Michigan Non-NBI Culvert Structure Inspection Guide

Michigan Transportation Asset Management Council

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Contents

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Purpose

The *Michigan Non-NBI Culvert Structure Inspection Guide* (Mi-NCSIG) has been developed to provide culvert safety inspectors and culvert owners with guidance for meeting the consistency standards required to submit culvert data to the Michigan Transportation Asset Management Council (TAMC) according to the "Policy for Collection of Inventory and Condition Data". This guide provides guidance for inspecting culvert structures that do not meet the National Bridge Inspection Standards (NBIS) definition of a bridge. Culvert-like structures that meet the NBIS definition of a bridge must be inspected per the *National Bridge Inspection Standards and the Michigan Structure Inspection Manual* (MiSIM).

Owners may decide to inspect larger culverts that do not meet the NBI bridge definition using the NBI and MiSIM standards. To support this decision, a comparison table is provided within this document to allow uniform submittal of condition data for the purposes of the TAMC. The Mi-NCSIG covers culvert inspection program considerations, inspection format, and inspection safety. The Mi-NCSIG also includes a culvert condition rating system for rating culverts located on Michigan roads.

References

There are several documents and manuals that are used as a reference throughout this manual. Several of these references provide the initial basis and background material for development of this manual.

Federal and National Manuals

- *Culvert & Storm Drain System Inspection Guide*, American Association of State Highway Transportation Officials (AASHTO) 1st Edition, 2020. Available for purchase: https://store.transportation.org/Item/CollectionDetail?ID=213
- *National Bridge Inspection Standards* (NBIS)
- *Bridge Inspector's Reference Manual* (BIRM), Federal Highway Association, 2012. Available: https://www.fhwa.dot.gov/bridge/nbis.cfm

Michigan Specific Guides and Manuals

- "Policy for Collection of Culvert Inventory and Condition Data", Michigan Transportation Asset Management Council, 2021
- *Michigan Structure Inspection Manual* (MiSIM), Michigan Department of Transportation, 2017. Available: https://www.michigan.gov/mdot/0,4616,7-151-9625_24768_24773_59525-326737--,00.html

Definitions

- **Agency**: The group of inspectors, whether private consultant or public owner, that has been assigned inspection responsibility for one or more culverts. Private consultants may perform the inspections for multiple owners.
- **Bridge**: Structures on public highways carrying traffic that span 20 feet or more measured from the center of the roadway. These structures must be inspected per the NBIS and the MiSIM, regardless of the structural configuration.
- **Culvert**: A linear drainage conduit(s) underneath a public roadway that are not considered a "bridge(s)" by the Federal Highway Administration (FHWA). Culverts are differentiated from storm sewers in that they are straight-line conduits that are open at each end and do not include intermediate drainage structures (e.g., manholes, catch basins).
- **Owner**: The public entity responsible for the highway carried by the culvert.

Chapter 1: Culvert Data Collection Program Considerations

1.1 Purpose for Collecting Culvert Inventory and Condition Data

Public Act 325 of 2018 requires large local road agencies to have an asset management plan that includes culvert assets; further information can be found in the TAMC's "Policy for Collection of Culvert Inventory and Condition Data".

Culvert inventory and condition data serve as the foundation and provides critical information for asset management planning and practice. Asset management enables road-owning agencies to manage and maintain their transportation assets efficiently and effectively. Furthermore, when local road-owning agencies across the state of Michigan submit their culvert inventory and condition data to the Michigan TAMC, this data supports the TAMC in their advisement to the Michigan Infrastructure Council (MIC) on a statewide transportation asset management strategy and the processes and tools needed to implement that strategy (see MCL 247.659a). This guide provides program considerations for identifying culverts, inspection intervals, inspection equipment, and safety resources, as well as an outline of the inventory data (see Chapter 2) and condition data (see Chapter 3) that can be collected and may be submitted to the TAMC. The outline of the culvert condition rating system in this guide serves to promote statewide consistency. This guide does not discuss how this information is to be included in an agency's asset management plan. Further information can be found in the most recently approved Michigan TAMC's "Policy for Collection of Culvert Inventory and Condition Data".

1.2 NBI Bridge or Culvert versus Non-NBI Culvert

Engineers, owners, and inspectors often refer to structures as culverts based upon the type of structure, regardless of span length. However, the span length of the structure is the critical factor for determining if

the provision of the NBIS apply. Those standards supersede the recommendations found in this guide. Culvert-like structures that meet the NBIS definition of a bridge must be inspected per the NBIS and the MiSIM. In addition, bridge-like structures that have a deck/superstructure/substructure but meet the span length definition of a culvert may be inspected using NBIS guidelines.

The NBIS provide the governing rules and regulations for the inspection of highway bridges located on all public roads throughout the entire United States. Section 650.305 of the provision provides the definition of a bridge which, briefly stated, includes those structures on public highways carrying traffic that span 20 feet or more measured from the center of the roadway. Michigan Act 354 of 1925 also has additional requirements regarding bridge safety inspection. Section 254.19a and 254.30 necessitates biennial inspection of all bridges and culverts under state transportation department jurisdiction. Culvert structures that meet the NBIS definition of a bridge must be inspected per the NBIS and the MiSIM.

Prior to revisions in the FHWA Bridge Inspector's Reference Manual (BIRM), culverts were defined as any structure that did not meet the NBIS length requirements of a bridge. This method of classifying culverts did not consider the dissimilarities present in the structural characteristics and design. The current BIRM defines a culvert as a structure designed hydraulically to take advantage of submergence to increase water carrying capacity. However, this definition is disconnected from the federal requirements for inclusion in the NBIS and, so, is not incorporated in this guide.

This guide defines a culvert as a linear drainage conduit underneath a public roadway that is not considered a "bridge" by the FHWA. In other words, a culvert does not meet the span-length minimum of the NBIS. The FHWA generally considers a "bridge" as having a combined span of more than twenty feet, which requires listing on the National Bridge Inventory. Culvert structures that meet the NBIS definition of a bridge must be inspected per the NBIS and the MiSIM.

Culverts are differentiated from storm sewers in that culverts are straight-line conduits that are open at each end, and do not include intermediate drainage structures (e.g., manholes, catch basins).

1.3 Inspection Intervals

Inspection intervals should be established to ensure an agency's data accurately reflects the culvert conditions to support efficient decision making. Inspection intervals that are too short result in little to no change between data sets and an inefficient work plan. Inspection intervals that are too long may result in significant changes, missed opportunities for maintenance, and potential risk of failure. An owner should establish risk-based inspection intervals for each culvert in the inventory. Since age and condition are common risk factors, the assigned intervals may need to be revisited for each culvert following each inspection. The maximum inspection interval set by the TAMC is 6 years if the condition data will be submitted to the statewide dashboard. Owners can develop their own risk-based interval schedule within that maximum or they may use the following recommendations.

A risk-based interval matrix could include the following risk-related culvert variables: condition rating, size, material, age, and roadway average daily traffic (ADT).

- **Condition rating**: Condition has the strongest impact on risk and, therefore, generally has the strongest impact on inspection intervals as the condition drops along the good-fair-poor-severe scale. In the case of poor or severe condition, in-depth inspections or structural analyses may be required.

- **Size:** As size increases, the impact of a failure tends to increase. Common culvert sizes are 24 inches or smaller, 24 to 48 inches (4 feet), 4 to 10 feet, and 10 feet or larger.
- **Material**: More-frequent (than otherwise required) inspection intervals may be needed where there are material-specific concerns such as corrosion potential or alkali aggregate reactivity (AAR).
- **Age**: Age of the culvert is incorporated into an agency-specific rating if it is known that certain standards or processes, which would decrease the risk of failure or premature deterioration, where not in place when the culvert was construction.
- **Roadway ADT**: Higher average-daily-traffic (ADT) roadways would lead to greater impact and could be included as a way for an owner to prioritize limited inspection resources.

Owners can develop their own risk-based interval schedule, or they may use the following recommendations. Table 1-1 correlates the controlling (most frequent) inspection interval with the different variables for each specific culvert. In the case of poor or severe condition, in-depth inspections or structural analyses may be required.

Table 1-1 Recommended Maximum Inspection Intervals

Non-NBI Culvert Inspection*	Maximum Inspection Interval (in months)			
	≤12	≤24	≤48	≤72
Condition Rating				
Good				X
Fair			X	
Poor		X**		
Severe	X**			
Size (inches)				
≤24				X
>24 and ≤48				X
>48 and ≤120			X	
>120 (10 feet) and <240 (20 feet)		X		
Material				
No material-specific concerns				X
Material-specific concerns			X	
Age**				
Consider reducing frequency as appropriate				
ADT**				
If limited resources require an agency to exceed the above recommendations for some structures, ADT maybe used to prioritize which culverts pose the least risk to extended frequencies.				
* Culvert structures that meet the National Bridge Inspection Standards (NBIS) definition of a bridge MUST be inspected per the NBIS and the *Michigan Structure Inspection Manual* (MiSIM) ** In the case of poor and severe condition in-depth inspections or structural analysis may be required; use engineering judgment to obtain culvert-specific frequencies				

1.4 Inspection Equipment

A variety of equipment may be necessary for proper culvert safety inspections. Hand tools or other aids for field inspection help ensure efficient and comprehensive results. The equipment should be well organized and easily accessible to limit time spent searching for particular items while parked near traffic. In addition, specialized access equipment may be necessary to observe elements that cannot be viewed from the culvert's adjacent surfaces and to perform in-depth inspections when necessary. This section describes recommended equipment that the inspection team may desire during routine culvert inspections as well as other equipment that may be needed for in-depth inspections. Prior to performing field work, the agency's lead inspector should review the AASHTO *Culvert & Storm Drain System Inspection Guide* for other beneficial and advanced inspection equipment recommendations.

Personal protective equipment (PPE) should be used in accordance with MIOSHA and the employing agency's safety plan. Commonly-used PPE include safety vests, steel- or composite-toe boots, gloves, hard hats, and safety glasses. When working near water, life jackets are recommended. Waders or hip boots are suggested in order to decrease the likelihood of contact with pollutants and organisms and to provide insulation while working in cold surface waters. Other personal protective equipment may be needed when working in confined spaces, at heights above 6 feet, or in the presences of other vulnerabilities. MIOSHA standards contain precaution and preparedness items that should be implemented before exposure to hazards at the culvert site.

During the culvert file review, the lead inspector should review the previous inspection findings to determine whether specialized equipment or particular tools are required for assessing a culvert's condition. The standard equipment that every lead inspector should have access to during field work may be categorized according to gear required for improving visual observation, for diagnosing or identifying defects that are not visible, and for accurate recording of the deficiencies identified. Failure to have access to these tools may result in repeated visits to the structure causing inefficient use of time and increased labor costs. A summary of recommended equipment is provided in **Error! Reference source not found.**2. Additional information regarding tools typical for culvert inspection can be found in the *AASHTO Culvert and Storm Drain System Inspection Guide* section 3.8.

Table 1-2 Recommended Inspection Equipment		
Visual Observation	**Diagnosis or Identification of Unexposed Defects**	**Recording Equipment**
Binoculars	Rock pick hammer, sounding rod, or chain	Camera
Ladder	Scour or probing rod or shovel	Measuring tools
Flashlight	Boat or raft	Level
Cleaning tools	Fathometer	Smartphone

Binoculars, ladders, and flashlights are practical tools that allow enhanced visual observation of surfaces from a distance or surfaces that are shielded from daylight. These items improve judgment on whether additional investigation beyond a routine inspection is needed. Inexpensive hand tools like putty knives, steel brushes, and other apparatuses that allow cleaning or removal of rust and debris.

Rock pick hammers, steel sounding rods, or chains are necessary for detecting delamination or decay in horizontal and vertical surfaces. Generally, surface areas that are sounded during a routine inspection are limited by accessibility. Rods are used to probe for scour and feel for irregularities on submerged components. Shovels may be necessary to expose the end of the culvert. Boats or rafts are essential when the water depth adjacent to submerged culvert elements is less than 10 feet but too deep for the inspector to wade. Fathometers are recommended for underwater inspections conducted from a boat or raft. Fathometers are inexpensive devices that improve detection of active scour but may not substitute for probing since scour holes filled with loose streambed materials may not be detected with the instruments.

Cameras are necessary to record the condition of culvert at the time of inspection. Photographs should be made of the transverse view of the roadway, elevation of the structure, and any elements that experienced a rating change from the previous inspection. Tools like tape measures and crack gauges measure defects and provide a scale for photographs. The lead inspector should carry tape measures of adequate length for accurate inventory, appraisal, and element condition state coding. Electronic distance meters may also be used at locations where measurements with a physical tape are inefficient or difficult. Levels measure the extent that items are out of plumb, such as when settlement, displacement, or rotation has occurred. Smartphones, tablets, or laptops are beneficial for viewing previous inspection findings, for immediate verbal contact or correspondence with the culvert owner, and for verification of the longitude and latitude values.

1.5 Safety Resources

Local road-owning agencies can find safety information pertaining to culvert and bridge inspection in the following resources:

- *Culvert & Storm Drain System Inspection Guide* Section 3.10, AASHTO, 1st Edition, 2020. Available for purchase: https://store.transportation.org/Item/CollectionDetail?ID=213
- *Michigan Structure Inspection Manual (MiSIM)* Chapter 13 – Bridge Inspection Safety, Michigan Department of Transportation, 2017. Available: https://www.michigan.gov/mdot/0,4616,7-151-9625_24768_24773_59525-326737--,00.html

- *Bridge Inspector's Reference Manual* (BIRM) Chapter 2- Safety Fundamentals for Bridge Inspectors, Federal Highway Association, 2012. Available: https://www.fhwa.dot.gov/bridge/nbis.cfm
- Agency's in-house policies and procedures pertaining to culvert and bridge inspection.

The information contained in these resources can be used to guide local road-owning agencies in the development of a culvert data collection program.

Chapter 2: Culvert Inventory Data Collection

2.1 Why Collect Inventory Data?

Asset inventory data serves as the foundation for asset management practice. Having current and accurate culvert inventory data allows road-owning agencies to know what kinds of culvert assets they have and where those assets are located, to plan for and conduct inspection and condition rating (see Chapter 3), and to develop and execute a maintenance program. Typically, initial collection of culvert inventory data is time consuming. Subsequent culvert inventory data collection efforts tend to proceed more quickly since they focus on verification of previously-collected data. If data is revised during subsequent culvert inventory data collection efforts, it is recommended to keep a record of the previous data and to make an indication of which data is new.

2.2 Inventory Data

Basic inventory data for culverts include location, material type and features, and roadway surface. Therefore, culvert inventory data should consist of the following information:

- Inventory identification number
  An agency-specific identification number that uniquely identifies the culvert
- Inspection date
  Date of most recent inspection
- GPS coordinates – representative point (both ends optional)
  Location of culvert. A single point representative of the culvert establishes the approximate location of the culvert for the purposes of finding it in the field. Coordinates for both ends of the culvert may be helpful for hydrological or other modeling purposes.
  - Latitude
    Latitude coordinate for culvert

- Longitude
  Longitude coordinate for culvert
- Elevation (optional)
  Elevation above sea level of the upstream or downstream culvert invert

- Material type (user can add custom sub-types)
  Culvert material classified according to the following material types used in the shared database. Users may add custom sub-types for their agency's records. Sub-types may describe the material in greater detail or the presence of a liner.
  - Plastic
  - Concrete
  - Steel corrugated metal pipe (CMP)
  - Steel plate
  - Aluminum corrugated metal pipe (CMP)
  - Aluminum plate
  - Masonry
  - Timber
  - Other
- Shape (see Figure 1)
  Shape of the culvert classified according the following descriptions. Custom shapes may be defined as sub-types under "Other"
  - Round
  - Horizontal ellipse
  - Vertical ellipse
  - Pipe arch
  - Arch
  - Low-profile arch
  - High-profile arch
  - Pear
  - Box
  - Multi-cell box
  - Three-sided
  - Slab/superstructure and abutment
  - Other

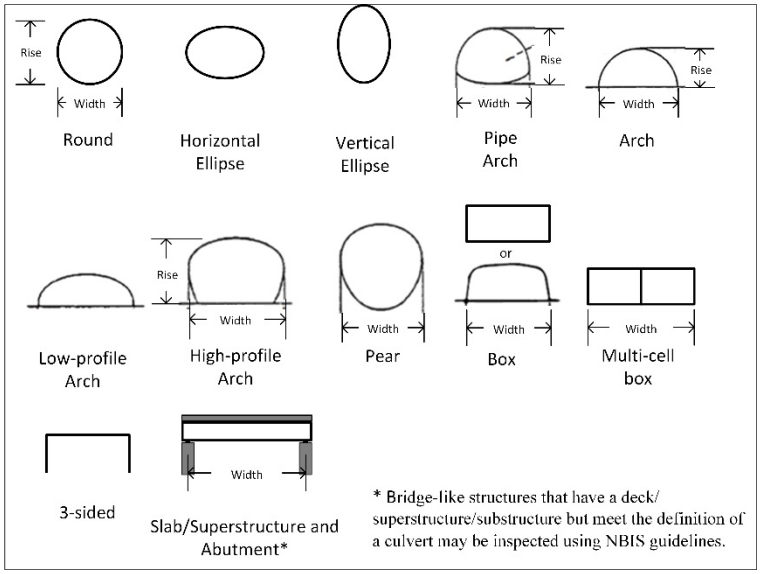

Figure 1 Culvert shapes

- Skew angle (degrees between -90 and 90; optional only if defining both ends of the culvert) (see Figure 2)
  Angle that the culvert is skewed away from a line perpendicular to the roadway (zero skew). Based on the acute angle formed by the intersection of road centerline with the culvert centerline, the angle is positive if the end rotation is clockwise and negative if the end rotation is counterclockwise.

- Length (reported in feet)
  Length of the culvert barrel from inlet to outlet

- Rise (reported in feet)
  Height or diameter of the culvert barrel at its tallest point

- Width (required for single barrels) (reported in feet)
  Side-to-side measurement of a single culvert barrel
- Span (required for multiple barrels) (reported in feet)
  Measurement of entire culvert opening when consisting of several barrels placed side by side
- Number of barrels
  Number of barrels at the culvert location
- Depth of cover (reported in feet)
  Depth of material above the culvert barrel including the road surface
- Roadway surface type
  Surface type of the road over the culvert; value may be asphalt, brick, concrete, earth, gravel, or sealcoat
- Condition rating (see Chapter 3)

Culvert inventory data may also include the following *optional* data:

- Physical route (PR) number
  PR number for the road over the culvert
- Road name
  Physical route name for the road over the culvert
- Mile point (use three digits of precision)
  Mile point on the physical route for the road over the culvert
- Installation date
  Culvert installation date, if known.
- Photographs

A road-owning agency may wish to collect additional inventory data depending on their individual needs. Culvert inventory data should be submitted along with condition data (see Chapter 3) to the Michigan TAMC.

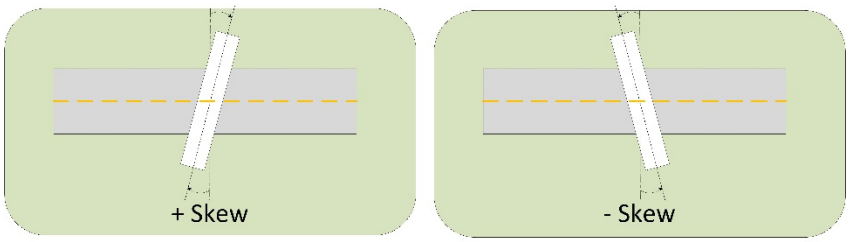

Figure 2 Culvert skew angles

Chapter 3:
Culvert Condition Rating System and Data Collection

3.1 Why Collect Condition Data?

Asset condition data provides critical information for optimizing asset management practice. Having current and accurate culvert condition data allows road-owning agencies to know the condition of their culvert assets, understand how that condition is progressing, and time an effective maintenance and replacement program that ensures a desired level of service across the road network. If condition data is revised during subsequent culvert condition data collection efforts, it is recommended to keep a record of the previous data and to make an indication of the new condition ratings.

3.2 Condition Data

Basic condition data for culverts include ratings for two culvert component categories, consisting of ratings for components and/or characteristics. Therefore, culvert condition data should consist of the following component category ratings:

- Inventory data (see Chapter 2)
- Vicinity and appurtenant structures (component category)
    - Rated as good, fair, poor, or severe
- Culvert barrel (component category)
    - Rated as good, fair, poor, or severe

A road-owning agency may optionally collect condition data for culvert characteristics; agencies may find this beneficial depending on their individual needs. Culvert condition data should be submitted along with inventory data (see Chapter 2) to the Michigan TAMC.

3.3 Use of the Culvert Condition Rating System on Michigan Roads

The culvert condition rating system outlined in this guidebook is based on a qualitative scale ranging from "good" to "severe". A rating from this qualitative scale is made for each culvert component category, based on ratings for each component and/or characteristic. A "good" rating indicates a like-new component with little or no deterioration, structural soundness, and functional adequacy. This good rating will change to "fair" and then "poor" and "severe" as a component's condition degrades. A "severe" rating indicates the component requires special inspection with a structural evaluation or immediate maintenance, depending on the component being evaluated.

The condition rating categories are a comparison of the existing condition with the as-designed condition. A new culvert that is properly designed and constructed would have condition ratings of "good" for all of its components. Condition ratings of culvert components and component characteristics assess structural condition, ability to perform the intended function, and possible negative impact to the entire culvert or the roadway above.

Components and characteristics that may be rated using this culvert condition rating system include the vicinity and appurtenant structures component category—roadway, channel scour and blockage, and end treatments and appurtenant structures—and culvert barrel component category—barrel condition, alignment, joints, and seams. Each component category's rating—that is, the rating of the vicinity and appurtenant structures component category and the culvert barrel component category—is determined by rating the culvert's components and characteristics and assigning an overall score (see Figure 3). A component-category-level assessment identifies distresses more effectively and provides a better understanding of the appropriate action to address those distresses.

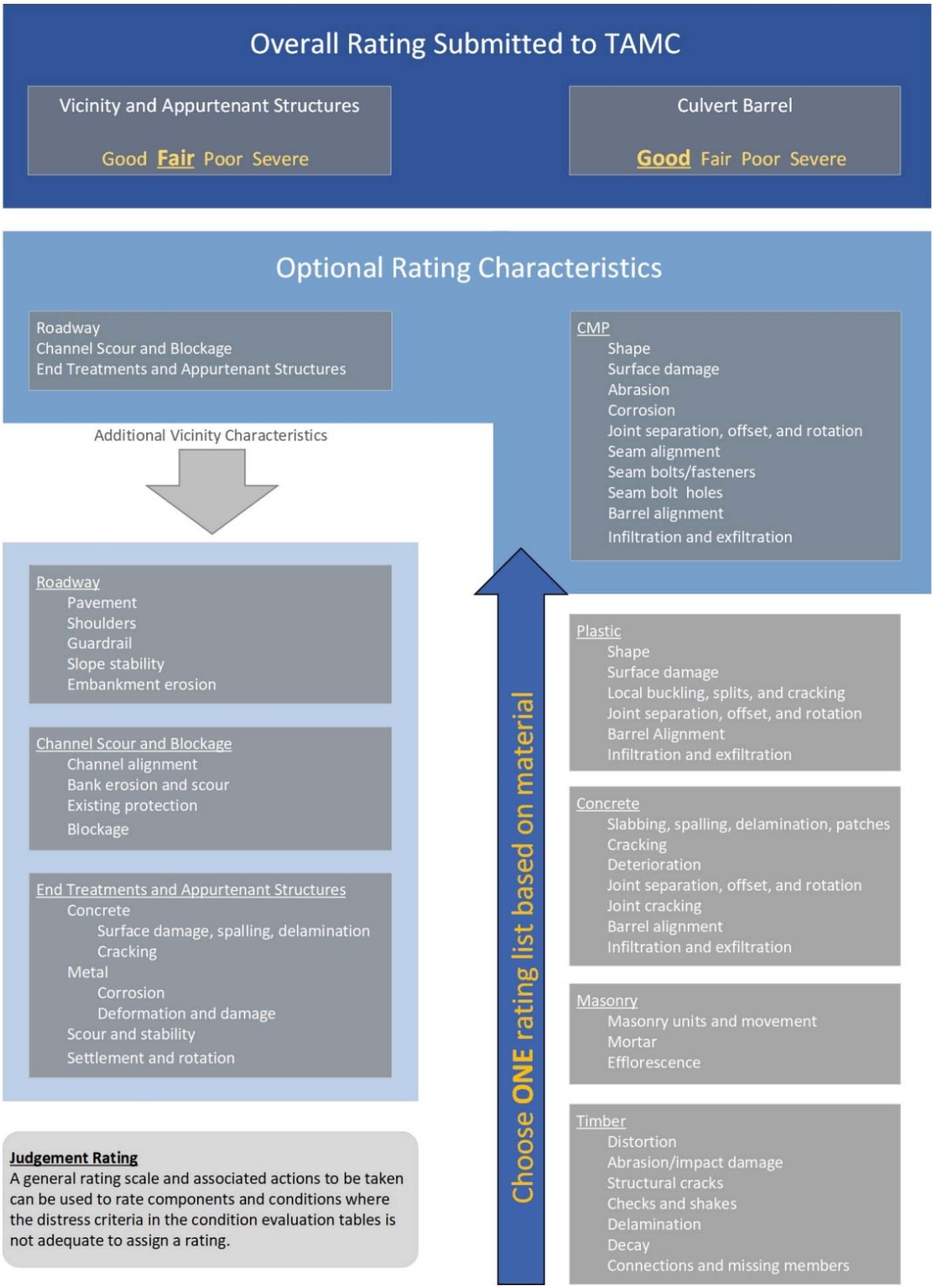

Figure 3 *Culvert condition rating component flowchart*

The sections of this chapter detail each culvert component, associated distress types, and condition rating descriptions for each characteristic related to that component. Each section includes a culvert condition rating table that outlines the rating scales for each culvert component. To use the culvert condition rating tables:

- Rate each culvert component's characteristic, listed in the left-hand column, using the scale from "good" to "severe" based on the worst defect or distressed condition identified during the on-site inspection. Quantified criteria may require physical measurement.
- The poorest-rating criterion determines the condition rating for a system component or characteristic where there are more than one criterion for evaluation. For example, a flexible culvert barrel may receive a "poor" rating for local poor shape even if all other factors rate as "good" along the culvert length.
- The "Not Rated" (NR) designation should be assigned if a component is not applicable to a system or inaccessible for evaluation. Reasons for not rating should be documented.
- Significant condition changes since the last inspection should be evaluated and noted even if the structure is still in "good" or "fair" condition.
- Overall component category ratings for the vicinity and appurtenant structures and culvert barrel should generally correspond to the lowest of the associated components and/or characteristics; however, this value can be recorded based on engineering judgement. For example, an inspector may wish to record that a culvert has been blocked by sediment or debris and rate the characteristic accordingly but may be able to remove the debris while on-site thus negating the need to rate the overall condition according to that characteristic.
- Agencies may submit their vicinity and appurtenant structures and culvert barrel ratings to the TAMC for use in statewide culvert data analysis.

In the event that the culvert condition rating tables are unable to facilitate an adequate assessment of component distress criteria, the culvert condition rating for a component or characteristic may be based on Table 3-1's "Action Indicated" and an inspector's judgement. The AASHTO *Culvert & Storm Drain System Inspection Guide* 's section 4 and appendix A may be resources to determine the appropriate rating.

Table 3-1 General Condition Ratings, Actions, and Descriptions

Condition Rating	Good	Fair	Poor	Severe	Not Rated
Action Indicated	Action: none Note in inspection report only.	Action: none, but more frequent inspection may be warranted Inform maintenance personnel.	Action: corrective action based on inspector's evaluation. Recommendations made in inspection report.	Action: corrective action based on engineering evaluation to specify appropriate repair. Required action is urgent.	Action: none
Condition Description	Like new Deterioration: none to little Structurally sound Functionally adequate	Deterioration: some Structurally sound Functionally adequate	Deterioration: significant AND/OR Functionally inadequate Requires maintenance or repair	Very poor Deterioration: severe Structurally unsound Functionally inadequate Possible imminent failure or threat to public safety	Not part of the culvert design or structure Functional adequacy not required Not an inspection item at last culvert inspection. Excludes items missing due to vandalism, damage, or deterioration.

Descriptive information collected about a culvert can be stored in Roadsoft or an agency's asset management database. This information may include:

- Photo documentation and supplemental sketches (if necessary) of severity, extent, and location of significant and typical distress in order to allow for accurate comparisons of condition during future inspections.
- References of a culvert's distress locations using offsets measured from the outlet end, identified by photographs.
- Location of points on circular, elliptical, and arch-shaped cross sections referenced like hours on a clock with orientation of the clock looking upstream from the outlet. Locations of points on non-round-shaped cross sections measured using offsets from discrete locations such as corners, longitudinal seams, and foundations.
- Joints identified using offsets and stationing measured from the culvert outlet end rather than counting joint numbers. This joint identification method allows for easy transitioning of records for common changes, such as culvert barrel length extensions for roadway widening.

3.4 Vicinity

3.4.1 Roadway

Figure 4 The condition of the roadway and embankment can help identify distress within a culvert below. Characteristics to inspect include the pavement, guardrail, shoulders, slope stability, and embankment erosion.

Component Description

The **roadway** is the length of roadway and embankment above the buried culvert that is influenced directly by the performance of the buried culvert system. The roadway inspection area should encompass a minimum length of 20 feet either side of the culvert plus the culvert span or to the extents of any wingwall structures. Inspection of the roadway and embankment may indicate problems with the culvert below and can help identify erosion and slope stability concerns, which may lead to misalignment of the barrel.

Poor compaction, loss of backfill material, poor backfill quality, movement of the culvert, and embankment slope failures are all examples of culvert degradation that may appear as damage to the roadway. Roadway distress may also be due to other factors, such as temperature-induced expansion and contraction of the pavement, fatigue from vehicle load, shoulder settlement, frost action, and poor drainage.

What to Look For

The roadway is a single component rated by the minimum condition of five characteristics: pavement, shoulders, guardrail, slope stability, and/or embankment erosion.

- **Pavement or shoulder settlement** can be assessed with indicators like sags, humps, and rutting. Deflection of flexible pipe barrels at their crown is indicative of the embedment soil not providing adequate lateral support and may result in settlement of the pavement above the culvert. Settlement on either side of rigid culverts and a hump over the buried barrel is indicative of poor compaction or low-quality embedment soil.
    - **Sags and humps** are localized depressions or elevated areas of the pavement. Severity of sags and humps can be measured as the maximum deviation from a 10-foot straight edge placed on the pavement parallel to the centerline of the roadway.
    - **Rutting** is a surface depression in the wheel path that runs parallel to the direction of travel. Rutting can be measured as the maximum deviation from a 10-foot straight edge placed on the pavement perpendicular to the centerline of the roadway.
- **Pavement or shoulder maintenance history** can be seen in indicators like repeated patching of the area over the barrel.
- **Pavement or shoulder cracks** can be categorized according to its shape, pattern, and direction. All open pavement cracks in the roadway should be probed for the presence of voids.
    - **Transverse cracking** runs perpendicular to the direction of the road and is a primary distress indicator (with the exception of regularly-spaced transverse cracks along long stretches of the road).
    - **Longitudinal cracking** runs parallel to the direction of the road. Longitudinal cracking is not typically a culvert distress indicator except for when longitudinal cracking exists within one foot of the lane edge.
- **Guardrail** that is sighted along its length can reveal misalignments and should be rated visually based on the amount of misalignment over the culvert.
- **Slope stability** considers the movement of the embankment immediately above the culvert and to the extents of the wingwall structures or inspection length. Its stability can be affected by the type of soil, loads, saturation, and steepness of the slope. Slope stability can be ascertained by inspecting for signs of movement of the soil in mass. Two key identifiers of slope stability issues are sloughing, or the sliding or collapse of a layer of soil that appears as a vertical cut or drop, and tension cracks, cracks that appear at the top of the slope and run parallel to the roadway. These identifiers generally indicate instability leading to slope failure.
- **Embankment erosion** is loss of the embankment surface materials, including any protective measures used for slope stability such as vegetation. Sheet erosion is the washing away of thin layers of soil or vegetation as runoff water flows in sheets down the slope. When water flows down the slope in streams the resulting erosion forms channels in the slope. Rill erosion describes this type of erosion when these stream channels are less than 1 foot deep while gullying describes this type of the erosion when these stream channels are greater than 1 foot deep. Piping is a form of internal erosion where water flows along the outside of a barrel and removes backfill. Piping is ascertained by the presence of voids or tension cracks in the embankment soil or streams of water exiting the face of the slope near the culvert.

Table 3-2 Approach Roadway Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Pavement	Potential distress: none for 20-foot minimum length on either side of crossing culvert or full length of storm drains	Transverse cracking: low severity (less than 0.25 inches in width) Sags or humps: low severity (less than 2 inches over 10 feet) over culvert barrel	Transverse cracking: medium severity (up to 0.5 inches in width) Sags or humps: medium severity (up to 4 inches over 10 feet) over culvert barrel Rutting in wheel path: localized over culvert/storm drain Patching: evidence of repeated patching	Transverse cracking: high severity (greater than 0.5 inches in width with pavement raveling over culvert) Longitudinal cracking: high severity (greater than 0.5 inches in width with pavement raveling over culvert) Sags or humps: high severity with voids beneath pavement
Shoulders	Potential distress: none for 20-foot minimum length on either side of crossing culvert or full length of storm drains	Transverse cracking: low severity local to shoulder Longitudinal cracking: low severity local to shoulder Sags: low severity over culvert	Transverse cracking: moderate severity Longitudinal cracking: moderate severity Settlement: around catch basins Patches: evidence of repeated patching	Transverse cracking: high severity Longitudinal cracking: high severity Sags: high severity over culvert Voids: in roadway near culvert (piping or infiltration) Soil cracking in shoulder area Slope stability: movement in shoulder area
Guardrail	Potential distress: none for 20-foot minimum length on either side of crossing culvert or full length of storm drains	Post alignment: slight misalignment due to shoulder settlement or sliding	Post alignment: misalignment due to ground movement (not impact damage) Settlement or sags: medium severity due to ground movement Post rotation: exists due to ground movement	Settlement or sags: high severity Post rotation: exists due to ground movement (not impact damage) Guardrail may be ineffective

Condition Rating	Good	Fair	Poor	Severe
Slope Stability	Slope stability: no movement Soil sloughing: none	Slope stability: no issues	Slope stability: stable with minor sloughing	Slope stability: failure likely Soil sloughing: embankment sloughing (causes loss of support to guardrails and/or roadway, and culvert end section joint distress) Soil tension cracks: parallel to roadway (indicates shifting or settlement)
Embankment Erosion	Embankment soil erosion: none due to runoff Piping: none in embankment	Rill erosion/gullying: minor rill erosion Sheet erosion: minor (up to 10% bare ground) Embankment soil erosion: indication of storm water runoff Structure stability: not affected Structure exposure: not affected	Rill erosion/gullying: moderate rill erosion, backfill around culvert slightly displaced Piping: evidence Sheet erosion: moderate (11 to 40% bare ground), requires protection and investigation Structure exposure: early-stage exposure of inlet barrel, outlet barrel, or previously-buried end treatment	Rill erosion/gullying: severe gullying Sheet erosion: severe (greater than 40% bare ground) Embankment soil erosion: significant loss of material Structure stability: loss of support for inlet barrel, outlet barrel, or end treatments Structure exposure: fully-exposed barrel ends with rotation of end section or end section drop-off

3.4.2 Channel Scour and Blockage

Figure 5 Culvert placement can cause damage to the area around the culvert due to scour or ineffectiveness due to blockage. The characteristics to inspect include channel alignment, bank erosion & scour, existing scour protection, and blockage.

Component Description

The channel consists of the stream bed and adjacent banks. Channel scour and blockage inspection involves the stream leading into the culvert inlet and moving away from the outlet in the vicinity of the culvert structure.

What to Look For

Channel scour and blockage is a single component rated by three characteristics: channel alignment; bank erosion and scour; existing protection; and blockage.

- **Channel alignment** is an evaluation of the horizontal and vertical position of the culvert with respect to the channel. Damage to the embankment, roadway, and adjacent property can result from misaligned culverts along with increased erosion and sedimentation of the channel.
- **Bank erosion and scour** is the loss of stream bed from flowing water. Bank erosion is the loss of material from the sides of the channel. Local scour is caused by a specific flow obstruction that causes a directional change in flow and is typically found at the culvert outlet. General scour extends further along the streambed away from obstructions and may appear as a sudden change in the stream bed elevation.
- **Existing protection** may be in place to prevent scour or erosion and may be in the form of rip-rap, vegetation, or sheet piling of the embankment or headwalls, wingwalls, or end treatments of a culvert.
- **Blockage** at the inlet or within the culvert barrel can be caused by an accumulation of debris and sediment.

Table 3-3 Scour and Blockage Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Channel Alignment	Channel stream: aligned with culvert (horizontally and vertically) Erosion: none Flow capacity: no restrictions	Channel stream: slight angle or offset relative to culvert centerline Flow capacity: not affected Ponding: minor	Channel stream: early-stage altered alignment, channel enters or exits at moderate angle Erosion: embankment erosion Undercutting: barrel or end sections Ponding: occurring at inlet or outlet	Channel stream: severe misalignment, channel directed at bank with threat of immediate collapse Erosion: severe bank erosion
Bank Erosion and Scour	Structure stability: stable Bank erosion: none Scour: none	Structure stability: stable Bank erosion: intermittent Scour: local scour near inlet or outlet Scour exposing previously-buried features: none	Structure stability: undercutting and sod-root overhangs Bank erosion: general erosion leading to channel widening Scour: local scour or headcutting near outlet, or signs of downstream scour	Structure stability: danger of collapse with next flood event Scour: scour causing (or leading to) of bank, culvert, end treatment structure, and/or roadway
Existing Protection	Protective material: installed protection meets design requirements; no noted channel bank distress	Protective material: minor material degradation Displacement: localized displacement or undermining of individual rip-rap, armor units, or other protection measures	Protective material: moderate material degradation Displacement: significant displacement of rip-rap, armor, or other protective measures, undermining or deteriorating performance of protective measures	Protective material: partial failure of rip-rap, armor, or other protective measures; culvert, embankment, roadway, or other elements in danger of collapse
Blockage	Waterway blockage: none, free flowing with no obstructions	Waterway blockage: to depth of less than 10% of barrel diameter Sedimentation/debris: minor sedimentation or debris accumulation Scour: none Ponding: evidence	Waterway blockage: to depth of 10% to 30% of barrel diameter Sedimentation/debris: sedimentation, debris, trees, or shrubs creating partial blockage of channel Ponding: deeper than 10% of diameter	Waterway blockage: to depth of greater than 30% of barrel diameter Sedimentation/debris: mass drift accumulation creating blockage or severe restriction Ponding: frequent flooding, high water marks indicating roadway overtopped in high flows

3.4.3 End Treatments and Appurtenant Structures

Figure 6 End treatments are designed to protect the culvert barrel and surrounding area from erosion and seepage. Concrete end treatments are checked for cracking and surface damage. Metal treatments are inspected for deformation and corrosion. Additionally, end treatments should be evaluated for scour and stability and for settlement and rotation.

Component Description

End treatments and appurtenant structures may be found at the inlet and outlet of the culvert barrel. These components help reduce erosion by retaining fill material and reducing seepage, they can improve the hydraulic efficiency and provide structural stability to the culvert ends.

What to Look For

The end treatments and appurtenant structures is a component rated by six characteristics: cracking (concrete); surface damage, spalling, and delamination (concrete); deformation and damage (metal); corrosion (metal); scour and stability; and settlement/rotation. Generally, four characteristics would be applicable for a culvert with end treatments (either concrete or metal) and one of these would be applicable if no end treatments are present (scour and stability).

- **Surface damage, spalling, and delamination (concrete)** should be assessed on the concrete end treatments.
- **Cracking (concrete)** should be assessed on concrete end treatments.
- **Corrosion (metal)** should be assessed on metal end treatments.
- **Deformation and damage (metal)** may occur on metal end treatments due to impact and abrasion as well as corrosion.
- **Scour and stability** problems are indicated by missing soil around the barrel end or end treatment. Perched culverts (those without end structures that project out without support underneath) are one example.

- **Settlement/rotation** in the end section can occur in rigid barrels generally as the result of scour and erosion at the culvert ends. This can happen in flexible barrels due to buoyancy if the material around the culvert becomes saturated.

Table 3-4 End Treatments and Appurtenant Structures Condition Descriptions

	Condition Rating	Good	Fair	Poor	Severe
CONCRETE	**Surface Damage, Spalling, Delamination (Concrete)**	Scaling: none Abrasion: none Surface damage: none Spalling: none Hollow sounds: none (delamination) Patches: areas remain sound	Scaling: light or moderate (less than 0.25 inches exposed aggregate) Abrasion: less than 0.25 inches in depth over less than 20% of surface Surface damage: localized superficial (less than 0.25 inch) impact damage Spalling: localized, less than or equal to 6 inches in diameter Rebar: not exposed Hollow sounds: small areas Patches: edges tightly bonded	Scaling: moderate to severe (aggregate exposed) Abrasion: 0.25 to 0.5 inches in depth over more than 30% of the surface Surface damage: impact damage Spalling: areas greater than 6 inches in diameter; rust staining from spalled areas Rebar: exposed Hollow sounds: areas greater than 6 inches in diameter Patches: areas are delaminated Weep holes: multiple plugged weep holes (water cannot drain from backfill)	Surface damage: extensive Spalling: widespread spalling or delamination; rebar exposed and corroded; structure unstable Rebar: significant exposed and/or corroded
	Cracking (Concrete)	Cracking: none greater than hairline (maximum 0.01 inches)	Cracking: between 0.01 to 0.05 inches in width (thickness of dime); no increase from previous inspection Infiltration: none Efflorescence: moderate and no rust staining emanating from cracks	Cracking: 0.05 to 0.1-inches in width; local areas of exposed rebar Infiltration: minor water infiltration through cracks Efflorescence: efflorescence and/or rust staining emanating from cracks	Cracking: greater than 0.1 inches in width; widespread exposed rebar with significant corrosion, soil infiltration through cracks Efflorescence: efflorescence and widespread rust staining emanating from cracks

	Condition Rating	Good	Fair	Poor	Severe
METAL	**Corrosion (Metal)**	Corrosion: none	Corrosion: freckled rust or other signs Section loss: none Pitting: none	Corrosion: corrosion present, penetration possible with hammer strike or sharp point Section loss: less than 10% of thickness Pitting: deep pronounced thinning Holes: less than or equal to 1 inch in diameter, several	Corrosion: widespread, local through-thickness penetrations Holes: greater than 1 inch in diameter OR many smaller, grouped holes allowing soil migration
	Deformation and Damage (Metal)	Dents/impact damage/deformation: none Abrasion: none	Dents/impact damage/deformation: small Abrasion: coating abraded, no breaches exposing structural wall	Dents/impact damage/deformation: large Abrasion: protective coating abraded with breaches exposing structural wall	Dents/impact damage/deformation: restricts flow capacity or results in scour or erosion of embankment
ALL	**Scour and Stability**	Scour exposing buried footings/structures: none Undermining of footing: none Rotation: none from installed condition	Scour exposing buried footings/structures: any surface Undermining of footing: none Rotation: none from installed condition	Scour exposing buried footings/structures: vertical face Undermining of footing: none	Scour exposing buried footings/structures: scour present Undermining of footing: significant Rotation: severe, leading to structure distress (kinking of metal culvert, cracking of concrete culvert, cracking of mortar, displacement of masonry units)
	Settlement/ Rotation	Movement: none from installed condition	Movement: exists within tolerable limits (if known) Vertical offset: none at cracking	Movement: exceeds tolerable limits (structure-dependent) Vertical offset: less than or equal to 0.25 inches at cracking Distress/distortion of structure: none	Movement: exceeds tolerable limits (structure-dependent) Vertical offset: greater than 0.25 inches at cracking Distress/distortion of structure: present (wrinkling of metal culvert; cracking of concrete culvert)

3.5 Culvert Barrel

3.5.1 Plastic Barrel Condition Descriptions

Figure 7 Plastic barrels need to be checked for changes to their cross-sectional shape, surface damage, local buckling, joints, alignment, and infiltration and exfiltration.

Component Description

Plastic-barrel culverts are flexible structures that rely on soil-structure interaction by design. These culverts are pipe structures and are typically constructed of high density polyethylene (HDPE), polyvinyl chloride (PVC), polypropylene (PP) or fiberglass-reinforced plastic (FRP).

What to Look For

Plastic barrels are rated by considering six characteristics: shape; surface damage; local buckling, splits, and cracking; joint separation, offset, and rotation; barrel alignment; and infiltration and exfiltration.

- **Shape** should be monitored over time for changes in comparison to the original shape of the culvert. Because flexible culverts rely on soil-structure interaction, changes in the culvert's cross-sectional shape may be indicative of instability of the supporting soil or loads greater than design.
- **Surface damage** can cause loss of structural capacity or lead to infiltration of backfill. Surface damage can be caused by abrasion, splitting (generally at welded seams or abrupt changes in geometry), and photodegradation (at culvert ends due to ultraviolet light).
- **Local buckling, splits, and cracking** may be found in the barrel wall. Local buckling appears as rippling around the circumference of the barrel. It is important to note that the culvert shape will remain round under local buckling although the capacity will be significantly reduced.
- **Joint separation, offset, and rotation** are openings in excess of the manufacturer's tolerance and can lead to accelerated damage caused by infiltration and exfiltration.
- **Barrel alignment** should be checked by sighting along the crown and sides of the culvert to verify straightness. Sagging traps water and debris, which can reduce flow capacity.

- **Infiltration and exfiltration** occurs when there are openings in the barrel. Infiltration allows groundwater to enter the culvert and may transport backfill material leading to voids, settlement, and misalignment of the barrel. Exfiltration occurs if the groundwater table is below the barrel, leading to water within the barrel seeping out of the barrel and subsequently causing soil saturation and misalignment of the barrel.

Table 3-5 Plastic Barrel Condition Michigan Descriptions

Condition Rating	Good	Fair	Poor	Severe
Shape	Shape: round Wall flattening: none Vertical deformation: less than 5% of original diameter	 Wall flattening: minor Vertical deformation: 5% to 7.5% of original diameter	Shape: visible out-of-roundness Wall flattening: significant OR increased wall curvature Vertical deformation: 7.5% to 10% of original diameter	Shape: significant visible out-of-roundness Wall flattening: extreme with reversal of curvature (global buckling) and/or kinks Vertical deformation: greater than 10% of original diameter
Surface Damage	Wear and/or abrasion: none Impact damage: none UV degradation or staining: none	Wear and/or abrasion: minor, less than 10% of wall thickness UV degradation or staining: minor Blistering: less than 25% of barrel inner surface (FRP)	Wear and/or abrasion: equal to or greater than 10% of wall thickness UV degradation or staining: degradation of barrel ends, discoloration Blistering: equal to or greater than 25% of barrel inner surface (FRP)	Wear/abrasion: greater than 25% of wall thickness UV degradation or staining: degradation of barrel ends, cracked or broken barrel wall
Local Buckling, Splits, and Cracking	Local buckling: smooth interior wall Splits: none in welded seams Wall cracking: none in wall	Local buckling: buckling indicated by rippling in wall Splits: less than 25% of circumference Infiltration: none Wall cracking: less than 25% of circumference Longitudinal cracking: none	Local buckling: advanced and widespread indicated by extensive rippling of interior surface Splits: 25% to 50% of circumference Infiltration: minor water infiltration but no soil infiltration Wall cracking: 25% to 50% of circumference Longitudinal cracking: less than or equal to 12 inches in length	Local buckling: inward, kinks through the full wall thickness Splits: greater than 50% of circumference Infiltration: water infiltration through cracks with indication of soil infiltration Wall cracking: greater than 50% of circumference Longitudinal cracking: greater than 12 inches in length
Joint Separation, Offset, and Rotation	Joints: tightly installed Offset: proper alignment Functioning well	Joints: separation, no distress Offset: exists but with no distress Rotation: present but with no distress Gaskets: not exposed	Joints: separation in one or more joints Offset: exists in one or more joints Rotation: present in one or more joints Gaskets: materials exposed or missing	Joints: separation with exposed backfill material Offset: exists with exposed backfill material Rotation: present with exposed backfill material Gaskets: gasket materials exposed or missing in multiple locations

Condition Rating	Good	Fair	Poor	Severe
Barrel Alignment	Horizontal alignment: no signs of movement from installed condition (straight or smooth bends) Vertical alignment: no sagging or heaving	Horizontal alignment: small visible deviations from installed condition that do not affect barrel or joints Vertical alignment: minor sagging or heaving	Horizontal alignment: deviations from installed condition that may affect barrel or joints (refer to joint inspection) Vertical alignment: misalignment causing sagging with ponding or sediment accumulation of 10% to 30% of diameter	Horizontal alignment: distress in barrel or at joints with barrel section offsets Vertical alignment: misalignment causing sagging with ponding or sediment accumulation of greater than 30% of diameter; distress in barrel or at joints with barrel section offsets Flow capacity: indication of significant flow restriction
Infiltration and Exfiltration	Infiltration or exfiltration: no signs	Water infiltration: minor, through leak-resistant joints/seams Soil infiltration: none	Water infiltration: significant, through joints/seams Soil infiltration: fine soils, through joints/seams	Soil infiltration: coarse soils, through joints/seams Exfiltration: evidence of piping due to exfiltration Hollow sounds: possible, behind structure wall near seam/joint indicating loss of backfill support

3.5.2 Concrete Barrel Condition Descriptions

Figure 8 Concrete barrels should be checked for cracking, spalling, deterioration, joints, alignment, and infiltration and exfiltration (photo: Kent County Road Commission)

Component Description

Concrete-barrel culverts are rigid structures that do not deform under heavy loads. They may be either precast or cast-in-place concrete structures. These culverts may be pipes or may be single-cell or multi-cell box shapes.

What to Look For

Since concrete culverts do not deform under heavy loads, shape is not evaluated. Concrete culverts are evaluated by considering six characteristics: cracking; slabbing, spalling, delamination, and patches; deterioration; joint separation, offset, and rotation; barrel alignment; and infiltration and exfiltration.

- **Slabbing, spalling, delamination, and patches** indicate section loss of the original concrete material. Slabbing is a radial failure of the concrete from inadequate concrete cover and involves large slabs of concrete peeling away from the barrel walls. Spalling is a fracture of a portion of concrete parallel to its surface. Delamination is a separation of the concrete parallel to its surface prior to the section loss that occurs with spalling. Patched areas from previous maintenance on spalled sections should be monitored for delamination and/or spalling. These characteristics may be identified visually or by sounding with a hammer.
- **Cracking** is important to monitor. Longitudinal cracks in the crown and invert can develop due to tensile stress from circumferential bending. Small hairline cracks should be noted but cracks with increased thicknesses need to be investigated further as this is indicative of overloading or poor backfill support. Transverse or circumferential cracks are indicative of poor backfill.
- **Deterioration** of concrete can occur for many reasons. Causes of deterioration include freeze-thaw cycles, chemical attack, and abrasion. Deterioration is generally identified by exposure of aggregate, scaling, or crumbling of the concrete.

- **Joint separation, offset, and rotation** are openings in excess of the manufacturer's tolerance and can lead to accelerated damage caused by infiltration and exfiltration.
- **Joint cracking** may occur as a result of mis-handling during shipping/installation or movement/settlement of the pipe due to poor compaction.
- **Barrel alignment** should be checked by sighting along the crown and sides of the culvert and noting any differential displacement between sections of the barrel. Sagging traps water and debris, which can reduce flow capacity. Trapped water can also cause saturation of supporting soil through leaking joints.
- **Infiltration and exfiltration** occurs when there are openings in the barrel. Infiltration allows groundwater to enter the culvert and may transport backfill material leading to voids, settlement, and misalignment of the barrel. Exfiltration occurs if the groundwater table is below the barrel, leading to water within the barrel seeping out of the barrel and subsequently causing soil saturation and misalignment of the barrel.

Table 3-6 Concrete Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Slabbing, Spalling, Delamination, Patches	Slabbing: none as indicated by wall visual appearance Spalling: none, as indicated by wall visual appearance Delamination: none Patches: areas remain sound	Slabbing: none Spalling: localized, less than 0.25 inches in depth and less than 6 inches in diameter; rebar not exposed Delamination: small, indicated by hollow sounds at patches Patches: areas remain stable	Slabbing: none Spalling: 0.5 to 0.75 inches in depth and greater than 6 inches in diameter; rebar not exposed, some rust staining; structure stable Delamination: greater than 6 inches in diameter and 0.5 to 0.75 inches in depth; rebar not exposed, some rust staining; structure stable Patches: areas are deteriorating and delaminated	Slabbing: slabbing of concrete Spalling: widespread, greater than 0.75 inches in depth; rebar exposed, structure unstable Delamination: present with rebar exposed; structure unstable
Cracking	Cracking: none greater than hairline (maximum 0.01 inch)	Longitudinal cracking: 0.01 to 0.05 inches in width (thickness of dime), spacing is equal to or greater than 3 feet Circumferential cracking: some Water infiltration: none	Cracking: no increase from previous inspection Longitudinal cracking: 0.05 to 0.1 inches in width, spacing is 1 to 3 feet; rebar not exposed Circumferential cracking: present Cracking with vertical offset: none Water infiltration: through circumferential cracks Efflorescence: present, rust staining emanating from cracks	Longitudinal cracking: greater than 0.1 inches in width; rebar exposed Cracking with vertical offset: present Water infiltration: significant Soil migration: significant Efflorescence: present, large areas of rust staining emanating from cracks

Condition Rating	Good	Fair	Poor	Severe
Deterioration	Scaling: none Abrasion: none Other damage: no surface damage	Scaling: light or moderate (less than 0.25 inches exposed aggregate) Abrasion: less than 0.25 inches in depth over less than 20% of barrel surface Other damage: impact damage localized and superficial (less than 0.25 inches) Rebar: not exposed Weep holes: multiple plugged	Scaling: moderate to severe (aggregate exposed) Abrasion: 0.25 to 0.5 inches in depth over greater than 30% of barrel surface Other damage: impact damage Rebar: exposed	Scaling: extensive Abrasion: extensive Other damage: extensive surface damage and aggregate pop-out Rebar: exposed and/or corroded Complete invert deterioration and loss of barrel wall section
Joint Separation, Offset, and Rotation	Joints: tightly installed Alignment: proper Functioning well	Joints: separation, no distress Alignment: offset with no distress Rotation: present but with no distress Gaskets: not exposed	Joints: separation in one or more joints Alignment: offset in one or more joints Rotation: present in one or more joints Gaskets: exposed or missing gasket materials	Joints: separation with exposed backfill material Alignment: offset with exposed backfill material Rotation: present with exposed backfill material Gaskets: exposed or missing gasket materials in multiple locations
Joint Cracking	Joint cracking: none	Longitudinal cracking: 0.01 to 0.05 inches in width (thickness of dime) emanating from joint Spalling: none or small spalls along edge of spigot and reinforcing or joint sealant not exposed	Longitudinal cracking: 0.05 to 0.1 inches in width emanating from joint Spalling: moderate spalls along edge of spigot end, reinforcing or joint sealant possibly exposed	Longitudinal cracking: greater than 0.1 inches in width emanating from joint Spalling: large spalls along edge of spigot end with associated structural cracking
Barrel Alignment	Horizontal alignment: no signs of movement from installed condition (straight or smooth bends) Vertical alignment: no sagging or heaving	Horizontal alignment: small visible deviations from installed condition that do not affect barrel or joints Vertical alignment: minor sagging or heaving	Horizontal alignment: deviations from installed condition that may affect barrel or joints (refer to joint inspection) Vertical alignment: misalignment causing sagging or heaving with ponding or sediment accumulation of 10% to 30% of diameter	Horizontal alignment: misalignment causing distress in barrel or at joints due to barrel section offsets Vertical alignment: misalignment causing sagging with ponding or sediment accumulation of greater than 30% of diameter; distress in barrel or at joints due to barrel section offsets Flow capacity: indication of significant flow restriction

Condition Rating	Good	Fair	Poor	Severe
Infiltration and Exfiltration	Infiltration/exfiltration: no signs	Water infiltration: minor, through leak-resistant joints/seams Soil infiltration: none	Water infiltration: significant, through joints/seams Soil infiltration: fine soils, through joints/seams	Soil infiltration: coarse soils, through joints/seams Exfiltration: evidence of piping due to exfiltration Hollow sounds: possible, behind structure wall near joints/seams indicating loss of backfill support

3.5.3 Corrugated Metal Barrel Condition Descriptions

Figure 9 Corrugated metal barrels are checked for surface damage, corrosion, abrasion, shape, joints and seams, alignment, and infiltration and exfiltration

Component Description

Corrugated metal pipe (CMP) and corrugated metal plate culverts are flexible structures that depend on soil-structure interaction for their structural stability. These culverts are constructed of aluminum or steel.

What to Look For

CMP/plate barrels are rated by considering ten characteristics: shape; surface damage; corrosion; abrasion; joint separation, offset, and rotation; seam alignment; seam bolts and fasteners; seam bolt holes; barrel alignment; and infiltration and exfiltration.

- **Shape** should be monitored over time for changes in comparison to the original shape of the culvert. Because flexible culverts rely on soil-structure interaction to provide strength, shape is an important characteristic.
- **Surface damage** includes dents or other small localized damage generally caused by impact.
- **Corrosion** is deterioration of metal due to electrochemical or chemical reactions with the surrounding environment. For example, steel corrodes in the presence of salts and acidic soils, and aluminum corrodes in the presence of alkaline soils.
- **Abrasion** is caused by erosion of the culvert material by sediments within the stream.
- **Joint separation, offset, and rotation** are openings in excess of the manufacturer's tolerance and can lead to accelerated damage caused by infiltration and exfiltration.
- **Seam alignment** issues are visibly apparent as cocked or cusped plates, which generally occurs during fabrication from misalignment between the bolt holes in the connection. When bolts are inserted and tightened, the plates can shift and produce a cocked seam. The cusp effect occurs when the end of one plate bears directly against the surface of the other plate, causing the free end

to curl away from the culvert wall, leading to loss of backfill and reduction in ring compression strength.

- **Seam bolts and fasteners** should be inspected for loose or missing fasteners. Tightness may be checked by tapping lightly with a hammer and looking for movement. Seams in aluminum structural plates should be checked with a torque wrench and verified against values provided by the manufacturer.
- **Seam bolt holes** should be checked for signs of bolt tipping and cracking. Bolt tipping is a rotation of the bolts with subsequent elongation of the bolt hole due to bearing against the shank of the bolt, caused by slipping of the plates. Deflection of the culvert can cause longitudinal cracking along the bolt holes.
- **Barrel alignment** should be checked by sighting along the crown and sides of the culvert to verify straightness. Sagging traps water and debris, which can reduce flow capacity.
- **Infiltration and exfiltration** occurs when there are openings in the barrel. Infiltration allows groundwater to enter the culvert and may transport backfill material leading to voids, settlement, and misalignment of the barrel. Exfiltration occurs if the groundwater table is below the barrel, leading to water within the barrel seeping out of the barrel and subsequently causing soil saturation and misalignment of the barrel.

Table 3-7 Corrugated Metal Pipe Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Shape	Curvature: smooth barrel Rise measurement: within tolerance Span measurement: within tolerance Deformation: less than 5% of original diameter	Curvature: smooth top half Bulges/kinks: minor bulges or flattening of bottom Deformation: 5% to 10% of original diameter	Curvature: significant distortion or flattening Bulges/kinks: lower third may be kinked Deformation: greater than 10% to 15% of original diameter Out-of-roundness: visible	Curvature: extreme distortion throughout barrel, local areas of reverse curvature Bulges/kinks: local area of kinks Deformation: greater than 15% of original diameter Out-of-roundness: significant
Surface Damage	Dents or localized damage: none	Dents or localized damage: small dents or impact damage to barrel wall or end section Wall breaches: none	Dents or localized damage: large dents or impact damage to barrel wall or end section Wall breaches: localized, no more than one corrugation over 6 inches in circumferential length	Dents or damage: warrants engineering evaluation Wall breaches: through-wall holes, more than one corrugation over greater than 6 inches in circumferential length allowing unimpeded soil infiltration

Condition Rating	Good	Fair	Poor	Severe
Abrasion	Abrasion: none	Abrasion: small or local abrasion of wall or coating Wall breaches: none in the coating exposing structural wall Corrosion: none	Abrasion: widespread abrasion of protective coating Wall breaches: breaches exposing the barrel wall material Penetration: through-wall penetration when probing with a pick	Abrasion: significant, large holes through the metal barrel more than one corrugation for greater than 6 inches in circumferential length
Corrosion	Rust: isolated areas of freckled rust	Rust: freckled rust, corrosion of barrel wall material Section loss: none Penetration: no through-wall penetration	Rust: corrosion of barrel material Section loss: widespread, less than 10% of wall thickness. Pitting: localized and deep Holes: less than or equal to 1 inch in diameter, several Penetration: possible with hammer pick strike	Section loss: invert missing localized sections Holes: greater than 1 inch in diameter OR many smaller, closely-grouped holes Penetration: widespread through-wall penetration
Joint Separation, Offset, and Rotation	Joints: tightly installed Alignment: proper Functioning well	Joints: separation Offset or rotation: exists but with no distress Gasket: not exposed	Joints: separation Offset or rotation: exists in one or more joints Gaskets: exposed or missing gasket materials	Joints: separation Offset or rotation: exists with exposed backfill material Gaskets: multiple locations of exposed or missing gasket materials
Seam Alignment	Alignment: no visible misalignment	Alignment: slight cocked seams Cusp effect: none Shape: cross section not affected	Alignment: cocked seams Cusp effect: present with local wall bending Shape: cross section affected	Alignment: cocked seams Cusp effect: present with seam cracking Shape: cross section severely affected Seam capacity loss imminent
Seam Bolts and Fasteners	Bolts/fasteners: none loose or missing	Bolts/fasteners: less than 5% loose or missing in any seam	Bolts/fasteners: 5% to 15% loose or missing in any seam	Bolts/fasteners: greater than 15% loose or missing in any seam

Condition Rating	Good	Fair	Poor	Severe
Seam Bolt Holes	Bolt holes: no yielding or deformation Wall prying: none due to bolt tipping	Bolt holes: localized minor yielding of steel and/or cracking or splitting less than 1 inch in length Corrosion: minor corrosion around bolt holes or on bolts	Bolt holes: localized yielding of steel and/or cracking or splitting 1 to 3 inches in length Corrosion: corrosion with section loss around bolt holes or on bolts	Bolt holes: localized significant yielding of steel and cracking/splitting of greater than 3 inches in length Corrosion: corrosion with section loss around bolt holes or on bolts
Barrel Alignment	Horizontal alignment: no signs of movement from installed condition (straight or smooth bends) Vertical alignment: no sagging or heaving	Horizontal alignment: small visible deviations from installed condition that do not affect barrel or joints Vertical alignment: minor sagging or heaving	Horizontal alignment: deviations from installed condition that may affect barrel or joints (refer to joint inspection) Vertical alignment: misalignment causing sagging with ponding or sediment accumulation of 10% to 30% of diameter	Horizontal alignment: misalignment causing distress in barrel or at joints due to barrel section offsets Vertical alignment: misalignment causing ponding or sediment accumulation of greater than 30% of diameter; distress in barrel or at joints, barrel section offsets Flow capacity: indication of significant flow restriction
Infiltration and Exfiltration	Infiltration/exfiltration: no signs	Water infiltration: minor, through leak-resistant joints/seams Soil infiltration: none	Water infiltration: significant, through joints/seams Soil infiltration: fine soils, through joints/seams	Soil infiltration: coarse soils, through joints/seams Exfiltration: evidence of piping due to exfiltration Hollow sounds: possible, behind structure wall near joints/seams indicating loss of backfill support

3.5.4 Masonry Barrel Condition Descriptions

Figure 10 Masonry barrels are checked for movement of masonry units, mortar, and efflorescence (photo: St. Clair County Road Commission)

Component Description

Masonry-barrel culverts are rigid structures. These culvert structures are constructed of stone, brick, or concrete block units generally mortared together.

What to Look For

Masonry barrels are rated by considering three characteristics; masonry units and movement, mortar, and efflorescence.

- **Masonry units and movements** should both be evaluated. The individual masonry units should be checked for displacement, cracking, and surface deterioration. Movement can occur with an individual unit or a group of units; causes of movement include freeze-thaw cycles, vegetation, deterioration of the mortar, or stress.
- **Mortar** should be checked to ensure its bond to the masonry units. Cracked, deteriorated, or missing mortar should be noted. Presence of dirt can indicate loss of backfill.
- **Efflorescence** is the leachate of salts or chlorides caused by water infiltration through the joints. This is generally cosmetic but can lead to spalling and deterioration and, thus, should be noted.

Table 3-8 Masonry Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Masonry Units and Movements	Cracking: none Splitting: none Movement: none displaced Missing: none Surface deterioration: none	Cracking: isolated individual units Movement: none Surface deterioration: weathering or spalling	Cracking: several masonry units Splitting: split masonry units Movement: pronounced movement or dislocation, does not warrant engineering evaluation Surface deterioration: large areas of moderate spalling, scaling, or weathering .	Cracking: widespread Splitting: widespread Movement: significant movement of individual units Missing: widespread crushed or missing units Surface deterioration: large areas of heavy spalling, scaling, or weathering Structure wall: holes through wall Shape: cross section has visible movement or distortion; structure appears unstable
Mortar	Cracked/missing: none, intact Deterioration: none	Cracked/missing: localized Deterioration: widespread areas of shallow mortar deterioration Infiltration/exfiltration: possible minor water infiltration (no active flow) or exfiltration through joints	Cracked/missing: extensive Deterioration: extensive Infiltration/exfiltration: small water flow but no soil/fines infiltration or exfiltration through joints	Cracked/missing: missing Infiltration/exfiltration: backfill infiltration Voids: possible in roadway
Efflorescence	Efflorescence: localized areas	Efflorescence: widespread areas Rust staining: none	Efflorescence: heavy buildup Rust staining: present	No severe rating

3.5.5 Timber Barrel Condition Descriptions

Figure 11 Timber barrels should be checked for connections and missing members, decay, checks and shakes, structural cracks, delamination, abrasion and impact, and distortion (photo: Fleis & Vandenbrink Engineering)

Component Description

Timber-barrel culverts are rigid structures. They are primary constructed of wood. Timber barrel are generally box-structures but can also be other shapes.

What to Look For

Timber barrels should be inspected for signs of material deterioration and mechanical damage. They are rated by considering seven characteristics: distortion, abrasion and impact damage, structural cracks, checks and shakes, delamination, decay, and connections and missing members.

- **Distortion** is generally identified by warping, sagging, or localized crushing of wood members. Warping is generally caused by uneven shrinkage during the drying process and results in a member that is not flat. Sagging generally occurs due to overloading or through creep caused by constant loading over a period of time. Localized crushing commonly occurs at bearing connections perpendicular to the grain.
- **Abrasion and impact damage** is caused by erosion of the culvert material by sediments within the stream.
- **Structural cracks** occur from overloading of a timber member and may originate at knots.
- **Checks and shakes** should be investigated. Checks are cracks that occur along the radius, perpendicular to the growth rings, of a timber due to shrinkage as the wood dries. The structure's design typically accounts for checks but, in some cases, checks may affect connections. Shakes occur when the growth rings separate. These extend longitudinally in the timber and can affect the bending strength of the member.
- **Delamination** of glu-lam members (members constructed by gluing smaller members together) affects the structural capacity of the member, particularly if they occur at connections.

- **Decay** is checked visually and through soundings. Visible decay is most apparent during its later stages. Sounding and probing can be used to evaluate the extent of decay. Contributors to decay include fungi, insects, and fire.
- **Connection and missing members** should be checked for distress and deterioration. Metal connections should be checked for corrosion and missing fasteners.

Table 3-9 Timber Barrel Condition Descriptions

Condition Rating	Good	Fair	Poor	Severe
Distortion	Shape: cross section has no change Members: no warping, crushing, or sagging	Members: warping or sagging of single or few members not requiring mitigation or previously mitigated	Shape: cross section has warping, sagging causing distortion Members: crushing	Shape: cross section has significant distortion or widespread warping, crushing, or sagging
Abrasion/ Impact Damage	Abrasion: no section loss	Abrasion: section loss of less than 10% of the member cross section	Abrasion: section loss of 10% to 20% of the member cross section	Abrasion: section loss of greater than 20% of the member cross section
Structural Cracks	Structural cracking: none	Structural cracking: arrested	Structural cracking: exists, but projects less than 5% into the member cross section	Structural cracking: exists with differential movement across crack
Checks and Shakes	Checks or shakes: penetrating less than 5% of member thickness	Checks or shakes: penetrating 5% to 50% of member cross section away from connections and tension zones of bending members	Checks or shakes: penetrating greater than 50% of member cross section OR penetrating less than or equal to 10% near connections or tension zone of bending member	Checks or shakes: penetrating greater than 10% near connections or tension zone of a bending member
Delamination	Delamination: none	Delamination: length less than the total member depth and away from connections, or has been arrested	Delamination: length equal to or greater than the total member depth, but only present away from connections.	Delamination: near connections, imminent collapse of member or structure
Decay	Members: no sunken faces, staining, or discoloration of surfaces Fruiting bodies: no signs	Members: decay allowing probe penetration of less than or equal to 10% of the cross section Hollow sounds: localized	Members: decay allowing probe penetration of 10% to 20% of the cross section; away from connections and tension zone of bending member	Members: decay allowing probe penetration of greater than 20% of the cross section or greater than 10% of the cross section near connections or tension zone of a bending member Fruiting bodies: present

Condition Rating	Good	Fair	Poor	Severe
Connection and Missing Members	Bolts: none loose Welds: none broken Rivets: none missing Fasteners: none missing Surface rust: none	Bolts: loose bolts Fasteners: loose Surface rust: freckled rust (no pitting or section loss), rust staining on face of members Connection: functioning as designed	Bolts: missing Welds: broken Rivets: missing Fasteners: missing Surface rust: present with some pitting, pack rust without distortion Connection: functioning as designed	Bolts: missing, causing movement in connected elements Welds: broken, causing movement in connected elements Rivets: missing, causing movement in connected elements Fasteners: missing, causing movement in connected elements Surface rust: heavy rusting with section loss, and/or pack rust causing distortion Connection: integrity is in question Imminent collapse

Appendix

Table A-1 may be used to provide a general understanding of how previous culvert ratings used by agencies involved in the Michigan TAMC pilot culvert data collection effort compare to the rating system outlined in this guide. This comparison may be useful for understanding how a historically-rated culvert may have rated for the pilot; however, this comparison should not be construed as a means for directly converting historical data since rating criteria may not directly relate or fully encompass the current components and characteristics rating system.

The 2020 *TAMC Culvert Condition Assessment Final Report* contains a detailed breakdown of rating descriptions for the elements and components/characteristics identified by AASHTO, TAMC Pilot, and MDOT, which may be helpful for determining an approximate rating in another system. The full report can be found at https://www.michigan.gov/documents/tamc/2020_TAMC_Culvert_Condition_Assessment_Final_Report_713402_7.pdf

Culvert Structure Inspection Guide Inventory Fields compared to TAMC Pilot

	Table A.1 Culvert Inventory Fields and Valid Entries Compared to the TAMC Pilot			
	Inventory Field	**TAMC Guide Description**	**Valid Entries**	**TAMC Pilot**
VICINITY & APPURTENANT STRUCTURES	Roadway	The approach roadway is the length of roadway, shoulder and guardrail above the culvert and the embankment below that is influenced directly by the performance of the buried system and should encompass a minimum length of 20 feet either side of the culvert plus the culvert span or the full width of any wingwall structure, whichever is greater.	Good, Fair, Poor or Severe, Not Rated	Not rated
	Channel scour and blockage	The channel consists of the stream or river, its bed, and the adjacent banks.	Good, Fair, Poor or Severe, Not Rated	Channel blockage and scour – minimum of two ratings
	End treatments and appurtenant structures	The components that are used to reduce erosion, retain fill material, inhibit seepage, improve hydraulic efficiency, provide structural stability to the culvert ends, and improve the appearance of the culvert.	Good, Fair, Poor or Severe, Not Rated	Not rated
CULVERT BARREL	Barrel	Condition tables are given for plastic, concrete, corrugated metal, masonry and timber barrel type which contain descriptions for individual characteristics that are rated. Barrel alignment, applicable to plastic, metal, and concrete culverts is a measure of horizontal and vertical deviation from the design profile Joints and seams consider the transverse transitions between barrel sections (joints) and the longitudinal or helical transitions between barrel sections (seams)	Good, Fair, Poor or Severe, Not Rated	Structural deterioration – straight conversion Invert deterioration-straight conversion Section deformation – straight conversion Joint/seam condition – straight conversion
	Overall rating	**Minimum of evaluated components**		**Minimum of all available ratings**
	General Descriptions			
	Good	No action is recommended. Note in inspection report only.		Ratings 10-8
	Fair	No immediate action is recommended, but more frequent inspection may be warranted. Maintenance personnel should be informed.		Ratings 7-6
	Poor	Inspector evaluates need for corrective action and makes recommendation in inspection report		Ratings 5-4
	Severe	Corrective action is required and urgent. Engineering evaluation is required to specify appropriate repair		Ratings 3-1

Data Dictionary

Table A-2 outlines the fields from the web service class used by the Center for Shared Solutions.

Table A.2 Culvert Fields from the Center for Shared Solutions Web Service Class

Field	Field	Field
double DepCovrField;	string MatlTypeField;	int RoadSoftIDField;
int DepCovrUnitField;	double MilepointField;	string RoadSurfField;
int FrameworkField;	int NumCulvsField;	string RoadSurfTypeField;
double HeigthDiamField;	string PRNameField;	string ShapeField;
int HeigthUnitField;	int PRNoField;	double SkewAngleField;
string IntNameField;	int RatingField;	double SpanField;
string InventoryIDField;	System.DateTime RatingDateField;	int SpanUnitField;
double LatitudeField;	string RatingMemoField;	string UserCvrtNoField;
double LengthField;	double RefMilesField;	double WidthField;
int LengthUnitField;	double RiseField;	int WidthUnitField;
double LongitudeField;	int RiseUnitField;	