National Register of Historic Places
Multiple Property Documentation Form

Stone Highway Culverts in New Hampshire
1750 to 1930

Prepared for:
New Hampshire Department of Transportation, Bureau of Environment, Concord, NH

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

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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 New Hampshire

B. Associated Historic Contexts

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

Stone Box Highway Culverts in New Hampshire 1750 to 1930.
Stone Arch Highway Culverts in New Hampshire 1750 to 1930.

C. Form Prepared by

name/title Richard M. Casella, Architectural Historian

organization Historic Documentation Company, Inc. **date** August 2008

street & number 490 Water Street **telephone** (401) 683-3483

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 New Hampshire — Name of Multiple Property Listing)

New Hampshire — 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

Paperwork Reduction Act Statement: This information is being collected for applications to the National Register of Historic Places to nominate properties for listing or determine eligibility for listing, to list properties, and to amend existing listings. Response to this request is required to obtain a benefit in accordance with the National Historic Preservation Act, as amended (16 U.S.C. 470 et seq.).

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E. STATEMENT OF HISTORIC CONTEXTS

Introduction

> "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."[1]

The historic context of Stone Highway Culverts is composed principally of the work of civil engineers, builders and stone masons and includes highway, bridge and hydraulic engineering, highway and bridge construction, and stone quarrying, cutting and masonry.

The relationship of stone highway culverts to the historic context has been examined by studying the origins and development of the resource in its various forms (property types) within the study area. This project has been undertaken by the New Hampshire Department of Transportation using two approaches to resource identification and inventory: a geographical-based approach – the State of New Hampshire – and a management-unit approach – the state's road and highway system.

Stone culverts are specialized structures for which very little prior study and analysis has been done. To the extent that the available information has allowed, the characteristics of the property types and their relationship to the contexts are discussed including: principal types, time period, methods of construction; principal builders, craftsmen, engineers; relationship to the geographic area and transportation; development of the type and method of construction in relation to the environment of the study area.

Stone highway culverts in New Hampshire are of two main types: box culverts and arched culverts. Box culverts have vertical stone walls that carry a stone slab spanning the opening. Arch culverts are essentially small versions of stone arch bridges and consist of shaped stones arranged to form an arched opening by wedging against one another. 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."

The discussion of the historic contexts examines the history of the stone arch and stone box structures, their application to drainage and road building and their engineering features that stem largely from their application by the railroads during the late 19th century.

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[1] "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.

Definitions

The 1903 unabridged edition of Webster's Dictionary defines a culvert as "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. The following definitions further the understanding of the use of the term culvert.

Culvert according to the 14th Edition of *Encyclopaedia Britannica* (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.[2]

Culvert according to the *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.[3]

Culvert according to a 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.[4]

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[2] "Culvert," *Encyclopaedia Britannica* [14th ed.] (New York: Encyclopaedia Britannica, Inc, 1928): 858.
[3] Oxford English Dictionary, 1989.
[4] Walter L. Webb. *Railroad Construction, Theory and Practice* (New York: John Wiley and Sons, 1900): 202-203.

Culvert according to a 1924 structural engineering textbook:

> 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.[5]

Culvert according to a 1947 highway-engineering textbook:

> 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.[6]

Culvert according to the 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.[7]

The distinction between bridges and culverts, particularly from the standpoint of the structural engineer and those charged with inspecting and maintaining their safety, has generally been based on span length. The Federal Highway Administration's *Bridge Inspector's Training Manual* considers structures beneath highways less than 20 feet in span length to be culverts. This definition is based in part on the Federal Highway Act of 1968 that mandated each state to institute a bridge inspection program for bridges 20 feet and longer within the Federal-Aid Highway System. Structures less than 20 feet were typically classified as culverts. Several states, including the New Hampshire Department of Transportation, define culverts as structures with spans of less than 10 feet, and bridges as structures with spans of 10 feet or greater. For this study, stone culverts and bridges structures up to 20 feet in span are included.

Some consider stone arch and box culverts as just small bridges that lack the structural engineering necessary for larger structures such as foundation design and material strengths. Drawing the distinction between bridges and culverts on the basis of span can be a generalization of convenience that overlooks characteristics that make them different or the same. In comparing an 8-foot stone arch and a 20-foot stone arch built by the same builder at about the same time

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[5] 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.
[6] John H. Bateman, *Introduction to Highway Engineering.* (New York: John Wiley and Sons, Inc., 1947): 48-49.
[7] U.S. Department of Transportation, Federal Highway Administration. *Bridge Inspector's Reference Manual.* (2002).

with stone from the same quarry, for example, the character defining features of both structures could be identical.

Culverts differ from bridges primarily in their structural and hydraulic characteristics. Stone box culverts with slabs or lintels spanning the opening were seldom if ever the product of design by an engineer. [Note: the difference between slabs and lintels is in their width dimension, lintels being narrower. See "Section F: Associated Property Types" for further description]. When box culverts exceed a span of 10 feet they are called stone slab or lintel bridges in the states that use 10 feet as a categorical separation point. The great variability in the strength of stone, especially when placed under tension as a beam span, and the inability to see internal flaws or fine cracks initially present or formed later by mishandling during transport or placement, has limited the use of stone by engineers to very short spans in which a large factor of safety could be assumed. In stone arches on the other hand, the stones are in compression and spans can be safely designed to span beyond 200 feet. Spans greater than about 30 feet, in particular segmental or elliptical arches of low rise – so-called flat arches – can induce very large forces in the arch stones and abutments and have generally been the product of an engineer's calculations.

Culverts are usually in embankments and covered by earth fill and therefore designed to carry a large and significant dead load depending on the depth and type of the cover material. The embankment material plays an important role in culvert design: it assists structurally in the culvert's live-load carrying capacity by distributing vertical loads laterally, and it acts as an earthen dam during flood events that exceed the capacity of the culvert and submerge the inlet.

The engineered culvert may have observable engineering characteristics in its physical design and construction, or only the area of the opening may have been the result of calculated design. The work of the engineer, if one was involved, typically leaves no physical trace and can only be verified with documentary evidence such as plans or records.

Historical Background & Context

Culverts are believed to have originated with man's desire to drain away surface water to claim swampy land for cultivation and may date back in some form several thousand years. Archaeological remains indicate the Romans drained their arable lands in Europe and England with both open and covered drains. 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 even grade or following a straight line provided long term efficiencies that offset the cost of "fills."

Although the basic design of stone box and stone arch culverts developed from the ancient practices of stone post-and-lintel and stone-arch construction, their refinement was an outgrowth of the building of the railroads. The design and sizing of culverts based on the mathematical analysis of the particular structural and hydraulic requirements of a given situation, was almost exclusively developed by the railroads in the late 19th century. The lessons learned by the railroad engineers shaped the design of the highway culverts and bridges that followed.

Stone Slab Bridges and Culverts

A stone box culvert consists of a stone slab, or series of slabs in parallel, spanning between two stone channel walls. Structurally, the slab functions as a simple beam, one of the oldest forms of human building. In architecture, a beam supported at each end to create a roof or opening in a wall for a door or window is known as post and lintel (beam) construction, or column and beam construction. Archeological and anthropological evidence suggests that early forms in wood or bound papyrus reeds may date back several hundred thousand years. Surviving stone examples that have been accurately dated are usually of roughly shaped stone, Stonehenge in England, built 3800 years ago, being perhaps the best known example. An exception is the Valley Temple in Giza, built by the Egyptians about 2500 BC, in which finely polished square lintel beams of red granite rest on square piers of the same material."[8] The Greeks elevated column and beam construction to an art form, exemplified by the Parthenon, built c. 448 BC.

The idea of using a 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, primitive man undoubtedly muscled them into a resting place atop other stones to bridge small streams. The earliest of England's famous "clapper" bridges are believed date 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.[9]

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8 Leland M. Roth, *Understanding Architecture: Its Elements, History and Meaning* (Bolder, Colorado: Westview Press 2006): 29.
9 Eric deMare'. *The Bridges of Britain.* (London: B.T. Batsford Ltd., 1954): 36-37.

The Anping Bridge in the Fujian (also spelled Fukien or Fu-Chien) Province of China consists of a series of granite slabs, some as large as 35 feet long and 2.5 feet thick. It dates to about 1000 AD and is over a mile in length overall. A later example by 12th century Fujian builders is the Lo-yang Bridge with a single slab span of 70 feet, perhaps the longest stone span ever built.[10]

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 may have been 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 to America.

Stonemasons built stone slab bridges intuitively. They assessed the character and strength of the available stone and determined the thickness necessary to span a certain distance on the basis of experience and perhaps limited testing. Determining the safe limits of stone to span openings cannot be precise not only for the obvious reason that it is a natural substance of great variation in composition, but also because imperfections such as hairline cracks, inherent or induced by transporting, prying, lifting or dropping, can often not be seen or predicted. While stone has great strength in compression, it has little tensile strength, 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 effectively eliminated further use of stone slabs or lintels for large culverts and short span bridges.

Stone slab or stone lintel bridges survive and remain in service in New Hampshire and the neighboring states. Eight bridges are listed in the New Hampshire bridge inventory dating from 1900 to 1930. [Note: the accuracy of these dates is not assured and certain bridges might be much older]. In Massachusetts there are 56 stone slab bridges, the oldest dates from 1765 and many others are from the early 19th century.[11] Maine and Vermont also have a substantial number of stone slab bridges.[12]

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[10] *Ibid.*, p. 36.
[11] Steven Roper, MassHighway Structures Historian, Personal Communication.
[12] Vermont Agency of Natural Resources. *Vermont Stream Geomorphic Assessment*. Appendix G, Bridge and Culvert Assessment. April 2007; TransSystems/Lichtenstein Corporation. *Maine Historic Bridge Inventory Phase II.* (partial copy of document with no further citation information provided).

Stone Arch Bridges and Culverts

During archeological excavations south of Bagdad, Iraq during the 1930's, the oldest known so-called true arch, or voussoir arch, as distinguished from pointed and corbelled arches, was discovered dating from roughly 3500 BC. The tiny stone arch was supporting the roof of a burial tomb in Ur, an area of Mesopotamia between the Tigris and Euphrates Rivers.[13]

The Etruscans were the first to put large voussoir arches into common use in building construction, and the Romans who followed them in time were the first to employ the voussoir arch in bridge building. The era of Roman stone arch bridge building spans from about 241 BC to about 200 AD.[14] The Romans used only semi-circular arches, the Pons Palatinus (181 BC) with 80' spans being an early monumental example.[15] 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.[16]

The segmental arch offers advantages over the semi-circular arch when it comes to longer spans. The span and rise of a semi-circular arch is equal, meaning that as the semi-circular arch increases in span it's rise increases in direct proportion. The rise of an arch is defined as the vertical distance between the plane of the spring point of the arch and the highest point of the intrados (the bottom of the keystone). The great height of long-span semi-circular arch bridges is unsuitable for many situations. The segmental arch, representing only a segment of a circle, has a span greater than its rise and provides a larger opening with less material and labor than a semi-circular arch. Segmental arches occur very rarely in culvert spans less than ten feet, but are fairly commonly found 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.

In Europe, the benefits of the segmental arch bridge were not realized until the Renaissance when the first bridges of the type were built; their designs however, were based on architectural precedents rather than engineering developments. The first major development in arch theory was put forth by French engineer Phillippe de la Hire in his 1695 *Traite de Macanique*, in which he described his graphical method of analyzing forces acting on bodies in equilibrium, known as graphic statics today. 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." [17]

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13 Rudyard A. Jones, "The Origin of the Voussoir Arch." *Civil Engineering* (April 1941): 259.
14 Jean-Pierre Adam, *Roman Building Materials and Techniques.* Translated by Anthony Mathews. (Bloomington, Indiana: Indiana University Press, 1994): 162.
15 Conde B. McCullough, and Edward S. Thayer, *Elastic Arch Bridges.*)New York: John Wiley and Sons, Inc., 1931): 6.
16 Roland Turner and Steven L. Goulden, Editors. *Great Engineers and Pioneers in Technology* (New York: St. Martin's Press, 1981): 118.
17 *Ibid.*, pp. 227-228.

The pinnacle in stone arch bridge design can be considered to have been reached in the late 18th century by French engineer Jean-Rodolphe Perronet who applied the newly established principles of graphic statics to stone arch bridge design. Perronet was the first director of the Ecole des Ponts et Chausses, the first civil engineering school in the world. His Pont de Neuilly over the Seine near Paris consisted of five arches, each with a span of 120' and a rise of 30'. Although considered the most beautiful stone arch bridge ever built, the French government demolished and replaced the Pont de Neuilly with a modern span in 1956. The design survives however, in a copy built by the great English bridge builder Thomas Telford over the River Severn in Gloucester in 1827.[18]

Although hundreds of notable stone arch bridges were built throughout the world during the first half of the 19th century, England in particular possessing many exceptional examples, the construction technology of the stone arch remained essentially unchanged during the period. In the United States the best examples of the relatively few stone monumental stone bridges built during this period were semi-circular arches, including the Carrollton Viaduct (1829) on the B&O Railroad, High Bridge (1839-1848) in New York City and Starrucca Viaduct (1847) in Susquehanna, Pennsylvania.[19]

In spite of the fact that the form and methods of constructing stone arches changed little during the 19th century, great advances were made in the theories of their design. Up until the mid-19th century the majority of voussoir arches continued to be designed and built by the rule-of-thumb practice established by masons rather than in accordance with mathematical theory.

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. This was especially true in the United States where the railroads – during their initial building and period of expansion – demanded cheap and rapidly constructed bridges, characteristics stone arches did not possess. Railroads were speculative enterprises and naturally pursued a policy of least possible capital investment, which translated to scant concern for a bridge's potential service life. During the second-half of the 19th century the weight of trains increased so greatly and rapidly that railroad bridges were replaced after as little as ten years service.

A number of factors came together toward the end of the 19th century that ushered in a revival of the stone arch bridge in America and Europe. According to engineer Albert Buel, bridge building at that time was marked by "a tendency toward building more substantial structures" that stimulated "renewed interest in that most beautiful class of bridges, the masonry arch."[20] Buel

[18] James Kip Finch.. "Transportation and Construction, 1300-1800." In *Technology in Western Civilization, Volume 1.* Melvin Kranzberg and Carroll W. Pursell, Jr., Editors. (New York: Oxford University Press, 1967): 201-202.
[19] 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.
[20] Buel, 1899, p. 23.

attributed the revival to not only the beauty and permanence of stone arches, but "the recent development and promulgation of methods [of arch analysis] that compare favorably in exactness and simplicity with those used for the truss."[21] The London journal *The Engineer* editorialized that the revival of the stone arch was due to it being "incompressible, inflexible, indeformable, and practically, under normal conditions, imperishable."[22]

A significant attribute of the stone arch bridge is its great dead weight, which being many times greater than the live loads, makes it more resistant to vibration, overloading and the shock of impact loads (moving live loads) than other bridge forms. This "insistent ponderosity," as the British put it, and its permanence, was what made the stone arch an attractive choice for railroad bridges and culverts. Railroads used the arch for bridges somewhat during their initial period of construction during the first half of the 19th century, and then again at the end of the century when they tired of continually replacing metal bridges that had deteriorated or were too light for the ever increasing weight of new locomotives. For large culverts however, the stone arch remained the first choice of railroads throughout the 19th century for its ability to resist displacement by flowing water due to shear mass and its strength under high loads.[23]

The development in the latter half of the century of steam powered quarrying equipment and stone saws increased production and lowered the material's cost. In the U.S. demand for stone for building construction skyrocketed while the cost of railroad transportation – vital to cut-stone trade – dropped. There was an abundance of immigrants available to work cheaply, many of whom were skilled stonemasons who came to America for the opportunities. Common laborers either knew the work of a mason's assistant or could be quickly trained in it. Buel also credits the advancements in cement technology, particularly Portland cement, over the last decade of the 19th century, as having advanced the return to the masonry arch bridge and the emergence of extraordinary arches of reinforced concrete.[24]

Two important textbooks covering masonry arch construction were published at this time. *A Treatise on Masonry Construction* by Ira O. Baker (1889) was considered "a standard and excellent work" by Harvard Professor George F. Swain who used it as a text in his classes.[25] Baker's text was reissued in many revised editions well into the 20th century. *A Treatise on Arches*, by M. A. Howe, published in 1898 and revised in 1906, is also widely cited by later writers. The many articles that appeared in the engineering press at the end of the 19th century, explaining the new arch analysis theories and describing the many stone arches being built around the country, undoubtedly fueled confidence and interest in using the form.

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21 Buel, 1899, p. 36.
22 "The Revival of the Stone Arch." *Engineer* (June 21, 1901): 638.
23 *Ibid*., p. 639.
24 Buel, 1899, pp. 39, 41.
25 Swain, 1927, p.369.

Highway Culverts

"The progress of civilization has everywhere been marked by good roads. It may even be said to be largely due to them." [26]

The story of the evolution of the stone highway culvert naturally follows the progress of road and highway development. It begins with the early stone arch and post and lintel construction being adapted for bridges and advances through the 19th century with the building of improved cart roads and railroads, finally reaching a high degree of efficiency by the end of the century with the advent of mechanized stone quarrying. Upon reaching the pinnacle of their development, the application of stone culverts came to an abrupt end with the introduction of reinforced concrete and corrugated steel pipe culverts. In rocky environs like New England, especially New Hampshire where excellent quality granite and able stone masons remained affordable, the building of stone culverts persisted into the early 20th century as a practical alternative to the other less permanent types.

The history of stone highway culverts is a subject that has received very little scholarly attention. The engineering literature of the 19th century pertaining to road engineering contains sparse mention of culverts and then 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 has made tracing the developmental progress of stone culverts difficult. Much has been written on Roman roads but none of the sources examined discuss the building of culverts under them. Historians may have considered them small bridges and ignored them because of their commonness and apparent insignificance. The fact that the Romans built stone covered drainage and aqueduct structures that resemble the construction of box culverts is well documented in the literature.

According to the Oxford English Dictionary, it was in France about 1770 that the term culvert came into use 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."[27]

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, have been extensively 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 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

[26] Francis V. Greene. "Roads and Road-Making," *Harpers Weekly* 33 (August 10, 1889):633.
[27] Oxford English Dictionary, 1989.

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.[28] 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 of culverts.

In the US even the best early roads such as those built by subscription or the toll roads built by "turnpike companies," were built 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."[29]

Shortly after the American Revolution, 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 so-called Cumberland Road after the systems of Macadam and Telford, was begun."[30] 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." [31] The Cumberland Road, also called the National Road, was later continued on to Illinois; by 1856 the federal government has transferred all ownership and jurisdiction to each of the states it passed through.[32] Presumably small stone bridges and culverts would have been built along the way, particularly through Pennsylvania where stone was abundant, but whether any have been described or survive is unknown.

In New Hampshire in the mid-to-late 18th century, early roads were laid out in some areas of the interior along straight property lines coinciding with the edges of a range of square or rectangular parcels of land.[33] Known as range roads, they were typically two to four rods wide (a rod equals 16.5 feet) but occasionally up to ten rods wide.[34] 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.

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 first New Hampshire turnpike corporation was chartered in 1796 and by 1810 fifty turnpikes had been incorporated in the state although nearly half were never

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28 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.
29 Charles L. Whittle, "Ancient and Modern Highways." *New England Magazine* 17 (February 1898):763.
30 *Ibid.*
31 *Ibid.*
32 *Ibid.*
33 James L. Garvin, "Range Roads." In *Old Stone Wall* (Newsletter of the New Hampshire Division of Historical Resources, Concord, NH), Spring 2002.
34 J. W. Goldthwait, “Old Range Roads in New Hampshire,” *New Hampshire Highways* (December, 1930):4.

constructed. "As in Massachusetts, the custom in New Hampshire generally called for the location and building of entirely new roads, although there were cases were old roads were utilized."[35] There is mention in the literature of wood covered bridges built by the turnpike companies, but the nature of smaller bridges or culverts is not discussed. Like the railroads that would shortly follow, initial construction of the road was rushed in order to get the road open and revenue flowing. The first bridges and culverts along the turnpikes would have been mostly of timber construction.[36]

It can be assumed that many of the earliest stone culverts were repeatedly repaired and often entirely rebuilt after damage by floods. Some were undoubtedly repaired "in-kind" using the original stones, but if the road had gained importance or the necessary stream opening was considered undersized, then a wider, higher or better-constructed culvert would take the place of the original. Existing stones might be "worked" (split or squared-up) and incorporated with new quarry stone into the faces and abutments. Original field and rubble stone previously located on the faces and abutments was typically reused to armor the inlet and outlet embankments or extend facewall and retaining walls. The resulting mix of materials and methods confounds efforts to date stone structures located on New Hampshire's earliest roads on the basis of physical evidence alone.

When stone was used for culverts and small bridges in the late 18th and early 19th centuries, the method for quarrying and splitting large stones were the same that had been used for centuries. A new more efficient method of splitting stone known as plug-and-feathers was introduced in New Hampshire by about 1830.

> Prior to about 1830, the procedure for splitting granite entailed the cutting of a line of shallow slots in the face of the stone, using a tool called a cape chisel, struck with a heavy hammer. Small, flat steel wedges were placed between shims of sheet iron and driven into these slots, splitting the stone. The new splitting method of circa 1830 used a "plug drill," which had a V-shaped point and was rotated slightly between each blow of the hammer, creating a round hole two or three inches deep. Into this hole were placed a pair of half-round steel shims or "feathers," and between these was driven a wedge or "plug" which exerted outward pressure and split the stone. The advantage of the "plug-and-feathers" method of splitting was the greater depth within the stone at which the wedges exerted their pressure, thus allowing larger pieces to be split more accurately. The new splitting technology seems to have spread rather rapidly through the granite quarrying centers of New England, although one is likely to find evidence of both old and new methods being used concurrently in stonework of the 1830s, especially in rural areas. The technique employed on a given stone can usually be seen on the split face, and provides some aid in dating granite masonry. The flat-wedge method is marked by a series of slot-like depressions which extend inward an inch or so from the edges of the split stone. The plug-and-feathers method leaves a row of rounded holes, two or three inches deep and usually about six inches apart. Until the introduction of the new technique, most granite for buildings and posts was split from surface boulders that had been strewn across the

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[35] Frederick J. Wood. *The Turnpikes of New England* (Boston: Marshall Jones Company, 1919.):215-216, 247-248.
[36] See: J. W. Goldthwait, "Six Old New Hampshire Turnpikes," *New Hampshire Highways* (July-December 1932).

> New England landscape at the retreat of the glaciers. Such stone had been transported by the ice from many points of origin, and each boulder challenged the stonecutter with different grain and behavior when split. The introduction of the plug drill and plug-and-feathers seems to have enhanced stonecutters' ability to quarry granite from ledges. Ledge stone was more uniform in nature and predictable in behavior than granite split from surface boulders.[37]

Drill holes made by the small one-hand chisel-point drills used in the plug and feather method are typically 3/8" to 3/4" in diameter and 8" to 12" deep.[38] In stone quarrying operations particularly in hard rock such as granite, large sections of rock were broke free using explosives and then split into smaller pieces by men using the plug and feather method. Drill holes were filled with gunpowder followed by clay tamped into the hole to seal it and contain the force of the blast. Holes made by hand for blasting with gunpowder needed to be deeper and were made with longer, larger diameter drills called jumpers or churn drills that created holes 1.5 to 2 inches in diameter. The jumper drill, roughly 3 feet long, was held by a man sitting down (the *holder*) who gripped the drill in two hands and rotated it slightly as two men (*strikers*) alternately struck the drill, each wielding 8 to 12 pound hammers. The churn drill was operated by one man but only in the vertical position. It was 6 to 8 feet long, usually 1.25" in diameter and weighed 25 to 30 pounds. The driller lifted the churn drill a few inches, let it fall into the hole, caught it on the bounce giving it a small quick turn and then let it fall again. This was repeated until the desired hole depth was achieved, sometimes in excess of 4 feet. One man operating a churn drill in granite could drill 7 to 8 feet of hole 1.75" in diameter in a 10-hour work day.[39]

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. Two methods were used, the percussion drill which pounded the chisel-type drill bit with short fast blows from a piston while it gradually rotated, and the rotary drill which smoothly and continuously turned a round or cylindrical bit with hardened cutting teeth. The Ingersoll Drill was the first steam powered percussion drill and used the air to blow the stone bits from the hole. The rotary drill was a European invention and by the 1880s was equipped with diamond bits and water-cooling that washed the stone bits out of the hole. A variety of improved steam and air powered percussion drills were in widespread use in the US for mining and quarrying by the 1880s capable of drilling holes from ½" to 6" in diameter and from 4 to 40 feet deep.[40]

Stone road culverts of both the box and arch type have been documented in New Hampshire with construction dates from the early 19th century. An arched bridge through a stone causeway was

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[37] James L. Garvin, "Granite Splitting Tools and Techniques," (no date). Manuscript on file at New Hampshire Division of Historical Resources, Concord.
[38] Ira O. Baker. *A Practical Treatise on Masonry Construction*. New York: John Wiley & Sons, 1899, p 117. See Baker's entire chapter on quarrying, pp. 116-124.
[39] John C.Trautwine. *The civil engineer's pocket-book, of mensuration, trigonometry, surveying, hydraulics ... etc.* New York, J. Wiley & Sons, 1885, p. 651.
[40] Trautwine, 1885, pp. 652-660. Trautwine gives and extensive discussion of the various types of drills in use in the US.

built at High Bridge in New Ipswich in 1819.[41] During the 1830s and 1840s there was a marked increase in the use of split stone and quarried granite for bridge and culvert building in New Hampshire. This trend has been attributed to the introduction of the plug drill and plug-and-feathers method of splitting stone and the need to replace vulnerable wooden bridges with permanent ones of stone.[42]

Beginning in the 1830s, a few arched granite highway bridges were built in southern New Hampshire under the supervision of engineers from major manufacturing centers.[43] In the Contoocook River Valley there was a concentration of stone arch bridges built beginning about 1835 when a double-arch bridge – the first in New Hampshire – was erected in the town of Henniker. A consulting engineer, Isaac C. Flanders of Lowell, Massachusetts, prepared detailed construction specifications for the two forty-foot spans that included the dimensioning, squaring and finishing of the arch stones, the minimum overlap of the joints (six inches) and the length of the foundation stones (ten feet), to name a few.[44] The quality of construction of the Henniker bridge appears to have set a benchmark that later bridges strived to achieve. The bridge quickly gained recognition and admiration by neighboring towns that followed suit by also constructing stone arch bridges.[45] In Hillsborough alone twelve stone arches were built at the urging of Hiram Monroe (1799-1871), an individual active in town affairs.[46] Six remain, most still in service.[47] Among the local builders were Reuben E. Loveren (1817-1883)[48] and brothers Calvin A. Gould (1826-1877) and James H. Gould (1828-1890).[49] All three worked on the double-arched Sawyer Bridge in Hillsborough built in 1866, bypassed but still standing near the intersection of Routes 9 and 202.[50]

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41 James L. Garvin, "Notes on the Origins of Arched Stone Bridges in the Contoocook River Valley of New Hampshire," (November 20, 2004). Manuscript on file at New Hampshire Division of Historical Resources, Concord.
42 *Ibid.*
43 *Ibid.*
44 *Ibid.*
45 See Garvin, "Notes on the Origins of Arched Stone Bridges…," cite above, for a detailed discussion of impact of the Henniker bridge on stone arch bridge construction in New Hampshire.
46 George Waldo Browne, *The History of Hillsborough, New Hampshire, 1735-1921*. Two volumes. (Manchester, N. H.: John B. Clarke Company, 1921), Vol. I, p. 302. For Monroe's birth and death dates, see Richard S. Munroe, *History and Genealogy of the Lexington, Massachusetts Munroes* (Florence, MA: by the author, 1966): 71, 126.
47 The six remaining bridges are: 1. Sawyer Bridge, 2 arches, bypassed beside Route 202; 2. Second Turnpike Bridge or Bridge at Fuller's Tannery, 2 arches separated by causeway, Hillsborough Lower Village; 3. Carr-Jones Bridge over Beard's Brook, 2 arches; 4. Gleason Falls Bridge over Beard's Brook, one arch; 5. Bridge north of Gleason Falls over Beard's Brook, 2 arches separated by long causeway; 6. Tuttle (?) Bridge, now underwater off Breezy Point, Jackman Reservoir or Franklin Pierce Lake. The bridge at Hillsborough Bridge, built in 1893 by Ward and Douglass of Barre, Vermont, is a mortared bridge and is not included among the dry-laid spans discussed here.
48 For Loveren's birth and death dates, see George Waldo Browne, *The History of Hillsborough, New Hampshire, 1735-1921*. Two volumes. (Manchester, N. H.: John B. Clarke Company, 1921), Vol. II, p. 377. Browne says of Loveren, "he was a lumber dealer and res[ided] at [Hillsborough] Bridge Village most of his business life."
49 Benjamin Apthorp Gould, *The Family of Zaccheus Gould of Topsfield* (Lynn, Mass.: Thomas P. Nichols, 1895), p. 155 (for birth dates); New Hampshire Vital Records files, Death Records, "Calvin A. Gould" and "James H. Gould." (for death dates).
50 *Hillsborough Town Report*, 1866.

In Auburn, Rockingham County, a stone box culvert with a span of approximately 8 feet was constructed under Coleman Road about 1844. The culvert was determined eligible for listing in the National Register and documented in 2002 prior to its removal.[51] The seven stone beams or lintels, that form the top of the culvert, called stringers in the documentation report, measure 24-27 inches wide, 10-18" deep, and 9-11 feet long.

Another early stone box culvert that is no longer extant was the Dame's Brook Culvert, formerly located on West Milton Road in Farmington. It was an eight-foot culvert with an attributed date of 1857 and like the Coleman Road Culvert consisted of a series of parallel lintels with fill over top.[52]

In addition to the Dame's Brook and Coleman Road culverts, the 1982 NH Historic Bridge Inventory identified four multi-span highway culverts assigned bridge numbers. Amherst bridge 109/090 has two spans with clear widths of 6'-0" each. Amherst bridge 159/105 has four spans with clear widths of approximately ten feet center-to-center. Candia bridge (151/123) has two spans, one with a clear width of 10'-0" and the second with a clear width of 6'-6." Fitzwilliam bridge (148/078) has two spans of about six feet each.

It should be noted that the New Hampshire structures described above and essentially all stone bridge and culvert structures built in the state prior to perhaps the 1880s, were of dry-laid masonry, meaning laid-up without the use of mortar. By the 1850s, rural stonemasons had mastered the art of building bridges without mortar. Prior to the invention of Portland cement in England in 1824 and its belated introduction to the US in 1868, hydraulic-cement mortars were prohibitively expensive for most common masonry work. Unlike simple lime mortars that disintegrated in water, hydraulic-cement mortars not only withstood indefinite submergence but also actually hardened under water. First manufactured in the US about 1872, it was not until 1880 that large-scale manufacture of Portland cement was fully underway in the US and its use became widespread.[53] The use of cement mortar to fill the gaps between stones provided a uniform bearing between stones and bonded the entire structure together solidly. Stones no longer needed to be so precisely squared and smoothed which saved labor and offset the cost of the mortar.

For the purposes of culverts, bridge abutments and retaining walls, dry-laid masonry usually sufficed nicely, although attaining tight joints was labor intensive. The lack of mortar provided porosity to the structure that allowed water in the backfill to drain out through the faces thereby reducing hydraulic pressure on the masonry and the damaging effects of frost and ice. The lack

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[51] New Hampshire Historic Property Documentation No. 504, "Coleman Road Culvert, Auburn, NH." July, 2002. On file at New Hampshire Division of Historical Resources, Concord.

[52] New Hampshire Individual Property Inventory Form FAR0015, "Dame's Brook Culvert, Farmington, NH." September, 1999. On file at New Hampshire Division of Historical Resources, Concord.

[53] 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;

of mortar also allowed the stones to move slightly, giving the structure an overall flexibility that some argue is an advantage when subjected to excessive live loads, impact loads or vibration that can fracture and pulverize mortar in some cases.

In America, one of the earliest and most important discussions of road building was an essay entitled "The Science of Road Making" written in 1870 by the famous engineer Clemens Herschel of Boston. The paper won the "First Prize Treatise" award in a competition for papers on roads sponsored by the Massachusetts State Board of Agriculture. In 1877 the essay was printed in its entirety with additions by the author in *Engineering News*. The material was later expanded and printed in book form under the same title in 1890.

Herschel identifies the three steps involved in making a road: 1) laying out the road by survey; 2) making the roadbed, which includes all earthworks, cutting and filling, culverts, drains, bridges, tunnels; and 3) the making of the road surface.[54] He does not discuss design features of culverts but gives the following advice:

> 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.

Rolla C. Carpenter, a professor of civil engineering at the Michigan State Agricultural College, wrote a detailed paper in 1877 on the subject of road drainage entitled "Turnpiking and Underdraining Common Roads." His discussion concentrated mainly on "turnpiking" which was the construction of road with a crown for runoff; culverts are only briefly mentioned as necessary for conducting the water from one side ditch to the other for discharge into a watercourse.

Other writers were more specific:

> 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 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.[55]
>
> 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.[56]

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[54] Clemens Herschel, "The Science of Road Making," *Engineering News* 4 (June 2, 1877): 148.
[55] C.G. Elliott, "Road Improvement," *Engineering News and American Contract Journal* 15 (March 13, 1886): 161.
[56] Charles C. Brown, "Gravel Roads," *Engineering News and American Contract Journal* 15 (April 24, 1886): 262.

The suitability of pipe culverts over those of stone was promoted by some writers and rejected by others:

> 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.[57]

> 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.[58]

Good Roads Movement

By the end of the 1880s the movement for better roads gained momentum. 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.* Some articles, such as "Roads and Road-Making, by Captain Francis V. Greene, provided an overview of the history and social importance of roads, along with a discussion of the state-of-the-art of road design, construction methods and machinery in use in the United States. Nearly all articles made clear their purpose of stimulating public interest in the call for better roads.[59]

This clamor led the civil engineering department of the University of Pennsylvania to offer a competition and cash prize for the best paper on "the construction and maintenance of common roads." The entries were published in book form *A Move for Better Roads, Essays on Roadmaking and Maintenance and Road Laws* published in 1891. The introduction stated:

> Since Peter Cooper built the first American locomotive sixty years ago, there has been a prodigious growth and improvement in the railroads of the country, until a system of transportation has been developed that infinitely transcends that of any previous age known. This marvelous development was only possible through the employment of the highest scientific and, engineering and financial talent and skill. During the same period our common roads, while necessarily increasing with the settlement of new territory, have exhibited no marked improvement in character, and since the death of Macadam in 1836, his mantle appears to have fallen on no other great prophet or apostle of better roads.

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57 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.
58 Ontario Legislative Assembly. "Stone Culverts," Sessional Papers (No. 36) Legislature of the Province of Ontario, (1894): 51.
59 Greene, 1889, pp. 633-636.

During the 1890s the movement for better roads resulted in a great many papers regarding the importance of drainage in road design and the accompanying need for proper culverts but few mentioned specific designs of culverts for highway use.[60] Professor Emory Johnson of the University of Pennsylvania summed it up this way: "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."[61]

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 with the subtitle *devoted to the construction of roads and streets* (later absorbed by *Roads and Streets* magazine). Another organization called "The Good Roads Movement" published *Highways* magazine about the same time.

Progressive states passed road legislation, two of the earliest being Massachusetts in 1892, which created the Massachusetts Highway Commission, and New York in 1893, which created a county highway system with engineers in each county responsible for road improvement.[62] Road legislation in New Hampshire would not be passed until 1905 [discussed below].

Very little has been found written on the subject of highway culverts in New Hampshire in the late 19th and early 20th centuries. The City of Concord built stone culverts under streets during the 1890s.[63] The listing of highway expenditures in the city's Annual Report for 1895 includes the following entries:

Building stone culvert on Pennacook street . . .	$25.49
Building stone culvert on Noyes street	$12.70
Building stone culvert on Gully hill	$10.25
Building stone culvert on River road in District No. 4 . .	$60.50
Extending stone culvert on School street west of Giles . .	$48.80
Extending stone culvert on Clinton street . . .	$45.40

The lack of any mention by Concord's reporter of the type or size of the culverts or who built them supports the idea that stone culverts were a relatively minor expense or commonplace enough that details were unnecessary.

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60 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.

61 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.

62 Johnson, 1894: 269-270.

63 City of Concord. *Forty-third Annual Report of the Receipts and Expenditures of the City of Concord for the Year Ending December 31, 1895*. Concord, NH: Ira C. Evans Printer, 1896.

Beginning in 1897, the New Hampshire Board of Agriculture began holding annual "Institutes" on the subject of good roads. The first was held in Concord, the second in Keene and the third in Lancaster. Talks were presented by both engineers and community leaders on the need for more and better roads and on the methods of their proper design, construction and drainage. Papers at the 1899 convention included "Approved Methods of Road Drainage," by Professor C. H. Pettee of Durham, "Drainage of Country Roads" by Arthur W. Dudley of Brentwood and "Bridges and Culverts on Country Roads" by William B. Howe of Concord.[64]

Howe gave the following guidance on the construction of culverts in New Hampshire:

> After the water has been collected in the [side] ditches we naturally look for some way to dispose of it. Where there is no natural stream on the same side of the road, we must construct a passageway through which the water can be led toward the natural water-course; which means that a culvert is required.
>
> Where the culvert is well built, and the filling over it is of a suitable character, the discharging capacity of the culvert can be greatly increased by allowing the water to dam up over it. It becomes necessary in many cases to provide some kind of a catch-pit to stop logs, poles or any other floating debris from entering and clogging the culvert, and thereby causing a washout or other serious damage.
>
> When it is necessary to provide more waterway than a thirty-six inch pipe furnishes, a stone culvert is required. If good stone is easily obtained near the site of the proposed culvert, it should be built of large, roughly squared stone laid in cement mortar. Lime mortar should not be used in culvert masonry. If the horizontal opening in a culvert exceeds about four feet it is probable that a rough-cut arch culvert would be cheaper than a box culvert, as the increased expense of suitable covering stones would more than pay for the rough work in the arch and the larger dimensions required in the side walls. In the absence of a quarry or large bowlders [sic] from which suitable stone can be quarried, a culvert can be built of field stone if care is used in selecting and laying them in good cement mortar.

In 1905 New Hampshire enacted a State Aid Highway law (Chapter 35, Laws of 1905) that required towns to make annual appropriations for highway improvements and created the post of state highway engineer to which Governor John McLane appointed State Engineer Arthur W. Dean.[65] In his first report, Dean noted that $80,000 in State Aid went to the towns in 1905 and was used for widening, reducing steep grades, and constructing permanent culverts, underdrains and side ditches. In several cases only grading and drainage improvements were undertaken in anticipation of adding crushed stone surfacing the following year.[66]

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[64] The papers presented at the Board of Agriculture's 1899 Institute on Good Roads are published in: N.J. Bacholder, *Report of the New Hampshire Board of Agriculture from October 1, 1898 to January 1, 1901*. (Manchester, NH: Arthur E. Clarke Public Printer, 1901). Howe's paper, cited in the text, is on pages 481-488.

[65] James L. Garvin. *New Hampshire Good Roads Projects, 1904-2004.* Manuscript on file at New Hampshire Division of Historical Resources, dated July 23, 2003.

[66] State of New Hampshire. *First Biennial Report of the Governor and Council and of the State Engineer Relative to Highway Improvement.* Concord: State of New Hampshire, 1906:11,19.

Dean developed a standard contract and specifications for grading and improving town roads with state aid monies to insure a uniform high quality of work. In regards to stone masonry work for culverts the specifications were very detailed as shown by the following sample of the requirements:

- all stone shall be free of structural defects;
- selected stone, roughly squared and pitched to line, shall be used at all angles and ends of walls;
- stones shall be at least 6 inches thick;
- stone shall be laid in full cement mortar beds;
- length of the stretchers shall not exceed three times the rise;
- width of stretchers shall not be less than the rise or less than 12 inches;
- at least one-fourth of the stone in the face shall be headers, evenly distributed throughout the wall;
- all stones shall break joints six inches or more;
- no joint on the face shall be more than two inches;
- end walls shall be capped with stone roughly squared extending across the entire width of the wall;
- stone culvert bottoms, when specified on the plans, shall be rammed to a firm bearing and uniform surface and the joints filled with cement mortar; etc.

Culverts in New Hampshire that survive from this early period of the 20th century could be expected to retain some of the features listed above.

As the 20th century progressed, the gap between the cost of concrete and pipe culverts compared to more costly stone culverts continued to grow. Some textbooks no longer included any mention of stone as a choice. A 1915 textbook on highway construction gave this summation on culverts:

> "The selection of the type of culvert and material to be used is largely a question of economy, particularly in the case of small waterways. The availability of materials, their first cost, freight charges, cost of handling and cost of construction all have to be considered. Other considerations such as the depth of fill over the culvert, or when large areas of waterway are required box or arch culverts may be required since certain types of pipe is limited to three feet in diameter." [67] [Note: The box and arch culverts being recommended were of both plain and reinforced concrete.]

In New Hampshire where there was a combination of harsh environment, continued availability of cheap quarry stone and conservative highway engineers that favored the tried and true, stone persisted as a material for culvert construction. The figure below shows the New Hampshire Highway Department's use of granite for the walls and floor of a 4-foot box culvert in combination with a reinforced concrete slab span. This design took advantage of the properties of each material: stone is better able to resist the effects of water and ice than concrete; reinforced concrete is strong and predictable in tension.

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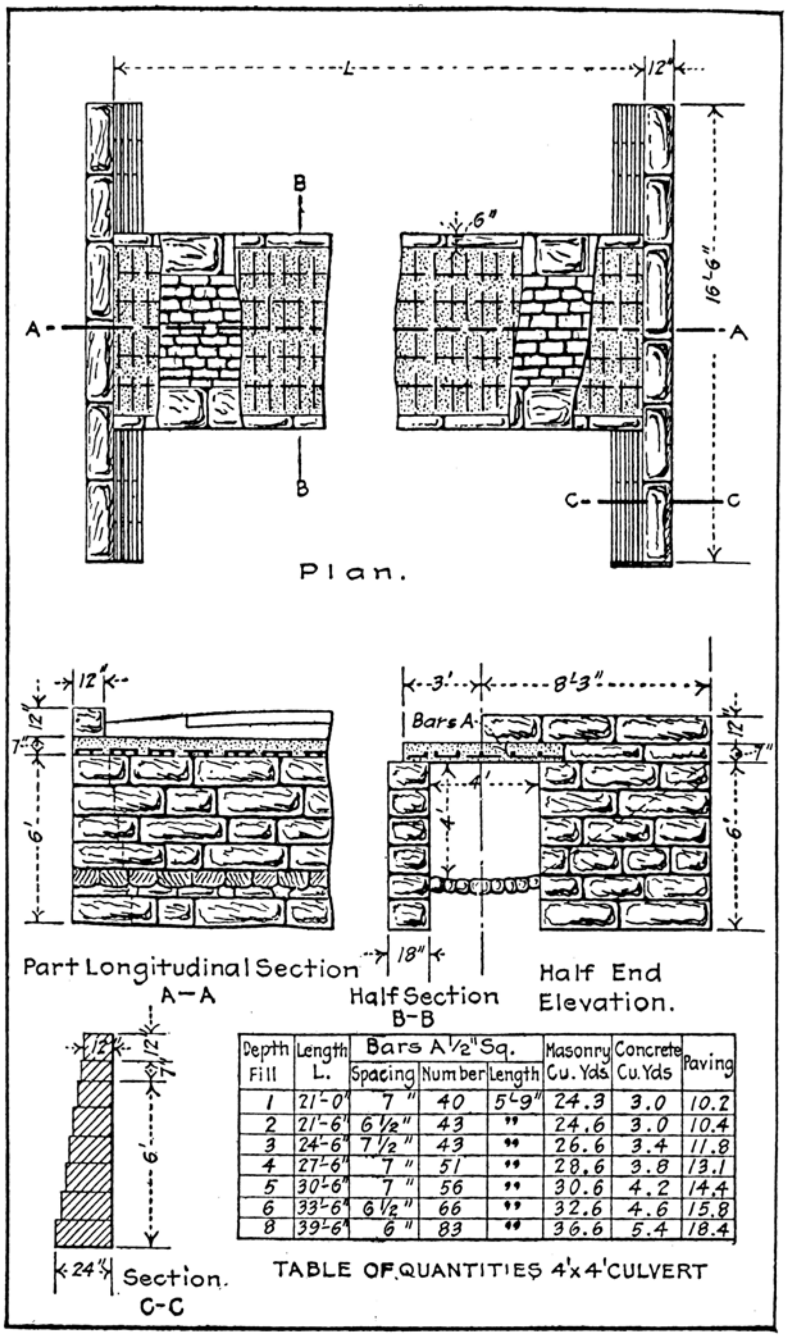
67 Arthur H. Blanchard, *Elements of Highway Engineering*. (New York: John Wiley and Sons, Inc., 1915):423.



Depth Fill	Length L.	Bars A ½" Sq.			Masonry Cu. Yds.	Concrete Cu. Yds	Paving
		Spacing	Number	Length			
1	21'-0"	7"	40	5'-9"	24.3	3.0	10.2
2	21'-6"	6 ½"	43	"	24.6	3.0	10.4
3	24'-6"	7 ½"	43	"	26.6	3.4	11.8
4	27'-6"	7"	51	"	28.6	3.8	13.1
5	30'-6"	7"	56	"	30.6	4.2	14.4
6	33'-6"	6 ½"	66	"	32.6	4.6	15.8
8	39'-6"	6"	83	"	36.6	5.4	18.4

TABLE OF QUANTITIES 4'x4' CULVERT

FIG. 64.—Typical masonry culvert. State of New Hampshire.

Figure No. 1: Standard design stone box highway culvert with reinforced concrete span used by the New Hampshire State Highway Department in the early 20th century.[68]

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[68] Harger and Bonney, *Handbook for Highway Engineering*, 1927, p. 22.

Engineered Culverts

The largest body of literature on the design and engineering of stone culverts pertains to those built by the railroads and was published in the last quarter of the 19th century. Prior to this time, stone culvert design and construction was based on traditional knowledge of the component elements such as the strength of the local stone and characteristics of a particular water course and drainage area. Stone culverts designed and constructed by bridge builders or masons can be called "vernacular in design" and the majority of stone highway culverts undoubtedly fall into this category. With the exception of the military works, canals, hydropower and a few great water supply and sewerage projects, civil engineering in America during the 19th century was dominated by railroad work. The majority of knowledge of the engineering of bridges, culverts and land drainage resulted from the building of what became the world's greatest railroad system.

When highway culverts were engineered, there was a high probability that the engineer had previous experience designing railroad culverts. Many if not most civil engineers who received a formal engineering education in the mid-19th century or later, started their professional career in the employ of a railroad company. In the early part of the century, military-trained engineers were involved in canal and railroad building, which involved the construction of stone culverts and culvert-type structures. As mentioned above, an engineer from Lowell, Massachusetts, possibly with experience in canal design, was responsible for the design of stone arch highway bridges in Henniker, New Hampshire. Research, however, has not established a positive connection between canal engineers and early stone highway culvert design.

The work of building, maintaining and renewing railroads called on many branches of civil engineering and the position of Engineer or Chief Engineer with a major railroad was prestigious. Except for the largest cities, municipalities employed few engineers until the very end of the 19th century when large water, sewerage and road infrastructure projects justified them. Most public projects were designed by consulting engineers who entered private practice after a career with a railroad. Some engineers held a position with a railroad company and operated a private consulting business at the same time. Furthermore, the hundreds of skilled and semi-skilled masons that built stone bridges and culverts for the railroads also found work building them for roads.

Everything about building and operating a railroad was incredibly expensive from the actual construction of the road to the equipment and means to repair and maintain it all. The roads were built as straight as possible to keep them short and absent of troublesome curves, and as level as possible to avoid equally troublesome inclines. This required the building of many long filled embankments and causeways across valleys and wetlands with culverts passing through them to allow the free passage of water. When the road wound around the base of a mountain it was cut into the slope and fitted with frequent culverts to accommodate the many intermittent streamlets running during rainstorms. Because of the huge outlay of borrowed capital involved, the engineer of the road was expected to prepare designs as the construction proceeded, make fast calculations in the field, and when in doubt, make judgments in favor of less cost. The result of such "fast-tracking" was that many culverts were inadequately designed and later washed out with a great loss of life and property.

Boston engineer Charles Folsom addressed the problem of "railroad washouts" in 1886.[69] Folsom made a tally of newspaper reports over the previous two years and counted 80 bridges and 125 railroad culverts washed out, resulting in the death of 34 people, dozens injured, and property losses in the millions of dollars. He concluded that "the provision for the passage of streams alongside and under the road-bed has not always received the attention which its importance demands…culverts have been 'sprinkled in' where well defined streams presented themselves without much inquiry as to how large a district they drained."[70]

During the last quarter of the 19th century nearly all the major rail lines in the east were reconstructed to handle heavier rolling stock and extended with branch lines to serve new markets. The larger railroad companies with full-time engineering departments developed standard designs for culverts that were sometimes published in the railway and engineering journals of the day. For their eastern extension into Maine in the 1880s, the Canadian Pacific Railway developed standard designs for stone box culverts of 2', 2-1/2' and 3' widths, and arch culverts of 6', 8' and 12' widths.[71]

In New England, due to the ready availability of good granite throughout the region, the railroads built culverts almost exclusively of stone from the start. Railroads provided the means of transportation to deliver the stone directly to where it was to be used and then unload it with a derrick car. The wide use of high quality split and cut quarry stone for bridge abutments and retaining walls meant that the same was available for culvert construction. The Boston and Maine Railroad (B&M) built stone box and arch culverts along their lines and the lines they took over throughout New Hampshire. In the western US, where distances were great and stone scarce, the usual practice was to first build wood trestles or wood culverts and then replace them later with stone once the line was open to bring in the stone and fill material. This also allowed the engineer to make observations on the characteristics of the waterway crossing to better estimate the required size of the culvert opening.[72]

Some eastern railroad engineers, such as A. J. Swift, Chief Engineer of the Delaware & Hudson Railroad, considered stone box culverts to be "better laid dry, except for end walls and curbs" providing the joints are no wider than one inch.[73] This practice was apparently widely used on the construction of the early railroads but the danger of the practice was demonstrated by the failure of a stone culvert on the B&M line in Exeter, New Hampshire in 1897. On June 9 and 10

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69 Charles W. Folsom, "Railroad Washouts." *Journal of the Association of Engineering Societies* 5 (1885-1886): 304-308.
70 Folsom, p. 306.
71 "Minor Structures; Canadian Pacific Railway." *Engineering News* 20 (December 29, 1888): 500-501. "Arch Culvert Plans, Canadian Pacific Railway." *Engineering News* 21 (April 6, 1889): 302.
72 A.J. Swift, "Some Methods of Meeting the Ordinary Requirements of Railroad Maintenance." *Engineering News* 25 (May 30, 1891): 522—524; (June 6, 1891): 548-549.
73 *Ibid.*

of that year, seven and a half inches of rain fell. The resulting freshet washed out a stone box culvert six feet high and five feet wide that passed through a "long high embankment known as Fernald's fill."[74] The engineer and two brakemen were instantly killed, which led to an inquiry by the state Board of Railroad Commissioners. The finding was that the old portion of the culvert, built about 1850, was dry laid (without mortar) and that "when the water rose above the top of the culvert the fill material washed though the joints between the cover stones and that if the culvert had been a modern one constructed of split stones, cemented together, the accident would not have occurred. Beyond this it is impossible to fix responsibility upon any human being. The culvert was as good as any that were originally put into the railroads."[75]

By the 1880s engineers were expressing their need for more information on the design of culverts: "These minor structures are often those which an engineer most desires to obtain details of from the practice of other roads, and yet finds most lightly treated in engineering publications."[76] Articles on the importance of culverts, the features of their design and their cost began to appear with greater regularity in the engineering literature through the end of the nineteenth century and into the twentieth. Specifications and tables for the allowable spans for stone box culverts based on the thickness of the cover stone and the depth of the fill above them were published.[77] The cost of masonry work for the construction of culverts in New York in 1888 was as follows: "masons and skilled laborers paid $2.25 per day for a 12 hour work day, minus 1 hour for dinner."[78]

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 the culvert under all foreseeable conditions. The loading must also be calculated: dead loads consisting of the weight of the overlying fill and roadway; live loads consisting of over passing traffic 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. Sizing is a simple calculation, but first the engineer must calculate the maximum anticipated flow of water that will reach the culvert opening, which is unfortunately not a simple calculation.

In *Railroad Construction*, a treatise that would be released in many editions through the 20th century, Professor W. L. Webb of the University of Pennsylvania devoted an entire chapter to "Culverts and Minor Bridges," noting that "in localities where a good quality stone is cheap, stone box culverts are the cheapest form of permanent construction for culverts of medium

[74] New Hampshire Railroad Commissioners. *Fifty-third Annual Report of the Railroad Commissioners of the State of New Hampshire, 1897.* Manchester, NH: Arthur E. Clarke Public Printer, 1898, p. 82.
[75] *Ibid.*, p. 83.
[76] "Minor Structures; Canadian Pacific Railway." *Engineering News* 20 (December 29, 1888): 500.
[77] Emile Low, "Maximum Spans of Box Culverts." *Engineering News and American Contract Journal* 14 (July 25, 1885): 55.
[78] "Cost of Masonry in Detail." *Engineering News* 20 (December 8, 1888): 446.

capacity, but their use is decreasing owing to the frequent difficulty in obtaining really suitable stone within a reasonable distance of the culvert."[79] Webb discusses the design of box culverts:

> The required thickness of the cover stones is sometimes calculated by the theory of transverse strains on the basis of certain assumptions of loading – as a function of height of the embankment and the unit strength of the stone used. Such a method is simply another illustration of a class of calculations which look very precise and beautiful, but which are worse than useless (because misleading) on account of the hopeless uncertainty as to the true value of certain quantities which must be used in the computations. In the first place the true value of the unit tensile strength of stone is such an uncertain and variable quantity that calculations based on any assumed value for it are of small reliability. In the second place the weight of the prism of earth lying directly above the stone, plus an allowance for live load, is by no means a measure of the load on the stone nor of the forces that tend to fracture it. All earthwork will tend to form an arch above any cavity and thus relieve an uncertain and probably variable proportion of the pressure that might otherwise exist. The higher the embankment the less the proportionate loading, until at some uncertain height an increase in height will not increase the load on the cover stones. The effect of frost is likewise large, but uncertain and not computable. The usual practice is therefore to make the thickness such as experience has shown to be safe with a good quality of stone, i.e., about 10 or 12 inches for 2 feet span and up to 16 or 18 inches for 4 feet span. The sidewalls should be carried down deep enough to prevent their being undermined by scour or heaved by frost. The use of cement mortar is also an important feature of first-class work, especially when there is rapid scouring current of a liability that the culvert will run under a head.[80]

Sizing culvert openings

Sizing the culvert opening or determining the "required area of the waterway" as it was usually called in the literature, was chiefly done either on the basis of field measurements and observations or with the use of an empirical formula. Regardless of the method used, the necessary area of the waterway was a function of variables that were (and are) difficult to quantify:

> a. Rainfall: particularly peak rainfall amounts during heavy storms for a given area;
> b. Area of watershed: determined by analysis of topographic maps or by original surveys of the line of roadway, or by special survey when information lacking;
> c. Character of soil and vegetation: impermeable soils bare of vegetation will run off quickly and tax the capacity of the culvert for a short time; densely vegetated and permeable soils will retard the runoff making it more nearly uniform and the maximum flow at any one time much less;
> d. Shape and slope of the watershed: for long, narrow watersheds, the water from areas farthest away will require more time to reach the culvert, making the flow relatively

[79] Walter L. Webb, *Railroad Construction, Theory and Practice.* (New York: John Wiley and Sons, 1900): 212.
[80] *Ibid.*, pp. 212-213.

> uniform, especially when the slope of the watershed is low. When the slope of the remoter portions of the watershed is steep, water from all parts of the watershed may reach the culvert at nearly the same time and tax its capacity.

Designing on the basis of data gathered from field observations and measurements was considered "by far the best for permanent work," and consisted of "observing the high water marks on contracted channel openings which are on the same stream and as near as possible to the proposed culvert."[81] The Boston and Maine sized their culvert openings "wholly by observation" by gathering high water marks on other openings on the same stream or along the banks where freshets have pushed debris, and from the knowledge of area residents.[82] When lacking in good data and information, a common practice was to construct a temporary wood pile trestle across the waterway with a more than ample opening and then gather data on the volume and velocity of the water during storms over the life of the structure, typically ten years or less.[83] The temporary structure was then replaced with a stone culvert sized on the basis of the actual requirements calculated from the measurements.

Calculation of the required area of waterway for a culvert using formulas was practiced at least as early as the 1870s. Culverts are frequently 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. The handbook was reprinted in many editions – the 20th edition was published in 1919 – and was apparently widely used by engineers. 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. The Buerkli-Ziegler method was developed by German engineers for calculating runoff in urban areas for sewer designing and not well suited for the huge variance in soils and terrain in America. In the late 1880s two new formulas for sizing culverts were published. The one proposed in 1887 by E.T.D. Meyers, an engineer and President of the Richmond, Fredericksburg & Potomac Railroad, was considered most effective for smaller culverts and became the one most used by engineers in New England. It was a simple formula with only a square root calculation. The other, "Talbot's formula," was proposed in 1888 by Professor A. N. Talbot of the University of Illinois and was a bit more complicated requiring a 3rd and 4th root calculations but became "the one most generally employed by engineers."[84]

Both Meyer's and Talbot's formulas employed a coefficient to factor in the nature and slope of the terrain that was draining into the culvert. For example, Meyer's coefficients were 1.0 for rolling prairie, 1.5 for hilly ground and 4.0 for rocky and mountainous ground. Talbot considered more variables such as "rolling agricultural country subject to floods at times of melting snow," the length-to-width ratio of the valley being drained, and the location of steep side slopes in a valley relative to the culvert.

81 Webb, 1900, p. 205.
82 J.P. Snow, in Berg, 1898, p. 566.
83 A.J. Kelley, in Berg, 1898, p. 566.
84 Ira O. Baker, *A Practical Treatise on Masonry Construction*. New York: John Wiley & Sons, 1910.

The debate over culvert sizing in the literature showed writers to be about equally divided in their preference for Talbot's or Meyer's methods. The editors of *Engineering News* published their own assessment of "How To Determine Size and Capacity of Openings for Waterways" in which they reviewed several published methods and discussions on the subject from railroad engineers in letters sent to the editors.[85] By the turn of the century a substantial body of information on the design and engineering of culverts was beginning to be amassed. In a compilation of all the technical articles and discussions published from 1890 to 1898 in the reports of Association of Railway Superintendents, Bridge and Buildings, culvert sizing and design was one of the largest sections.[86]

Hydrodynamic Design

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 the form of the approach, inlet and outlet. When circumstances justify the investment of the engineer's time, the variables can be carefully designed to provide the highest possible flow rate and velocity through the culvert while limiting destructive turbulence that can erode and undermine it. Culverts with a segmental arch profile instead of a semicircular arch were recommended by some for their advantages that include greater overall opening area for a given cost, lower arch height which usually meant less roadway fill required, and a wider opening allowing freer passage of debris with less likelihood of obstruction and clogging.[87]

Some 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.

Planning for a culvert to operate submerged under pressure on a regular basis not only presents more difficult engineering issues in the design, it also raises the potential for more frequent and more severe maintenance issues over the life of the culvert. For the railroads, a disincentive to building culverts designed to operate submerged was the potential for claims of damage by adjoining land owners whose crops or other property suffered under the submergence of the backed-up water. As private entities, the railroads were not only vulnerable to being sued; they had the money to pay damages and were therefore frequent targets of lawsuits.

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[85] "How to Determine Size and Capacity of Openings for Waterways." *Engineering News* 38 (October 21, 1897): 267. See also "Culvert Formulas." *Engineering News* 23 (January 11 1890): 37; Chamier, George, "Capacities for Culverts and Flood Discharge." *Engineering News* 41 (January 26, 1899): 61-62.
[86] Walter G. Berg, *American Railway Bridges and Buildings, Official Reports, Association of Railway Superintendents, Bridge and Buildings.* (Chicago: B.S. Wasson & Company, 1898.). Berg was Assistant Engineer of the Lehigh Valley Railroad.
[87] Daniel B. Luten, "The Design of Arch Culverts." *Engineering News* 45 (June 13, 1901): 435.

When the water level rises and submerges the culvert opening two conditions occur that threaten its structural integrity: the embankment acts as a dam and the hydrodynamic characteristics of the water flow through the culvert change from of "flow in an open channel" to those of "flow in a pipe."

The embankment acting as a dam presents several concerns: the type of fill over and around the culvert, the quality of the masonry in the facewalls (or endwalls), and the inlet and outlet design, i.e., the nature of embankment protection such as stone aprons and rip-rap. When a culvert discharges under pressure the intensified force and turbulence of the water can undermine the outlet channel if it is not designed for it. The fill is all-important since the embankment can become saturated and swell, allowing the finer particles to wash away until voids and channels open along the exterior of the culvert. In the case of arches, which depend on uniform loading on the arch stones for stability, failure can result fairly quickly as the water pressure pushes the stones into voids in the backing fill. Voids formed behind the walls of the culvert will typically result in the walls bursting under the internal pressure of the water.

The main factors affecting the flow rate of water in a "pipe" – a pipe being a structure that confines the water on all sides – are the degree of roughness of the interior surfaces of the culvert, its length, and the pressure of the water or "head" as determined by the depth of the water over the top of the culverts opening. [Flow rate is measured in units of volume over time, typically cubic feet or gallons per second]. A textbook on railroad construction gave the following guidance on the culverts designed to discharge submerged under a head:

> A well-designed culvert must afford such free passage to the water that it will not " back up" over the adjoining land nor cause any injury to the embankment or culvert. The ability of the culvert to discharge freely all the water that comes to it evidently depends chiefly on the area of the waterway, but also on the form, length, slope, and materials of construction of the culvert and the nature of the approach and outfall. When the embankment is very low and the amount of water to be discharged very great, it sometimes becomes necessary to allow the water to discharge "under a head," i.e., with the surface of the water above the top of the culvert. Safety then requires a much stronger construction than would otherwise be necessary to avoid injury to the culvert or embankment by washing. The necessity for such construction should be avoided if possible.[88]

A common cause of failure of culverts was known to be the clogging of the inlet with trees and brush – known as drift - during floods effectively creating a dam that is soon overtopped and then quickly destroyed. Various "improved" designs for "non-obstructable" culverts were designed, built and reported on. A design that that provided a wide-mouth beveled-wing masonry inlet absent of sharp corners was used by the Indianapolis, Decatur & Springfield Railway.[89] Another recommended detail was the rounding of the intrados of the arch stones to eliminate the

[88] Walter L. Webb, *Railroad Construction, Theory and Practice.* (New York: John Wiley & Sons, 1900): 202-203.
[89] E.D. Hill, "Arch Culvert and Steam Shovel Work, I.. D. & S. Railway." *Engineering News* 21 (June 8, 1889): 523-525.

sharp corner that could snag logs. This smoothing of the "inlet nozzle" also increased the velocity and resultant flow rate through the culvert. Increases in velocity were also achieved by specifying very narrow joints between the stones and flush, smoothly tooled mortar joints on the faces on the arch barrel stones to provide the least possible resistance to the flow.

Another method used for a "non-obstructable " culvert consisted of building two stone sidewalls to the height of high water, projecting up-stream from the inlet. The ends of the walls are sloped so that logs are either stopped well before the culvert proper, or can ride up and rest across the sidewalls, either way leaving an effective drain opening in front of the culvert.[90]

The drop-inlet design provided for a pool or basin in front of the inlet of the culvert to collect sediment, gravel and cobbles before they washed into the culvert. The drop-inlet not only helped to prevent clogging, but the pool also acted as a buffer to the scouring and undermining action of the water during peak flow events.

In the late 19th century the B&M experimented with clay and iron pipe but found them cost-competitive with stone only for the smallest culverts, generally under 2 feet in diameter. Other railroads in the northeast also used pipe under certain circumstances at least as early as the 1870s.[91] Pipe culverts have advantages over stone when operating submerged: they are smoother and resist water pressure better. By the 1880s, iron pipe culverts of one to two feet in diameter set in concrete face and outlet walls were being used by western railroads but were recommended only "in prairie country where suitable stone for culvert masonry is scarce and dear."[92] Pipe culverts needed to be bedded in stone with a stone or concrete facewall to prevent water from channeling along the outside of the pipes and washing out the embankment during peak flows and submergence events. Since masons or concrete workers were still required on the job for a proper pipe culvert installation, as late as 1898 it was found just as cheap or cheaper to build the culvert entirely of stone.[93]

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90 "A Non-Obstructible Water-Way." *Engineering News* 21 (June 22, 1889): 564. Several successful culverts of this type were designed and built by engineer J.C. Goodridge.
91 Iron pipe culverts were installed about 1878 during the construction of the Hoosac Tunnel in western Massachusetts. (Berg 1898, p. 32.)
92 "Standard Pipe Culverts; Kansas City & Omaha R.R." *Engineering News* 18 (October 22, 1887): 300.
93 American Railway Bridge and Building Association. "Culverts." *Proceedings of the Eight Annual Convention of the American Railway Bridge and Building Association* 8 (1898): 88-89.

F. ASSOCIATED PROPERTY TYPES

INTRODUCTION

Stone highway culverts in New Hampshire are of two main types, box culverts and arched culverts. Based on the current inventory, box culverts outnumber arch culverts roughly ten to one in New Hampshire. This is due primarily to the fact that arches are generally used for longer spans than box structures can achieve and therefore the arches fall into the category of 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 culverts were built in locations where permanent or seasonal streams of small volume intersect the routes of range roads, turnpikes and highways. They were also built through causeways across wetlands to equalize the water levels and pressures on each side. In a few occasions where roadways are curbed, small box culverts channel storm water from curbside catch basins under the road to the opposite side.

New Hampshire has attained recognition as the location of some of New England's most skillfully built stone highway structures. Those pre-dating about 1875 are mostly dry-laid (without the use of mortar) and therefore required a high degree of masonry workmanship to insure a structurally sound structure.

Water flowing from a wide flat stream bed through a comparatively narrow culvert often increases in depth and velocity. Upon exiting the culvert, the increased energy of the focused water stream erodes the floor of the culvert and creates scour depressions at the outlet. To prevent scour and undermining of the culvert walls the floor may be armored with flat stone "paving." The pavers may be extended out in front of the outlet to prevent scour of the outlet basin and the stream banks armored with riprap to prevent erosion and direct the intensified flow downstream away from the culvert structure. In most cases, culvert paving is an original design feature evidenced by the extension of the paving stone under the wall stone of the culvert. Outlet armoring may also be an original feature or it may be a feature added later to check erosion. To discern the difference, the physical evidence must be examined such as quarry stones with drill or chisel marks, remnant of walls or other unnatural-appearing arrangements of stone.

Surviving stone culverts may retain full structural integrity, or may be compromised by damage or alteration. Culverts sometimes become obstructed or clogged with sediment or debris but otherwise retain their structural integrity. Clogged culverts are in extreme danger of being overtopped and damaged or "washed out" in the next major runoff event. Culverts exhibiting damage such as displaced or lost stones, broken cover stones, or partial collapse of facewalls or sidewalls, may or may not retain integrity depending on the severity of the condition and the potential for practical repair. Many culverts have been repaired by pointing the joints with cement mortar or with the installation of corrugated metal or plastic pipe through the culvert. These alterations do not always significantly diminish the historical or structural integrity of the resource. [See Integrity Evaluation section below].

PROPERTY TYPE: STONE BOX CULVERT

Description

Box culverts have vertical stone sidewalls across which span stone slabs or lintels that in turn carry fill and the roadway. 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 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.

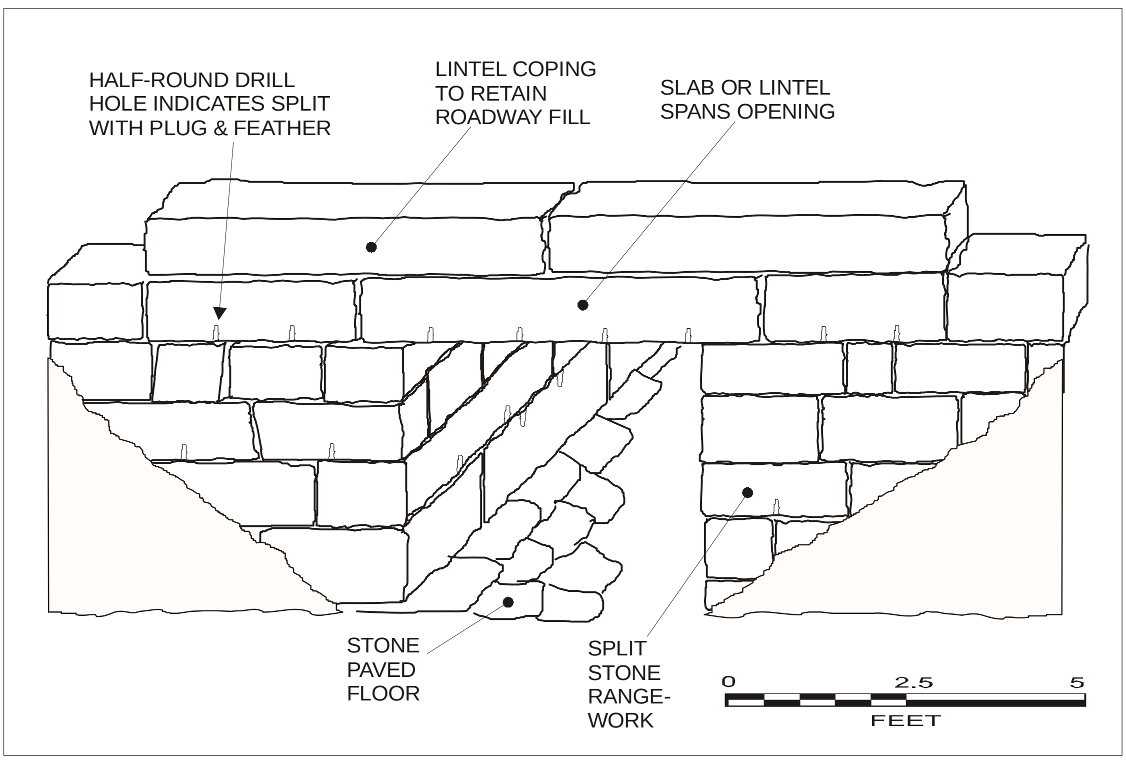


Figure No. 2: Typical 4-foot stone box culvert of split and cut granite quarry stone

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 10-foot lintel might be 12" wide by 16 inches deep.

In New Hampshire the average span of stone box culverts identified in the culvert field survey is about 3.5 feet, with the maximum being 11.5 feet and the minimum 1.0 foot. Stone box culverts rarely exceed 10 feet in span and generally attain lengths over 5 feet only when high quality stone is readily available like in New England. In the survey only two box culverts exceeded 10 feet in span: Culvert POR0119 with a span of 11'-7" and Culvert HIL0019 with a span of 10'-5". Five additional box culverts exceeded eight feet in span. All box culverts over 6 feet in span were of cut stone (ashlar) construction. **[see Photo No. 1]**

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. **[see Photo No. 2]**

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 squat rectangle, square or horizontal rectangle shape. **[see Photo No. 3]**

Multiple-channel box culverts were built when a large waterway opening was required greater than the opening height or span ability of the available stone would allow. The use of stone slabs or lintels to span greater than about 8 feet was usually impractical due to the immense size and weight of the stones required and the hardship in transporting and placing them without hoisting equipment. The use of hoisting equipment increased the project cost, defeated the economy of using readily available stone, and made other culvert materials more attractive. Since stone cannot span greater than 10 or 12 feet in most highway culvert applications, when a waterway opening of that size was needed the practical solution was to simply build two small culverts side by side sharing a center wall. **[see Photo Nos. 4 and 5]**

In rare cases, box culverts with more than two waterway openings – also called channels, cells or barrels – were built. An exceptional example with four channels is Amherst Bridge 159/105, a bypassed historic bridge that formerly carried Boston Post Road over Beaver Brook. **[see Photo No. 6]**

Multi-channel box culverts may exhibit a higher level of workmanship because of the need for a continuous center wall between to the two channels. Unless the culvert walls bear directly on bedrock, care must be taken to insure a solid foundation for the center wall since it will be subjected to erosion and undermining from two sides. Since the center wall sits in the middle of the water course it is also subject to greater water velocities and the force of direct impacts from floating debris during flooding. Multi-channel box culverts built with cut stone often have well squared stones laid with tight joints to insure the greatest area of frictional contact and resistance to movement. Cement mortar may be present to increase the bond between the stones. Those built with fieldstone may use very large stones for the center wall that resist movement by their sheer mass.

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 with little if any cutting or trimming to improve the fit. Coursed rubble (or 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. **[see Photo No. 7]**

The nature of split stone depends on its geology and varies widely by locality and quarry. The homogenous nature of much of New Hampshire granite means that with skill it can be split evenly along straight lines to yield a rough but relatively planar surface. [The splitting methods, by chisel and wedge and then after about 1830 by drilling and using a "plug and-feathers," are described in the preceding discussion of contexts.] Split stone lintels of uniform size and suitable for use without cutting can be readily produced in long lengths. Lintels that break are sold as-is in random lengths, the ends 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.

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 Photo No. 8]**

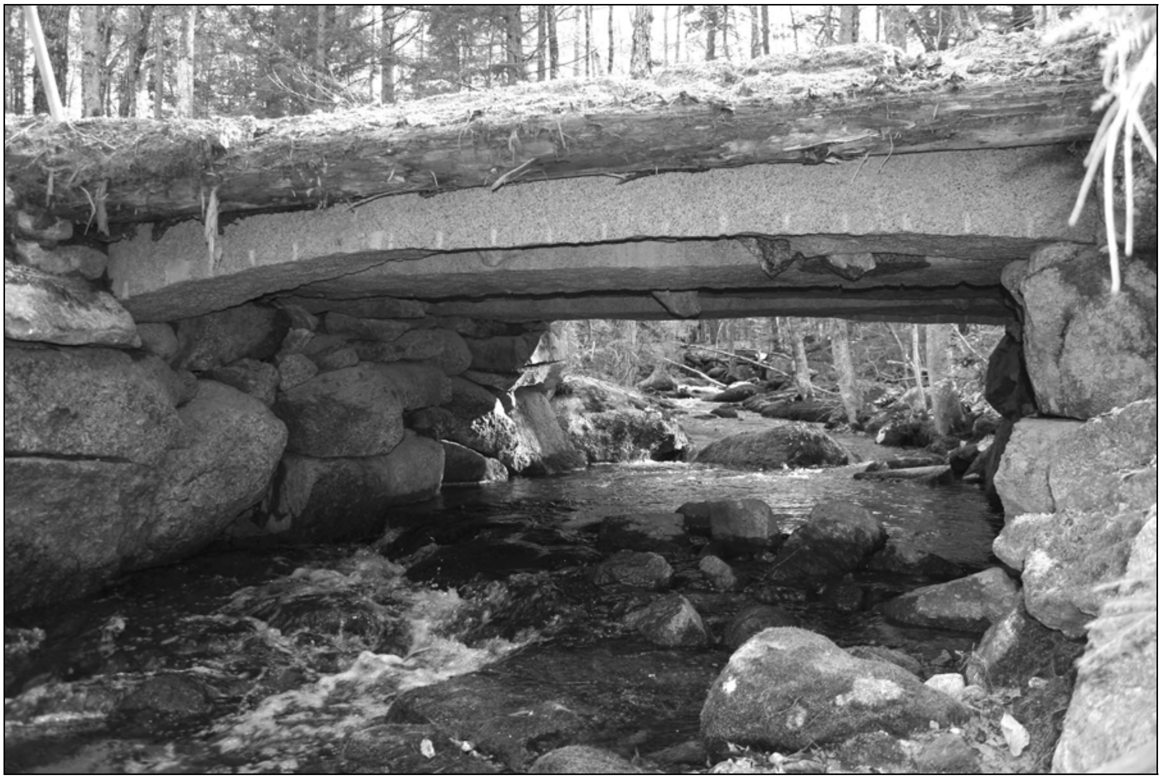


Photo No. 1: Culvert HIL0019 (Hillsborough)

This box culvert in Hillsborough, NH, is of exceptional span with a 10'-6" opening width. It is built with split granite lintel spans and fieldstone walls. The outside lintel seen in the picture is particularly interesting in that it was cut from a quarry face with a slight curve to it, giving the lintel an bit of an arch shape with thickened ends. While unsuitable for many purposes the builder perhaps saw the structural advantage of such a stone beam for use in this culvert project.

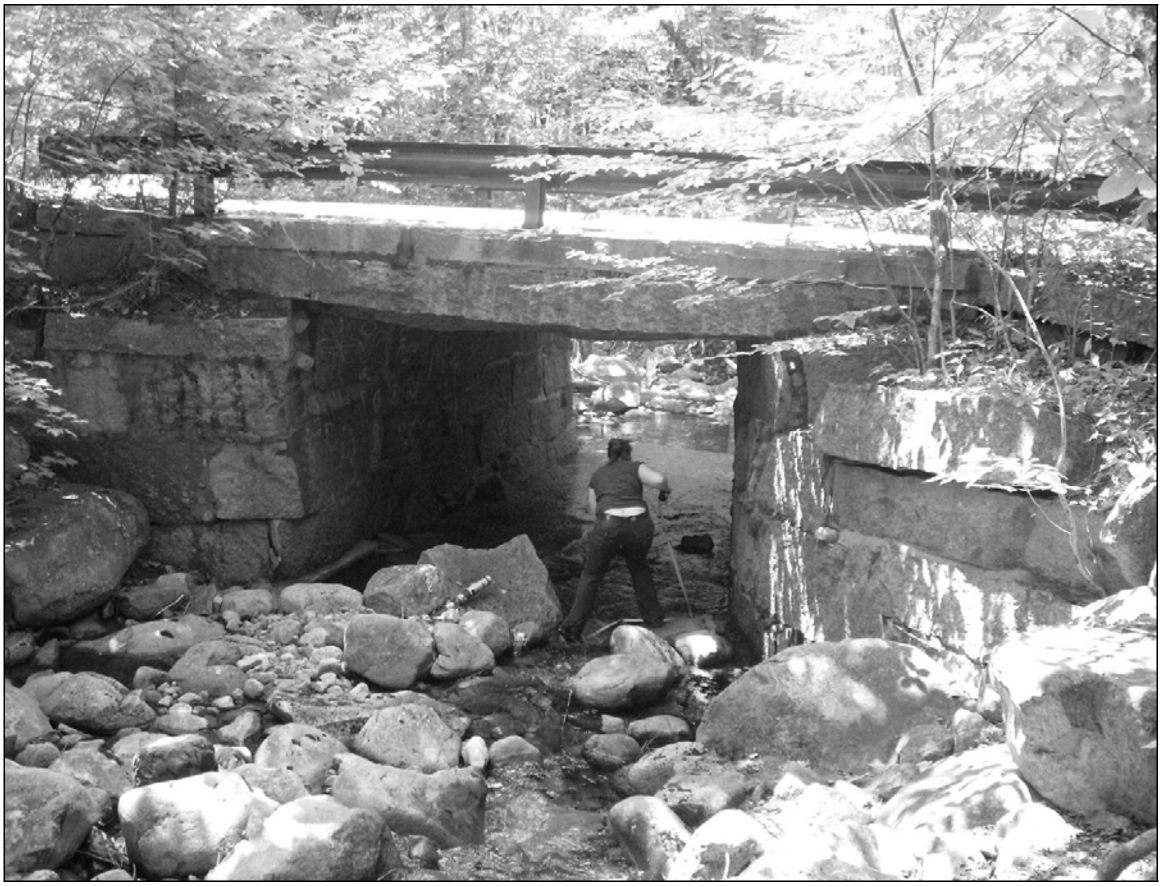


Photo No. 2: Culvert ALB0045 (Albany)

This box culvert in Albany, NH has an unusually large area of waterway opening, with a 9'-4" opening width (span) and 8'-0" opening height. The channel walls are built with very large dimension cut stones bedded in mortar, notable for both their length at 25'-9" and their craftsmanship. Note the massive lintel.

Photo No. 3: Culvert TUF0007 (Tuftonboro)

A tall narrow box culvert in Tuftonboro, NH, with a 2'-10" opening width (span) and a 7'-6" opening height. When conditions allow, increasing the area of the opening by increasing the height may be cost effective if lintels or slabs capable of longer spans are not economically available. Note the very large dimension fieldstone that would have required oxen power and perhaps a small A-frame to place.


Photo No. 4: Culvert FIT0017 (Fitzwilliam)

This is a double box culvert in Fitzwilliam, NH, with two approximately 6-foot-wide channel openings. It is built with cut lintels and mortared cut-stone channel walls. Culvert channels are sometimes referred to as cells or barrels.

Photo No. 5: Culvert CNT0007 (Canterbury)

A double box culvert in Canterbury, NH, with two 3'-6" wide openings, split stone slab spans and a center wall built with large-dimension fieldstone.

Photo No. 6: Amherst Bridge 159/105 (Amherst)

This four-span stone slab structure once carried Boston Post Road over Beaver Brook in Amherst, NH. It provides an example of the variability in assigning the term culvert or bridge to certain structures. On the basis of the length of the individual spans, which do not exceed 8 feet, it can be labeled a four-barrel stone box culvert. But with a primary function to convey traffic, the absence of an overlying filled embankment, and most importantly, the need to regularly inspect the structure due to its greater susceptibility to catastrophic collapse than a single channel culvert, it was designated a bridge by NHDOT. This large and very rare example of a stone culvert with more than two spans is now bypassed by a modern bridge.

Photo No. 7: Culvert WOL0026 (Wolfeboro)

This typical fieldstone box culvert located in Wolfeboro, NH, is of average size (3'-6" opening width) with split lintel spans and fieldstone walls. The dry-laid rubble stone masonry has a sloppy, if not precarious appearance due to it being "loosely built," meaning poorly fitted joints, in this case from using an abundance of rounded boulders that offer limited bearing surface. Typically this type of rough work would be chinked and mortared. The culvert stands due to the immense weight of the overlying earthen fill that presses the structure tightly together from all sides. If the fill is permitted to erode away, the structural integrity of this type of culvert can be quickly compromised, as shown in the photo above where the facewall on the left has been undermined, allowing the round facewall boulders to tumble into the streambed.

Photo No. 8: Culvert MAR0015 (Marlborough)

This is an example of a typical cut-stone (ashlar) box culvert located in Marlborough, NH. It is of average size (4'-0" opening width), built with split lintel spans, ashlar channel walls and mixed cut and field stone facewalls.

Significance

Stone box highway culverts have served as important links in the state's developing road network and as such typically possess characteristics that associate them with early highway design and construction. The resource would have significance for the National Register under the category of Transportation, and for the NH State Register under the category of Transportation, Pre-Automobile Land Travel, 1630-1920 (#82). Some stone box culverts passing under highways may be associated with nearby mill and waterpower resources of importance to local or state history. The resource may therefore be considered for National Register eligibility under Criterion A, for association with events that have made a significant contribution to the broad patterns of New Hampshire history.

Stone box 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 box culverts exhibit vernacular or 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 box culverts or stone structures found locally or statewide. The stone box culvert is essentially a smaller, shorter-span version of the stone slab or lintel bridge, a very rare bridge form, and therefore provides information relevant to the understanding of that resource as well. Stone box 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

The period of significance for stone box culverts includes the entire study period from 1750 to 1930. Limited construction of stone culverts and bridges are believed to have begun in New Hampshire with the early road building during the mid-18th century and continued into the 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. More information is available to estimate the endpoint than the beginning. As noted in the historical context, the New Hampshire Board of Agriculture, State Highway Department, City of Concord, and others discussed, published specifications and built stone culverts up until about 1930. The City Beautiful Movement, which extended from the 1890s to the Great Depression, was closely associated with the aesthetic design of public parks and parkways. Stone arch bridges can be found in many parks and along parkways from this period, but in most cases they are reinforced concrete arches with a stone veneer or "stonefacing" applied to create a rustic aesthetic appearance. Stone culverts in urban or park environments that can be directly attributable to the City Beautiful Movement may very well have been built, but none were discovered in this survey, and research did not uncover any examples elsewhere discussed in the literature.

Culverts that meet Registration Requirements must also retain integrity of location, design, setting, materials, workmanship, feeling and association. See "Integrity Evaluation" section below for guidance on assessing integrity. 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 box culvert established on one of New Hampshire's range roads or turnpikes.

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

3. A stone box 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 box 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 box 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 box culverts attributed to engineers or builders that have made important and recognized contributions to the field may be eligible under this consideration. Presently research has identified only one early stone arch bridge (not culvert) attributed to an engineer. Further research of individual culverts is necessary to determine the designer/builder involved. Information gathered on the physical characteristics of culverts designed/built by a specific person or firm could be compared to other culverts.

4. Innovative or specialized designs:

Stone box 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). [Note: No examples of box culverts with innovative or specialized design were found in the field survey].

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 width, i.e., the distance from inlet to outlet, when they cross under wide highways. As the width or 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 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.

PROPERTY TYPE: STONE ARCH CULVERT

Description

The stone arch culvert is rare in comparison to the box culvert, representing only ten percent of the total culverts surveyed and inventoried in this study. The rarity of arched stone culverts is due to their high cost, which results from the high quality materials, highly skilled labor, and special construction methods usually necessary to build them. 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 stone vaulting is completed, wedges and blocking supporting the centering are removed allowing it to be lowered and pulled out from the culvert. Since the height and width of the culvert must allow for the centering and its removal, culverts of small dimensions do not lend themselves readily to arched construction. Stone arches are therefore mainly used for culverts for spans exceeding those capable of stone slabs or lintels, generally the range of 10 to 20 feet at which point they may be classified as bridges.

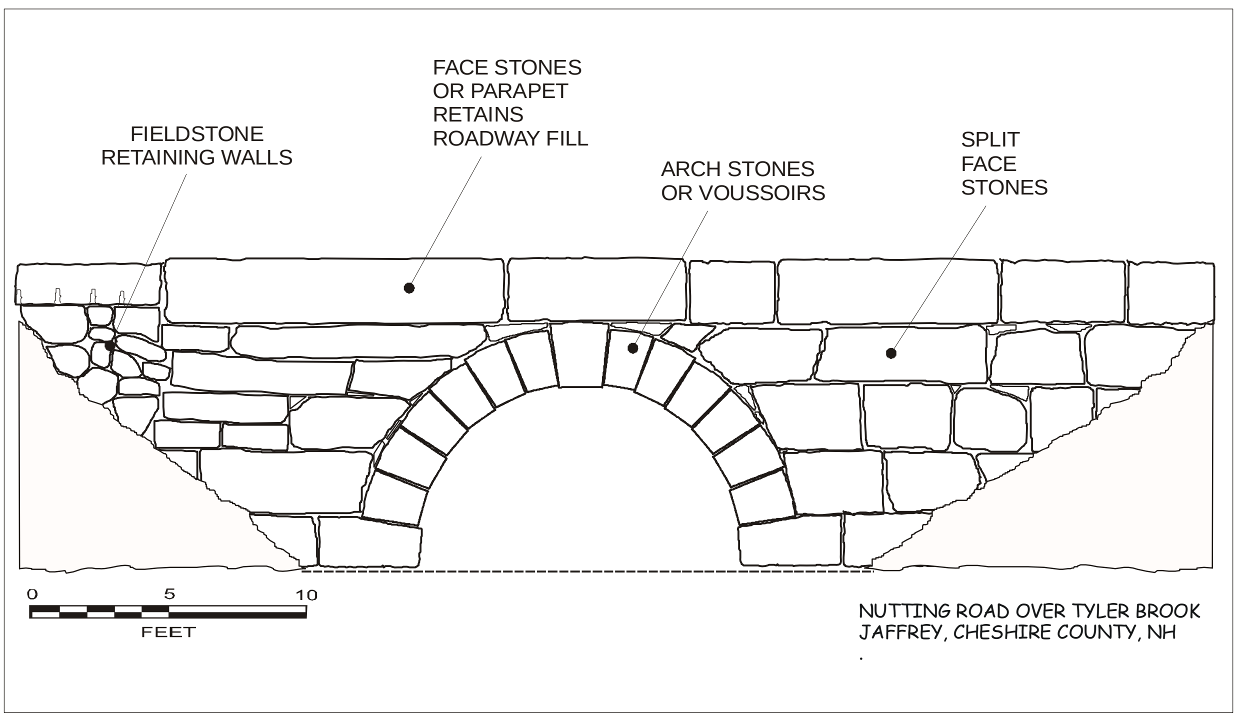


Figure No. 3: Typical stone arch culvert with semi-circular arch of split and cut granite quarry stone.

Most stone arch culverts are semi-circular in shape. Segmental arches are more often found in longer span culverts in the range of 10 to 20 feet. **[Refer to Photos 9 to 13 below that accompany this discussion].** 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. The stone at the center of the arch is often somewhat larger than the others and known as the keystone, a shape most are familiar with. These wedge-shaped arch stones are called voussoirs. 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.

Stone arch culverts may be constructed of fieldstone or rubble, split stone, or cut stone squared and smoothed to varying degrees of finish. The arch stones are usually cut voussoirs with a high degree of squaring and smoothing. The facewalls are often of split or rough-cut fieldstone; retaining walls are typically fieldstone. Please refer to the preceding description of stone box culverts for a detailed discussion of stone types and methods of splitting and cutting.

Photo No. 9: Culvert JAF0464 (Jaffrey)

This is an outstanding "textbook" example of a semi-circular cut-stone arch culvert located in Jaffrey, NH. It displays a very high degree of skilled masonry craftsmanship in the tightly fitted arch stones, enlarged keystone and massive cut facewall stones.

Photo No. 10: Culvert LIT0010 (Litchfield)

This culvert with a roughly semi-circular arch spanning 7'-0" is located in Litchfield, NH. The arch springs from tall sidewalls giving the opening a horseshoe shape and the common name of horseshoe arch. The arch was lengthened (or "widened") with a concrete arch culvert (not visible in photo) when the road above was widened. [see Photo No. 16].

Photo No. 11: Culvert HIL0022 (Hillsborough)

This stone arch culvert and another similar but larger one only 100 feet away (HIL0023) carry Beard Brook under Gleason Falls Road in Hillsborough, NH. This is a tall (nearly semi-circular) segmental arch spanning 12 feet, while the other is a very flat segmental arch that spans 29 feet. Twelve stone arch bridges and culvert-size bridges were built in Hillsborough during the 19th century. [see historical context and Photo No. 13].

Photo No. 12: Culvert WIL0006 (Wilton)

This culvert is also located in Hillsborough County, in the town of Wilton and is an exceptional example of an entirely dry-laid segmental arch (nearly semi-circular) built with split and cut stone. Much of the stone was thinly bedded and split readily into thin manageable slabs that could then be easily squared and tightly fitted with a minimum of chinking required. An occasional untrimmed fieldstone is mixed in for economy and speed. Not visible are concrete roadway curbs that support railing posts, a visual but necessary detriment that does not significantly diminish the integrity of the resource.

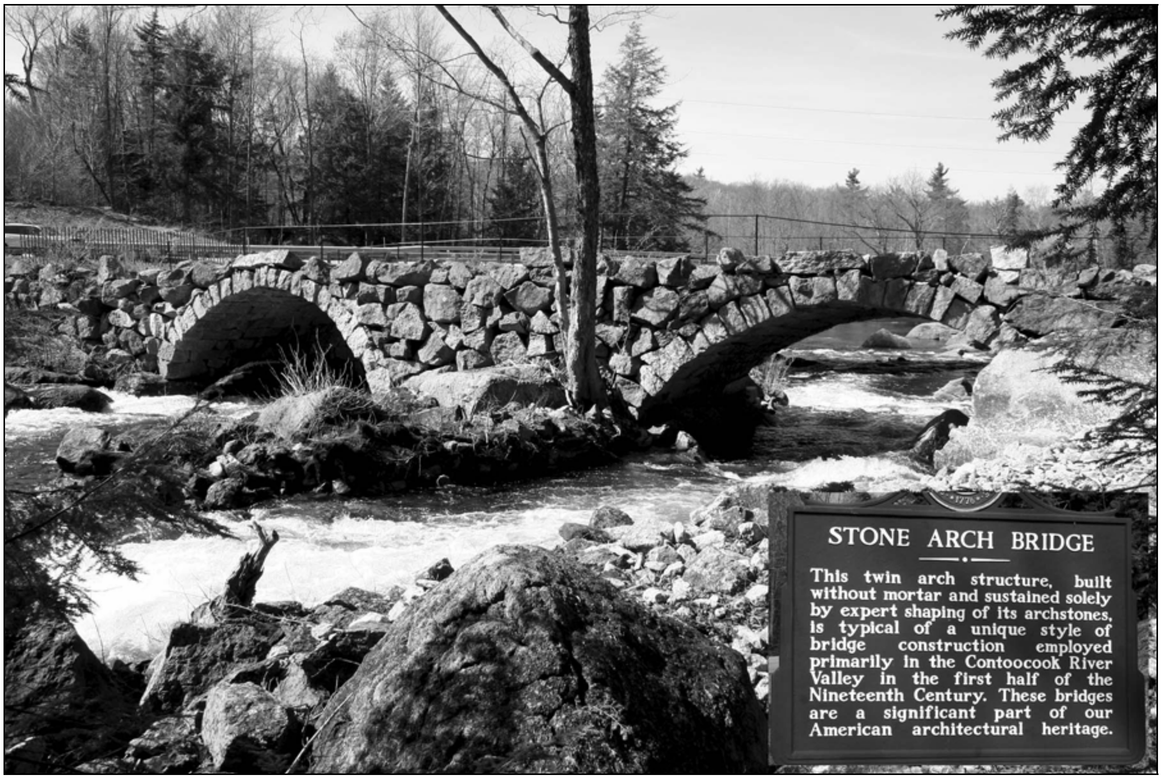


Photo No. 13: Twin Stone Arch Bridge (Hillsborough, NH Bridge No.182/105)

This bridge is similar to the twin bridges on Gleason Road in Hillsborough (see Photo No. 11), which also are segmental arches, cut arch stones and fieldstone facewalls. Located in Stoddard, NH, spanning the North Branch of the Contoocook River near the Antrim town line, it is now bypassed by a new bridge and preserved in a small public roadside park visible from Route 9. A historical marker (inset) commemorates this important historic artifact.

Significance

Stone arch highway culverts have served as important links in the state's developing road network and as such typically possess characteristics that associate them with early highway design and construction. The same considerations given to stone box culverts above apply to stone arch culverts. The resource would have significance for the National Register under the category of Transportation, and for the NH State Register under the category of Transportation, Pre-Automobile Land Travel, 1630-1920 (#82). Some stone arch culverts passing under highways may be associated with nearby mill and waterpower resources of importance to local or state history. The resource may therefore be considered for National Register eligibility under Criterion A, for association with events that have made a significant contribution to the broad patterns of New Hampshire history.

Stone arch 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 arch culverts exhibit vernacular or 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 arch culvert provides information about stone arch masonry construction practices and may help in the understanding of other stone arch culverts or stone structures found locally or statewide. The stone arch culvert is essentially a smaller, shorter-span version of larger stone arch bridges, a rare highway bridge form, and therefore provides information relevant to the understanding of that resource as well. Stone arch 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

The period of significance for stone arch culverts is the same as for box culverts: the entire study period from 1750 to 1930. The prior discussion regarding the determination of the period of significance for stone box culverts applies to arch culverts and is repeated hereafter.

Limited construction of stone culverts and bridges are believed to have begun in New Hampshire with the early road building during the mid-18th century and continued into the 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 as new information warrants. More information is available to estimate the endpoint than the beginning. As noted in the historical context, the New Hampshire Board of Agriculture, State Highway Department, City of Concord, and others discussed, published specifications and built stone culverts up until about 1930. The City Beautiful Movement, which extended from the 1890s to the Great Depression, was closely associated with the aesthetic design of public parks and parkways. Stone arch bridges can be found in many parks and along parkways from this period but in most cases they are reinforced concrete arches with a stone veneer or "stonefacing" applied to create a rustic aesthetic appearance. Stone culverts in urban or park environments that can be directly attributable to the City Beautiful Movement may very well have been built, but none were discovered in this survey, and research did not uncover any examples elsewhere discussed in the literature.

Stone arch culverts that meet Registration Requirements must also retain integrity of location, design, setting, materials, workmanship, feeling and association. See "Integrity Evaluation" section below for guidance on assessing integrity. The primary character defining features of a stone arch culvert are the stones of which the culvert itself and its integral facewalls are constructed. Secondary features include associated roadway retaining walls. The eligibility considerations for stone arch culverts are for the most part the same as those for stone box culverts.

Considerations for eligibility under Criterion A:

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

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

3. A stone arch 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 arch 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 arch 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 arch culverts attributed to engineers or builders that have made important and recognized contributions to the field may be eligible under this consideration. Presently research has identified only one early stone arch bridge (not culvert) attributed to an engineer. Further research of individual culverts is necessary to determine the designer/builder involved. Information gathered on the physical characteristics of culverts designed/built by a specific person or firm could be compared to other culverts.

4. Innovative or specialized designs:

Stone arch 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). [Note: No examples of arch culverts with innovative or specialized design were found in the field survey].

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 width, i.e., the distance from inlet to outlet, when they cross under wide highways. As the width or 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.

6. Multiple-span arch culverts:

Stone arch 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 widening 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 observation and may or may not compromise the integrity of the culvert. The degree of loss of integrity 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.

Photographic examples and further discussion of culverts with various types of diminished integrity are presented on the following pages.

Photo No. 14: Culvert HIL0144 (Hillsborough)

Damage. Deterioration or 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 above has suffered partial collapse of the ashlar facewall at the outlet. from what appears to be runoff from the roadway or from stream overtopping. At this point, enough of the facewall stonework remains in place to understand the method and workmanship of its construction. Further collapse of the outlet masonry would necessitate the preservation of the inlet facewall in order for the resource to retain sufficient integrity to be fully interpreted in a meaningful way. Stone culverts with both facewalls completely collapsed, with the stone jumbled about, lack the ability to be accurately evaluated in terms of design and workmanship.

Photo No. 15: Culvert TEM0002 (Temple)

Damage. The near total destruction of this arch culvert resulted when the roadway was overtopped by floodwaters and the roadway, road fill and a portion of the facewall was washed away. Miraculously, the bevel-cut arch stones or *voussoirs* withstood the torrent, evidence of the skill with which they were shaped and tightly fitted. The method of construction and level of workmanship of the masonry remains evident in the surviving arch and portion of the facewall. The culvert was determined to retain the necessary integrity for National Register eligibility and was subsequently reconstructed as shown in Photo No. 24.

Photo No. 16: Culvert LIT0010 (Litchfield)

Widening. Lengthening the culvert channel, or widening, typically accompanies widening the roadway or shoulders above. It is safe to say that most stone culverts built in the 19th and early 20th centuries were under narrow roads and have since been replaced with pipe culverts. Stone culverts that proved of adequate size to handle the flows asked of it and of enduring construction and strength to be trusted with carrying modern traffic were sometimes widened. Small box culverts were widened by mating a steel or concrete pipe of similar size to it and cementing the connection. For larger box culverts and arched culverts, concrete form work was constructed and a matching concrete box or arch culvert was poured as shown in the photo above. Widening results in the visual and sometimes the physical loss of the inlet or outlet facewall and therefore diminishes the integrity of design, materials, feeling and setting. If the remaining culvert retains a high level of integrity or possesses notable or unusual characteristics, such as the parallel arch rings seen above constructed of what appears to be standard size quarry-split lintel stones, then the diminished integrity due to widening should not disqualify its National Register eligibility.

Photo No. 17: Culvert SWA0019 (Swanzey)

Replacement with Pipe. In over a third (38) of the culverts surveyed in the study, steel, concrete or plastic pipe was present in some capacity. No instances of intact stone culverts lined with pipe, cast-in-place concrete, pneumatically applied concrete, or trowel-applied mortar, were found in the survey. Although deteriorated stone, concrete and tile culverts are typically repaired by inserting smaller diameter pipe of concrete, steel, tile, or plastic and then pump-grouting the void between them, no examples were found. There were 18 steel or concrete pipe culverts with cut stone in the facewalls and/or retaining walls suggesting that a stone box culvert may have once stood in its place. The pipe culvert above, with an abundance of large fieldstone and cut stone lintels used to cap the wall and curb the road is an example. The second smaller pipe, added for additional capacity, supports the theory that a low wide box culvert with a greater cross-sectional area than the single large replacement pipe may have been replaced. Even if research could proved the existence of an earlier stone culvert, the integrity of design has been fully compromised and therefore this culvert would not qualify as a National Register eligible stone culvert.

Photo No. 18: Culvert PEM0040 (Pembroke)

Replacement with Pipe. This example shows a concrete pipe culvert with split lintel facewalls, again suggesting the possibility that a stone box culvert once stood in its place and the stone was reused. It is equally plausible that is not the case however, and this example would not qualify as a National Register eligible stone culvert.

Photo No. 19: Culvert NBR0004 (Newbury)

Simple Pipe Culvert with Stone Facewalls. This is an example of a typical early to mid-20th century corrugated steel pipe culvert constructed by local road crews with common labor. Several large fieldstone boulders were simply placed around the opening to serve as a rudimentary facewall and retain the earth fill around the pipe. There is no apparent physical evidence to suggest a stone culvert predated the pipe culvert. Roughly one-quarter (25) of the culverts surveyed qualify as pipe culverts with stone facewalls and do not qualify as a National Register eligible stone culvert.

Photo No. 20: Culvert TRO0344 (Troy)

Reconstruction with Pipe: This example shows a concrete pipe culvert set in a concrete facewall with long split lintels and other split and cut stone used for the upper part of the facewalls. Like other examples, there is the possibility that a stone box culvert once stood in its place and the stone was reused. The concrete facewall supports the theory: why haul in both concrete and stone for the job? Regardless, any understanding of what may have preceded the pipe culvert is lost and culverts such as this would not qualify for National Register listing.

Photo No. 21: Culvert WAK0010 (Wakefield)

Roadway Alterations: Parapets, Curbing, & Railings. Alterations to stone culverts made at the roadway level may adversely affect the feeling and setting but not adversely affect the majority of the historic stonework as in the example shown above (WAK0010). Here a heavy reinforced concrete curb has been cast-in-place across the top of the culvert facewall with the dual purpose of providing a strong anchorage for the railing and a curb capable of redirecting tire impacts back into the travel lane. By eliminating the need to anchor the railing posts into the facewall, the culvert is protected from damage that could result from a forceful impact. The curb or cap beam helps consolidate and protect the top of the facewall from loosening due to erosion and vibration and is therefore an acceptable alteration. Similar alterations that encase and obscure a large portion of the culvert stonework, including the facewall and/or voussoirs for arched culverts, and the lintel and/or slab spans for a box culvert, would likely have an adverse effect on the integrity and in most cases disqualify it from National Register eligibility.

Photo No. 22: Culvert LON0112 (Londonderry)

Roadway Alterations: Span Reinforcement or Replacement. In some instances the stones that span the culvert opening have been removed and replaced with wood or steel beams or a concrete slab, as the example above shows. This alteration invariably destroys the integrity of the resource. In other cases, reinforcing beams or slabs may be placed under the stone spans to reinforce them or above the spans to completely assume the traffic loads. These alterations should be considered on a case-by-case basis to determine their affect on the integrity of design and materials.

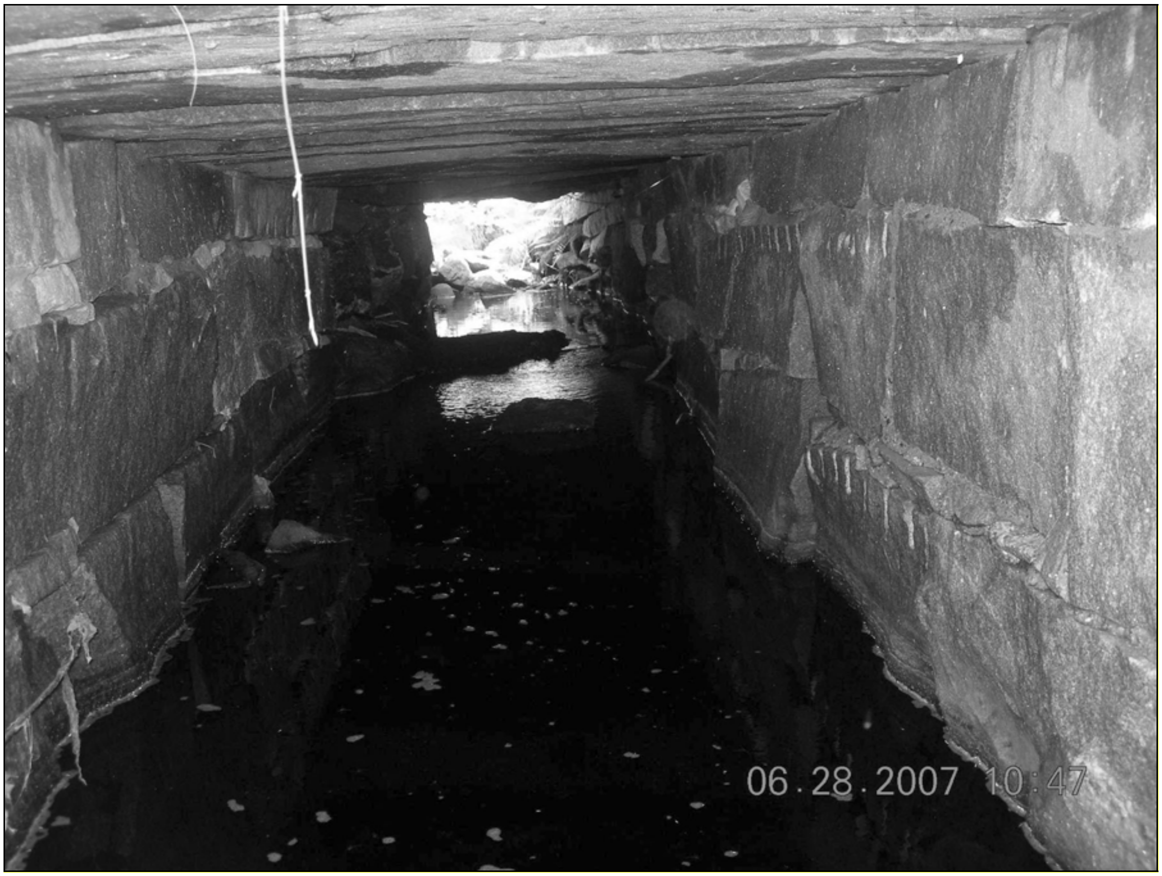


Photo No. 23: Culvert FIT0015 (Fitzwilliam)

Pointing or Re-Pointing 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. As seen above, 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. 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 cheap compared to labor and a mason effecting repairs likely applied it liberally for a job done "once and for all." Such repairs are obvious to the experienced eye, and the burden is on the surveyor to recognize when mortared repairs have ruined or obscured the original masonry craftsmanship and compromised the historic integrity of the resource.

Photo No. 24: Culvert TEM0002 (Temple)

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 usually bypassed because of their inadequate flow capacity due to improper sizing, increased stream flow, or diminished capacity due to clogging or collapse. 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 functional stonework is left undisturbed and unaltered. When other types of areas of integrity are also diminished, then bypassing should be assigned a relative "weight" to be factored into the overall loss of integrity assessment.

Highway Bypassing. [see Photo No. 13] 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.

RESOURCE INVENTORY TABLE

The following six pages present a table of data pertaining to the 98 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 other column headings and abbreviations used in the table are as follows:

NHDHR #: This is the individual inventory number assigned by the New Hampshire Division of Historical Resources for each historic resource in a town.

Type: This refers to the type of culvert, box culvert (B), arch culvert (A), pipe culvert (P), or wood (W).

Work: This refers to the predominate type of stone masonry work used in the construction of the culvert, either fieldstone (F), or Ashlar (A). These terms were loosely defined for the purposes of speeding the fieldwork: fieldstone meaning of local uncut or roughly hammer split or shaped stone; Ashlar meaning cut stone, either quarry split and squared – the usual case of lintels or local stone fully squared-up with hammer and chisel or otherwise split and cut to provide multiple flat faces. In the case of pipe culverts with stone facewalls that lack integrity, the stone work was considered uninterruptable and therefore not applicable (n/a).

Span ft.: This refers to the distance in feet between the culvert channel walls, also called the 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.

Lgt. ft.: 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.

Cells: This refers to the number of separate culvert channels, also known as cells or barrels. A double box culvert, for example, has two cells.

Altered: This refers to whether the culvert shows evidence of being altered in some way – yes (Y) or no (N). Refer to the corresponding notes (on table pages 4-6) for explanation.

NR: This refers to the potential eligibility of the culvert for listing in the National Register of Historic Places: yes (Y), likely eligible, or no (N), not likely eligible. The assessment is the opinion of the project architectural historian only.

RESOURCE INVENTORY TABLE

	County	Town	NHDHR #	Street	Crossing	Type	Work	Span ft	Lgt ft	Cells	Altered	NR
1	Belknap	Gilford	GLF0069	Belknap Mtn. Rd	Unknown	B	F	2.6	20.8	1	N	Y
2	Carroll	Albany	ALB0045	Dugway Rd.	Big Br.	B	A	9.3	25.8	1	Y	Y
3	Carroll	Ossipee	OSS0028	Browns Ridge Rd.	Youngs Br.	B	A	9.2	25.6	1	Y	Y
4	Carroll	Ossipee	OSS0027	Browns Ridge Rd.	Unknown	P	n/a	2.0	40.3	1	n/a	N
5	Carroll	Tuftonboro	TUF0007	NH 109A	Twentymile Br.	B	F	2.9	32.6	1	N	Y
6	Carroll	Wakefield	WAK0010	Canal Rd.	Unknown	A	F	11.5	27.0	1	Y	Y
7	Carroll	Wolfeboro	WOL0026	Pleasant Valley Rd.	Unknown	B	F	3.6	30.0	2	Y	N
8	Cheshire	Fitzwilliam	FIT0015.	NH 119/Holman Rd.	Unknown	B	A	5.2	38.0	1	N	Y
9	Cheshire	Fitzwilliam	FIT0016	Royalston Rd.	Horseshoe Pond	P	n/a	3.5	33.0	1	Y	N
10	Cheshire	Fitzwilliam	FIT0017	Templeton Turnpike	Stone Pond	B	A	6.5	19.3	2	N	Y
11	Cheshire	Hinsdale	HIN0023	NH 119/ Canal Street	Kilburn Br.	A	A	12.5	62.6	1	Y	Y
12	Cheshire	Jaffrey	JAF0463	Dublin Rd.	Stoney Br.	B	A/F	6.0	38.8	1	Y	N
13	Cheshire	Jaffrey	JAF0464	Nutting Rd.	Unknown	A	A	11.5	20.0	1	Y	Y
14	Cheshire	Keene	KEE0210	Court Street	Trib. Ashuelot R.	B	F	3.0	n/a	1	N	Y
15	Cheshire	Marlborough	MAR0014	Frost Hill Rd.	Unknown	P	n/a	1.5	34.5	1	Y	N
16	Cheshire	Marlborough	MAR0015	Roxbury Rd.	Glen Br.	B	A	4.0	23.0	1	N	Y
17	Cheshire	Marlborough	MAR0016	Dilingham Rd.	Unknown	P	n/a	2.0	40.0	2	Y	N
18	Cheshire	Marlow	MRL0013	off Mansfield Rd.	Unknown	B	F	1.5	14.0	1	Y	N
19	Cheshire	Richmond	RIC0006	Martin Cook Rd.	Rice Br.	B	F	2.8	26.0	1	N	Y
20	Cheshire	Richmond	RIC0007	Sprague Rd.	Unknown	P	n/a	3.9	31.3	1	Y	N
21	Cheshire	Richmond	RIC0008	Sprague Rd.	Unknown	B	F	1.9	21.6	1	Y	Y
22	Cheshire	Richmond	RIC0009	Old Winchester Rd.	Unknown	P	n/a	1.5	25.5	1	n/a	N
23	Cheshire	Surry	SUR0003	Webster Rd.	Unknown	W	F	2.5	14.5	1	Y	N
24	Cheshire	Swanzey	SWA0019	Cobble Hill Rd. East	Unknown	P	n/a	3.0	31.6	1	Y	N
25	Cheshire	Troy	TRO0344	Old Keene Rd.	Unknown	P	n/a	3.0	48.0	1	Y	N
26	Cheshire	Winchester	WIN0017	Old Chesterfield Rd.	Unknown	P	n/a	3.5	37.5	1	Y	N
27	Coos	Errol	ERR0005	NH 16	Trib. Androscoggin	B	A/F	5.0	34.0	1	Y	Y
28	Coos	Erroll	ERR0006	NH 16	Trib. Androscoggin	B	A	8.8	37.5	1	N	Y
29	Grafton	Alexandria	ALX0003	Perkins Pond Hill Rd.	Unknown	P	n/a	2.0	42.0	1	n/a	N
30	Grafton	Alexandria	ALX0004	Gove Rd.	Unknown	B	F	2.0	29.0	1	Y	N
31	Grafton	Enfield	ENF0022	NH 4A	Knox River	B	A/F	8.5	?	1	N	Y
32	Grafton	Grafton	GRA0013	Wild Meadow Rd.	Hoyt Br.	B	F	4.2	19.0	1	N	Y
33	Grafton	Lebanon	LEB0012	Mill Rd.	Trib. Mascoma R.	P	n/a	2.0	28.0	1	Y	N

RESOURCE INVENTORY TABLE (continued)

	County	Town	NHDHR #	Street	Crossing	Type	Work	Span ft	Lgt ft	Cells	Altered	NR
34	Grafton	Lyme	LME0003	Smith Mountain Rd.	Grant Br.	B	F	3.2	17.0	1	Y	Y
35	Grafton	Orford	ORF0008	Tillotson Falls Rd.	Unknown	P	n/a	1.5	20.0	1	n/a	N
36	Hillsborough	Goffstown	GOF0059	Elm Street	Unknown	P	n/a	2.0	126.0	1	n/a	N
37	Hillsborough	Goffstown	GOF0060	Elm Street	Trib. Piscataquag	B	F	4.5	45.5	1	Y	N
38	Hillsborough	Greenville	GRV0007	Route 123	Trib. Souhegan R.	B	A/F	4.5	13.6	1	N	Y
39	Hillsborough	Hillsborough	HIL0019	Colby Rd.	Nelson Br.	B	A/F	10.5	14.2	1	N	Y
40	Hillsborough	Hillsborough	HIL0020	Concord End Rd.	Nelson Br.	B	A/F	7.0	19.3	1	Y	Y
41	Hillsborough	Hillsborough	HIL0021.	Beard Rd.	Beard Br.	B	A/F	3.0	31.0	1	N	Y
42	Hillsborough	Hillsborough	HIL0022	Gleason Falls Rd.	Beard Br.	A	A/F	12.0	19.5	1	N	Y
43	Hillsborough	Hillsborough	HIL0023	Gleason Falls Rd.	Beard Br.	A	A/F	29.5	23.2	1	N	Y
44	Hillsborough	Hollis	HLL0144	Depot Street	Sucker Br.	B	A	6.0	43.5	1	Y	Y
45	Hillsborough	Litchfield	LIT0009	NH 3A	Trib. Merrimack R.	P	n/a	1.3	68.0	1	Y	N
46	Hillsborough	Litchfield	LIT0010	NH 3A	Watts Br.	A	A/F	7.0	60.0	1	Y	Y
47	Hillsborough	Pelham	PEL0002	Old Gage Hill Rd. N.	Unknown	B	F/B	2.5	?	1	n/a	N
48	Hillsborough	South Weare	WEA0006	Deering Center Rd.	Unknown	B	A/F	4.0	100.0	1	Y	Y
49	Hillsborough	Temple	TEM0002	Memorial Highway	Unknown	A	A/F	9.2	16.0	1	Y	Y
50	Hillsborough	Temple	TEM0003	Fish Rd.	Unknown	B	F	2.0	21.5	2	Y	N
51	Hillsborough	Weare	WEA0002	Sawyer Rd.	Unknown	P	F	2.5	21.8	1	Y	N
52	Hillsborough	Weare	WEA0003	Deering Center Rd.	Unknown	P	F	2.5	47.0	2	Y	N
53	Hillsborough	Weare	WEA0004	off Oliver Rd.	Unknown	B	F	3.5	27.0	1	Y	N
54	Hillsborough	Wilton	WIL0006	King Br. Rd.	King Br.	A	A	9.9	31.0	1	Y	Y
55	Merrimack	Allenstown	ALL0009	Bachelder Rd.	Unknown	B	A	8.0	23.8	1	Y	Y
56	Merrimack	Bow	BOW0010	Br. Londonderry Tp	Unknown	P	A/F	3.0	25.0	2	Y	N
57	Merrimack	Bow	BOW0011	Page Rd.	Unknown	P	A/F	4.0	38.5	1	Y	N
58	Merrimack	Bradford	BRA0013	Forest Street	Unknown	B	F	2.6	19.0	1	N	Y
59	Merrimack	Bradford	BRA0014	Forest Street	Unknown	B	F	1.5	20.5	1	Y	N
60	Merrimack	Bradford	BRA0015	High Street	Unknown	B	F	3.1	132.0	1	N	Y
61	Merrimack	Bradford	BRA0016	West Main Street	Unknown	B	F	4.5	52.0	1	N	Y
62	Merrimack	Canterbury	CNT0005	New Rd.	Burnham Br.	P	F	4.0	32.5	1	Y	N
63	Merrimack	Canterbury	CNT0006	Scales Rd.	Burnham Br. (?)	B	F	4.0	31.0	1	N	Y
64	Merrimack	Canterbury	CNT0007	Abberton Rd.	Unknown	B	F	3.5	21.0	2	N	Y
65	Merrimack	Canterbury	CNT0008	off Shaker Rd.	Unknown	B	F	4.3	24.5	1	N	Y
66	Merrimack	Canterbury	CNT0009	off Hacklboro Rd.	Unknown	B	F	3.0	26.5	1	N	Y

RESOURCE INVENTORY TABLE (continued)

	County	Town	NHDHR #	Street	Crossing	Type	Work	Span ft	Lgt ft	Cells	Altered	NR
67	Merrimack	Newbury	NBR0003	Old Post Rd.	Unknown	P	n/a	1.2	34.8	1	n/a	N
68	Merrimack	Newbury	NBR0004	Old Post Rd.	Unknown	P	F	1.5	32.8	1	Y	N
69	Merrimack	Newbury	NBR0005	Old Post Rd.	Unknown	B	F	5.0	30.0	1	Y	Y
70	Merrimack	Pembroke	PEM0040	N. Pembroke Rd.	Unknown	P	F	2.0	41.8	1	Y	N
71	Merrimack	Pembroke	PEM0041	N. Pembroke Rd.	Unknown	P	F	2.0	46.0	1	Y	N
72	Merrimack	Warner	WAR0005	West Joppa Rd.	Trib. Bartlett Br.	B	F	3.9	18.6	1	N	Y
73	Merrimack	Warner	WAR0006	Lowd Rd.	Trib. Beard Br.	B	F	2.0	25.6	1	Y	N
74	Merrimack	Warner	WAR0007	Bade(r) Rd.	Unknown	B	F	2.0	30.8	1	Y	N
75	Merrimack	Warner	WAR0008	Colleague Pd. Rd.	Unknown	B	F	4.0	20.0	1	N	Y
76	Merrimack	Warner	WAR0009	Gore Rd.	Trib. Meadow Br.	B	F	4.0	15.2	1	Y	Y
77	Merrimack	Wilmot	WLM0004	Stearns Rd.	Unknown	B	F	3.0	20.0	2	Y	Y
78	Merrimack	Wilmot	WLM0005	Stearns Rd.	Unknown	B	F	4.5	22.0	1	N	Y
79	Merrimack	Wilmot	WLM0006	Stearns Rd.	Kimpton Br.	B	F	4.9	27.1	1	N	Y
80	Merrimack	Wilmot	WLM0007	Stearns Rd.	Unknown	B	F	4.2	22.0	1	N	Y
81	Rockingham	Atkinson	ATK0004	Main Street/ NH121	Unknown	B	F	1.0	53.0	1	n/a	N
82	Rockingham	Chester	CHE0006	Haverhill Rd/NH121	Unknown	B	F	4.1	39.2	1	N	Y
83	Rockingham	Danville	DAN0006	Main St./ 111A	Unknown	B	F	5.1	42.3	1	Y	N
84	Rockingham	Epping	EPP0010	Blake Rd.	Unknown	P	F	1.5	41.0	1	n/a	N
85	Rockingham	Exeter	EXE0022	Hampton Rd./Rt. 27	Unknown	B	F/A	3.3	43.8	1	Y	N
86	Rockingham	Hampstead	HMP0005	Walnut Hill Rd/NH121	Unknown	B	F	2.8	55.0	1	N	Y
87	Rockingham	Hampstead	HMP0006	Walnut Hill Rd/NH121	Unknown	B	F	4.0	?	1	Y	N
88	Rockingham	Hampton Falls	HMF0003	Kensington Rd./ RT84	Dodge R.	A	A	11.3	31.0	1	N	Y
89	Rockingham	Londonderry	LON0112	Mammoth Rd.	Chas Brook	B	F	7.0	33.0	1	Y	N
90	Rockingham	Newfields	NWF0004	Piscassic Rd./Rt. 87	Unknown	B	F	1.9	47.0	1	Y	N
91	Rockingham	Newmarket	NWM0023	Grant Rd.	Unknown	B	F	1.1	50.6	1	N	Y
92	Rockingham	Northwood	NOR0002	Old Turnpike Rd.	Flat Meadow Br.	B	F	3.3	35.0	1	N	Y
93	Rockingham	Portsmouth	POR0119	Woodbury Avenue	Hodgson Br.	B	A	11.5	250+	1	Y	Y
94	Rockingham	South Hampton	SHM0002	Burnt Swamp Rd.	Unknown	B	F	1.5	42.0	1	Y	N
95	Rockingham	Windham	WND0001	off Church Rd.	Golden Br.	B	F	4.1	27.5	1	N	Y
96	Sullivan	Acworth	ACW0008	Breier Rd.	Unknown	P	n/a	2.5	25.0	1	n/a	N
97	Sullivan	Acworth	ACW0009	NH 123A	Honey Br.	B	F	5.0	9.0	1	N	Y
98	Sullivan	Claremont	CLA0058	Maple Avenue	Meadow Br.	B	F	5.4	36.5	1	Y	N

RESOURCE INVENTORY TABLE NOTES

	Culvert Resource Table Notes [row numbers correspond to data row numbers]
1	Culvert is located on an abandoned road/causeway, which runs parallel to Belknap Mtn. Road
2	Large culvert. Interior joints pointed or re-pointed. Concrete floor added with drop spillway at outlet
3	Large culvert. Interior joints pointed or re-pointed. Fieldstone retaining walls.
4	Steel pipe culvert with fieldstone inlet/outlet retaining walls.
5	Some mortar present. Some ceiling stones have drill hole marks (plug & feather).
6	Associated with Great Falls Mfg. Co. mill power canal. Concrete curb beam added.
7	Second cell appears later addition, then altered later with addition of concrete pipe. Dimished integrity.
8	Secondary steel pipe culvert installed alongside
9	Concrete pipe with split stone face walls, possibly reused from pre-existing box culvert.
10	Good example of double box culvert
11	Widened with concrete box culvert as part of road widening.
12	Widened 10 feet with corrugated metal pipe on downstream side; upstream end reinforced with concrete lintel. Dimished integrity.
13	Excellent example of arch culvert. Joints reportedly pointed or re-pointed with epoxy mortar.
14	Small rudimentary box culvert. Steel pipe from street catch basin discharges near culvert outlet.
15	Steel pipe with split stone face walls. Stone possibly reused from preexisting box culvert. Upstream retaining wall failing.
16	Nice example of typical 4' box culvert.
17	Double steel corrugated pipe culvert with split and fieldstone facewalls. Stone possibly reused from preexisting box culvert.
18	Overgrown. Wood boards or beams present, possible curbing or decking. Common type with dimished integrity.
19	Small rudimentary box culvert or rough fieldstone; not readily visible, unable to determine integrity.
20	Steel corrugated pipe culvert with split and fieldstone facewalls. Stone possibly reused from preexisting box culvert.
21	Widened or repaired at inlet end with corrugated metal pipe. Stone box remains at outlet end.
22	Steel pipe culvert with fieldstone inlet/outlet retaining walls; outlet wall rebuilt with mortared fieldstone.
23	Timber stringer wood deck span on stone abutments. No stone lintels or slabs present to suggest this was a box culvert at one time.
24	Two steel pipes with stone facewalls, one 36," one 72". Split stone wall coping and road curbing may have been lintels of pre-existing box culvert.
25	Concrete pipe and concrete facewalls with split stone retaining walls above. Stone may have been from pre-existing box culvert.
26	42" steel pipe culvert with quarried stone and fieldstone facewalls. Split stones may have been from pre-exiting box culvert.
27	Culvert widened downstream about 8' with addition of concrete pipe. Facewalls repaired with fieldstone in mortar. Box section retains integrity.
28	Box built with very large dimension cut stone.
29	Concrete pipe culvert with fieldstone facewalls.
30	Box culvert appears widened or repaired with corrugated steel pipe; downstream facewall looks rebuilt, upstream may be original. Dimished integrity.
31	Large box, good workmanship; culvert extends under building; long stone-built channel; appears associated with other historic resources.
32	Example of small rudimentary box culvert.
33	Plastic pipe culvert with stone facewalls. Stone possibly reused from pre-existing box culvert.

RESOURCE INVENTORY TABLE NOTES (continued)

	Culvert Resource Table Notes [row numbers correspond to data row numbers]
34	Concrete and wood visible in ceiling of culvert.
35	Steel pipe culvert with fieldstone facewalls.
36	Concrete pipe culvert with fieldstone facewalls.
37	Box culvert apparently widened 16' with concrete pipe; outlet facewall fieldstone, inlet facewall appears original. Dimished integrity.
38	Good example of box culvert and skilled workmanship. Associated with stone channel and possibly other nearby historic mill resources.
39	Prime example of large box culvert of split lintel and fieldstone construction.
40	Same construction and workmanship to nearby HIL0019. Upstream facewall collapsed, stone fill repair added.
41	Good example of split stone box.
42	Rough-cut arch stones with fieldstone facewalls. Segmental but nearly semi-circular arch. Adjacent to HIL0023
43	Rough-cut arch stones with fieldstone facewalls. Segmental arch. Adjacent to HIL0022
44	Good example of 5' box culvert with split and cut lintels. Downstream lintels have collapsed into the stream.
45	Steel corrugated pipe culvert with split and fieldstone facewalls. Inlet facewall stone possibly reused split lintels from preexisting box culvert.
46	Cut arch stones with fieldstone facewalls. Semi-circular arch on tall fieldstone walls. Mortar present between voussoirs. Widened with concrete arch culvert.
47	Catch basin drainage culvert. Inlet is brick catch basin feeding small stone box culvert of fieldstone and split lintels.
48	Culvert may have been associated with former mill operation. Inlet altered and incorporated into concrete dam, circa 1920.
49	Road and fill washed away and facewalls collapsed. But arch ring remains and provides important information on construction of rare stone arch culvert.
50	One small box culvert with 3' concrete pipe bypass culvert recently added to the side. Pipe may have replaced second box culvert. Dimished integrity.
51	Plastic pipe culvert with fieldstone facewalls. Stone possibly reused from preexisting box culvert.
52	One concrete pipe, one steel pipe with integral mortared fieldstone facewalls. Facewall stone possibly reused from pre-existing box culvert.
53	Apparently former small box culvert on abandoned path, now completely washed out and collapsed. Dimished integrity.
54	Rare segmental arch culvert with ashlar ring stones and facewall. Concrete road curbs and pointing of inlet facewalls do not substantially diminish integrity.
55	Large cut stone box culvert widened downstream with concrete box.
56	Double concrete pipe culvert. Facewall stone, which includes long split lintels, possibly reused from pre-existing box culvert.
57	Concrete pipe culvert with cut and fieldstone facewalls. Facewall stone, which includes long split lintels, possibly reused from pre-existing box culvert.
58	Example of small rudimentary fieldstone box culvert. A corrugated metal pipe has been installed to the west to supplement capacity.
59	Example of small rudimentary fieldstone box culvert. The outlet facewall was rebuilt in 2006 using existing stone.
60	Example of small rudimentary fieldstone box culvert.
61	Downstream elevation is completely submerged.
62	Concrete pipe culvert with cut and fieldstone facewalls. Facewall stone possibly reused from pre-existing box culvert.
63	Good example of rare tall narrow fieldstone box culvert (4 feet by 8 feet.
64	Good example of rare double box culvert of slab and fieldstone construction.
65	Good example of slab and fieldstone box culvert.
66	Example of typical small slab and fieldstone box culvert.

RESOURCE INVENTORY TABLE NOTES (continued)

	Culvert Resource Table Notes [row numbers correspond to data row numbers]
67	Steel pipe culvert with fieldstone facewalls.
68	Steel corrugated pipe culvert with stone facewalls. Stone possibly reused from pre-existing box culvert.
69	Example of typical slab and fieldstone box culvert. Possibly reconstructed.
70	Concrete pipe culvert with cut and fieldstone facewalls. Facewall stone, which includes long split lintels, possibly reused from pre-existing box culvert.
71	Concrete pipe culvert with cut and fieldstone facewalls. Facewall stone, which includes long split lintels, possibly reused from pre-existing box culvert.
72	Example of typical small lintel and fieldstone box culvert. Lintels appear to be quarried, although there is no evidence of quarrying marks.
73	Example of small rudimentary fieldstone box culvert. Inlet facewall collapsing. Common type with diminished integrity.
74	Example of small roughly built fieldstone box culvert. Outlet facewall collapsing. Common type with diminished integrity.
75	Example of typical small slab and fieldstone box culvert.
76	Good example of medium size slab and fieldstone box culvert. The outlet facewall is partially collapsed.
77	Good example of rare small double box culvert of slab and fieldstone construction. Outlet lintel of east culvert is collapsing.
78	Example of typical small slab and fieldstone box culvert.
79	Example of typical small slab and fieldstone box culvert.
80	Example of typical small slab and fieldstone box culvert.
81	Small catch basin drain. May be pipe with box outlet. The culvert is an outlet to a catch-basin across the street. Common type with diminished integrity.
82	Good example of less common vertically rectangular box culvert. Mortared joints appear original.
83	Example of small roughly built fieldstone box culvert. Culvert appears mortared through; concrete lintel added. Common type with diminished integrity.
84	Steel pipe culvert with fieldstone facewalls.
85	Example of small roughly built fieldstone box culvert with cut lintels. Inlet partly reconstructed. Common type with diminished integrity.
86	Example of typical small fieldstone box culvert.
87	Typical rough fieldstone box culvert widened with addition of concrete pipe at upstream end. Common type with diminished integrity.
88	Outstanding semi-circular arch culvert/bridge and ashlar masonry. Associated with mill site and dam structures on upstream side.
89	Stone slab or lintels removed and concrete slab roadway span installed ca. 1917. Dimished integrity.
90	Small rough fieldstone box culvert. Outlet facewall integrated with roadway retaining wall. Inlet wall collapsed. Common type with diminished integrity.
91	Example of typical very small fieldstone box culvert.
92	Example of mid-size fieldstone box culvert. Two plastic pipe culverts added 100' northwest. Road washed out during a flood, but culvert survived intact.
93	Rare very large & long box culvert of large block ashlar construction. Carries stream under buildings, parking lot and road. Later added concrete inlet facewall.
94	Example of very small roughly built fieldstone box culvert. Inlet has collapsed. Common type with diminished integrity.
95	Good example of medium size slab and fieldstone box culvert.
96	Steel pipe culvert with fieldstone facewalls.
97	Good example of medium size slab and fieldstone box culvert. Carries portion of Tucker Road now abandoned.
98	Example of medium size slab and fieldstone box culvert. New outlet facewall of concrete construction 3'-10" thick. Common type with diminished integrity.

G. GEOGRAPHICAL DATA

The geographic area encompasses the entire state of New Hampshire

H. SUMMARY OF IDENTIFICATION AND EVALUATION METHODS

Purpose

The purpose of this study is to identify stone highway culverts in New Hampshire built prior to 1958 (fifty years of age or older) 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 New Hampshire Department of Transportation (NHDOT) to aid in the planning and performance of culvert maintenance, repair and replacement. The findings will also be used by the New Hampshire Division of Historical Resources (NHDHR) 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

Research for this project was conducted using information compiled by the NHDOT Environmental Bureau, from the files of the New Hampshire Division of Historical Resources and at academic libraries including the University of New Hampshire, Brown University Libraries, Providence Public Library, University of Rhode Island and Roger Williams University. Research was conducted online using a variety of databases and resources that in-turn led to a number of rare sources being acquired through inter-library loan.

Resource Field Survey

The field survey component of this report was conducted by the NHDOT in 2007. Preparation began with collection of locations for potentially historic stone culverts. Culvert locations were recovered from the DHR Survey and Review and Compliance files, responses to a email list-serve notification sent out to state offices and road agents, a hydrology study of the Ashuelot River conducted by The Nature Conservancy, a search of the DOT bridge database (known as PONTIS), and from a DOT water quality study in the southern section of the state. Once all the data was assembled, culvert locations were organized by town and each town was then filed with its county. The intern surveyors approached the study one county at a time, moving across the southern section of the state from west to east, and then moved into the northern counties.

Since culverts are not listed in the PONTIS database and no other comprehensive inventory or listing of culverts had ever been compiled, a systematic approach was not economically feasible: all road and stream intersections would have to be individually inspected, a task well beyond NHDOT manpower and budgetary resources. The Nature Conservancy's Ashuelot River Watershed study sought to understand the river's capacity and potential for flooding and compiled a Road Stream Crossing Inventory. A specific objective of the study was locating, measuring and mapping culverts that might be restrictions or impediments to the natural flow. The fieldwork portion of the study used a large team of volunteers that identified 730 culverts (forty of which were stone) over a study period of three years.

Before beginning actual fieldwork of this study, a significant amount of office time was dedicated to preparation. As culverts are small structures under the roadway, they pose a particular problem in finding their exact location. Project interns assembled all available locational information on each culvert before heading into the field. This information included location of the roadway on Google Maps and on large county maps, exact location of the culvert via GIS (Geographical Information System) if a GPS (Geographical Positioning System) or UTM (Universal Transverse Mercator) location was already known, photographs of the culvert and roadway if available, and any descriptive information provided by the original source.

In the field, culverts were measured, photographed, and sketched. Information regarding the location of the culvert was collected, including the UTM, GPS, street, and crossing of the culvert, and compiled on a special resource inventory form developed specifically for the project [see form example at end of this section]. Some locations were not surveyed if the culvert had undergone significant alterations that clearly negated integrity as a historic culvert, although culverts that retained readability as a historic structure with alterations present were surveyed. Culverts with some new material, mortar, bypass culverts, and pipes were included in the study. Culverts that had been replaced with all new material with a few stones showing historic quarry marks retained were not surveyed. Stone culverts constructed in the mid-twentieth century were not included in this study. Pipe culverts with stone headwalls to hold back erosion, but not a stone channel, were not surveyed (unless landscape features or quarry marks in the stone proved that the culvert may have historic association if not historic integrity.) Culverts showing damage from natural processes were not excluded.

The goal of the fieldwork was not to survey only pristine examples of stone culverts. Rather, the goal was to establish an understanding of how these stone structures fair under flood conditions, what appropriate alterations may be, and to begin to establish an understanding of the construction and change in these structures over time.

Analysis and Reporting

The historic contexts within which New Hampshire's stone culverts were built and evaluated for significance are described in Sections E above. The resources have been evaluated for their association with events that have made a significant contribution to the broad patterns of New Hampshire history (NR Criterion A) and/or for their 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 data collected on the culvert survey form [see below for sample survey form] and then compiled in table form for comparison and analysis. The findings of this study have been compiled in this report.

SAMPLE STONE CULVERT INVENTORY FORM

New Hampshire Division of Historical Resources Page 1 of 6

STONE CULVERT INVENTORY FORM **INVENTORY #JAF0464**

Location
1. City or Town: Jaffrey
2. County: Cheshire
3. Road: Nutting Road
4. Crossing: Tyler Brook
5. USGS Quad: Monadnock Mountain, NH
6. UTM: 18 743795E 4745699N
7. GPS: N 42° 49.501' W 72° 1.051'

Function or Use
8. Current use(s) Culvert
9. Historic use(s) Culvert

Site Features
10. Setting: Wooded, residential
11. Landscape features:
12. Water Quality: Good, some trash upstream

Descriptive Information
13. Overall Width: (U) 32'5" (D) 30'11"
14. Size of opening (see attached worksheet)
15. Number of openings: 1
16. Number of travel lanes: 2
17. Roadway type: Paved town road
18. Material:

Feature	Ashlar		Fieldstone		Other		Mortared	
	U	D	U	D	U	D	U	D
Ceiling	X	X					X	X
Floor	X	X					X	X
Left Wall	X	X					X	X
Right Wall	X	X					X	X
Lintel	X	X					X	X
Retaining/wing walls	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Channel	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Parapet	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

19. Quarrying technique: Plug and feather

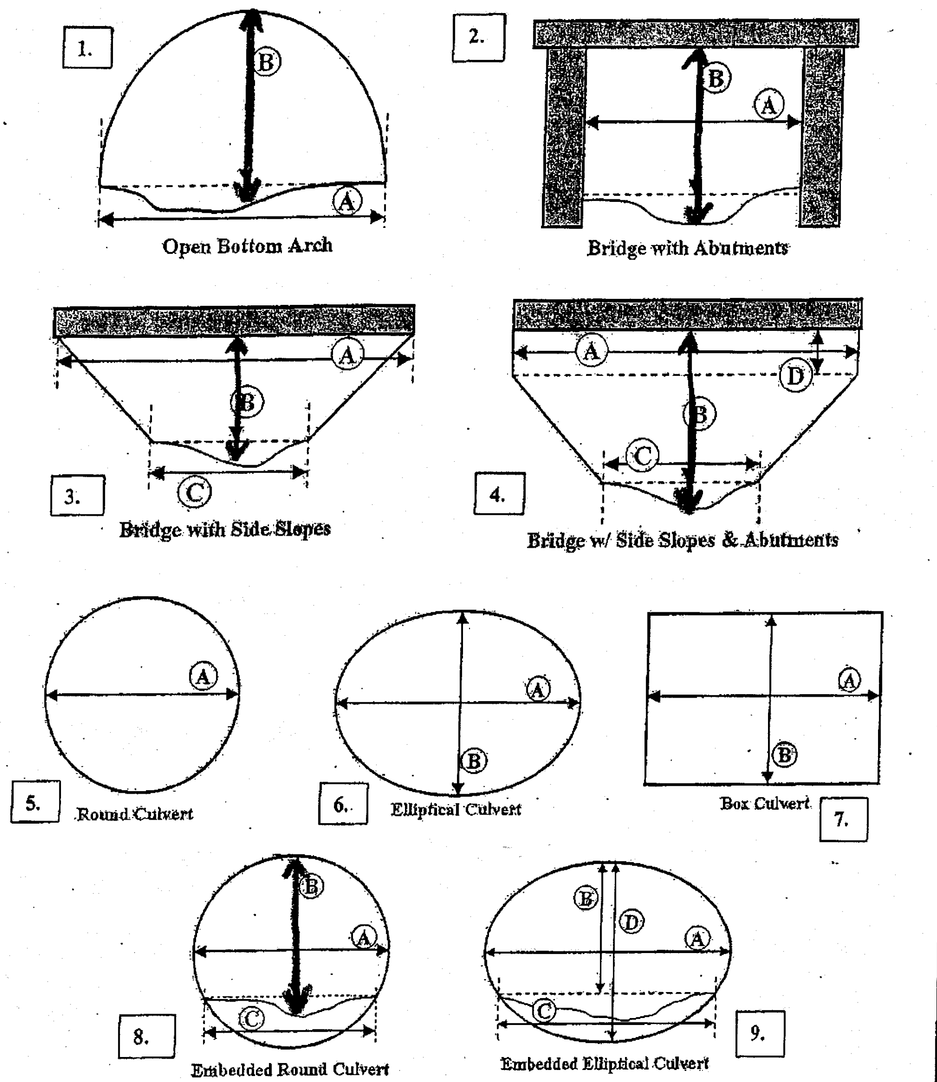
Condition
20. Intact (Altered)
21. Describe (also use Notes section):

Form prepared by
22. Name: Ashley Bushey, Sarah Ganley
23. Organization: NHDOT: Bureau of Environment
24. Date of survey: June 21, 2007

SAMPLE STONE CULVERT INVENTORY FORM (continued)

JAF 0464
Page 2 of 6

rossing Dimensions



Crossing Type (from above): (1.) 2. 3. 4. 5. 6. 7. 8. 9. Ford

Upstream Dimensions (ft.): A) 11'5" B) 7'5" C) D)

Downstream Dimensions (ft.): A) 11'3" B) 8' C) D)

Length of stream through crossing (ft.): 19'11"

Adapted from: Commonwealth of Massachusetts
Riverways Program – River Restore

Department of Fisheries, Wildlife and Environmental Law Enforcement
251 Causeway Street, Suite 400, Boston, MA 02114; 617-626-1542 (1526)

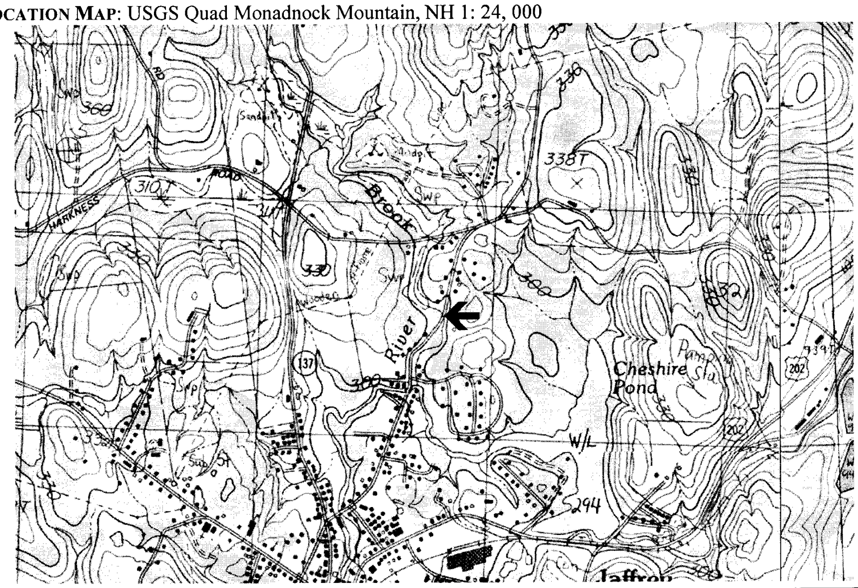
SAMPLE STONE CULVERT INVENTORY FORM (continued)

New Hampshire Division of Historical Resources Page 3 of 6

STONE CULVERT INVENTORY FORM **INVENTORY #JAF0464**

NOTES: Mortared stone. Mortar appears to be some type of epoxy.

LOCATION MAP: USGS Quad Monadnock Mountain, NH 1: 24, 000

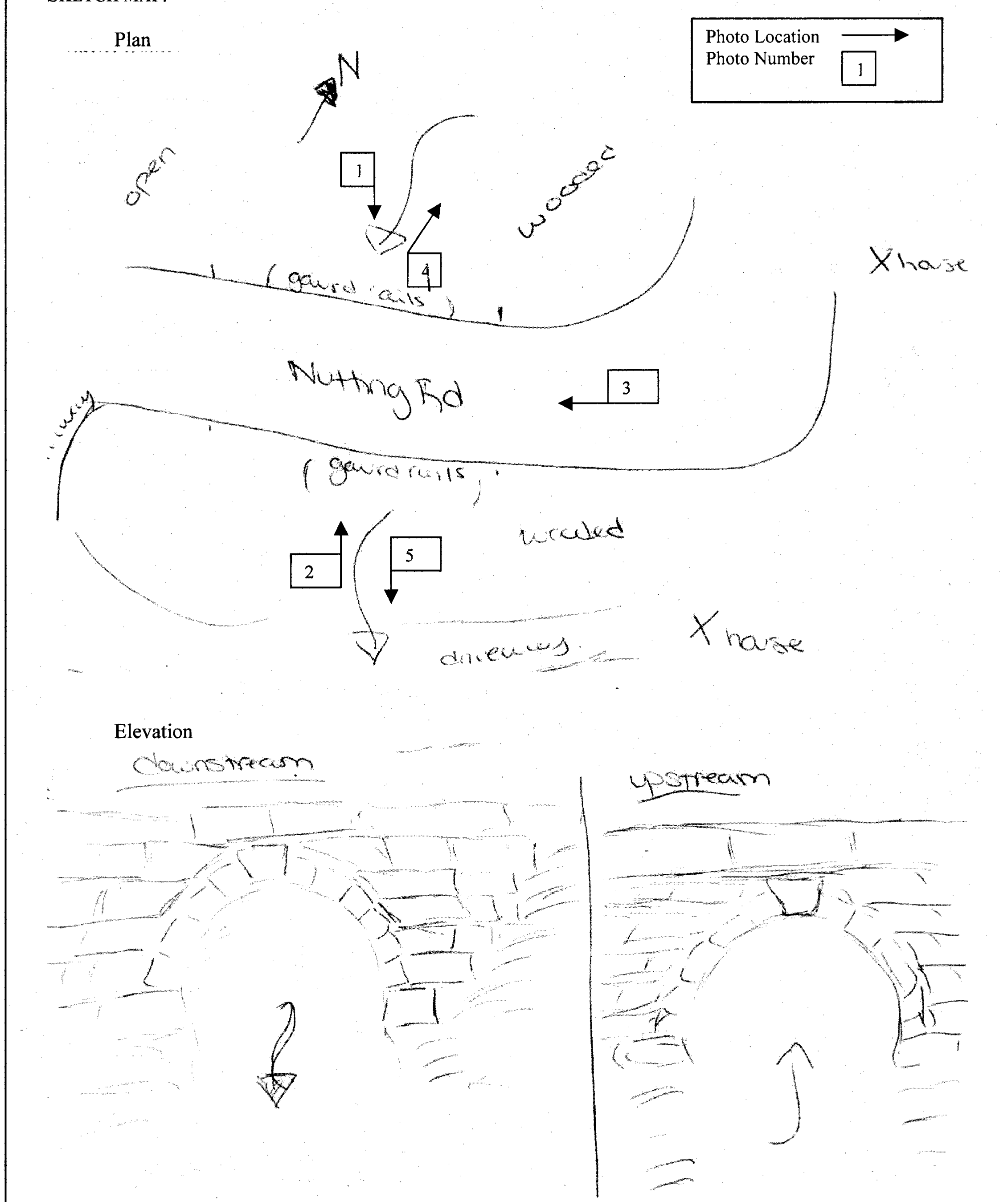


SAMPLE STONE CULVERT INVENTORY FORM (continued)

New Hampshire Division of Historical Resources — Page 4 of 6

STONE CULVERT INVENTORY FORM — **INVENTORY #JAF0464**

SKETCH MAP:



SAMPLE STONE CULVERT INVENTORY FORM (continued)

New Hampshire Division of Historical Resources Page 5 of 6

STONE CULVERT INVENTORY FORM **INVENTORY #JAF0464**

Location: Jaffrey, NH
Roll #(s): 5

Date taken: June 21, 2007
Frame #(s): 13—18

Negative stored at: NH DOT

Photo #2 description: Downstream Elevation
Roll #: 5 Frame #: 18 Direction: NW

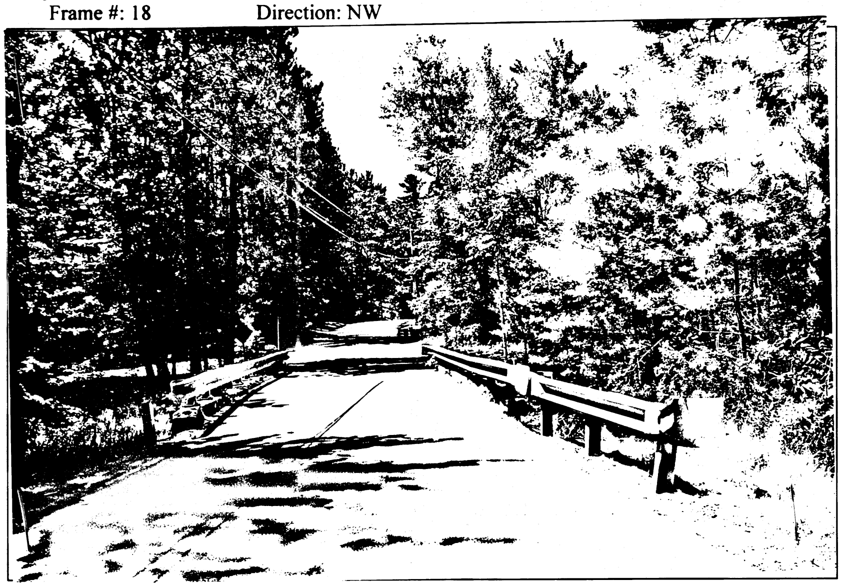


Photo #3 description: Nutting Road
Roll #: 5 Frame #: 13 Direction: SW

SAMPLE STONE CULVERT INVENTORY FORM (continued)

New Hampshire Division of Historical Resources Page 6 of 6

STONE CULVERT INVENTORY FORM INVENTORY #JAF0464

Photo #4 description: Upstream Overview
Roll #: 5 Frame #: 14 Direction: N

Photo #5 description: Downstream Overview
Roll #: 5 Frame #: 17 Direction: SE

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