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CHAPTER 1
BRIDGE SITE EXPLORATION

1.1 SURVEY FOR BRIDGES

1.1.1 GENERAL

The following are the minimum survey requirements for bridge projects and the reasons for them. Additional survey beyond these requirements may be needed depending on the complexity of either the proposed bridge structure or the site. The MassDOT Survey Manual shall be used for any additional information on survey theory and methods as practiced by the MassDOT.

1.1.2 BRIDGE GRID SURVEY

The bridge grid is taken in order that the proposed bridge may be fitted to the topography and an accurate calculation can be made of excavation quantities. It shall be plotted to either ⅛" = 1'- 0" or ¼" = 1'- 0". The frequency of shots and extent is a matter of judgment of the survey party. In general, shots should be taken on a 10-foot grid with additional shots as necessary for abrupt changes in contour. Shots should extend at least 50 feet beyond the edges of the highway or 25 feet beyond the anticipated end of splayed wingwalls, whichever is furthest, and should cover enough ground for any type of structure. The grid should be extended to reflect topography under existing structures.

1.1.3 BRIDGE DETAIL SURVEY

The following survey information shall be requested when: a new superstructure is to be built on existing substructures; an existing bridge is to be replaced in stages; an existing bridge is to be widened, repaired, or rehabilitated; or when the underclearances for the existing bridge are important to the underclearances to be provided at the replacement, such as for replacement bridges over water or railroads. The accuracy of surveys on bridge locations shall be greater than on general highway work. A copy of all field notes shall be provided to the Designer.

1. The angles of the abutments to the baseline, the location of tops and bottoms of batters, the widths of bridge seats and backwalls, the location of the angles of the wingwalls to abutments, the length of wingwalls and widths of copings shall be measured and the footings located, if possible. The type of masonry in the substructure and its condition should be noted.
2. Detail shall be provided for all main superstructure elements, including beam lines, girder lines, truss lines, floorbeam lines, curb lines, sidewalks, fascia lines, utilities, copings, ends of bridge, etc. The stations of the centerlines of bearings and the skew angle between them and the survey baseline shall be established or verified at each abutment and at piers.
3. Bottom of beam elevations shall be taken on every beam at: the face of each abutment, both sides of each pier and span quarter points for spans less than 50 feet, span eighth points for spans over 50 feet. These elevations are needed for calculating the depth of haunches and top of form elevations.
4. Elevations shall be taken of all parts of the substructure and superstructure, such as the bridge seats, tops and ends of wingwalls, gutters, top of curb at intermediate points and at the ends of curbs, tops of slab and footings, if possible. All elevations shall be referred to the North American Vertical Datum (NAVD) of 1988. If only the National Geodetic Vertical Datum

(NGVD) of 1929 is available at the site, the Designer shall contact the MassDOT Survey Engineer and obtain the relationship between NAVD and NGVD at the site.

5. Locate and establish the minimum horizontal and vertical underclearances of the existing structure.

1.1.4 ADDITIONAL SURVEY FOR BRIDGES OVER RAILROADS

Whenever a railroad is crossed, the railroad baseline should be reproduced and sections taken a minimum of 50 feet perpendicular to and on both sides of the exterior rails for a distance of about 300 feet left and right of the survey baseline.

1.1.5 SURVEY FOR STREAMS

The detail and amount of survey data to be collected vary based on the complexity of the hydraulics at the site. The survey must capture the stream's bathymetry in addition to its cross section. Thus, a meandering stream would require more survey than one that is relatively straight. For this reason, the survey scope of work, including its limits and locations as required for hydraulic analysis, shall be as directed and approved by the MassDOT Hydraulics Engineer.

The stream shall be surveyed for a **minimum** distance of 500 feet along the path of the stream up and downstream from the face of the existing or proposed bridge. The survey of the stream shall extend 50 feet beyond the top of bank. See Figures 1.1.5-1 and 1.1.5-2. When, based on project requirements, the survey limits extend beyond 50 feet from the top of bank, the Survey Consultant shall obtain existing LiDAR data available from MassGIS and NOAA for these locations instead of performing this survey in the field. The Survey Consultant shall incorporate this LiDAR data into their survey CAD drawings prior to submitting them to MassDOT. All elevations shall refer to the North American Vertical Datum of 1988 (NAVD 88).

Any stream confluence within the 500 feet of the bridge site as measured along the path of the stream from the bridge, either above or below the bridge site, shall be surveyed for a distance of at least 500 feet from its junction along these additional stream's paths, with stream topography and LiDAR coverage as mentioned above (Figure 1.1.5-2). Locations and sizes of visually accessible drainpipes shall be noted. The survey performed for the relocation of an existing stream shall be taken to encompass the entire relocation area. The survey for stream relocation shall be performed to greater detail and accuracy than the above stated survey for hydraulic analysis. In the case of very wide flood plains or in locations with challenging site conditions, the MassDOT Hydraulics Engineer should be consulted in order to establish reasonable requirements and limits for the survey.

Where there is a dam or other water flow control device within the 500 foot stream survey limits, or beyond that are expected to impact the hydrologic and hydraulic analysis, either up or down stream, the survey shall include: its distance from the bridge; elevations of the spillway; the top of the dam; and water and riverbed soundings both upstream and downstream of the dam. Any hydraulic structure within the 500 feet distance shall have the elevations defining its hydraulic opening taken. In addition to the full bathymetry of the stream, the survey shall include upstream and downstream elevation of the bridge, culverts, and spillways with surveyed elevations (Figure 1.1.5-3 through 1.1.5-7).

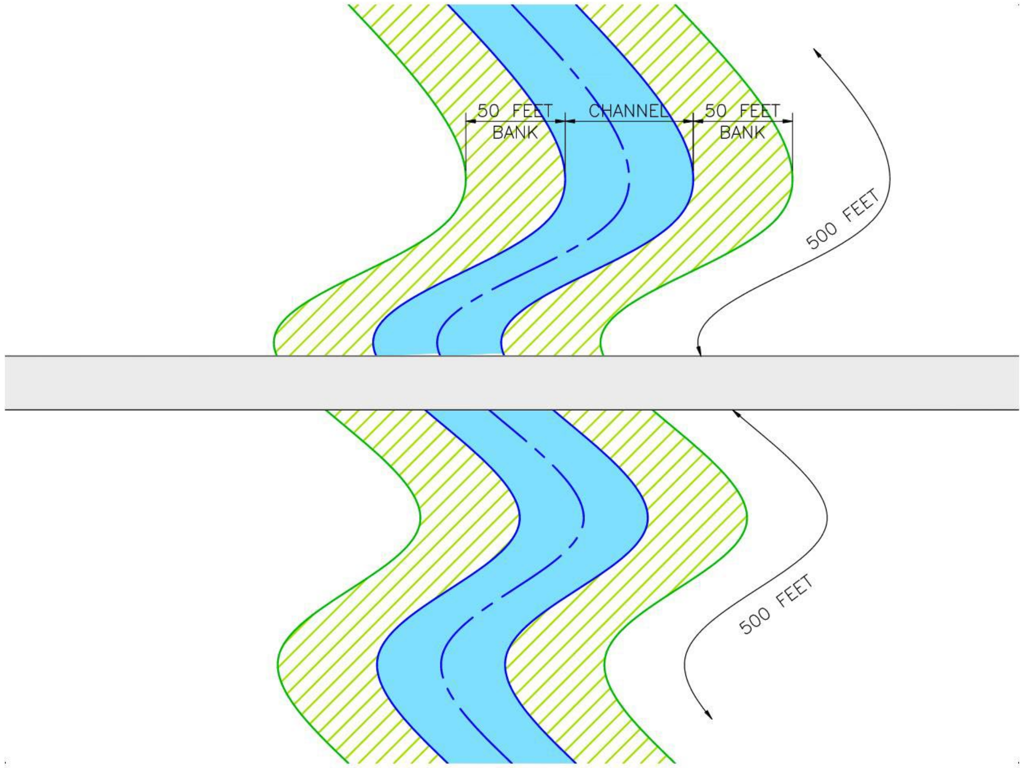

Figure 1.1.5-1: Stream Survey Limits

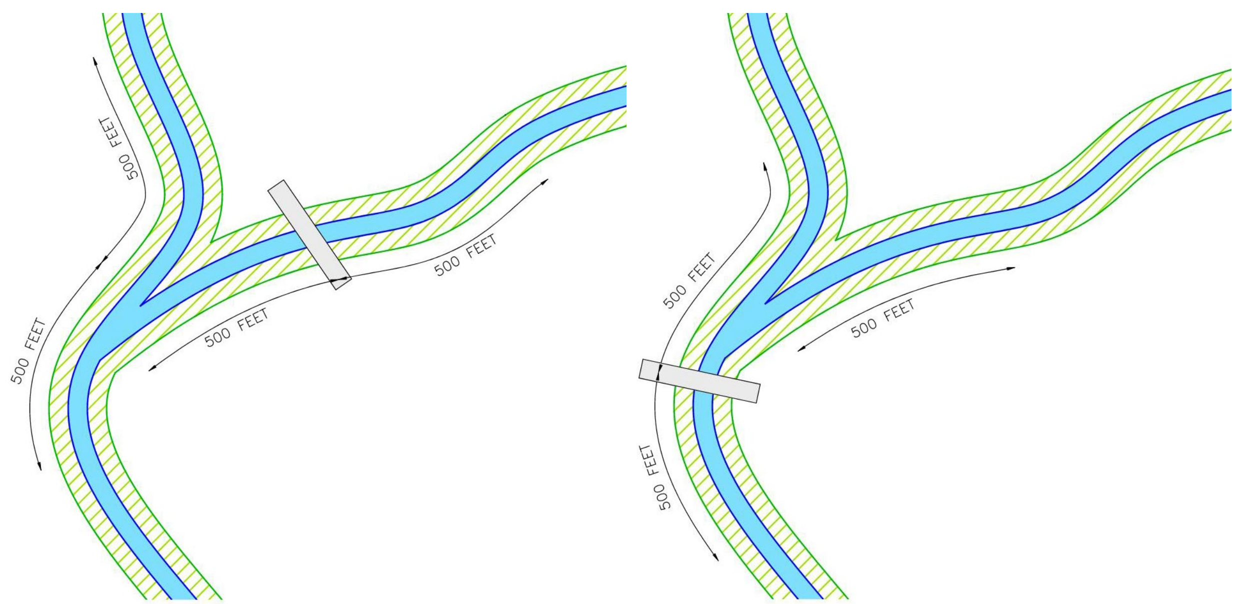

Figure 1.1.5-2: Survey Limits for Stream Confluence

All stream surveys must be coordinated with the Hydraulic Unit. All survey CAD drawings should be submitted to the MassDOT Survey Engineer for review and approval. All CAD drawings should utilize the current horizontal datum as designated by MassDOT's Survey Section. Currently, that datum is the Massachusetts State Plane, Mainland/Island Zone, NAD83(2011) Epoch 2010.00.

Figure 1.1.5-3 (a): Example for Single-Span Structure (Open Bottom) Survey Locations

Figure 1.1.5-3 (b): Single-Span Structure (Open Bottom) Survey Locations

Figure 1.1.5-3 (c): Single-Span Bridge Survey Locations

Figure 1.1.5-4 (a): Multi-Span Structure (Open Bottom) Survey Locations

Figure 1.1.5-4 (b): Multi-Span Box Culvert (Closed Bottom) Survey Locations

Figure 1.1.5-4 (c) : Multi-Span Bridge Survey Locations

Figure 1.1.5-4 (d): Multi-Span Three-Sided Structure (Open Bottom) Survey Locations

Figure 1.1.5-5 (a): Arch Bridge Survey Locations

Figure 1.1.5-5 (b): Arch Bridge Survey Locations

Figure 1.1.5-5 (c): Multi-Arch Bridge Survey Locations

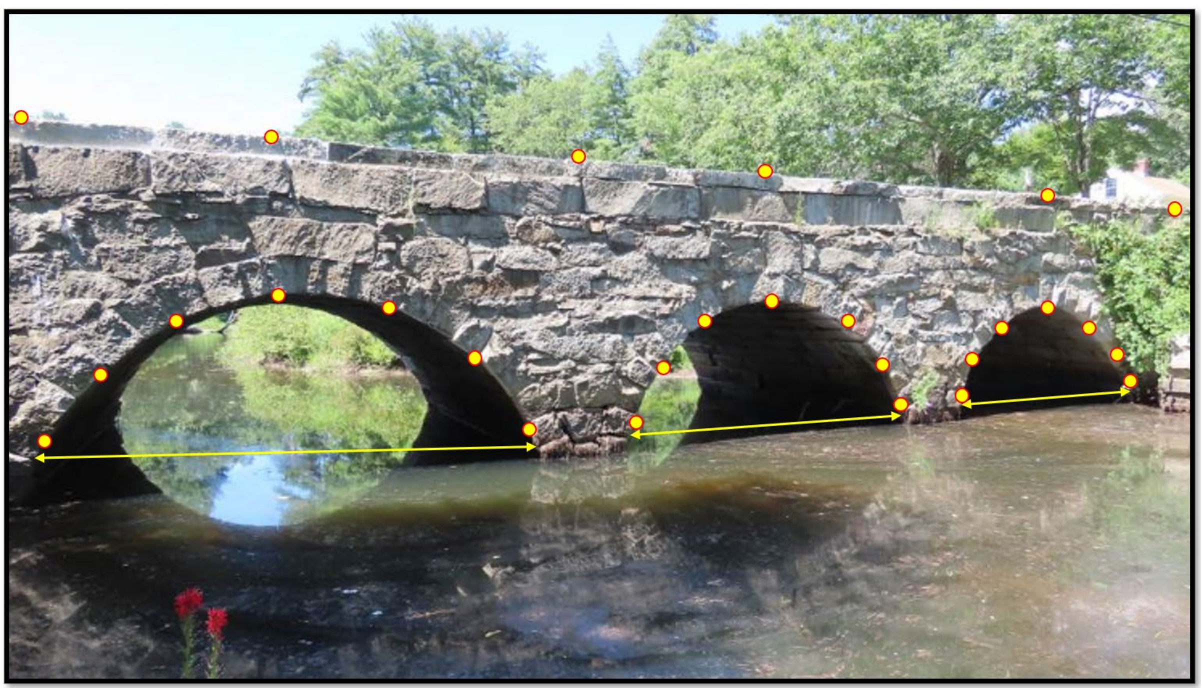

Figure 1.1.5-5 (d): Multi-Arch Bridge Survey Locations

Figure 1.1.5-6 (a): Single Pipe Survey Locations

Figure 1.1.5-6 (b): Multi-Pipe Survey Locations

Figure 1.1.5-7 (a): Spillway Survey Locations

Figure 1.1.5-7 (b): Spillway Survey Locations

1.2 BORINGS FOR BRIDGES

1.2.1 GENERAL

No structure can be stronger than the foundation of its substructure elements. Borings are taken for these elements and the study of the results and samples aids in the determination as to the type of foundation support.

In general, all design borings are typically made at one time. On major projects involving the construction of multiple bridges, pilot borings may be required.

1.2.2 BORING PLAN

Boring plans for bridges shall be prepared as outlined in Section 1.3 of Part II of this Bridge Manual. They will be drawn on a single sheet of paper no smaller than 8½" x 11" and shall contain the following information:

1. The standard Title Block (Drawing No. 1.3.1 of Part II of this Bridge Manual).
2. A 1" = 40' plan view of the proposed structure, with the boring locations indicated by the standard symbol and a table specifying the following: boring's number, station and offset from baseline, Northing and Easting coordinates, approximate surface elevation, and specified highest bottom elevation (Drawing No. 1.3.2 of Part II of this Bridge Manual).
3. Boring Request Notes, from Drawing No. 1.3.3 of Part II of this Bridge Manual, and modified as indicated on the drawing.

The proposed boring plan shall be submitted to the MassDOT Project Manager as an electronic file in PDF format. The Project Manager will transmit the boring plan via email to the Geotechnical Section and the Bridge Section for review. The Geotechnical Section will review the proposed boring plan in the office and in the field, accept and review the Bridge Section's comments, resolve any conflict between the two sets of comments, and shall transmit all comments to the Designer for boring plan modification and resolution. The Designer shall then forward the revised (if applicable) boring plan to the Geotechnical Section, through the Project Manager, for acceptance. Upon acceptance, the Designer shall initiate and conduct the subsurface investigation.

1.2.3 DEFINITIONS

1.2.3.1 Pilot Borings. Major projects involving the construction of multiple bridges may require pilot borings, which are those made during the preliminary stage of a project. These borings shall be located by the Designer to yield only sufficient soil information to enable the Designer to:

1. Prepare a preliminary foundation assessment.
2. Fix the profile, alignment of the highway, and position of the structures.
3. Prepare a preliminary cost of the project.

1.2.3.2 Design Borings. Design borings are made to furnish all subsurface data and soil samples required by the Designer to complete the design of the project. Depending on the situation, design borings may either be taken all at once or they may consist of control and complementary borings. Design borings are typically taken after the profile and alignment of the road have been set and the structure type has been advanced sufficiently to identify the number, alignment and location of all substructure units. Borings in the pilot set that fit into the pattern of the design borings shall not be duplicated.

1.2.3.3 Control Borings. Control borings are the initial design borings. The results obtained from control borings are reported immediately to the Designer so that, at each area and location, the depth to which all remaining complementary borings should be taken can be determined.

1.2.3.4 Complementary Borings. Complementary borings are the remaining design borings required for design and construction purposes. They are made after an analysis of the results obtained from the control borings, to the depth specified by the Engineer. Usually, the Designer and the MassDOT's Geotechnical Section and/or Bridge Section jointly review the results of the control borings to determine the depths of the structural complementary borings. Complementary borings are not used for a pilot boring program.

1.2.4 DEPTH AND LOCATION

1.2.4.1 Pilot Borings.

Depth: For structures, the specified highest bottom elevation shall be set 10 feet below the preliminary footing elevation at the boring location. Each boring shall be made to the specified highest bottom elevation or to refusal, whichever is deeper. Refusal is defined as 120 blows for 12 inches (or fraction of 12 inches) of penetration by using the Standard Penetration Test (SPT). If rock is encountered above highest bottom elevation, a 10-foot long rock core is taken and the borehole is terminated.

Location: One boring per bridge site. Consideration of a rock core should be made at this time if rock would influence the foundation design.

1.2.4.2 Design Borings.

Depth: For structures, the specified highest bottom elevation shall be set at the depth equal to two footing widths below the preliminary footing elevation at the boring location. For perched abutments, the specified highest bottom elevation shall be set 15 feet below existing ground. At least one boring shall be made to bedrock and a 10-foot long core taken at each bridge location. Where a viaduct of considerable length is to be designed, every other pier may have one boring made to bedrock, if deemed necessary by the Engineer. Where structure foundations may be pile or drilled shaft supported, one boring shall be made to bedrock under each substructure unit.

Location: Borings shall be taken for every bridge, metal arch, box culvert with a span greater than 8 feet, retaining wall, and "highmast lighting foundation". Borings may be required for sign supports. For other smaller structures, engineering judgment should govern.

One boring shall be made at each end of each pier or abutment and at the outer end of each wingwall longer than 30 feet. Where piers and/or abutments are more than 100 feet long, additional borings may be required. These additional borings could consist of both control and complementary borings, as specified by the Designer.

For retaining walls up to 100 feet in length, at least one boring shall be taken at each end of the wall. For walls longer than 100 feet, borings shall be spaced no more than 100 feet apart. Wall borings shall be alternately control and complementary.

For culverts up to 50 feet in length, two borings will be required. For culverts longer than 50 feet, three or more borings will be required.

The preceding description is given as a guide and should not pre-empt sound engineering judgment. Likewise, the depth to which borings are carried may vary, depending on design requirements. Where utilities are present, the borings shall be accurately located no closer than 5 feet from the nearest edge of the utility.

1.2.5 OTHER SUBSURFACE EXPLORATORY REQUIREMENTS

1.2.5.1 The additional subsurface explorations outlined below will be included as part of the boring program. Any laboratory test program on recovered boring samples to be done at an outside testing laboratory shall be approved by MassDOT before any work is done. Upon completion of all boring operations, the samples shall be delivered to the MassDOT storage facilities or as directed by the Geotechnical Engineer. No soils and/or rock samples shall be removed from the referenced facilities without formal approval of the Geotechnical Engineer.

1.2.5.2 Under certain conditions, test pits may be needed to disclose certain features of existing structures that may be retained. Test pits shall be dug to establish the elevations of the top and bottom of the footing toe as well as the projection of the toe from the face of the abutment or wall. A minimum of two test pits shall be dug at each abutment, one approximately at each end of the abutment.

1.2.5.3 Exploratory probes will be taken, in conjunction with coring through concrete decks/abutments and horizontal cores, if required, for all abutments and walls which may be retained and for which accurate plans do not exist. These exploratory procedures are needed to determine the cross sectional geometry of the wall, such as width, batter and footing thickness, from which the re-use potential of the structure can be evaluated. Provisions for this type of investigation will be included as part of the boring program.

1.2.5.4 If a clay stratum or other compressive material is encountered, in-situ tests and/or undisturbed samples may be required for laboratory tests and analysis. Generally, this type of work is accomplished in the complementary boring program after the results of the control borings are reviewed.

1.2.6 GROUND WATER OBSERVATION WELLPOINT

Ground water level as reported during a soil-test boring operation may not be accurate, since the water level in a test boring may not have had sufficient time to stabilize or may be affected by the use of water in the drilling process. When a study of the pilot or control borings indicates that an excavation in granular soil must be made below ground-water level, observation wellpoints should be installed. Not more than one (1) observation wellpoint should be installed at a bridge except with prior approval of the Engineer. Unless otherwise directed, the bottom of the point shall be located approximately 10 feet below the proposed bottom of footing.

Water levels shall be measured and reported weekly for the first month and monthly thereafter to the Engineer, unless more frequent readings are required. This information is to be tabulated on the Sketch Plans and Construction Drawings.

1.2.7 INACCESSIBLE BORING LOCATIONS

Because of certain physical conditions, such as existing buildings, overhead wires, underground utilities, or because of problems with abutters, boring crews may have no access and certain borings specified for the structure cannot be taken. In such cases, the additional required borings may be included in the construction contract. This allows the successful bidder for the contract to take these additional borings without interference, since the project site must be cleared of all structures prior to commencing construction.

The additional borings shall be examined in the Bridge Section to determine if any changes will be required in the design of the foundations. The estimated linear footage of the borings and their cost shall be included in the Designer's estimate. The location of these additional borings shall be shown on the contract plans. It should be noted, however, that every possible effort should be made to obtain the required substructure information during the design stage.

1.2.8 PRESENTATION OF SUB-SURFACE EXPLORATION DATA

All borings, test pits, or seismic information that have been taken must appear on the plans, even though some of the borings may be exploratory. This is true even though some of the borings are taken for one site and later something changes so that new borings are required. It is mandatory that all available borings be shown on the plans.

The exact logs, as specified in the borings, must be shown on the plans. If the logs are transcribed on plan sheets, the transcriptions must copy all information exactly as it appears on the logs, including any abbreviations and misspellings. It is not necessary to show the blow count for driving the casing. Data relative to core recovery shall be shown on the boring log. It is the responsibility of the Project Geotechnical Engineer to accurately describe the soils obtained with the sampler. In printing the description of soils, abbreviations shall be avoided.

All borings are completed through the Designer. The Project Geotechnical Engineer shall prepare and draft the boring logs. In rare cases the boring contractor will draft and prepare the logs. The Project Geotechnical Engineer shall review these logs to ensure that they accurately describe the soils sampled. Discrepancies shall be reviewed and discussed with the boring contractor; however, the descriptions in the final logs are the responsibility of the Project Geotechnical Engineer.

The elevations of ground water level at the completion of the boring, unless otherwise specified on the log, shall be shown on the boring log. This elevation may be of great importance in order to determine water control measures for constructing the footing in the dry.

The bottom (top, if on rock) of the proposed footing of each element of the substructure shall be plotted adjacent to the appropriate boring log. Borings shall be plotted in groups as they apply to substructure units for ready reference. In the case of a trestle, the bottom of each pile cap shall be shown on the boring logs.

The estimated tip or length of rock socket of piles or drilled shafts shall be plotted adjacent to the appropriate boring log.

Boring results shall be plotted to true relative elevation to a scale of not less than ⅛” = 1’- 0”. Deep borings may offset or show discontinuity only in the event that they cannot be completed in one column.

When posting boring logs on the plans the Designer shall post both depth and elevation at each change in strata.

1.3 HYDRAULIC PRELIMINARY DATA COLLECTION

The purpose of this phase is to gather technical data necessary to support the hydrologic and hydraulic analyses to be performed for the project. The effort expended should be commensurate with the significance and complexity of the project.

Although each individual crossing site is unique, the following procedure should be applied to MassDOT bridges unless indicated otherwise by MassDOT.

1.3.1 PRELIMINARY DATA COLLECTION

Preliminary data collection includes the following:

1.3.1.1 Stream Survey

- Stream survey limits established by the MassDOT Hydraulic Engineer
- Survey request shall be initiated by MassDOT Project Manager
- Field survey operations must be conducted in a manner consistent with the guidelines set forth in Subsection 1.1.5 of this Bridge Manual and the MassDOT Field Survey guidelines and base plan requirements for survey and design consultants.

1.3.1.2 Stream Bed Sediment Particle Size Analysis. The following are guidelines for locations of soil samples and tests to be conducted for scour evaluations. Also included, when required, are the tests necessary to design granular and geotextile filter designs for scour countermeasures. These guidelines are the minimum requirements. Please note that, if the project's site exhibits signs of aggradation or degradation, a sediment transport analysis may be required, and additional soil samples may be needed. Please consult the MassDOT Hydraulic Engineer to determine if these guidelines are sufficient or if more soil samples are required.

The location of the samples to be collected for a given type of structure, in both Riverine and Tidal locations, are as indicated in Figures 1.3.1-1 through 1.3.1-4. The location of all samples shall be determined by the project's hydraulic engineer and approved by the MassDOT Hydraulic Engineer.

For all stream crossings regardless of the stream bed material determine the bed material size characteristics based upon Table 1.3.1-1 below. The following test should be used based on the channel bed grain range size (S):

Table 1.3.1-1: Tests for Stream Bed Particle Size and Physical Properties

Size Range Inches (mm)	Soil Classification	Test
$0.5 < S < 40$ ($12.7 < S < 1016$)	Coarse sands and gravels	**Wolman Pebble Count** (D_{10}, D_{16}, D_{50}, D_{60}, D_{84})
$0.002 < S < 1.25$ ($0.0625 < S < 32$)	Fine sands and gravels	**ASTM D6913** *Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis* (D_{10}, D_{16}, D_{50}, D_{60}, D_{84}) **ASTM D4318**[1] *Standard Test Methods for Liquid Limit, Platic Limit and Plasticity Index of Soils* (PI) **ASTM D5084**[1] *Standard Test Mehods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter* (k)

[1] *Stream bed physical property test required for granular and geotextile filter designs for scour countermeasures.*

Table 1.3.1-1 (Continued): Tests for Stream Bed Particle Size and Physical Properties

Size Range Inches (mm)	Soil Classification	Test
S < 0.002 (S<0.0625)	Clay and Silt	**ASTM D7928** *Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils using the Sedimentation (Hydrometer) Analysis* (D_{10}, D_{50}, D_{60}, % Clay) **ASTM D1140** *Standard Test Methods for Determining the Amount of Material Finer than 75-µm (No. 200) Sieve in Soils by Washing* (F) **ASTM D4318** *Standard Test Methods for Liquid Limit, Platic Limit and Plasticity Index of Soils* (PI) **ASTM D2216** *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass* (w) **ASTM D2166** *Standard Test Method for Unconfined Compressive Strength of Cohesive Soil* (q_u) **ASTM D5084**[1] *Standard Test Mehods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter* (k)

[1] *Stream bed physical property test required for granular and geotextile filter designs for scour countermeasures.*

1.3.1.3 National Flood Insurance Program (NFIP) Flood Insurance Study (FIS) Data

- NFIP FIS data request form shall be completed by MassDOT Hydraulic Engineer
- MassDOT Project Manager or consultant shall submit the completed NFIP FIS data request and all required administrative fees to the Federal Emergency Management Agency (FEMA) Engineering library.

1.3.1.4 Tidal Monitoring (for coastal zone crossing)

- Consultant shall deploy and obtain at least two continuous data logging pressure-transducer tide gages within the affected reach of the crossed waterway;
- At least one gage should be located near the mouth of the waterway to assure capture of local off-shore (un-damped) tidal signal;
- Ideally, gages should be installed within 100 feet upstream and downstream of the bridge crossing location;
- Each instrument's location and elevation must be accurately surveyed with all measurements referenced to known benchmarks and corrected to the project's horizontal and vertical datum;
- Each instrument should be deployed for a 30-day period to capture the influence of a full lunar cycle and at a depth sufficient to assure constant instrument submersion over that deployment period;
- Each instrument should be programmed to record data at 10-minute intervals;
- The consultant should download the information recorded by each deployed instrument, check the raw data for accuracy, process the same into tidal elevation time series data set

worksheets compatible with MS Excel, and submit the final worksheets to the MassDOT Hydraulic Section.

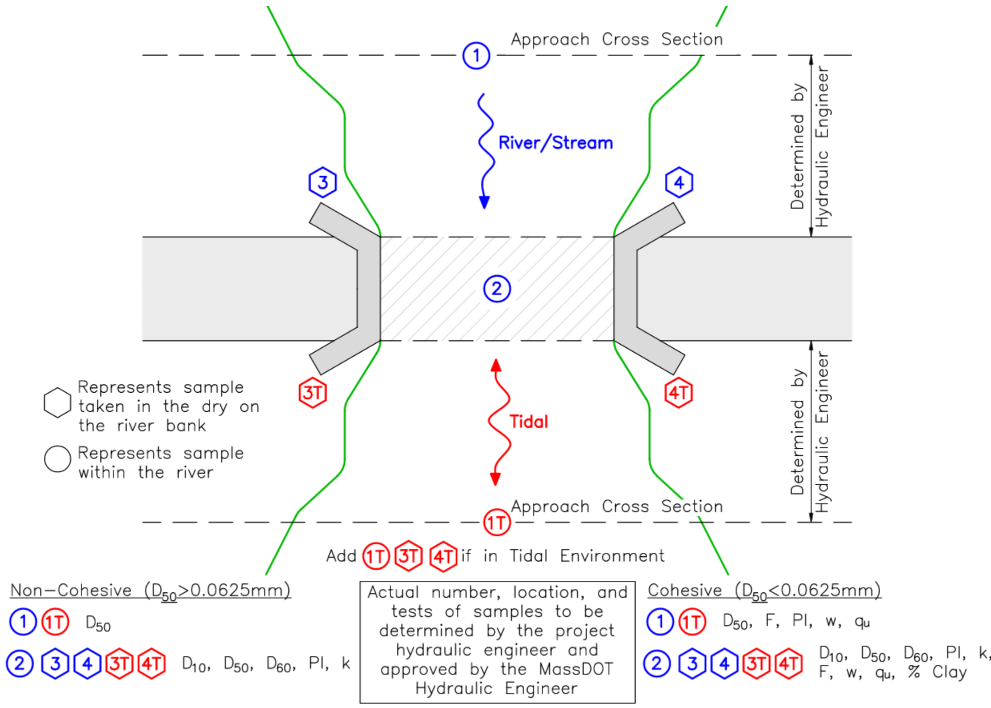

Figure 1.3.1-1: Single Span Bridge & Open Bottom Culvert in Riverine and Tidal Environment

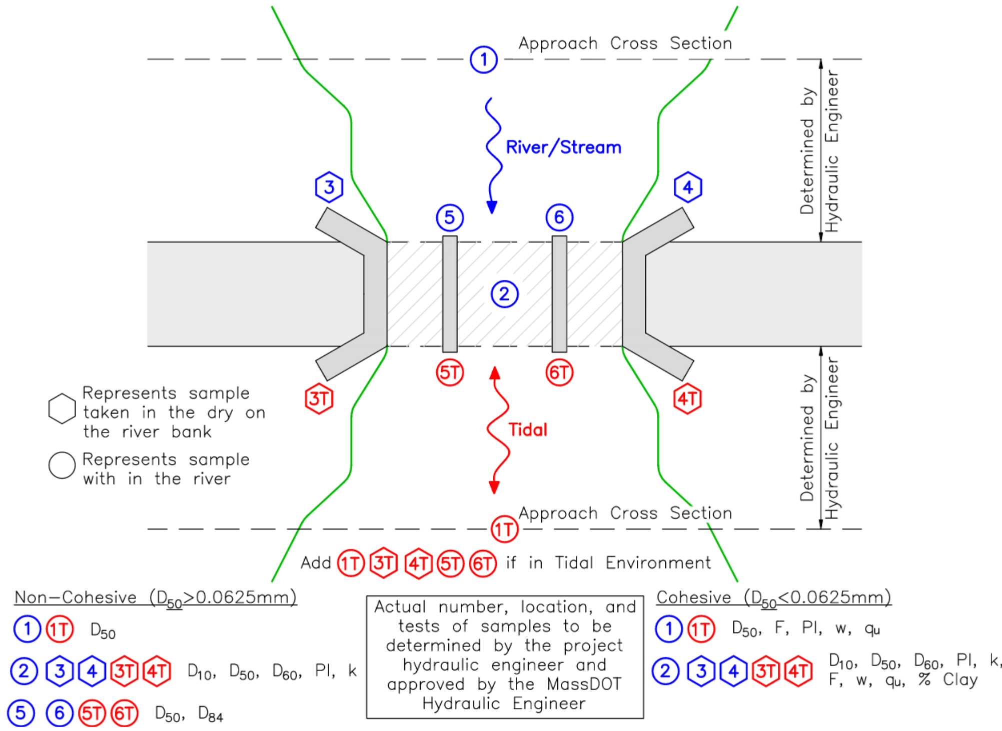

Figure 1.3.1-2: Multi Span Bridge in Riverine and Tidal Environment

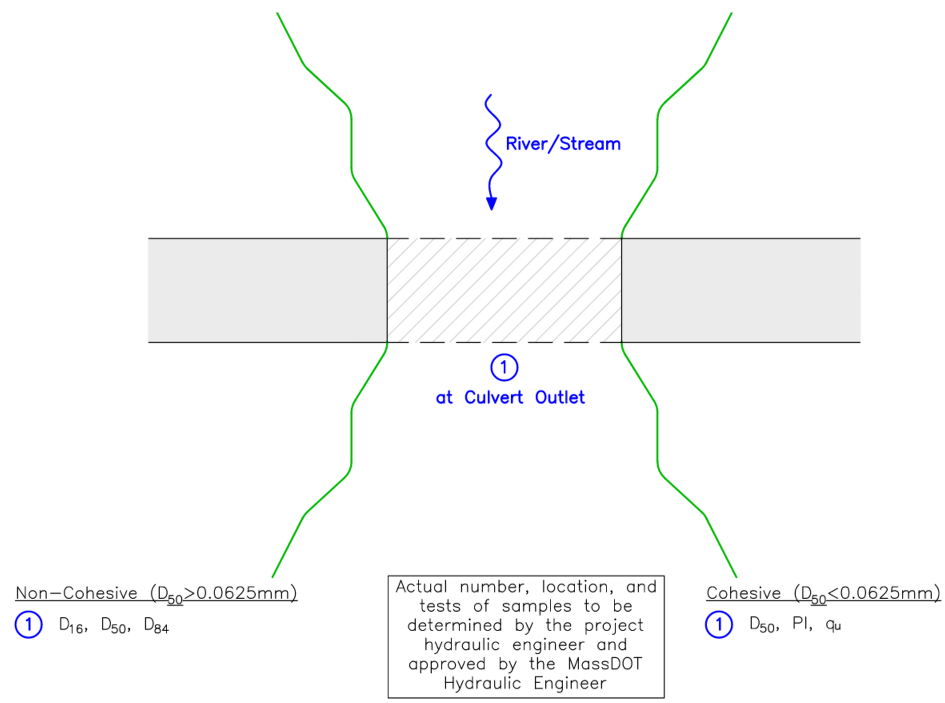

Figure 1.3.1-3: Closed-Bottom Single Culvert in Riverine Environment

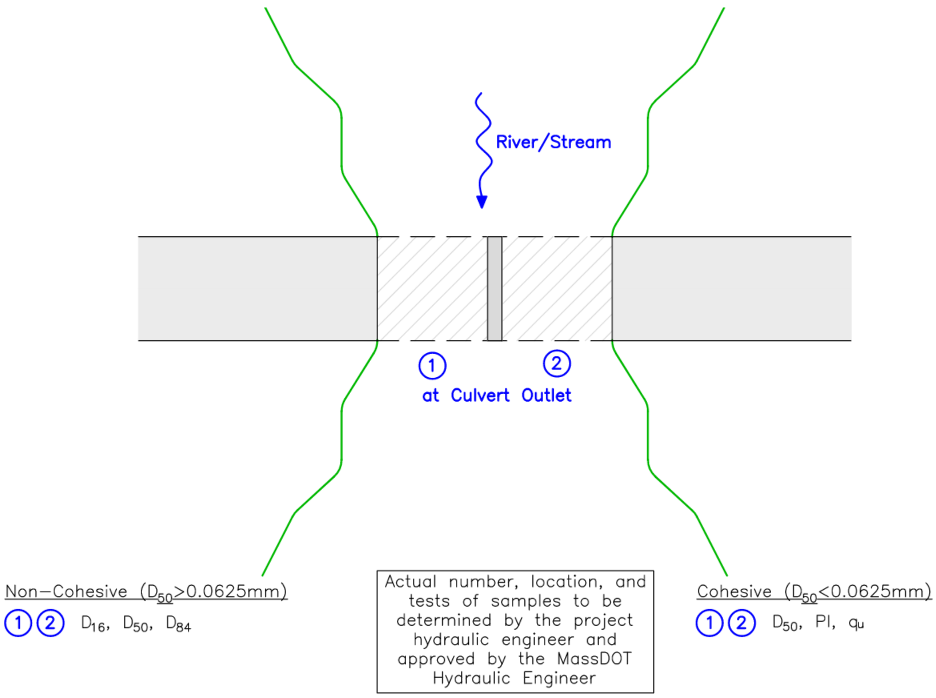

Figure 1.3.3-4: Closed-Bottom Multi Barrel Culverts in Riverine Environment