Cut stone is typically dimension stone – specified to be of a certain uniform size enabling it to be laid in equal parallel courses known as range-work. The term cut stone, as used during the 19th century implies hand-cut as opposed to machine cut and includes stone that is squared and dressed using a hammer and a variety of specialized chisels.

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[42] James L. Garvin, "Granite Splitting Tools and Techniques," (no date). Manuscript on file at New Hampshire Division of Historical Resources, Concord.

Highway culvert walls are often built as low in height as practical in order to limit the height of the roadway and the need for fill. The lower the masonry wall the less pressure exerted on it by the backfill and the less need for careful and tightly fitted stonework. Rubble masonry suffices for most small culverts; ashlar masonry is more commonly found in large and tall culverts and with high energy streams that require the most durable stonework.

Dry Laid versus Mortared Stone Masonry

Dry laid stone masonry is simply stone stacked without the use of mortar between the stones; mortared being the opposite. Roughly ninety percent of Vermont stone highway culverts surveyed are dry laid. Essentially all smaller culverts built with field and rubble stone were laid without mortar. The New Hampshire study concluded that nearly all stone culverts built prior to about the 1880 were dry-laid and the same may be presumed of Vermont's culverts. Prior to the introduction of Portland cement to the US in 1868, hydraulic-cement mortars were prohibitively expensive for most common masonry work and local masons and road builders simply did not possess it. Simple lime mortars used in building construction disintegrate in water and were not used for culvert or bridge masonry. Hydraulic-cement mortars harden under water and withstand indefinite submergence. It was not until 1880 that large-scale manufacture of Portland cement was fully underway in the US and its use became widespread.[43] The use of cement mortar to fill the gaps between unsquared stones provided a uniform bearing between stones and bonded the entire structure together solidly. Random stone no longer needed to be laboriously selected and fitted tightly or trimmed for a good fit.

However, for culverts, dry-laid masonry was preferred by many builders because it provided a flexible and porous structure that allowed water in the backfill to drain between the joints and the stones to move slightly when subjected to freezing or excessive loads – movement that can fracture and pulverize mortar.

Engineered Culverts

Stone culverts may be engineered structurally, hydraulically, or both. A structurally engineered culvert is one that has been designed by calculating the strength of the stone and the masonry design so that it can resist the loads that will be exerted on it. Loading calculations include the dead load consisting of the weight of the overlying fill and roadway and live loads consisting of the weight of the vehicles passing over it and pressures exerted by water, ice and vibration. Hydraulic engineering involves the sizing of the culvert opening according to the principals of fluid dynamics to accommodate the maximum anticipated flow of water. The physical design of the culvert can have a large influence on its hydrodynamic characteristics. Design variables include slope of culvert, length, form of cross section, the roughness of the channel surfaces, and

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[43] Portland cement was patented in 1824 by Joseph Aspin, an English bricklayer who named it for its resemblance to a high quality quarry stone from Portland, England. It was first used in mortars and concrete in applications where hydraulic characteristics were needed. For more on hydraulic cement mortars see: Frank E. Kidder, *Kidder-Parker Architects' and Builders' Handbook.* (New York: John Wiley & Sons, Inc., 1904):194-195; Baker, *Masonry Construction* 1904, pp. 51-53;

the form of the approach, inlet and outlet. Sizing is a straightforward calculation, but first the engineer must calculate the maximum anticipated flow of water– runoff – that will reach the culvert opening, a difficult calculation based on assumptions. To estimate the runoff the area of the watershed must be calculated and its slopes and character of its soils and vegetation measured. A peak rainfall amount is assigned and formulas developed by railroad engineers in the 1870s applied.[44]

Some stone railroad culverts, particularly long culverts set near the bottom of high fills, were designed to function submerged under a head of water pressure proportional to the height of the water above the top of the culvert. This practice was used both to reduce the cost of long culverts and as a precaution against rare and extreme runoff events like those resulting from cloud bursts or coincidences like heavy rain during a period of sudden heavy snow melt.

Engineered stone culverts were almost exclusively a product of the railroads who had major liabilities resting on the ability of a culvert to resist washout. Surviving stone highway culverts in Vermont appear to have been designed entirely by local intuition and do not exhibit evidence of structural or hydraulic engineered design.

[44] Calculation of the required area of waterway for a culvert using formulas was practiced at least as early as the 1870s. Culverts are mentioned in the engineering literature as having been sized "according to Trautwine" or "by Trautwine's handbook." The reference is to the Civil Engineer's Pocket-Book, first published by John C. Trautwine in 1876. Trautwine recommended using the "Buerkli-Ziegler formula" for calculating rainfall runoff, and then provided a table for selecting the proper culvert opening based on the flow rate. "Talbot's formula," proposed in 1888 by Professor A. N. Talbot of the University of Illinois, required more complicated calculations but became the one most generally employed by engineers. See: Ira O. Baker, *A Practical Treatise on Masonry Construction*. New York: John Wiley & Sons, 1910.

F. ASSOCIATED PROPERTY TYPES

Stone highway culverts in Vermont are of two types, box culverts and arched culverts. The field survey accompanying this report inventoried 119 box culverts and one arch culvert in Vermont. Arches are typically used for longer spans than box structures can achieve and in Vermont structures over 6 feet span are categorized as bridges. Both types vary in span and opening size depending on the nature of the watercourse they conduct, and vary in length depending on the width of the roadway they carry. Each type also exhibits variations in materials, design and workmanship that are dependent on several factors discussed below.

Stone highway culverts were built in locations where permanent or seasonal streams of small volume intersect the routes of range roads, turnpikes and highways. In Vermont stone culverts are mostly dry-laid without the use of mortar between the joints. Nearly half the culverts, particularly smaller culverts under about 3 feet, are built entirely with fieldstone without evidence of splitting or working the stone with tools. Culverts with larger openings up to 6 feet and in some cases larger, require long flat cover stones that are uncommon as fieldstones and must be split from large boulders, outcrops or quarried. Large culverts, especially those with tall openings to provide a larger waterway opening, benefit from more tightly fitted stones that have been squared-up on site or obtained from quarries in uniform split and cut sizes that can be moved and placed by two men. Finely built culverts of ashlar masonry survive under highways near some of Vermont's many quarries.

Vermont's surviving stone culverts, all expected to be 100 years or more in age, exhibit a range of structural integrity from good to poor. The onslaught of Hurricane Irene in 2011 destroyed culverts of all types in its path including many historic stone culverts. In some cases new culverts of large diameter corrugated plastic pipe have replaced them and the stone from the destroyed culvert reused to build the inlet and outlet walls (Figure 3). About 10 percent of the culverts surveyed are clogged or partly buried with sediment and/or debris and in extreme danger of being overtopped and "washed out" in a flood event. About 20 percent of the culverts exhibit damage such as displaced or lost stones, broken cover stones, or partial collapse of facewalls or sidewalls and may or may not retain integrity depending on the severity of the condition and the potential for practical repair. Culverts often show signs of repair made over the years, including restacking, pointing the joints with cement mortar, or the installation of corrugated metal pipe through the culvert. Such alterations do not always ruin the historical or structural integrity of the resource and should be evaluated on a case-by-case basis. [See Integrity Evaluation section below].

FIGURE 3: Post Hurricane Irene culvert on Hobby Hill Road, Newfane, using plastic pipe and stone salvaged from preceding culvert.

STONE BOX CULVERT PROPERTY TYPE:

Description

Box culverts have vertical stone sidewalls across which span stone slabs or lintels that in turn carry fill and the roadway **(Figure 4)**. The sidewalls, or channel walls, would be considered abutments in bridge structures. Stones that span an opening act as beams, tending to bend under their own weight and under the weight of loads applied to it. The bending stresses are concentrated at the middle of the span where the upper half of the beam is under compression and the lower half is under tension. Stone is weak in tension, therefore the allowable spans of stone beams is very limited and a function of the type and quality of the stone and its thickness.

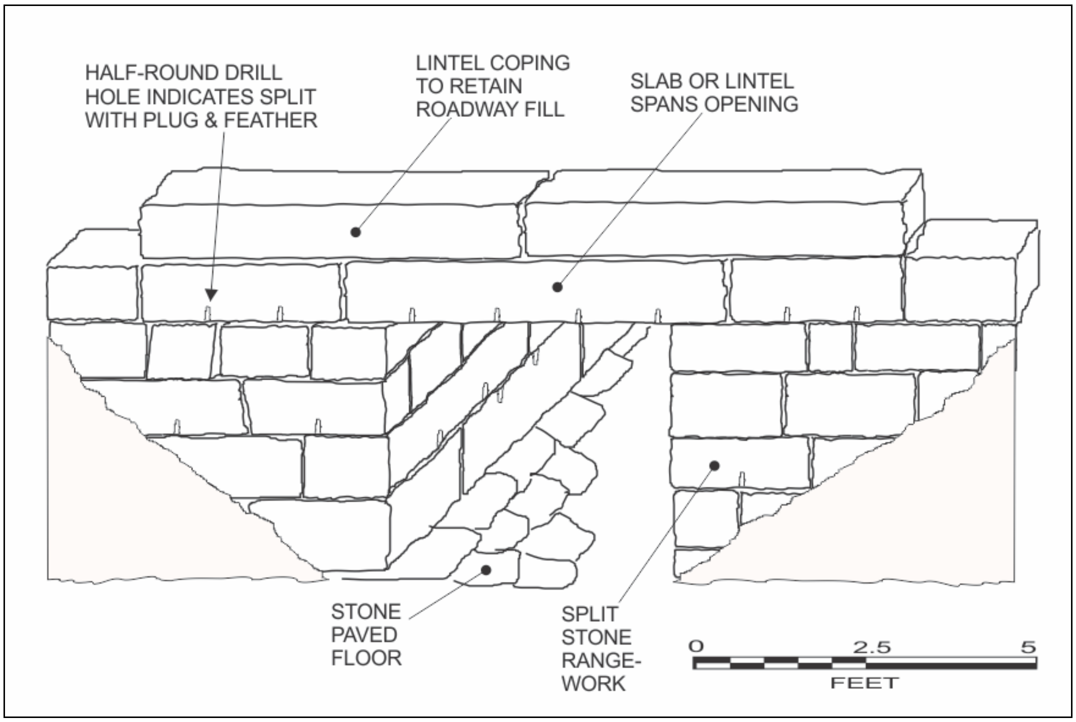

FIGURE 4: Typical box culvert of split and cut granite quarry stone. See Figure 5 for a typical Vermont example.

The difference between slabs and lintels is their width dimension, lintels being narrower. Length is the stone's longest dimension, usually used to span the culvert opening. Depth is the vertical thickness of the stone. The depth of the stone beam must increase as its length increases in order to maintain the same strength and carrying capacity. Width is the variable that distinguishes slabs from lintels: lintels are commonly as wide as they are deep (square) or nearly so, while slabs may be many times as wide as thick, limited only by the ability to quarry, handle, and transport them. Lintels are typically 8, 10 and 12 inches square since they were used in brick wall construction over door and window openings. Long lintels, generally over 8 feet, may be deeper than wide, for example, a typical 10-foot lintel might be 12" wide by 16 inches deep.

FIGURE 5: Box culvert of split and cut granite quarry stone on Sterling Hill Road, Barre Town (Inventory # WA-BAT-005).

In Vermont the average span of stone box culverts identified in the survey is about 38" with the maximum being 80" and the minimum 12 inches. Stone spans (culverts or bridges depending on the state) rarely exceed 10 feet in span and generally attain lengths over 5 feet only when high quality granite stone is readily available like in New England. The largest span stone box culvert in the survey is located near granite quarries in Barre Town and shown in **Figure 6**.[45]

When a large culvert opening was needed to handle freshets and flood events there were two additional ways to increase the total area-of-waterway or opening area other than simply increasing the span: increase the height of the culvert opening or increase the number of culvert openings. If the roadway was high above the streambed, or could be readily raised in height, then the culvert sidewalls could be increased in height to give the opening a tall narrow rectangular shape rather than the more common square or horizontal rectangular shape. A culvert of exceptional vertical opening size located in Windham is shown in **Figure 7**.

[45] Other stone slab span structures with spans over 72" and classified as bridges may exist in Vermont but were not surveyed as part of this study. One surveyed culvert on Kelton Road in East Montpelier (WA-EAS-003) has a span of 119" but is now a concrete slab span with other concrete additions added at some time.

FIGURE 6: This box culvert of split and cut granite quarry stone on Sterling Hill Road in Barre Town (WA-BAT-001) is the longest span culvert surveyed with an opening 84" wide and and 24" high.

In rare cases, box culverts with more than two waterway openings – also called channels, cells or barrels – were built. Although several double channel and a four channel box culvert survive in New Hampshire, none were recorded in the Vermont survey.

Box culverts may be constructed of fieldstone or rubble, split stone, or cut stone squared and smoothed to varying degrees of finish. The terms fieldstone and rubble implies local loose stone gathered and laid-up as-is without cutting or trimming to improve the fit. Coursed rubble or coursed fieldstone walls exhibit an effort by the mason to periodically level-off the work to keep the forces in vertical alignment to the greatest degree possible and provide a tighter and more stable wall. A chipping hammer is used to roughly shape the more irregular stones. Random rubble work is laid with no attempt at horizontal coursing and typically requires a large amount of "chinking" – using small stones to fill the irregularly shaped gaps between the larger stones. Chinking fills gaps to retain the backfill but equally importantly locks the wall together by insuring contact between adjacent stones which distributes the load and prevents shifting and loosening of the stones. **Figure 7 and Figure 8** show typical fieldstone construction.

FIGURE 7: This extraordinary box culvert in on Windham Hill Road in Windham (WI-WIN-001), has a large area of waterway opening, with a 54" opening width (span) and 102" opening height. It is built entirely with fieldstone, some of astounding size that would have required several oxen to move and probably an A-frame derrick to place. The upstream facewall reaches a total height of over 25 feet. When the highway was widened, the culvert was lengthened with the addition of a concrete box structure and concrete block facewall on the downstream side, shown in Figure 17 below.

The nature of split stone depends on its geology and varies widely by locality and quarry. Fine grain Vermont granite can be split evenly along straight lines to yield lintels and blocks of uniform size with a rough but relatively planar surface. Lintels that break are sold as-is in random lengths, the ends cut and squared up by the mason and used to build tight range-work walls. Split stone used in culverts may also be the product of boulders and ledge outcrops "quarried" by the mason from the immediate area. Rock outcrops with distinct bedding planes often split naturally from freeze-thaw weathering producing flat rubble and slabs of uniform thickness that are ideal for wall building.

FIGURE 8: Wiswall Hill Road, Newfane (WI-NEW-003). This rubble and fieldstone box culvert consists mostly of flat rubble stone with no evidence of splitting. The stone was evidently gathered from an outcrop that had naturally broken up along its thin bedding planes – a desirable source of wall stone. The dry-laid masonry utilizes stones of all shapes and sizes and small chinking stones to achieve a tight and stable wall. But the use of large round fieldstone boulders at the base (at lower left) that are more easily displaced than flat stone, was a poor decision.

Cut stone is typically dimension stone – specified to be of a certain uniform size enabling it to be laid in equal parallel courses known as range-work. Ashlar-work also uses cut squared stone, but of unequal sizes resulting in uneven courses. The term cut stone, as used during the 19th century implies hand-cut as opposed to machine cut and includes stone that is squared and dressed using a hammer and a variety of specialized chisels (**see Figures 5, 9).**

FIGURE 9: White Hill Loop, Morgan (OL-MOR-001). This box culvert consists of quarry split and cut granite mostly of imperfectly squared shapes and random sizes, offered by the quarry at less cost than stone cut to uniform dimensions. Not the stone floor with drop outlet which helps prevent clogging.

FIGURE 10: Goldwaite Road, Chester (WN-CHE-008). This field and rubble stone box culvert was built on a stream bed of exposed ledge, an ideal foundation were it not sloping. The "downhill" channel wall was not given sufficient buttressing and has slipped to the point of imminent collapse, in part due to the oblique loading of the massive cover stone.

FIGURE 11: Jenneville Road, Hartland (WN-HRL-002). This 4-foot box culvert was built with fieldstone walls and 12" x 16" x 80" split lintel spans which seem a typical size, probably "rough stock" from a local quarry. Note the large pre-cast concrete blocks used to extend the channel beyond the outlet; the alteration does not significantly diminish the historic integrity of the resource.

STONE ARCH CULVERT PROPERTY TYPE:

Description

The arched stone culvert stone arch culvert is rare in Vermont with only one surveyed and inventoried in this study. The rarity of arched stone culverts is primarily due to their high cost, due to the more specialized materials, labor, and construction methods usually required to build them. For those examples exhibiting the highest workmanship, the size and number of arch stones or *voussoirs* required must be calculated and then each stone carefully cut and fitted. Heavy timber formwork known as centering must be constructed in the streambed in the shape of the finished arch. The arch stones are then erected on the forms and wedged against one another. When the arch is completed, the centering is dropped and pulled out of the culvert. Small culverts do not lend themselves readily to arched construction due to the difficulty in removing the centering. Arches are therefore used for spans exceeding those of stone slabs, generally the range of 10 to 20 feet at which point they are usually classified as bridges.

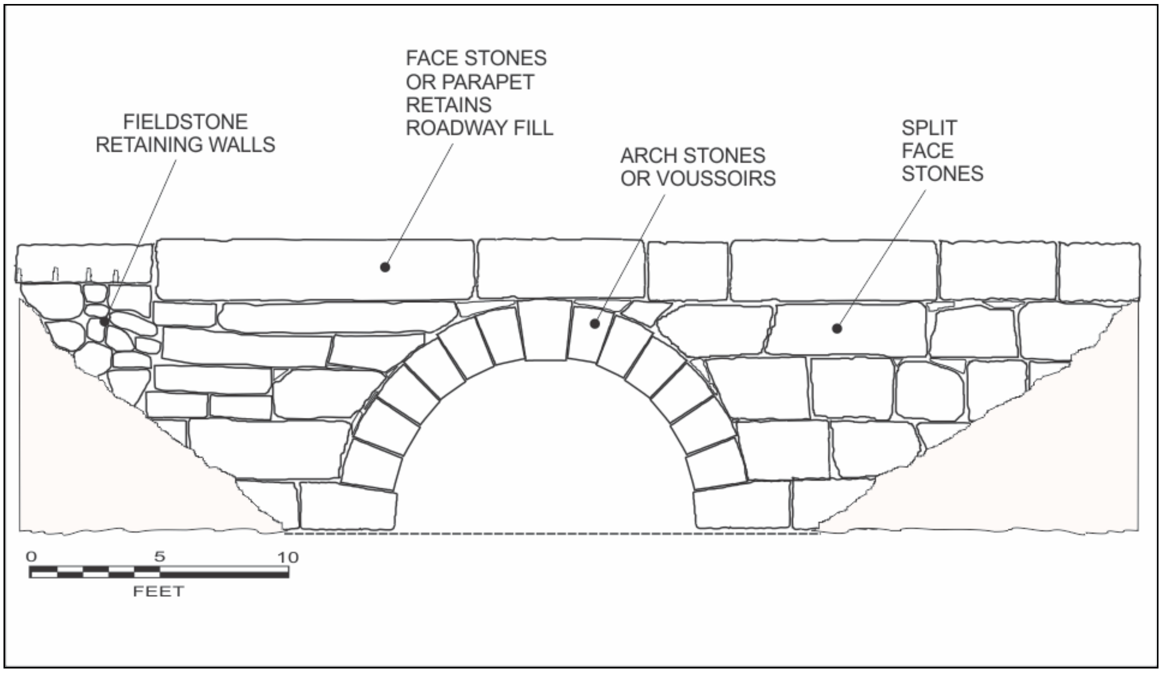

Figure No. 12: Typical stone arch culvert with semi-circular arch of split and cut quarry stone.

Most stone arch culverts under 10-foot span are semi-circular in shape. Segmental arches are more often found in longer span culverts in the range of 10 to 20 feet. The arches are carried on stone abutments with stone retaining walls typically extending some distance back from the abutments to support the roadway approaches. Above the arch stones are the facewall stones that merge with the retaining wall stones. The area of the facewall to each side of the arch is known as the spandrel wall; the area directly above the arch extending up to the roadway grade is called the facewall or parapet.

Large arched stone culverts and bridges, whether semi-circular or segmental, typically use arch stones that are split and cut with an angle of taper that corresponds to the radius of the arch. These wedge-shaped arch stones are called voussoirs and may exhibit a high degree of smoothing, squaring and tapering. The stone at the center of the arch is often somewhat larger than the others and known as the keystone. Smaller stone arch culverts are occasionally built of fieldstone, or rough-split stone, with little or no visible evidence of shaping or tapering. Arched stone culverts are found both dry laid without mortar and mortared, the latter occurring after about 1880 when Portland cement came into common use in the United States.

FIGURE 13: Stone arch culvert on Hill Road, Brookline (WI-BRO-001). This is the one stone arch culvert inventoried by the Vermont culvert survey. It is a segmental arch with a span of 80 inches. It is built entirely of fieldstone including the arch which includes a few naturally wedge-shaped stones, flat stones and shims to establish good contact (bearing) between the primary arch stones. The upstream end of the culvert was lengthened about 12 feet with the addition of a concrete arch, visible above in silhouette thru the opening and also in Figure 16 below.

Significance of Stone Box and Stone Arch Culverts

Stone box and arched highway culverts have served as important elements in Vermont's developing road network and as such typically possess characteristics that associate them with early highway design and construction; as such they possess significance for the National Register under the category of Transportation. Some stone box culverts may be directly associated with local quarries and the stone masonry trade or associated with nearby mill and waterpower resources of importance to local or state history. Stone culverts therefore may be considered for National Register eligibility under Criterion A, for association with events that have made a significant contribution to the broad patterns of Vermont history.

Stone culverts would rarely be found eligible under Criterion B; association with an important person such as the engineer or builder would be considered under Criterion C.

Stone culverts may exhibit vernacular to highly refined levels of stone masonry methods, practices and craftsmanship that are now lost in terms of their application to modern culvert construction. The design, materials and craftsmanship of a particular stone box culvert provides information about stone masonry construction practices and may help in the understanding of other stone culverts or stone structures found locally or statewide. The stone box culvert is essentially a smaller, shorter-span version of the stone slab or stone lintel bridge, a rare bridge form, and therefore provides information relevant to the understanding of that resource. Likewise, stone arch culverts may provide information relevant to their larger bridge counterparts. Stone culverts may therefore be considered for National Register eligibility under Criterion C, for their embodiment of distinctive characteristics of type, period and method of construction.

Registration Requirements for Stone Box and Stone Arch Culverts

The period of significance for stone box and stone arch culverts includes the entire study period from 1750 to 1930. Limited construction of stone culverts is believed to have begun in Vermont with early road building during the mid-18th century and continued into the early 20th century. Specific stone culvert examples have not been positively dated to anchor either end of this period and it is therefore an estimate that is subject to adjustment with new information. The Vermont Highway Commission published recommendations and specifications for stone culverts from the mid-1890s and into the first two decades of the 20th century when metal and concrete pipes made stone culverts obsolete.

Culverts that meet Registration Requirements must also retain integrity of location, design, setting, materials, workmanship, feeling and association. The primary character defining features of a stone box culvert are the stones of which the culvert itself and its integral facewalls are constructed. Secondary features include associated roadway retaining walls.

Considerations for eligibility under Criterion A:

1. An early stone culvert established on one of Vermont's range roads or turnpikes.

2. A stone culvert directly associated with historic waterpower or mill resources.

3. A stone culvert directly associated with the Good Roads movement or a specific late 19th or early 20th century road building or improvement program of known or demonstrable historical significance.

Considerations for eligibility under Criterion C:

1. Early well-preserved example of a type:

Stone culverts meeting the age requirement should be further evaluated for additional features that make them the best representative of the property type. Culverts that are suspected or determined to date from the early 19th century should be examined for evidence of stone-splitting marks that might indicate the approximate age of the stonework.

2. Rare survivor of a once common type:

Stone culverts are all rare survivors of a once common type that is being rapidly lost to replacement by modern more economical types. Examples that retain integrity can be evaluated as potentially eligible under this consideration.

3. Example of work by an important engineer or builder:

Stone culverts attributed to engineers or builders that have made important and recognized contributions to the field may be eligible under this consideration. The findings of this study have not identified stone culverts attributed to an engineer. Further research of individual culverts is necessary to determine the designer/builder involved.

4. Innovative or specialized designs:

Stone culverts may possess innovative or significantly specialized characteristics to warrant this consideration such as drop basins, inlet or outlet tapering or anti-fouling features. Documentary evidence that indicates that a culvert was sized using early hydraulic formulas would be of historical interest (it is impossible to determine from physical evidence alone if a stone culvert was sized or otherwise designed using any formulas or scientific methods).

5. Large examples of exceptional span or overall length:

This consideration generally applies to bridges that due to their exceptional individual span or overall length represent a major engineering and construction effort. Stone highway culverts on the other hand, were seldom engineered structures, instead relying on the craftsmanship of stonemasons who understood through apprenticeship and practice the limits of various stone types and methods used in the construction of lintels and arches. Culverts by definition are structures of short span, but may be of exceptional channel length, i.e., the distance from inlet to outlet, when they cross under wide highways. As the overall size of the structure increases, the work effort and cost increases which may be a measure of the importance of the structure or the roadway with which it is associated. Culvert size can represent the skill of its builders and the desire to erect a structure of exceptional permanence. Stone box culverts are limited in span due to the structural limitations of stone. Those exceeding 6 to 8 feet in span typically possess exceptionally large lintels or slabs and represent a major construction effort considering the limited tools and equipment available at the time.

6. Multiple-span box culverts:

Stone box culverts of more than one span are very rare and all examples should be evaluated as potentially eligible under this consideration.

INTEGRITY EVALUATION

To be eligible for the National Register, stone highway culverts must retain integrity of location, design, setting, materials, workmanship, feeling and association. Stone culverts are not a resource that is physically moved from its place of original construction so integrity of location is not applicable.

The types of integrity that embody most of the character defining features of stone highway culverts are those associated with design, materials and workmanship. These types of integrity can be diminished by natural causes such as damage and deterioration, or by alterations made to the culvert by man. The most common alterations made to culverts usually introduce new materials and may compromise the overall design and workmanship as well. These include lengthening the culvert channel and reconstruction usually using pipe and/or concrete.

Pointing dry-laid stone masonry with mortar or re-pointing original mortar joints with new mortar is a common alteration that generally does not compromise the integrity of the culvert, but should be evaluated on a case-by-case basis.

Less common alterations include those made to the roadway above, such as the introduction of concrete curbing or railing structures, or the construction of a bypass culvert to reduce or divert water flow through the historic culvert. Roadway and bypassing alterations may have a greater impact on the historic feeling of the resource and less of an impact on the design and workmanship of the culvert's structural stonework. The degree of loss of integrity in these cases should be evaluated on a case-by-case basis.

In rare instances the stone lintel or slab spans of a box culvert may have been completely removed and replaced with a new material. This alteration would be expected to destroy the integrity of the resource, unless the remaining masonry walls exhibited extraordinary characteristics.

Although a stone culvert is a relatively simple resource composed of just a few character-defining features, the evaluation of losses of integrity should carefully consider the relative importance of the features that do survive intact. For example, a long culvert that retains carefully cut lintels or voussoirs but has lost its rubble stone face-walls of rudimentary construction, may retain sufficient integrity for National Register eligibility.

Damage. Damage is usually the result of natural causes such as floods, erosion, freeze-thawing, roots, and chemical and biological agents that break down stone. The culvert shown in **Figure 14** suffers partial collapse of the downstream end from a flood event or ongoing erosion and undermining. The upstream end retains sufficient integrity to be interpreted as a good example of fieldstone box culvert construction.

FIGURE 14: Deer Ridge Road, Townsend, (WI-TOW-001). Partial collapse.

Lengthening. Increasing the length of the culvert channel typically accompanies widening the roadway or shoulders above. Most stone culverts built in the 19th and early 20th centuries were under narrow roads and have since been replaced with pipe culverts. In cases where the stone culvert remained in good condition of adequate size to handle the stream flows, they were lengthened by mating a steel or concrete pipe of similar size to it and cementing the connection (**Figure 15**).

FIGURE 15: Upper Dummerston Road, Dummerston (WI-DUM-003). Lengthened with pipe. Upstream end as originally built, top photo; downstream end showing steel pipe and stone probably salvaged from old facewall and reused.

For larger box culverts and arched culverts, concrete form work was constructed and a matching concrete box or arch culvert was poured (**Figures 16, 17**). Lengthening (sometimes called widening) results in diminished integrity of design, materials, feeling and setting. If the remaining culvert retains a high level of integrity or possesses notable characteristics, then the diminished integrity should not disqualify its National Register eligibility.

FIGURE 16: Hill Road, Brookline (WI-BRO-001). This is the upstream end of the one arch culvert surveyed in Vermont (see Figure 13) showing the lengthening of the culvert with cast-in-place concrete.

FIGURE 17: Windham Hill Road, Windham (WI-WIN-001). Lengthened with cast-in-place concrete (see Figure 7) and concrete block facewall added to downstream side.

Mortared or Re-Pointed with Mortar. Stone culverts were laid both dry (without mortar) and with cement mortar. Hydraulic mortar added expense and was used judiciously if not sparingly in utilitarian structures like culverts. Mortar was often used in critical spots to bond the work together and lock smaller stones and chinking, while leaving some joints open as "weep holes" for drainage. Original mortar work may be un-tooled, sloppy and appear to be a later addition as is probably the case shown in Figure 18. Culvert channel walls were seldom pointed or re-pointed at a later time, but fieldstone facewalls were often rebuilt and fully bedded in mortar. By the early 20th century cement mortar was affordable and effective for both new work and repair work. Assessment of the effect of mortared repairs on historic integrity should be made on a case by case basis.

FIGURE 18: Royalston Corner Road, Concord (ES-CON-001). Box culvert of cut stone laid in mortar.

Stream Bypassing. Stream or hydraulic bypassing of a culvert is done by rerouting the stream through a new culvert built to the side. Culverts are typically bypassed because they have become under-sized due to changes in runoff patterns. Damaged culverts facing potential collapse are bypassed to reduce the threat or effect repairs. Bypassing causes some loss of integrity of setting, feeling and association but may not substantially diminish the culvert's most important characteristics providing the majority of its design and materials are unaltered or repaired in-kind. No stream-bypassed culverts were found and recorded in this study.

Highway Bypassing. Abandoning the highway over a culvert removes the traffic load by realigning the highway and may significantly diminish the setting, its association and feeling. If the old road bed or pavement has been removed from above the culvert or its approaches, association with the original highway will likely be lost. Construction of the bypass highway and new culvert usually results in altered landscape feature including elevated roadway embankments and erosion mitigation structures. When the old road and culvert remains unaltered, the former context, although diminished, may be present to a sufficient degree to enable interpretation of the culvert's original purpose. Assessment on a case-by-case basis is recommended. No highway-bypassed culverts were found and recorded in this study.

G. GEOGRAPHICAL DATA

The geographic area encompasses the entire state of Vermont

H. SUMMARY OF IDENTIFICATION AND EVALUATION METHODS

Purpose

The purpose of this study is to identify and inventory stone highway culverts on public roads in Vermont that possess characteristics qualifying them for listing in the National Register of Historic Places (NR). The findings of this study will be used by the Vermont Agency of Transportation (VAOT or VTrans) to aid in the planning and performance of culvert maintenance, repair and replacement. The findings will also be used by the Vermont Division for Historic Preservation (VDHP) and cooperating federal agencies such as the Federal Highway Administration (FHWA) and the Federal Emergency Management Agency (FEMA) to make decisions about the eligibility of stone culverts for listing in the National Register of Historic Places. The criteria, methods and guidelines followed in evaluating and assessing historic properties are defined in *National Register Bulleting No. 15: How to Apply the National Register Criteria for Evaluation,* published by the National Park Service in 1997.

Research

Preliminary research for this project was conducted using a variety of print and online sources, both contemporary and historic. These sources include the database vtculverts.org (an evolving source for information about culverts around the state of Vermont), turn of the century Biennial Reports of the Vermont State Highway Commissioner, historic maps, engineering textbooks, the Library of Congress' Chronicling America newspaper database, etc.

VTculverts.org is a website created and maintained by the Vermont Agency of Transportation and the Vermont Regional Planning Commissions and served as the primary source of field information. According to the VTculverts website: "The Vermont Agency of Transportation was directed by the Vermont Legislature to complete and deploy an integrated software product to handle data entry, access and status reporting of town bridge and culvert inventories currently collected by the Regional Planning Commissions (RPCs), towns and their contractors. All town bridge and culvert inventory data which has been previously collected and submitted through the old VOBCIT website is currently located in this system. All bridge and culvert data that adheres to the requirements of this database may be entered into this application."

Resource Field Survey

Field surveys were completed over the course of 4 years, starting in 2014 and concluding the summer of 2017. The VTculverts database provided locational information for stone culverts for many towns. The database however is incomplete and in many cases entries for culverts of stone construction were proved to be pipe culverts with stone facewalls. The VTculverts database was augmented with the use of topographic and town highway maps to locate mapped and unmapped (seasonal) stream crossings with the potential to be carried under the roadway by a stone culvert.

When an intact stone culvert was located, it was documented according using the Statewide Historic Stone Culvert Survey form developed in conjunction with VTrans Environmental Division (see sample Statewide Historic Stone Culvert Inventory Form, below). This documentation entailed photographing and recording the size, shape and type of culvert and other information. The location of each culvert was noted on a USGS topographic map and the latitude and longitude coordinates recorded.

Fully intact culverts judged to possess good integrity were recorded. Culverts with one end intact and the other end altered or repaired with different materials including pipe and concrete were recorded only when the unaltered end possessed a notable degree of workmanship plus good integrity. Damaged culverts that may or may not retain sufficient design and structural integrity were also recorded to enable an integrity assessment to be made by others on a case-by-case basis. Culverts completely replaced with pipe or reconstructed to a degree that the original stonework pattern was no longer evident were not recorded.

Analysis and Reporting

The historic contexts within which Vermont's stone culverts were built are described in Section E above. The resources have been evaluated for their association with events that have made a significant contribution to the broad patterns of Vermont history (NR Criterion A) and/or for significance that would make them eligible for the NR under Criterion C for their embodiment of distinctive characteristics of a type, period, or method of construction, or as representing the work of a master. The primary data collected on the culvert survey forms is compiled in table format for comparison and analysis (see Vermont Stone Highway Culverts Inventory Table, below). The findings of this study have been compiled in this report.

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J. SUPPLEMENTAL MATERIALS

SAMPLE STATEWIDE HISTORIC STONE CULVERT INVENTORY FORM (3 Pages):

Statewide Historic Stone Culvert Inventory
FHWA Task 092
CA-WHE-002: Page 1 of 3

Culvert Reference Number *(first two letters of county name first three of town)*	CA- WHE- 002

LOCATION

City or Town	Wheelock
County	Caledonia
Road	Stannard Mountain Road
Stream	Stannard Brook
Stream Character	gentle
UTM Coordinate	18. 723680. 4936486
Lat/Long	44. 546989, -72.184081

STONE CULVERT CHARACTERISTICS

Type	Box X	Arch	Other:		
Upstream Dimensions	Width	32"	Height	28"	
Downstream Dimensions	Width	24"	Height	24"	
Culvert Length (estimate)	21'	Cover Fill Depth	16" downstream/ 32" upstream		
Masonry	Field stone	X	Note:		
	Split stone	X	Note:		
	Cut		Note:		
	Dressed		Note:		
Condition	Good X	Damage	Note:		
Threats	Vegetation	Erosion	Other		
Other Features/Notes: Downstream has large stone forming overhang with culvert recessed					
Upstream has two large lintels roughly 61" long and 13" wide.					

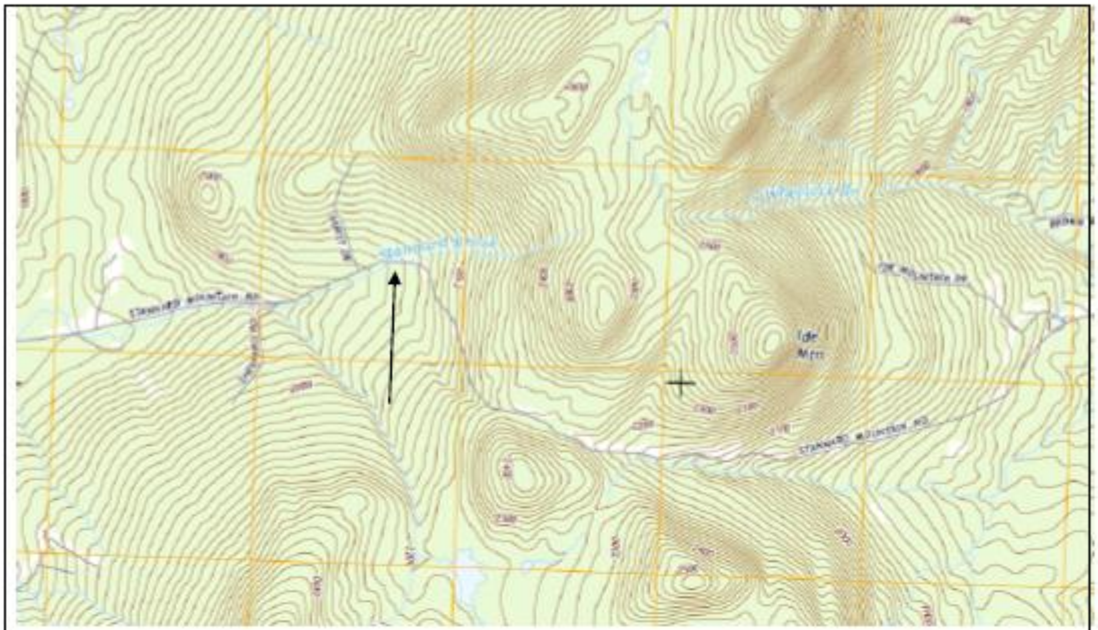
SITE CHARACTERISTICS

Setting	Urban	Suburban	Rural X	Note:
Roadway Type	Paved	Unpaved X	Guardrails	
Vegetation	Low X	Moderate	Dense	Wooded
Wing or channel walls	wingwalls			
Site Note	Waterfall on downstream side			

SURVEY INFORMATION

Date of Inspection	4-29-17
Prepared by	Suzanne C. Jamele
Organization	Vermont Agency of Transportation

Statewide Historic Stone Culvert Inventory
FHWA Task 092
CA-WHE-002: Page 2 of 3



LOCATION MAP	USGS Quadrangle	Stannard, VT

PHOTO No. 1	Downstream	Looking	S

PHOTO No. 2	Downstream overhang with culvert recessed inside	Looking	S

PHOTO No. 3	Upstream	Looking	N

VERMONT STONE HIGHWAY CULVERTS INVENTORY TABLE

The following four pages present a table of data pertaining to the 120 culverts inventoried in the field survey portion of this study. The resources are listed alphabetically first by county name and then by town name. The column headings and abbreviations used in the table are as follows:

Inventory #: This is a 3-part identification number assigned by VTrans made up of the first two letters of the county, first three letters of the town and a three digit number for each culvert surveyed in the town. For example, CH-WHE-002 is the inventory number of the culvert in Caledonia County, Wheelock Town, presented in the sample form above.

County, Town, Road, Latitude and Longitude: Self-explanatory.

Type: This refers to the type of culvert, either Box or Arch.

Work: This refers to the type or types of stone used in the construction of the culvert:

> Fieldstone (F): stone used as found in fields or at ledge outcrops without evidence of being worked.
> Split stone (S): stone exhibiting split faces, typically to reduce the size of large field stones or to break off slabs or blocks from outcrops or quarries.
> Cut stone (C): exhibiting evidence of cutting and trimming with hammer or chisel to create flat, parallel or squared faces and stones of uniform size or thickness.
> Dressed stone (D): Stone with faces that has been tool finished for aesthetic purpose.

Height: The distance in inches from floor to ceiling of the culvert.

Width: The distance in inches between the culvert channel walls, also called the span or width of the waterway. It is the unsupported span of the lintels or slabs that form the ceiling of the culvert, or the distance between the spring points of an arch.

Length: This refers to the distance in feet between the culvert inlet and outlet facewalls, also called the length of the waterway or length of the channel walls.

Highway Number: The local town highway number, where applicable.

	Inventory No.	County	Town	Road	Latitude	Longitude	Type	Work	Height "	Width "	Length '	Hwy #
1	AD-GOS-001	Addison	Goshen	Carlisle Hill Rd	43.856177	-73.01869	Box	F, S	24	40	21	2
2	CA-BAR-001	Caledonia	Barnet	Strobridge Hl	44.32201	-72.10974	Box	F	21	31	16	
3	CA-GRO-001	Caledonia	Groton	Coal Kiln Rd	44.21716	-72.21686	Box	C	52	48	17	
4	CA-GRO-002	Caledonia	Groton	Coal Kiln Rd	44.21515	-72.21607	Box	F, S	32	34	17	
5	CA-GRO-003	Caledonia	Groton	Coal Kiln Rd	44.21371	-72.21463	Box	S, C	30	30	16	
6	CA-HAR-001	Caledonia	Hardwick	Bridgman Hill Rd	44.51272	-72.3598	Box	S, C	73	56	25	10
7	CA-HAR-002	Caledonia	Hardwick	Houston Hill Rd	44.48162	-72.32001	Box	F, S	24	43	20	55
8	CA-HAR-003	Caledonia	Hardwick	Tucker Brook Rd	44.55142	-72.38093	Box	S, C	20	20	17	18
9	CA-HAR-004	Caledonia	Hardwick	Tucker Brook Rd	44.55185	-72.38017	Box	S	30	27	20	18
10	CA-HAR-005	Caledonia	Hardwick	Tucker Brook Rd	44.55398	-72.39275	Box	F, S	22	78	17	18
11	CA-HAR-006	Caledonia	Hardwick	Wapanaki Rd	44.55478	-72.39337	Box	F, S	74	32	17	18
12	CA-HAR-007	Caledonia	Hardwick	Ward Hill Rd	44.50666	-72.29238	Box	S	16	23	18	
13	CA-SHE-001	Caledonia	Sheffield	Town Farm Rd	44.6088	-72.0879	Box	F, S, C	45	50	14	
14	CA-WHE-001	Caledonia	Wheelock	Quarry Rd	44.618762	-72.192483	Box	F, S, C	57	37	23	
15	CA-WHE-002	Caledonia	Wheelock	Stannard Mtn. Rd	44.546989	-72.184081	Bos	F, S	28	32	21	
16	ES-CON-001	Essex	Concord	Royalston Corner Rd	44.43039	-71.88012	Box	S, C	47	55	24	
17	ES-CON-002	Essex	Concord	Royalston Corner Rd	44.43091	-71.84401	Box	F, S	48	36	27	
18	FR-HIG-001	Franklin	Highgate	Ballard Rd	45.01186	-73.051189	Box	F, S	24	20	20	10
19	FR-SWA-001	Franklin	Swanton	South River St	44.911564	-73.13019	Box	F, S	72	36	60	
20	LA-JOH-001	Lamoille	Johnson	Lendway Ln	44.62932	-72.70143	Box	F	32	32	23	44
21	LA-JOH-002	Lamoille	Johnson	Lendway Ln	44.62929	-72.70131	Box	F	35	32	23	44
22	OL-GLO-001	Orleans	Glover	Shadow Lake Rd	44.66723	-72.24184	Box	F, S, C	48	32	16	
23	OL-MOR-001	Orleans	Morgan	White Hill Loop	44.862106	-71.930282	Box	S, C	52	37	18	
24	OL-MOR-002	Orleans	Morgan	Oxbow Rd	44.907756	-71.990801	Box	F, S	46	30	28	
25	OR-BRO-001	Orange	Brookfield	Ralph Rd	44.05838	-72.5872	Box	F	20	24	20	13
26	OR-NEW-001	Orange	Newbury	Swamp Rd	44.11654	-72.18464	Box	F, S	33	35	22	2
27	OR-RAN-001	Orange	Randolph	Silloway Rd	43.9336	-72.58602	Box	F	12	16	25	52
27	OR-RAN-002	Orange	Randolph	Clay Wight Rd	43.88381	-72.57308	Box	F	19	41	18	44
29	OR-TOP-001	Orange	Topsham	Lime Kiln Rd	44.126	-72.20236	Box	F, S	21	41	18	32
30	RU-SHR-001	Rutland	Shrewsbury	Lottery Rd	43.514657	-72.878092	Box	F	20	24	14	
31	RU-SHR-002	Rutland	Shrewsbury	Eastham Rd	43.513778	-72.81648	Box	F	42	36	18	
32	WA-BAR-001	Washington	Barre City	Washington St	44.18981	-72.48873	Box	F, S, C	28	72	32	302
33	WA-BAR-002	Washington	Barre City	Washington St	44.1873	-72.48555	Box	S, C	71	32	32	302
34	WA-BAR-003	Washington	Barre City	Tremont St	44.19873	-72.49369	Box	S, C	72	46	24	0
35	WA-BAR-004	Washington	Barre City	Onward St	44.20131	-72.49114	Box	S, C	44	52	24	
36	WA-BAR-005	Washington	Barre City	Allen St	44.18836	-72.50666	Box	S, C	22	17	25	44
37	WA-BAR-006	Washington	Barre City	Prospect St	44.19724	-72.51587	Box	S, C	36	54	25	7
38	WA-BAR-007	Washington	Barre City	Railroad St	44.20525	-72.51782	Box	S, C	55	57	25	83

	Inventory No.	County	Town	Road	Latitude	Longitude	Type	Work	Height "	Width "	Length '	Hwy #
39	WA-BAT-001	Washington	Barre Town	Old Route 302	44.16418	-72.4535	Box	F, S, C	20	84	28	125
40	WA-BAT-002	Washington	Barre Town	Lowery Rd	44.13585	-72.44847	Box	S, C	35	44	22	73
41	WA-BAT-003	Washington	Barre Town	Church Hill Rd	44.15533	-72.47328	Box	S, C	38	67	63	
42	WA-BAT-004	Washington	Barre Town	Church Hill Rd	44.14867	-72.48183	Box	S, C	60	12	48	3
43	WA-BAT-005	Washington	Barre Town	Sterling Hill Rd	44.17033	-72.49205	Box	S, C	35	48	20	53
44	WA-BAT-006	Washington	Barre Town	Patch Rd	44.17743	-72.49154	Box	S, C	42	75	20	52
45	WA-BAT-007	Washington	Barre Town	Snowbridge Rd	44.15859	-72.53148	Box	S, C	36	60	45	59
46	WA-BAT-008	Washington	Barre Town	Sherman Dr	44.16692	-72.5404	Box	F	10	53	18	168
47	WA-CAB-001	Washington	Cabot	Pike Rd	44.43629	-72.29898	Box	F, S, C	60	45	22	
48	WA-CAB-002	Washington	Cabot	Bothfeld Hill Rd	44.40501	-72.32441	Box	F, S, C	54	60	20	35
49	WA-CAL-001	Washington	Calais	Martin Rd	44.3307	-72.50575	Box	F, S, C	36	60	23	53
50	WA-CAL-002	Washington	Calais	Haggett Rd	44.33001	-72.50386	Box	F, S, C	46	60	26	6
51	WA-CAL-003	Washington	Calais	Fowler Rd	44.35071	-72.49302	Box	F	9	14	19	46
52	WA-CAL-004	Washington	Calais	Max Gray Rd	44.32287	-72.43325	Box	F	40	33	23	38
53	WA-EAS-001	Washington	East Montpelier	Coburn Rd	44.2893	-72.45316	Box	F, S	44	30	16	
54	WA-EAS-002	Washington	East Montpelier	Factory St	44.30304	-72.4476	Box	F	15	30	25	11
55	WA-EAS-003	Washington	East Montpelier	Kelton Rd	44.28327	-72.48213	Box	F, S, C	94	119	25	
56	WA-EAS-004	Washington	East Montpelier	Center Rd	44.28586	-72.52192	Box	F, S, C	56	34	16	
57	WA-EAS-005	Washington	East Montpelier	Foster Rd	44.30434	-72.48894	Box	F, S, C	75	75	22	11
58	WA-EAS-006	Washington	East Montpelier	Sodom Pond Rd	44.30861	-72.49131	Box	F, S, C	58	62	16	8
59	WA-EAS-007	Washington	East Montpelier	Horn Of The Moon Rd	44.31996	-72.53582	Box	F	9	18	23	18
60	WA-FAY-001	Washington	Fayston	Ctr Fayston Rd	44.21616837	-72.83506195	Box	F	53	48	45	4
61	WA-PLA-001	Washington	Plainfield	Middle Rd	44.4632	-72.4362	Box	F	8	25	18	1
62	WA-ROX-001	Washington	Roxbury	Warren Mountain Rd	44.11516	-72.77644	Box	F	60	46	35	1
63	WA-ROX-002	Washington	Roxbury	Warren Mountain Rd	44.11503	-72.77476	Box	F	50	23	26	1
64	WA-WOO-001	Washington	Woodbury	Nelson Pond Rd	44.41174	-72.44818	Box	F, S	48	60	22	46
65	WA-WOO-002	Washington	Woodbury	Foster Hill Rd	44.40733	-72.42769	Box	F, S	12	20	24	1
66	WA-WOO-003	Washington	Woodbury	Blake Hill Rd	44.43258	-72.41217	Box	F, S, C	29	27	20	27
67	WA-WOO-004	Washington	Woodbury	Cranberry Meadow Rd	44.41493	-72.44904	Box	F, S, C	32	32	32	40
68	WA-WOR-001	Washington	Worcester	Minister Brook Rd	44.40513	-72.5985	Box	F	57	32	21	
69	WI-BRA-001	Windsor	Brattleboro	Ames Hill Rd	42.85266329	-72.65683347	Box	F, S	48	30	30	8
70	WI-BRA-002	Windsor	Brattleboro	Western Ave	42.85018341	-72.58618731	Box	F, S	24	24	25	2
71	WI-BRA-003	Windsor	Brattleboro	Sunset Lake Rd	42.88609637	-72.6424887	Box	F, S	18	18	30	12
72	WI-BRA-004	Windsor	Brattleboro	Hinesburg Rd	42.83372947	-72.64968418	Box	F, S	60	60	30	6
73	WI-BRO-001	Windsor	Brookline	Hill Rd	43.0156678	-72.62125497	Arch	F	60	80	28	2
74	WI-DUM-001	Windsor	Dummerston	Clark Rd	42.90732767	-72.54049263	Box	F	48	24	20	72
75	WI-DUM-002	Windsor	Dummerston	Upper Dummerston Rd	42.89925128	-72.60176174	Box	F, S, C	24	24	30	4
76	WI-DUM-003	Windsor	Dummerston	Upper Dummerston Rd	42.90395159	-72.60319401	Box	F, S	24	36	15	4

	Inventory No.	County	Town	Road	Latitude	Longitude	Type	Work	Height "	Width "	Length '	Hwy #
77	WI-DUM-004	Windsor	Dummerston	Kelly Rd	42.90302646	-72.64465999	Box	F	24	15	20	58
78	WI-GRA-001	Windsor	Grafton	Kidder Hill Rd	43.16362779	-72.5984652	Box	F	24	40	24	43
79	WI-JAM-001	Windsor	Jamaica	River Rd	43.07688601	-72.74757889	Box	F	15	15	24	41
80	WI-JAM-002	Windsor	Jamaica	Knight Rd	43.05832173	-72.79076318	Box	F	24	24	40	72
81	WI-JAM-003	Windsor	Jamaica	Turkey Mtn Rd	43.09500481	-72.73325143	Box	F	24	24	20	85
82	WI-LON-001	Windsor	Londonderry	Winhall Hollow Rd	43.20207933	-72.85591038	Box	F, S	12	12	40	6
83	WI-MAR-001	Windsor	Marlboro	Old Hogback Rd	42.85634555	-72.79758984	Box	F, S	36	36	25	33
84	WI-MAR-002	Windsor	Marlboro	Church Hollow Rd	42.88379939	-72.71651804	Box	F	12	12	20	20
85	WI-NEW-001	Windsor	Newfane	Newfane Hill Rd	42.98911377	-72.70893011	Box	F, S	30	30	20	
86	WI-NEW-002	Windsor	Newfane	Sir Issac Newton Rd	43.00861213	-72.71141678	Box	F	24	30	25	
87	WI-NEW-003	Windsor	Newfane	Wiswall Hill Rd	43.01232459	-72.67084616	Box	F, S	48	36	20	
88	WI-ROY-001	Winsor	Royalton	Stearns Rd	43.804677	-72.50622	Box	F, S	60	30	60	
89	WI-TOW-001	Windsor	Townshend	Deer Ridge Rd-1	43.0687146	-72.66334411	Box	F, S	60	48	20	24
90	WI-TOW-002	Windsor	Townshend	Deer Ridge Rd-2	43.07185679	-72.66458897	Box	F	45	30	16	24
91	WI-WAR-001	Windsor	Wardsboro	Shine Rd	43.03516276	-72.7793296	Box	F	36	48	35	27
92	WI-WES-001	Windsor	Westminster	Arnof Way	43.11177565	-72.54893717	Box	F	36	40	24	8
93	WI-WIN-001	Windsor	Windham	Windham Hill Rd	43.17566929	-72.7264057	Box	F	102	54	30	1
94	WI-WIN-002	Windsor	Windham	Harrington Rd	43.19089904	-72.72897359	Box	F	48	36	30	11
95	WN-BET-001	Windham	Bethel	Quarry Rd	43.85412	-72.6127	Box	C	37	18	18	
96	WN-CAV-001	Windham	Cavendish	S Reading Rd	43.42459859	-72.62175282	Box	F	12	12	30	
97	WN-CAV-002	Windham	Cavendish	Moriglioni Rd	43.4331353	-72.59883263	Box	F	36	24	20	
98	WN-CAV-003	Windham	Cavendish	High St	43.38600152	-72.60605961	Box	F	24	24	36	
99	WN-CHE-001	Windham	Chester	Water Farm Rd	43.28040136	-72.63704676	Box	F	48	48	27	48
100	WN-CHE-002	Windham	Chester	Green Mountain Tpke-10	43.25815065	-72.57654868	Box	F	12	36	38	6
101	WN-CHE-003	Windham	Chester	Green Mountain Tpke-12	43.25426383	-72.57092019	Box	F	36	36	32	6
102	WN-CHE-004	Windham	Chester	Green Mountain Tpke-24	43.23833205	-72.54997104	Box	F, S	24	36	40	6
103	WN-CHE-005	Windham	Chester	Green Mountain Tpke-25	43.2381849	-72.54982044	Box	F	24	24	30	6
104	WN-CHE-006	Windham	Chester	Lovers Ln Rd	43.27695539	-72.61227987	Box	F	36	24	30	43
105	WN-CHE-007	Windham	Chester	Stoodley Rd	43.28267272	-72.55415745	Box	F, S	48	36	40	105
106	WN-CHE-008	Windham	Chester	Goldthwaite Rd	43.28045985	-72.65092942	Box	F, S	48	36	25	42
107	WN-CHE-009	Windham	Chester	Reservoir Rd	43.27670467	-72.63530168	Box	F, S	96	48	20	47
108	WN-HRF-001	Windham	Hartford	Old River Rd	43.69220553	-72.40471981	Box	F	24	36	40	36
109	WN-HRL-001	Windham	Hartland	Garvin Hill Rd	43.57357769	-72.46614947	Box	F	36	48	40	22
110	WN-HRL-002	Windham	Hartland	Jenneville Rd	43.5428374	-72.47148598	Box	F	48	48	40	6
111	WN-HRL-003	Windham	Hartland	Densmore Hill Rd	43.54751048	-72.47528953	Box	F	48	36	30	23
112	WN-NOR-001	Windham	Norwich	Hopson Rd	43.70844392	-72.31836544	Box	F	18	30	25	58
113	WN-POM-001	Windham	Pomfret	Cherry Hill Rd	43.73247	-72.4749	Box	F	20	26	14	
114	WN-POM-002	Windham	Pomfret	Caper Rd	43.73551	-72.4793	Box	F	30	42	40	

	Inventory No.	County	Town	Road	Latitude	Longitude	Type	Work	Height "	Width "	Length '	Hwy #
115	WN-SHA-001	Windham	Sharon	Stationmasters Rd	43.7819	-72.4556	Box	F, S, C	40	50	22	40
116	WN-SHA-002	Windham	Sharon	Downer Rd	43.81655	-72.3868	Box	F	20	20	20	16
117	WN-SPR-001	Windham	Springfield	Poppe Rd	43.26083268	-72.53656295	Box	F, S	38	60	35	71
118	WN-WEA-001	Windham	Weathersfield	Maple St	43.36901726	-72.51484054	Box	F	48	48	50	
119	WN-WEA-002	Windham	Weathersfield	Brian Jones Rd	43.41260999	-72.41909002	Box	F	36	48	25	
120	WN-WES-001	Windham	West Windsor	Bryant Rd	43.51100029	-72.50601667	Box	F	36	24	36	8