2018

Michigan Local Agency Culvert Inventory Pilot Evaluation Report

Photo provided by the Center for Technology and Training

The Michigan Transportation Asset Management Council (TAMC), the TAMC Bridge Committee and the Centerfor Technology and Training at Michigan Technological University (CTT) wish to acknowledge the contribution of the transportation professionals who coordinated the culvert data collection at their respective agencies, and for the data, input and suggested best practices for the collection of culvert data for Michigan's local transportation agencies. Their input assisted in the development of this report.

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A full detailed report can be found on the TAMC website at *www.michigan.gov/tamc*

PURPOSE OF LOCAL AGENCY CULVERT INVENTORY PILOT

In 2018, the Transportation Asset Management Council (TAMC) Bridge Committee was tasked with managing a work plan for a pilot project for the inspection and inventory of culverts on the local road system. The project was related to a recommendation made by the 21st Century Infrastructure Commission and was informed by the pilot inspection and inventory of culverts done by MDOT in 2016 on the state trunkline highway system. The goal of the 21st Century Infrastructure Commission report is to have Michigan's road and rail systems designed to ensure that rivers, streams, and drains remain free-flowing to protect ecosystem health, as well as investments in transportation infrastructure.

ASSET MANAGEMENT

WHAT is asset management?

At the most basic level, asset management is a way to meet the goals of good ownership, effective management, and responsible stewardship. In the state of Michigan, asset management has traditionally been applied to maintaining pavements. However, a typical transportation network also comprises bridges, signs, culverts, guardrail, etc. The principles of asset management should be applied to the management of all these components of the asset. Asset management represents more than simply an integration of existing management systems and data. It builds on existing processes and tools to form a continuous improvement guide that complements and supplements existing practice.

WHY use asset management?

It is widely accepted that transportation infrastructure is vital to the economic well-being of our state. For most local authorities, their road network is the most valuable community asset under their control. Despite this, there is a growing realization that the management of these vital and valuable assets is not receiving the attention or funding required for the provision of the optimal state of repair and operation. Developing an asset management plan empowers public agencies to invest their scarce transportation funding in ways that will provide the greatest return. An asset management plan also allows a community to determine what an acceptable level of services is while informing residents and elected officials of the impacts declining transportation funding will have on the system.

HOW does a culvert pilot fit into asset management?

Michigan roads have hundreds of thousands of bridges, culverts, and other drainage infrastructure components, many of which are decades old and on the verge of failure. State agencies have identified at least 65,000 points throughout the state where Michigan's road and rail systems intersect with surface water systems. Many of these points may be undersized for current and future watershed conditions, increasing the potential for flooding. When flooding occurs or structures fail, there are safety, environmental, economic, and social impacts.

WHO participated in this program?

TAMC reached out to the Center for Technology and Training (CTT) at Michigan Technological University and the Center for Shared Solutions (CSS) and Michigan's regional and metropolitan planning agencies to assist with managing and facilitating the project. The CTT and the TAMC have a long-standing working relationship that, combined with the working structure that the TAMC has already established with local transportation agencies through previous projects, allowed the CTT and the TAMC to quickly initiate, launch, and complete the culvert data collection pilot project within the required timeline. The CSS was involved in the Michigan Infrastructure Asset Management Pilot and was prepared to receive and store the collected data to support a statewide integrated system.

In addition to these partners, 49 local transportation agencies (32 counties, 12 cities and five villages) collected and submitted data through the pilot.

GOALS

The intent of the culvert data collection pilot was to collect data on Public Act 51-certified roads in Michigan at a statewide level for the following goals:

1) Estimate the total number of culverts on the local system of Public Act 51-certified public roads.

2) Estimate the overall condition of culverts in the state using similar inspection components and rating.

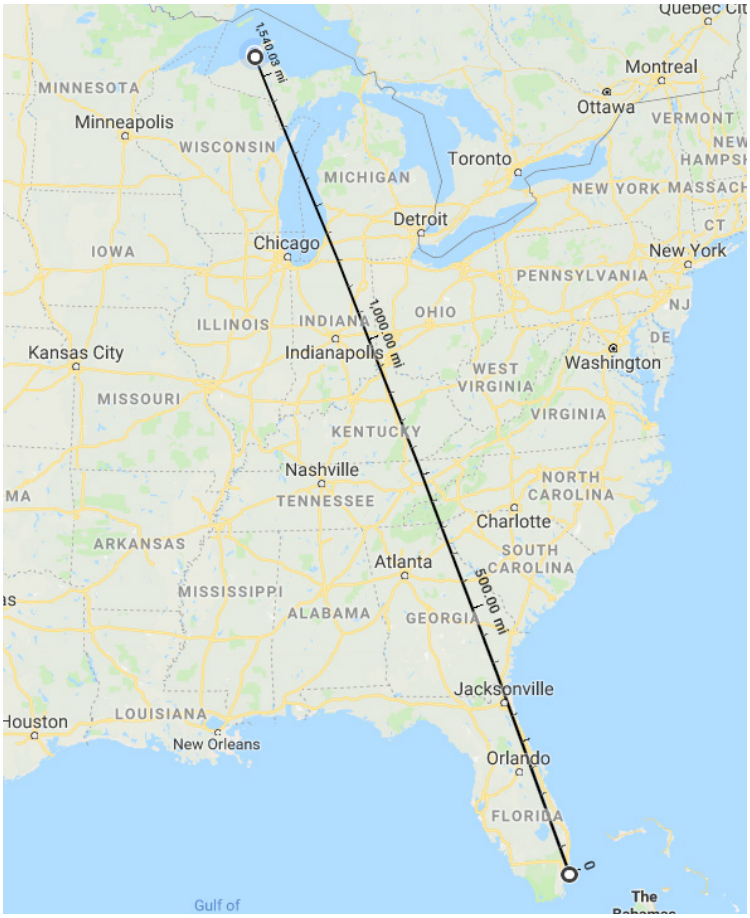
3) Determine the range of physical characteristics (inventory information) of culverts, such as material, size and depth, that may impact the cost to maintain or replace the asset.

4) Benchmark estimates of agency labor (time and materials) necessary to find and collect inventory data for culverts on a dollar per mile or other production rate basis.

5) Benchmark estimates of agency labor (time and materials) necessary to find and collect condition data for culverts on a dollar per mile or other production rate basis.

ESTIMATED STATEWIDE LOCAL AGENCY INVENTORY

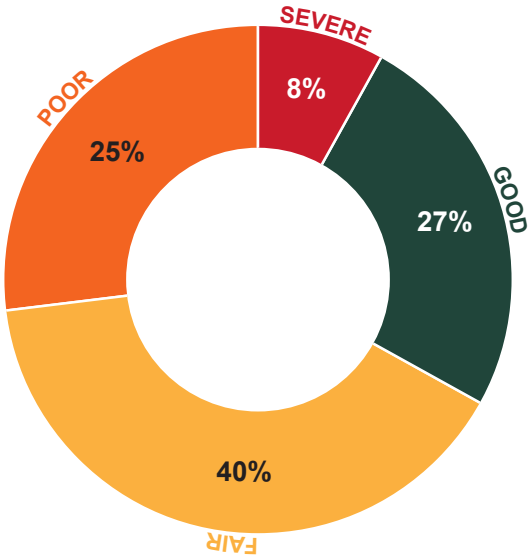
- Estimated number of local agency culverts: 196,000
- 27 percent of the culverts are in good condition
- 69 percent of the culverts are corrugated steel pipe
- Estimated time to inventory a culvert: 17 minutes
- Estimated time to inventory and inspect a culvert: 25 minutes
- Estimated length of local agency culverts: 7.3 million to 9.2 million feet (1,389 to 1,756 miles) of culvert. This is enough culvert pipe to build a single straight culvert from Houghton, Michigan, to the tip of Key West, Florida. (see map below)
- Estimated replacement cost of local agency culverts: $1.48 billion



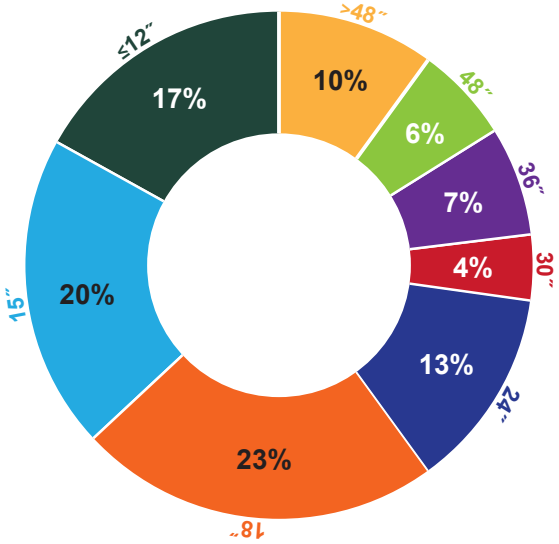
CULVERT COLLECTION BY THE NUMBERS

- Data collection training using Roadsoft: 78 participants
- Condition evaluation training: 83 participants
- Data submittal training: 65 participants
- Typical collection team size: 2 people
- Number of culverts inventoried in this pilot: 49,664

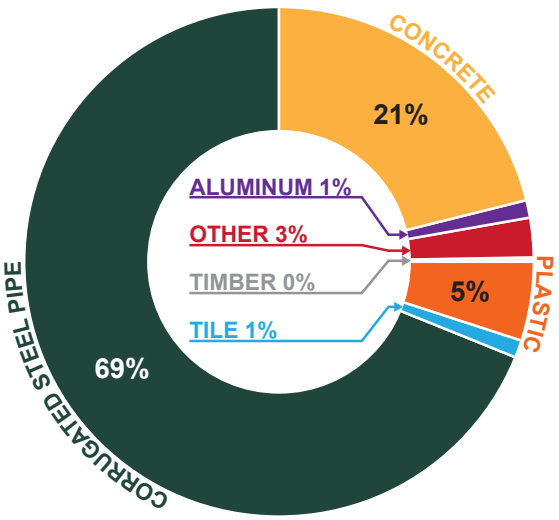
Estimated Local Agency Culvert Condition



Reported Culverts by Span or Diameter (in inches)



Reported Culverts by Material Type



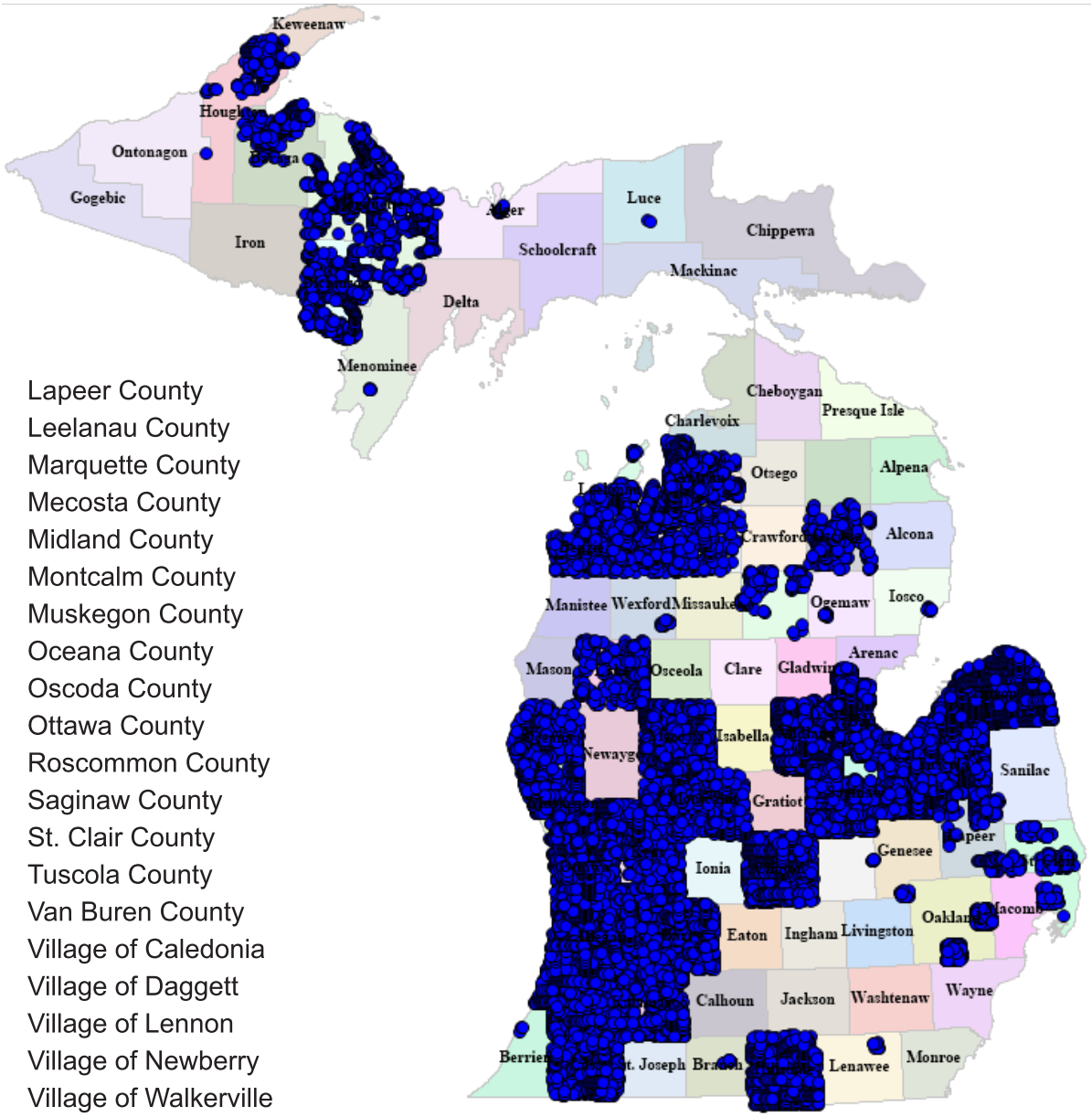
KEY FINDINGS

- The tools, training, business processes, and relationship building that the TAMC initiated for the collection of Pavement Surface Evaluation and Rating (PASER) road condition data has created a strong framework for the rapid collection of other asset data on the local agency road system.
- The repeating five-year costs associated with training and data collection for a culvert inventory and condition evaluation program are estimated at $10.5 million to $11.25 million ($2.1 million to $2.5 million annually). These estimates do not include costs associated with development and implementation of asset management programs for culverts.
- A post-pilot survey showed participant interest in continuing to collect inventory and condition evaluation data on their culverts beyond the pilot timeframe.
- Inventory data from culverts revealed that the majority (approximately 73 percent) of local agency-owned culverts are small (24 inches in diameter or less), made from corrugated steel, and are circular culverts that are located less than 6 feet from the surface. Larger and more deeply buried culverts are of specific interest because they present a larger consequence of failure in terms of risk to the public and expenditure of funds for repair.
- Condition data indicates that local agency-owned culverts are in serviceable shape, with 27 percent of the rated culverts holding condition ratings of 8 or better, and 67.2 percent of the rated culverts holding conditions ratings of 6 or better.
- It is estimated that it will take approximately $10 million and more than 131,000 collection team hours to complete the initial data collection of local agency culverts.

PARTICIPATING AGENCIES AND LOCATIONS OF INVENTORIED CULVERTS

Local Road Agencies:

Allegan County
Antrim County
Baraga County
Barry County
Bay County
Benzie County
Cass County
City of Benton Harbor
City of Big Rapids
City of Cadillac
City of Coldwater
City of East Tawas
City of Farmington Hills
City of Fenton
City of Munising
City of Muskegon Heights
City of Rochester Hills
City of Tecumseh
City of West Branch
Clinton County
Dickinson County
Grand Traverse County
Hillsdale County
Houghton County
Huron County
Kalamazoo County
Kalkaska County
Kent County
Lake County
Lapeer County
Leelanau County
Marquette County
Mecosta County
Midland County
Montcalm County
Muskegon County
Oceana County
Oscoda County
Ottawa County
Roscommon County
Saginaw County
St. Clair County
Tuscola County
Van Buren County
Village of Caledonia
Village of Daggett
Village of Lennon
Village of Newberry
Village of Walkerville



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LIST OF ACRONYMS

AHP	Analytical Hierarchy Process
AOP	Aquatic Organism Passage
ASCE	American Society of Civil Engineers
CMP	Corrugated Metal Pipe
CRC	County Road Commission
CSS	Center for Shared Solutions
CTT	Center for Technology & Training
DEQ	Department of Environmental Quality
DNR	Department of Natural Resources
DTMB	Department of Technology, Management, and Budget
FAQ	Frequently Asked Questions
FHWA	Federal Highway Administration
GIS	Geographical Information System
GPS	Global Positioning System
GUID	Globally Unique Identification
LDC	Laptop Data Collector
MiBridge	Michigan Web-based Structure Management System
MDOT	Michigan Department of Transportation
MPO	Metropolitan Planning Organizations
NBI	National Bridge Inventory
NCHRP	National Cooperative Highway Research Program
NJDOT	New Jersey Department of Transportation
Ohio DOT	Ohio Department of Transportation
PA	Public Act
PPE	Personal Protective Equipment
RCKC	Road Commission for Kalamazoo County
RPO	Regional Planning Organizations
TAMC	Transportation Asset Management Council
TAMS	Transportation Asset Management System
UTC	University Transportation Center
WAMC	Water Asset Management Council
Wisconsin DOT	Wisconsin Department of Transportation

EXECUTIVE SUMMARY

In 2018, the Transportation Asset Management Council (TAMC) Bridge Committee was tasked with managing a work plan for a pilot project for the collection of data and the evaluation of culverts owned by local transportation agencies within Michigan. The work was funded though House Bill 4320 (S-3) - Supplemental Appropriation Adjustments, which added $2 million to the fiscal year 2018 budget from the state restricted Michigan Infrastructure Fund.

Based on recommendations made in the 21st Century Infrastructure Commission Report, the TAMC decided to use the funding for a pilot project to assist local transportation agencies with the collection of culvert data on their local road network. All work was to be completed on the pilot project before the end of fiscal year 2018 (September 30, 2018) as a condition of the funding from the Legislature. Given the relatively short timeframe, and the scope and logistics of the pilot project, the TAMC reached out to the Center for Technology & Training (CTT) at Michigan Technological University to assist with managing and facilitating the project. The CTT and the TAMC have a long-standing working relationship that, combined with the working structure that the TAMC had already established with local transportation agencies through previous projects, allowed the CTT and the TAMC to quickly initiate, launch, and complete the culvert data collection pilot project within the required timeline.

Goals

The intent of the culvert data collection pilot was to collect data on Public Act 51 Certified Roads in Michigan at a statewide level for the following goals:

1) Estimate the total number of culverts in the state.
2) Estimate the overall condition of culverts in the state using similar inspection components and rating.
3) Determine the range of physical characteristics (inventory information) of culverts, such as material, size, and depth, that may impact the cost to maintain or replace the asset.
4) Benchmark estimates of agency labor (time and materials) necessary to find and collect inventory data for culverts on a dollar per mile or other production rate basis.
5) Benchmark estimates of agency labor (time and materials) necessary to find and collect condition data for culverts on a dollar per mile or other production rate basis.

Project Planning

All local transportation agencies in the state were invited to participate in the *Michigan Local Agency Culvert Inventory Survey* offered between March 5-16, 2018. The goal of the survey was to assist the TAMC Bridge Committee with the completion of the project work plan, the selection of participating agencies, and the identification of appropriate culvert data to collect. All agencies that responded to the survey were eligible to participate in the culvert pilot. Based

on the survey responses, agencies that were willing to participate in the pilot were divided into tiers according to their existing level of culvert inventory and "rounds" based on their tier and geographical proximity to other responding agencies.

Given the fixed budget, the unknown number of culverts that agencies would be collecting data on, and an unknown number of participating agencies, the TAMC Bridge Committee discussed several funding options and scenarios to distribute the funding equitably. It was determined that all participating agencies were to receive a fixed mobilization reimbursement for training, purchasing of equipment to be used on the pilot, and for other pilot-related activities. County road agencies received $10,000, and city/village road agencies received $5,000. In addition, all local agencies were to receive $30/per-centerline-mile where they drove to collect culvert data, not to exceed the agency's Public Act 51 certified total centerline-miles.

It was determined that local transportation agencies would collect data on culverts ranging from 1 to <20 foot span, as culverts that span 20 feet and larger should already be included in local agencies' bridge inventory. The TAMC Bridge Committee established a list of culvert attributes to be collected as part of the pilot, as well as six condition evaluation criteria.

Training

The CTT hosted an informational webinar on April 19, 2018 to outline the pilot project and solicit questions and feedback from potential participating agencies. The CTT then hosted training webinars on April 25 and 26, 2018 to go over culvert inventory data collection using the Roadsoft Laptop Data Collector (LDC), and culvert condition evaluation, respectively. Roadsoft is a roadway asset management system for collecting, storing, and analyzing data associated with transportation infrastructure. The Michigan Department of Transportation (MDOT) provides Roadsoft to local agencies at no cost as part of the statewide roadway asset management initiative spearheaded and supported by MDOT.

The CTT hosted a webinar on July 24, 2018 to instruct participating agencies on how to submit their culvert data.

Data Collection and Results

CTT staff visited nine agencies to observe their culvert data collection processes. Generally, all of the agencies visited had similar processes for data collection that varied slightly based on the tools they used.

The CTT worked closely with the Michigan Department of Technology, Management and Budget (DTMB) Center for Shared Solutions (CSS) to build additional Roadsoft functionality to enable users to upload the data directly to CSS. They also worked together to allow the five agencies not using Roadsoft to submit data.

Once the data was submitted, the CTT compiled and processed the information to provide answers for the five key objectives of the culvert pilot project.

1. **Estimate the total number of culverts in the state.**

After compiling the submitted culvert data and the data from the daily collection logs, the CTT calculated the estimated number of statewide local agency culverts to be between 178,939 and 213,649. The range is due to estimates or calculations using six different data subdivisions. The average of this range is 196,294 statewide local agency culverts. A breakdown of the six methods used to calculate the averages is shown in Table 1.

Table 1: Summary of statewide culvert estimation methods

Method Number	Density Factor Source	Road Network Subdivisions	Regionality	County Culverts	City Culverts	Statewide Culverts	Difference From Highest
1	Average of Collection Area	Single Network	Aggregate of Counties	164,893	19,590	**184,483**	86%
2	Average of Collection Area	Fed aid / NFA split	Aggregate of Counties	166,466	22,682	**189,148**	89%
3	Average of Collection Area	Single Network	County by region	159,349	19,590	**178,939**	84%
4	Average of Collection Area	Fed aid / NFA split	County by region	161,252	22,682	**183,934**	86%
5	Daily Logs	Single Network	Aggregate of Counties	190,839	22,810	**213,649**	100%
6	Daily Logs	Single Network	County by region	182,207	22,810	**205,017**	96%

2. **Estimate the overall condition of culverts in the state using similar inspection components and rating.**

Based on the submitted data, overall condition assessments indicate that the majority of the culverts inspected were in fair to good condition with 27.0% of the rated culverts holding condition ratings of 8 (good) or better, and 67.2% of the rated culverts holding conditions ratings of 6 (fair) or better. The condition rating scale for this pilot project ranged from 1 (failed) to 10 (new). Of the inventoried culverts, 69.2% included a condition rating. Of the culverts inventoried during the pilot, 78.0% had ratings collected in 2018, and 92.0% were rated in the last five years. The overall culvert condition ratings are represented in Figure 1.

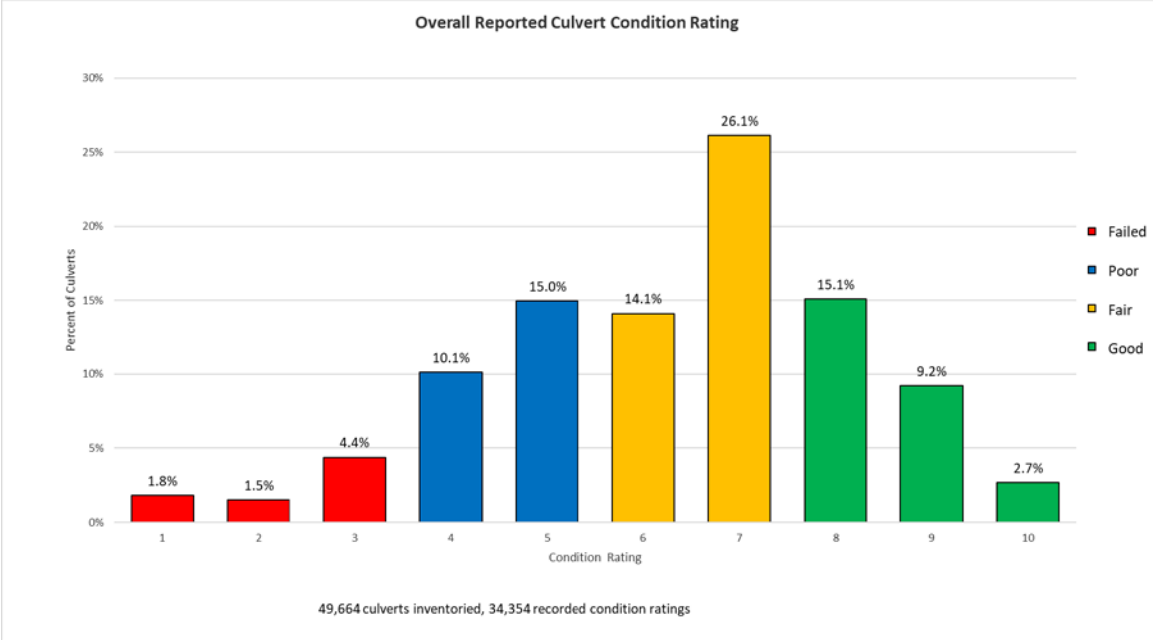


Figure 1: Overall culvert condition rating

3. **Determine the range of physical characteristics (inventory information) of culverts, such as material, size, and depth, that may impact the cost to maintain or replace the asset.**

Of the inventoried culverts, 69% were corrugated steel pipe, 21% were concrete, and 5% were plastic. The vast majority of reported culverts—88.%—were circular. Of the reported circular culverts, 90% were 48 inches or less in span, 36% have 24 inches or less of cover, and 49% have between 25-72 inches of cover. The most frequent road surface type was asphalt pavement at 66%, followed by gravel at 28%. The road surface type provides important information that can be used for the estimation of replacement costs, since restoration is a significant expense.

The total volume of culverts on the locally-owned road system represent a significant asset. Local agencies own an estimated 7.3 to 9.2 million feet (1,389 to 1,756 miles) of culvert. As a basis for comparison, this is enough culvert pipe to build a single straight culvert from Houghton, Michigan to Miami, Florida. This is represented in Figure 2. It is estimated that the total replacement value of locally-owned culverts in Michigan exceeds $1.48 billion.

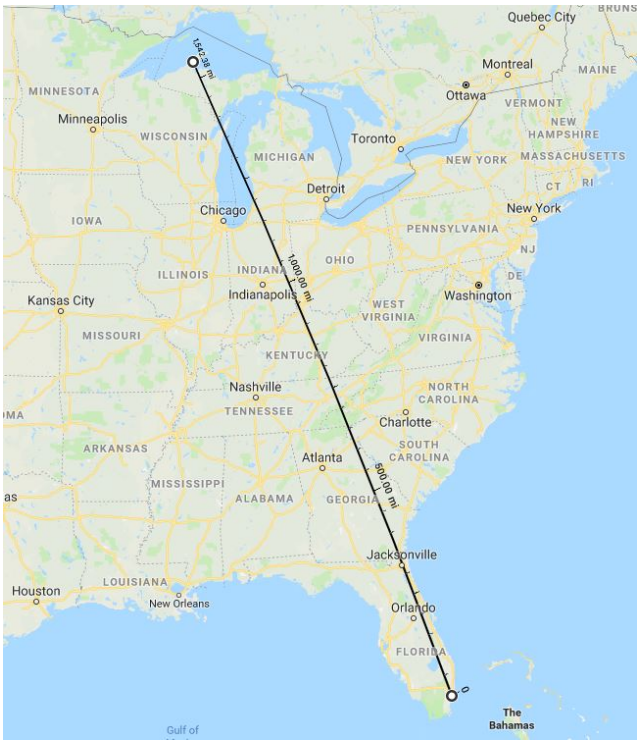


Figure 2: It is estimated that Michigan local transportation agencies own enough culvert pipe to build a single straight culvert from Houghton, Michigan to Miami, Florida

4. **Benchmark estimates of agency labor (time and materials) necessary to find and collect inventory data for culverts on a dollar per mile or other production rate basis.**

Estimating the expected costs to find and collect inventory data for culverts is difficult due to variables such as labor rates, culvert density, and culvert cover. Based on assumed crew size; pay; and benefit and overhead rates; the average culvert data collection labor cost is estimated to be $39.02 per mile for county road agencies and $69.17 per mile for cities and villages. These production rates are provided in Table 7-7 for use in estimating agency specific costs.

5. **Benchmark estimates of agency labor (time and materials) necessary to find and collect condition data for culverts on a dollar-per-mile or other production rate basis.**

The daily data collection logs did not contain a large enough data set to directly determine the time needed to collect condition rating information on known culverts. However, the daily logs show the average time per culvert to collect inventory data only was approximately 8 minutes faster than collecting inventory and condition rating data. This difference in average collection rate is likely the result of the added task of performing the condition rating activity.

Conclusions

This pilot project revealed that the tools, business processes, and relationship building that the TAMC initiated for the collection of Pavement Surface Evaluation and Rating (PASER) road

condition data has created a strong framework for the rapid collection of other asset data on the local agency road system. This is apparent from the significant capabilities that pilot participants demonstrated with their ability to collect a large volume of high-quality asset inventory and condition data on nearly 50,000 culverts in approximately three months. This number constitutes about 24% of the approximately 196,000 total local agency culverts in the state.

The pilot project also identified that a significant level of effort is required to inventory and rate local agency-owned culverts. It will take an estimated $10 million and over 131,000 collection team hours to complete the initial data collection of local agency culverts. Annual training expenses are estimated at $250,000 - $500,000 for development, provision, and participation in the training.

As part of an ongoing five-year condition evaluation cycle, the estimated annual cost will be approximately $2.1 to $2.25 million (in today's dollars) for continued training and data collection of culvert inventory and condition evaluation moving forward. This assumes 1/5 of all culverts will be inspected each year as part of a five-year repeating cycle where every culvert is inspected once every five years. Therefore, the five-year costs associated with training and data collection for a culvert inventory and condition evaluation program are estimated at $10.5 to $11.25 million. These estimates do not include costs associated with development and implementation of asset management programs for culverts. There will be additional unknown expenses for training, equipment, and data handling.

All participants were invited to participate in a follow-up survey. Many respondents indicated their intent to use the data gathered to advance their culvert asset management programs. Many also indicated they plan to use the condition evaluations to either add to, or create, a maintenance plan for addressing culverts in need of replacement. Of special note was that many indicated that they intend to continue to collect inventory and condition data on the culverts in their network even though the culvert pilot project is over. Aside from the value of the data that was collected and the conclusions that can be drawn from it, having practical, actionable outcomes that participants intend to continue using should not be overlooked.

1. BACKGROUND

The TAMC was appointed by the State Transportation Commission on September 26, 2002 as required in Public Act (PA) 499. Their mission as defined by this act is to report the condition of the Michigan public road network to the Michigan Legislature [1]. The TAMC's mission is taken directly from PA 499 and states:

> "In order to provide a coordinated, unified effort by the various roadway agencies within the state, the transportation asset management council is hereby created within the state transportation commission and is charged with advising the commission on a statewide asset management strategy and the processes and necessary tools needed to implement such a strategy beginning with the federal-aid eligible highway system, and once completed, continuing on with the county road and municipal systems, in a cost-effective and efficient manner."

To this end, TAMC has successfully adopted an existing condition assessment system—Pavement and Surface Evaluation Rating, or PASER—for the paved road network in Michigan. The TAMC has successfully set up the data systems; funding mechanisms; collection and data handling methods; and data collection infrastructure to collect pavement condition data on the entire paved federal-aid system (approximately 39,000 centerline miles) in Michigan. In 2017, the TAMC expanded to provide for a system of condition assessment on unpaved roads.

The TAMC Bridge Committee was tasked with managing a work plan for the collection of data and the evaluation of culverts located within Michigan. The FY 2018 budget provided for $2,000,000 from the state restricted Michigan Infrastructure Fund to inspect and inventory culverts on the local road system. *House Bill 4320 (S-3) - Supplemental Appropriation Adjustments*, which spells out the appropriaton, can be viewed at: http://www.legislature.mi.gov/documents/2017-2018/billanalysis/House/pdf/2017-HLA-4320-361480C1.pdf

This project is related to a recommendation made by the 21st Century Infrastructure Commission in their *21st Century Infrastructure Report* that was published in November, 2016. More information about the 21st Century Infrastructure Commission can be found at: https://www.michigan.gov/snyder/0,4668,7-277-61409_78737---,00.html

The transportation recommendations, including recommendations related to culverts made in the *21st Century Infrastructure Report*, can be found at: https://www.michigan.gov/documents/snyder/Ch_6_-_Transportation_Recommendations_551285_7.pdf

The TAMC intended for the majority of this funding to pass down to cities, villages, and county road commissions (local agencies) to collect their data via a reimbursement, based on mobilization and centerline miles travelled. All work was to be complete on this pilot before the

end of FY18 (September 30, 2018) as a condition of the funding from the Michigan Legislature. A schedule for this pilot was created to fit this deadline and is shown in Table 1-1.

Table 1-1: Schedule of pilot activities

Task		Feb		Mar				Apr					May				Jun				Jul					Aug				Sep			
		19	26	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	3	10	17	24
	Contract and Funds Disbursement																																
Task 1	Literature Review of Best Practices																																
Task 2	Local Agency Survey - Data Availability and Extent																																
Task 3	Selection of Data Collection and Storage Methods																																
Task 4	Develop and Conduct Pilot Training																																
Task 5	Selection of Particpating Agencies																																
Task 6	Pilot Data Collection																																
Task 7	Pilot Centralized Data Storage Solution																																
Task 8	Evaluation of Pilot																																
Task 9	State-wide Collection Cost Estimate																																
Task 10	Final Report																																

Culverts, for the purposes of this pilot, are defined as linear drainage conduits underneath a public roadway that are not considered “bridges” by the Federal Highway Administration (FHWA). In general, the FHWA considers a “bridge” as having a combined span of more than twenty feet, which would include listing on the National Bridge Inventory (NBI). 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 (manholes, catch basins etc.). Only culverts found within PA 51 Certified Roads are eligible for collection as part of this data collection effort; culverts found beneath private driveways or commercial drives are not eligible for inclusion or reimbursement.

The goal is to ensure the TAMC has a strategy that can be used across the state to further streamline and standardize the collection of culvert data and to develop best practices for the asset management of culverts in the state. Obtaining local culvert inventory and condition evaluation data in a representative group of local agencies will help determine the level of effort and cost to advance a similar effort statewide in the coming years.

2. INTRODUCTION

Asset management is crucial to planning and executing maintenance operations and replacing roadway assets in the most efficient and cost-effective manner. In order to effectively draw conclusions and make decisions, a complete inventory with regular condition evaluations is crucial to asset management. Agencies have created effective, standardized inventory and condition assessment programs for bridges and road surfaces for the purpose of asset management, but culvert inventory and condition assessment programs are often not executed with the same sophistication, or they are not established at all.

The need for culvert asset management is clear; there have been numerous documented culvert collapses in recent years that have led to damage and injuries, costing agencies significant money in emergency repairs and public safety concerns. In the early morning of June 17, 2018, Houghton County experienced an extreme rainfall (1000-year event) causing widespread damage in which many culverts failed, resulting in damage to surrounding areas, as depicted in Figure 2-1 and Figure 2-2. These culverts failed due to an extreme event that could not have been prevented through sound asset management, but they are representative of the roadway damage that can occur from culvert failures.

Figure 2-1: Culvert failure in Houghton, Michigan leading to roadway damage

Figure 2-2: Houghton county culvert failure in Ripley, Michigan

Culvert inventory and condition assessment programs assist in mitigating culvert problems before their condition becomes critical and allows culvert work to be coordinated with road work: saving money and maintaining public safety. Many of Michigan's local agencies do not have an established culvert inventory and condition assessment program. Of the local agencies that do have a program, there is little consistency between local agencies in how the programs operate, and many inventories are incomplete. The TAMC Local Agency Culvert Pilot seeks to provide standardization between local agencies by providing guidance on the inventory and condition evaluation of culverts.

This document serves as the final report for the TAMC pilot program implementing the inventory and condition evaluation of culvert assets owned by Michigan's local agencies. The intent of the pilot was to collect data to be used in generating the following information on PA 51 Certified Roads in Michigan at a statewide level:

1) Estimate the total number of culverts in the state.
2) Estimate the overall condition of culverts in the state using similar inspection components and rating.
3) Determine the range of physical characteristics (inventory information) of culverts, such as material, size, and depth, that may impact the cost to maintain or replace the asset.
4) Benchmark estimates of agency labor (time and materials) necessary to find and collect inventory data for culverts on a dollar per mile or other production rate basis.
5) Benchmark estimates of agency labor (time and materials) necessary to find and collect condition data for culverts on a dollar per mile or other production rate basis.

This report reviews existing literature on inventory and evaluation programs in other states; presents results from a statewide survey of current culvert asset management practices; establishes a standard inventory and condition evaluation program based on best practices by local, state, and federal agencies; establishes a culvert assessment training program for field inspectors; documents the implementation of this program; discusses implementation of local inventories into a statewide database; and draws conclusions and implications for future research resulting from this pilot.

3. REVIEW OF CURRENT BEST PRACTICES

3.1. Literature Review

The purpose of the literature review was to identify best practices used by county, state, and federal agencies that may be applicable to the pilot. This included identifying current data collection, storage, and evaluation tools in use by these agencies. A detailed literature review is included in Appendix A and summarized here. Once these tools, techniques, and methodologies were identified, an assessment was undertaken to determine those which warranted inclusion in the pilot.

3.1.1. *Pilot Studies*

Numerous pilot studies have been conducted throughout the country. A 2014 FHWA study stressed the importance of getting a system in place. Once locations are established with some capacity for condition assessment, the assessment portion can be improved with time by adding additional data. "Internal groups and stakeholders can identify large lists of potential data to be collected; however, the agency should make sure it knows how the data will be used and how often it may be used" (Venner 2014).

In September 2016, the MDOT published the *Asset Collection & Condition Assessment Guide for 1'-<10' Span Culverts*. The guide can be viewed at https://www.michigan.gov/documents/mdot/MDOT_RFP_SS_REQ2435_Tams_Culvert_Colection_616748_7.pdf.

This assessment guide highlights the pilot project to collect location and assessment data for 1 to <10 foot culverts under MDOT-owned roadways in six counties; Eaton, Ingham, Isabella, Mackinac, Osceola, and Saginaw. Isabella County was inventoried under a separate pilot program in 2016, and condition evaluation was performed as part of the larger pilot in 2017. The MDOT report describes the Transportation Asset Management System (TAMS) interaction and integration in the collection of culvert data. In addition to the data collection process using TAMS, the guide provides information on attribute and condition assessment. The guide provides a comprehensive overview of the process of locating and assessing culverts and associated attributes (end treatments, footings, etc.). It should be noted that MDOT effectively considers 10 to 20 foot culverts as bridges, and inspections are included as a subset of their bridge inventory (MDOT 2016). Table 3-1 summarizes the number of culverts that MDOT collected data on with a breakdown of the miles covered by road class.

Table 3-1: MDOT culvert pilot summary

County	Final Invoice	Culverts Collected 1 to <10 ft	Culverts Collected 10 to <20ft	Trunk Line Miles	Freeway Miles	Non-Freeway Miles	Total Federal-Aid Non-Trunk Line Miles
Eaton County	$61,506.95	479	24	155	39	116	377
Ingham County	$88,667.92	1103	11	158	55	103	493
Mackinac County	$84,174.38	561	13	178	28	150	212
Osceola County	$75,211.75	376	8	99	25	74	253
Saginaw County	$62,353.00	356	60	199	33	166	566
Total	**$371,914.00**	**2,875**	**116**	**789**	**180**	**609**	**1,901**

3.1.2. *Culvert Size*

Culverts are defined as structures that span less than 20 feet. In general, agencies with established programs tend to collect data on culverts that span from 1 to 20 feet and many choose to divide these into at least two categories based on size (1 to 10 foot and 10 to 20 foot sets are common) with different inspection criteria applied to each.

3.1.3. *Frequency of Inspections*

The frequency of culvert inspections varied widely by agency. Some choose to conduct annual inspections, while others spread them out up to once every six years. Some states require more frequent inspections for culverts with poor condition evaluations. Culvert size is another factor in establishing inspection frequency. Some agencies choose to inspect smaller culverts with less frequency than larger culverts. The National Cooperative Highway Research Program (NCHRP) Report 14-26, *Culvert and Storm Drain System Inspection Manual*, recommends establishing an inspection frequency based on both the condition and size of the culvert, but leaves the frequency decision to the agency. Under the recommended system, culverts that span greater than 10 feet should be inspected every two years regardless of condition, and culverts less than 10 feet should be inspected at intervals depending on their size and last reported condition.

3.1.4. *Commonly Used Equipment*

The following equipment was commonly cited in the literature review as needed for culvert inspection and condition evaluation programs:

- Data collection device (paper template, laptop, tablet, etc.)
- Database software or spreadsheet for data storage
- Camera
- Personal protective equipment (PPE)
- Measuring tape and wheel
- Flashlight
- Shovel

- Waders
- Stability pole
- Probing rod or rock hammer
- Global Positioning System (GPS) device

3.1.5. *Condition Evaluation*

FHWA issued report number FHWA-IP-86-2, *Culvert Inspection Manual: Supplement of the Bridge Inspector's Training Manual* in 1986. This manual provides information on culvert types, inspection procedures, and a culvert components inspection guide for approaches, end treatments, waterways, corrugated metal, precast concrete, cast-in-place concrete, and masonry culverts. The report provides guidance on data that should be collected for inventory and data that should be collected for condition evaluation of the culverts. The recommended rating system is a 0 to 9 scale, with 9 indicating that no repairs are needed and 0 indicating that the facility is closed for repairs.

The Ohio Department of Transportation (Ohio DOT) developed their own Culvert Management System, detailed in their 2017 *Culvert Inspection Manual*. This document is based on the FHWA system but provides additional quantitative and qualitative rating descriptors for rating corrugated metal, concrete, masonry, and plastic culvert structures beyond what is described by the FHWA (ODOT 2017).

The 2018 Wisconsin Department of Transportation (Wisconsin DOT) *Bridge Inspection Field Manual* provides descriptors for condition rating timber bridges whereas timber culvert condition ratings are not covered under the existing FHWA system. These condition ratings relate to deterioration problems experienced by culverts as well, and thus is a useful resource in developing a timber culvert condition rating system (WisDOT 2018).

The NCHRP 14-26, *Culvert and Storm Drain System Inspection Manual*, was published in May, 2016 and serves as a proposed update to the FHWA *Culvert Inspection Manual*. The NCHRP report contains several changes from the FHWA method. The largest change is a proposed five-point rating system which the authors feel more directly correlates to observed conditions. Rating descriptions have been reorganized to a component-level evaluation to be consistent with the American Association of State Highway and Transportation Officials (AASHTO) *Bridge Element Inspection Manual*.

The Midwest Regional University Transportation Center (UTC) developed a culvert rating procedure in 2008 in an attempt to give more insight for asset management of culverts. In this method, individual element ratings are combined into a single rating value based on a weighted average algorithm that uses an analytical hierarchy process (AHP) based on a pairwise comparison approach (i.e. "this is ___ more important than that").

3.2. Local Agency Survey – Data Availability and Extent

A comprehensive survey of Michigan local road-owning agencies was conducted to determine the extent of culvert inventory and condition evaluation data already being collected by local agencies. The results showed that local agencies range from not having a data collection program, to having a general inventory, to having a detailed inventory including culvert type, geo-referenced location, maintenance records, condition assessment, and other attributes. The survey also helped identify tools used for data collection and best practices employed by local agencies.

The *Michigan Local Agency Culvert Inventory Survey* was created by the TAMC Bridge Committee and distributed to local agencies with a letter summarizing the importance of this survey. The survey was conducted from March 6, 2018 through March 14, 2018 and is included in Appendix B. Response to the survey was overwhelming; 141 responses were received from local agencies. From this survey, conclusions were made about the current status of local agency culvert inventories; the data available in these inventories; condition rating methods; data storage methods; inventory/inspection differences related to culvert size; inspection equipment; frequency of inspection; and whether an agency would be interested in participating in this pilot study.

The map shown in Figure 3-1 shows the status of local culvert inventories compiled from the survey responses. The data represents complete responses (whose who filled out the entire survey) where the respondent indicated they were interested in participating in the pilot. Some agencies (60 respondents) completed the survey but indicated they would not be able to participate in the pilot. While those agencies do not show up in Figure 3-1, the data they provided was helpful in laying the groundwork for the inventory and condition evaluation components of the pilot. The data is broken into two categories based on the type of agency responding to the survey: city/village/township, and county road agencies. Those responses are then broken into three subcategories: Tier 1, Tier 2, and Tier 3. Counties where the MDOT Culvert Mapping Project occurred on state highways are also indicated.

- Tier 1 - identifies agencies (39 respondents) that have not inventoried or condition evaluated culverts within their jurisdiction.
- Tier 2 - identifies agencies (33 respondents) that have a portion of their culverts inventoried, but none or very few have had their condition evaluated on a routine basis (at least once every 5 years).
- Tier 3 - identifies agencies (9 respondents) that have most of their culverts inventoried and condition evaluated on a routine basis (at least once every 5 years).

The map shown in Figure 3-1 was generated based on the respondent's geographical information. If the respondent represents a county, that county is highlighted on the map. If they represent a city, village, or township, then a zip code was used and highlighted on the map. The regions identified on the map were generated using Excel's 3D Map add-on. Cities with multiple zip codes were assigned one zip code for the purpose of generating the map: exact agency boundaries may not be represented. A full list of the participating agencies, the county/zip code of the agency, and agency's tier is presented in Appendix C.

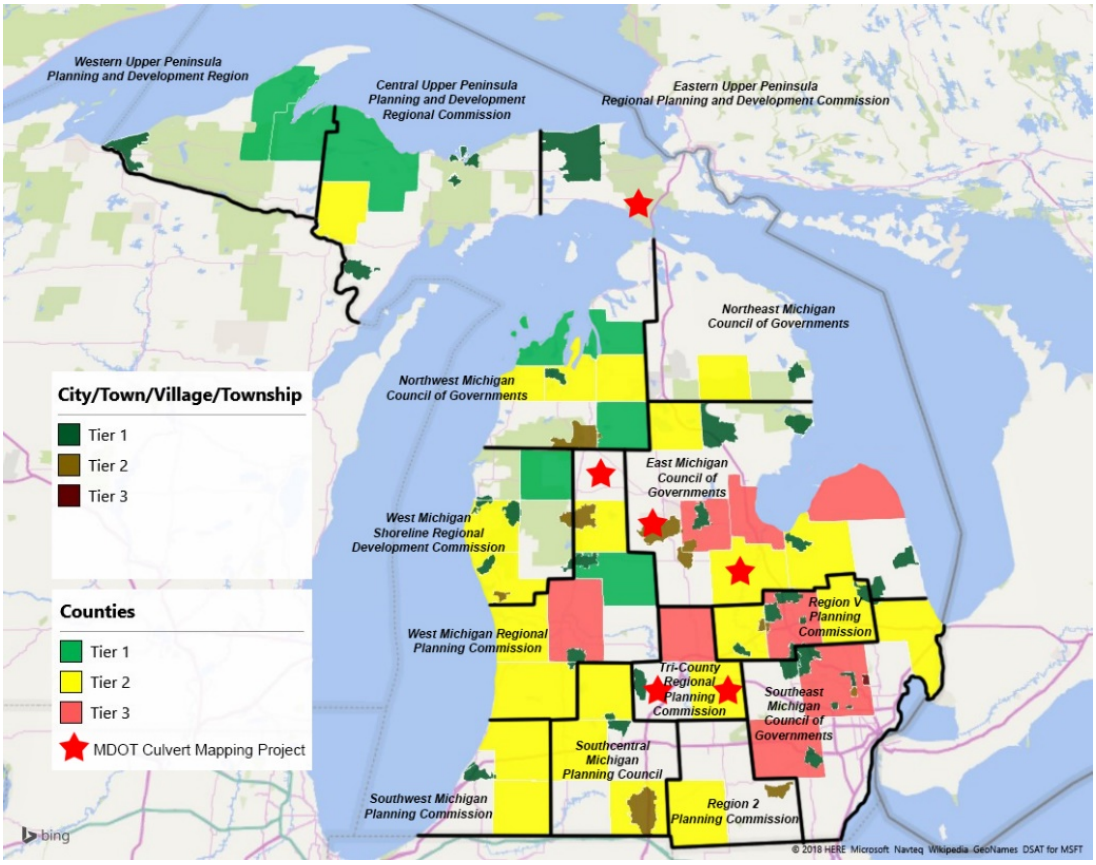


Figure 3-1: Willing pilot respondents & state of local inventories

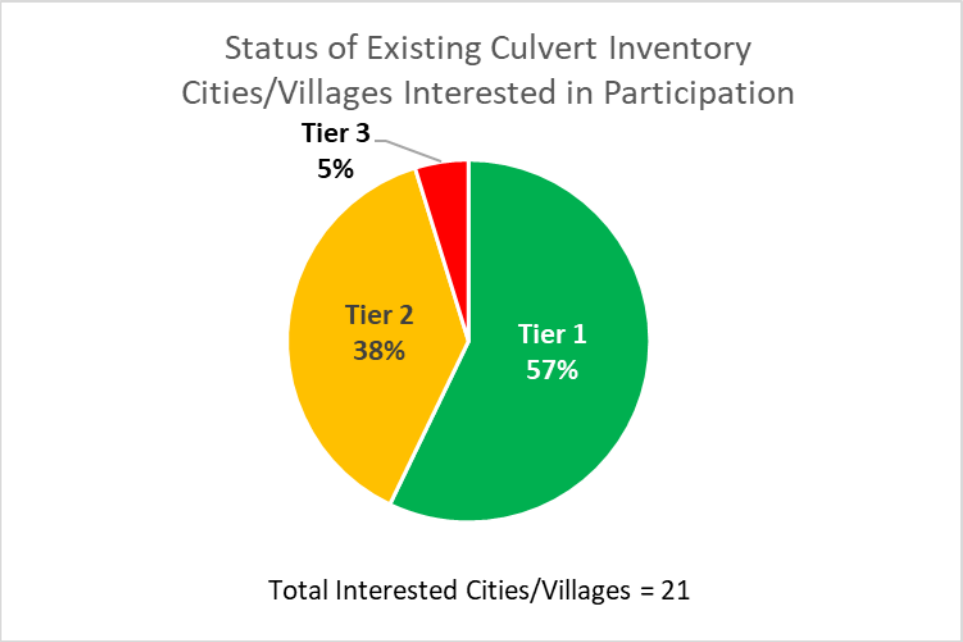


Figure 3-2: Willing pilot respondents by tier – city/village road agency

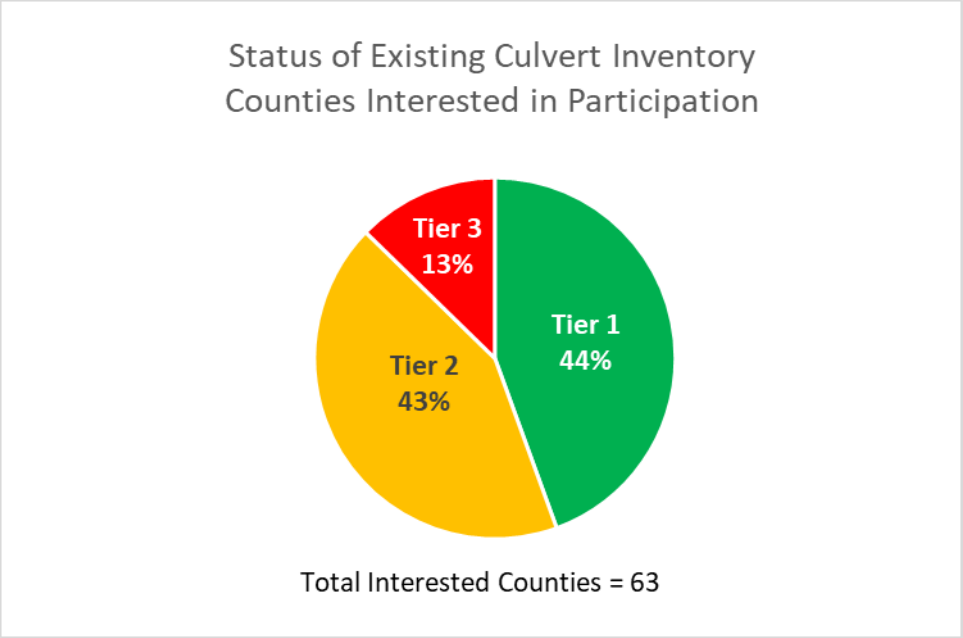


Figure 3-3: Willing pilot respondents by tier – county road agency

Table 3-2: Culvert pilot survey respondents

Tier	Round	RPO	Agency Type	Agency
2	1	WMRPC	County	Allegan County Road Commission
1	1	Networks Northwest	County	Antrim County Road Commission
1	2	WUPPDR	County	Baraga County Road Commission
2	2	SCMPC	County	Barry County Road Commission
3	1	EMCOG	County	Bay County Road Commission
2	1	Networks Northwest	County	Benzie County Road Commission
2	2	SCMPC	County	***Branch County Road Commission
2	2	SCMPC	County	Branch County Road Commission
2	2	SCMPC	County	Cass County Road Comission
1	2	SCMPC	City	City of Battle Creek
1	2	SWMPC	City	City of Benton Harbor
2	1	WMRPC	City	City of Big Rapids
2	2	SEMCOG	City	City of Bloomfield Hills
1	1	EMCOG	City	City of Brown City
1	2	GLS-Region V	City	City of Burton
2	1	Networks Northwest	City	City of Cadillac
1	2	GLS-Region V	City	City of Clio
2	2	SCMPC	City	City of Coldwater
1	1	EMCOG	City	City of East Tawas
1	2	SEMCOG	City	City of Farmington Hills
1	2	GLS-Region V	City	City of Fenton
1	2	WUPPDR	City	City of Ironwood
1	2	SEMCOG	City	City of Lake Angelus
2	2	SEMCOG	City	City of Marysville
2	1	EMCOG	City	City of Mt. Pleasant
1	2	CUPPAD	City	City of Munising
2	2	WMSRDC	City	City of Muskegon Heights
3	1	SEMCOG	City	City of Rochester Hills
1	2	SEMCOG	City	City of Southfield
2	1	EMCOG	City	***City of St. Louis
2	2	Region 2 PC	City	City of Tecumseh
1	1	EMCOG	City	City of West Branch
1	2	WMSRDC	City	City of Whitehall
3	1	TCRPC	County	Clinton County Road Commission
2	2	CUPPAD	County	Dickinson County Road Commisison
3	1	GLS-Region V	County	***Genesee County Road Commission
2	1	Networks Northwest	County	Grand Traverse County Road Commission
2	2	Region 2 PC	County	Hillsdale County Road Commission
1	2	WUPPDR	County	Houghton County Road Commission

Tier	Round	RPO	Agency Type	Agency
3	1	EMCOG	County	Huron County Road Commission
2	2	TCRPC	County	Ingham County Road Department
2	1	Networks Northwest	County	Kalkaska County Road Commission
3	1	WMRPC	County	Kent County Road Commission
1	2	WMSRDC	County	Lake County Road Commission
2	2	GLS-Region V	County	Lapeer County Road Commission
1	1	Networks Northwest	County	Leelanau County Road Commission
1	2	CUPPAD	County	Marquette County Road Commission
2	1	WMRPC	County	Mecosta County Road Commission
3	1	EMCOG	County	Midland County Road Commission
1	1	Networks Northwest	County	Missaukee County Road Comm.
1	1	WMRPC	County	Montcalm County Road Commission
2	2	WMSRDC	County	Muskegon County Road Commission
2	2	WMSRDC	County	Oceana County Road Commission
2	2	NEMCOG	County	Oscoda County Road Commission
2	1	WMRPC	County	Ottawa County Road Commission
3	1	SEMCOG	County	Road Commission for Oakland County
2	2	SCMPC	County	Road Commission of Kalamazoo County
2	1	EMCOG	County	Roscommon County Road Commission
2	1	EMCOG	County	Saginaw County Road Commission
2	2	GLS-Region V	County	Shiawassee County Road Commission
2	2	SEMCOG	County	St Clair County Road Commission
2	1	EMCOG	County	Tuscola County Road Commission
2	2	SWMPC	County	Van Buren County Road Commission
1	1	EMCOG	City	Village of Carsonville
1	1	WMRPC	City	Village of Caledonia
1	2	CUPPAD	City	Village of Daggett
1	1	EMCOG	City	Village of Fairgrove
1	2	SEMCOG	City	Village of Holly
1	1	WMRPC	City	Village of Howard City
2	2	GLS-Region V	City	Village of Lennon
1	2	NEMCOG	City	Village of Lincoln
1	2	GLS-Region V	City	Village of Morrice
1	2	EUPPRDC	City	Village of Newberry
1	2	WMSRDC	City	Village of Pentwater
1	1	EMCOG	City	Village of Sanford
1	2	TCRPC	City	Village of Vermontville
1	2	WMSRDC	City	Village of Walkerville
3	1	SEMCOG	County	Washtenaw County Road Commission

Agencies marked with *** initially committed to participate in the culvert pilot but had to withdraw once the pilot started due to various reasons.

Note: In Table 3-2, the colored cells represent agencies willing to participate as depicted similarly on the map in Figure 3-1. Table cells without a background color represent agencies that responded to the survey but were unwilling or unable to participate.

As shown in Figure 3-2 and Figure 3-3, it is evident that many of the agencies fall in either Tier 1 or Tier 2, with a much smaller number of agencies falling under Tier 3. Therefore, the need for such a pilot study is apparent; most Michigan local agencies are currently not collecting culvert inventories and condition evaluations or are doing so infrequently.

Respondents were asked about the culvert attributes (items) for which they collect data as part of their inventory and condition evaluations. The number of respondents collecting each of the items identified in the survey is presented in Figure 3-4. All responses to the survey were used to create this chart, not just those indicating an interest in participating in the pilot. The top four inventory items were; material type, shape, length, and height/diameter. Some inventory items recorded that were not included on this chart include footing type and railing information, which were recorded by only one agency. Many Tier 2 responses indicated that data was; often collected during maintenance operations, was based on existing drawings, and/or was basic and incomplete. Guidance and common statewide inventory and condition evaluation practices would help to standardize the data collected by local agencies.

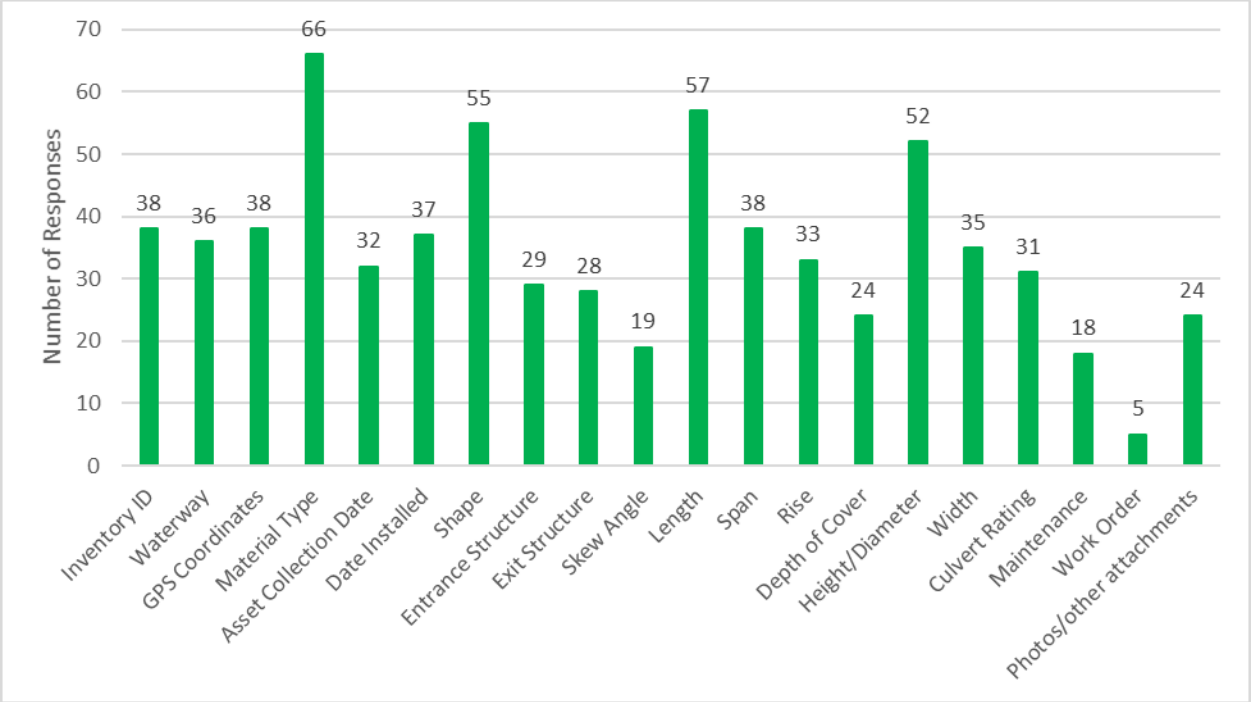


Figure 3-4: Inventory data collected by agencies surveyed

3.2.1. *Data Storage*

Of the survey respondents, there were many variations in how inventory data was organized and stored. Common data storage methods included Roadsoft, paper files, spreadsheets, Geographical Information System (GIS) databases, or other asset management software such as MiBridge or Lucity. Many agencies indicated that they currently store inventories on paper or spreadsheets but are moving towards incorporating the data into an asset management software program or GIS database. Figure 3-5 shows a breakdown of data storage methods used by participating agencies.

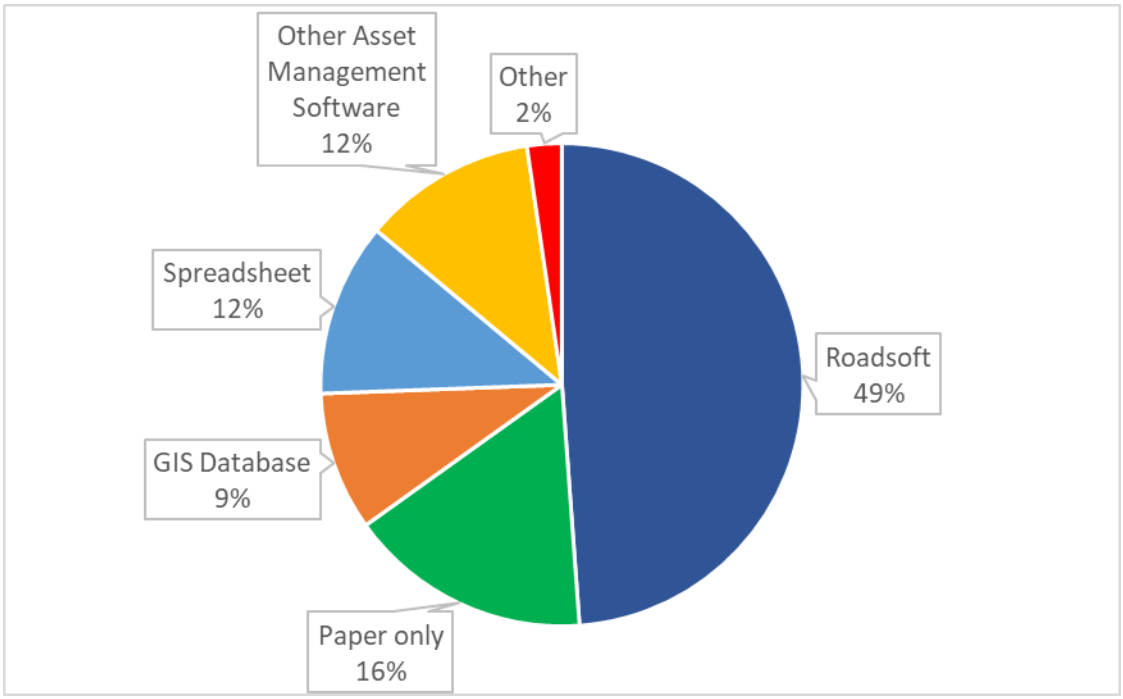


Figure 3-5. Breakdown of data storage methods from participating agencies

3.2.2. *Culvert Sizes*

Most responding agencies did not indicate they subdivide their culverts for the purpose of inventory and condition evaluation, either by a lack of response or by directly indicating so. However, of the participating agencies that do subdivide their culverts, there were several different methods of subdivision, mainly by size, material type, and need for maintenance. Some county road agencies were found to separate culverts by size into categories 2 to 5 feet and below, and 5 to 20 feet. Tuscola County Road Commission (CRC) indicated this was due to different funding sources for maintaining different sized culverts, and Kent CRC indicated this was for inspection frequency: giving priority to the larger culverts. Bay CRC separated culverts into less than 10 feet and 10 to 20 feet. Branch CRC separated culverts into 3 feet and below, 3 to 6 feet, 6 to 10 feet, and 10 to 20 feet. MDOT separated culverts into categories of 1 to <10 feet and 10 to <20 feet.

Subdivision of culverts by size was primarily due to establishing maintenance priorities linked to the condition rating of the culvert for the purpose of asset management practices. Agencies also subdivided culverts by material type to assist with evaluating culvert deterioration and to effectively plan maintenance projects.

3.2.3. *Condition Rating*

Several different condition rating systems are used by agencies that evaluate the condition of their culverts. Many agencies use the previously described FHWA system presented in the 1986 *Culvert Inspection Manual*, which is the system used by Roadsoft. Other common rating systems indicated by local agencies were a good/fair/poor system, and a simple visual inspection system with no rating scale. Bay CRC uses the National Bridge Inventory (NBI) inspection criteria to rate culverts spaning 10 to 20 feet in accordance with the MDOT pilot proposal (MDOT 2016). It appears that most agencies store the condition evaluation data in the same location as their inventory data.

3.2.4. *Inspection Frequency*

The level of inspection varied greatly between agencies. Some agencies rated the condition of the pipe and structural components, while others also rated: the flow conditions, erosion around the culvert, amount of sediment obstructing the culvert, entrance/exit structure conditions, pavement condition, and guardrail condition, among other ratings. There was little consistency in what should be rated to meet the needs of the local agencies.

Inspection frequency varied greatly among Tier 3 agencies. Inspections occur once every three to five years depending on the agency, with some variation based on culvert size and condition. Many agencies responded that inspection frequency varies by culvert size with more frequent inspection performed on larger culverts rather than smaller culverts. Some agencies indicated they do not evaluate the condition of their smaller culverts at all. Some agencies perform inspections based on the last recorded culvert condition: the worse the culvert condition, the more frequent the inspection.

3.2.5. *Equipment*

Equipment used to perform these inspections also varied between agencies, although there are similarities. Most agencies provided waders, tape measures, pick hammers, and flashlights to their inspectors. Other common inspection equipment included a GPS, cameras, laptops with asset management software, probe rods, and shovels.

4. ASSESSMENT OF BEST PRACTICES FOR USE IN PILOT

Based on the results of the literature review and survey, best practices were developed for recommendation in the local agency pilot. These best practices are summarized in this section.

4.1. Culvert Sizes to be Inventoried

Culvert sizes to be inventoried and condition evaluated in this pilot will match the FHWA definition of a culvert; all structures under 20 feet. The nationwide literature review indicated that many agencies collecting data on culverts break them down into two categories; small structures that mostly serve hydrological roles, and larger structures that tend to be treated more like bridges when it comes to inspection and evaluation. MDOT has an established system for inspecting structures between 10 to 20 feet. While local agencies may not have inventory or condition evaluation data on structures less than 20 feet, there is a precedent for breaking the inventory down into two categories.

For the purposes of this pilot, it was decided that the culverts to be inventoried will range from 1 to <20 feet with no subdivision leading to different levels of effort in inventory or inspection. This was done to focus on one set of requirements for the pilot and to allow feedback from the participating agencies to determine if there was a need to subdivide culvert inventory or inspection by culvert size.

4.2. Inspection Frequency

The literature review found a great amount of variability in the inspection frequency practiced by states and local agencies with established culvert inspection programs. These frequencies varied between 1 and 10 years and set different intervals depending on culvert size and the last reported condition. Larger culverts and those with lower condition ratings were inspected with greater frequency than smaller culverts and those in better condition. The MDOT culvert pilot resulted in a recommended culvert condition evaluation frequency of two years for culverts 10 to <20 feet and five years for culverts 1 to <10 feet.

Since the duration of the culvert pilot is less than one year, there was no need to establish a frequency at the beginning of the pilot; however, condition evaluation frequency is one of the items to be recommended by the TAMC Bridge Committee as a result of feedback from this pilot.

4.3. Inventory Data

The TAMC Bridge Committee established the following list of items to be collected as part of the pilot:

1. Inventory ID
2. GPS Coordinates
3. Material Type
4. Asset Collection Date
5. Shape
6. Skew Angle
7. Length
8. Span (width)
9. Rise (height/diameter)
10. Depth of Cover
11. Roadway Surface Type
12. Culvert Condition Rating
13. Photographs (optional)

Detailed descriptions of these inventory items were provided to pilot participants during the training sessions and as a handout, both of which are located in the Appendix D. The items selected for the minimum data to be collected as part of the pilot were commonly referenced in the literature review, survey results, and had been used as part of the data collected in the previous MDOT pilot. Additional condition ratings, such as waterway, road surface, and inlet and outlet structure condition ratings were not selected for this pilot to maintain simplicity. Other inventory data was excluded for varying reasons; for example, date installed was excluded because this information is not readily obtainable during a field inspection, and may be unknown, although an agency could maintain this information for their records. Data such as municipality and road name are included in the inventory ID, and therefore do not need separate entries in data collection. A comparison was performed between the data selected for this pilot and the data collected in the MDOT pilot; inventory data inputs in Roadsoft; and inventory inputs to the Michigan Geographic Framework to ensure all required data could be stored in existing databases and was consistent with other pilots conducted in Michigan. A table showing this comparison is displayed in Appendix E.

4.4. Data Collection Software

Roadsoft was selected as the software data collection tool to be used for training aspects of the pilot. Roadsoft is a roadway asset management system for collecting, storing, and analyzing data associated with transportation infrastructure. Roadsoft is built on an optimum combination of database engine and GIS mapping tools. Roadsoft is provided at no cost to all local road agencies in the state. Survey results showed that local agencies were already familiar with Roadsoft, thereby lessening any learning curve and making the overall training process more efficient. Use of a common software program helps ensure data consistency, format, structure, and compliance statewide. Roadsoft was not required for participation in the pilot,

however. Participants were free to use their own data collection system as long as they were able to upload their data electronically into the statewide data system.

4.5. Recommended Data Collection Equipment

Recommended equipment to be used in the pilot included:

- Standard Personal Protective Equipment (PPE, for safety)
- A flashlight (for inspection)
- A tape measure (for measuring culvert width and height/diameter)
- A probe rod / shovel (for inspection and culvert locating)
- A chipping hammer (for inspection)
- Magnet (to assist in identifying steel culverts)
- A rugged tablet with:
    - Roadsoft LDC (or similar software for data storage)
    - A compass app (for measuring skew angle)
    - Camera (for photographs)
- A laser distance measure (for culvert length, was selected over a measuring wheel for safety by reducing the need for crossing the road to make measurements)
- An auto level and grade rod (for depth of cover).

4.5.1. *Windows 10 Ruggedized Tablet*

With Roadsoft LDC and Roadsoft being the primary software tools for the collection and storage of culvert data for the pilot project, the CTT investigated several mobile and portable computing devices to streamline collecting data in the field. It was assumed that field conditions would be challenging with difficult terrain, moisture, and heavy cover all making it difficult to use a typical laptop during data collection. The CTT wanted to find devices that had a built-in GPS for geolocating the culverts, had the computing power to efficiently run Roadsoft LDC, had a built-in camera, and most of all was rugged enough to withstand field-use conditions. After a thorough search and comparison of various devices on the market, it was decided that a ruggedized Windows tablet would meet the criteria.

The CTT then did a comprehensive comparison of ruggedized tablets on the market taking into consideration the tight timeframe of the pilot project, the availability of the tablets as there would potentially be forty or more needed, specifications, performance, user reviews, and price. The CTT found that to ensure accuracy and software compatibility, a dedicated GPS receiver chip was needed, not a shared LTE chip that many mobile network compatible computers use. During the research it was discovered that the vast majority of the tablets on the market with dedicated GPS receivers all used the same internal GPS chip manufactured by u-blox. With that being the case, it was assumed that all the tablets would perform equally regarding GPS performance. Based on specifications (screen size, memory, processor, battery,

etc.) the CTT narrowed the choices down to three possible tablets – Getac F110, MobileDemand T1600, and Trimble T10. All three tablets had similar specifications, similar physical size, the same GPS receiver, and were all roughly in the $2-3k range.

Based on comments and technical support calls received, there was a learning curve and general issues with running Windows 10 in tablet mode, as well as some GPS connection issues. Even with these minor issues, the tablets ran Roadsoft LDC well and worked as intended in the field.

Based on technical support calls and emails, and comments received in person and over the phone, the CTT created a short guide for tablet users to configure Roadsoft LDC to work with the built-in GPS. The instructions are included in Appendix F.

4.6. Condition Evaluation Method

The FHWA condition evaluation method, as presented in the 1986 *Culvert Inspection Manual,* was selected as the method to be used for the pilot because it is well established and widely implemented by numerous agencies. The FHWA method was modified to include a rating approach for plastic pipe and timber culverts based on content found in the literature review. Other condition evaluation methods were considered but not selected. Due to its additional qualitative and quantitative rating descriptions to the FHWA *Culvert Inspection Manual*, the 2017 Ohio DOT *Culvert Inspection Manual* was used as the primary source for developing the rating descriptions for corrugated metal; concrete; plastic; masonry; and slab and abutment culvert types. It was also used to develop descriptions for joints/seams, blockage, and scour. These rating descriptions were supplemented with rating descriptions directly from the FHWA manual when necessary, such as for the CMP Section Deformation rating chart. Because there was limited information for evaluating timber culverts in these sources, the rating chart for timber culverts was created based on the 2018 Wisconsin DOT *Bridge Inspection Field Manual,* which provided useful descriptions of problems affecting timber structures and associated ratings. Rating evaluation charts were developed to assist inspectors with assigning ratings in the field. These charts are provided in Appendix G along with supporting documentation.

Figure 4-1: Antrim CRC inspecting a concrete box culvert

The NCHRP method was not selected due to its draft status pending implementation as an AASHTO standard. The 2008 Midwest Regional UTC method was not picked due to its complexity and the resulting single overall rating value was not considered helpful for asset management practices as it makes maintenance assessment difficult. For example, debris could lower the culvert's overall rating as could structural failure of a pipe. Debris can be removed through standard maintenance whereas the structural failure likely requires replacement of the culvert.

4.7. Inventory and Condition Evaluation

Culverts were rated based on six condition criteria:

- **Invert deterioration** is the condition of the invert of the culvert, or the condition of the structure's footings if no invert is present on the structure. Conditions affecting inverts include abrasion-related damage and corrosion.
- **Structural deterioration** refers to the state of the culvert outside of the invert area. Conditions related to structural deterioration include corrosion-related damage resulting from soil acidity.
- **Section deformation** can be identified as changes from a culvert's original shape; deflections, and buckling, mainly due to stresses from loading. Section deformation is evaluated by inspecting the culvert shape and comparing it to the original design.
- **Joint/seam condition** describes the condition and alignment of the culvert segments or plates. Joints and seams are inspected for misalignment, offset, soil infiltration, and water exfiltration.

- **Channel blockage** from soil and/or debris affecting the flow of water through the culvert is evaluated and reported as the amount of blockage in the culvert and whether there is presence of pooling water.
- **Scour** is erosion of the embankment or trenching of the inlet/outlet due to water flow or debris. Inspectors will look for scour holes and their severity, condition of the embankment erosion as it affects any cutoff walls or headwalls, and any undermining of the footings at the inlet/outlet.

Roadsoft LDC allows inspectors to input individual ratings for each of these culvert components, and Roadsoft LDC will automatically select the lowest of these six ratings as the overall culvert condition rating. Inspectors can, however, overwrite this lowest rating selection with the rating of another culvert condition if it is believed to be more representative of the overall culvert condition.

Rating evaluation charts were developed to assist inspectors with assigning ratings in the field. A chart was developed for each culvert type considered in the pilot; corrugated metal pipe (CMP), concrete, plastic, masonry, slab and abutment, and timber culverts. These charts are provided in Appendix G along with supporting documentation.

5. DEVELOPMENT OF PILOT TRAINING AND RESOURCES

Statewide training programs for local agencies and consultants were developed to help ensure inventory and condition evaluation data were collected, reported, and submitted consistently. Three training webinars were developed; one for inventory collection and data storage, another for condition evaluation, and a third to demonstrate how to submit the collected culvert data. The first two training sessions, which were held prior to the culvert pilot commitment deadline, were each offered twice for increased participation in an effort to give potential participating agencies the information they needed to decide whether to participate in the pilot project. Recordings of all three training webinars were made available for viewing shortly after the conclusion of each of the training sessions.

5.1. Culvert Pilot Training

5.1.1. *Culvert Data Collection Using Roadsoft*

This training module was developed to provide an overview of the pilot and focus on three of its primary aspects: equipment, data collection, and data validation. The webinar included details on recommended equipment for culvert data collection, completing data collection with Roadsoft using visual walk-throughs of the software to explain the processes needed to collect each piece of information, and covered the overall process of data management and reporting methods for the completion of the pilot.

This training module was presented as a webinar on April 25, 2018 and again on May 1, 2018. Attendance totaled 78 and positive feedback was received. The presentation slides from this webinar are located in Appendix I. The recording of the April 25, 2018 webinar is available at http://mtu.adobeconnect.com/pgqdij7ilhma/

5.1.2. *TAMC Michigan Local Agency Culvert Pilot Condition Evaluation Training*

This training module gave an overview of the required inventory data categories and provided a standardized method for collecting each piece of information. Recommended data collection equipment was also presented. Culvert characteristics and related vocabulary were addressed to clarify what each measurement or condition evaluation was analyzing. Rating tables were provided to assist in the field with condition evaluation. Example culvert photos were presented and participants were asked to rate them appropriately. These culvert photos included examples on every material type considered in the pilot, along with a variety of culvert conditions. Once participants attempted to rate each picture, the correct condition evaluation was shown and discussed with reference to the culvert rating table. This process was crucial for participants to understand how to use the culvert rating tables in the field to produce consistent, standardized condition ratings. The training also explained how the individual component ratings would be combined into a single overall culvert rating.

This training module was presented as a webinar on April 26, 2018 and again on May 2, 2018. Attendance totaled 83 and positive feedback was received. The presentation slides from this webinar are available in Appendix J. The recording of the April 26, 2018 webinar is available at http://mtu.adobeconnect.com/pnbo6uxmkt07/

5.1.3. *Michigan Local Agency Culvert Data Submittal Training*

This training module provided an overview of the culvert pilot data submittal process using Roadsoft. The training also covered data submission for agencies not using Roadsoft. A refresher was presented on building networks in Roadsoft for tracking the centerline-miles traveled in the data collection efforts. Submitting the daily logs and any other data related to the project to the CTT was presented at the end of the training.

This training module was presented as a webinar on July 24, 2018. Attendance totaled 65. The presentation slides from this webinar are available in Appendix K. The recording is available at http://mtu.adobeconnect.com/p0gdmzzygp35

5.2. Other Resources

5.2.1. *Frequently Asked Questions*

The CTT created a "living" Frequently Asked Questions (FAQ) document based on questions asked during the webinars, via email, and over the phone. The document was updated periodically as the pilot project proceeded. The document covered questions ranging from important dates, to funding specifics, to overall project guidance. The FAQ document is included in Appendix H.

5.2.2. *Daily Data Collection Logs*

In addition to the FAQ, the CTT also created a daily data collection sheet template for agencies to record and track activities related to the culvert pilot. The collection sheet is a typical daily log asking for date; start and end times; specifics about the activity being performed; the number of people on the collection team; the miles driven; the number of culverts rated and/or inventoried; and any notes. These logs allowed the CTT to estimate the amount of effort needed per culvert, culverts per hour, etc. The CTT also created a list of equipment recommendations.

5.2.3. *TAMC Culvert Pilot Web Page*

The CTT created a *TAMC Culvert Pilot* web page to house commonly used working files including a *Windows Tablet Setup Guide*, various driver files for the Windows tablet, and links to the various webinar recordings. The CTT *TAMC Culvert Pilot* web page can be found at: http://ctt.mtu.edu/tamc-culvert-pilot

The FAQ and other culvert pilot related files, along with copies of the presentations given during the two training webinars, are hosted on the Support page of the Michigan Transportation Asset Management Council's website at : https://www.michigan.gov/tamc/0,7308,7-356-82159---,00.html

5.3. Participating Local Agencies & Reimbursement Policy

Given the fixed budget, an unknown number of culverts that agencies would be collecting data on, and an unknown number of agencies that were going to commit to participate in the pilot, the TAMC bridge committee discussed several funding options and scenarios to equitably distribute the funding amongst the participating agencies. The TAMC bridge committee decided that all agencies that responded to the survey were eligible to participate in the pilot project. Based on the survey results, agencies were divided into tiers based on their existing level of culvert inventory as discussed in Section 3.2. Agencies were then organized into "rounds" based on their tier and geographical proximity to other responding agencies. The first round included

all Tier 3 agencies, and all other agencies that fell within the overall RPO/MPO boundary of the response hotspots. The second round included all other agencies that responded to the survey.

It was determined that all participating agencies were to receive a fixed mobilization reimbursement for training, purchasing of equipment to be used on the pilot, and for other pilot-related activities. Counties received up to $10,000, and cities/villages received up to $5,000.

The TAMC bridge committee determined the number of Public Act 51 certified centerline-miles for all agencies that responded to the survey was the upper bound quantity and the only known variable (as opposed to a per-culvert reimbursement) and could therefore be budgeted. It was also believed that much of the culvert inventory effort would be related to the number of centerline-miles traveled while collecting culvert data. Based on that, they determined that the first round agencies were to receive $30/per-centerline-mile where they drove to collect culvert data, not to exceed the agency's Public Act 51 certified total centerline-miles. The TAMC bridge committee couldn't determine the amount of per-centerline-mile funding, if any, for the second round agencies until after the April 30, 2018 commitment deadline. Fifty-two agencies initially agreed to be part of the pilot project. This included twenty-five first round agencies and twenty-seven second round agencies. Once the number of participating agencies was known, the TAMC bridge committee determined that the second round agencies would also receive $30/per-centerline-mile where they drove to collect culvert data, not to exceed the agency's Public Act 51 certified total centerline-miles. Details regarding the first round and second round reimbursements can be found in Section 5.4 and Section 5.5, respectively.

Several agencies approached the committee after the April 30, 2018 commitment deadline indicating their willingness to participate. Those agencies were allowed to participate as volunteers with no reimbursement for expenses. None of the agencies that indicated that they were willing to participate as volunteers submitted data, however. Also, three of the agencies that initially indicated that they were willing to participate decided to withdraw from the pilot after funding was allocated. Participating agencies are shown in Figure 5-1, as well as in Table 5-1.

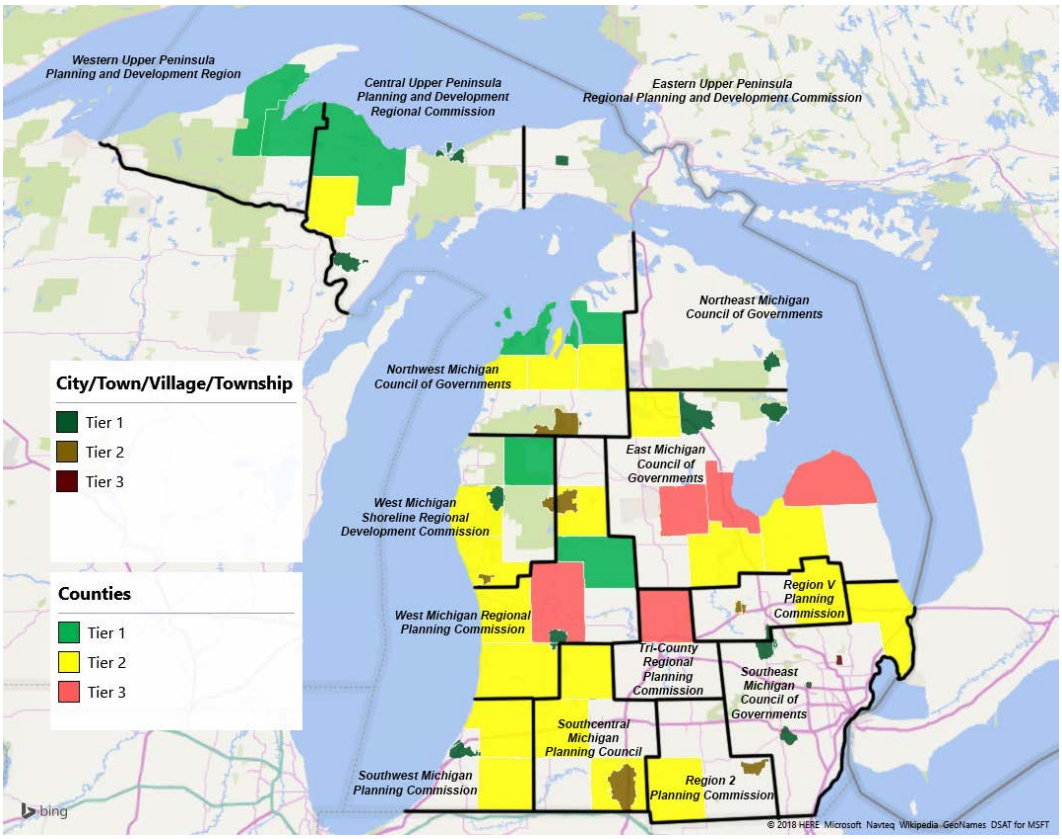


Figure 5-1: Culvert pilot participating road agencies

Table 5-1: Culvert pilot project participating road agencies

Tier	Round	RPO	Agency Type	Agency
2	1	WMRPC	County	Allegan County Road Commission
1	1	Networks Northwest	County	Antrim County Road Commission
1	2	WUPPDR	County	Baraga County Road Commission
2	2	SCMPC	County	Barry County Road Commission
3	1	EMCOG	County	Bay County Road Commission
2	1	Networks Northwest	County	Benzie County Road Commission
2	2	SCMPC	County	Cass County Road Commission
1	2	SWMPC	City	City of Benton Harbor
2	1	WMRPC	City	City of Big Rapids
2	1	Networks Northwest	City	City of Cadillac
2	2	SCMPC	City	City of Coldwater
1	1	EMCOG	City	City of East Tawas
1	2	SEMCOG	City	City of Farmington Hills
1	2	GLS-Region V	City	City of Fenton

Tier	Round	RPO	Agency Type	Agency
1	2	CUPPAD	City	City of Munising
2	2	WMSRDC	City	City of Muskegon Heights
3	1	SEMCOG	City	City of Rochester Hills
2	2	Region 2 PC	City	City of Tecumseh
1	1	EMCOG	City	City of West Branch
3	1	TCRPC	County	Clinton County Road Commission
2	2	CUPPAD	County	Dickinson County Road Commission
2	1	Networks Northwest	County	Grand Traverse County Road Commission
2	2	Region 2 PC	County	Hillsdale County Road Commission
1	2	WUPPDR	County	Houghton County Road Commission
3	1	EMCOG	County	Huron County Road Commission
2	1	Networks Northwest	County	Kalkaska County Road Commission
3	1	WMRPC	County	Kent County Road Commission
1	2	WMSRDC	County	Lake County Road Commission
2	2	GLS-Region V	County	Lapeer County Road Commission
1	1	Networks Northwest	County	Leelanau County Road Commission
1	2	CUPPAD	County	Marquette County Road Commission
2	1	WMRPC	County	Mecosta County Road Commission
3	1	EMCOG	County	Midland County Road Commission
1	1	WMRPC	County	Montcalm County Road Commission
2	2	WMSRDC	County	Muskegon County Road Commission
2	2	WMSRDC	County	Oceana County Road Commission
2	2	NEMCOG	County	Oscoda County Road Commission
2	1	WMRPC	County	Ottawa County Road Commission
2	2	SCMPC	County	Road Commission of Kalamazoo County
2	1	EMCOG	County	Roscommon County Road Commission
2	1	EMCOG	County	Saginaw County Road Commission
2	2	SEMCOG	County	St Clair County Road Commission
2	1	EMCOG	County	Tuscola County Road Commission
2	2	SWMPC	County	Van Buren County Road Commission
1	1	WMRPC	City	Village of Caledonia
1	2	CUPPAD	City	Village of Daggett
2	2	GLS-Region V	City	Village of Lennon
1	2	EUPPRDC	City	Village of Newberry
1	2	WMSRDC	City	Village of Walkerville

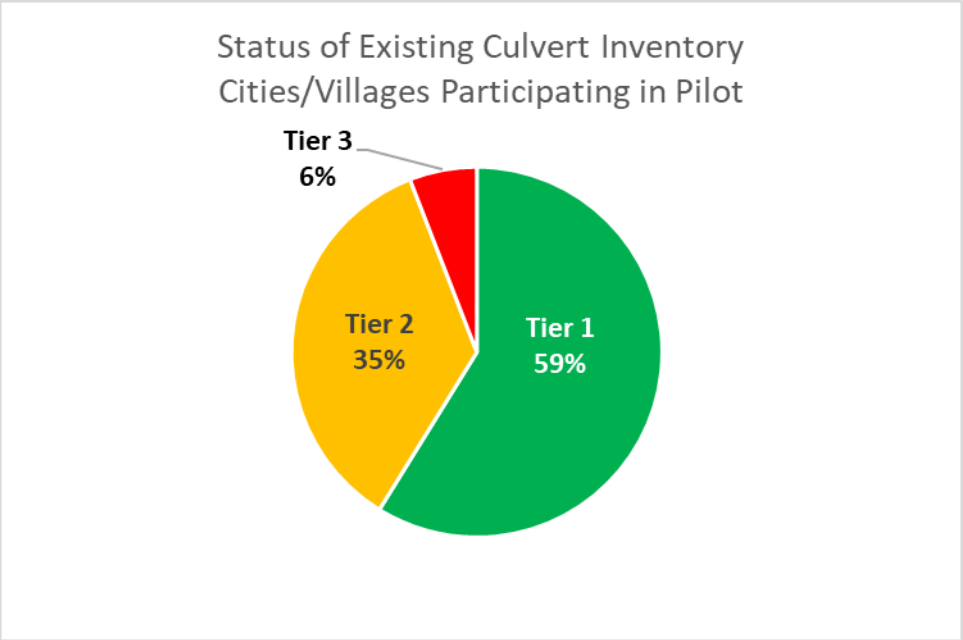


Figure 5-2: Participating agencies by tier - cities/villages

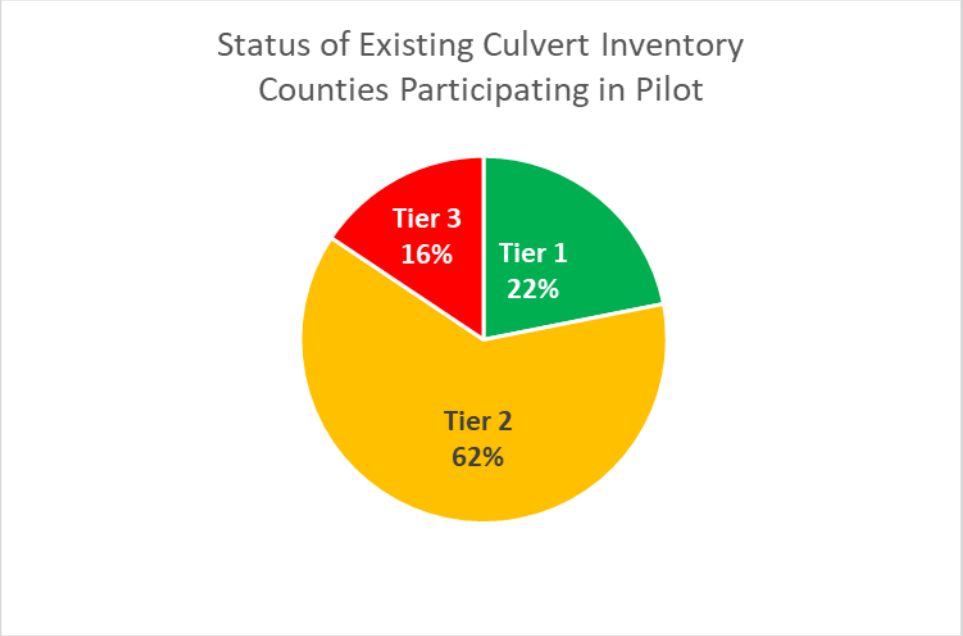


Figure 5-3: Participating agencies by tier – counties

5.4. First Round Local Agencies

The TAMC initially selected twenty-five local agencies to be involved in the pilot based on their willingness to participate and their ability to provide data that would contribute to the statewide determination of the pilot goals. The selection of agencies to participate was at the

sole discretion of the TAMC. First round agencies committed to participate were guaranteed financial support for their pilot activity using the following guidelines:

1) Each first round agency was given a fixed mobilization budget that was based on the relative expense to commit to the pilot. The mobilization budget was intended to compensate agencies for the time necessary to train staff, participate in meetings, and purchase necessary collection equipment. The lump sum amount for each first round agency was awarded as follows:
    a. County road agencies were awarded $10,000.
    b. Cities and villages were awarded $5,000 so long as they certify mileage of public roadways.
    c. Townships that expressed interest in participation of this pilot were not eligible to receive an award; resources will be allocated to the respective County road agencies.
2) First round agencies committed to participate were awarded a per-centerline-mile payment for every centerline mile of road where all data elements are collected for all roadway culverts present in that section. Road mileage that did not contain a culvert is still eligible for reimbursement as long as the agency had field checked and verified that no culverts are present. Existing culvert data could be used for this pilot, but it was to have been field collected in 2013 or later, must reflect the current asset, and be complete.
3) The per-centerline-mile payment for county road agencies will be $30 per-centerline-mile of road where all roadway culverts are submitted
4) The per-centerline-mile payment for cities and villages will be $30 per-centerline-mile of road where all roadway culverts are submitted
5) The total centerline miles of reimbursement cannot exceed an agency's Public Act 51 certified total centerline miles
6) All data will be collected and stored electronically using an approved method (such as Roadsoft) compatible with a state-wide database.
7) All data must have been submitted to the TAMC by July 30, 2018 to qualify for reimbursement.

5.5. Second Round Local Agencies

To maximize the volume of data collected for the TAMC allocated funds, the TAMC also determined that second round local agencies (any local agency that participated in the TAMC culvert survey that was not selected as a first round agency) could also choose to be involved in the pilot. Second round agencies agreeing to participate in the pilot were guaranteed a mobilization budget; however, they were not guaranteed centerline mileage reimbursement for their data collection activity unless there were remaining funds in the $2 million that had not been allocated for other mandatory expenses. Remaining funding that was not allocated by

August 10, 2018 was to be allocated to the secondary funding pool. Twenty-seven agencies initially agreed to participate in the culvert pilot as second round agencies. This pool was allocated to second round agencies using the following distribution guidelines:

1) Each second round agency was given a fixed mobilization budget that was based on the relative expense to commit to the pilot. The mobilization budget was intended to compensate agencies for the time necessary to train staff, participate in meetings, and purchase necessary collection equipment. The lump sum amount for each second round agency was awarded as follows:
    a. County road agencies were awarded $10,000
    b. Cities and villages were awarded $5,000 so long as they certify mileage of public roadways.
    c. Townships that expressed interest in participation of this pilot were not eligible to receive an award; resources were allocated to the respective County road agencies.
2) Second round agencies committed to participate were awarded a per-centerline-mile payment, if funds were available, for every centerline mile of road where all data elements were collected for all roadway culverts present in that section. Road mileage that did not contain a culvert was still eligible for reimbursement as long as the agency field checked and verified that no culverts were present. Existing culvert data could be used for the pilot, but it should have been field collected in 2013 or later, and must reflect the current asset, and be complete.
3) The per-centerline-mile payment for second round agencies was determined to also be $30 per-centerline-mile.
4) The per-centerline-mile rate of reimbursement for second round agencies could not exceed the first round agency rate
5) The total centerline miles of reimbursement could not exceed an agency's Public Act 51 certified total centerline miles
6) All data was collected and stored electronically using an approved method (such as Roadsoft) compatible with a state-wide database.
7) All data must have been submitted to the TAMC by July 30, 2018 to qualify for reimbursement.

5.6. Payment

All reimbursements for first and second round local agencies were processed through existing project authorizations under the Asset Management Unified Work Program with regional and metropolitan planning organizations (RPO/MPO).

Invoices for mobilization payments for first and second round agencies were submitted upon the completion of the required data collection training and the pilot kickoff meeting;

mobilization reimbursement requests were submitted by RPO/MPO on behalf of local agencies using MDOT's standard invoice format with activity reports.

First and second round agency per-centerline-mile payments were approved if all required data was submitted to the TAMC prior to July 30, 2018. A breakdown of the allotted budget is presented in Table 5-2.

Table 5-2: Breakdown of culvert pilot budget

TAMC Culvert Pilot Cost Breakdown				
	Item	**Rate**	**Quantity**	**Total**
Administration, Overhead, & Contingency				
	Administration			164,857
	Overhead	5%	$1,646,153	82,308
	Contingency			106,682
Subtotal				*$353,847*
Round 1 Agencies				
	Mobilization ($10,000/County, $5,000/City or Village)		215,000	215,000
	Centerline Mile Reimbursement	$30	23,126	693,792
Subtotal				*$908,792*
Round 2 Agencies				
	Mobilization ($10,000/County, $5,000/City or Village)		215,000	215,000
	Centerline Mile Reimbursement	$30	17,412	522,361
Subtotal				*$737,361*
Total Pilot Budget				**$2,000,000**
• **Administration includes development and provision of training, data processing, and development of the final report.**				

6. PILOT DATA COLLECTION

Data collection for this pilot occurred over thirteen weeks; local agencies collected and logged data from April through July 2018. This section describes some of the inspection techniques used by local agencies during data collection. It was the responsibility of each participating agency to determine their own best practices and to prioritize culvert data collection based on the types, locations, road classifications, etc.

6.1.1. *Site Visit Information*

Staff from the CTT rode along with nine local agencies to observe their culvert data collection processes. Antrim, Baraga, Benzie, Houghton, Kalamazoo, Lake, Oceana, Roscommon, and Van Buren county road agencies all hosted the site visits. The site visits were conducted in late June

and early July. Site visits were planned for later in the data collection cycle to allow for a "learning curve" and to observe the process after some trial and error in the collection process.

The agencies were selected based on their classifications from earlier in the pilot project representing different Rounds and Tiers; the collection and storage tools that they were using (Roadsoft LDC & tablet vs ArcGIS Collector as an example); and their availability and willingness to participate in a short timeframe.

- Generally, all of the agencies had similar processes for data collection that varied slightly based on the tools they used. The overall process was similar for all agencies regardless of the number of people on the crew. Once the culvert was located, the location was marked in Roadsoft LDC, and the various physical attributes were measured and recorded. If condition evaluation was done, the values and ratings were recorded as well.
- All of the county road agencies visited, except for Antrim, were using Roadsoft LDC to collect their culvert data. Of those eight counties, six were running Roadsoft LDC on a tablet, and the other two were running Roadsoft LDC on a laptop that they kept in the vehicle.
- All of the county road agencies collected data on previously located culverts, while also searching for other unknown culvert locations and collecting data on them if found.
- Benzie, Houghton, Kalamazoo, and Roscommon used a one-person crew to collect data. Antrim used one to two-person crews depending on the day. Baraga, Lake, Oceana, and Van Buren used two-person crews.
- Van Buren also recorded a full stream crossing survey for each applicable culvert, as they received a grant from the Michigan Department of Natural Resources (DNR) to collect aquatic organism passability data.
- Some agencies used a tape, roller wheel, or both to measure the culvert length. Depending on the amount of traffic, they might measure from the end of the culvert to the edge of the road, then measure the road width, then measure from the other edge of road to the other end of the culvert. Others used a laser-measuring device either shot through the culvert to the other side, shot to a marker above the roadway, or in steps similar to the tape method.

Figure 6-1: The Van Buren CRC collected stream crossing survey information in addition to collecting data for the pilot project

6.1.2. *Special Equipment & Techniques*

Agencies that had tools, equipment, or techniques that varied greatly from the other agencies are noted below.

The Antrim CRC was the only county road agency visited that was not using Roadsoft LDC to collect culvert data. Antrim had recently made an investment into the ArcGIS suite of software and tools, including a custom-built ArcGIS Collector interface that replicated the Roadsoft LDC Culvert Module, that they used to collect their data. They sent out one to two-person crews to collect data using an Arrow 100 GNSS remote GPS receiver mounted on a graduated rod at a fixed height of 3.5 feet and an iPad running ArcGIS Collector. The culverts had already been roughly located prior to the data collection by either placing marks on a paper map, or by crews as they traveled the road segments. Once in the vicinity, the actual location was found, the GPS sensor was placed on top of each end of the culvert, and the positions were recorded using the iPad. Depending on the depth of cover, the graduated rod was used, or possibly a tape. If the depth was greater than approximately 6 feet, the elevation data from the GPS points was used. The other physical attributes and condition were then recorded on the iPad.

The Baraga CRC used an older optical Sokkia automatic-level (auto-level) mounted on a tripod at a known fixed height. The auto-level was aligned at the edge of the roadway directly above the culvert and the base angle measuring guide was reset so 90° was parallel with the roadway. They then used a survey rod at the near end to determine the height and then calculate the depth of cover. They then spun the auto-level and put the rod on the far end of the culvert to get a height reading to determine that end's depth of cover. Without moving the auto-level

they were then able to get an angle reading from the base which was used to calculate the skew angle.

The Benzie CRC consultant had a Leica Disto D810 Touch laser measuring device that worked extremely well. The device has a built-in screen to make aiming at a target easy, even in bright sunlight, which was a common complaint with the Bosch unit that CTT suggested. In addition, the unit was able to measure and compute a horizontal distance and vertical distance when measuring at an angle. This was useful for deep or difficult depth-of-cover measurements, as well as culvert length measurements. When possible, the device was used to shoot the distance straight through the culvert to the other end. They also had an older hand-held sight level that was used in difficult or deep depth-of-cover situations when several setups might be required. One interesting thing is that the consultant only recorded the deeper of the two depth of cover readings in Roadsoft LDC, in the event they were different. The reasoning for this was for cost estimating in the event the culvert needed to be replaced. While this reasoning is valid for cost estimation purposes, the smaller depth of cover would likely be the control for structural calculations.

The Road Commission for Kalamazoo County (RCKC) used a Spartan Explorer L200 Sewer Camera System to visually inspect the inside of culverts, if needed or applicable. The system has a camera mounted on the end of a flexible, but somewhat rigid hose on a reel that can be fed through the culvert to view, record video, or take pictures. There are remote controlled LEDs around the perimeter of the camera head to illuminate the inside of the culvert. The entire system is mounted on a wheeled frame to make it fairly portable and easy to maneuver. Once a culvert was located, if not already present the RCKC installed blade-style flexible markers with a retro-reflective RCKC sticker indicating the year. The markers were driven into the ground as near to the culvert as possible but offset from the edge of the road and outside of the obvious mowing path.

The Roscommon CRC used a Quickview airHD wireless sewer camera. This was a completely different type of camera than the Spartan model that Kalamazoo used. The Quickview airHD was a fixed camera head mounted on an extendable, folding rod. The camera was wirelessly controlled via an application that was installed on their Windows tablet. The camera could record HD video or pictures, could be zoomed in to effectively look further into the culvert, and had a laser rangefinder to measure the culvert length. In addition, Roscommon had a Leica Rugby 810 rotating laser level mounted at a fixed height on a tripod. The inspector would set it up at the edge of the roadway, then use a survey rod at the top of each end of the culvert and record the readings.

Many of the agencies also had a survey style metal detector to help find buried metal culverts, which worked well.

Figure 6-2: Oceana CRC using a metal detector to try and locate a culvert

6.2. Jurisdictional Boundaries

For the purposes of this pilot, responsibility for inventory and condition evaluation of culverts located within jurisdictional boundaries was to be determined on a case-by-case bases. Over the course of the pilot no jurisdictional questions were brought before the TAMC Bridge Committee for discussion.

6.3. Collection Strategy

Agencies selected to take part in this pilot were free to propose a collection strategy that best fit their workforce. It was suggested that culverts be located and evaluated at the same time by properly trained field inspectors. However, it was understood that an agency may have unique circumstances whereby efficiency could be found by traveling some routes twice: once to locate culverts and once to evaluate them, as an example.

Some of the selected agencies had a portion of their data already collected. This may have been a partial or complete location inventory of their culverts and may have even included varying amounts of condition evaluation data. Differing evaluation strategies for these agencies was also important in determining the costs for location and condition evaluation of culverts throughout the state.

Lastly, some agencies may have already had an established inventory and condition evaluation system in place. Integration of the data from this system into a centralized database was another important part of the pilot study.

An agency's tier determined their immediate tasks to perform. Agencies with no data would start in Tier 1, whereas agencies with all culverts located and inspected would fall under Tier 3 and would engage in the data processing portion of the pilot. This multi-tiered approach allowed the pilot to extract data at each level of the collection strategy in a shorter amount of time. If an agency starting in Tier 1 was not able to fully process all data in the allotted time frame the process will still be able to be tested by those agencies starting in one of the other tiers.

6.4. Follow-Up Survey

The CTT and the TAMC Bridge Committee sent out a follow-up survey to all participating agencies after the submittal deadline to garner information on lessons learned from the culvert pilot. Thirty-six of the participants responded to the survey. The follow-up survey is included in Appendix L.

Many of the respondents indicated an interest in continuing to collect inventory and condition evaluation data on their culverts. Figure 6-3 indicates the frequencies with which respondents plan to update their inspection and condition evaluations.

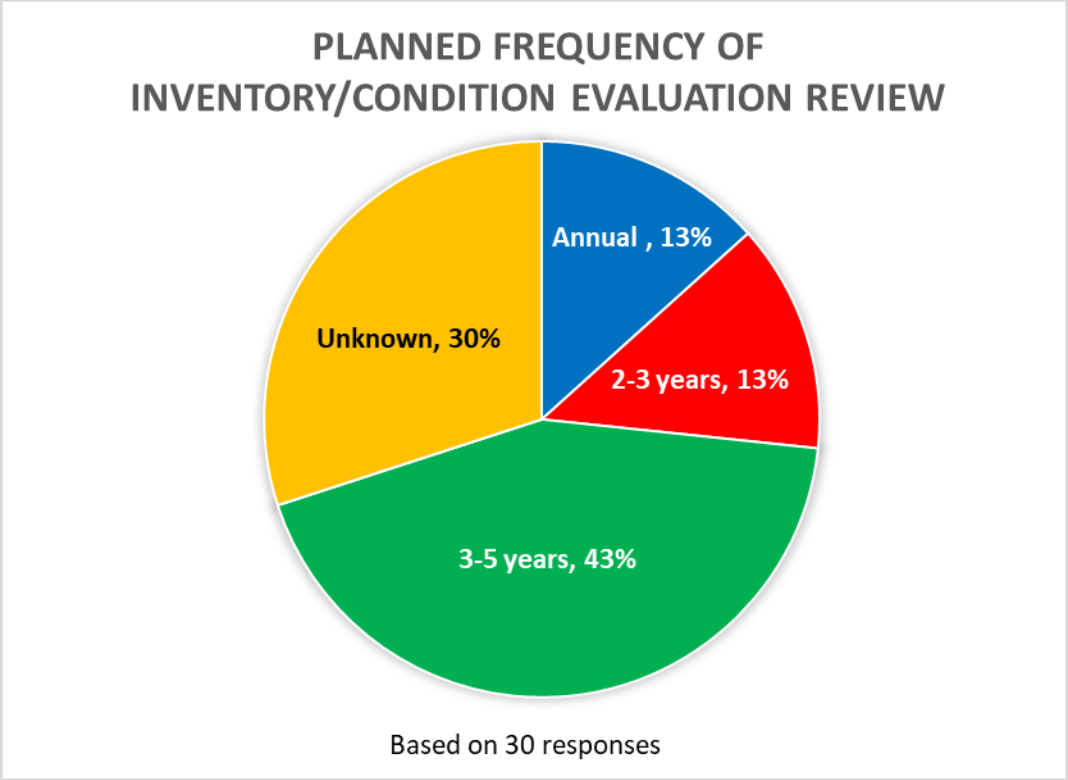


Figure 6-3: Response to question: How frequently do you plan to evaluate the condition of your culverts?

When asked if an agency would vary their collection frequency based on any criteria, many stated that they would conduct an inspection on culverts outside of their determined frequency when a roadway was scheduled for construction; for culverts rated as poor; and for larger culverts.

Nearly all respondents indicated their intent to use the data gathered during the culvert pilot to advance their culvert asset management programs. Many indicated use of the condition evaluations to either add to or create a maintenance plan for addressing culverts in need of replacement. Some indicated the value of knowing GPS located coordinates for culvert locations, as in the past culverts had been located physically in the field, but that practice was no longer being performed. A few respondents mentioned how they had already put their condition evaluation data to work by sending maintenance crews out to clean culverts.

Agencies were not limited in their means of collecting inventory and condition evaluation data. Agencies determined the size of their crew and whether inventory and condition evaluation data was collected by the same crew or different crews. 68% of agencies collected both inventory and condition evaluation data at the same time.

When asked to describe the process used to conduct inventory and condition evaluation data collection at the same time, many of the responses followed the same procedure; drive slowly

down the road looking for signs of culverts, stop and visually confirm location (sometimes requiring a metal detector), take inventory measurements, and conduct condition evaluation. A few participants mentioned already having many of their culverts located electronically and using that as a guide for field-locating. Others, who didn't already have their culverts located electronically, found this to be a more efficient route and spent some time in the office gathering information to assist in field-locating the culvert.

> "Early in the pilot project we just drove the roads looking for culverts and rating them as we came to them. After it became clear to me that some culverts were being missed I went back to construction plans and annual reports (where the information was available) to record the location, size and length and add them into the "Culvert Module" in Roadsoft while in the office. This cut down on the missed culvert and improved our accuracy on size which we verified in the field."

Participating agencies were asked to list the tools they used to participate in the pilot. In addition to those listed in Section 4.5, the following tools were found to be useful or recommended:

- Machete
- Cardboard or mat - for kneeling/laying on to see inside of culvert to prevent contact with poison ivy and other harmful plants, moisture from dew or rain, and heat protection when making contact with the culvert.
- Measuring wheel
- Telescoping level rod for measuring culvert span
- Camera with floatation device/360 degrees
- 3,500 lumen flashlight

Figure 6-4: The Road Commission for Kalamazoo County used a sewer camera to inspect some culverts

Those agencies who separated the inventory and condition evaluation procedures generally sent one crew ahead of the condition evaluation crew to locate culverts, mark them in the field, and if they were not already on a GIS map they were added. The condition evaluation crew could then use the collected location data to quickly find each culvert and conduct the evaluation.

Several agencies found efficiencies by sending out several crews for inventory and condition evaluation:

> "We purchased three sets of equipment. We trained two people from each of our three garages so that we had backup. Anticipating that we would not have enough time to cover all roads, I wanted to get as much rating time as possible. Only one person to a crew so we had three different crews operating most of the time once we started. We were able to cover all roads in the time we had using the three – one-man crews. Each

person would locate, shoot the GPS points and rate the conditions at each location at one time."

Another agency sent out two crews in an organized pattern for standard culverts and combined the two crews for deep culverts which required a greater effort to locate and condition evaluate:

> "We focused on the section line roads in the county first and when those were complete we went into the subdivision streets. We would complete one township before moving to the next township. One crew would survey the east/west section line roads and another would survey the north/south section line roads. For the culverts that appeared to be less than 10' deep the crews would get all measurements and evaluate at that time. For the ones that appeared to be greater than 10' in depth they would mark the GPS location and then team up with the other crew once the rest of the township was finished to get the information on the deep culverts."

The crew sizes varied for each agency, see Figure 6-5. While many of those using one-person crews felt this was adequate, they expressed that two-person crews would be ideal. Those using two-person crews tended to express this as most beneficial. Agencies with two-person crews cited several reasons for this selection; safety concerns (especially with flowing water), division of measuring and recording tasks, and increased efficiency by paring an experienced full-time employee with a summer intern.

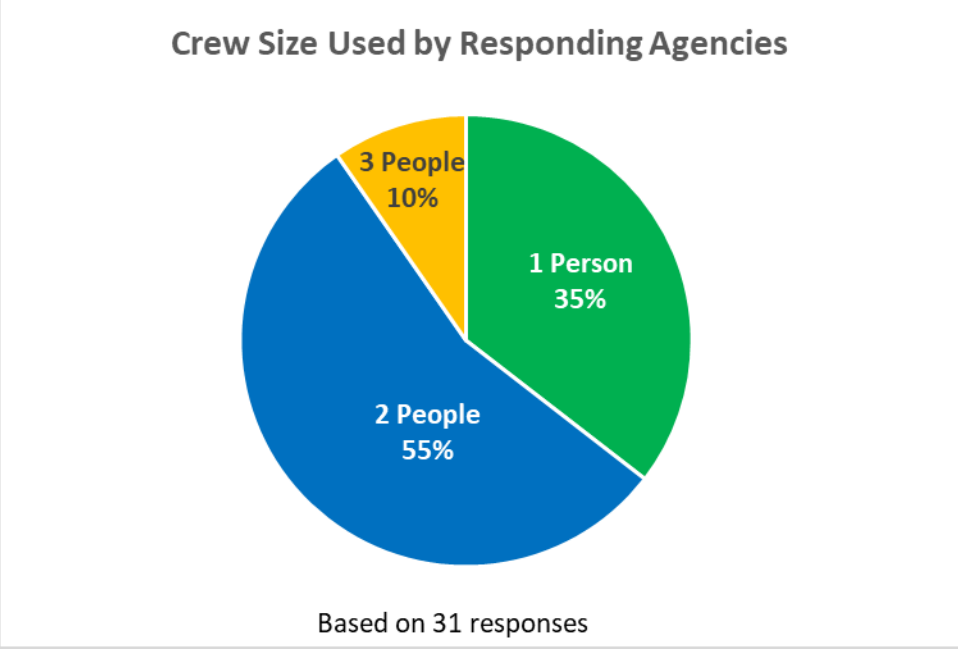


Figure 6-5: Reported crew size used by local agencies for pilot

Survey respondents were asked to estimate the time spent on the inventory and evaluation of each culvert, on average. While the results indicated a wide range of values, with a few more

than an hour, most respondents indicated between 10 and 40 minutes per culvert, see Figure 6-6.

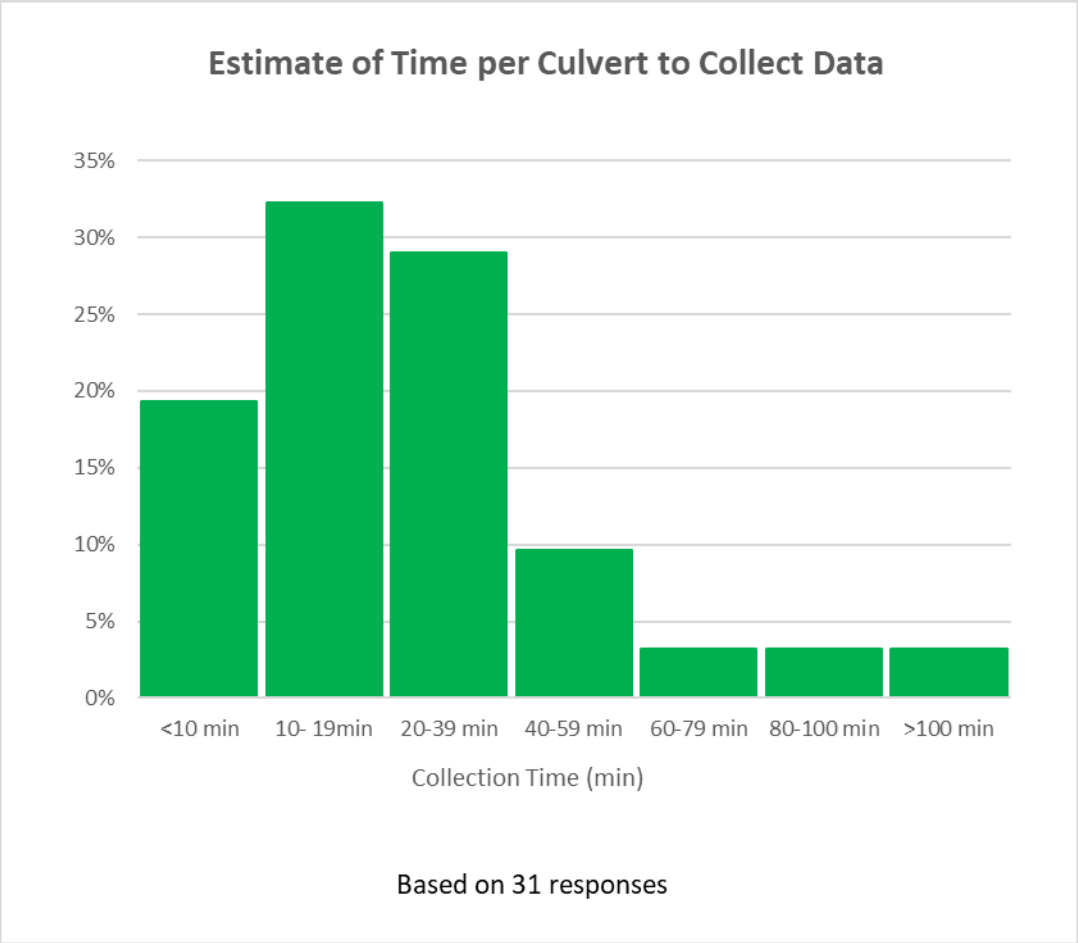


Figure 6-6: Estimated time per culvert for data collection

Survey respondents were asked to recommend an ideal time of year for collecting culvert data. The responses varied greatly; however, the rationale behind most recommendations can be summarized as a balance between minimal vegetation and enough flowing water to help identify culvert locations but not so much to prevent safe evaluation. Many respondents cited poison ivy and thick vegetative growth as a primary issue with the time of year established for the pilot collection. Many cited early spring or late fall as the ideal times for culvert data collection.

Figure 6-7: Many follow-up survey respondents indicated that gathering culvert data would be easier with minimal ground cover

Pilot participants were asked if they did not complete their culvert inventory and condition evaluation, did they plan to do so outside of the culvert pilot. 78% said they planned to complete their inventory and 72% said they planned to complete their condition evaluation, see Figure 6-8 and Figure 6-9, respectively.

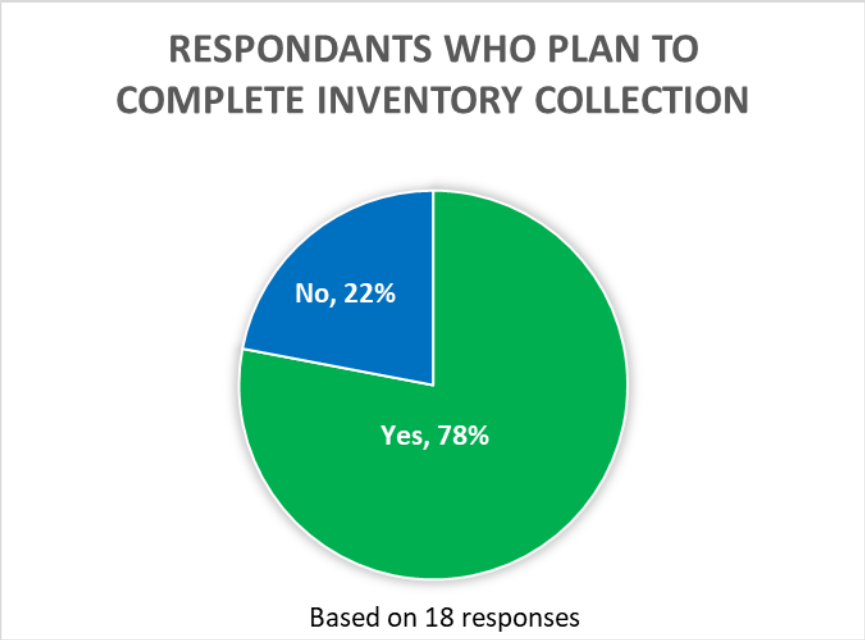


Figure 6-8: Response to question: If you did not complete your inventory, do you have plans to do so?

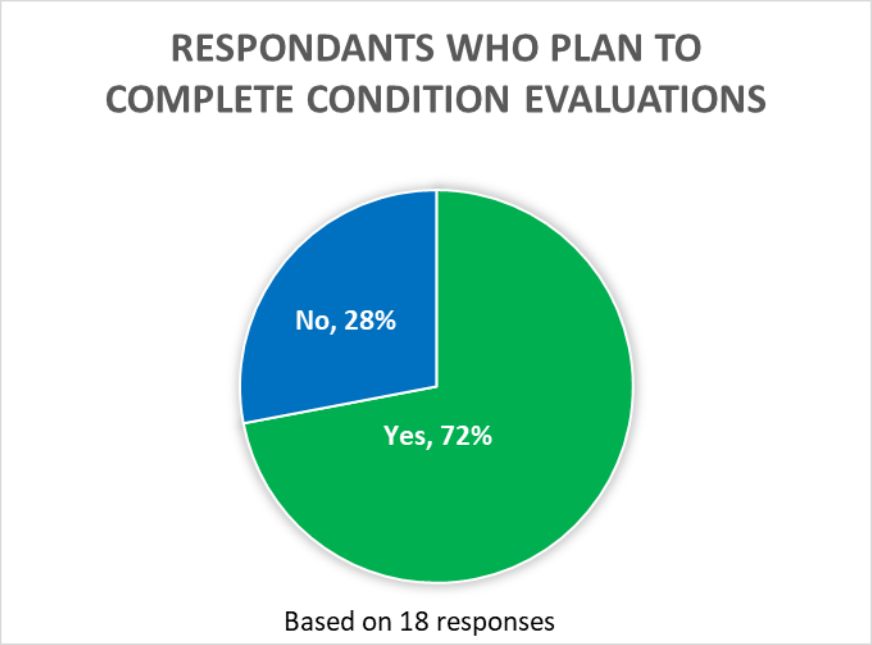


Figure 6-9: Response to question: If you did not complete your condition assessments, do you have plans to do so?

When asked about anything unexpected discovered while conducting the inventory and condition evaluations many agencies cited poison ivy, small animals (ground hogs, skunks, raccoons, mink, and porcupines), and ticks as things to be aware of when approaching a culvert.

In conclusion, survey respondents were asked to share any final comments that they had on the culvert pilot. Representative comments are provided below:

- It was a rushed timeline but we knew that at the start. We would like to continue this process and expand it to other facilities. We already have the primary road guardrail logged but would like to include curb & gutter, catch basins and signs.
- I think the culvert rating system is too complicated. Having 10 rating levels on each category is far more information than we require. The first three categories on the rating, Structural Deterioration, Invert Deterioration, and Section Deformation can all be lumped into one. If anyone of the three are failing, then the culvert is failing. Joints and Seams are usually difficult to determine unless the culvert is large enough to walk into. If we rate the culverts "Good, Fair, Poor and Failed" that would serve the purpose. We replace culverts if we think they have 10 years of life or less when we are resurfacing a road. In other words, if we can poke holes in them anywhere we replace them. Lack of adequate length can also trigger replacement.
- This was a good Pilot Project and we were given adequate guidance and means to be able to collect the data.
- We will continue to evaluate and rate culverts for our own use as time allows. This was a great way to kick-start something that has been a necessity for our county to do for years.
- Hope in the future that the TAMC funds culvert inventory like they do the local road rating.
- Absolutely needs to be completed for every road agency for management and funding. Major, major concern in our county

7. DATA ANALYSIS

During the culvert pilot, local agencies were encouraged to use any methods they preferred to field collect and store data. The wide adoption of Roadsoft as a “one stop application” for local agency asset management, and its fully-developed culvert module with associated GPS enabled data collector made it a popular choice for data collection and storage during the pilot. Roadsoft LDC and Roadsoft were updated during the pilot project to add extra functionality required to address specific needs for the pilot project. At the conclusion of the data collection period, the majority of participants used Roadsoft to submit their culvert data and road network of miles covered directly to the Michigan Department of Technology, Management and Budget (DTMB) Center for Shared Solutions (CSS). The DTMB CSS coordinates the integration, storage, and use of data within the Michigan Geographic Framework. The CTT worked closely with CSS to build the Roadsoft functionality to allow users to upload the data directly to CSS.

Of the 49 agencies that participated in the pilot project, 44 of them used Roadsoft to submit their data. Four agencies used ArcGIS to collect and store their culvert data during the pilot project. One agency used a Microsoft Access database to store their collected data. These five agencies submitted their data to the CTT, who in turn submitted the data to DTMB CSS for processing and placement into the statewide geographic database.

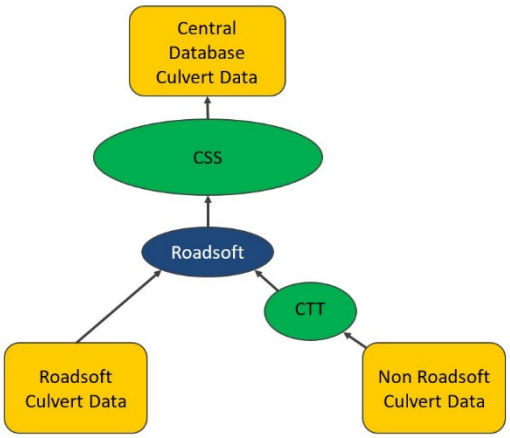


Figure 7-1: Culvert pilot data submittal flow chart

7.1.1. *DTMB Recommendations to Improve Culvert Collection*

Based on their experience with processing and managing data submitted from participating agencies, the DTMB provided suggestions for any larger scale future culvert data collection projects. Data standardization for non-Roadsoft users is one of the biggest things they noted. In addition, they suggested the following:

- Domains for key attributes:
    - Material Type
    - Shape
    - Units
    - Limits for height and width
    - Rating
    - Surface Type
- Required fields should be established that meet the minimum requirement for a valid culvert. Some of the non-Roadsoft agencies submitted data that didn't include all of the data fields that were asked for. There wasn't a way to validate the data or ensure that the minimum requirement was met.
- While the point location in the center of the road can facilitate culvert location, DTMB feels there is greater utility in having the upstream opening and downstream opening located. This conveys directionality, length, and lends itself to hydrologic modeling. It also reduces the error that can come from incorrectly guessing the skew angle. If

elevation could be collected even better. The caveat to this is that it also requires an extremely accurate, survey-grade GPS for data collection.

- Ownership is being inferred from the road network (MGF); however, the source of the culverts should be collected. This can be cross referenced with the road network to identify incongruities. It would also ensure that the agency responsible for the data can be properly identified and contacted if need be.

7.1.2. *CTT Recommendations to Improve Culvert Data*

- Submission from Roadsoft needs to include a FIPSCODE (for City/Village) or FIPSCO (for County) to indicate the agency that is submitting the data to better collate the data and differentiate between collections on boundary roads or on roads that according to Framework are not theirs.
- Passing data through the CTT for collation before passing a complete set to CSS for inclusion in a central database would increase efficiency in data processing.
- Data mapping should be incorporated into Roadsoft to consolidate Culvert Materials identified by various agencies. The pilot data contained numerous labels for corrugated metal pipe due to agency naming preference and misspelling.
- Including photos in the submission may be helpful to an agency but with differing upload speed this could present upload and storage issues. For example, an agency with 1500 culverts could have 6 photos each at ~250KB (conservatively) which would be about 2 GB to upload. Average upload speed is between 1 and 25 mbps, so a 2GB file could take from 20 minutes up to 4 hours for a slow (DSL) connection.

7.2. Evaluation of Pilot Collection Data

7.2.1. *Extent of Collection*

Pilot studies are important steps in implementing any large-scale effort because they prove the viability of a scaled-up effort, as well as provide refinements that ease implementation. Pilot studies also provide tangible data that can be used to estimate the scope and needed resources for a full-scale implementation.

The culvert pilot collected inventory data on nearly 50,000 culverts from a number of geographical locations, agency sizes, agency types, and a variety of road functional classes. Figure 7-2 illustrates the geographic location of all the culverts submitted by local agencies during this pilot. Appendix M includes regional maps similar to Figure 7-2 showing culvert locations on a smaller scale where the distribution of culverts is more evident.

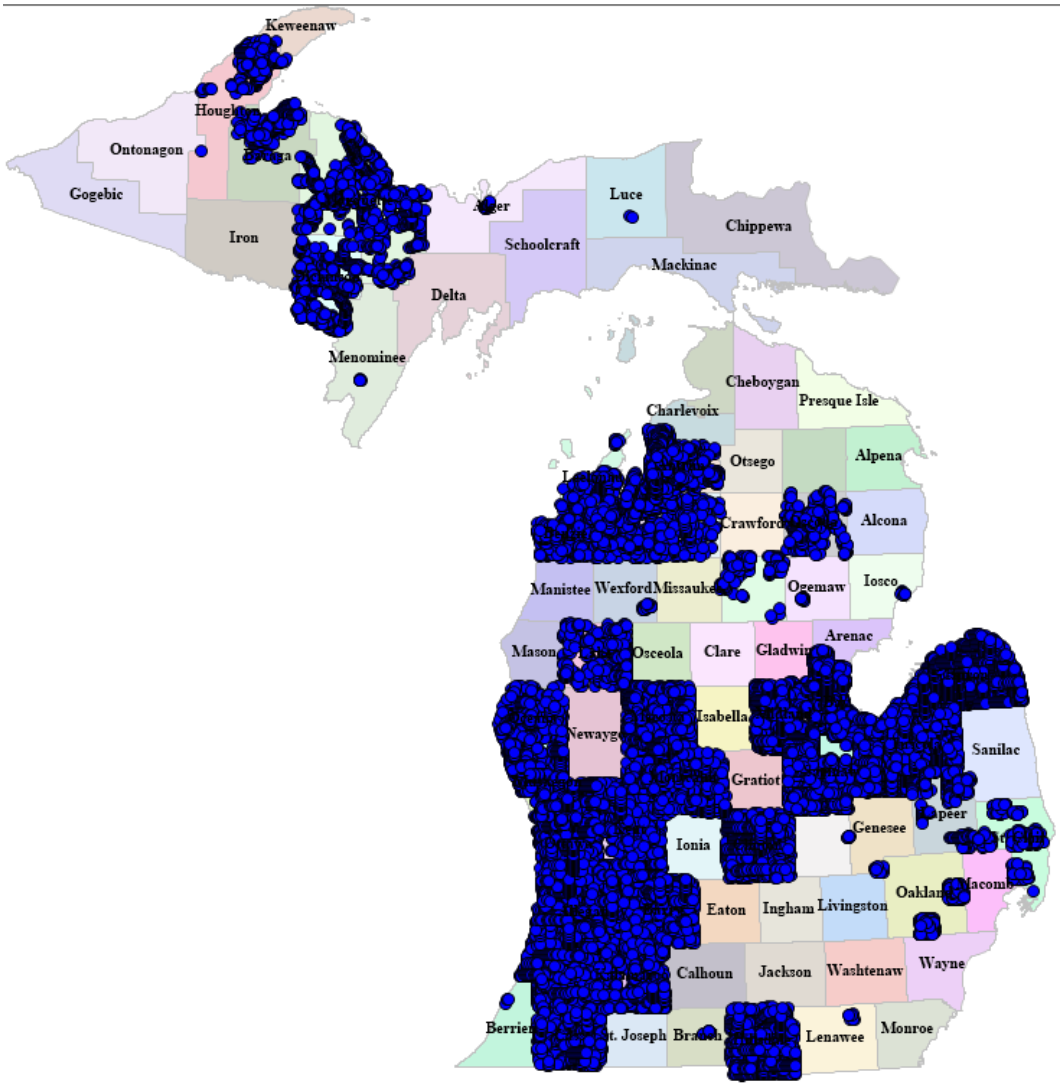


Figure 7-2: Roadsoft screenshot showing statewide culvert data from the pilot

Table 7-1 and Table 7-2 illustrate the network size of roads owned by pilot agencies, the individual pilot collection network within each agency, and the total number of culverts each agency has in their inventory. The approximate total road network size was derived from the Michigan Geographic Framework V17 base map using the county left/right field to designate ownership. This method produces minor over-estimations in mileage as boundary roads are counted twice. Analysis indicates this over estimation is approximately 1.79% for county road agencies and 3.80% for cities and villages.

Table 7-1: Number of submitted culverts and road network size by county pilot agency participants

Owner Agency	Number of Culverts Recorded in Inventory*	Approximate Road Network Size (miles)	Inventory Considered Complete **
Allegan County	2,303	1,813	
Antrim County	1,317	874	
Baraga County	708	487	
Barry County	970	1,095	✓
Bay County	1,883	1,061	✓
Benzie County	563	632	
Cass County	1,506	1,024	
Clinton County	2,202	1,200	
Dickinson County	821	525	
Grand Traverse County	922	1,022	
Hillsdale County	1,497	1,205	
Houghton County	961	829	
Huron County	3,632	1,635	
Kalamazoo County	1,620	1,278	✓
Kalkaska County	399	857	✓
Kent County	2,399	1,996	✓
Lake County	491	1,005	✓
Lapeer County	305	1,339	
Leelanau County	231	587	
Marquette County	1,923	1,245	
Mecosta County	2,805	1,138	
Midland County	2,594	901	✓
Montcalm County	727	1,546	
Muskegon County	2,065	1,131	
Oceana County	972	1,090	
Oscoda County	579	733	
Ottawa County	3,084	1,697	✓
Roscommon County	253	867	
Saginaw County	2,401	1,882	
St. Clair County	292	1,552	
Tuscola County	4,329	1,655	✓
Van Buren County	1,968	1,354	
County Total	**48,722**	**37,256**	

* Inventoried culverts represent those already on an agencies inventory and those identified and added during the pilot

** An agency's inventory was considered complete if their reported inventoried mileage was at least 97% of their Public Act 51 certified centerline miles to allow for discrepencies due to boundary roads

Table 7-2: Number of submitted culverts and road network size by city/village pilot agency participants

Owner Agency	Number of Culverts Recorded in Inventory*	Approximate Road Network Size (miles)	Inventory Considered Complete **
Benton Harbor	3	57	✓
Big Rapids	10	38	✓
Cadillac	29	63	✓
Caledonia	10	8	✓
Coldwater	12	58	
Daggett	10	5	✓
East Tawas	28	27	
Farmington Hills	468	305	✓
Fenton	32	53	✓
Lennon	12	4	✓
Munising	28	19	✓
Muskegon Heights	10	69	
Newberry	5	14	✓
Rochester Hills	260	260	✓
Tecumseh	10	46	✓
Walkerville	1	5	
West Branch	14	14	✓
City Total	**942**	**1,044**	

* Inventoried culverts represent those already on an agencies inventory and those identified and added during the pilot

** An agency's inventory was considered complete if their reported inventoried mileage was at least 97% of their Public Act 51 certified centerline miles to allow for discrepencies due to boundary roads

The pilot collection network describes the size of the area where new data was collected for this pilot; however, submitted data sets also included historical culvert data which was considered to be outside of the collection network established by this pilot. While the historic data may be helpful, especially for the inventory of culverts, the data collected may not have been consistent with the collection and evaluation methodology established for the pilot. Approximately 14,000 historical culverts were included in the data set that were outside the collection network.

Some pilot cities included more miles of road in their collection networks than they owned, resulting in over 100% completion. These cities included boundary roads or other jurisdictional owner's roads in their network.

The pilot collected culvert data on over 19,500 center line miles of local roads, which represents approximately 18.4% of all local roads in the state. This figure should be viewed as an absolute minimum, since many agencies included historical culverts in their reported data.

Table 7-3 compares the percentage of all Michigan local agency-owned roads with respect to federal-aid and Act 51 classification to the pilot agencies. The data indicates that there is an over-representation of county roads and a corresponding under-representation of city and village roads in the pilot. This over/under-representation is apparent in the percentage of roads in the pilot agency networks relative to the remainder of the state. Table 7-3 also includes the network distribution of culverts collected on the pilot, which also show the bias toward county roads in the pilot.

The over-representation of county roads in this pilot should not be a concern, since the county owned network is significantly larger than the city/village owned network (4.7 times the size). The additional data density will allow a more precise estimate of this important road network. County road agencies own 109,685 miles, whereas cities/villages make up 23,227 miles in the state.

This data suggests that the data collected during the pilot will be representative of the rest of the culverts in the state due to its broad geographic distribution, the varied types of local agency sizes, and varied functional classes of roads where culvert data was collected.

Table 7-3: Statewide and pilot agency network metrics

	Approximate Total Miles	Fed Aid (miles)	Non Fed Aid (miles)	County Primary (miles)	County Local (miles)	City Major (miles)	City Minor (miles)
All county	91310	23215	68096	27433	63878	NA	NA
All City	20550	4340	16209	NA	NA	6318	14231
Total	111860	27555	84305	27433	63878	6318	14231
Percent of Total		**25%**	**75%**	**25%**	**57%**	**6%**	**13%**
Pilot County	37256	8785	28471	10456	26800		
Pilot City	1030	208	836			288	757
Total	38286	8993	29307	10456	26800	288	757
Percent of Pilot		**23%**	**77%**	**27%**	**70%**	**1%**	**2%**
Percent Pilot of All Roads	**34%**	**23%**	**77%**	**27%**	**70%**	**1%**	**2%**

	Total Culverts	Fed Aid Culverts	Non Fed Aid Culverts	County Primary Culverts	County Local Culverts	City Major Culverts	City Minor Culverts
All county	48722	12900	35822	15216	32728	125	90
All City	942	163	779	3	9	203	710
Total	49664	13063	36601	15219	32737	328	800
Percent of Pilot		**26%**	**74%**	**31%**	**66%**	**1%**	**2%**

7.2.2. *Classification of Culverts from Data*

Inventory data collected from the culvert pilot provides a rich source of data that can be used to draw conclusions about the characteristics of the overall local agency road network. Inventory data can be described as having a long "shelf life" since it does not change once a culvert is installed unless construction or maintenance work occurs.

Figure 7-3 illustrates the road surface type that was present during pilot data collection. Not surprisingly, the most frequent road surface type was asphalt pavement followed by gravel. The road surface type provides important information that can be used for the estimation of replacement costs, since restoration is a significant expense.

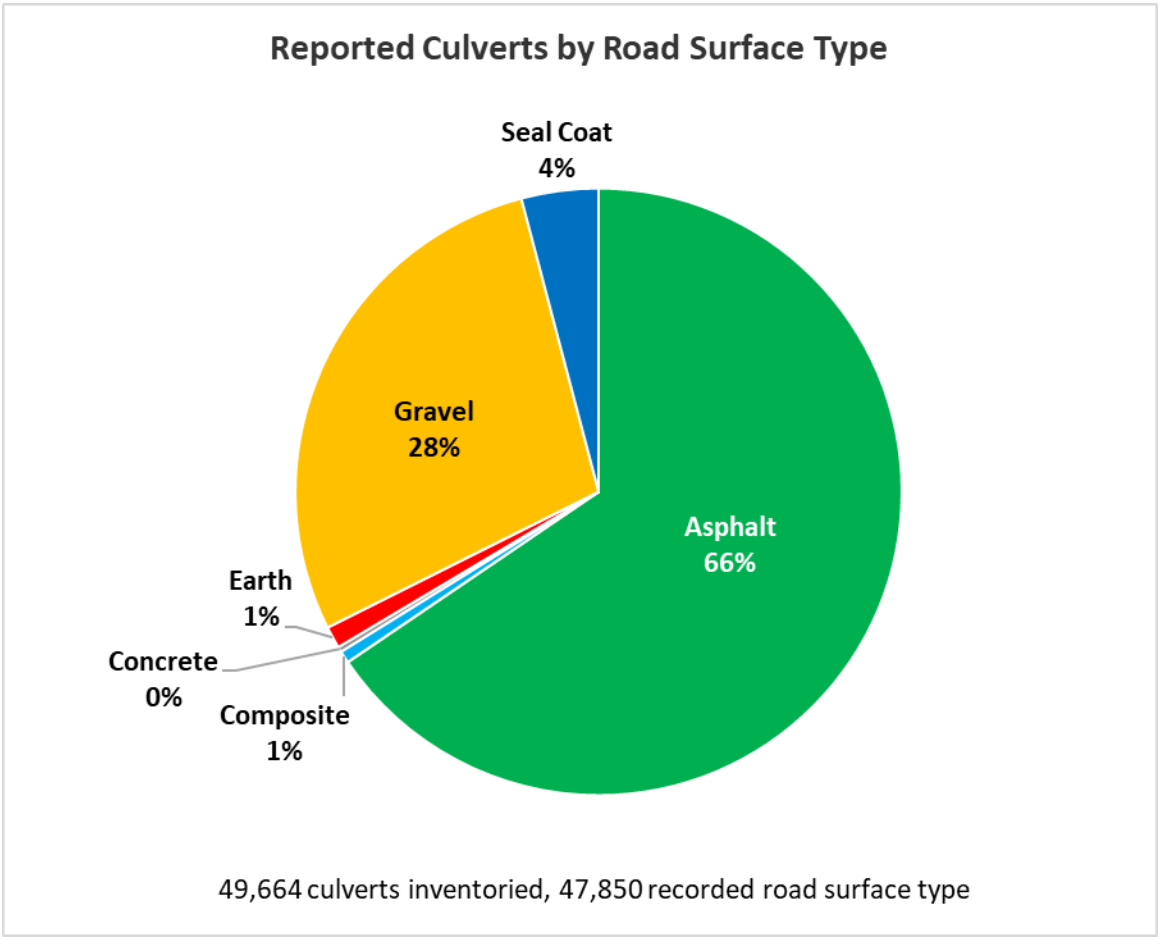


Figure 7-3: Reported culverts by road surface type

Figure 7-4 illustrates the culvert depth of cover for the pilot data collection. Depth of cover is measured from the top of the road to the top of the culvert. Of culverts collected in the pilot, 85% were located less than 6 feet deep.

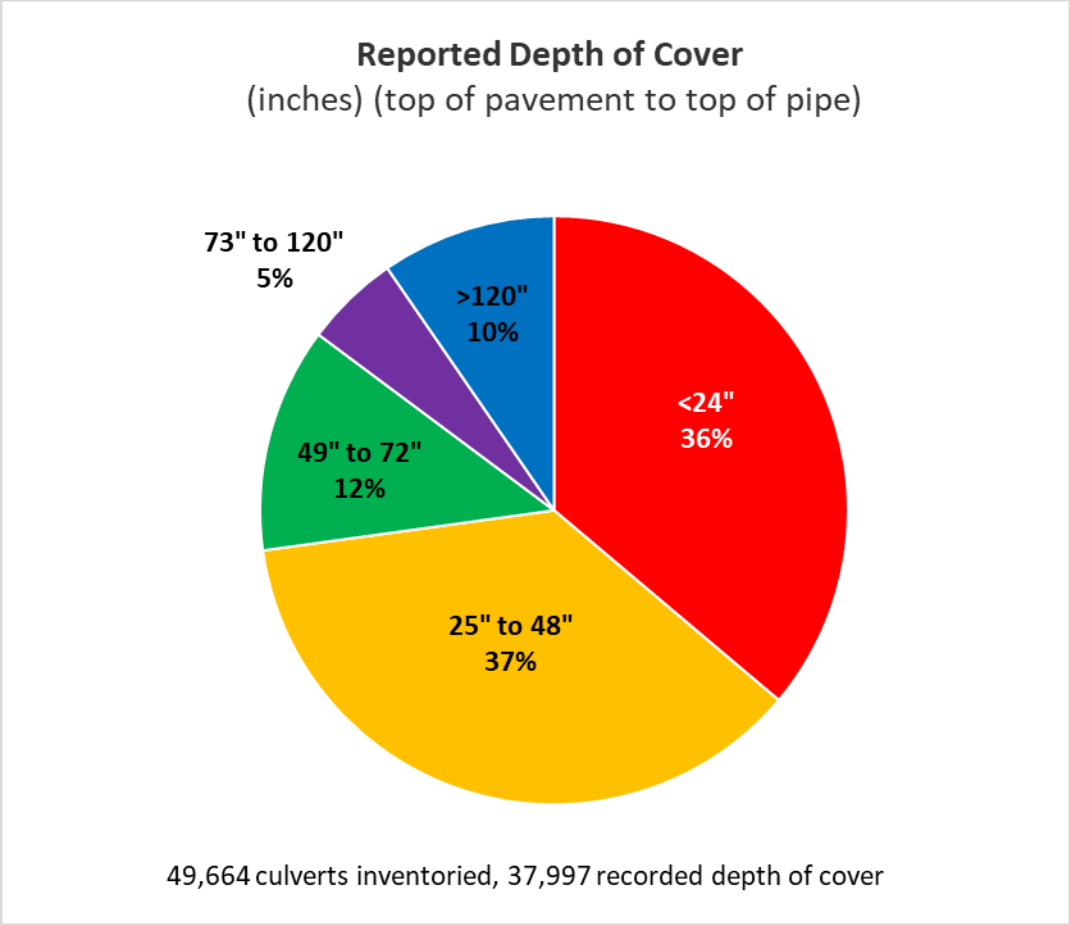


Figure 7-4: Culvert depth of cover measured from top of pavement to top of culvert

Culvert depth data provides information that can used to determine the difficulty of replacing a culvert as well as the specific costs associated with it. This data can also be used as a measure of the risk of failure of a culvert, since deeper culverts typically have a higher capacity to retain, then catastrophically release water in the event of a culvert failure.

Figure 7-5: Baraga CRC using the auto-level and rod to measure depth of cover

Figure 7-6: A graduated rod, tape measure, and sight level were also used to determine depth of cover

Figure 7-7 illustrates the material of construction for culverts from the pilot data collection. The majority of culverts are constructed of corrugated steel, followed by concrete. The culvert material is a factor in determining the useful life and replacement cost of a culvert asset. This data can also be used to provide clues to the culvert's age, since masonry and tile culverts are typically older conduits, while newer material like plastic and aluminum are typically of a more recent construction.

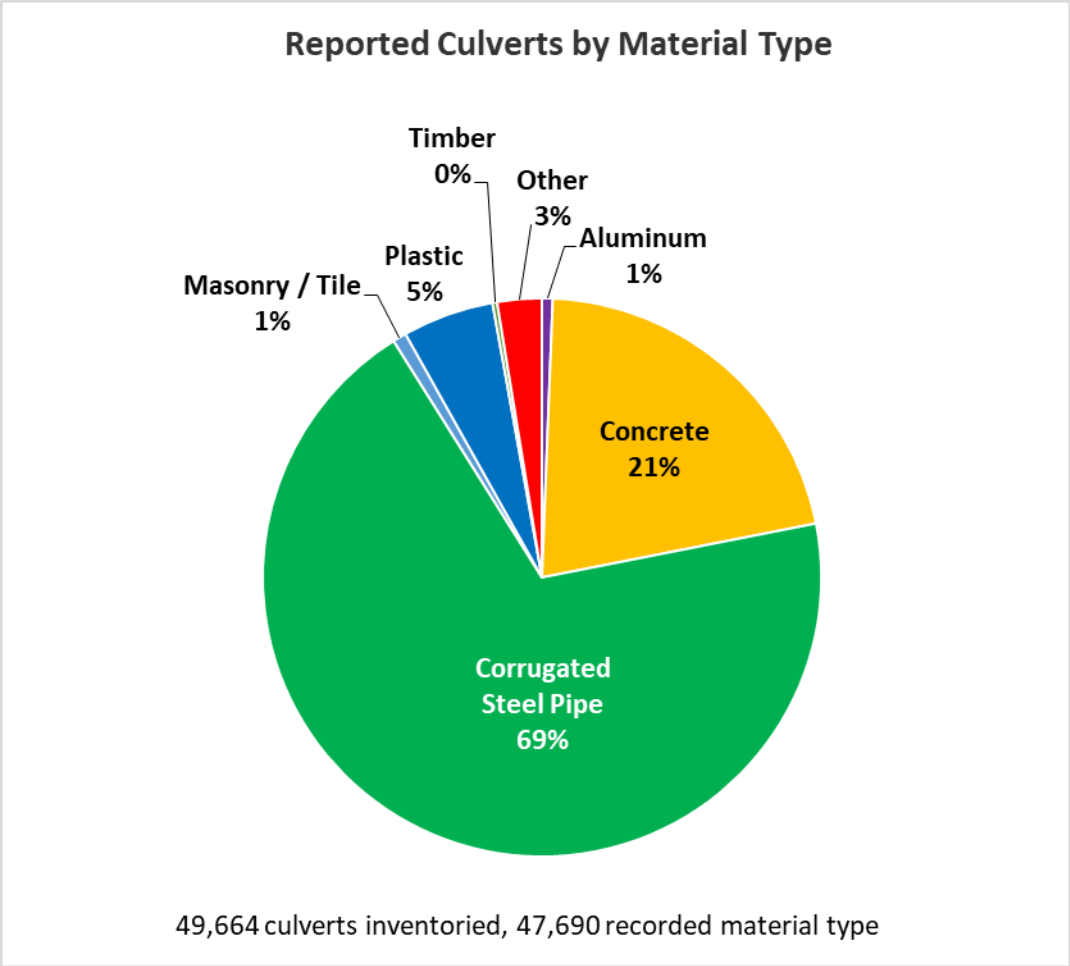


Figure 7-7: Reported culverts by material type

Figure 7-8 illustrates the shape and form of culverts collected during the pilot. Of all culverts collected, 88.9% were circular. Circular culverts are used for simple crossings that do not require a large opening area to pass stream flows. Circular culverts larger than 60 inches in span are less common since other culvert shapes and forms such as arches, boxes and slab/superstructures can accommodate larger openings with fewer design considerations and lower cost. Culvert shape has a significant impact in estimating culvert cost, since circular culverts are relatively inexpensive and are typical of smaller crossings. Culvert shape also influences the type of distresses or failure modes that may be a concern. For example, bottom scour is not typically an issue for round culverts but can be very catastrophic for open bottomed three sided culverts.

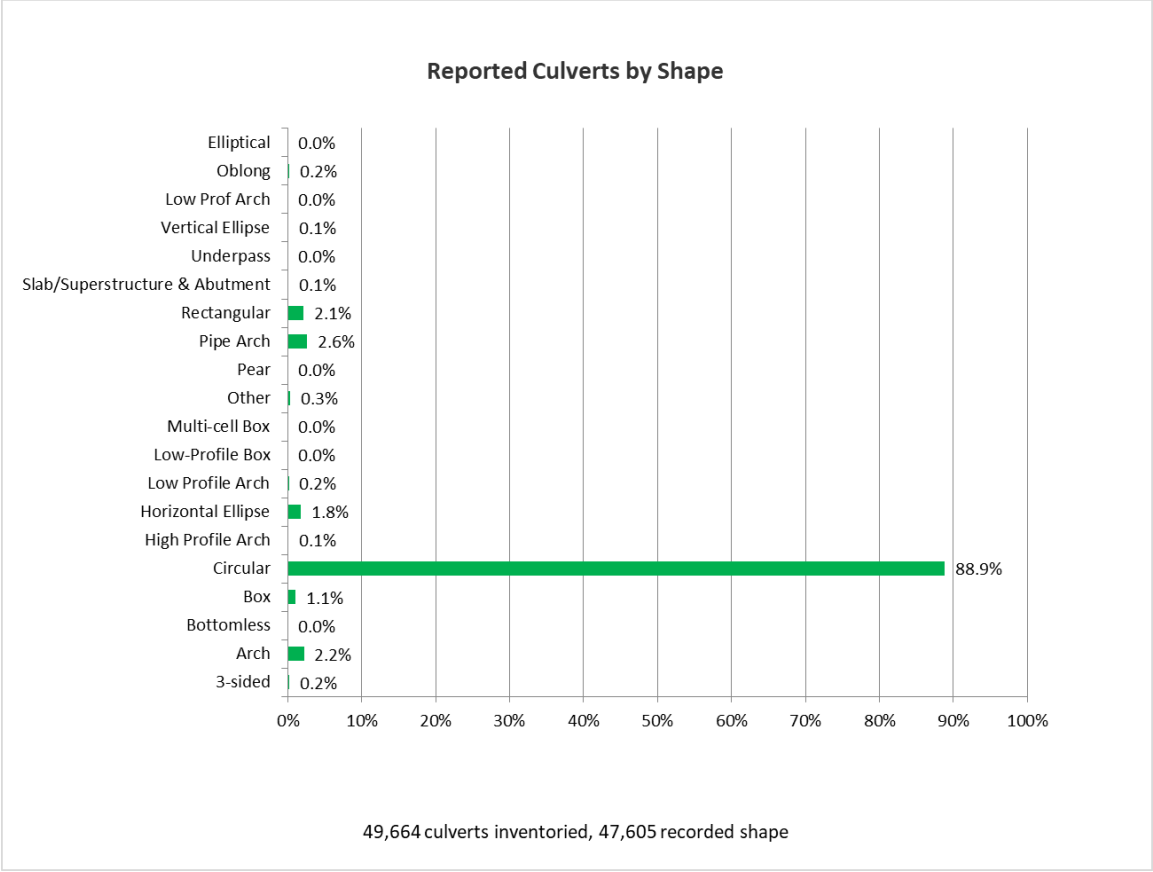


Figure 7-8: Culvert shape and form by percent of all culverts

Figure 7-9 illustrates the various spans for circular culverts collected during the pilot. Of the reported culverts, 90% were 48 inches in span or smaller. The number of culverts in each classification generally decrease with increasing size. Culvert span is a significant factor in determining the cost of replacing a culvert. Culvert size is also a major factor in the consequence of failure of a culvert, since larger culverts typically pass larger water flow and cause more severe disruption during a failure.

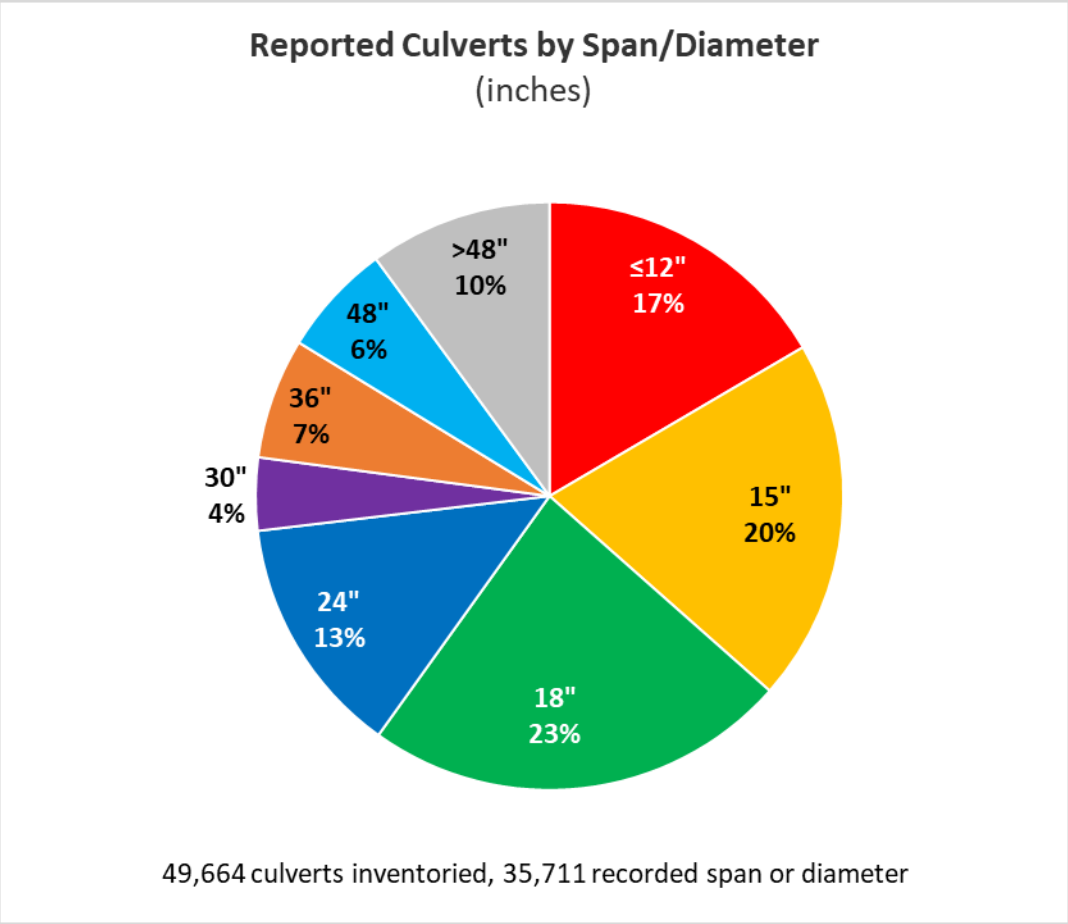


Figure 7-9: Circular culvert span/diameter by percent and number. Culvert size ranges include all sizes below the marked range and the next lowest range

The pilot data set represents over 2.2 million feet (425 miles) of culvert pipe. Most culverts in the pilot were of similar length, with an overall average 43.6 feet. Pipe length along with pipe span are the key determinants in culvert cost.

7.2.3. *Culvert Condition*

Approximately 69% (34,354 culverts) of the culverts collected from the pilot included a condition rating. Of the rated culverts, 78% (27,234) had ratings collected in 2018 and 92%

were rated in the last five years. Figure 7-10 illustrates the breakdown of culvert condition data by date into percentages.

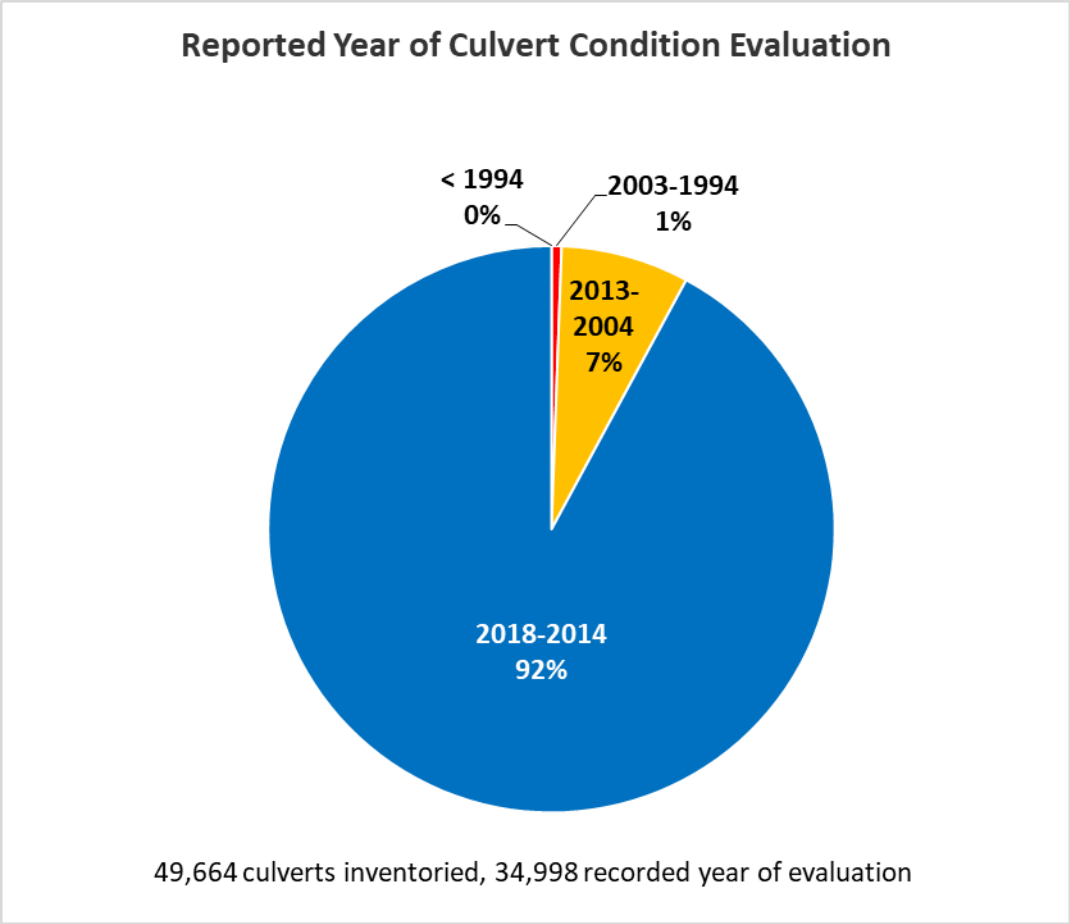


Figure 7-10: Culvert ratings percentage by year

Condition assessments indicate that the majority of the culverts inspected were in good condition with 27.0% of the rated culverts holding condition ratings of 8 (good) or better, and 67.2% of the rated culverts holding conditions ratings of 6 (fair) or better. The condition rating scale for this pilot project ranged from 1 (failed) to 10 (new). 69.2% of the culverts inventoried for the pilot included a condition rating. Figure 7-11 illustrates the overall reported culvert condition.

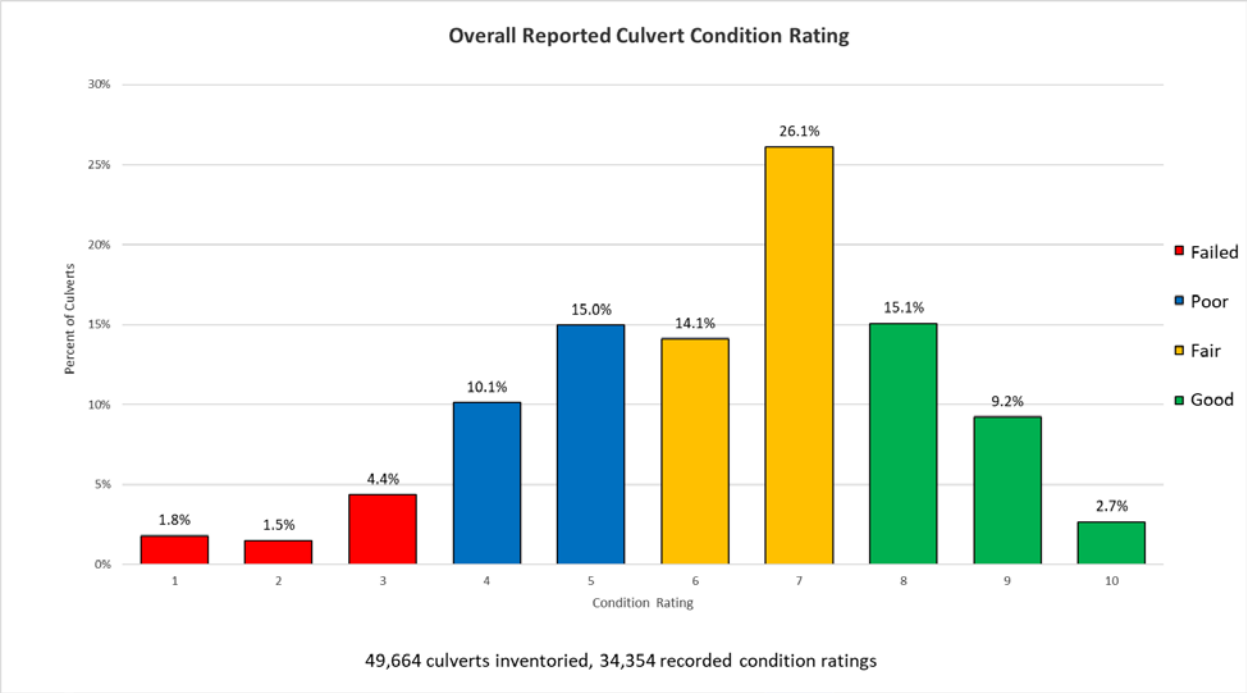


Figure 7-11: Overall culvert condition rating

The culvert condition rating exhibits a strong bell-shaped distribution with a reduction in frequency of ratings further away from the mode. This bell shape is typical of normally distributed data and has been observed in pavement condition data from Michigan. There is a secondary peak in condition data at the 4 rating.

Figure 7-12 illustrates the condition of the pilot culverts with respect to material of construction. The secondary condition peak at rating 4 appears to be the result of corrugated steel culverts which make up a disproportional number of culverts in this peak. It is also interesting to note that overall plastic culverts appear to be in slightly better shape than their counterparts with a mode of 8, which is one rating higher than the overall trend. This may be related to the relative newness of plastic culverts; however, without age of construction data this is merely conjecture. Please note that the TAMC does not support any particular culvert material type. The reported condition rating results represent culverts over a wide range of service life. Some materials have been historically available, others may represent new construction, age of culvert is not represented in these figures.

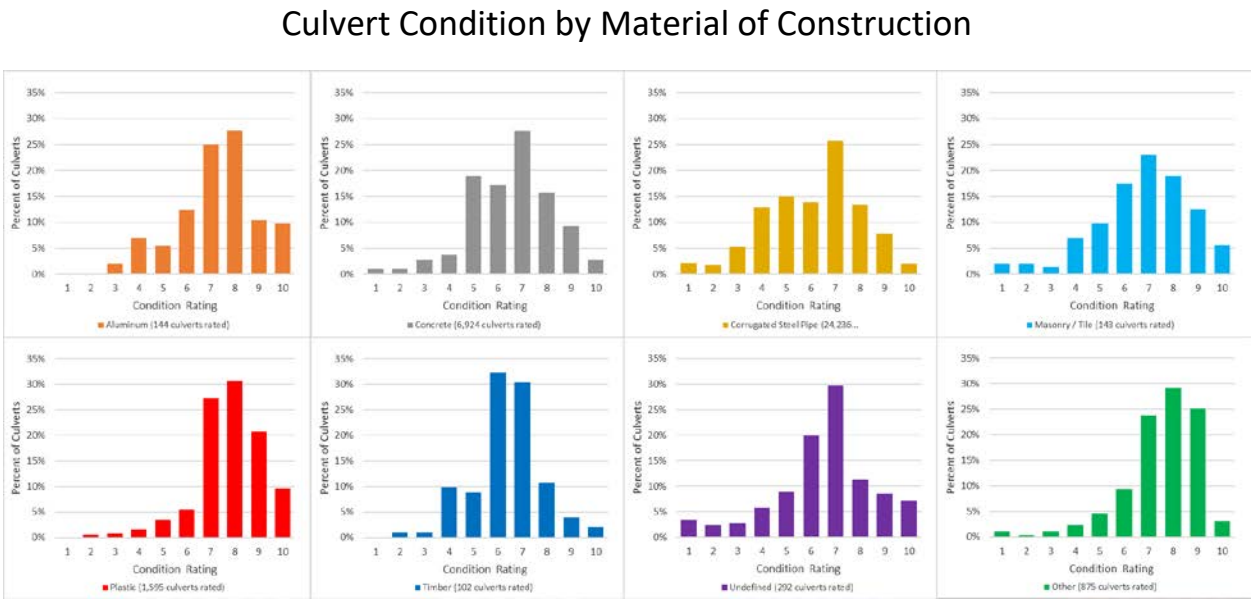


Figure 7-12: Culvert condition by material of construction

Figure 7-13 and Figure 7-14 illustrate the condition of the pilot culverts with respect to span, and depth of cover, respectively. There does not appear to be a significant difference in condition relative to span or depth of cover.

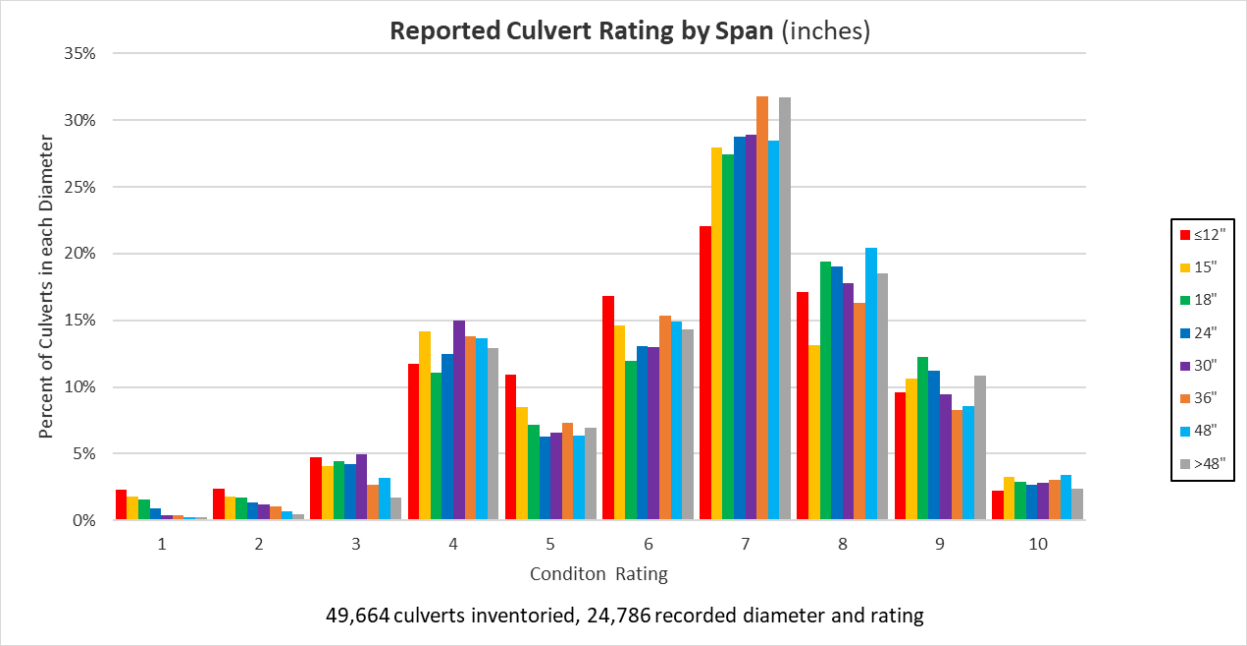


Figure 7-13: Culvert condition by size ranges of span and height for all culvert shapes

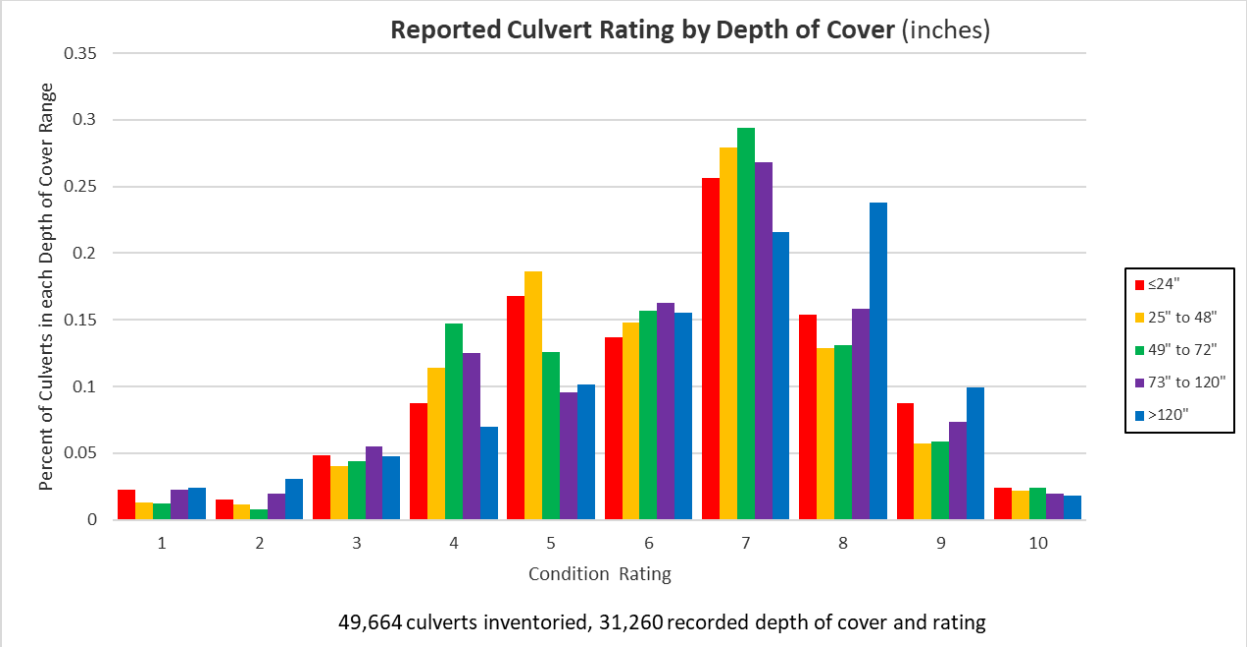


Figure 7-14: Culvert condition by depth of cover

7.3. Statewide Estimate of Culvert Quantity

The pilot project collected two data sets which were used to create culvert density factors using three road network subdivision schemes (single network, federal-aid/non-federal-aid split, and county by region). This combination of data sets and geographic subdivisions results in six sets of density factors.

Culvert density factors relate the number of culverts per mile on a given road network. These factors are multiplied by the total lane miles of roads on the local agency owned road system to make estimates of the statewide quantity of culverts.

7.3.1. *Collection Area Data Set*

Pilot agencies were required to create a GIS file that outlined the geographic area that they collected data for the pilot. This collection area defines the boundaries where all culverts were identified. The collection area included 36,251 miles of county roads and 1,044 miles of city and village roads. Culverts within the collection area were counted and summarized by each agency. The collection area data set included approximately 48,321 county culverts and 942 city and village culverts.

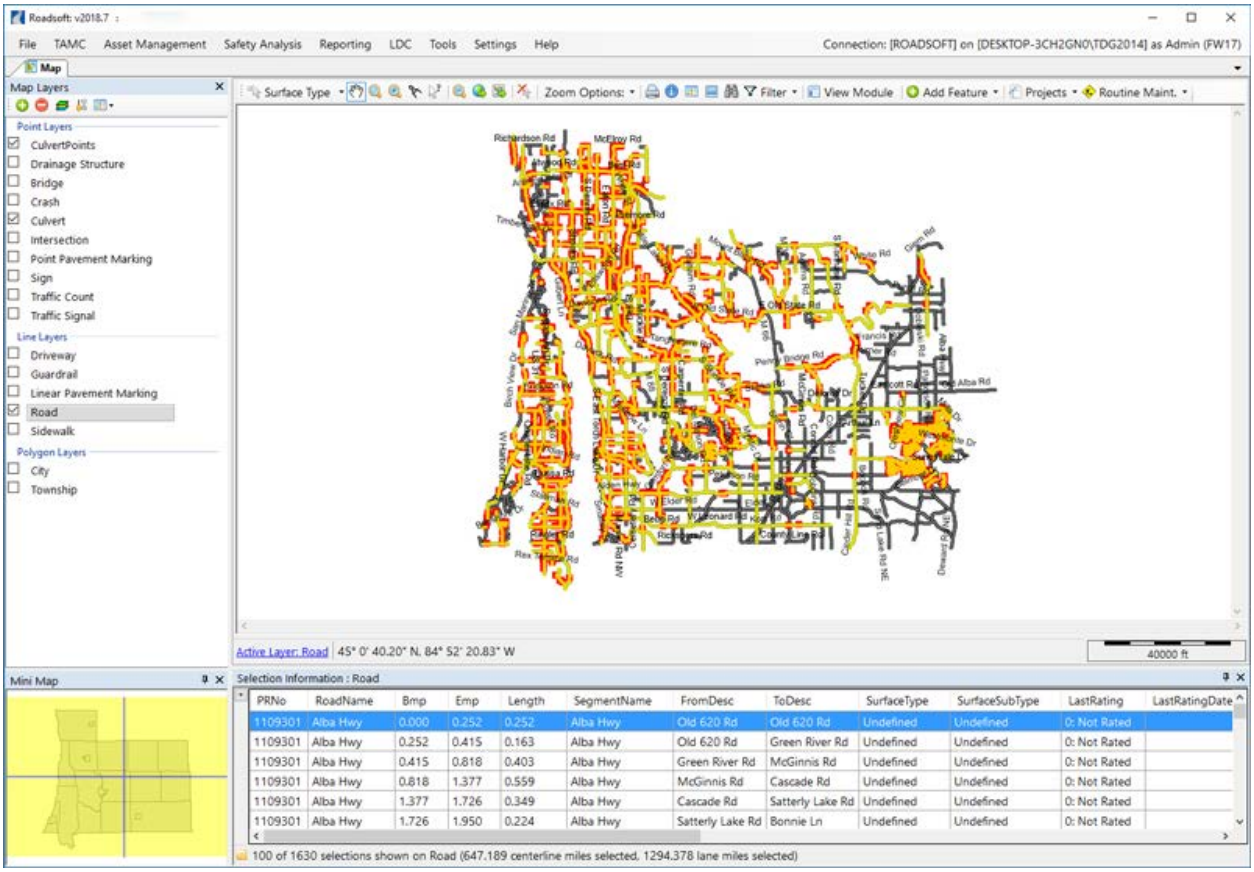


Figure 7-15: Example Roadsoft screenshot showing culvert locations and the road network where culvert data was collected

Culvert density factors were calculated by dividing the miles of road in the collection area by the number of culverts identified in the collection area. Density factors were calculated as an aggregate for each agency in the single network analysis and were subdivided by the federal-aid road status on the federal-aid/nonfederal-aid split analysis. These methods resulted in one set of average density factors for county road agencies as an aggregate and cities as an aggregate.

The regional impact of geography, population density and road density were examined by calculating culvert density factors for three regions in the state: The Upper Peninsula, Northern Lower Michigan, and Southern Michigan. The subdivision between the Northern Lower and Southern Michigan data sets were divided based on a line running from the north edge of Muskegon County to the north end of Macomb County and subdividing counties based on where the majority of their mass fell along this line. Cities/villages were not subdivided by region but were aggregated together as a unit.

7.3.2. *Daily Progress Log Data Set*

Pilot agencies were requested to take daily progress logs during field work which specified the number of culverts inventoried in a day and the number of miles of road where all culverts

were inventoried for the day. This data set provides culvert density factors as well as data collection production rates which is described in the next section of this report. Daily logs only produced an aggregate culvert density for the agency and was not specific enough to subdivide by federal-aid/non-federal-aid road networks. Regional impacts were assessed by subdividing counties in the same method as described above.

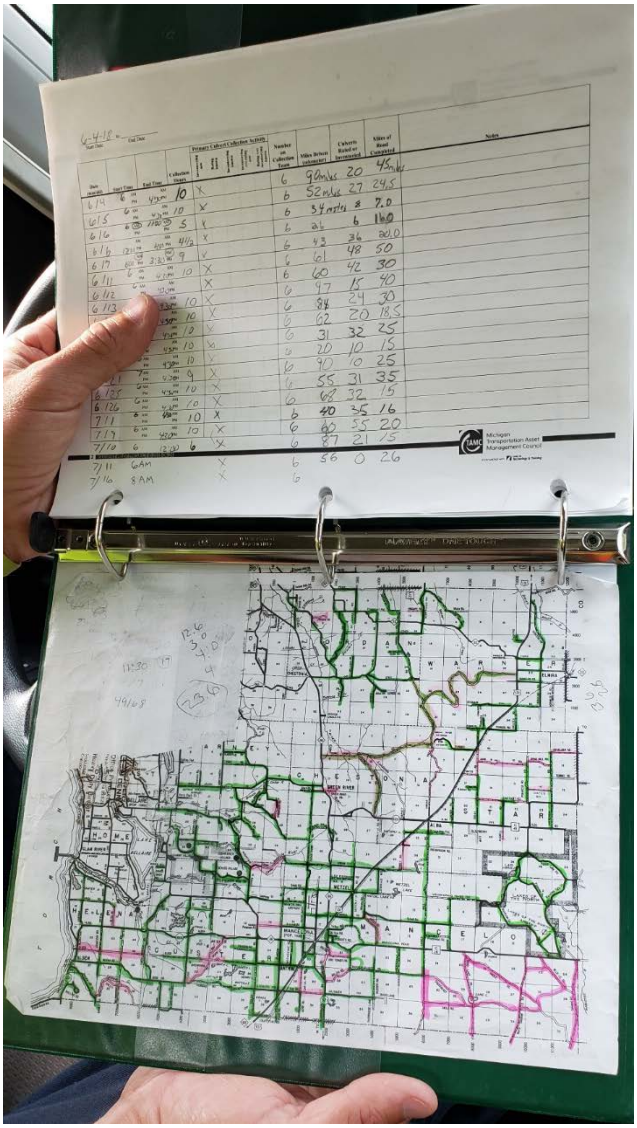


Figure 7-16: Example daily collection log and highlighted map as used in the field. Note that this is the same agency as the Roadsoft screenshot shown in Figure 7-15.

Table 7-4 illustrates the range of culvert density factors and their association with the methods for calculating statewide culvert estimates.

Table 7-4: Culvert density factors calculated for local road agencies considering regionality, road network type, and agency type

				Single Network	Fed Aid/ NFA Network		Single Network	Fed Aid/ NFA Network	
Method Number	Density Factor Source	Road Network Subdivisions	Regionality	County Culverts / Mile	County Fed Aid	County NFA	City Culverts / Mile	City Fed Aid	City NFA
1	Average of Collection Area	Single Network	Aggregate of Counties	1.81	NA	NA	0.95	NA	NA
2	Average of Collection Area	Fed aid / NFA split	Aggregate of Counties	NA	1.84	1.82	NA	0.89	1.16
3	Average of Collection Area	Single Network	County by region						
			Upper Peninsula	3.17	NA	NA	0.95	NA	NA
			Norther Lower	1.74	NA	NA	0.95	NA	NA
			Southern Lower	1.41	NA	NA	0.95	NA	NA
4	Average of Collection Area	Fed aid / NFA split	County by region						
			Upper Peninsula	NA	3.99	2.84	NA	0.89	1.16
			Norther Lower	NA	1.69	1.79	NA	0.89	1.16
			Southern Lower	NA	1.28	1.49	NA	0.89	1.16
5	Daily Logs	Single Network	Aggregate of Counties	2.09	NA	NA	1.11	NA	NA
6	Daily Logs	Single Network	County by region						
			Upper Peninsula	3.89	NA	NA	1.11	NA	NA
			Norther Lower	1.76	NA	NA	1.11	NA	NA
			Southern Lower	1.75	NA	NA	1.11	NA	NA

The statewide total culvert estimates were calculated using six discrete methods. Each method used a different combination of culvert density factors and geographic subdivisions. All methods used separate average culvert densities for county road agencies and cities/villages because there is a significant difference in how each agency employs culverts, resulting in a lower density for cities than county road agencies.

The center line road mileage for each of the 535 cities/villages and 83 county road agencies that own roads in Michigan were multiplied by the respective culvert density factors to produce an estimated number of culverts. Table 7-5 illustrates the calculated total of locally-owned culverts for both cities and county road agencies using the six calculation methods.

Table 7-5: Summary of statewide local agency culvert estimation methods

Method Number	Density Factor Source	Road Network Subdivisions	Regionality	County Culverts	City Culverts	Statewide Culverts	Difference From Highest
1	Average of Collection Area	Single Network	Aggregate of Counties	164,893	19,590	**184,483**	86%
2	Average of Collection Area	Fed aid / NFA split	Aggregate of Counties	166,466	22,682	**189,148**	89%
3	Average of Collection Area	Single Network	County by region	159,349	19,590	**178,939**	84%
4	Average of Collection Area	Fed aid / NFA split	County by region	161,252	22,682	**183,934**	86%
5	Daily Logs	Single Network	Aggregate of Counties	190,839	22,810	**213,649**	100%
6	Daily Logs	Single Network	County by region	182,207	22,810	**205,017**	96%

All of the calculation methods appear to produce reasonable results. Subdividing between regions and federal-aid networks did not appear to make a significant difference in the estimate, which was a surprise, since regional culvert density factors ranged from 3.99 culverts per mile for the upper peninsula federal-aid system, to 1.28 culverts per mile for the southern-lower peninsula federal-aid system.

The largest differences in the estimates of statewide culvert volume resulted from differences in the two data sources which each have their own source of error. The difference between the high and low estimates of all methods is 45,054 culverts, which is 21% of the highest estimate.

The total number of culverts that are on the locally-owned road system represent a significant asset. It is estimated that local agencies own between 7.3 to 9.2 million feet (1,389 to 1,756 miles) of culvert, using data from the state-wide culvert estimate and the pilot average culvert length of 43.6 feet per culvert. As a basis for comparison, this is enough culvert pipe to build a single straight culvert from Houghton, Michigan to Miami, Florida.

7.4. State Wide Culvert Replacement Value

A broad estimation of culvert replacement cost was calculated for the locally-owned road system. Average unit prices were analyzed from MDOT bid letting on culvert end sections and culvert pipe bid in 2016 and 2017. The quarterly average bid letting prices were aggregated based on pipe size for round culverts. An average of each quarterly letting was calculated for each pipe size. The average cost by pipe span were plotted and a nonlinear function was fit through the points
Figure 7-17 illustrates this process. These same techniques were used to derive a function for culvert end sections which is illustrated in Figure 7-18.

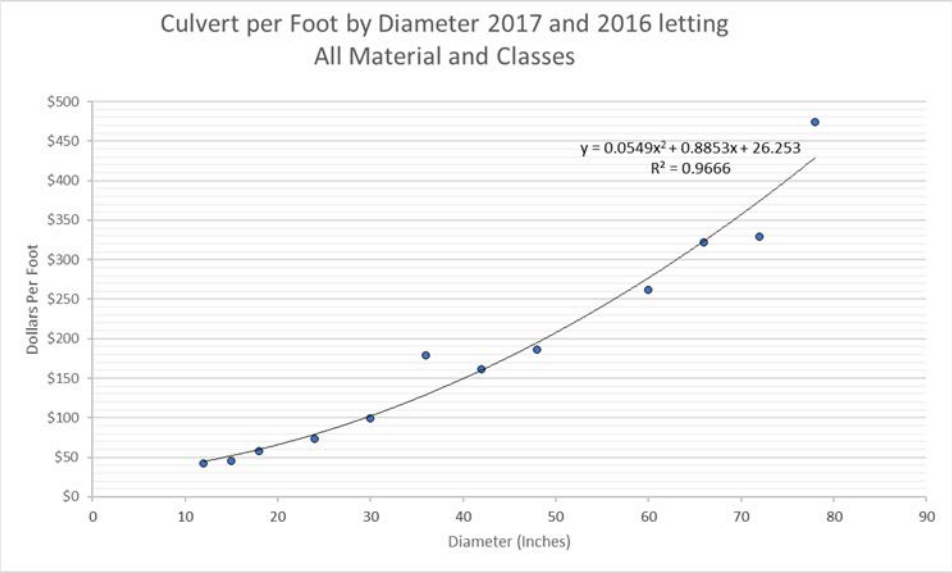


Figure 7-17: Average cost per foot of round culvert pipe and end culvert end sections calculated by size regardless of material from 2016 and 2017 lettings.

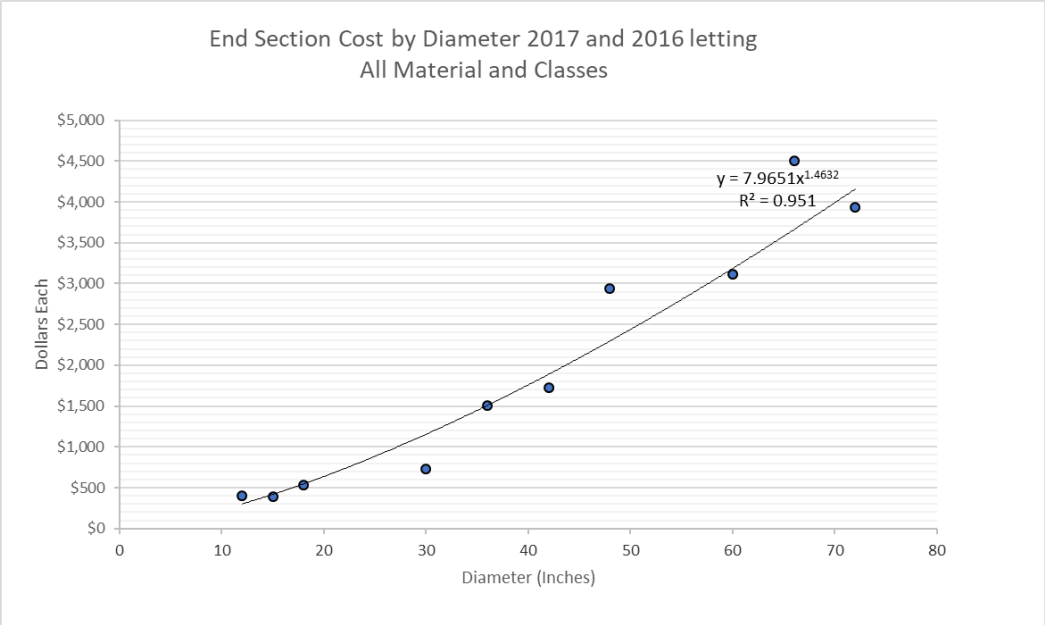


Figure 7-18: Average cost per each for culvert end sections calculated by size regardless of material from 2016 and 2017 lettings

The formula expressions of cost for culvert pipe and culvert end sections as they relate to size were used to create a typical culvert replacement project. The typical project includes 32 feet of culvert pipe and two 8-foot end sections. Construction activity on the typical project includes removing the existing culvert and installing a new culvert, end sections, and related restoration costs. These costs were again plotted against size and reduced to a total project cost formula with is illustrated Figure 7-19.

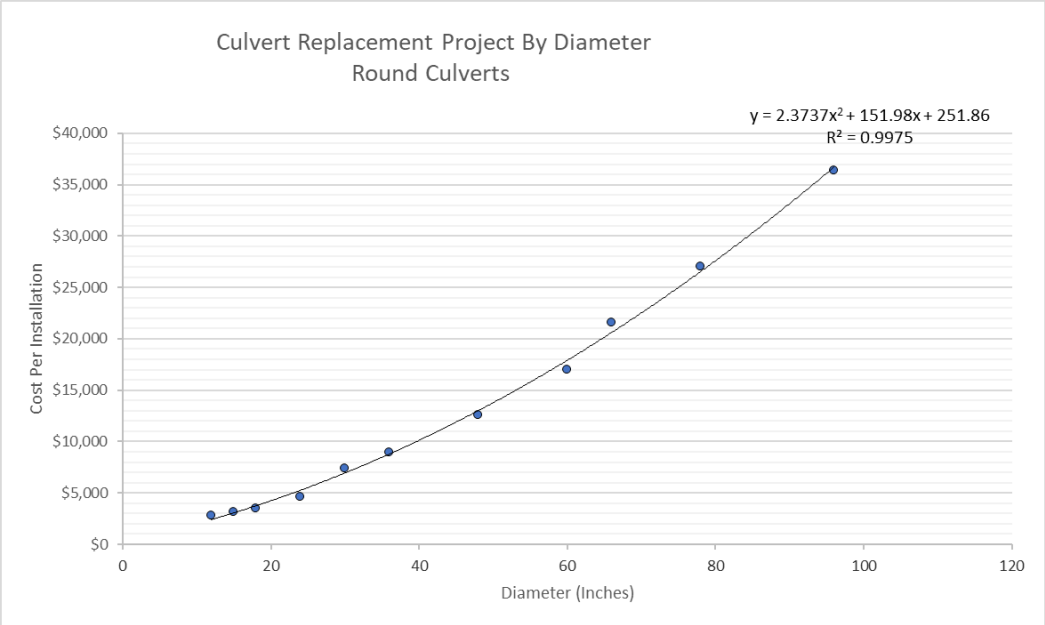


Figure 7-19: Typical culvert replacement cost by span. Cost includes installation of 32 feet of culvert pipe and two eight-foot end sections with associated restoration.

The distribution of circular culvert sizes observed in the local agency culvert pilot were used as a proxy to estimate statewide culvert value by multiplying the percentage of each size range by the total estimated number of culverts (196,000) that are locally-owned. The total project cost formula was multiplied by each span range to calculate a cost for each span size. Table 7-6 illustrates the calculations of state-wide culvert cost. 88.9% of all pilot culverts were identified as circular, so while this method may underestimate the cost for other culvert shapes, it does provide a simple method to estimate an order of magnitude for the asset value.

Table 7-6: Estimation of total cost of local agency owned culverts in Michigan

Pilot Culvert Total	Culvert Span (in)	Pilot Size Distribution	Estimated Number of Culverts In State	Cost / Each Culvert Project	Cost For All Project
5911	12	16.6%	32,443	$ 2,416	$ 78,392,329
7132	15	20.0%	39,144	$ 3,064	$ 119,948,327
8344	18	23.4%	45,796	$ 3,755	$ 171,961,955
4721	24	13.2%	25,911	$ 5,264	$ 136,408,675
1430	30	4.0%	7,849	$ 6,945	$ 54,507,322
2368	36	6.6%	12,997	$ 8,796	$ 114,322,341
2212	48	6.2%	12,141	$ 13,012	$ 157,967,973
304	54	0.9%	1,669	$ 15,376	$ 25,654,305
1018	60	2.9%	5,587	$ 17,911	$ 100,071,693
215	66	0.6%	1,180	$ 20,616	$ 24,327,973
810	72	2.3%	4,446	$ 23,493	$ 104,443,420
517	84	1.4%	2,838	$ 29,759	$ 84,444,101
347	96	1.0%	1,905	$ 36,709	$ 69,913,291
188	120	0.5%	1,032	$ 52,660	$ 54,336,566
194	240	0.5%	1,065	$ 173,431	$ 184,663,661
		100.0%	196,000		$ 1,481,363,931

It is estimated that the total replacement value of locally-owned culverts in Michigan exceeds approximately $1.48 billion.

7.5. State-Wide Collection Labor Estimate

Pilot agencies were requested to complete daily progress logs during field work which specified: the number of culverts inventoried, number of miles driven, miles of road where all culverts' data was collected, the type of collection activity, and the number of people on the collection team. This data set provides data for determining collection productivity benchmarking which can be used to estimate the labor commitment for a scaled-up data collection.

A summary of the data collected in the culvert daily progress logs is shown in Table 7-7. Data collection time was calculated based on the time actively rating or inventorying culverts or transiting to and from culverts based on log entries. Breaks for lunch and switching of rating crews were deducted from actual productive rating time. Collection rates were calculated as an average for each agency. Agency averages were aggregated by regional and agency type subdivisions.

The regional impact of geography, population density, and road density were examined by calculating production rates for three regions in the state: The Upper Peninsula, Northern Lower Michigan, and Southern Michigan. The subdivision between the Northern Lower and Southern Michigan data sets were divided based on a line running from the north edge of Muskegon County to the north end of Macomb County and subdividing counties based on

where the majority of their mass fell along this line. Cities/villages were not subdivided by region but were aggregated together as a unit.

Table 7-7: Daily pilot collection log summaries. Note labor hours per culvert are based on the team size and the collection productivity rate of hours per culvert

Agency Type	Average Collection Team Size	Collection Team Labor Cost ($/hr)	Total Miles Driven (odometer)	Total Culverts Rated or Inventoried	Total Miles of Road Completed	Total Certified Act 51 Miles	Culverts /Mile	Collection Team Time /Culvert	Labor hours /Culvert	Collection Hours	Miles /Hour	Estimated Labor Cost for Collection Team ($/MI)
Cities	2.27	$ 82.69	1,101	477	494	52	1.11	0.86	1.71	222	1.24	$ 66.69
All Counties	1.96	$ 71.61	83,959	29,528	17,973	1,133	2.09	0.38	0.67	6,706	1.96	$ 36.54
UP Counties	1.81	$ 65.88	6,039	3,072	1,329	783	3.89	0.34	0.60	779	0.79	$ 83.39
Northern Lower Counties	2.20	$ 80.33	36,160	18,561	9,956	1,082	1.76	0.40	0.71	4,021	1.92	$ 41.84
Southern Counties	1.56	$ 57.04	41,759	7,895	6,688	1,409	1.75	0.37	0.61	1,906	2.64	$ 21.60
Miles Driven per mile of road collected			4.61									

Data from daily collection logs were used to generate productivity measures to determine the time spent per culvert rated. Overall county road agencies spent less time per culvert collecting data than cities and villages did. On average county road agencies spent 22.8 minutes per culvert collecting inventory and rating data, while cities and villages spent 51.6 minutes per culvert. This difference is likely a result of the lower density of culverts in cities and villages and slower travel speeds which reduced productivity per culvert site.

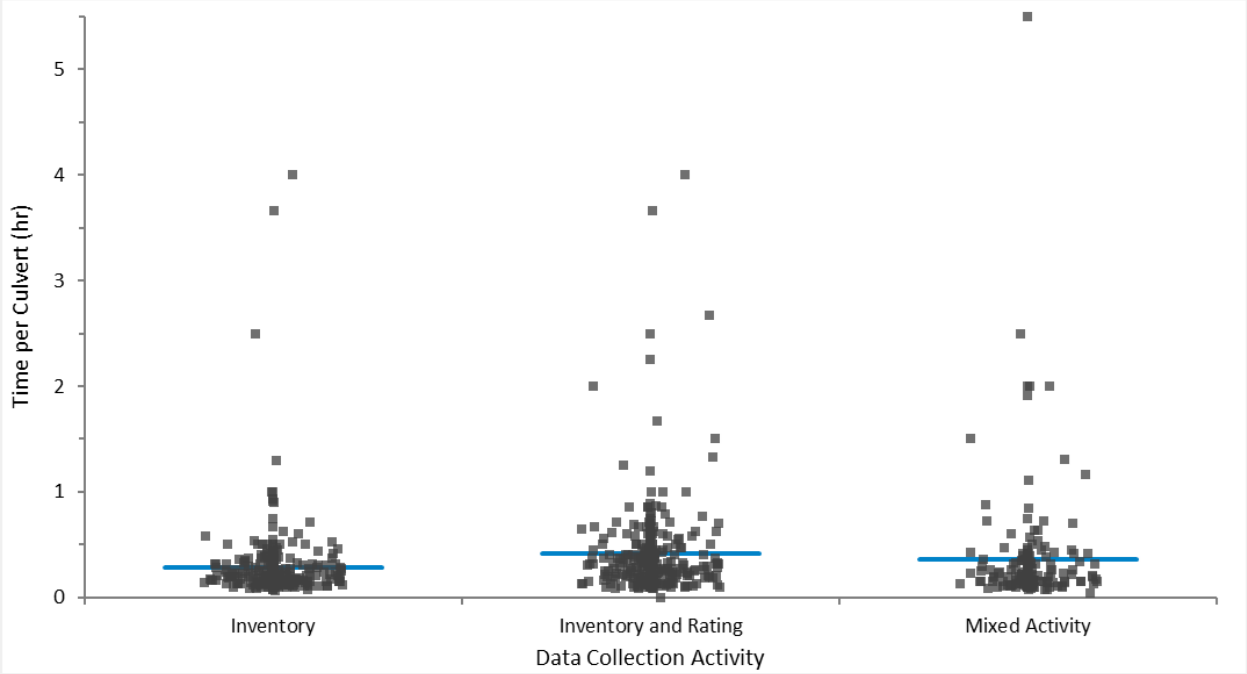
Daily collection logs for county road agency data collection were subdivided into three basic activities to analyze production rates for the type of collection activity being carried out. This analysis was only performed on the county road agency data set as cities and villages did not include enough samples for each of these three subdivisions. The subdivisions include: inventorying only, inventorying and rating, and a mix of inventory and rating activity. Figure 7-20 illustrates the range of productivity ratings between these three subdivisions. As expected, the data indicates that inventorying culverts without rating was found to be the highest productivity activity. Inventory and rating combined in the same activity was found to be significantly slower. The mixed activity was on average between these two extremes.

A Student's T-test was performed on combinations of each of the subdivided data sets to determine if the differences in average collection time per culvert were significant. T-Test results indicated that the differences between average collection time for inventory only, as well as inventory and rating combined, are significant using a 5% significance level. This result indicates that the averages from the two data sets are significantly different statistically and are not a result of sampling error.

Student's T-Test results comparing mixed activity with inventory only to mixed activity and inventory and rating combined were found not to be statistically significant at the 5% significance level, indicating that the mixed activity data set has a wide enough variability that it may not be discrete from the other two sets.

The data collection logs did not contain a large enough data set to directly determine time to collect rating information on known culverts. However, the average time per culvert to collect inventory only was 7.8 minutes faster than collecting inventory and rating data. This difference

in average collection rate is likely the result of the added task of performing the condition rating activity. However, no agencies performed both types of data collection, so there is a possibility that the difference between the two averages is in part, or wholly due to factors related to the individual agencies in both sets (team experience, traffic, culvert density, team efficiency, etc.)



Time Per Culvert	N	Mean	Mean SE	SD
Inventory	272	0.286	0.023	0.376
Inventory and Rating	300	0.416	0.025	0.435
Mixed Activity	162	0.366	0.044	0.562

Figure 7-20: County rating log averages for subdivided data collection activity

Local agencies used a number of different data collection configurations, ranging from one to three people in a team. The average team size was calculated for each agency. Agency averages were aggregated by regional and agency type subdivisions. Aggregate team size ranged from 1.56 to 2.27.

Figure 7-21: The effort needed to inspect and evaluate culverts varied greatly based on conditions

Collection teams appeared to consist of a mix of full time staff, including engineers, technicians, and managers, along with summer help which included student interns and seasonal part time employees. Table 7-8 illustrates an example labor calculation assuming a mix of full time and part time staff. These costs are illustrative and are not based on any actual data from local agencies. Using the illustrative collection team cost in Table 7-8 and correcting for average team size and production rates of miles per hour from Table 7-7 results in an average cost per mile for the collection of culvert data, which is shown in the last column of Table 7-7.

Table 7-8: Estimation of collection team labor costs.

Collection Team Employee	Hourly Pay	Benefit Rate	Overhead Rate	Total
Technician	$ 25.00	50%	35%	$ 50.63
Summer Intern	$ 15.00	10%	35%	$ 22.28
			Total rate/ h	$ 72.90

Based on the assumed pay; benefit and overhead rates; and reimbursement rate of $0.54 per mile and the average of 4.6 miles driven per mile collected, the average county data collection labor cost is estimated to be $39.02 per mile for county road agencies and $69.17 a mile for cities/villages (production rates are provided in Table 7-7 for estimating agency costs). The labor cost ranged significantly for county road agencies primarily because of the density of culverts per mile which lowered collection productivity rates. Even though the Upper Peninsula county road agencies had the lowest collection time per culvert and had the second smallest average collection team size, they had over twice the density of culverts which lead to labor costs per mile of collection significantly over the county average. Upper peninsula county road agency collection labor is estimated at $83.39 per mile of collection.

These costs do not include equipment purchase, time for training, field preparations/planning, or post processing of data.

7.6. System Wide Culvert Collection Estimates

The center line road mileage for each of the 535 cities and 83 counties that own roads in Michigan was multiplied by the respective miles per hour productivity rate to produce an estimate of the total labor hours needed to collect all the locally-owned culverts in the state. Subdividing counties by their respective regions and using regional productivity factors produced a similar estimate to using aggregate county averages. The overall average team size for all of the data logs is close to two. Table 7-9 illustrates the estimated two-person team collection time to collect all the local agency culverts in the state. It is estimated that each county road agency would likely need almost 1,200 labor hours, and each city and village would need nearly 400 labor hours, to do a full collection of culverts. An estimated cost was determined for both statewide and per agency by combining the estimated hours with the team labor rate estimated in Table 7-8. The pilot effort revealed a wide variety in staffing employed by each agency to accomplish the requirements for the pilot. The estimated team labor cost reflects an estimate of labor that may compose a collection team; however, the experience level of the team members, benefit rate, and overhead rate may vary significantly from agency to agency. With the assumptions identified in this report, it is estimated that the field activity for statewide culvert data collection efforts will be approximately $10 million. There will be additional expenses for training, equipment, and data handling.

Table 7-9: Total labor estimate for collecting a full round of culvert data

	Total Collection Team (hr)	Collection Team Size	Estimated Team Labor Cost ($/hr)	Total Labor Comittment (hr)	Aggregate Statewide Cost Estimate	Average Labor per Agency (hr)	Average Labor Cost per Agency ($)
Counties	49,082	2	$72.90	98,165	$7,156,212	1183	$86,219
Cities	16,572	2	$72.90	33,144	$2,416,233	399	$29,111
State Total	65,655			131,309	$9,572,445		

Ongoing inventory and condition evaluation programs are important for establishing healthy asset management programs. Training is important for these programs to maintain consistent data over multiple years, which allows for development of accurate models for asset management purposes. Various options for program development are presented in Section 8.2. The option presented in 8.2.1 is similar to the current PASER program, whereby a training program is paired with collection of data over a portion of roadways each year. If the inventory and condition evaluation of culverts statewide were to be conducted on a five-year cycle, on average 20% of culverts would be evaluated each year. In 8.2.2 an option is presented for conducting inventory and condition evaluation activities over one year with no activity for the remaining years within the collection cycle. Two additional options are presented in 8.2.3 and

8.2.4 whereby fixed location sampling and non-compulsory collection are discussed respectively.

Annual training expenses are estimated at $250,000 for development, provision, and participation in the training. This estimate is applicable for all options except for where all activities occur over one year where the costs associated with training are estimated to be twice as large; as a greater number of crews would be required to collect data over the shortened timeframe. The training cost associated with the collection activity described in 8.2.2 is approximately $500,000.

As part of an ongoing five-year condition evaluation cycle, the estimated annual cost will be approximately $2.1 to $2.25 million (in today's dollars) for continued training and data collection of culvert inventory and condition evaluation moving forward. This assumes 1/5 of all culverts are inspected each year as part of a five-year repeating cycle where every culvert is inspected once every five years. Therefore, the five-year costs associated with training and data collection for a culvert inventory and condition evaluation program are estimated at $10.5 to $11.25 million. These estimates do not include costs associated with development and implementation of asset management programs for culverts. There will be additional unknown expenses for training, equipment, and data handling.

8. CONCLUSIONS

This section provides key points from this study and provides a framework to assist the TAMC with the development and implementation of a strategy that can be used across the state to further streamline and standardize the collection of culvert data assets owned by local agencies throughout Michigan.

This pilot project revealed that the tools, business processes, and relationship building that the TAMC initiated for the collection of PASER road condition data has created a strong framework for the rapid collection of other asset data on the public road system. This is apparent from the significant capabilities that pilot participants demonstrated with their ability to collect a large volume of high quality asset inventory and condition data in a little over three months. This data was assembled and analyzed using existing business processes and resources. The majority of local agencies used their own forces for collection of data which indicates a domestic capacity to complete this type of activity.

- 49 participating local road agencies
- 13-week data collection window
- 49,644 culverts inventoried
- 90% of local agencies reported using Roadsoft

- 73% of local agency culverts are 24 inches in span or less, 90% are less than 48 inches in span
- 85% are buried 6 feet or less
- 67.2% of rated local agency culverts were 6 or higher out of 10
- Estimated local agency culverts in state – 196,000
- Estimated cost for initial data collection - $10 million

Pilot agencies successfully located nearly 50,000 culverts in the 13-week data collection window (April 30 – July 30). It is estimated that this number constitutes approximately 24% of the approximately 196,000 total local agency culverts in the state. While it is impressive that this level of effort can be mustered on short notice, the study also identified that a significant level of effort is required to inventory and rate local agency-owned culverts. It is estimated that it will take approximately $10 million and over 131,000 collection team hours to complete the initial data collection of local agency culverts.

Local agencies involved in the pilot collected data using a variety of tools. Over 90% of local agencies involved in the pilot used the Roadsoft LDC and Roadsoft to collect and store culvert asset data. The use of a unified tool such as Roadsoft provides data collection and storage consistency that eases downstream data processing and analysis due to data consistency. Local agencies illustrated that using other software systems such as ArcGIS can allow the fulfillment of local data needs while still allowing integration with statewide systems if data schemas are set up correctly.

Inventory data from culverts revealed that the majority (approximately 73%) of local agency owned culverts are small (24 inches in span or less), corrugated steel, circular culverts that are located less than 6 feet from the surface. Approximately 90% of culverts are 48 inches in span or less and over 85% of culverts have a depth of cover less than 6 feet. Larger and more deeply buried culverts are of specific interest because they present a larger consequence of failure in terms of risk to the public and expenditure of funds for repair.

Condition data indicates that local agency owned culverts are in serviceable shape with 27.0% of the rated culverts holding condition ratings of 8 or better, and 67.2% of the rated culverts holding conditions ratings of 6 or better. The mode (most frequent rating) for condition assessments was a 7.

Michigan has had a long history of applying asset management principals to roadway infrastructure. In 2018, the principles of asset management have grown to include a broader set of infrastructure assets. The Michigan legislature established the Michigan Infrastructure Council (MIC) through Public Act 323. The MIC shall develop a multiyear work plan, budget, and funding recommendation for asset management of infrastructure including but not limited to stormwater systems, drains, roads, and bridges. Public Act 324 amended PA 451 to form the Water Asset Management Council (WAMC) which in part will develop templates for the asset management of stormwater systems amongst other assets, including but not limited to culverts

and bridges. Lastly, Public Act 325 revises the enacting legislation for the TAMC by, in part, stating that the TAMC shall advise the MIC on infrastructure assets including culverts. Through these acts, the work of the TAMC, and the results of pilot projects like this, the future of asset management for Michigan infrastructure is looking bright.

Recommendations for Implementation

- Establish responsibility for division of infrastructure asset management between the TAMC and the WAMC
- The inventory fields established in the pilot should continue to be recommended by the TAMC as a minimum with local agencies expanding on those to meet their needs
- Provide a baseline data model and data standard for culvert data collection
- Training delivery and tool development for asset management should continue
- Continue maintenance of inventory and condition evaluation data
- Promote shared data use – many agencies are interested in some facet of culvert inventory data. Each agency may need to collect specific data but much of the inventory data could be shared between agencies to minimize repeated effort.
- Develop and support a state-wide culvert data collection program
- Future research
    - AASHTO is currently working on an updated condition assessment system which will need to be reviewed, modified if needed, and accepted for use in Michigan.
    - Establish globally unique identification (GUID) for culvert assets to assist in identifying and updating culvert data inventory
    - Create a cost model that relates physical features of culvert inventory to replacement and maintenance costs.

8.1. General Recommendations

8.1.1. *Overlap of Management Council Responsibility*

One of the first issues for the TAMC to address is the overlap in responsibility for managing statewide culvert assets that was recently created by Public Act 324 and 325 of 2018. Public Act 324 created the WAMC, which is charged with the management and oversight of drinking water, waste water, and storm water infrastructure. The act further defines storm water assets as including "*catch basins, curbs, gutters, ditches, … pipes, storm drains, …. culverts, bridges*".

Public Act 325 of 2018 is a revision of the enacting legislation for the TAMC. The Act states: *"The transportation asset management council shall advise the Michigan infrastructure council on a statewide transportation asset management strategy and the processes and tools needed to implement that strategy, beginning with the federal-aid eligible highway system and infrastructure assets that impact system performance, safety, or risk management, including signals and culverts.*"

The TAMC also clearly has a mandate to oversee bridge assets and has been doing so since its inception. This overlap in responsibility runs the risk of creating a procedural confusion which may slow forward progress on bridge and culvert assets until rectified.

Drinking water and waste water, and to an extent, storm water assets, all have an ongoing regulatory and compliance component associated with them. In that aspect there is a significant difference between the assets that WAMC is responsible for overseeing and the transportation assets that the TAMC is responsible for. This difference may provide a potential dividing line between the two council's responsibilities as it relates to culverts and bridges. For example, WAMC may provide guidance and support to asset owners for culvert and bridge assets as they relate to water quality issues. This could include items like aquatic organism passage, sediment load, or flooding and environmental issues related to a failure. This focus would allow the TAMC to continue to provide support and guidance relating to the overall functioning of culverts and bridges as they impact transportation.

8.1.2. *Tools and Training*

The pilot project developed a number of tools and training that are targeted at local road-owning agencies. These include condition rating guides, data handling processes, and data collection training using a standardized condition assessment. Roadsoft contains reporting tools which allow agencies to generate summary reports of their culverts by city/village/township and by culvert material type and allows agencies to create customized detailed reports showing information related to their continuing asset management needs. Many local agencies involved in the pilot said that they would continue to collect culvert data even after the culvert pilot data submittal deadline. This indicates that the tools and training not only made a coordinated pilot of this size possible, but it also spurred "spin off" activity that was of the local agency's own volition.

The training delivery and tool development for culvert asset management should continue regardless of the level of involvement and support the TAMC decides to provide for local agency culvert owners. Training and tools are the most basic level of support that allow local agencies to build a sustainable asset management process and culture. Providing recurring training will ensure that local agencies always have the technical knowledge to adopt asset management.

8.1.3. *Condition Assessment System and Inventory Fields*

Condition data for the modified FHWA culvert condition assessment system used in the pilot appears to have been relatively rapid to collect. Daily progress logs did not show a significant difference in the production rate for finding new culverts and finding and rating new culverts. The system provides an extensive list of distresses and includes a system to roll up distresses into a one number metric for aggregated reporting. Several local agencies commented that the

system should be simplified to a one number rating which would simplify collection and still provide specific condition data necessary for determining replacement.

The inventory fields collected during the pilot provide a high level of information that can be readily used to classify culverts and identify risk and cost factors associated with them. This level of data also provides a sound basis for local management of culvert assets. It is recommended that the TAMC continue to use the pilot inventory fields as a baseline minimum while allowing local agencies to collect more extensive data to meet local needs.

8.1.4. *Data Collection*

The free availability of Roadsoft and Roadsoft LDC, and the experience that Michigan local agencies have in collecting pavement data, are some of the reasons that the pilot was able to accomplish the large volume of data collection over a short timeframe. Approximately 90% of local agencies involved in the pilot used Roadsoft and Roadsoft LDC for the pilot data collection. Roadsoft is available for no cost to local transportation agencies in Michigan and has been widely adopted by Michigan's local transportation agencies prior to the start of the pilot. As such, many agencies already had the basic collection equipment and trained staff familiar with the software before the pilot started.

The predominate use of one asset management system provides opportunities for efficiency among local agencies, both in supporting the development and maintenance of the system, and also in the area of training and maintaining local agency staff. Commonly used systems allow local agencies to share staff resources and to act as peer mentors to one another.

Widely adopted single systems like Roadsoft also provide a consistent data format that speeds the roll up of data from a local level, to a regional and state level. The relationship between the CTT team that develops and supports Roadsoft and the State of Michigan ensures that the system will always provide the necessary functions for statewide collection.

While Roadsoft is used by the vast majority of Michigan local agencies, it is not the ideal tool for every local agency. Five local agencies involved in the pilot opted to collect data using other tools ranging from ArcGIS to a spreadsheet. The pilot illustrated that allowing a variety of tools for data collection can still allow a state-wide effort to be accomplished, and the data to be used at a state and local level, as long as basic data handling rules are followed.

At least two of the local agencies that opted to use ArcGIS developed their data model from the existing Roadsoft format. In a sense, the Roadsoft data model has become the de facto data format for the pilot. The TAMC should provide a baseline data model and data standard for culvert data collection. This unified data schema will allow the use of a variety of tools and the evolution of the data collection process. This ensures that local agency needs are met while still allowing easy compilation, sharing, and reuse of data.

The TAMC data standard should also include provisions for assignment, transfer, and update of a globally unique identification (GUID) for all culvert assets between local asset management systems and the TAMC state and regional databases. GUID's create a method for identifying assets that are already present to avoid duplication of asset registers or deletion of assets in close proximity which may be mistaken as duplicates.

Inventory data should be updated on a regular basis as culverts are replaced. Culvert conditions should be evaluated on a regular basis to ensure the data represents the current field condition of the culvert. Section 8.2 provides several options for process management of a culvert data collection.

8.1.5. *Shared Data Use*

There has historically been a significant interest in culvert data by fisheries, MDOT, Department of Environmental Quality (DEQ), DNR, and other natural resource agencies. Fisheries professionals are interested in many of the same inventory features that road owners are, but for different reasons. Fisheries professionals are primarily interested in the relative ease of aquatic organism passage (AOP) at culverts which are stream crossings. Figure 8-1 illustrates a culvert which is perched above the downstream flow line. This type of a culvert is a complete barrier to AOP leading to stream habitat fragmentation.

In many cases natural resource agencies have funded data collection of culvert data, and have frequently provided additional funding to road agencies to make culvert stream crossings more AOP friendly. In most cases this includes increasing the size of the culvert conduit and decreasing flow velocity through the culvert, both of which provide an increased flow capacity during rain events. This additional resiliency benefits both the natural resources and transportation agencies.

Figure 8-1: Perched culvert which presents a significant barrier to aquatic organism passage. Photo credit Bradley Link, Link Engineering Services, LLC.

The TAMC should provide access to culvert data for natural resources and fisheries agencies to promote the shared use of the culvert data. This data has the potential to provide the framework for joint funding of culvert reconstruction projects and shared data collection efforts between fisheries and transportation agencies.

The TAMC may need to consider adding data fields to the inventory collection standard to accomplish AOP analysis if there is significant cooperation between resource agencies and transportation agencies on culvert funding issues.

8.2. Process Management Recommendations

The TAMC has several options for developing and supporting a state-wide culvert data collection program, each with benefits and drawbacks. This section outlines the general concept behind each of the options but is not intended to be a fully developed program plan. This narrative may prove helpful as a starting point for discussions on next steps for the TAMC. Each of the options presented in this section were developed with the premise that a successful program must provide benefit for both the local asset owner and the state agency, which has always been a tenant of the TAMC's policies.

- Routine Coordinated Collection
    - A portion of asset network is collected each year with the entire network collected on a several-year cycle

- Infrequent Extensive Collection
    - Entire asset network collected at one time on a several-year cycle
- Fixed Location Sampling
    - A sample of the asset network is collected and results are extrapolated to the entire network
- Non-Compulsory Collection
    - No requirement to collect data on asset network but data would be accepted from volunteers.

8.2.1. *Option 1: Routine Coordinated Collection*

This method mandates an annual data collection cycle where a portion of the asset network is collected each year. A cycle of several years is required to collect data on the entire network. The TAMC's PASER pavement condition assessment collection is a good example of a routine coordinated data collection. PASER pavement condition data is collected on a two-year cycle, meaning that the entire network is updated every two years.

Culvert data would not require a short collection cycle like pavement data because culvert assets are designed to last for 50 to 100 years, while pavements are designed to last 15 to 25 years. Culvert data cycles could be as long as five to ten years, since this frequency would allow 10 to 20 data collection points over a culvert's design life and would only require a small portion (10 to 20 percent) of the road network to be collected each year.

Routine coordinated collection requires ongoing annual training and support to local agency infrastructure owners to maintain the consistency of data collection and maintain the process. This is not to say that every person involved in data collection would need to be trained every year, but rather that the training would need to be offered to allow people new to the process and people needing a refresher to have access to training.

A potential modification of this method would be to include a biased subset of culvert locations that are collected on more frequent data cycles. As an example, the TAMC could consider that any culvert rated 4 or lower needs to be inspected every year, or that culverts over a specific size or depth require more frequent inspections. These more frequent inspections provide increased data density on a population of interest. Inspecting poor quality culverts on an increased cycle ensures that local agencies are aware of risks are more likely to provide information to the TAMC on outcomes from culvert projects.

Benefits of Routine Coordinated Collection

Maintaining an ongoing, consistent collection activity provides a high likelihood that culvert asset management will develop as a business process and become part of the culture of the road owning agency. An annual effort allows local agencies to anticipate staffing needs and equipment resources. It also allows the formation of relationships between state, region, and

local agency employees. Ongoing processes typically become self-sustaining because the resources and knowledge to accomplish the process become routine.

Annual collection of culvert data on a portion of the road system increases the quality of the data at a state level by ensuring there are samples from each agency. This reduces sampling error and provides a consistent source of data that can be used as a proxy to monitor the overall condition of culvert assets both at a state and local level. This system also allows local agencies to maintain a full set of recent data on their entire network.

Drawbacks of Routine Coordinated Collection

Ongoing annual data collection becomes less efficient as the annual portion of the network that is required to be collected gets smaller. This is because all local agencies would need to train and maintain staff to collect a small portion of their network. At some point it becomes advantageous to sub-contract out these small local data collection efforts across jurisdictional boundaries to remain efficient; however, this negates some of the positive aspects of this method. Allowing local agencies to decide if they self-collect or join with others to group collect provides the largest flexibility to meet their local needs.

8.2.2. *Option 2: Infrequent Extensive Collection*

This method mandates periodic, system-wide, data collection efforts to create a snapshot of state wide conditions at specific periods in time. There is no ongoing, annual effort with this method, but rather one large event that targets a nearly complete collection every five to ten years. The United States Census is an example of this type of data collection mode.

Benefits of Infrequent Extensive Collection

Since collection only occurs once every several years, there is not an ongoing cost to maintaining human and equipment resources or costs associated with recurrent training. Training and staffing efforts would ramp up before a collection effort and spin down after the collection is complete. Data collected using this method can eliminate sampling error since the goal would be to collect all of the network in a single year. Data from a full collection would also be continuous in the sense that the state and local agencies would have a full, continuous sets of data on all culverts for each collection period. The level of effort necessary to complete this collection option would be similar to the level of effort necessary to compete a full data cycle of Option 1, with some potential savings in efficiency on training and travel.

Drawbacks of Infrequent Extensive Collection

This method has large labor and cost swings associated with it which may cause issues with local agency forces. Staffing up for a collection event may prove costly to individual agencies, and a spin down of staffing after a collection event means that the human resources to do asset management do not reside domestically in owner agencies. This ebb and flow of human capital

can result in significant barriers to adoption of asset management business processes and loss of institutional knowledge.

8.2.3. *Option 3: Fixed Location Sampling*

This method mandates periodic data collection on a fixed set of culvert locations throughout the state. The sampling locations would be pre-defined based on criteria that minimizes sampling error. The sampling size for this method would depend on the granularity of the analysis that the TAMC would like produce. For example, fewer samples are necessary to produce a state-wide estimate of overall culvert condition than would be necessary to differentiate condition based on geographic location, or other factors like material type. Sampling could be competed each year or on a longer cycle depending on the need the TAMC has to detect changes in condition. The quality control data collection that MDOT does for the TAMC is an example of this type of process.

Benefits of Fixed Location Sampling

This option provides one of the lowest-cost methods for obtaining data on a state level. The small size of the collection makes it possible to collect this data with shared resources such as regional contractors which further saves costs. This method would allow the TAMC to make general statements about culvert condition with a very low investment.

Drawbacks of Fixed Location Sampling

This method does not provide much if any benefit to individual local agencies because the small size of the sample needed to characterize state conditions provides almost no strategic or tactical information on the local level. Increasing the sample size to be able to provide benefit for local agencies negates the financial benefit of this option. This option is not likely to encourage the adoption of asset management as a business practice since there is negligible benefit at the local agency level. This option may in fact dissuade local agency implementation of culvert asset management because sampling will be seen as a low benefit activity.

8.2.4. *Option 4: Non-Compulsory Collection*

The first three options for data collection all assumed a required collection event. Required events provide the most control of the nature, extent, and frequency of data collection, but they also come with a downside in the form of cost. Non-compulsory collection would be the lowest cost option for the TAMC to collect some data from local agencies. This option would essentially relegate the TAMC to collecting any data local agencies wish to share on their culverts whenever they feel like sharing it.

Benefits of Non-Compulsory Collection

This method would be extremely low cost since the TAMC would only be maintaining an upload system and providing training guidance for data collection.

Drawbacks of Non-Compulsory Collection

This method would likely not produce a stable sample or census of data for analysis purposes. There is a high likelihood that data may be biased based on the agencies that participate each year. This method is not likely to create implementation of asset management.

8.3. Maintenance Data

Data on culvert maintenance and replacement is necessary in order for any of these methods to provide high quality data. Replacement and maintenance data provides the basis to determine needed budgets, replacement cycles and is necessary with any modeling effort. Regardless of the method for data collection that is chosen, submitting culvert maintenance and replacement projects annually to the state provides continuity and context to existing condition data.

8.4. Recommendations for Future Research

The pilot outlined a few areas that should be investigated when going to full scale production. The TAMC should investigate the following items:

8.4.1. *Condition Assessment Systems*

The rapid schedule for the pilot did not allow a full discussion on the integration of the culvert pilot rating system with the system MDOT uses, or discussion on the integration and migration of data to the new rating standard that is currently under development at the federal level. Generally speaking, these three systems have the same general function, assess similar defects, and have a similar scale direction. Options may exist to develop a migration function that will allow translation from one rating system to another.

AASHTO is currently in the final stage of publishing an updated culvert condition assessment system to replace the FHWA method. MDOT is also considering its system and how it will translate or integrate with the new AASHTO method. The TAMC will need to address the issue of either migrating to this new standard, remaining with the current standard, or creating a new, simplified rating system as some local agencies have suggested. Regardless of the system chosen, it will take time to develop the tools, training, and institutional knowledge to execute such a change.

8.4.2. *Globally Unique Identification (GUID) and Data Storage System*

GUID's allow the coordinated update and maintenance of assets across multiple databases. The TAMC needs to develop a standard system and business process for assigning and updating GUID's for culvert assets. This work will also be transferrable if the TAMC works with other non-road assets such as signals or signs.

The TAMC has clearly learned a significant amount about data storage and transfer while collecting PASER data over the last decade. A culvert data handling process needs to be developed after the TAMC decides on the data collection method. CSS will need to be closely consulted for this data handling process.

8.4.3. *Cost and Condition Model*

The TAMC will need to create a cost model that relates physical features of culvert inventory to replacement and maintenance costs. This model could be updated using bid costs or project reporting.

The TAMC should develop a simple network deterioration model which can be used to make projections on the condition of the state's culvert assets. More extensive deterioration models may also be considered for slab on abutment style culverts which are more similar to small bridges than pipe structures.

9. REFERENCES

Arnoult, JD. 1986. Culvert Inspection Manual. Federal Highway Administration (FHWA). IP-86-2. [Available from: https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=31&id=57]

Beaver JL & Richie MC, 2016. Culvert and Storm Drain System Inspection Manual. Transportation Research Board of The National Academies. NCHRP 14-26. [Available from: http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP14-26_FR.pdf]

Beaver JL, McGrath TJ, Leonard B, 2004. Condition Assessment of Utah Highway Culverts and Determination of Culvert Performance Measures. World Water Congress 2004. American Society of Civil Engineers (ASCE). [Available from: https://ascelibrary.org/doi/abs/10.1061/40737%282004%29393]

Bowers, J. D., Magers, S. R., Pyrz, J., & Bullock, D. M., 2014. Processes of small culvert inspection and asset management. Joint Transportation Research Program Publication. FHWA/IN/JTRP-2014/08). [Available from: http://dx.doi.org/10.5703/1288284315502]

Davidson JS & Grimes TC, 2006. Culvert Management System Implementation and Seminar. University Transportation Center for Alabama. Report 05209. [Available from: utca.eng.ua.edu/files/2011/08/05209fnl.pdf]

FHWA, 2004. National Bridge Inspections Standards Regulation (NBIS). Federal Highway Administration (FHWA). [Available from: https://www.fhwa.dot.gov/bridge/nbis.cfm]

FHWA, 2007. Culvert Management Systems. Federal Highway Administration (FHWA). IF-07-032. [Available from: https://www.fhwa.dot.gov/infrastructure/asstmgmt/tamcs_cms00.cfm]

Hunt JH, Zerges SM, Roberts BC, & Bergendahl B, 2010. Culvert Assessment and Decision-Making Procedures Manual For Federal Lands Highway. Federal Highway Administration (FHWA). CFL/TD-10-005. [Available from: https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=208&id=166]

MDOT. 2016. Asset Collection & Condition Assessment Guide for 1’ - <10’ Span Culverts. Michigan Department of Transportation (MDOT). [Available from: https://www.michigan.gov/documents/mdot/MDOT_RFP_SS_REQ2435_Tams_Culvert_Colection_616748_7.pdf]

Meegoda JN, Juliano TM, Tang C, 2009. CULVERT INFORMATION MANAGEMENT SYSTEM – DEMONSTRATION PROJECT. New Jersey Department of Transportation (NJDOT). FHWA-

NJ-2009-017. [Available from: http://www.nj.gov/transportation/refdata/research/reports/FHWA-NJ-2009-017.pdf]

Najafi M et. al, 2008. An Asset Management Approach for Drainage Infrastructures & Culverts. Midwest Regional University Transportation Center (UTC), University of Wisconsin-Madison. [Available from: https://minds.wisconsin.edu/handle/1793/53919]

ODOT, 2017. Culvert Inspection Manual. Ohio Department of Transportation (ODOT). p. 29-67. [Available from: http://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Culvert%20Management/Pages/Culvert-Management.aspx]

Venner M, 2014. Culvert and Storm Drain Management Case Study: Vermont, Oregon, Ohio, and Los Angeles County. Federal Highway Administration (FHWA). HIF-14-008. [Available from: https://www.fhwa.dot.gov/asset/pubs/hif14008.pdf]

Villwock-Witte N, Clouser K, & Fay L, 2016. Culvert Asset Management System: Best Practices/Pilot Project. Western Transportation Institute. [Available from: https://westerntransportationinstitute.org/wp-content/uploads/2016/07/4W5947-Culvert_Asset_Management.pdf]

WisDOT, 2018. Bridge Inspection Field Manual. Wisconsin Department of Transportation (WisDOT). p. 48-57. [Available from: http://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/strct/inspection-manual.aspx]

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APPENDIX A: LITERATURE REVIEW OF BEST PRACTICES

The purpose of the literature review was to identify best practices being used by county, state, and federal agencies that may be applicable to the pilot. This included identifying current data collection, storage, and evaluation tools in use by these agencies. Once these tools, techniques, and methodologies were identified, an assessment was undertaken to determine those which warranted inclusion in the pilot.

A study by the New Mexico Department of Transportation (DOT) determined that out of forty-seven responsive state DOTs, thirty-three states inspect their culverts (structures 20 feet or less), with nineteen having a culvert inspection manual and twenty-one having some form of culvert inspection training. However, each state had a widely varying number of culverts, a variety of culvert materials, varying inspection frequencies, varying condition-rating scales, varying collected inventory data, and varying data collection / storage methods (Villwock-Witte et. al. 2016).

Several state agencies were found to have a complete culvert management system in place for locating, inspecting, and storing data associated with culverts. Alabama (state and county level), Indiana, Los Angeles County, Maryland, Michigan, Minnesota, New Mexico, Ohio, Oregon, Utah, Vermont, and Wisconsin all have published studies or documentation outlining processes and procedures in their respective areas related to culvert data collection and inspection, which were used as the basis for this literature review.

In 2007, the Federal Highway Administration (FHWA) issued a report analyzing Culvert Management Systems specific to Alabama, Maryland, Minnesota, and Shelby County (FHWA 2007). In June 2014, the FHWA issued a similar report titled Culvert Management Case Studies: Vermont, Oregon, Ohio, and Los Angeles (LA) County. These reports summarized best practices from these locations and identified specific details on how they integrate their culvert inventory and evaluations with asset management plans for maintenance of their culverts (Venner 2014).

The FHWA has also released a Culvert Inspection Manual outlining procedures for conducting and documenting culvert inspections regarding the existing hydraulic capacity, structural integrity, and durability of culverts. However, published in 1986, it is noted that this document is dated and an American Association of State Highway and Transportation Officials (AASHTO) replacement document is under development, which will be based on a document released by the National Cooperative Highway Research Program (NCHRP), which suggests new procedures for conducting and documenting culvert inspections. Additionally, there is another system proposed for inventorying and inspecting culverts generated as the result of Midwest Regional University Transportation Center research study that bases condition ratings on a pairwise comparison of culvert components. However, this system provides little reference on how to conduct inspections, focusing instead on proposed condition evaluation procedures. The condition evaluation portions of these systems will be discussed in depth in section 1.1.6.

1.1.1. Culvert Sizes Considered

As stated in the FHWA Culvert Inspection Manual, “structures over 20 feet in span parallel to the roadway are usually called bridges; and structures less than 20 feet in span are called culverts even though they support traffic loads directly” (Arnoult 1986). This is the generally accepted culvert definition; the NCHRP report agrees with this definition (Beaver & Richie 2016) and state DOTs inventory and inspect structures under 20 feet as culverts. However, DOTs have varying minimum sizes for inspection of culverts and some DOTs separate inspection levels into different groups of culvert sizes. Generally, most state DOTs are moving towards inventorying and inspecting culverts down to around 1 foot, and separating culvert inspection into groups of 1 to 10 feet and 10 to 20 feet if group separations are made. Specific state practices are presented below.

Oregon has collected culvert data for culverts as small as 3 feet since the mid 1980’s before expanding that to culverts down to 1 foot. Ohio DOT also inventories and evaluates culverts down to 1 foot in two groups; 1 to 10 feet and 10 to 20 feet. Vermont has been collecting data on culverts from 6 to 20 feet for decades and in 2002 started collecting data on smaller culverts. The Maryland State Highway Administration’s Bridge Inspection and Remedial Engineering Division has inventoried and inspected culverts down to a 5 feet span and select culverts in the 3 to 5 feet range. Minnesota DOT separates their culvert management and inspection into two categories: 1-10 feet and 10-20 feet, with the larger spans inspected by their Bridge Inspection Unit and the smaller ones inspected by the Hydraulics Unit. Alabama inventories all culverts between 15 inches and 20 feet (Venner 2014). In 2014, Indiana DOT performed a research project regarding expansion of their culvert management program to include inventorying and inspection of culverts smaller than 48 in, whereas these structures were previously not considered (Bowers et. al. 2014). In 2016, Michigan DOT released a document regarding inventorying and condition assessment of culverts between 1 foot and <10 feet (culverts between 10 and 20 feet were evaluated previously) (MDOT 2016). The Office of Federal Lands Highway inspects all culverts under 20 feet with no grouping of culvert sizes (Hunt et. al. 2010).

1.1.2. Frequency of Inspection

The New Mexico DOT study found that state DOTs use varying inspection periods for their culverts; inspections on culverts are made anywhere from annually to every six years, depending on the state. Many states have provisions to their established regular inspection cycles; Colorado, Oregon, and other states inspect culvert structures more frequently if the culvert condition warrants more frequent monitoring, and Utah, Oklahoma, and Nebraska inspect culverts after storm events (Villwock-Witte et. al. 2016). Some inspection frequencies are decided based on culvert size as well. Specific state and county practices are presented below.

LA County (approximately 5,000 culverts) conducts an annual inspection of their culverts and Ohio (approximately 80,000 culverts) conducts inspections every 10 years on culverts between 1 and 4 feet and every five years for culverts between 4 and 10 feet. LA County was the only agency in the case study that used their culvert management system to track maintenance work history and for describing repair/replacement strategy and improvement projects (FHWA 2007). The Maryland State Highway Administration typically inspects culverts on a four-year cycle with two-year inspections if condition warrants. The Minnesota DOT inspects culverts 10 feet and larger located on the state trunk highway system on an annual or biennial basis depending on condition. Minnesota law as of 2007 did not allow inspection intervals greater than two years though they were trying to amend that to four years on some structures like concrete box culverts. Culverts less than 10 feet are inspected as needed - there is no required inspection frequency on these structures. Alabama has no required culvert inspection frequency and performs inspections as-needed, though annual inspections are recommended if deemed necessary. Shelby County (Alabama) conducts culvert inspections on a regular two-year cycle in conjunction with their National Bridge Inspection Standards (NBIS) inspection program (Venner 2014). Indiana DOT performs annual inspection of their culverts, but only inspects one fourth of their culverts annually (Bowers et. al. 2014). In Michigan, culverts 10 to 20 feet are also inspected on a regular two-year cycle in conjunction with the NBIS rating system, while the condition of culverts 1 to <10 feet governs their inspection frequency (MDOT 2016).

The FHWA Culvert Inspection Manual suggests that culverts be inspected every two years, but allows less frequent inspection if justified (Arnoult 1986). The NCHRP report recommends establishing an inspection frequency based on both the condition and size of the culvert, but leaves the frequency decision to the agency. Under the recommended system, culverts greater than 10 feet should be inspected every two years regardless of condition and culverts less than 10 feet should be inspected at intervals depending on their size and last reported condition. This recommended system also suggests that all culvert sizes should be inspected prior to or during regular maintenance activities on the roadway where the culvert is located. It also provides other criteria for agencies to consider when deciding inspection frequency, including age of the structure, ADT, environmental conditions, and consideration of extra criteria for special function structures (Beaver & Richie 2016).

1.1.3. Equipment Used

In the New Mexico study, it was found that states inventorying and inspecting their culverts do not have a common method for recording inventory and condition data. Recording methods include paper reports, laptop, iPad, Trimble, or some combination of these methods. As for software used to record data, some states indicated that they were using AASHTOWare software, some states indicated that they were using Agile Assets, and some states indicated that they were using a state-specific inventory program (Villwock-Witte et. al. 2016). In one of

the FHWA studies, it was found that of states inventorying and inspecting their culverts, eight states use Pontis (AASHTOWare), thirteen use an in-house developed (state-specific) database, and eight states use a combination of these methods. It should be noted that no state uses the FHWA Culvert Management System to record data (FHWA 2007),2 however one county studied, Shelby County, uses the software (Davidson & Grimes 2006).

LA County uses cameras with built-in GPS to both document culvert condition and provide location information (Venner 2014). Indiana DOT provides their inspection crews with a digital camera, personal protective equipment (PPE), a measuring tape, a measuring wheel, flashlights, and a shovel (Bowers et. al. 2014). Michigan DOT provides their inspection crew with measuring tools, hand tools, an approved data collection device (such as a tablet or laptop), flashlight, PPE, properly sized waders, and a stability pole (MDOT 2016).

The Office of Federal Lands Highway recommends a full list of equipment for inspection, separating equipment into on-person equipment and in-vehicle equipment. On-person equipment for a two-person crew includes an assessment form, a clipboard, a geologist pick hammer, a 25-foot measuring tape or folding carpenters ruler, a digital camera (shock-resistant and waterproof), a flashlight (500k to 1m candle) and/or head lamp, a handheld mirror, a probing rod (graduated survey rod section), personal air monitoring devices, traffic safety vests and personal field safety gear, extra car keys, tool belts for hands-free carrying of inspection equipment, cell phones and/or field radios, and a concrete crack comparator card. In-vehicle equipment for a two-person crew includes a Global Positioning System (GPS) device, project files & maps, an assessment guide, a culvert entry guide, a first aid kit w/snake bite and poisonous vegetation provisions, OSHA traffic cones, extra batteries, bulbs, and storage cards for camera, GPS, and lights, waders and life jackets, a 100-foot tending line, hardhats or climbing helmets, crack gauge or calipers, a folding shovel, a machete, a pry-bar, emergency contact information and equipment, a 100-foot measuring tape, a distance wheel, or a range finder, and an inclinometer (Hunt et. al. 2010).

1.1.4. Pilot Studies

Best practices identified in a 2014 FHWA study stress the importance of getting a system in place. Once locations are established with some capacity for condition assessment, the assessment portion can be improved with time by adding additional data. “Internal groups and stakeholders can identify large lists of potential data to be collected; however, the agency should make sure it knows how the data will be used and how often it may be used” (Venner 2014).

Oregon DOT conducted a culvert inventory and inspection pilot study in 2006. By 2010, Oregon DOT had refined their collection assessment to include 45 data fields for the site, 27 for condition, and 13 photos per culvert. In 2011, they chose to use a smaller number of fields noting the “delicate balance between collecting enough data to provide useful information and

the time and resources necessary to collect, manage, and maintain the data." Their management system still has the ability to capture additional fields but they are not mandatory or regularly collected (Venner 2014).

Like Oregon, Utah performed a 2004 pilot study on how to create a system for monitoring culvert condition based on qualitative and quantitative measures, based on a numerical 0-9 scale (Beaver et al. 2004). However, based on the New Mexico study, they have not yet developed an inspection manual, and still use a qualitative scale to rate culverts rather than a numerical scale (Villwock-Witte et. al. 2016).

A pilot program on culverts under 48 in. was performed in Indiana in a trial region, the goal was to inventory and inspect culverts based on existing rating scales and look for improvements. The study found that under the current 0-9 rating scale, a majority of the culverts were rated as a 9 (highest rating), and there was ambiguity between what constitutes a specific rating, such as the difference between an 8 and a 9. The results of the pilot proposed that the scale be modified for small culverts, using a 1-9 scale that only considers odd numbers and more descriptive rating definitions. These changes were proposed so that the range of rating values matched the existing 1-9 scale while reducing ambiguity between ratings. The study also recommended that photos be implemented into the inventory process, and that improvements be made to the inventory database (Bowers et. al. 2014).

In New Jersey, a pilot program was performed to switch asset management of culverts from a simple linear depreciation model to a condition based model that complies with the then new Governmental Accounting Standards Bureau (GASB) regulations (GASB-34). This pilot proposed a 1-5 rating method (1 being an excellent rating, 5 being a very poor rating), with ratings based on the level of overall deterioration. It also proposed that frequency of inspections be based on sediment damage to the culvert, pH levels, corrosivity/erosion potential of the area, and age vs design life. Many different culvert liners and materials were considered, and the results were used to predict remaining service life for use in asset management decisions (Meegoda et al. 2009).

In September 2016, MDOT published the Asset Collection & Condition Assessment Guide for 1 to <10 feet Span Culverts. This assessment guide highlights the pilot project to collect location and assessment data for 1-10 feet culverts under MDOT owned roadways in six counties; Eaton, Ingham, Isabella, Mackinac, Osceola, and Saginaw. Isabella County was inventoried under a separate pilot program in 2016 and condition evaluation was performed as part of the larger pilot in 2017. The MDOT report describes the Transportation Asset Management System (TAMS) interaction and integration in the collection of culvert data. In addition to the data collection process using TAMS, the guide provides information on attribute and condition assessment. The guide provides a comprehensive overview of the process of locating and assessing culverts and associated attributes (end treatments, footings, etc.). It should be noted that MDOT effectively considers 10 – 20 feet culverts as bridges, and inspections are included as a subset of their bridge inventory (MDOT 2016).

1.1.5. Inventory Data Collected

The New Mexico study identified key inventory data fields from their literature review and survey of state practices, as well as the frequency of their appearance. A summary of these findings are presented in Table 1 (Villwock-Witte et. al. 2016).

Table 1: Key Inventory Data Field (Villwock-Witte et. al. 2016)

Field	Frequency in Literature	Frequency in State Review	Total
Culvert Shape	8	11	19
Culvert Material	8	10	18
Culvert Length	7	10	17
Comments	6	8	14
Current Overall Condition Rating	8	5	13
Inspection Date	7	5	12
Asset Identification	6	5	11
County Code	4	7	11
Mile Marker	5	6	11
Inspector Name	6	5	11
Culvert Latitude	4	6	10
Culvert Longitude	4	6	10
Road Name	3	7	10
Depth of Cover	5	4	9
Construction Date	5	3	8
Culvert Width	2	6	8
Culvert Span	3	4	7
Culvert Height	2	5	7
Number of Barrels	1	6	7
Road ID	2	5	7
Average Daily Traffic of Roadway Above Culvert	4	1	5
Culvert Diameter	2	3	5
Maintenance Responsibility	2	3	5
Municipality	2	3	5
Inlet Condition Rating	2	3	5
Outlet Condition Rating	2	3	5
Inventory Date	1	4	5
Roadway Surface Condition Rating	4	1	5

Additionally, some agencies, such as Indiana (Bowers et. al. 2014), LA County (Venner 2014), and the Office of Federal Lands Highway (Hunt et. al. 2010), are finding that photographs of the culvert conditions are useful. In their small culvert pilot study, Indiana DOT recommended that a minimum of four photos be taken of every small culvert inspected; a wide angle overview photo of both the culvert inlet and outlet, and one inside view photo from both the culvert inlet and outlet. They also suggest taking additional pictures of irregular or concerning conditions in the culvert or on the roadway above the culvert (Bowers et. al. 2014).

1.1.6. Condition Evaluation Methods:

1.1.6.1. Federal Highway Administration (FHWA)

FHWA issued report number FHWA-IP-86-2, Culvert Inspection Manual: Supplement of the Bridge Inspector's Training Manual in 1986. This manual provides information on culvert types, inspection procedures, and a culvert components inspection guide for approaches, end treatments, waterways, corrugated metal, precast concrete, cast-in-place concrete, and masonry culverts. The report provides guidance on data that should be collected for inventory and data that should be collected for condition evaluation of the culverts. The recommended rating system is a 0 to 9 scale, with 9 indicating that no repairs are needed and 0 indicating that the facility is closed for repairs. Condition assessments are made for the following items (Arnoult 1986):

- Approach roadway condition
- End treatment and appurtenant structures
- Waterway adequacy
- Channel and channel protection
- Corrugated metal culverts
- Corrugated metal culvert barrels
- Corrugated metal long-span structures
- Concrete culverts
- Precast concrete culvert barrels
- Cast-in-place concrete culvert barrels
- Masonry culverts
- Overall culvert ratings

1.1.6.2. National Cooperative Highway Research Program (NCHRP)/American Association of State Highway Transportation Officials (AASHTO)

NCHRP 14-26, Culvert and Storm Drain System Inspection Manual, was published in May 2016 and serves as a proposed update to the FHWA Culvert Inspection Manual. The NCHRP report contains several changes from the FHWA method. The largest change is a proposed five-point

rating system which the authors feel more directly correlates to observed conditions. Rating descriptions have been reorganized to a component-level evaluation to be consistent with the AASHTO Bridge Element Inspection Manual. Culvert materials including plastic and timber have been added. New rating descriptions were added to focus on incorporating quantitative measures of distress. The final NCHRP report was submitted to AASHTO for adoption (Beaver & Richie 2016).

The Culvert and Storm Drain System Inspection Manual is currently under review by AASHTO. It is not known what changes may be made to the NCHRP report and when publication by AASHTO may occur.

1.1.6.3. 2008 Midwest Regional UTC (Madison)

This method was developed as the result of a research project performed by the Midwest Regional University Transportation Center (UTC) in an attempt to give more insight for asset management of culverts. In this method, individual element ratings are combined into a single rating value based on a weighted average algorithm that uses an analytical hierarchy process (AHP) based on a pairwise comparison approach (i.e. “this is ___ more important than that”). This method is broken down into two tiers, Basic Condition Assessment (BCA) and Advanced Condition Assessment (ACA). In BCA, individual culvert components such as the invert, structure, and footings are rated on a 1-5 scale (5 being excellent and 1 being failure/critical) and then multiplied by a computed relative weight determined by an algorithm based on the decided importance of the component relative to other culvert components. These weighted component ratings are then summed to achieve an overall culvert rating. Each inspected culvert undergoes a BCA; if the structure scores higher than a 2.5, then the BCA score is assigned as the culvert condition rating. If the structure scores below a 2.5 on the 5-point scale, an ACA is performed to determine the overall culvert rating (Najafi et al. 2008).

In ACA, culvert conditions that lead to deterioration are rated rather than the components of the culvert themselves. These conditions are specific to the culvert material; for example, concrete culverts would be rated based on the conditions of cracking, scouring, settlement, joint openings, misalignment, and the concrete surface. Corrugated metal structures would be rated on different criteria. These conditions are rated on the same 1-5 scale, multiplied by a factor determined during the AHP, and then summed to achieve an overall culvert rating. Both the BCA and ACA culvert ratings are reported if ACA is performed (Najafi et al. 2008).

This analysis tool for condition ratings is more rigorous than other methods and is designed to make a greater distinction between culvert ratings in attempt to be a more useful tool for asset management. Additionally, this system proposes the collection of a specific and extensive set of inventory data, which it titles Culvert Inventory Data Collection Format (CIDCF) (Najafi et al. 2008).

1.1.6.4. Agencies' Methods

Vermont DOT uses a 0-9 scale National Bridge Inspection Standards (NBIS) rating system to evaluate their culverts between 6 and 20 feet and uses a five-level (excellent, good, fair, poor, critical) system to evaluate culverts less than 6 feet (FHWA 2004). Vermont has been collecting data on culverts between 6 and 20 feet as part of their bridge program for decades. Los Angeles County also uses descriptive condition ratings such as "good", "in need of repair", "blocked", "eroded", or "collapsed" (Venner 2014). Maryland uses the NBIS Item 62 (0-9 scale) for their culvert condition ratings. Minnesota inspects large culverts (10-20 feet) with a condition ratings system based on Pontis and NBIS. Smaller culverts (1-10 feet) are rated using a scale of 1 to 4 with 1 being the best condition. Pipes rated as 4 indicate an immediate fix may be required and those rated as 3 indicate repairs should be conducted as time and resources allow. Alabama does not require formal inspection reports, and written data is not collected or gathered into a database. Inspection is not based on a formal rating or NBIS condition evaluation system. Shelby County (Alabama) uses a condition rating system based on NBIS Item 62 ranging from 0-9 with 9 indicating "no deficiencies" and 0 indicating "structure closed and needing replacement" (FHWA 2007). Michigan's inspection guide uses a 1-9 scale, where 9 equals no repairs needed, and 1 indicates that emergency action is required and the roadway should be closed (MDOT 2016). The Office of Federal Lands Highway uses a good, fair, poor, critical system to rate their culverts, with different condition evaluation rating tables created for varying culvert types (Hunt et. al. 2010).

Ohio DOT had previously collected location and condition data for culverts with 10-20 feet spans using the 0-9 NBIS rating system and opted to continue and adapt that rating system for culverts less than 10 feet (Venner 2014). They have also developed their own Culvert Management System, detailed in their 2017 Culvert Inspection Manual. This document is based on the FHWA system, but provides additional quantitative and qualitative rating descriptors for rating corrugated metal, concrete, masonry, and plastic culvert structures beyond what is described by the FHWA (ODOT 2017).

The 2018 Wisconsin Department of Transportation (WisDOT) Bridge Inspection Field Manual provides descriptors for condition rating timber bridges whereas timber culvert condition ratings are not covered under the existing FHWA system. These condition ratings relate to deterioration problems experienced by culverts as well, and thus is a useful resource in developing a timber culvert condition rating system (WisDOT 2018).

1.1.7. Training Programs

A few states provide explanations of their training processes. Ohio DOT conducts a focused one-day training on their 0-9 culvert rating system (Venner 2014). Minnesota DOT does not require NBIS training for inspectors of 1-10 feet culverts; however, most participate in a one-day course focused on condition, codes, problems, and data formatting (FHWA 2007).

In 2006, Alabama conducted a training program for engineers and engineering technicians from the Alabama DOT and local agencies on the use of asset management software. The format was three separate full-day seminars where attendees were introduced to culvert asset management, introduced to the FHWA Culvert Management System software, and performed practice problems regarding use of the software. Responses to this training session yielded mostly positive results from attendees (Davidson & Grimes 2006).

APPENDIX B: PRE-CULVERT PILOT SURVEY

Which of the following best describes your current culvert inventory and condition evaluation program:

Culverts have not been inventoried or condition evaluated.

- What is your best estimate for the number of culverts in your jurisdiction?

A portion of agency culverts have been inventoried, but none or very few have had their condition evaluated on a routine basis (at least once every 5 years).

- How many culverts have been inventoried?
- What percentage of the culverts in your jurisdiction do you feel this represents? (Note: enter 100% if you believe every culvert is included in your inventory data)
- Culverts may be subdivided into categories to facilitate various needs such as condition evaluation techniques, asset management, or maintenance. If your agency subdivides culverts, what criteria is used and what benefit is gained?
- What culvert characteristics do you record?

    a. Inventory ID
    b. Waterway
    c. GPS Coordinates
    d. Material Type
    e. Asset Collection Date
    f. Date Installed
    g. Shape
    h. Entrance Structure
    i. Exit Structure
    j. Skew Angle
    k. Length
    l. Span
    m. Rise
    n. Depth of Cover
    o. Height/Diameter
    p. Width
    q. Culvert Rating
    r. Maintenance
    s. Work Orders
    t. Photos
    u. Other -

- How do you organize and store your culvert inventory data? (e.g., paper files, spreadsheet, database, asset management software, etc.)
- If some of your culverts have had their condition evaluated, please describe your strategy for evaluating culverts and the rating system that you used.

Most culverts have been inventoried and their condition evaluated on a routine basis (at least once every 5 years)

- How many culverts have been inventoried?
- What percentage of the culverts in your jurisdiction do you feel this represents? (Note: enter 100% if you believe every culvert is included in your inventory data)
- Culverts may be subdivided into categories to facilitate various needs such as condition evaluation techniques, asset management, or maintenance. If your agency subdivides culverts, what criteria is used and what benefit is gained?
- What culvert characteristics do you record?

    a. Inventory ID
    b. Waterway
    c. GPS Coordinates
    d. Material Type
    e. Asset Collection Date
    f. Date Installed
    g. Shape
    h. Entrance Structure
    i. Exit Structure
    j. Skew Angle
    k. Length
    l. Span
    m. Rise
    n. Depth of Cover
    o. Height/Diameter
    p. Width
    q. Culvert Rating
    r. Maintenance
    s. Work Orders
    t. Photos
    u. Other -

- How do you organize and store your culvert **inventory** data? (e.g., paper files, spreadsheet, database, asset management software, etc.)
- How many culverts have been condition evaluated?

- What rating system do you currently use? (please note if different rating systems are used for different subcategories of culverts, for example culverts 1 – 9.9 feet vs 10 – 19.9 feet)
    - FHWA (1986) (the system used by RoadSoft)
    - Other, please provide more information:
- What components of the culvert system are considered in your overall condition evaluation? (e.g., upstream end, culvert pipe, downstream end, apron, etc.)
- How frequently do you evaluate the condition of your culverts? Does the frequency vary depending on culvert size, material, condition of roadway above, or other properties?
- What tools and equipment do you use to conduct condition evaluation of culverts?
- How do you organize and store your culvert **condition** data? (e.g., paper files, spreadsheet, database, asset management software, etc.)

Other comments you would like to share with the TAMC Bridge Committee regarding the Michigan Culvert Mapping Pilot Program or your agency's current culvert inventory and condition evaluation program:

Would you be interested in participating in the pilot? We are looking for agencies with all levels of existing culvert inventory and condition data. Participants must be able to complete their inventory, condition evaluation, and reporting by August 2018.

Agency –
Name –
Email –
Phone number –
May we contact you with any questions?

APPENDIX C: PARTICIPATING LOCAL AGENCIES

Agency	County	Tier
Antrim County Road Commission	Antrim County	Tier 1
Baraga CRC	Baraga County	Tier 1
Charter Township of Clayton		Tier 1
Charter Township of Ypsilanti		Tier 1
Charter Township of Flushing		Tier 1
City of Battle Creek		Tier 1
City of Benton Harbor		Tier 1
City of Brown City		Tier 1
City of Burton		Tier 1
City of Clio		Tier 1
City of East Tawas		Tier 1
City of Fenton		Tier 1
city of ironwood		Tier 1
City of Lake Angelus		Tier 1
City of Munising		Tier 1
City of Southfield		Tier 1
City of West Branch		Tier 1
City of Whitehall		Tier 1
Farmington Hills		Tier 1
Houghton County Road Commission	Houghton County	Tier 1
Lake County Road Commission	Lake County	Tier 1
Leelanau County Road Commission	Leelanau County	Tier 1
Marquette County Road Commission	Marquette County	Tier 1
Marquette CRC	Marquette County	Tier 1
Missaukee County Road Comm.	Missaukee County	Tier 1
Montcalm County Road Commission	Montcalm County	Tier 1
Networks Northwest		Tier 1
Village of Vermontville		Tier 1
village of Carsonville		Tier 1
Village of Caledonia		Tier 1
village of Daggett		Tier 1
Village of Fairgrove		Tier 1
Village of Holly		Tier 1
Village of Howard City		Tier 1
Village of Lincoln		Tier 1
Village of Morrice		Tier 1
Village of Newberry		Tier 1

Agency	County	Tier
Village Of Pentwater		Tier 1
Village of Sanford		Tier 1
Village of Walkerville		Tier 1
Roscommon Co. Road Comm.	Roscommon County	Tier 2
Tuscola County Road Commission	Tuscola County	Tier 2
City of Tecumseh		Tier 2
Cass County Road Commission	Cass County	Tier 2
City of Cadillac		Tier 2
Oceana County Road Commission	Oceana County	Tier 2
Oceana County Road Commission	Oceana County	Tier 2
Oscoda County Road Commission	Oscoda County	Tier 2
Shiawassee County Road Commission	Shiawassee County	Tier 2
City of Muskegon Heights		Tier 2
Kalkaska County Road Commission	Kalkaska County	Tier 2
Hillsdale County Road Commission	Hillsdale County	Tier 2
Lapeer County Road Commission	Lapeer County	Tier 2
Barry CRC	Barry County	Tier 2
Saginaw County Road Commission	Saginaw County	Tier 2
City of Marysville DPW		Tier 2
City of Big Rapids		Tier 2
City of St. Louis		Tier 2
Road Commission of Kalamazoo County	Kalamazoo County	Tier 2
Van Buren County Road Commission	Van Buren County	Tier 2
Village of Lennon		Tier 2
HRC - City of Bloomfield Hills		Tier 2
St. Clair County Road Commission	St. Clair County	Tier 2
City of Coldwater		Tier 2
Branch County Road Commission	Branch County	Tier 2
City of Mt. Pleasant		Tier 2
Grand Traverse County Road Commission	Grand Traverse County	Tier 2
Ottawa County Road Commission	Ottawa County	Tier 2
Benzie County Road Commission	Benzie County	Tier 2
Mecosta County Road Commission	Mecosta County	Tier 2
Allegan County Road Commission	Allegan County	Tier 2
Ingham County Road Department	Ingham County	Tier 2
Dickinson County Road Commission	Dickinson County	Tier 2
St Clair County Road Commission	St. Clair County	Tier 2
Muskegon County Road Commission	Muskegon County	Tier 2

Agency	County	Tier
Genesee County Road Commission	Genesee County	Tier 3
City of Rochester Hills		Tier 3
Washtenaw County Road Commission	Washtenaw County	Tier 3
Clinton County Road Commission	Clinton County	Tier 3
Road Commission for Oakland County	Oakland County	Tier 3
Huron County Road Commission	Huron County	Tier 3
Bay County RC	Bay County	Tier 3
Kent County Road Commission	Kent County	Tier 3
Midland County Road Commission	Midland County	Tier 3

APPENDIX D: TRAINING DOCUMENT

INTRODUCTION

This document will provide guidance on how and what inventory data to collect for the TAMC Michigan local agency culvert pilot, particularly with regards to condition evaluation of culverts. It will outline the inventory data input into Roadsoft as described in the Condition Evaluation webinar presented on April 26, 2018 and May 2, 2018, and provide information regarding what culvert aspects should be inspected for a given culvert type.

For determining a specific condition rating of a culvert, inspectors should use the Culvert Rating Charts provided during the webinars. The purpose of this document is to provide further detail on the condition ratings provided on those rating charts.

It is noted that this pilot considers any structure with a span under twenty feet as a culvert, and any span larger than twenty feet is considered a bridge. Around twenty feet, it may be unclear whether to rate the structure as a bridge or culvert; the inspector should make this judgement. If it is determined to rate a structure as a bridge, the inspector should use the MDOT bridge inspection form.

INVENTORY DATA INPUT INTO ROADSOFT

Inventory ID – Automatically generated by Roadsoft.

GPS Coordinates – Latitude and longitude of the culvert, measured at the middle of the road overtop the structure and recorded in decimal degrees.

Material Type – The primary material of the culvert structure.

- Undefined
- Aluminum Box Culvert
- Aluminum Long Span Structure
- Cast-in-place Concrete Culvert
- Corrugated Aluminum Pipe
- Corrugated Steel Box Culvert
- Corrugated Steel Pipe
- Long Span Corrugated Steel Structure
- Masonry Culvert
- Other
- Pre-Cast Concrete Pipe
- Structural Plate Aluminum Pipe
- Structural Plate Steel Pipe
- None

Modified Roadsoft Fields

- Plastic
- Timber
- Steel
- Aluminum
- Concrete

Asset Collection Date – Date at which the condition ratings were collected.

Shape – Original shape of the culvert, reference Figure 1 for common shapes.

- Undefined
- Arch
- Circular
- High Profile Arch
- Horizontal Ellipse
- Low Profile Arch
- Other
- Pear
- Pipe Arch
- Rectangular
- Underpass
- Vertical Ellipse

Modified Roadsoft Fields

- Box
- Multi-cell box
- 3-sided
- Slab/superstructure & abutment

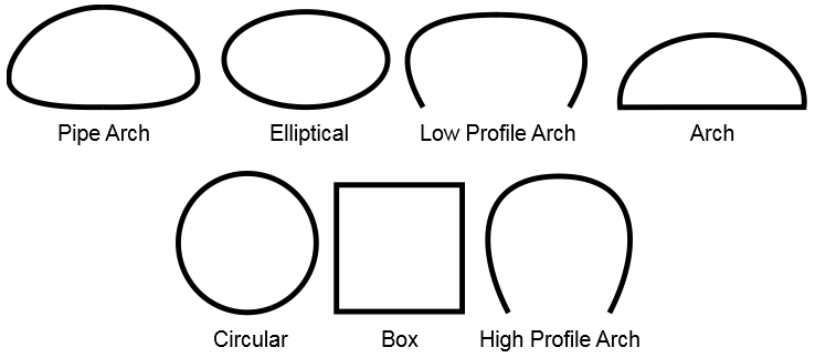


Figure 1. Common Shapes (Note that arch and box shapes may be 3-sided, supported by footings)

Skew Angle – The acute angle formed by the intersection of the line normal to the centerline of the road with the centerline of the road with the centerline of a culvert. Reference Figure 2.

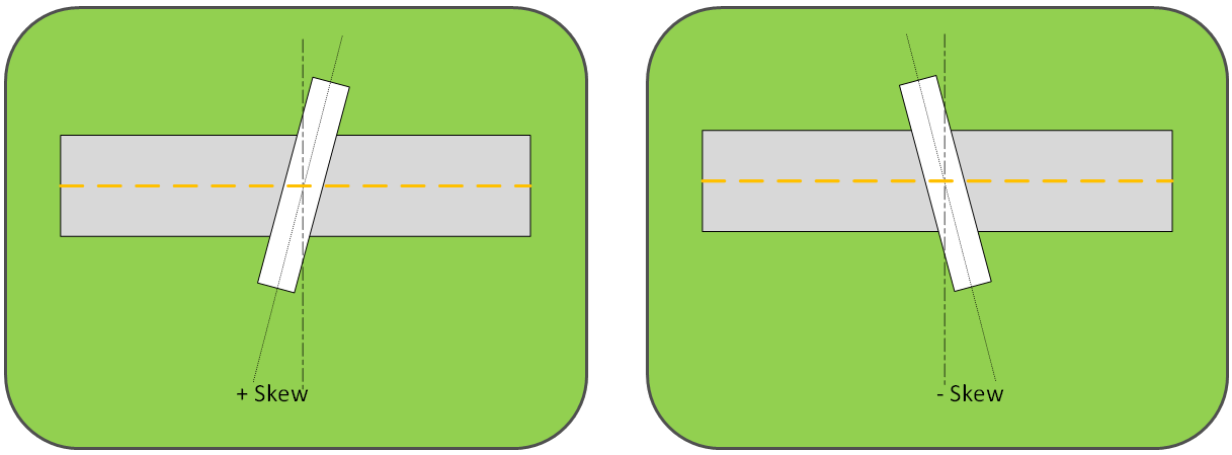


Figure 2. Positive and Negative Skew Angles

Length – Horizontal distance of the culvert from inlet to outlet. Reference Figure 3.

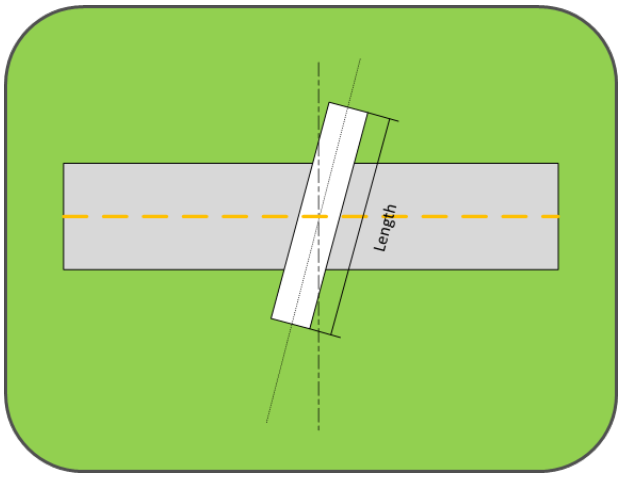


Figure 3. Length of Culvert

Width – The original distance of the culvert opening (perpendicular to the length). Reference Figure 4.

Height / Diameter – The original height of the culvert opening. Reference Figure 4.

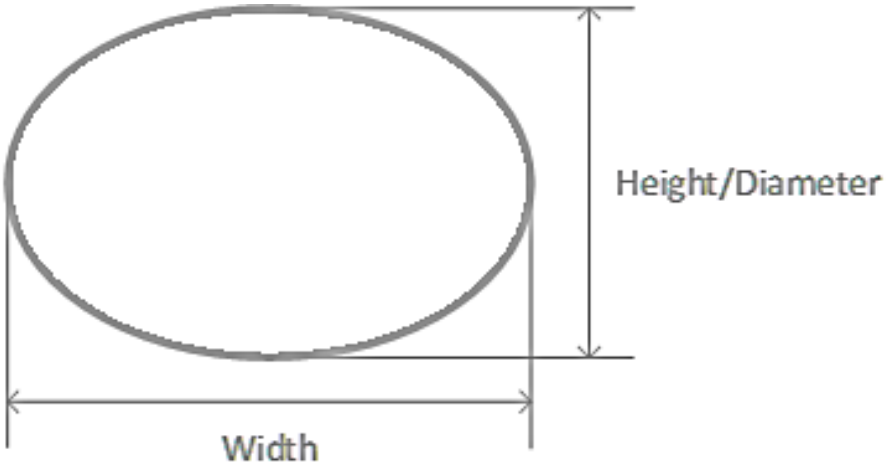


Figure 4. Width & Height/Diameter of Culvert Structures

Depth of Cover – The depth of soil from the roadway to the peak of the culvert structure. Reference Figure 5 on how to take measurement.

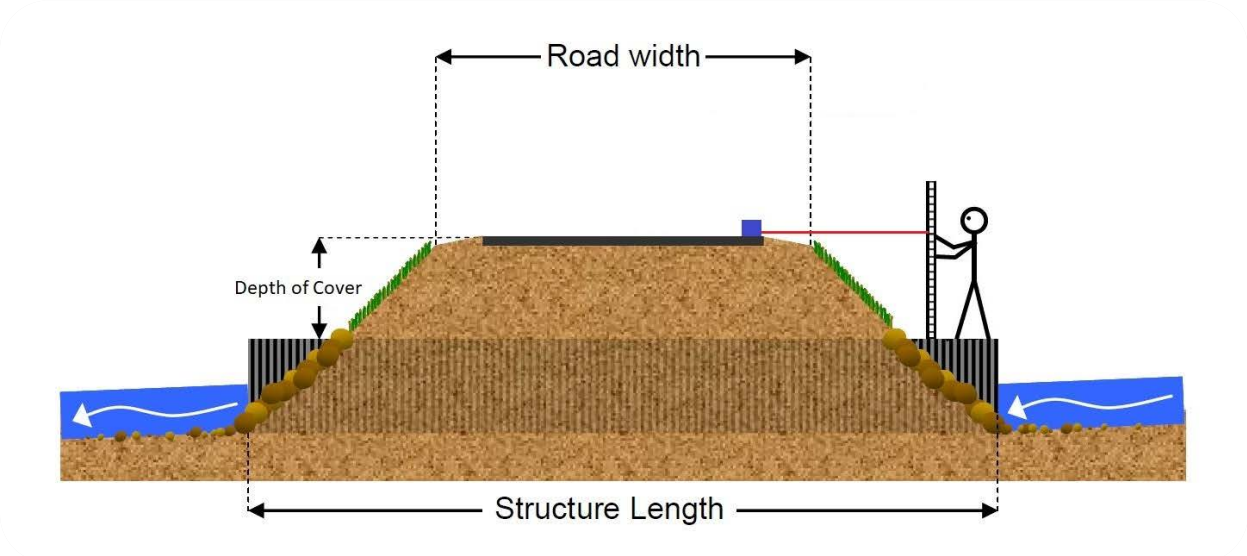


Figure 5. Measuring Depth of Cover

Roadway Surface Type – Surface type of the roadway above the culvert.

Culvert Condition Rating – An overall culvert condition rating entered into the statewide database.

- Based on Structural Deterioration, Invert Deterioration, Structural Deformation, Joints/Seams, Blockage, and Scour element ratings for the culvert.
- Generally represents the weakest link.
    - Can be overridden by inspector for site-specific circumstances
    - Please add comment if rating different than the lowest of the 6 element ratings

Photographs (optional) –

- Primary photos:
    - 2 from each end (4 total)
        - One looking at the inlet/outlet and some surroundings
        - One looking into the culvert
- Secondary photos:
    - At the discretion of the inspector
        - Road Surface
        - Blockage
        - Scour
        - Etc.

CONDITION RATING DEFINITIONS

Abrasion: Wearing or grinding away of material by water laden with sand, gravel, or stones. Abrasion is generally most serious in steep areas where high flow rates carry sand and rocks that wear away the culvert invert. Abrasion can also accelerate corrosion by wearing away protective coatings.

Backfill: The material used to refill the trench, or the embankment placed over the top of the bedding and culvert.

Bedding: The soil used to support the load on the pipe. For rigid pipe, the bedding distributes the load over the foundation. It does the same thing for flexible pipe except that it is not as important a design factor.

Bed Load: Sediment that moves by rolling, sliding, or skipping along the bed and is essentially in contact with the streambed.

Buckling: A bend, warp, or crumpling in flexible materials (usually as a result of compression).

Backfill: The material used to refill the trench, or the embankment placed over the top of the bedding and culvert.

Capacity: Maximum flow rate that a channel, conduit, or structure is hydraulically capable of carrying. The units are usually cubic feet per second (CFS) or gallons per minutes (GPM).

Coating: Any material used to protect the integrity of the structural elements of a pipe from the environment and add service life to the culvert.

Cover: The depth of backfill over the top of the pipe.

Compaction: The process by which a sufficient amount of energy is applied to soil to achieve a specific density.

Corrosion: Deterioration of metal due to electrochemical or chemical reactions. Culverts are subject to corrosion in certain aggressive environments. Can apply to reinforcement in concrete and masonry structures, or for corrugated metal structures directly.

Crack: A fissure in installed precast concrete culvert.

Crown: The top or highest point of the internal surface of the transverse cross section of a pipe.

Culvert: A drainage opening beneath an embankment, usually a pipe, designed to flow according to open channel equation.

Debris: Any material including floating woody materials and other trash, suspended sediment, or bed load, moved by a flowing stream.

Degradation: General progressive lowering of the stream channel by erosion.

Deflection: A deviation from the original design shape without the formation of sharp peaks or valleys.

Delamination: Subsurface separation of concrete into layers. Separation of reinforcement from concrete.

Differential Settlement: Unequal movement of structural components previously aligned creating differences in vertical positioning.

Dimpling: Used to describe a wavy or waffling pattern that occurs in the inner wall of plastic pipe due to local instability.

Efflorescence: Deposits on concrete or brick caused by crystallization of carbonates brought to the surface by moisture in the masonry or concrete

Embankment: A bank of earth, rock or material constructed above the natural ground surface over a culvert.

Erosion: Wearing away of the streambed (or embankments) by flowing water

Flexible Structures: A structure with relatively little resistance to bending. CMP and plastic structures are flexible structures.

Footings (Foundation): The in-place material beneath the pipe, arch, or three-sided box. Usually made of concrete and supports the main structure.

Galvanizing: A protective coating of zinc applied to corrugated metal to resist corrosion and rust damage

Hairline cracking: Very small cracks that form in the surface of the concrete pipe due to tension caused by loading. Small hairline cracks with hardly perceptible widths are common and are not cause for alarm in concrete structures. Moisture, leakage, and staining will make these cracks more severe over time.

Hinging: Used to describe yielding of the flexible material due to excessive bending moment in the pipe wall. Pipe wall exhibits a sharp crease pointed inward or outward. Hinges usually form at the 3 o'clock and 9 o'clock positions.

Honeycombs: Areas in concrete where mortar has separated and left spaces between the coarse aggregate, usually caused by improper vibration during concrete construction

Invert: The bottom or lowest point of the internal surface of the transverse cross section of a pipe.

Joint: A connection between two pipe sections, made either with or without the use of additional parts

Leakage: Water infill through concrete cracks

Piping: A process of subsurface erosion in which surface runoff flows along the outside of a culvert and with sufficient hydraulic gradient erodes and carries away soil around or beneath the culvert.

Pitting corrosion (pitting): A form of extremely localized corrosion in corrugated metal that leads to the creation of small holes in the metal.

Pop-outs: Conical fragments broken out of a concrete surface by pressure from reactive aggregate particles

Rigid Structures: A pipe with a high resistance to bending. Concrete and Masonry structures are rigid structures.

Rip Rap: Rough stone of various sizes placed compactly or irregularly to prevent scour by water or debris.

Scaling: Gradual but continuing loss of mortar and aggregate over an area due to the chemical breakdown of the cement bond. Occurs in concrete and masonry culverts.

Scour (Outlet): Degradation of the channel at the culvert outlet as a result of erosive velocities.

Seepage: The escape of water through the soil, or water flowing from a fairly large area of soil instead of from one spot, as in the case of a spring.

Spalling: Depressions in concrete caused by a separation of a portion of the surface concrete, revealing a fracture parallel with or slightly inclined to the surface. Exposed reinforcing bars can be present.

Springline: The points on the internal surface of the cross section of a pipe intersected by the line of maximum horizontal dimension; or in box sections, the mid-height of the internal vertical wall.

Wall Crushing: Used to describe yielding of plastic material in the wall produced by excessive compressive stresses. Pipe wall exhibits a wrinkled effect.

CORRUGATED METAL PIPE

Structural Deterioration

Corrosion of the culvert structure can be a serious problem with adverse effects on the culvert's structural performance. Extensive corrosion along the culvert structure is a common indication that the soil surrounding the culvert has corrosive action influenced by the soil's electrical resistivity, chloride content, and pH level. This corrosion can weaken the structural capacity of the culvert over time and can lead to collapse. The condition of the metal in corrugated metal culverts and any coatings, if used, should be considered when assigning a rating to the culvert structure. Extensive pitting corrosion is of critical importance; section loss plays a large role in structural stability depending on location and significance of the pitting.

The inspection should include visual observations of invert metal corrosion and abrasion. As steel corrodes it expands considerably. Relatively shallow corrosion can produce thick deposits of scale. A geologist's pick-hammer can be used to scrape off heavy deposits of rust and scale permitting better observation of the metal. A hammer can also be used to locate unsound areas of exterior corrosion by striking the culvert wall with the pick end of the hammer. When severe corrosion is present, the pick will deform the wall or break through it. The inspector should document the extent & location of surface deterioration problems along the invert.

Localized denting and cracking damage should also be inspected for, especially if this damage occurs under the roadway. When examining dents in corrugated steel culverts, the opposite side of the plate should also be checked, if possible, for cracking or de-bonding of the protective coating.

Invert Deterioration

Closed Bottom Structures-

Corrosion and abrasion of culvert inverts can be serious problems with adverse effects on the culvert's water conveyance. If excessive corrosion and abrasion occur along the invert, the invert can become perforated and significant undercutting can occur. Damage due to corrosion and abrasion is a common cause for culvert replacement. The condition of the metal in corrugated metal culverts and any coatings, if used, should be considered when assigning a rating to the culvert invert.

Corrosion along the invert is commonly due to acidity of water flowing through it and should be inspected for in the same manner as corrosion of the structure. Abrasive damage of the invert is due to soils and/or debris carried through the culvert. The invert and any protective coatings should be examined for abrasion damage, tearing, cracking, and removal.

Corrugated metal culverts may be paved with concrete inverts. Paved concrete inverts are usually floating slabs used to carry water. Invert slabs provide protection against erosion and

undercutting and are also used to improve hydraulic efficiency. Concrete inverts are sometimes used in circular, as well as other culvert shapes, to protect the metal from severe abrasive or severe corrosive action. Concrete invert slabs should be checked for undermining and damage such as spalls, open cracks, and missing portions. The significance of the damage will depend on its effect on the corrugated metal. Inspectors should note the condition of any liner if present but should rate the condition of the corrugated metal.

Arches-

See *Invert Deterioration – Footings* section

Structural Deformation

The deformation inspection should begin by approaching the culvert from the ends and sighting the sides and top. Also check for signs of pavement depression, guardrail movement, or gaps between headwalls and the pipe barrel. The cross-sectional shape of the culvert barrel should be observed and measured when inspecting flexible culverts. The deformation rating for the culvert is to account for irregularities transverse to the culvert barrel.

Measurements should be taken at the ends of the structure, and at additional intermediate locations depending on the size and condition of the structure. Monitoring programs might be needed to determine the rate of movement.

Significant changes in shape since the last inspection should be carefully evaluated, even if the structure is still in fairly good condition. Dimensional checks should be made for suspect structures, and these dimensions should be monitored over time. If there is instability of the backfill, the pipe will continue to change shape. When distortion or curve flattening is apparent, the extent of the flattened area, in terms of arc length, length of culvert affected, and the location of the flattened area should be described in the inspection report.

For structures with shallow cover, the inspector shall make observations of the culvert with a few live loads passing over it. Discernible movement in the structure may indicate possible instability and a need for more in-depth investigation. Different culvert shapes will be rated by different criteria.

Closed Bottom Structures-

Each closed bottom shape will deform in different manners depending on its geometry. Generally, for round pipes, smooth curvature will start to form on the crown of the structure and flattening will occur in the invert of the structure as deformation occurs. Severity of these deformations will depend on how much the structure has deformed in its horizontal direction and severity of isolated deformations, such as kinks.

Different shapes have different percentages of horizontal direction expansion to indicate severity of damage. For example, a Fair condition round structure can deform 10-15% greater

than its original design while a Fair Pipe Arch can deform only 5-7% greater than its original design. Refer to the CMP Section Deformation Rating Chart to rate specific shapes.

Arches-

Arches are fixed on concrete footings, usually below or at the springline. The springline is the horizontal line connecting the furthest horizontal extents of the culvert. This difference between pipes and arches is that an arch tends to deflect differently during the placement of backfill. Backfill forces tend to flatten the arch sides and peak its top. As a result, important deformation factors to look for in an arch are flattened sides, peaked crown, and a flattened top arc.

Another important deformation factor in arches is symmetry. If the arch was erected with the base channels not square to the centerline, it can lead to a racking of the cross section. A racked cross-section is one that is not symmetrical about the centerline of the culvert. One side tends to flatten; the other side tends to curve more while the crown moves laterally and possibly upward. If these distortions are not corrected before backfilling the arch, they usually get worse as backfill is placed.

Joints/Seams

If there are joints between pipe segments not connected by seams, refer to *Joints* section.

Corrugated metal structures often have overlapping seams bolted together that connect plates at the joints (Circumferential Seams). Additional seams also exist on structural metal plate culverts longitudinal to traffic that link plates together to form a cross section (Longitudinal Seams). All bolted splice seams should be checked for loose or missing bolts, corrosion on the bolts or metal at the connections, and tears or cracks in metal at the bolt lines. Longitudinal seams must be checked for additional criteria. If a structural metal plate culvert is being inspected, the worse rating of the longitudinal and circumferential seams shall be selected as the controlling rating.

Circumferential Seams- The circumferential seams in helical pipe, like joints in factory pipe, do not carry ring compression thrust in the pipe. They do make the conduit one continuous structure. Distress in these seams is rare and will ordinarily be the result of a severe differential deflection or distortion problem or some other manifestation of soil failure. For example, a steep sloping structure through an embankment may be pulled apart longitudinally if the embankment moves down. Plates should be installed with the upstream plate overlapping the downstream plate to provide a “shingle” effect in the circumferential seam. Seam distress is important to note during inspections since it would indicate a basic problem of stability in the fill. Circumferential seam distress can also be a result of foundation failure, but in such cases should be clearly evident by the vertical alignment.

Longitudinal Seam Defects in Structural Metal Plate Culverts - Longitudinal seams should be visually inspected for open seams, cracking at bolt holes, plate distortion around the bolts, bolt tipping, cocked seams, cusped seams, and for significant metal loss in the fasteners due to corrosion. In riveted or spot welded pipes, the seams are longitudinal and carry the full ring compression in the pipe. These seams must be sound and capable of handling high compression forces. When inspecting the longitudinal seams of bituminous-coated corrugated metal culverts, cracking in the bituminous coating may indicate seam separation.

Seam Defects in Structural Plate Culverts:

(1) Loose Fasteners- Seams should be checked for loose or missing fasteners. For steel structural plate structures, longitudinal seams are bolted together with high-strength bolts in two rows; one row in the crests and one row in the valleys of the corrugations. These are bearing type connections and are not dependent on a minimum clamping force of bolt tension to develop interface friction between the plates. Fasteners in steel structural plate may be checked for tightness by tapping lightly with a hammer and checking for movement.

For aluminum structural plate structures, the longitudinal seams are bolted together with normal strength bolts in two rows with bolts in the crests and valleys of both rows. These seams function as bearing connections, utilizing bearing of the bolts on the edges of holes and friction between the plates.

(2) Cocked and Cusped Seams- The longitudinal seams of structural plate are the principal difference from factory pipe. The shape and curvature of the structure is affected by the lapped bolted longitudinal seam. Improper erection or fabrication can result in cocked seams or cusped effects in the structure at the seam. Slight cases of these conditions are fairly common and frequently not significant. However, severe cases can result in failure of the seam or structure. When a cusped seam is significant the structure's shape appearance and key dimensions will differ significantly from the design shape and dimensions. The cusp effect should lead to the structure to receive very low ratings on the shape inspection if it is a serious problem. A cocked seam can result in loss of backfill and may reduce the ultimate ring compression strength of the seam.

(3) Seam Cracking- Cracking along the bolt holes of longitudinal seams can be serious if allowed to progress. As cracking progresses, the plate may be completely severed and the ring compression capability of the seam lost. This could result in deformation or possible failure of the structure. Longitudinal cracks are most serious when accompanied by significant deflection, distortion, and other conditions indicative of backfill or soil problems. Longitudinal cracks are caused by excessive bending strain, usually the result of deflection. Cracking may occasionally be caused by improper erection practices such as using bolting force to “lay down” a badly cocked seam.

(4) Bolt Tipping- The bolted seams in structural plate culverts only develop their ultimate strength under compression. Bolt tipping occurs when the plates slip. As the plates begin to

slip, the bolts tip, and the bolt holes are plastically elongated by the bolt shank. High compressive stress is required to cause bolt tipping. Structures have rarely been designed with loads high enough to produce a ring compression that will lead to bolt tip. However, seams should be examined for bolt tip particularly in structures under higher fills. Excessive compression on a seam could result in plate deformations around the tipped bolts and failure is reached when the bolts are eventually pulled through the plates.

Blockage

Refer to Blockage Section

Scour

Refer to Scour Section

CONCRETE PIPE

Structural Deterioration

In concrete structures, reinforcing steel is designed to assume some of the imposed loads. Therefore, small hairline cracks (with widths that are hardly perceptible) are expected and are not cause for alarm. Larger cracks, especially those with evidence of efflorescence or rust staining, are a greater cause of concern that will influence the criticality of the cracks. Inspectors should look for cracking and note the extensiveness of the individual cracks, and the number of overall cracks.

The location of cracking in concrete structures can indicate the type of problems being experienced. In concrete pipe, longitudinal cracks at the 3, 6, 9, and 12 o'clock positions indicate flexure cracking caused by poor side support. Longitudinal cracking in the invert at the 5 and 7 o'clock positions indicate shear cracking caused by poor haunch support. Likewise, cracking at the 11 and 1 o'clock positions may be the result of shear forces from above the structure. Cracking at comparable locations in box culverts indicate similar failure types. Transverse cracks may also occur and are usually the result of non-uniform bedding or fill material causing point loads on the pipe. Inspectors should note the locations of cracking in their report for determination of their cause.

Spalling and delamination affect the structural performance of concrete structures as well. Spalled sections indicate failing structural performance of the reinforcement due to corrosion, especially if pop-outs have occurred, which can critically affect structural stability if the spalled section is large enough or there are multiple spalled sections. Delamination is similar to spalling, if the concrete delaminates, the structural performance is reduced significantly, especially if the reinforcement separates from the concrete. Inspectors should note any and all sections with evidence of spalling and delamination and note any exposed rebar and visible corrosion of the reinforcement.

Abrasion leading to scaling should be noted in the inspection as well. Surface scaling allows for continued abrasion to be more destructive to the concrete and can wear away at the material more quickly. This can expose reinforcement, reduce the structure's durability, and shorten the service life of the culvert. The inspector should note the amount of scaling and its depth along the invert.

Invert Deterioration

Closed Bottom Structures-

Invert deterioration of closed bottom structures should be rated using the same criteria as structural deterioration.

Open Bottom Structures-

See *Invert Deterioration – Footings* section

Structural Deformation

Not Applicable

Joints/Seams

Refer to *Joints* section

Blockage

Refer to *Blockage* section

Scour

Refer to *Scour* section

PLASTIC PIPE

Structural Deterioration

Plastic pipe materials may experience splits that can affect structural performance of the culvert. A split, rip, tear, or crack is any separation in the wall material other than at a designed joint. Inspectors should note any split in the plastic material; their criticality will depend on the size and number of splits. Larger splits and multiple splits have a larger chance of structural failure.

Buckling damage, such as bends, warps, or crumpling, are reported under the section deformation rating and should not be considered in the Structural Deterioration rating.

Invert Deterioration

Plastic pipe materials are prone to abrasive damage due to soils and debris flowing through the culvert; perforations due to abrasion on the invert should control for plastic invert inspection. The severity of these perforations depends on their location along the length of the culvert, and the size and amount of perforations.

Structural Deformation

There are several things to be considered determining shape deformations in plastic pipe. Deflection, or a deviation from the original design shape should be inspected for. Deflection becomes critical when the pipe deforms completely under its load, causing severe, sharp bends at the peak of the structure. Multiple types of buckling (bends, warps, or crumpling) should be inspected for as well, caused by hinging, wall crushing, or dimpling. All these deformations are indicators of the culvert's failing condition and functionality.

Joints/Seams

Refer to *Joints* section

Blockage

Refer to *Blockage* section

Scour

Refer to *Scour* section

MASONRY

Structural Deterioration

Much like concrete culverts, cracking and spalling can have a large impact on the structural performance of masonry culverts. When this damage is widespread, the culvert condition is more critical. Inspectors should note significant cracking, and spalling of the masonry blocks as well as their locations.

Displacement of individual masonry units can have an effect on the overall structure performance as well. This is most true when the displaced masonry units are at the bottom of the structural sidings; if these units become dislodged, the units they support above are prone to collapse as well. The inspector should note significantly displaced masonry units, especially if there are multiple in close proximity to each other.

Invert Deterioration

See *Invert Deterioration – Footings* section

Masonry structures also commonly have concrete inverts. If the structure under inspection has a concrete invert, rate the invert based on the *Concrete Closed Bottom Structure* rating.

Structural Deformation

Not Applicable

Joints/Seams

Refer to *Joints* section

Joints in masonry culverts are rated in a slightly different manner; the joints in a masonry structure are not aligned between specific segments, but rather they are present between masonry blocks. These joints are inspected for mortar cracks, water exfiltration, backfill infiltration, vegetation in the cracks, and misalignment due to lack of mortar. All of these problems can indicate a failing masonry culvert structure.

Blockage

Refer to *Blockage* section

Scour

Refer to *Scour* section

SLAB AND ABUTMENT

Structural Deterioration

The slab is the primary load-carrying member and should be inspected top and bottom for evidence of leakage, deterioration and structural adequacy. The edge of the slab, approximately the first 12 inches, will not govern the condition rating.

Visually inspect the concrete deck for cracks, spalls, and other defects. Hammers and chain drags can be used to detect areas of delamination. A delaminated area will have a distinctive hollow “clacking” sound when tapped with a hammer or revealed with a chain drag. A hammer hitting sound concrete will result in a solid “pinging” type sound.

Documentation should be placed on the form stating if the reinforcing steel bars are exposed on all surfaces. Note length, number of bars exposed, and location.

Common concrete deck defects may include:

- Cracking
- Scaling
- Delamination
- Spalling
- Efflorescence
- Honeycombs
- Pop-outs
- Wear
- Collision damage
- Abrasion
- Corrosion of reinforcing bars

Invert Deterioration

See *Invert Deterioration – Footings* section

Concrete / Masonry Abutment

An abutment is a substructure unit located at the ends of a bridge or slab culvert. Its function is to provide end support for the bridge and to retain the approach embankment. Wingwalls are also located at the ends of a bridge or culvert. Their function is only to retain the approach embankment and not to provide end support for the bridge. Wingwalls are considered part of the abutment component only if they are integral with the abutment. When there is an expansion joint or construction joint between the abutment and the wingwall, that wingwall is defined as an independent wingwall and not considered in the evaluation of the abutment component.

Inspection procedures for abutments involve examining material deterioration and settlement. However, because stability is a paramount concern, checking for various forms of movement are required.

The most common problems observed during the inspection of abutments are:

- Vertical movement
- Lateral movement
- Rotational movement
- Material defects
- Drainage system malfunction

Blockage

Refer to *Blockage* section

Scour

Refer to *Scour* section

TIMBER

Structural Deterioration

Crushing due to rot, insect or rodent damage, and abrasion or wear are the largest threats to timber culvert structures. Insects or rodents can penetrate the structure and eat away at the wood members while leaving holes, creating section loss of the member's cross section, and lessening the member's structural capacity. Inspectors should look for evidence of infiltration by searching for the small holes on the surface of wood members. Minor insect or rodent damage can have little effect on structural capacity, but when significant damage has occurred, the structural capacity will be reduced.

Rotting members, particularly those near the bottom of the structure, will threaten the structural capacity of the member as well. When a wood member is significantly rotted, it is prone to crushing from the weight it supports. Inspectors should note any significant areas of rot, especially on primary structural members.

Abrasion is another factor causing section loss of structural members in timber structures. Abrasion due to soils and debris will wear down and chip away the wood surface over time, reducing the durability of the invert. Typical abrasion damage in wood inverts appears as chips and reduced thicknesses. Inspectors should note any significant abrasion resulting in significant member section loss.

Checks and cracking of key structural members, particularly stringers, is a sign of imminent collapse and is of critical importance. Heavy loading or consistent fatigue loading on these members will increase the stress on these members, causing the cracks and checks to extend, and may lead to failure of the members. Inspectors should note any visible structural cracks on structural members. It should be noted that standard drying cracks in wood are normal and expected, and do not constitute structural problems.

The connecting fasteners should also be inspected for rusting, loosening, or any other damage that will threaten the integrity of the connection. The severity of the fastener conditions on the structural deterioration will depend on the extent and severity of damage.

Invert Deterioration

See *Invert Deterioration – Footings* section

Timber structures also commonly have concrete inverts. If the structure under inspection has a concrete invert, rate the invert based on the *Concrete Closed Bottom Structure* rating.

Structural Deformation

Not Applicable

Joints/Seams

Refer to *Joints* section

Blockage

Refer to *Blockage* section

Scour

Refer to *Scour* section

INVERT DETERIORATION – FOOTINGS

For structures supported by footings, such as CMP arches, three-sided box culverts, and slab and abutment structures, the “invert” considered in rating is the footings. These footings are assumed to be made of concrete and suffer from the same deterioration problems as concrete structures, such as spalling, scaling, and cracking. For more specifics on these deterioration problems, refer to the Concrete Structural Deterioration section.

Erosion of the streambed over time can expose the footings to water flow and lead to damage of the footings. Additionally, if the erosion is severe enough, differential settlement of the structure can occur due to the footings unequal movement from their original positions resulting from loss of soil support. Damage in the structure is often apparent if differential settlement has occurred; distress in the walls will occur resulting in an unusual cross section.

Inspectors should note the severity of erosion around the culvert’s footings based on the depth of the footing that is exposed to water flow, and any damages or settlement that has occurred as a result of this erosion.

JOINTS

Key factors to look for in the inspection of joints is if there are openings, the severity of any openings, misalignment between segments, and indications of soil infiltration and water exfiltration due to seepage through open joints. Inspectors should record joint defects with their locations and severity indicated. If the structure is one continuous structure (i.e. not segmented or bolted at joints), this rating can be skipped. If the joints are held together by seams, the condition of the seams should be rated in addition to any joint openings.

Joint defects may include:

1. Open joints
2. Seepage at the joints
3. Misalignment of joints
4. Surface sinkholes over the culvert

Movement of the structural segments from their original position due to settlement and erosion can lead to openings to form at the joints between segments, known as open joints. The vertical offset between pipe segments should be examined to determine severity. Open joints can seepage to occur through the joints and lead to misalignment between structural segments if the separation is severe. Excessive seepage through an open joint can lead to soil infiltration or erosion of the surrounding backfill soil material, reducing lateral support. The larger the joint opening, the more severely that this is likely that this is to occur. Open joints may be probed with a small rod or flat rule to check for voids. Misalignment of joints should be apparent when looking down the culvert from the end. If there are open joints and the structure appears to be running irregularly, there is likely some misalignment.

Seepage along the outside of the culvert barrel may also remove supporting material. This process is referred to as “piping”, since a hollow cavity similar to a pipe is often formed. Piping can also occur through open joints. Piping is controlled by reducing the amount and velocity of water seeping along the outside of the culvert barrel. Piping at open joints should be considered in the joint rating as well.

BLOCKAGE

Scour and upstream streambed degradation can be increased due to inadequate waterway area caused by blockage. The geometry of the culvert barrel, the amount of debris carried by the channel during high water periods, and the adequacy of freeboard should be considered in determining waterway adequacy. Check for the formation of sandbars or debris which could change the direction of flow or other obstructions which could influence the adequacy of the waterway opening. Accumulation of drift and debris at the orifice of the culvert should be noted on the inspection form and included in the condition rating.

Some culverts installed in recent years were intentionally placed below the normal streambed elevation. This is done to promote the formation of a natural stream bottom through the culvert barrel and is required in some streams for migratory fish species. The burial of the invert should be noted in the construction plans on the culvert detail sheets. When inspecting such culverts, the Culvert Waterway Blockage rating should not be down rated if the culvert was originally designed with a buried invert.

SCOUR

The removal of a streambed or bank area by stream flow is called scour. If not addressed, scour can lead to the undermining of footings, headwalls, and culvert end sections through the continual removal of supporting material. Eventually, serious structural problems such as piping and the rotation of footings can take place as additional supporting material is removed. Additionally, scour can affect the culvert's water conveyance and its ability for aquatic organisms to pass. The depth of any scouring should be measured with a probing rod by the inspector. In low flow conditions, scour holes have a tendency to fill up with debris or sediment. The inspector should also indicate the location and extent of any undercutting around footings, headwalls, wingwalls, and the end sections of the culvert. Scour holes can eventually cause cantilevered pipe end sections to detach and collapse or bend down, restricting stream flow.

Culverts supported by footings, such as three-sided box culverts and arches without an invert slab are considered to be scour critical structures. The inspector should check such structures for evidence of scour and undermining of the footings. The inspector should also look for any indication of footing rotation.

REFERENCES

Arnoult, JD. 1986. Culvert Inspection Manual. Federal Highway Administration (FHWA). IP-86-2. [Available from: https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=31&id=57]

Hunt JH, Zerges SM, Roberts BC, Bergendahl B. 2010. Culvert Assessment and Decision-Making Procedures Manual For Federal Lands Highway, First Edition. Federal Highway Administration (FHWA). CFL/TD-10-005. p. B.1-B.74. [Available from: https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=208&id=166]

MDOT. 2016. Asset Collection & Condition Assessment Guide for 1' - <10' Span Culverts. Michigan Department of Transportation (MDOT). [Available from: https://www.michigan.gov/documents/mdot/MDOT_RFP_SS_REQ2435_Tams_Culvert_Colection_616748_7.pdf]

MDOT. 2017. Michigan Structure Inspection Manual (MiSIM). Michigan Department of Transportation (MDOT). [Available from: https://www.michigan.gov/mdot/0,4616,7-151-9625_24768_24773-326737--,00.html]

ODOT. 2017. Culvert Inspection Manual. Ohio Department of Transportation (ODOT). p. 29-67. [Available from: http://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Culvert%20Management/Pages/Culvert-Management.aspx]

WisDOT. 2018. Bridge Inspection Field Manual. Wisconsin Department of Transportation (WisDOT). p. 48-57. [Available from: http://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/strct/inspection-manual.aspx]

APPENDIX E: INVENTORY ITEMS

	MDOT Pilot	Roadsoft	Michigan Geographic Framework (MGF) Database	TAMC Culvert Pilot (per 2-22-18 meeting)
Inventory				
City/Township		x		
Reference Intersection	x	x		
Reference Distance		x		
Beneath	x			
Milepoint		x		
Inventory ID	x	x	x	x
Waterway		x		
GPS Coordinates		x		x
Description		x		
Material Type	x	x	x	x
Asset Collection Date	x	x	x	x
Date Installed	x	x	x	
Number of Culverts		x		
Shape	x	x	x	x
Entrance Structure	x	x		
Exit Structure	x	x		
Skew Angle		x		x
Length		x	x	x
Span		x	x	x
Rise		x	x	x
Depth of Cover	x	x		x
Height/Diameter	x	x	x	x
Width	x	x	x	x
Liner	x			
Liner Material	x			
Liner Diameter	x			
Spatial Quality Index	x			
Road Surface Elevation Upstream		x		
Road Surface Elevation Downstream		x		

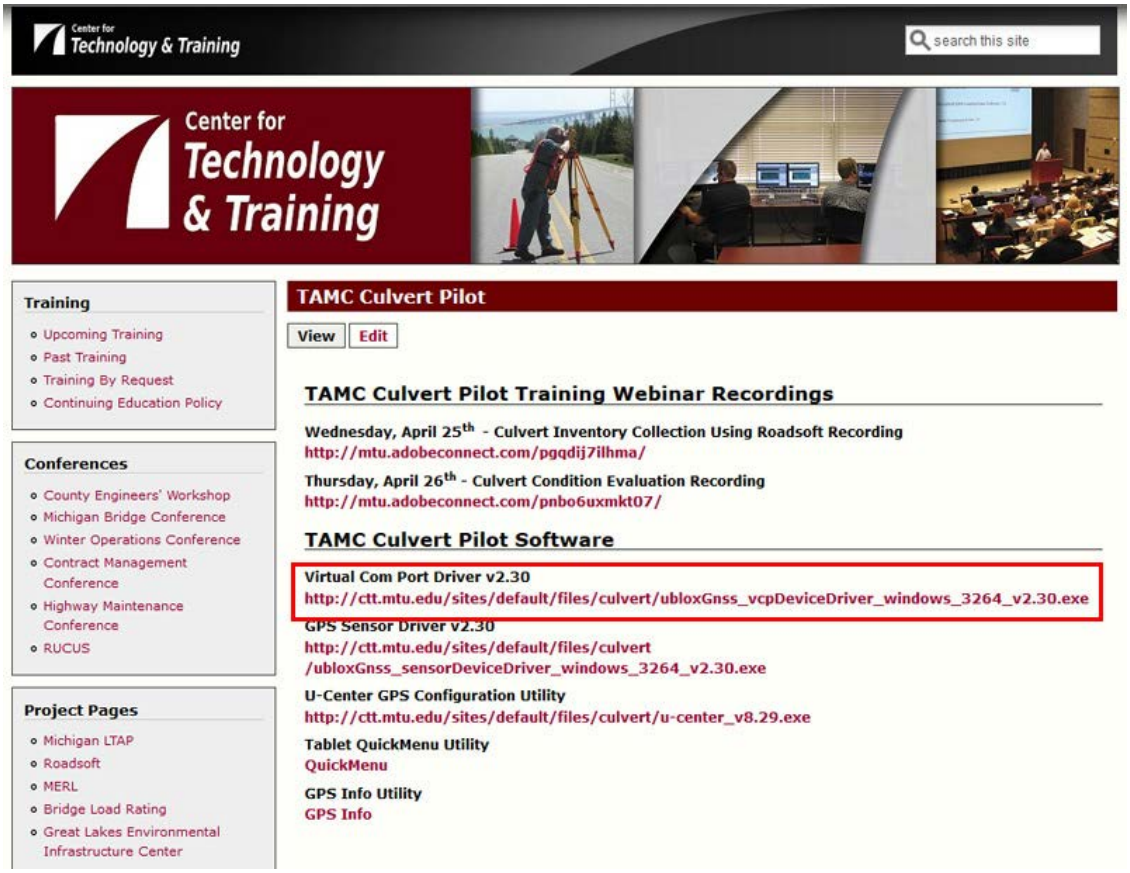
Invert Elevation Upstream		x		
Invert Elevation Downstream		x		
Invert Above Channel Bottom	x			
Riprap (Y/N)	x			
Safety Grate (Y/N)	x			
End Extension (Y/N)	x			
Extension Material Same as Original (Y/N)	x			
Extension Shape Same as Original (Y/N)	x			
Extension Dimensions Same as Original (Y/N)	x			
Wetland Protection Act		x		
Inland Lakes Act		x		
Memo		x		
Scheduled Maintenance/Inspection Activity		x		
Surface Type		x	x	x
Collection Type			x	
Condition Evaluation				
Culvert Rating	x	x	x	x
invert deterioration		x		x
joints/seams		x		x
section deformation		x		x
corrosion		x		x
scour		x		x
blockage		x		x
Channel Rating		x		
Waterway Rating		x		
Maintenance		x		
Work Order		x		
Stream Crossing Survey		x		
Photos/other attachments		x		

APPENDIX F: WINDOWS TABLET GPS SETUP

The MobileDemand T1600 tablet, as well as the Trimble T10 tablet, have an internal GPS chip manufactured by u-blox. The internal GPS on these tablets needs to be configured so that Roadsoft LDC will communicate with it.

The first thing to do is ensure the correct COM port driver is installed. Automatic Windows 10 updates often update the drivers to the latest version, which can lead to problems. The correct driver is located on the CTT website at http://ctt.mtu.edu/tamc-culvert-pilot.

Download the Virtual COM Port Driver v2.30 file as highlighted below.



Check COM Port Driver

1. Right-click the Windows icon in the lower left of the screen, or if using the touch screen, press and hold the icon until a transparent square appears, then release. The

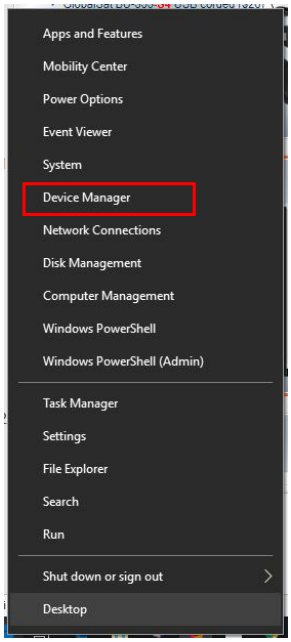


Figure 6 - Windows 10 Start Menu

Windows Start Menu will pop up, select Device Manager from the list.

2. Scroll down and click the arrow to expand Ports (COM & LPT).

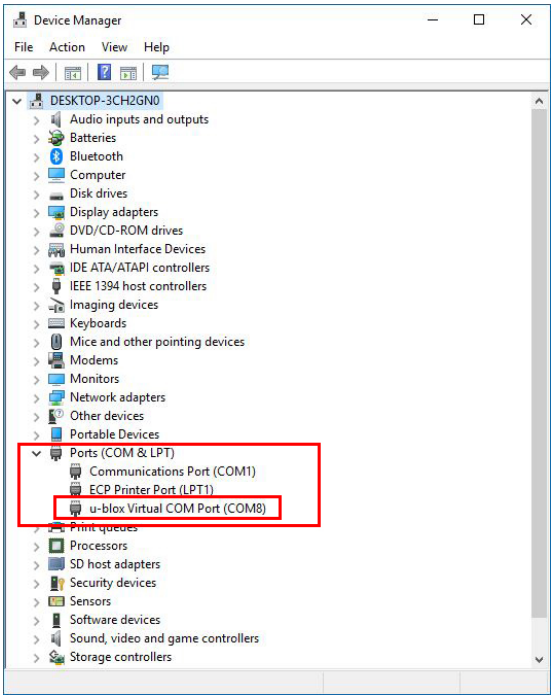


Figure 7 - Device Manager Ports

3. Double-click or right-click on u-blox Virtual COM Port (COM# - the number will vary based on the machine) and select Properties, then select the Driver tab on the window that appears. Note the driver version that is installed. If the driver is newer (numerically higher) than 2.30.0.0, it will need to be replaced as newer versions of the driver lead to issues.

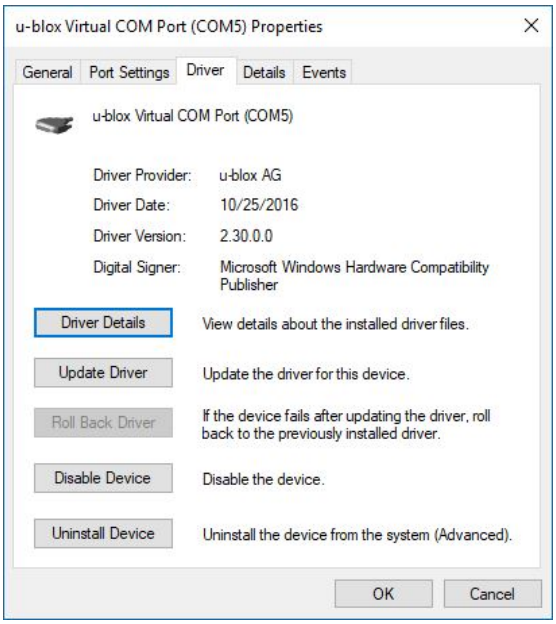


Figure 8- COM Port Settings

4. If there is a newer version of the driver installed, click the Uninstall button to uninstall the device. A confirmation window will appear - **select the check box next to the Delete the driver software for this device. Click Uninstall.**

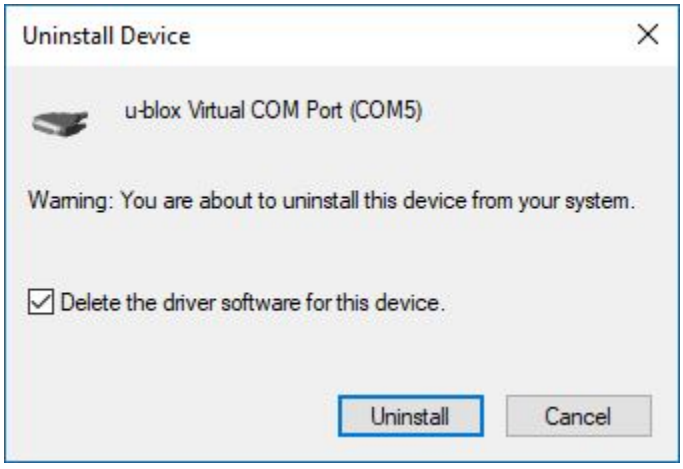


Figure 9- Uninstall Device Confirmation Screen

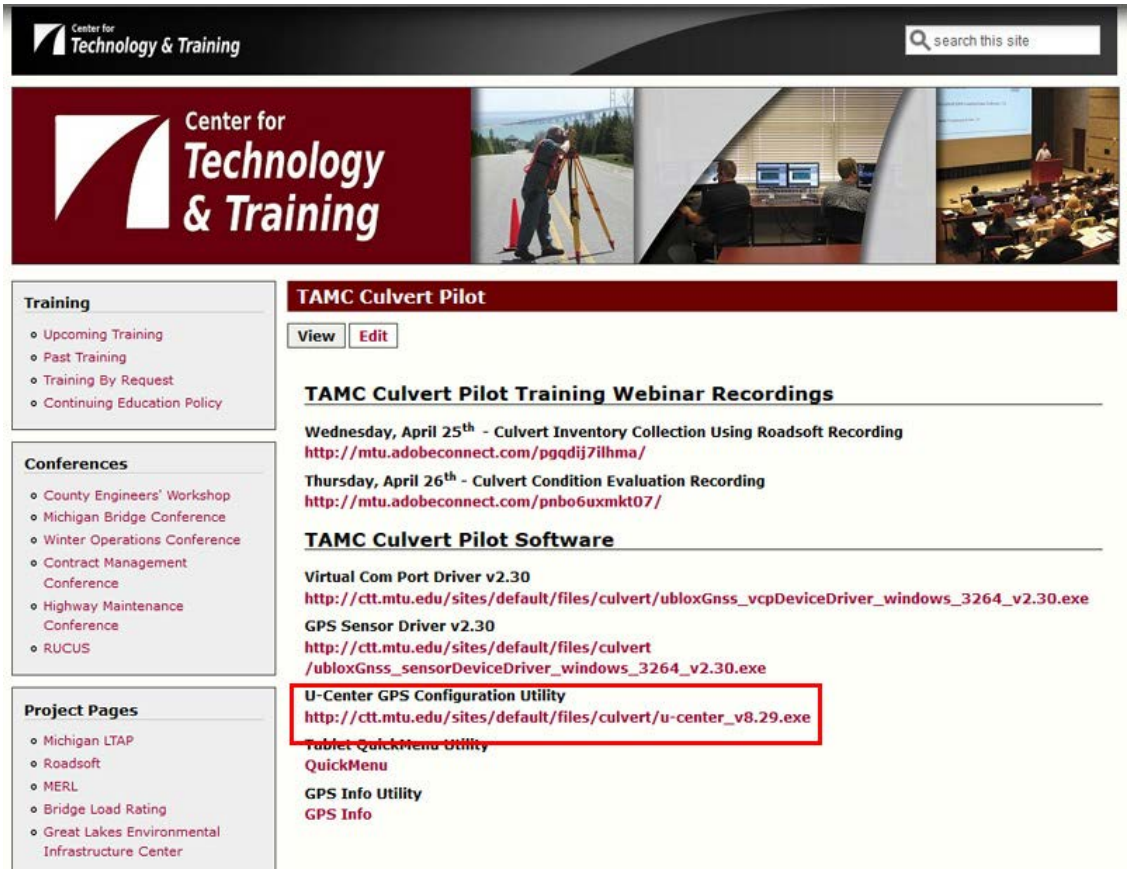
5. Browse to the file location for the previously downloaded u-blox Virtual COM port driver.

6. Double-click on the ubloxGnss_vcpDeviceDriver_windows_3264_v2.30.exe file, follow the on-screen prompts to install the driver.
7. Windows may or may not prompt to reboot the tablet. **Regardless if prompted or not, reboot the tablet to ensure the COM port is recognized and functioning properly.**
8. Open the Device Manager again and verify that the COM driver is version 2.30.00, and take note of the COM port assigned as it might be different than the number previously assigned, and it will be needed to connect the GPS to Roadsoft LDC.

Configure Internal GPS to work with Roadsoft LDC

Once the correct driver is installed, the internal GPS needs to be configured in order for Roadsoft LDC to communicate with it. The MobileDemand T1600 tablet has a pre-installed u-center GPS configuration utility that allows the user to set parameters so Roadsoft LDC can recognize the GPS output. Some agencies reformat new computers and rebuild them with standardized software. If this applies, or for those that purchased the Trimble T10 tablet that doesn't have the u-center utility pre-installed, follow the steps below to download and install u-center.

If u-center isn't currently installed, browse to http://ctt.mtu.edu/tamc-culvert-pilot and download the u-center installation program as highlighted below.



1. Browse to the location of the downloaded file, double click on the u-center_v8.29.exe file and follow the on-screen prompts to install.
2. Once installed, start the u-center application, and either click on the down-arrow button next to the connect icon on the left-hand side of the bottom icon ribbon, or click on the Receiver pull-down menu, then click on Ports, then select the COM port that matches the virtual u-blox COM port that was installed earlier.

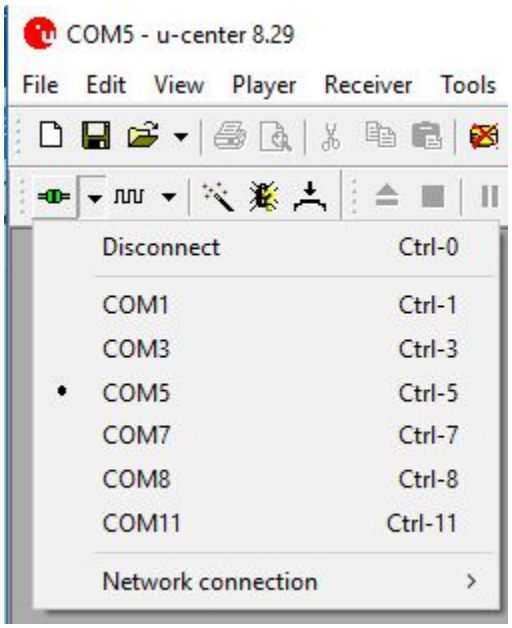


Figure 10 - u-center Connect to COM port via the icon

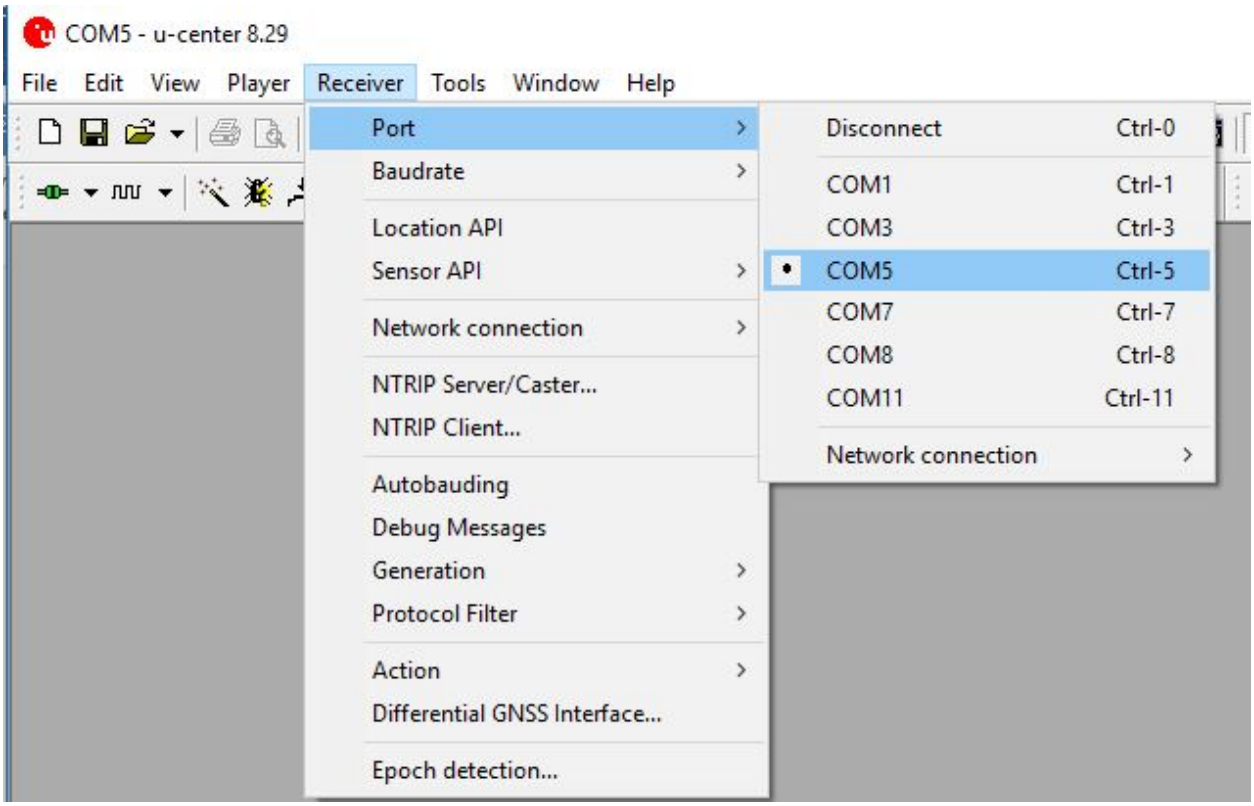


Figure 11 - u-center Connect to COM port via the menu

3. Once connected, the various u-center windows on the right should start to react and green and blue bars should begin to appear as the GPS communicates with satellites, etc.
4. Select Configuration View under the View pull-down menu, then scroll down the left-hand list of options and click on NMEA (NMEA Protocol).
5. Change the various settings to match those that are highlighted below.
6. Once the settings have been changed, hit the Send button in the lower left to send the settings to the GPS.

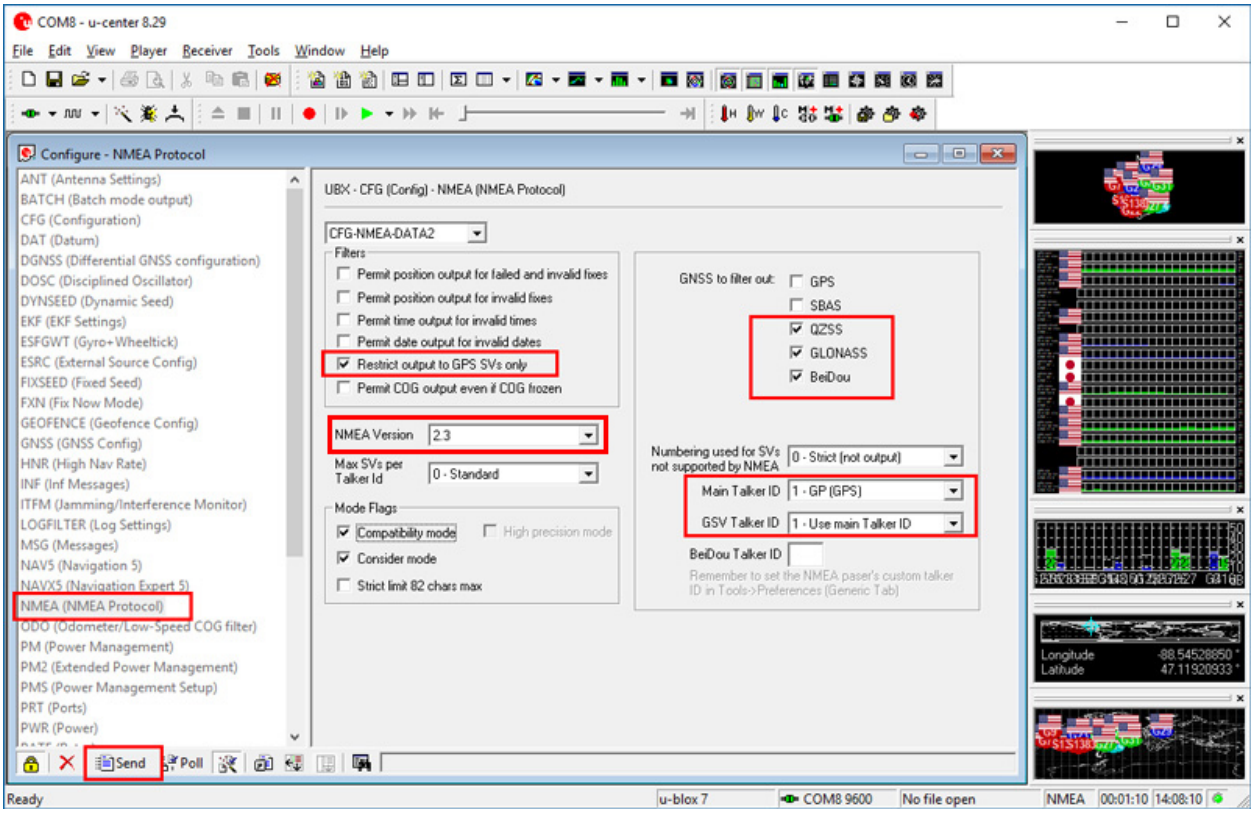


Figure 12 - u-center GPS Configuration Settings

- In the event that u-center is unable to connect to the GPS, ensure that the GPS is running. The easiest way to check that it is running is to use the built-in Quick Menu application on the tablet (T1600 only).
    1. Click on the upward pointing arrow in the Windows Taskbar at the lower right-hand corner of the screen. This will show hidden icons for programs running in the background.

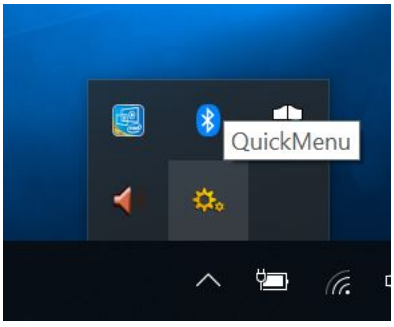


Figure 13 - Quickmenu launch icon is in the hidden icons area of the Windows Taskbar

    2. Click on the gear icon to open up Quick Menu
    3. Ensure that the GPS is running in Quick Menu – the GPS icon in the upper-right will be blue if the GPS is running, and gray if the GPS isn't running. If the GPS isn't running, click the icon to start it up.

Figure 14 - Quickmenu Control Screen – if the GPS icon in the upper-right is blue the GPS is running

Connect Roadsoft LDC to GPS

Now that the correct GPS Virtual COM port driver has been installed, and the GPS is configured, it can be connected to Roadsoft LDC.

1. Within Roadsoft LDC, select the GPS Settings under the GPS pull-down menu.

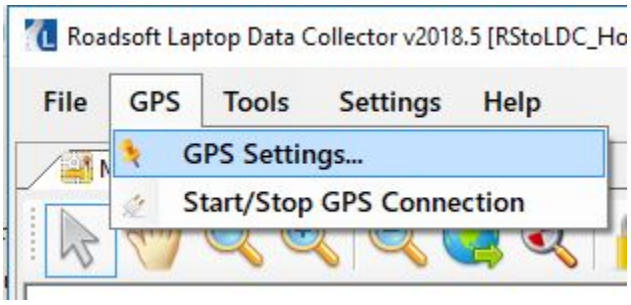


Figure 15 - Roadsoft LDC GPS Settings Location

2. In the GPS Configuration window that appears, select the COM port for the GPS as mentioned above.

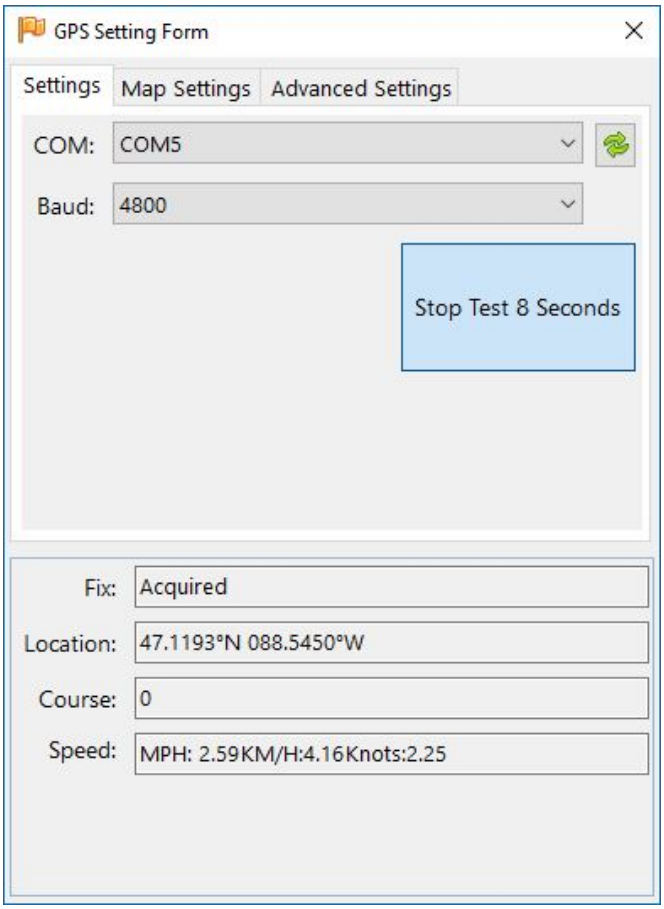
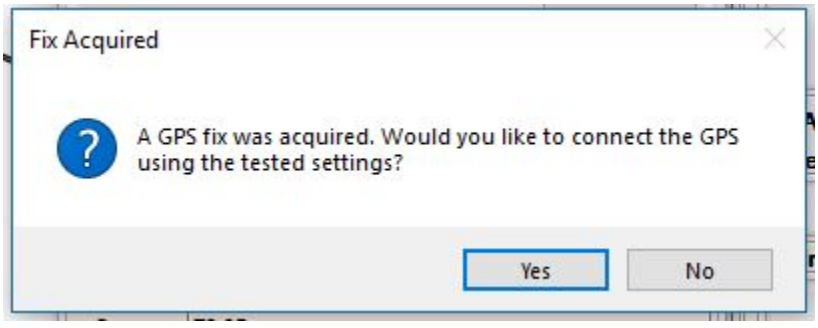


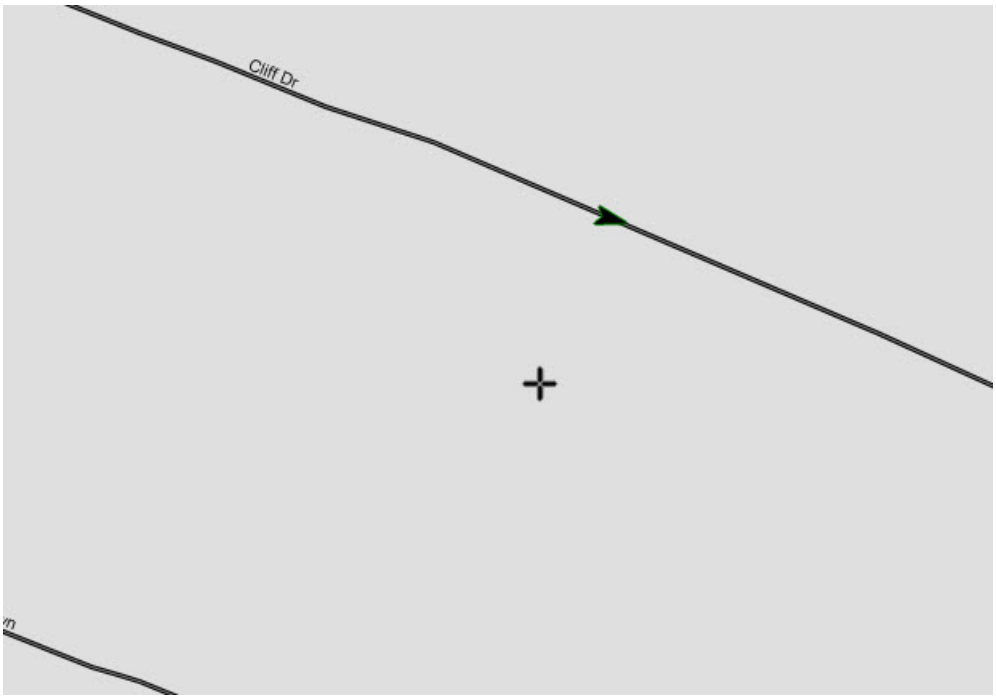
Figure 16 - Roadsoft LDC GPS Settings

3. Click the **Test Settings** button. If this is the first time the GPS has run, it may take a minute to locate itself, but the form fields at the bottom of the window should begin to fill in as the GPS gets a location lock.

4. At the conclusion of the test, if a signal was received, a confirmation window will appear asking to use the settings and connect, click **Yes**.



5. Once connected, your location will be indicated on the map.



*If a COM port error (shown below) appears in Roadsoft LDC when connecting to the internal GPS, follow the steps above to ensure that the u-blox Virtual COM Port is using driver version 2.30.00. **Also, be sure that u-center isn't running, as only one program can use the COM port at one time**.

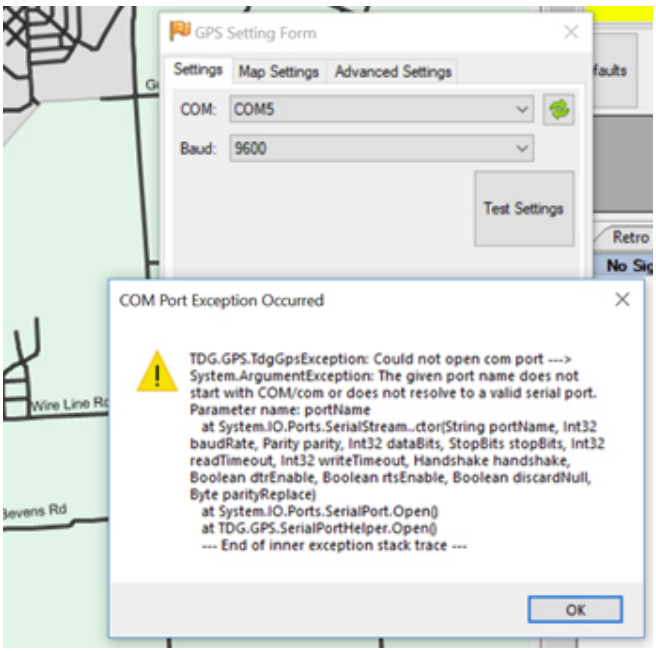


Figure 17 - Roadsoft LDC Potential COM port error

APPENDIX G: RATING TABLES

CMP

CMP	Structural Deterioration (Corrosion)	Closed Bottom Invert Deterioration	Open Bottom Invert Deterioration	Section Deformation	Joints/ Seams (FH)	Condition
10	New condition. Galvanizing intact. No corrosion.	New condition; galvanizing intact; no corrosion.	New condition	Reference CMP Shape Deformation Table	Reference CMP Joints / Seams Table	Excellent
9	Discoloration of surface. Galvanizing partially gone. No layers of rust.	Discoloration of surface. Galvanizing partially gone along invert. No layers of rust.	Good with no invert erosion			Very Good
8	Discoloration of surface. Galvanizing gone along invert but no layers of rust. Minor section loss at ends of pipe not located beneath roadway.	Discoloration of surface. Galvanizing gone along invert but no layers of rust. Minor section loss at ends of pipe not located beneath roadway.	Good with only minor invert erosion			Good
7	Galvanizing gone with layers of rust. Moderate section loss at ends of pipe not located beneath roadway. Moderate section loss: Less than 6 in^2/ft^2.	Galvanizing gone along invert with layers of rust. Moderate section loss at ends of pipe not located beneath roadway. Moderate section loss: Less than 4% of invert area.	Minor erosion near footings			Satisfactory
6	Heavy rust and scale throughout. Heavy section loss with perforations not located under the roadway. Heavy section loss: Up to 15 in^2/ft^2.	Heavy rust and scale throughout. Heavy section loss with perforations in invert not located under the roadway. Heavy section loss: Up to 10% of invert area.	Moderate erosion along footing; protective measures may be required			Fair
5	Extensive heavy rust and scaling throughout. Perforations throughout with an area less than 30 in^2/ft^2. Overall thin metal, which allows for an easy puncture with chipping hammer.	Extensive heavy rust and scaling throughout. Perforations throughout invert with an area less than 20% of invert area. Overall thin metal, which allows for an easy puncture with chipping hammer.	Erosion along footing with slight undermining. protection required			Poor
4	Extensive heavy rust and scaling throughout. Perforations throughout with an area less than 36 in^2/ft^2.	Extensive heavy rust and scaling throughout. Perforations throughout invert with an area less than 25% of invert area.	Severe undermining with slight differential settlement causing minor cracking or spalling in footing and minor distress in walls			Serious
3	Perforations throughout with an area greater than 36 in^2/ft^2.	Perforations throughout invert with an area greater than 25% of invert area.	Severe undermining with significant differential settlement causing severe cracks in footing and distress in walls			Critical
2	Pipe partially collapsed.	Pipe partially collapsed.	Structure partially collapsed or collapse is imminent.			Imminent Failure
1	Total failure of pipe.	Total failure of pipe.	Total failure of structure.			Failed

CMP	Blockage	Scour	Condition
10	No blockage. Designed condition.	No evidence of scour at either inlet or outlet of culvert.	Excellent
9	Minor amounts of sediment build-up with no appreciable loss of opening.	Minor scour holes developing at inlet or outlet. Scour protection placed.	Very Good
8	Culvert waterway blockage is less than 5% of the cross sectional area of the opening. Bank and channel have minor amounts of drift.	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.	Good
7	Culvert waterway blockage is less than 10% of the cross sectional area of the opening. Sediment buildup causing flow through 1 of 2 pipes. Silt and Gravel buildup restricts half of the channel. Tree or bush growing in the channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Satisfactory
6	Culvert waterway blockage is less than 30% of the cross sectional area of the opening. Tree or bush growing in channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Fair
5	Culvert waterway blockage is less than 40% of the cross sectional area of the opening. Occasional overtopping of roadway. Large deposits of debris are in the waterway.	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.	Poor
4	Culvert waterway blockage is less than 80% of the cross sectional area of the opening. Overtopping of roadway with significant traffic delays.	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.	Serious
3	Culvert waterway blockage is 80% or greater of the cross sectional area of the opening. Frequent overtopping of roadway with significant traffic delays.	Streambed degradation causing severe settlement.	Critical
2	Culvert waterway completely blocked and causing water to pool. Road closed because of channel failure.	Culvert closed because of channel failure.	Imminent Failure
1	Total failure of pipe.	Total failure of culvert because of channel failure.	Failed

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CMP

Michigan Transportation Asset Management Council

In cooperation with Local Technology & Training

CONCRETE PIPE

Concrete Pipe	Structural Deterioration	Invert Deterioration*	Section Deformation	Joints/Seams	Condition
10	New Condition. Superficial and isolated damage from construction.	New condition	Not Applicable: Rigid material pipes are not rated for deformation	Straight line between sections.	Excellent
9	Hairline cracking without rust staining or delamination(s). Surface in good condition.	Good with no invert erosion		No settlement or misalignment. Tight with no defects apparent.	Very Good
8	Hairline cracking: Less than 1/16th inch wide parallel to traffic without rust staining. Light scaling: Less than 1/8th inch deep with less than 10% of exposed area. Delaminated or Spalled area: Less than 1% of surface area. Note: cast-in-place box culverts may have a single large crack less than 3/16th inch on each surface parallel traffic direction.	Good with only minor invert erosion		Minor misalignment at joints. Minor settlement. Distress to pipe material adjacent to joint.	Good
7	Hairline and map cracking: Cracks less than 1/8th inch parallel to traffic with minor efflorescence or minor amounts of leakage. Scaling: Less than 1/4th inch deep or 20% of exposed area. Spalled areas with exposed reinforcing: Less than 5% Total delaminated and spalled areas less than 5% of surface area.	Minor erosion near footings		Misalignment of joints but no infiltration. Settlement. Dislocated end section. Extensive areas of shallow deterioration. Minor cracking.	Satisfactory
6	Map cracking with hairline cracks less than 1/8th inch parallel to traffic or less than 1/16th inch transverse to traffic with efflorescence, or rust stains, or leakage or all. Scaling 3/16th inch deep on less than 30% of surface area. Spalled areas with exposed reinforcing on less than 10% of surface area. Total delaminated and spalled areas less than 15% of surface area.	Moderate erosion along footing; protective measures may be required		Joint open and allowing backfill to infiltrate. Significant cracking, spalling, or buckling of pipe material. Joint offset less than 3 inches. End sections dislocated and about to drop off from main portion of the structure. Infiltration staining apparent.	Fair
5	Transverse cracks open greater than 1/8th inch with efflorescence and rust staining. Spalling at numerous locations. Extensive surface scaling on invert greater than 1/2 inch. Extensive cracking with cracks open more than 1/8th inch with efflorescence. Spalling has caused exposure of heavily corroded reinforcing steel on bottom or top of slab. Extensive surface scaling on invert greater than 3/4th inch or approximately 50% of culvert invert.	Erosion along footing with slight undermining, protection required		Differential movement and separation of joints. Significant infiltration or exfiltration at joints. Joint offset less than 4 inches. Voids seen in fill through offset joints. End sections dropped off at inlet.	Poor
4	Extensive cracking with spalling, delaminations, and slight differential movement. Scaling has exposed all surfaces of the reinforcing steel in bottom and top slab or invert with approximately 50% loss of wall thickness at invert. Concrete very soft.	Severe undermining with slight differential settlement causing minor cracking or spalling in footing and minor distress in walls		Significant openings. Dislocated joints at several locations exposing fill material with joint offsets greater than 4 inches. Infiltration or exfiltration causing misalignment of pipe and settlement or depressions in roadway. Large voids seen in fill through offset joints.	Serious
3	Full depth holes. Extensive cracking greater than 1/2 inch. Spalled areas with exposed reinforcing greater than 25%. Over 50% of the surface area is delaminated, spalled, or punky. Reinforcing steel bars have extensive section loss and bar perimeter is completely exposed.	Severe undermining with significant differential settlement causing severe cracks in footing and distress in walls		Culvert not functioning due to alignment problems throughout. Large voids seen in fill through offset joints.	Critical
2	Culvert partially collapsed or collapse is imminent.	Structure partially collapsed or collapse is imminent.		Pipe partially collapsed or collapse is imminent.	Imminent Failure
1	The culvert is collapsed.	Total failure of structure.		Total failure of pipe.	Failed

* For open bottom structures, rate footing condition. If concrete invert present, rate invert based upon Concrete Structural Deterioration.

TAMC Michigan Transportation Asset Management Council
In cooperation with Local Technology & Training

CONCRETE PIPE

Concrete Pipe	Blockage	Scour	Condition
10	No blockage. Designed condition.	No evidence of scour at either inlet or outlet of culvert.	Excellent
9	Minor amounts of sediment build-up with no appreciable loss of opening.	Minor scour holes developing at inlet or outlet. Scour protection placed.	Very Good
8	Culvert waterway blockage is less than 5% of the cross sectional area of the opening. Bank and channel have minor amounts of drift.	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.	Good
7	Culvert waterway blockage is less than 10% of the cross sectional area of the opening. Sediment buildup causing flow through 1 of 2 pipes. Silt and Gravel buildup restricts half of the channel. Tree or bush growing in the channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Satisfactory
6	Culvert waterway blockage is less than 30% of the cross sectional area of the opening. Tree or bush growing in channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Fair
5	Culvert waterway blockage is less than 40% of the cross sectional area of the opening. Occasional overtopping of roadway. Large deposits of debris are in the waterway.	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.	Poor
4	Culvert waterway blockage is less than 80% of the cross sectional area of the opening. Overtopping of roadway with significant traffic delays.	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.	Serious
3	Culvert waterway blockage is 80% or greater of the cross sectional area of the opening. Frequent overtopping of roadway with significant traffic delays.	Streambed degradation causing severe settlement.	Critical
2	Culvert waterway completely blocked and causing water to pool. Road closed because of channel failure.	Culvert closed because of channel failure.	Imminent Failure
1	Total failure of pipe.	Total failure of culvert because of channel failure.	Failed

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PLASTIC PIPE

Plastic Pipe	Structural Deterioration	Invert Deterioration*	Section Deformation	Joints/Seams	Condition
10	New Condition.	New Condition.	Smooth wall. Span dimension up to 2% greater than design.	Straight line between sections.	Excellent
9	Isolated rip or tear less than or equal to 6 inches caused by floating debris or construction. Minor discoloration at isolated locations.	Minor discoloration at isolated locations.	Smooth wall. Span dimension up to 5% greater than design.	No settlement or misalignment. Tight with no defects apparent.	Very Good
8	Split less than or equal to 6 inches but not open more than 1/4th inch at two or three locations. Damage due to cuts, gouges, or distortion at end sections from construction or maintenance.	Perforations caused by abrasion located within 5 feet of outlet and not located under roadway.	Relatively smooth wall. Span dimension up to 7.5% greater than design.	Minor misalignment at joints. Minor settlement. Distress to pipe material adjacent to joint.	Good
7	Split less than 6 inches with width not to exceed ½ inch at two or three locations. Damage due to cuts, gouges, burnt edges, or distortion at end sections from construction or maintenance.	Perforations caused by abrasion located within 5 feet of inlet and outlet and not located under roadway.	Minor dimpling appearing at an isolated small area: Less than 1/16th of circumference area and 1 foot in length. Dimpling less than 1/4 inch deep. Span dimension up to 10% greater than design.	Misalignment of joints but no infiltration. Settlement. Dislocated end section. Extensive areas of shallow deterioration. Minor cracking.	Satisfactory
6	Split less than 6 inches with width exceeding ½ inch at two or three locations. Damage due to cuts, gouges, or distortion to end sections from construction or maintenance.	Perforations caused by abrasion located with 5 feet of inlet and outlet and not located under roadway.	Minor dimpling appearing over 1/16 to ⅛ of circumference area and 2 feet in length. Dimples between ¼ and ½ inch deep. Pipe deflection less than 12.5% from original shape.	Joint open and allowing backfill to infiltrate. Significant cracking or buckling of pipe material. Joint offset less than 3 inches. End sections dislocated and about to drop off from main portion of the structure. Infiltration staining apparent.	Fair
5	Split less than 6 inches with width exceeding ½ inch at several locations. Splits causing loses of backfill material.	Perforations caused by abrasion located throughout pipe.	Wall Crushing or hinging occurring with lengths less than 3 feet. Pipe deflection less than 15% from original shape.	Differential movement and separation of joints. Significant infiltration or exfiltration at joints. Joint offset less than 4 inches. Voids seen in fill through offset joints. End sections dropped off at inlet.	Poor
4	Split less than 6 inches with width exceeding 1 inch at several locations. Splits causing loss of backfill material.	Section loses caused by abrasion located throughout pipe.	Wall Crushing or hinging occurring with lengths greater than 3 feet. Moderate degree of dimpling appearing. Dimples more than ½ inch deep. Wall tearing or cracking in the buckled region. Pipe deflection less than 20% from original shape.	Significant openings. Dislocated joints at several locations exposing fill material with joint offsets greater than 4 inches. Infiltration or exfiltration causing misalignment of pipe and settlement or depressions in roadway. Large voids seen in fill through offset joints.	Serious
3	Split larger than 6 inches with width exceeding 1 inch at several locations. Splits causing loss of backfill material.	Section loss caused by abrasion located throughout pipe with at least a 2 foot in length by ½ foot in width invert section eroded away.	Wall Crushing or hinging occurring over the majority of the length of pipe under the roadway. Moderate degree of dimpling appearing. Dimples more than ½ inch deep. Wall tearing or cracking in the buckled region. Pipe deflection greater than 20% from original shape. Severe dimpling accompanied with wall splits.	Culvert not functioning due to alignment problems throughout. Large voids seen in fill through offset joints.	Critical
2	Pipe partially collapsed or collapse is imminent.	Pipe partially collapsed or collapse is imminent.	Pipe partially collapsed or collapse is imminent.	Pipe partially collapsed or collapse is imminent.	Imminent Failure
1	Total failure of pipe.	Total failure of pipe.	Total failure of pipe.	Total failure of pipe.	Failed

* For open bottom structures, rate footing condition. If concrete invert present, rate invert based upon Concrete Structural Deterioration.

PLASTIC PIPE

Plastic Pipe	Blockage	Scour	Condition
10	No blockage. Designed condition.	No evidence of scour at either inlet or outlet of culvert.	Excellent
9	Minor amounts of sediment build-up with no appreciable loss of opening.	Minor scour holes developing at inlet or outlet. Scour protection placed.	Very Good
8	Culvert waterway blockage is less than 5% of the cross sectional area of the opening. Bank and channel have minor amounts of drift.	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.	Good
7	Culvert waterway blockage is less than 10% of the cross sectional area of the opening. Sediment buildup causing flow through 1 of 2 pipes. Silt and Gravel buildup restricts half of the channel. Tree or bush growing in the channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Satisfactory
6	Culvert waterway blockage is less than 30% of the cross sectional area of the opening. Tree or bush growing in channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Fair
5	Culvert waterway blockage is less than 40% of the cross sectional area of the opening. Occasional overtopping of roadway. Large deposits of debris are in the waterway.	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.	Poor
4	Culvert waterway blockage is less than 80% of the cross sectional area of the opening. Overtopping of roadway with significant traffic delays.	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.	Serious
3	Culvert waterway blockage is 80% or greater of the cross sectional area of the opening. Frequent overtopping of roadway with significant traffic delays.	Streambed degradation causing severe settlement.	Critical
2	Culvert waterway completely blocked and causing water to pool. Road closed because of channel failure.	Culvert closed because of channel failure.	Imminent Failure
1	Total failure of pipe.	Total failure of culvert because of channel failure.	Failed

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MASONRY

Masonry	Structural Deterioration	Invert Deterioration*	Section Deformation	Joints/Seams	Condition
10	New Condition	New condition	Not Applicable: Rigid material pipes are not rated for deformation	Straight line between sections.	Excellent
9	No cracking. No missing or dislocated masonry. Surface in great condition.	Good with no invert erosion		No settlement or misalignment. Tight with no defects apparent.	Very Good
8	Surface deterioration at isolated locations.	Good with only minor invert erosion		Minor misalignment at joints. Minor settlement. Distress to pipe material adjacent to joint. Shallow mortar deterioration at isolated locations.	Good
7	Minor cracking in masonry units	Minor erosion near footings		Misalignment of joints but no infiltration. Settlement. Dislocated end section. Extensive areas of shallow deterioration. Missing mortar at isolated locations. Minor cracking.	Satisfactory
6	Minor cracking. Slight dislocation of masonry units. Large areas of surface scaling. Split or cracked stones.	Moderate erosion along footing; protective measures may be required		Joint open and allowing backfill to infiltrate. Significant cracking, spalling, or buckling of pipe material. Joint offset less than 3 inches. End sections dislocated and about to drop off from main portion of the structure. Mortar generally deteriorated. Loose or missing mortar at isolated locations. Infiltration staining apparent.	Fair
5	Extensive cracking. Significant dislocation of masonry units. Large areas of surface scaling. Split or cracked stones.	Erosion along footing with slight undermining, protection required		Differential movement and separation of joints. Significant infiltration or exfiltration at joints. Joint offset less than 4 inches. Voids seen in fill through offset joints. End sections dropped off at inlet. Mortar severely deteriorated. Significant loss of mortar. Significant infiltration or exfiltration between masonry units.	Poor
4	Severe cracking with spalling. Delamination(s). Slight differential movement. Individual lower masonry units of structure missing or crushed.	Severe undermining with slight differential settlement causing minor cracking or spalling in footing and minor distress in walls		Significant openings. Dislocated joints at several locations exposing fill material with joint offsets greater than 4 inches. Infiltration or exfiltration causing misalignment of pipe and settlement or depressions in roadway. Large voids seen in fill through offset joints. Extensive areas of missing mortar for masonry structures.	Serious
3	Cracking very severe with significant spalling, delamination, and differential movement. Individual masonry units in lower part of structure missing or crushed. Individual masonry units in top of culvert missing or crushed.	Severe undermining with significant differential settlement causing severe cracks in footing and distress in walls		Culvert not functioning due to alignment problems throughout. Large voids seen in fill through offset joints.	Critical
2	Structure partially collapsed or collapse is imminent.	Structure partially collapsed or collapse is imminent.		Pipe partially collapsed or collapse is imminent.	Imminent Failure
1	Total failure of structure.	Total failure of structure.		Total failure of pipe.	Failed

* For open bottom structures, rate footing condition. If concrete invert present, rate invert based upon Concrete Structural Deterioration.

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MASONRY

Masonry	Blockage	Scour	Condition
10	No blockage. Designed condition.	No evidence of scour at either inlet or outlet of culvert.	Excellent
9	Minor amounts of sediment build-up with no appreciable loss of opening.	Minor scour holes developing at inlet or outlet. Scour protection placed.	Very Good
8	Culvert waterway blockage is less than 5% of the cross sectional area of the opening. Bank and channel have minor amounts of drift.	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.	Good
7	Culvert waterway blockage is less than 10% of the cross sectional area of the opening. Sediment buildup causing flow through 1 of 2 pipes. Silt and Gravel buildup restricts half of the channel. Tree or bush growing in the channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Satisfactory
6	Culvert waterway blockage is less than 30% of the cross sectional area of the opening. Tree or bush growing in channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Fair
5	Culvert waterway blockage is less than 40% of the cross sectional area of the opening. Occasional overtopping of roadway. Large deposits of debris are in the waterway.	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.	Poor
4	Culvert waterway blockage is less than 80% of the cross sectional area of the opening. Overtopping of roadway with significant traffic delays.	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.	Serious
3	Culvert waterway blockage is 80% or greater of the cross sectional area of the opening. Frequent overtopping of roadway with significant traffic delays.	Streambed degradation causing severe settlement.	Critical
2	Culvert waterway completely blocked and causing water to pool. Road closed because of channel failure.	Culvert closed because of channel failure.	Imminent Failure
1	Total failure of pipe.	Total failure of culvert because of channel failure.	Failed

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SLAB & ABUTMENT

Slab/ Superstructure & Abutment	Structural Deterioration	Invert Deterioration*	Concrete Abutment	Masonry Abutment	Condition
10	No signs of distress. No discoloration.	New condition	No signs of distress. No discoloration.	No signs of distress. Minor spalling of stone surface.	Excellent
9	Minor scaling less than ¼ inch deep over 5% of deck surface. Hairline cracking without rust staining or delamination. No dampness. No leakage. No spalling. Isolated damage from construction.	Good with no invert erosion	Minor scaling less than ¼ inch deep over 5% of concrete surface. Hairline cracking. No rust staining, delamination(s), dampness, leakage, or spalling. Minor construction damage.	Minor spalling of stone surface. Scaling of stone surface less than ½ inch.	Very Good
8	Hairline cracking with no single crack greater than ⅛ inch parallel to the direction of traffic. Light scaling less than ⅛ inch deep on less than 10% of exposed area. Delaminated or spalled area less than 1% of surface area but not including the first 12 inches of the outside slab edges. Isolated damage from construction or vehicle impact. Slab may have a single large crack less than 1/16 inch on bottom surface parallel to the direction of traffic.	Good with only minor invert erosion	Hairline cracking. No single crack greater than ⅛ inch. No rust staining. Light scaling less than ⅛ inch deep on less than 10% of exposed area. Delaminated and spalled area less than 1% of surface area.	Diagonal or vertical shear crack in isolated stones. Fracture of stone surface less than 2 inches.	Good
7	Transverse cracks evident on bottom side: Spaced 10'-20' with or without water leaking through cracks. Some spalling may be present on 1% - 10% of total deck area. Spalled areas with exposed reinforcing on less than 5% of slab area. Hairline map cracking combined with mohled areas. Cracks less than ⅛ inch parallel to traffic with minor efflorescence or minor amounts of leakage. Scaling, less than ¼ inch deep, on less than 20% of slab area. Additional delaminated and spalled areas on less than 10% of surface area; Exclude the first 12 inches of the outside slab edges.	Minor erosion near footings	Hairline map cracking combined with mohled areas. Horizontal and diagonal cracks less than ⅛ inch with minor efflorescence or minor amounts of leakage. Scaling less than ½ inch deep on less than 20% of slab area. Spalled areas with exposed reinforcing on less than 5% of slab area. Delaminated and spalled area less than 10% of surface area. Minor differential settlement.	Diagonal or vertical shear cracks through several courses of stone with some minor displacement. Spalls along edge of seat area.	Satisfactory
6	Map cracking. Cracks less than ⅛ inch parallel to traffic and cracks less than 1/16 inch transverse to traffic with efflorescence or rust stain, leakage and mohled areas. Scaling, less than 3/16th inch deep, on less than 30% of exposed area. Spalled areas with exposed reinforcing less than 10%. Total delaminated and spalled areas less than 20% of surface area excluding the first 12 inches of the outside slab edges.	Moderate erosion along footing, protective measures may be required	Map cracking. Horizontal cracks less than ⅛ inch. Diagonal cracks less than 1/16 inch with efflorescence or rust stain or leakage, or mohled areas or all. Scaling less than 3/16 inch deep on less than 30% of exposed area. Spalled areas with less than 10% showing exposed reinforcing. Total delaminated and spalled areas on less than 20% of surface area. Moderate differential or rotational settlement.	Diagonal or vertical shear cracks through several courses of stone with displacement. Displacement may be bulge or leaning stones. Total displacement is less than ½ of stone depth.	Fair
5	Steel plates covering full depth holes. Map cracking with dark damp areas and efflorescs over at least 30% of deck bottom. Several transverse cracks open more than ¼ inch with efflorescence and rust staining. Spalling at numerous locations. Extensive surface scaling greater than ½ inch deep. Reinforcing steel bars have extensive section loss: 4 or more adjacent bars with more than 10% of original diameter lost. Total delaminated and spalled areas greater than 25% of surface area excluding the first 12 inches of the outside slab edges.	Erosion along footing with slight undermining, protection required	Map cracking with dark or damp areas, efflorescence, and unsound concrete over 30% of abutment face. Several horizontal and diagonal cracks open more than ¼ inch with efflorescence and rust staining. Spalling at numerous locations. Extensive surface scaling greater than ½ inch deep. Total delaminated and spalled areas on less than 25% of surface area. Reinforcing steel bars have extensive section losses greater than 10% of original diameter for more than 4 adjacent bars. Severe differential or rotational settlement.	Settlement causing diagonal or vertical shear cracks through several courses of stone with displacement. Total displacement is less than ½ of stone depth. Large fractures or erosion of stone surfaces less than 5 inches on adjacent stones. Spalls on beam seats cause reduced bearing area.	Poor
4	Refer to the above rating except reinforcing steel bars have extensive section loss: Greater than 20% of original diameter for more than 5 adjacent bars.	Severe undermining with slight differential settlement causing minor cracking or spalling in footing and minor distress in walls	Map cracking with dark or damp areas and efflorescs over at least 40% of abutment face. Several transverse cracks open more than ¼ inch with efflorescence and rust staining. Spalling at numerous locations. Extensive surface scaling greater than ½ inch. Total delaminated and spalled areas over more than 25% of surface area. Reinforcing steel bars have extensive section losses greater than 20% of original diameter for more than 5 adjacent bars. Severe differential or rotational settlement.	Large unsound areas. Several stones are displaced or missing. Misalignment of mortar joints. Large fractures or erosion of stone surfaces greater than 5 inches. Spalls on beam seats causing reduced bearing area.	Serious
3	Full depth holes. Total delaminated, spalled, map cracking, and punky concrete areas are greater than 50% of surface area. Reinforcing steel bars have extensive section loss: Greater than 30% of original diameter for more than 10 adjacent bars. Additional dark and damp areas over at least 50% of deck.	Severe undermining with significant differential settlement causing severe cracks in footing and distress in walls	Cracking and white efflorescence. Total delaminated, spalled, map cracking, and unsound concrete areas on over 50% of surface area. Reinforcing steel bars have extensive section losses greater than 30% of original diameter for more than 10 adjacent bars. Extreme differential or rotational settlement.	Numerous missing or displaced stones. Displacements greater than 1/3 of stone depth. Partially collapsed wingwall.	Critical
2	Structure partially collapsed or collapse is imminent.		Structure partially collapsed or collapse is imminent.	Pipe partially collapsed or collapse is imminent.	Imminent Failure
1	Total failure of structure.		Total failure of structure.	Total failure of pipe.	Failed

* For open bottom structures, rate footing condition. If concrete invert present, rate invert based upon Concrete Structural Deterioration.

SLAB & ABUTMENT

Slab/ Superstructure & Abutment	Blockage	Scour	Condition
10	No blockage. Designed condition.	No evidence of scour at either inlet or outlet of culvert.	Excellent
9	Minor amounts of sediment build-up with no appreciable loss of opening.	Minor scour holes developing at inlet or outlet. Scour protection placed.	Very Good
8	Culvert waterway blockage is less than 5% of the cross sectional area of the opening. Bank and channel have minor amounts of drift.	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.	Good
7	Culvert waterway blockage is less than 10% of the cross sectional area of the opening. Sediment buildup causing flow through 1 of 2 pipes. Silt and Gravel buildup restricts half of the channel. Tree or bush growing in the channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Satisfactory
6	Culvert waterway blockage is less than 30% of the cross sectional area of the opening. Tree or bush growing in channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Fair
5	Culvert waterway blockage is less than 40% of the cross sectional area of the opening. Occasional overtopping of roadway. Large deposits of debris are in the waterway.	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.	Poor
4	Culvert waterway blockage is less than 80% of the cross sectional area of the opening. Overtopping of roadway with significant traffic delays.	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.	Serious
3	Culvert waterway blockage is 80% or greater of the cross sectional area of the opening. Frequent overtopping of roadway with significant traffic delays.	Streambed degradation causing severe settlement.	Critical
2	Culvert waterway completely blocked and causing water to pool. Road closed because of channel failure.	Culvert closed because of channel failure.	Imminent Failure
1	Total failure of pipe.	Total failure of culvert because of channel failure.	Failed

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CMP SECTION DEFORMATION

CMP Section Deformation	Round/Vertical/ Elongated Pipes	Pipe Arch	Plate Arch	Box	Low Profile Long Span*	High Profile Long Span*	Pear*	Horizontal Ellipse*	Condition
10	New Condition	New Condition	New Condition	New Condition	New Condition	New Condition	New Condition	New Condition	Excellent
9	Good, smooth curvature in barrel. Horizontal diameter (span) dimension within 10% of original design.	Good with smooth curvature in barrel. Horizontal span dimension less than 3% greater than original design.	Good, smooth symmetrical curvature. Rise within +/- 5 percent of original design.	Good appearance, smooth symmetrical curvature. Top arc mid-ordinate within 11 percent of original design. Horizontal span within 5 percent of original design. Sides straight leg every slightly deflected inward or outward and curvature smooth.	Good appearance, smooth symmetrical curvature. Top arc mid-ordinate within 11 percent of original design. Horizontal span within 5 percent of original design.	Good appearance, smooth symmetrical curvature. Top arc mid-ordinate within 11 percent of original design. Horizontal span within 5 percent of original design.	Good appearance, smooth symmetrical curvature. Top arc mid-ordinate within 11 percent of original design. Horizontal span within 5 percent of original design. Side plates: smooth curvature	Good appearance, smooth symmetrical curvature. Top arc mid-ordinate within 11 percent of original design. Horizontal span within 5 percent of original design. Bottom arc: smooth curvature, mid-ordinate within 50 percent of original design.	Very Good
8	Generally good, top half of pipe smooth but minor flattening of bottom. Horizontal diameter (span) dimension within 10% of original design.	Generally good with smooth curvature, symmetrical, slight flattening of top or sides in one section. Rise within 3 to 4 percent of original design.	Generally good, curvature is smooth and symmetrical. Rise within 3 to 4 percent of original design.	Generally good, curvature is smooth and symmetrical. Top arc mid-ordinate within 11 percent to 15 percent of original design. Sides: straight leg slightly deflected inward or mid-deflected outward, curvature smooth.	Generally good, curvature is smooth and symmetrical. Top arc mid-ordinate within 11 percent to 15 percent of original design. Horizontal span within 5 percent of original design.	Generally good, curvature is smooth and symmetrical. Top arc mid-ordinate within 11 percent to 15 percent of original design. Horizontal span within 5 percent of original design.	Generally good, curvature is smooth and symmetrical. Top arc mid-ordinate within 11 percent to 15 percent of original design. Horizontal span within 5 percent of original design. Side plates: side flattened, mid-ordinate less than 50 percent of original design.	Generally good, curvature is smooth and symmetrical. Top arc mid-ordinate within 11 percent to 15 percent of original design. Horizontal span within 5 percent of original design. Bottom arc: bottom flattened, mid-ordinate less than 50 percent of original design.	Good
7	Fair: top half has smooth curvature but bottom half has flattened significantly. Horizontal diameter (span) dimension within 10% of original design.	Fair: smooth curvature in top half, bottom flat but non-symmetrical. Horizontal span 5 percent greater than original design	Fair, smooth curvature but non-symmetrical, slight flattening of top and sides throughout. Rise within 4 to 5 percent of original design.	Smooth curvature, shape is non-symmetrical. Top arc mid-ordinate within 15 percent of original design. Horizontal span more than +/- 5 percent of original design. Sides: straight leg moderately deflected inward or extremely deflected outward, curvature smooth.	Smooth curvature, shape is non-symmetrical. Top arc mid-ordinate within 15 percent of original design. Horizontal span more than +/- 5 percent of original design.	Smooth curvature, shape is non-symmetrical. Top arc mid-ordinate within 15 percent of original design. Horizontal span more than +/- 5 percent of design. Side plates: side flattened, mid-ordinate less than 35 percent of original design.	Smooth curvature, shape is non-symmetrical. Top arc mid-ordinate within 15 percent of original design. Horizontal span more than +/- 5 percent of design. Side plates: side flattened, mid-ordinate less than 25 percent of original design.	Smooth curvature, shape is non-symmetrical. Top arc mid-ordinate within 15 percent of original design. Horizontal span more than +/- 5 percent of design. Bottom arc: bottom flattened and irregular, mid-ordinate less than 50 percent of original design.	Satisfactory
6	Generally fair, significant distortion at isolated locations on top half and extreme flattening of the arrvet. Horizontal diameter (span) dimension 10% to 15% greater than original design.	Generally fair, significant distortion in top on one location, bottom has slight reverse curvature in one location. Horizontal span within 5 to 7 percent greater than original design.	Generally fair, significant distortion and deflection in one section, sides beginning to flatten, non-symmetrical. Rise within 5 to 7 percent of original design	Generally fair, significant distortion and deflection in one section, half top of arcs are 30 percent less than original design. Top arc mid-ordinate within 15 to 20 percent of original design. Horizontal span more than +/- 5 percent of original design. Sides: straight leg moderately deflected outward for distance of less than 1/4 span length.	Generally fair, significant distortion and deflection is one section, half top of arcs beginning to flatten, mid-ordinate of half top arc 30 percent less than original design. Top arc mid-ordinate within 15 to 20 percent of original design. Horizontal span more than +/- 5 percent of original design.	Generally fair, significant distortion and deflection is one section, half top of arcs beginning to flatten, mid-ordinate of half top arc 30 percent less than original design. Top arc mid-ordinate within 15 to 20 percent of original design. Horizontal span more than +/- 5 percent of original design.	Generally fair, significant distortion and deflection is one section, half top of arcs beginning to flatten, mid-ordinate of half top arc 30 percent less than original design. Top arc mid-ordinate within 15 to 20 percent of original design. Horizontal span more than +/- 5 percent of original design. Side plates: side flattened, mid-ordinate less than 35 percent of original design.	Generally fair, significant distortion and deflection is one section, half top of arcs beginning to flatten, mid-ordinate of half of half top arc 30 percent less than original design. Top arc mid-ordinate within 15 to 20 percent of original design. Horizontal span more than +/- 5 percent of original design. Bottom arc: bottom flattened and irregular, mid-ordinate less than 50 percent of original design.	Fair
5	Marginal significant distortion throughout length of pipe, lower third may be kinked. Horizontal diameter (span) dimension 10% to 15% greater than original design.	Marginal, significant distortion all along top of arch, bottom has reverse curve. Horizontal span: more than 7 percent greater than original design	Marginal, significant distortion and deflection throughout, sides flattened with radius 100 percent greater than design. Rise within 7 to 8 percent of original design	Marginal, significant distortion and deflection throughout, mid-ordinate of half top arc less than 50 percent of original design. Top arc mid-ordinate within 20 to 30 percent of design. Horizontal span: more than +/- 6 percent of design. Sides: straight leg bowed inward significantly or extremely bowed outward for distance of less than 1/4 span length.	Marginal, significant distortion and deflection throughout, mid-ordinate of half top arc less than 50 percent of original design. Top arc mid-ordinate within 20 to 30 percent of design. Horizontal span: more than +/- 5 percent of original design.	Marginal, significant distortion and deflection throughout, mid-ordinate of half top arc less than 50 percent of original design. Top arc mid-ordinate within 15 to 20 percent of design. Horizontal span: more than +/- 5 percent of original design.	Marginal, significant distortion and deflection throughout, mid-ordinate of half top arc less than 50 percent of original design. Top arc mid-ordinate within 15 to 20 percent of original design. Horizontal span: more than +/- 5 percent of design. Side plates: side flattened, mid-ordinate less than 25 percent of original design.	Marginal, significant distortion and deflection throughout, mid-ordinate of half top arc less than 50 percent of original design. Top arc mid-ordinate within 15 to 20 percent of original design. Horizontal span: more than +/- 5 percent of design. Bottom arc: bottom virtually flat over center half of arc	Poor
4	Poor, extreme deflection at isolated locations around the crown, creasing near 20 to 30 feet. Horizontal diameter (span) dimension in excess of 15% greater than original design.	Poor, extreme deflection in top arch in one location, bottom has reverse curvature. Horizontal span: more than 7 percent greater than original design.	Poor, extreme distortion and deflection in one section and flattened, extremely non-symmetrical. Rise within 8 to 10 percent of original design	Poor, extreme distortion and deflection in one section and ordinate of half top arc 50 to 70 percent less than original design. Top arc mid-ordinate 30 to 40 percent less than original design. Horizontal Rise within 20 percent of original design. Horizontal span: more than +/- 6 percent of original design. Sides: straight leg extremely bowed inward for a distance of 1/2 span length, curvature irregular	Poor, extreme distortion and deflection in one section and ordinate of half top arc 50 to 70 percent less than original design. Top arc mid-ordinate 20 to 30 percent less than original design. Horizontal span: more than +/- 6 percent of design.	Poor, extreme distortion and deflection in one section and ordinate of half top arc 50 to 70 percent less than original design. Top arc mid-ordinate 20 to 30 percent less than original design. Horizontal span: more than +/- 6 percent of design.	Poor, extreme distortion and deflection in one section and ordinate of half top arc 50 to 70 percent less than original design. Top arc mid-ordinate 20 to 30 percent less than original design. Horizontal span: more than +/- 6 percent of original design. Side plates: side flattened, mid-ordinate less than 20 percent of original design.	Poor, extreme distortion and deflection in one section and ordinate of half top arc 50 to 70 percent less than original design. Top arc mid-ordinate 20 to 30 percent less than original design. Horizontal span: more than +/- 6 percent of original design. Bottom arc: bottom reverse curved in center	Serious
3	Critical, extreme deflection throughout, flattening of the crown, crown radius over 30 feet. Horizontal diameter (span) dimension more than 20% greater than original design.	Critical, extreme deflection along top of pipe. Horizontal span: more than 7 percent greater than original design.	Critical, extreme deflection, throughout, sides flattened, extremely non-symmetrical. Rise greater than 10 percent of original design	Critical, extreme distortion and end deflection throughout, mid-ordinate of half top arc more than 70 percent less than design. Top arc mid-ordinate more than 40 percent of original design. Horizontal span: more than +/- 8 percent of design. Sides: straight leg extremely bowed inward for a distance of 1/2 to 3/4 span length, or leg bowed outward	Critical, extreme distortion and end deflection throughout, mid-ordinate of half top arc more than 70 percent less than design. Top arc mid-ordinate more than 40 percent of original design. Horizontal span: more than +/- 8 percent of design.	Critical, extreme distortion and end deflection throughout, mid-ordinate of half top arc more than 70 percent less than design. Top arc mid-ordinate more than 30 percent of original design. Horizontal span: more than +/- 8 percent of design.	Critical, extreme distortion and end deflection throughout, mid-ordinate of half top arc more than 70 percent less than design. Top arc mid-ordinate more than 30 percent of original design. Horizontal span: more than +/- 8 percent of design. Side plates: side flattened, mid-ordinate less than 10 percent of original design.	Critical, extreme distortion and end deflection throughout, mid-ordinate of half top arc more than 70 percent less than design. Top arc mid-ordinate more than 30 percent of original design. Horizontal span: more than +/- 8 percent of design. Bottom arc: bottom flattened and bulged	Critical
2	Partially collapsed with crown in reverse curvature	Structure partially collapsed	Severe due to partial collapse, top arc curvature flat or reverse curved.	Severe due to partial collapse, top arc curvature flat or reverse curved.	Severe due to partial collapse, top arc curvature flat or reverse curved.	Severe due to partial collapse, top arc curvature flat or reverse curved.	Severe due to partial collapse, top arc curvature flat or reverse curved. Side plates: side flat or reversed curved	Severe due to partial collapse, top arc curvature flat or reverse curved.	Imminent Failure
1	Structure collapsed	Structure collapsed	Completely collapsed	Completely collapsed	Completely collapsed	Completely collapsed	Completely collapsed	Completely collapsed	Failed

* These geometries are uncommon for spans under 20 feet.

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TAMC

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CMP SECTION DEFORMATION

CMP Joints & Seams	Pipe Joints or Seams	Multi-plate Joints or Seams	Condition
10	Straight line between sections.	Minor amounts of efflorescence or staining	Excellent
9	No settlement or misalignment. Tight with no defects apparent.	Light surface rust on bolts due to loss of galvanizing. Efflorescence staining.	Very Good
8	Minor misalignment at joints. Minor settlement. Distress to pipe material adjacent to joint.	Metal has cracking on each side of a bolt hole: Less than 3 in a seam section. Minor seam openings that are less than ½ inch. Potential for backfill infiltration. More than 2 missing bolts in a row. Rust scale around bolts.	Good
7	Misalignment of joints but no infiltration. Settlement. Dislocated end section. Extensive areas of shallow deterioration.	Evidence of backfill infiltration through seams.	Satisfactory
6	Joint open and allowing backfill to infiltrate. Significant cracking or buckling of pipe material. Joint offset less than 3 inches. End sections dislocated and about to drop off from main portion of the structure. Infiltration staining apparent.	Moderate cracking at bolt holes along a seam in one section. Backfill being lost through seam causing slight deflection. Less than 6 missing bolts in a row or 20% along the total seam.	Fair
5	Differential movement and separation of joints. Significant infiltration or exfiltration at joints. Joint offset less than 4 inches. Voids seen in fill through offset joints. End sections dropped off at inlet.	Major cracking of seam near crown. Infiltration of backfill causing major deflection. Partial cocked and unsped seams. 10% section loss to bolt heads along seams.	Poor
4	Significant openings. Dislocated joints at several locations exposing fill material with joint offsets greater than 4 inches. Infiltration or exfiltration causing misalignment of pipe and settlement or depressions in roadway. Large voids seen in fill through offset joints.	Longitudinal cocked and unsped seams. Metal has 3 inch crack on each side of the bolt hole run for the entire length of the culvert. Missing or tipping bolts.	Serious
3	Culvert not functioning due to alignment problems throughout. Large voids seen in fill through offset joints.	Seam cracked from bolt to bolt. Significant amounts of backfill infiltration.	Critical
2	Pipe partially collapsed or collapse is imminent.	Pipe partially collapsed or collapse is imminent.	Imminent Failure
1	Total failure of pipe.	Total failure of pipe.	Failed

* For open bottom structures, rate footing condition. If concrete invert present, rate invert based upon Concrete Structural Deterioration.

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Timber	Blockage	Scour	Condition
10	No blockage. Designed condition.	No evidence of scour at either inlet or outlet of culvert.	Excellent
9	Minor amounts of sediment build-up with no appreciable loss of opening.	Minor scour holes developing at inlet or outlet. Scour protection placed.	Very Good
8	Culvert waterway blockage is less than 5% of the cross sectional area of the opening. Bank and channel have minor amounts of drift.	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.	Good
7	Culvert waterway blockage is less than 10% of the cross sectional area of the opening. Sediment buildup causing flow through 1 of 2 pipes. Silt and Gravel buildup restricts half of the channel. Tree or bush growing in the channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Satisfactory
6	Culvert waterway blockage is less than 30% of the cross sectional area of the opening. Tree or bush growing in channel. Fence placed at inlet or outlet. Rock dams in culvert.	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.	Fair
5	Culvert waterway blockage is less than 40% of the cross sectional area of the opening. Occasional overtopping of roadway. Large deposits of debris are in the waterway.	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.	Poor
4	Culvert waterway blockage is less than 80% of the cross sectional area of the opening. Overtopping of roadway with significant traffic delays.	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.	Serious
3	Culvert waterway blockage is 80% or greater of the cross sectional area of the opening. Frequent overtopping of roadway with significant traffic delays.	Streambed degradation causing severe settlement.	Critical
2	Culvert waterway completely blocked and causing water to pool. Road closed because of channel failure.	Culvert closed because of channel failure.	Imminent Failure
1	Total failure of pipe.	Total failure of culvert because of channel failure.	Failed

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TIMBER

Michigan Transportation Asset Management Council

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APPENDIX H: FAQ DOCUMENTATION

2018 TAMC Culvert Data Collection Pilot Project

Frequently Asked Questions (FAQ)

Thank you for your interest in the Michigan Transportation Asset Management Council (TAMC) Culvert Data Collection Pilot Project! We know you likely have many questions and hope you are able to find your answer here, in this Frequently Asked Questions document. If you are participating in this pilot project as either a local road agency or a regional planning organization (RPO)/metropolitan planning organization (MPO), you will find answers to common questions in the following areas:

- About Participation and Commitment
- About the Startup Funding
- About the Reimbursement
- About Collection Teams
- About the Required Data Collection Elements
- About the Data Collection Tools
- About Data Collection
- General Questions

We will update this document regularly when we determine answers to any of your existing unanswered questions and when we receive new questions from you. If you do not find your answer here, we encourage you to send us your questions to Scott Bershing (sjbershi@mtu.edu) or Chris Gilbertson (cggilber@mtu.edu) at the Center for Technology & Training (CTT).

About Participation and Commitment

How do local road agencies officially commit?

To commit to the culvert data collection pilot project, contact Scott Bershing at sjbershi@mtu.edu. You can also reply to the e-mail that he sent on Friday, April 13, 2018. You will need to send him your response by the deadline, which is May 14, 2018.

How do we know if our local road agency is in Round 1 or Round 2?

You will find this information in the letter that your agency received on April 13, 2018.

When do Round 2 local road agencies need to commit?

Round 2 local road agencies need to commit by the same deadline as Round 1 local road agencies, which is May 14, 2018. We need all commitments by this date.

If a local road agency commits before May 14, 2018, can they begin collection right away?

Yes!

What would happen if a local road agency committed to participating in the pilot project but was unable to provide all of the data by July 30, 2018?

Local road agencies will receive reimbursement based on the centerline miles of road where all culverts are collected and submitted prior to July 30, 2018.

Are only local road agencies eligible for the pilot? Our agency, which is a planning organization, may be interested in having our staff conduct culvert ratings.

Only local road agencies are eligible for the culvert data collection pilot project funds. Planning organizations can take on a support role in the project by providing services to local road agencies to the extent that their current work plan and budget allows. Alternatively, planning organizations may act as field collection staff in support of a local road agency involved in the pilot; however, payment for these services should be negotiated with the individual local road agency directly.

How will the culvert data be used and/or is any data sharing agreement necessary?

There is no special agreement for this culvert data collection pilot. Participants will need to understand that this will be treated like Pavement Surface Evaluation and Rating (PASER) data collection and, thus, intended for public use. Information gathered will be detailed in a final report for further review and analysis by the TAMC and the state of Michigan.

About the Startup Funding

Will the fixed $10,000 for county road commissions or $5,000 for cities/villages be awarded as a lump sum?

The $10,000/$5,000 available for startup funding will be reimbursed for expenses up to $10,000 for county road commissions and up to $5,000 for cities/villages on a time and material basis. Invoices for labor, services and equipment will need to be submitted through your planning organization.

If the entire amount is not needed for startup funding, can the remaining portion be used toward data collection? Is there a listing of the items that are eligible under the startup funding?

Startup funding can be used toward data collection expenses such as labor, services, and minor tools or equipment necessary to do or prepare for data collection. Examples of acceptable equipment include a windows tablet or laptop to use as a data collector, a bright flashlight and camera for documenting culvert conditions, personal protective gear such as flotation or rescue devices that would be necessary for swift water inspection of culverts, and laser level or laser range finder to measure distances and elevations. Questions about acceptable uses of startup funding should be directed to

Roger Belknap, TAMC coordinator at the Michigan Department of Transportation, BelknapR@michigan.gov.

What documentation is required for startup funding?

Local road agencies must submit receipts and a detailed activity summary report containing labor hours for training to their planning organization. In turn, the planning organization will include these expenses with their Cost Breakdown by Activity and Regional Program Invoice Template for Asset Management.

When can we start purchasing equipment? How do we get reimbursed and what is the time frame for reimbursement?

As soon as your local road agency sends in a commitment to participate, you can begin purchasing equipment for the pilot project. You will receive reimbursement for your equipment purchases when we get your invoice, which you must submit through your planning organization by the end of the 2018 fiscal year (September 30, 2018). Any invoices received after September 30, 2018 will not be paid.

About the Reimbursement

Is there a guaranteed dollar amount per mile for Round 2 local road agencies?

No, determination of a per-centerline-mile reimbursement for Round 2 local road agencies depends on who is committing to participate from the Round 1 and Round 2 local road agencies. After the May 14 commitment deadline, we will be able to inform Round 2 local road agencies what their reimbursement rate will be.

***Update June 6, 2018**

TAMC approved a rate of $30/per centerline mile for Round 2 local agencies. A letter was sent to all participating Round 2 agencies informing them of this. The letter also provided the potential total level of funding for their agency based on their agency's Certified Act 51 mileage.

Can we submit data for a portion of our road system, for example just primary roads?

Yes, you will receive the same per-centerline-mile reimbursement for any roads that you inspect whether they have culverts or not. Local road agencies can decide to collect and submit all or some of their road network. For example, a county with 500 miles of road may choose to collect and submit data for several of their townships. The county will be reimbursed for centerline miles in those townships (collection area) for which all data was collected. Keep in mind that the final report will compare your startup funding to what you submitted for your data collection.

Also, just a reminder that TAMC has an objective to locate all culverts 12" to 20' in size (culverts beneath the Bridge definition). Therefore, TAMC encourages participants to

locate and evaluate these smaller culverts in addition to larger sized culverts in order to maintain a complete data set.

Will data submitted after July 30th be reimbursed?

No, local road agencies will only be reimbursed based on the centerline miles they submit prior to the close of business on July 30, 2018.

Are there separate invoice forms for PASER collection and the culvert data collection pilot project?

Yes, there will be separate forms, but they will be very similar.

***Update June 8, 2018**

The culvert pilot requires agencies and RPO/MPOs to account for culvert pilot actives separate from PASER activities. An updated invoice form is available on the TAMC webpage here: https://www.michigan.gov/documents/tamc/Asset_Management_Program_Invoice-Reporting_Forms_2018_625066_7.pdf

What is the time frame for reimbursement?

Reimbursement will be made after MDOT receives the invoice you submitted through the planning organization. All invoices are due by the end of the 2018 fiscal year (September 30, 2018).

Are there any issues with MDOT's contracts policy for expenses over $25,000?

There should not be any conflict with MDOT's contract policy as long as the invoices contain the required documentation as prescribed by MDOT Contract Services and referenced elsewhere in this FAQ. The TAMC will be amending the Unified Work Program contracts with the appropriate planning organizations for reimbursement purposes. You will be required to provide proper receipts and proof of payment for any direct expenses incurred over $2,500.

***Update June 8, 2018**

TAMC confirmed on June 7, 2018 an agreement between the MPO/RPO and MDOT Contract Services is required when the pass through costs exceed $25k. The TAMC has developed a template for this agreement in order to expedite the processing and reimbursements; this template has been shared with planning organizations that have local agency reimbursement budgets greater than $25,000. For questions about this requirement, please contact Roger Belknap at BelknapR@michigan.gov.

About Collection Teams

Will the individuals who are doing the inspections have to be certified, or can anyone who watches the webinars and participates in the trainings do the inspections? Also, can we train our interns to do the inspections?

> Selecting the data collection crew members is the local road agency's decision. Crew members do not need to be certified, and there is no certification for this pilot project.

PASER reimbursement requires a two (2)-person crew. Does culvert inventory and rating require a two-person crew as well?

> For safety and accuracy of culvert measurements, we recommend a two-person crew for inspecting the culverts. However, this is not mandatory.

Can culvert data collection be outsourced to an outside engineer?

> Yes. You may also be able to reach an agreement with your planning organization.
>
> ***Update June 8, 2018**
>
> Please refer to the note above. If the sub-contracted work done by the consultant will exceed $25,000, an agreement between the MPO/RPO and MDOT Contract Services is required.

What is the role of the planning organization? Will they be distributing the funding and/or hosting data? Will they be providing any other services? And, how is the planning organization to verify the costs reported by the local road agencies?

> The planning organizations are primarily reviewing requests/invoices from the local road agencies and approving requests for reimbursement. Culvert asset management expenditures will be reimbursed through the project authorization with each planning organization following the standard reporting and invoicing procedures. The Center for Shared Solutions (CSS) will provide planning organizations with a summary of centerline miles of roads collected in each local road agency's collection network that can be used for reimbursement.
>
> After the May 14 deadline identifies who is committing to participate in the culvert pilot project, the TAMC will notify the planning organizations and will work on an amended Unified Work Program. **Data from the culvert pilot will be sent directly from the local road agencies to the CSS, so planning organizations will not need to be an intermediary for the culvert data**. Information on what was collected for the per-centerline-mile reimbursement can be shared by the CSS with planning organizations for invoice verification.

About the Required Data Collection Elements

Are the required data collection elements finalized for the pilot project?

Yes. The data collection elements required for this pilot project are:

1) Inventory data for all culverts in the collection area:

    - Material Type
    - Asset Collection Date (applies to condition evaluation)
    - Shape
    - Skew Angle
    - Length
    - Width
    - Height/diameter
    - Depth of Cover
    - Roadway Surface Type
    - Inventory ID (automatic with Roadsoft)
    - GPS Coordinates (automatic with Laptop Data Collector)
    - Photographs are optional

2) Condition data for culverts in the collection area:

    - Condition assessment is required for all culverts in the collection area for local road agencies that have already completed the majority of their inventory.
    - Local road agencies that are collecting for the first time and do not have an existing inventory may forego condition assessment to focus on locating culverts.

3) Network export of the collected area including centerline miles collected. A tool will be available in Roadsoft for this.

4) Daily Data Benchmarking Logs (required for Round 1 local road agencies, optional for Round 2 and 3 local road agencies)

5) Invoicing details for the planning organization, summary of data collection activities (Employee, # of Hours, Dates) for startup funds

Are the data collection elements consistent with the state's infrastructure pilot?

Yes, the elements are consistent, but they are not exactly the same.

About the Data Collection Tools

Does Roadsoft have to be used for data collection, or can we use a GIS system or other systems?

You do not have to use Roadsoft; however, the training associated with the pilot will use Roadsoft. You can use other systems, and the TAMC will review each on a case-by-case basis. If you have used another system, you may be able to migrate your data into Roadsoft depending on what system you used and whether it has the same fields. The CTT is available to help with that process. Regardless of what system you use, you will need to verify that it is compatible with the requirements of the statewide central database as established by the Center for Shared Solutions in order to submit your data and get reimbursed.

TAMC Coordinator Roger Belknap indicated that a ruggedized tablet was considered as a recommended purchase for collecting data. Can you provide more information about that?

The CTT has been testing the MobileDemand xTablet T1600 Ruggedized tablet (www.ruggedtabletpc.com). It runs the Roadsoft Laptop Data Collector program well and has a number of features well suited for this project. Contact Amy Garman, MobileDemand North Region Inside Sales, at 1-319-739-3219 or agarman@mobiledemand.com. Mention that this will be for the Michigan TAMC Culvert Pilot Project and Amy will offer a discount. The TAMC is not advertising or promoting this particular tablet; it is listed here for informational/reference purposes only.

About the Data Collection

Do you know how long it will take to collect this data?

Current estimates from engineers who have collected similar data in the field indicate that it may take 20 minutes to collect required data and move to the next culvert site in a system where all the culverts have been previously located. A major role of the pilot is to collect benchmarking data on collection time.

What is considered a “culvert” for this collection?

Culverts for the purposes of this pilot are defined as linear drainage conduits underneath a public roadway that are not considered “bridges” by the Federal Highway Administration (FHWA). In general, the FHWA considers a “bridge” as having a combined span of more than twenty feet, which would include listing on the National Bridge Inventory. 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). Only culverts found within Public Act 51 Certified Roads are eligible for collection as part of this data collection effort; culverts found beneath private driveways or commercial drives are not eligible for inclusion or reimbursement. All culverts that are 12 inches in diameter or larger should be included in your collection; local road agencies can collect smaller culverts at their own discretion.

What is considered an open-end tube? For example, are equalizer culverts or fully-submerged culverts considered open-end tubes?

A culvert is considered an open tube if there is no manhole or other buried inlet structure on any part of it. Submerged culverts would be appropriate for this project.

How should we deal with a location that has multiple culvert barrels that are working together in one place? Would we consider it one culvert with multiple barrels or multiple culverts?

You can use the following as guidance. Local road agencies that have already collected data using a different set of collection rules should feel free to maintain consistency with those rules. For local road agencies that have not developed collection rules relating to multiple barrels, the following guidance should be helpful.

1) If the culvert shares common structural components (e.g., foundation walls, end wall structures) that do not allow replacement of one barrel without disturbing

the others or replacing common entrance units, it should be considered one culvert with multiple barrels (see examples below).

2) If a single barrel can be replaced without having to replace the other units or

replace associated structures, it should be logged as multiple culverts (see below).

The intent of this rule is to differentiate between two installation and replacement situations in the database: If a user sees **one culvert location with multiple barrels** in the database, this would denote that the unit needs to be replaced and/or maintained together as a unit and that options do not exist to replace only one barrel without significant work and expense. If a user sees **multiple culverts** in the database, this would denote that one or more of the units could be replaced while leaving the others in service.

Is there a rating system similar to the PASER system that will be used for this culvert data collection pilot project?

Yes, this project will rely on a modification the Federal Highway Administration system. Rating guide sheets are included on the TAMC website (www.michigan.gov/tamc).

What culvert rating guidance will be applicable for this pilot?

We will be providing you with the necessary culvert rating guidance for your data collection effort at the trainings during the week of April 30.

There are many more data elements in the Roadsoft LDC's Culvert module that we do not need to provide. Can we customize this module's view for the pilot project?

At the trainings during the week of April 30, you will learn how to hide elements in the Roadsoft LDC's Culvert module that are not needed.

The roadway surface type is already in the Roadsoft Road module. Do we need to collect this data again?

No.

Do we have to do surveying or provide elevation?

No, surveying and elevation are not required.

What if we have all the data in Roadsoft but are missing one or two pieces of information, would the data be valid?

Inventory data that was collected previously can be submitted if it is still representative of the culvert. Rating data should have been collected in the last five years. Missing *mandatory* data elements would require a subsequent field visit to collect.

General Questions

Was this part of Public Act 82 of 2018?

Yes.

Is there additional funding anticipated for the fiscal year 2018-2019 state budget for additional culvert collection?

At this time, it is unknown whether additional funding will be available. A key part of this culvert data collection pilot project is to determine what might be needed to fund a statewide data collection effort.

Are we on our own for collecting data, or is the TAMC or MDOT planning to help with the data collection?

Local road agencies must do this data collection on their own. The TAMC and MDOT will not be providing data collection assistance; however, the TAMC will provide guidance and training.

The 21st Century data is sensitive and cannot be shared. But, the data collected in this pilot seems similar to our PASER data, which is made publicly available. Will the data collected during the pilot project be public and made available to regions for the public?

Once the report is released, the data will be made available.

Why are the deadlines so strict? Is there any way to get an extension?

The deadlines were set due to the time frame that was set for the TAMC by the Legislature. The $2 million is only for the 2018 fiscal year, which ends on September 30, 2018, and the funds do not carry over into the next fiscal year. We realize this will be a challenge for everyone. Please remember that this is a pilot project.

Where can I find the training webinar recordings?

The webinar recordings can be found at http://ctt.mtu.edu/tamc-culvert-pilot

How do I set up my tablet so that Roadsoft LDC works with the internal GPS?

Instructions to configure the tablet internal GPS and connect it to Roadsoft LDC can be found at http://ctt.mtu.edu/tamc-culvert-pilot

Since the data must be collected in July, do we need to have everything done within this fiscal year?

The answer is yes. Data Collection and work performed after July 31 will not be reimbursed. Therefore, it is recommended that invoices for the Culvert Mapping Pilot

project be submitted before September 30. MPO/RPOs are able to submit separate invoices specifically for the Culvert Mapping Pilot to ensure all reimbursements are made in timely fashion and before the funds expire. Again, please use the revised invoice forms that are attached that accounts for the Culvert Mapping Pilot separately from PASER and other asset management work items.

How long will it be before we can get reimbursed?

This question is relative to the amount of information the local agency provides to the MPO/RPO. If the local agency provides the required reporting documents, such as copies of receipts for purchases and labor expense reports, and data collection logs, then the MPO/RPO will have the necessary documentation to submit an invoice to TAMC on behalf of the local agency. The TAMC will then pay the invoice to the respective MPO/RPO, and then the local agency is reimbursed by the MPO/RPO. Is important to use the revised invoice forms as this will ensure the invoice gets processed timely. If local agencies don't provide the required documentation, or the invoices do not contain the necessary back up that explains the costs incurred, then the timeframe for reimbursements is delayed until documentation is verified by TAMC.

Will the amount of money that each of the agencies receive going to show as revenue for the MPO's? Is there a way to only show the administrative fees for auditing purposes?

It was mentioned that MAR dues are based on revenues of planning regions; it is advisable to contact MAR and your agency's auditor to make sure these funds are identified as Pilot Project reimbursement funds, and not part of the agency's typical income.

APPENDIX I: DATA COLLECTION USING ROADSOFT WEBINAR SLIDES

Equipment Needed

- Tablet or Laptop
- GPS (if not built in)
- Flash Drive
- Power cord
- Vehicle
- Safety Equipment
- Measurement instruments (Laser level, tape measure, flashlight, magnet….)

Laptop Recommendations

- Windows laptop
- Same requirements as for PASER data collection
- GPS that outputs NMEA-0183
  - GlobalSat BU-353-**S4**
  - PL2303 device driver

Tablet Recommendations

- MobileDemand xTablet T1600
  - Ruggedized tablet
    - Windows 10 Pro
    - Intel i5 processor
    - 4' Drop MIL-STD-810G, IP65 Sealed
    - Built-in GPS
    - Built-in Camera
    - Sunlight Viewable, Shatterproof Screen
    - Attached Stylus, Handle, Flexible Rear Strap
    - Docking Station Available
    - Can use on-screen keyboard, or Bluetooth keyboard
  - www.ruggedtabletpc.com
  - Contact Amy Garman, MobileDemand North Region Inside Sales, 1-319-739-3219, AGarman@mobiledemand.com
  - *Mention that this will be for the Michigan TAMC Culvert Pilot and Amy will offer a discount*

MobileDemand T1600

GPS Recommendations

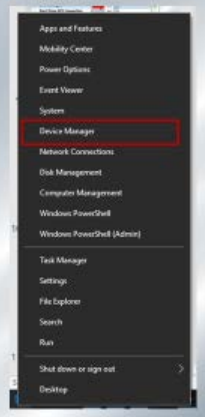
- Must output: NMEA-0183 communication language
- Low cost units or built-in work the best
  - ✓ GlobalSat BU-353-**S4** USB corded ($26)
  - ✓ GlobalSat ND-105C micro-USB ($29)
  - ✓ GlobalSat BT-821C Bluetooth ($45)

Bluetooth or USB "Button GPS"
Can't be used w/o computer
No aux power

Built-in GPS
Must be set to output NMEA-0183

Connect GPS

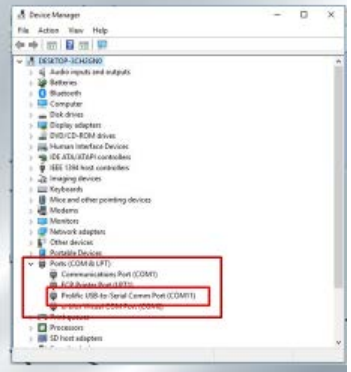
- Make sure device driver is installed prior to connecting the GPS to computer
- Right-click on the Windows menu
- Select Device Manager from the pop-up menu



Connect GPS

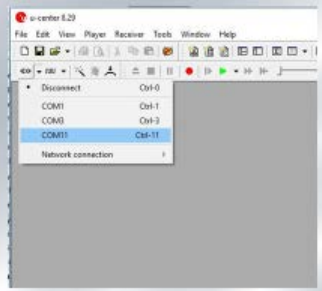
- Click on Ports (COM & LPT) to expand, find the COM port assigned to GPS

  (in this case, GPS is assigned COM11)



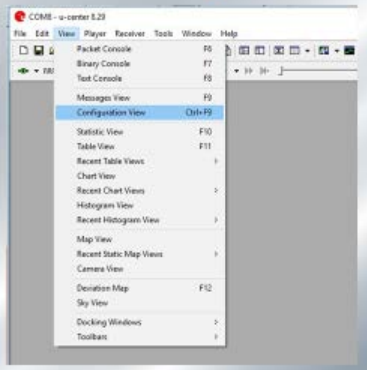
MobileDemand T1600 Internal GPS Setup

- Open the pre-installed u-center utility
- Connect the utility to the GPS



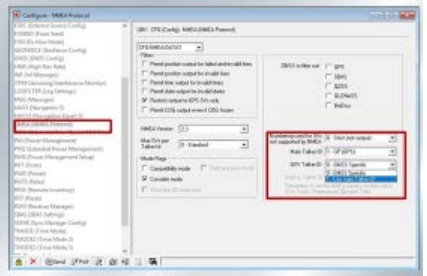
MobileDemand T1600 Internal GPS Setup

- Select "Configuration View" from the "View" pull-down menu



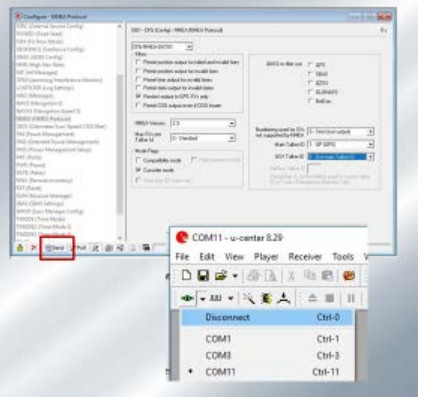
MobileDemand T1600 Internal GPS Setup

- Scroll on the left menu, select NMEA from the list of options
- Select I – GP(GPS) for the Main Talker ID
- Select I – Use Main Talker ID for the GSV Talker ID

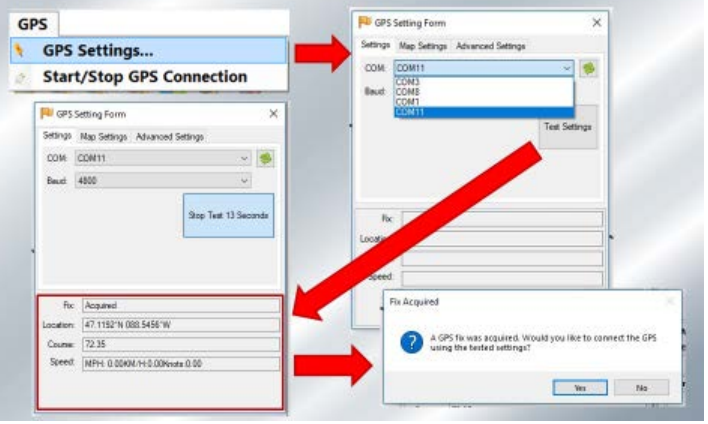


MobileDemand T1600 Internal GPS Setup

- Click the "Send" tab in the bottom left of the window to send the settings to the GPS
- When finished, disconnect the utility from the GPS

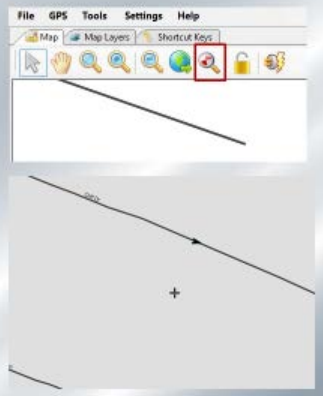


Connect GPS to Roadsoft



GPS point & snap point

- Once connected, click the "Zoom to GPS" icon to zoom in to your location.



SOFTWARE REQUIREMENTS

Required Software Versions

- Roadsoft
  - version 2018.4
    - SQL Server versions supported 2008, 2008R2, 2012, 2014, 2016
- Laptop Data Collector (LDC)
  - version 2018.4
- GPS device driver (if using external GPS)

Communicate before updating Roadsoft or the LDC!

- Make sure everyone involved is ready for updating:
  - Both Roadsoft and the LDC must be updated
  - Import outstanding LDC files back into Roadsoft before update

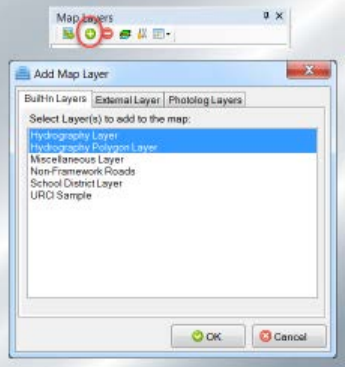
*Annual TAMC data collection (PASER & IBR) may be in progress. Make sure to coordinate with your region and within your own agency before updating.

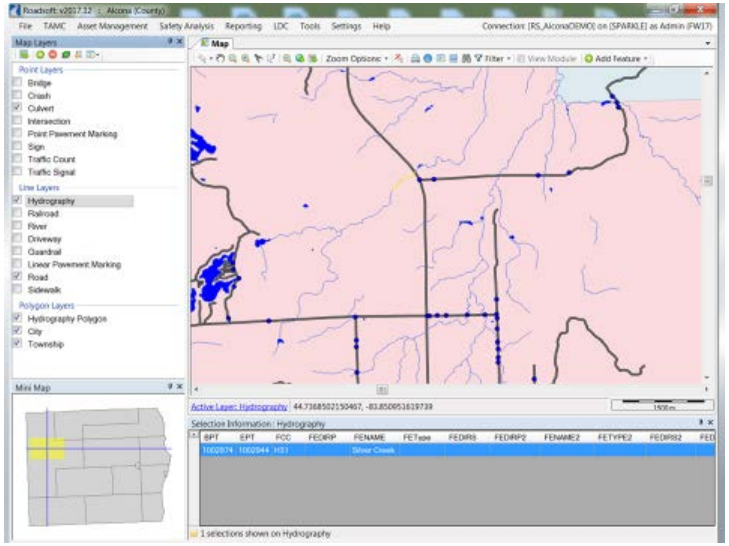
PREPPING TO COLLECT DATA

Roadsoft: Hydrography Layers

Use Map Layers Add Button to add Built-In Layers:

- River
- Hydrography
- Hydrography Polygon



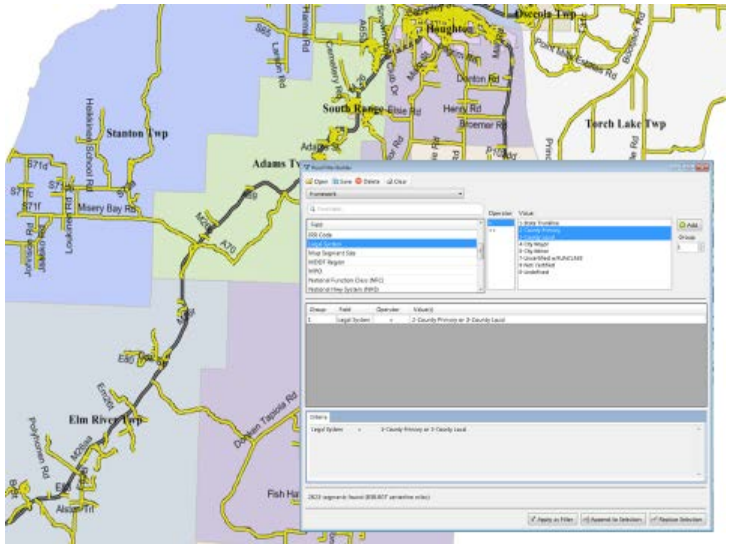


Layers can also be added in the LDC

- Locate the Hydro Layer Shapefiles:
  - FW_RiverV17.shp
  - FW_HydroV17.shp
  - FW_HydrographyV17.shp

Default location:
Documents/MTU-CTT/Roadsoft/FWData/Basemap.zip

- Copy them to the LDC machine



Where to collect Culvert Data?

- Culverts on which Roads?
  - On all but State Trunkline roads

*You need a method for tracking where you have collected

Culvert Definition

- Two open ends
- Less than 20 ft span
- 12" or bigger
- Not driveway culvert

Data Fields to be collected

- Inventory ID
- GPS Coordinates
- Material Type
- Asset Collection Date (Rating Date)
- Shape
- Skew Angle
- Photographs (optional)
- Length (and unit)
- Width (and unit)
- Height/Diameter (and unit)
- Depth of Cover (and unit)
- Roadway Surface Type
- Culvert Rating

Material Types

- Plastic
- Steel
- Timber
- Aluminum
- Concrete

*Other Roadsoft types will also be accepted

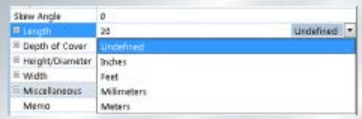
Culvert Shapes

- Box
- Multi-Cell Box
- 3-Sided
- Slab/Superstructure & Abutment
- Circular
- Elliptical
- Arch

*Other Roadsoft types will also be accepted

Units of Measurement

- Be sure to choose units associated with measured fields
  - Length
  - Width
  - Height/Diameter
  - Depth of Cover

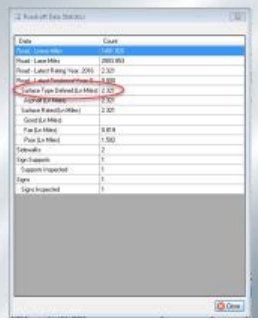


- Less than 6 feet? Use inches…

Roadway Surface Type

- If your agency has done PASER ratings on all of your roads, you will not need to collect surface type

Roadsoft Data Statistics
(Asset Management Menu)



LAPTOP DATA COLLECTOR (LDC)

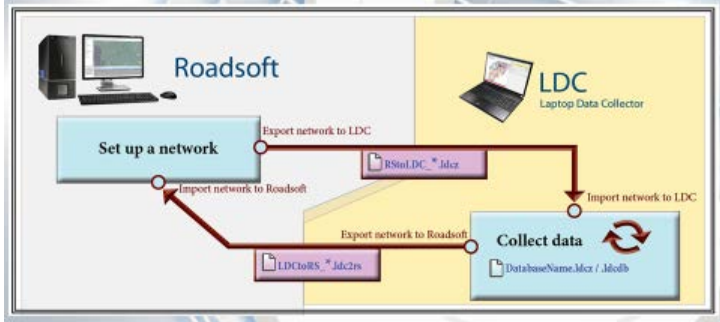
Laptop Data Collection (LDC)

- Windows machine (Tablet or Laptop)
- Light-weight companion for Roadsoft
- Designed to integrate with a GPS
- Designed with data collection in mind

Equipment Needed

The Data Collection Cycle

Always complete the entire data cycle BEFORE beginning the next cycle and BEFORE updating Roadsoft or the LDC.

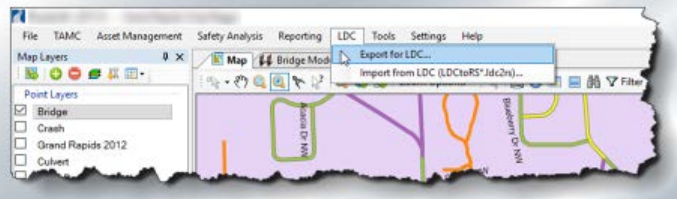


* Always perform a database backup before importing data *

Required: A method for tracking collection area by day

- Daily tracking of road segments examined for Culvert collection will ensure full coverage by your agency and will provide a state-wide evaluation of roads collected

1) Roadsoft LDC menu: Export for LDC



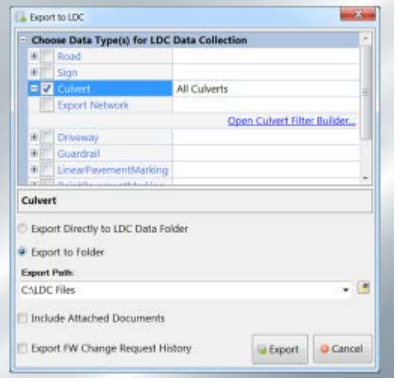
*This will create a file named: RStoLDC_[Jurisdiction]_[DateTime].ldcz

TAMC Collection?

- Are you collecting ROAD data for the Asset Management Council?
- No! – this is not ROAD data collection

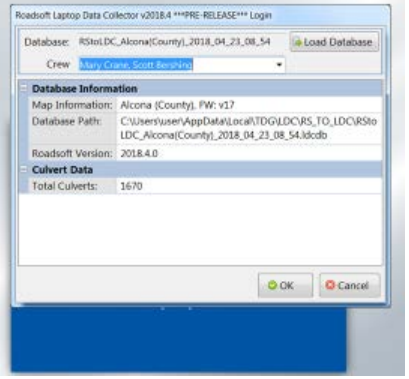
Create Export file/database for the LDC

- Culvert: Check the Culvert checkbox (for All Culverts)
- Export Path: Browse for folder to save file

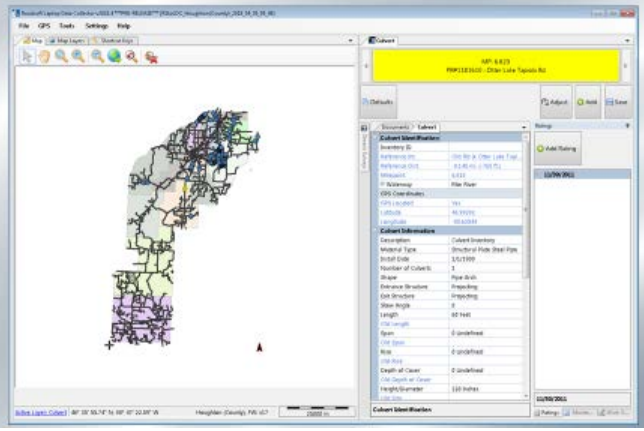


2) LDC: Login form - Load Database

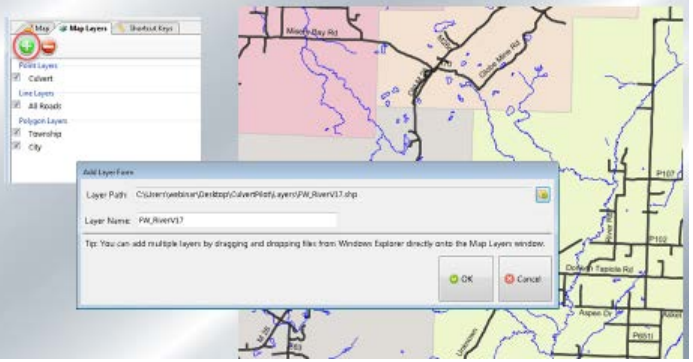
- Database: Browse for file created from Roadsoft
- Crew: can be entered new or selected from the drop-down of previously entered crews (use full names)



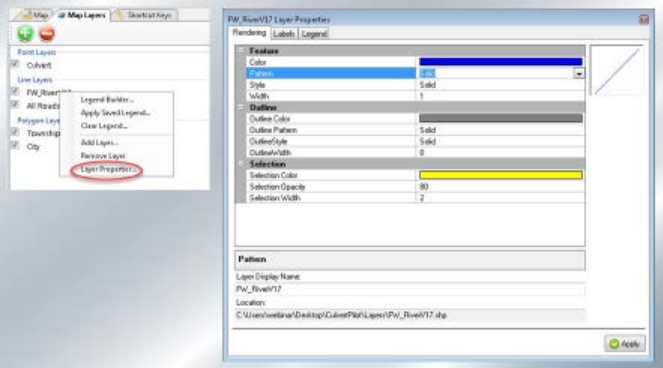
LDC: Map



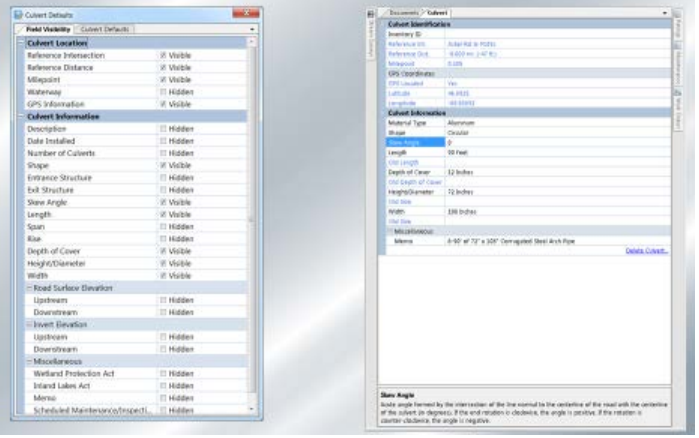
LDC: Add Hydrography Layers



LDC: Layer Properties

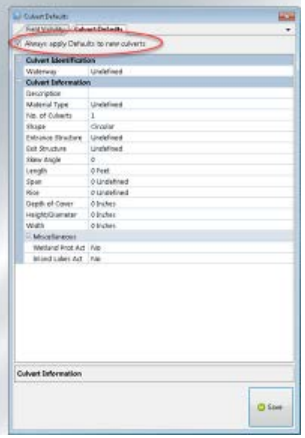


LDC: Field Visibility



LDC: Defaults

- Use **Defaults** checkbox
  - Uses set values when culvert is added
- **Apply** button
  - Will set values when you choose

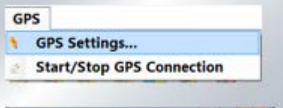


LDC: Shortcut Keys

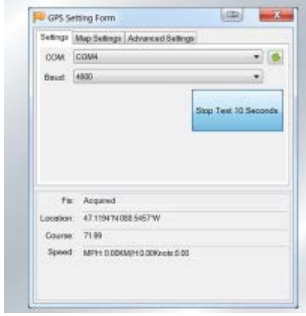
Map | Map Layers | **Shortcut Keys**

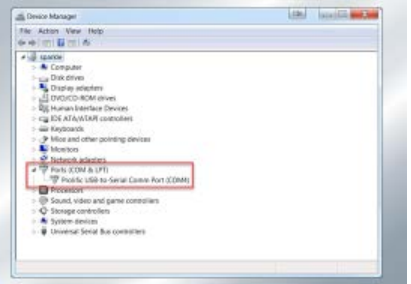
Map/GPS Shortcut Keys	
Ctrl G	GPS On/Off
Ctrl Z	Zoom to Selection
Ctrl Shift Z	Zoom to GPS
Ctrl +/-	Zoom In/Out
Ctrl Arrow	Pan
Culvert Shortcut Keys	
Ctrl Enter	Save Culvert Data
Ctrl A	Add New Culvert

LDC: Connecting the GPS

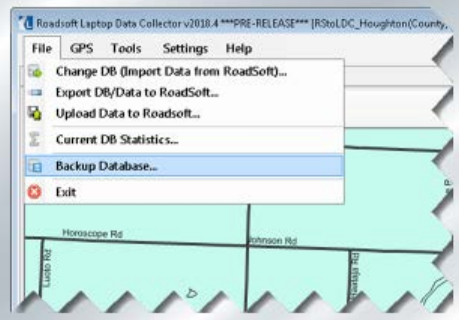


Windows Device Manager:





LDC: Backup

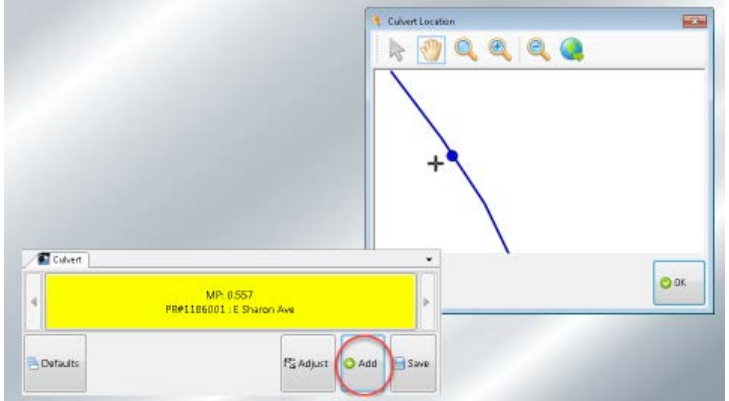


*This will create a file named: LDC_BKUP_[DateTime].ldcz

3) LDC: Collect Culvert Data

- Drive to Culvert location
- Stand on edge of road where the culvert crosses or stop vehicle at location
- Add Culvert (Add Button or Ctrl-A) and confirm

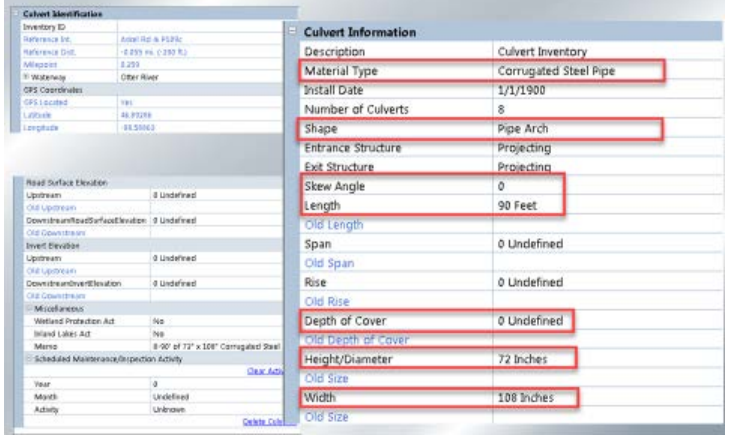
Add Culvert



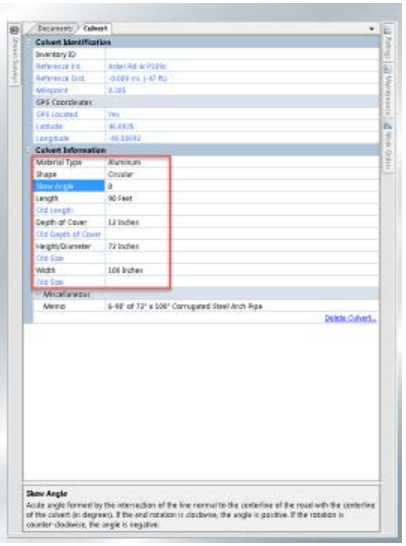
Data Fields to be collected

- Inventory ID
- GPS Coordinates
- Material Type
- Asset Collection Date (Rating Date)
- Shape
- Skew Angle
- Photographs (optional)
- Length (and unit)
- Width (and unit)
- Height/Diameter (and unit)
- Depth of Cover (and unit)
- Roadway Surface Type
- Culvert Rating

Culvert Tab

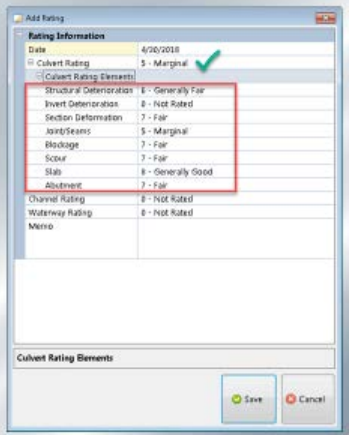


Culvert Tab with Field Visibility



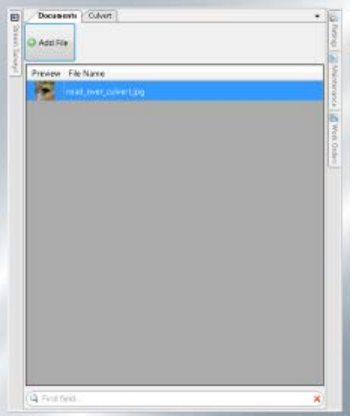
Ratings

- **Date:** defaults to current date
- **Culvert Rating:** will be determined based on the Rating Elements (can be overridden)
- **Culvert Rating Elements:** enter ratings for:
  - Structural Deterioration
  - Invert Deterioration
  - Section Deformation
  - Joint/Seams
  - Blockage
  - Scour
  - Slab
  - Abutment



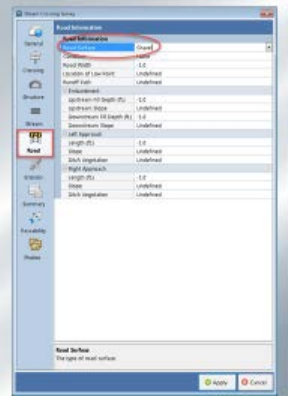
Attached Documents

- Documents tab
- Resize images if possible



Stream Crossing: Road Information - Surface Type

- You do not need to complete a full Stream Crossing Survey
- Add a survey and complete the Road Surface in the Road section (Apply to Save)



Where to Enter Collection Fields

Generated for you:
- Inventory ID
- GPS Coordinates

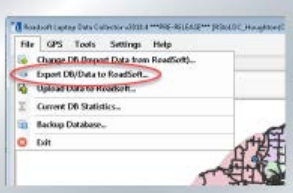
Culvert Tab:
- Material Type
- Shape
- Skew Angle
- Length
- Width
- Height/Diameter
- Depth of Cover

Ratings Tab:
- Asset Collection Date (Rating Date)
- Culvert Rating

Stream Surveys Tab: Road:
- Roadway Surface Type (or Road Module if collected)

Documents:
- Photographs (optional)

4) LDC: Create Export for Roadsoft

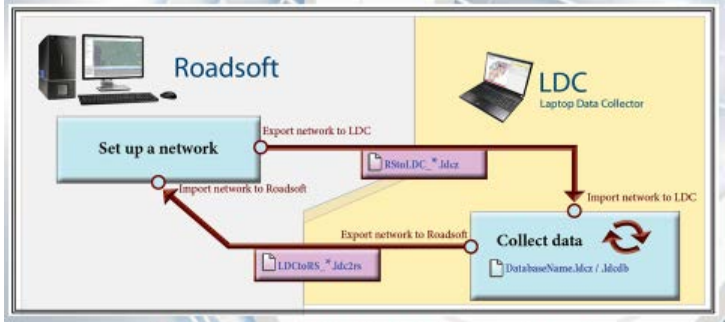


*This will create a file named: LDCtoRS_[Jurisdiction]_[DateTime].ldc2rs

5) Roadsoft LDC menu: Import from LDC

The Data Collection Cycle

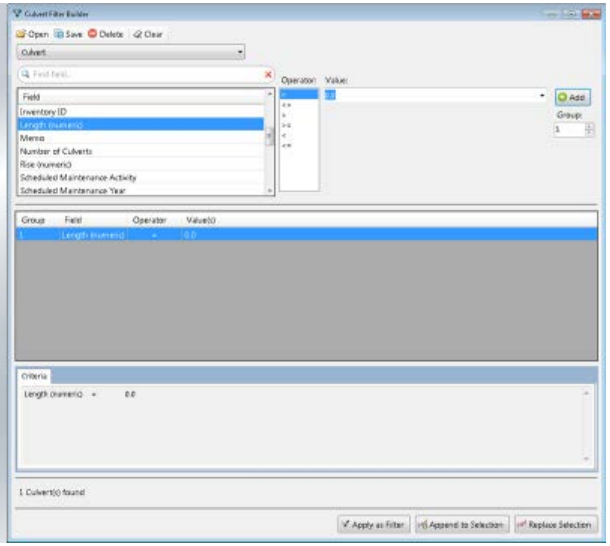
Always complete the entire data cycle BEFORE beginning the next cycle and BEFORE updating Roadsoft or the LDC.

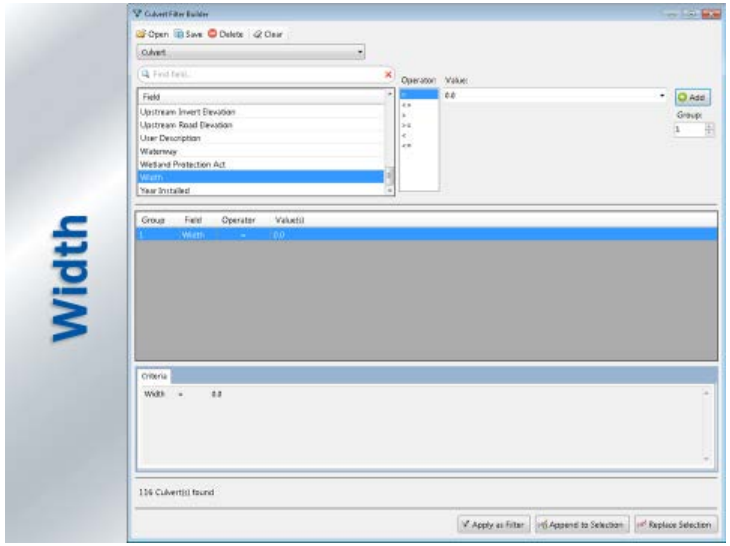


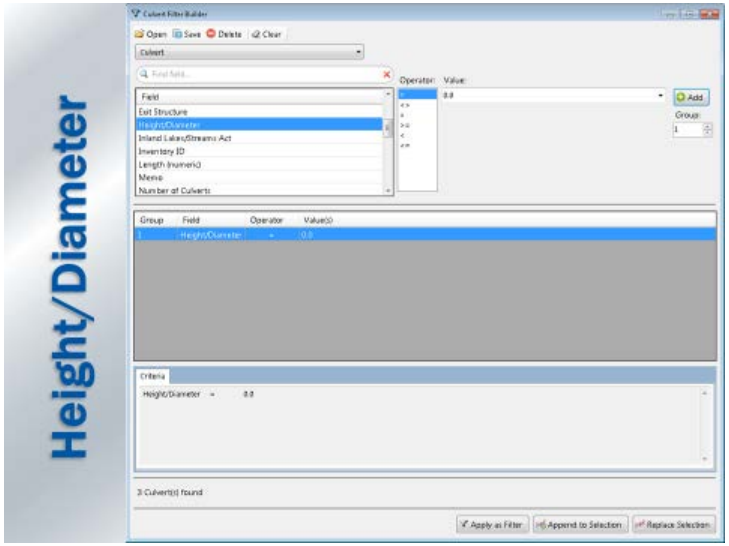
* Always perform a database backup before importing data *

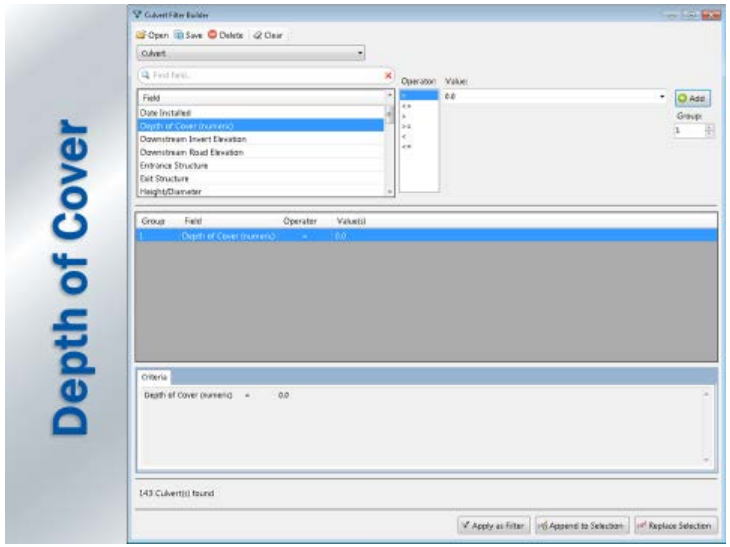
DATA VALIDATION SUGGESTIONS

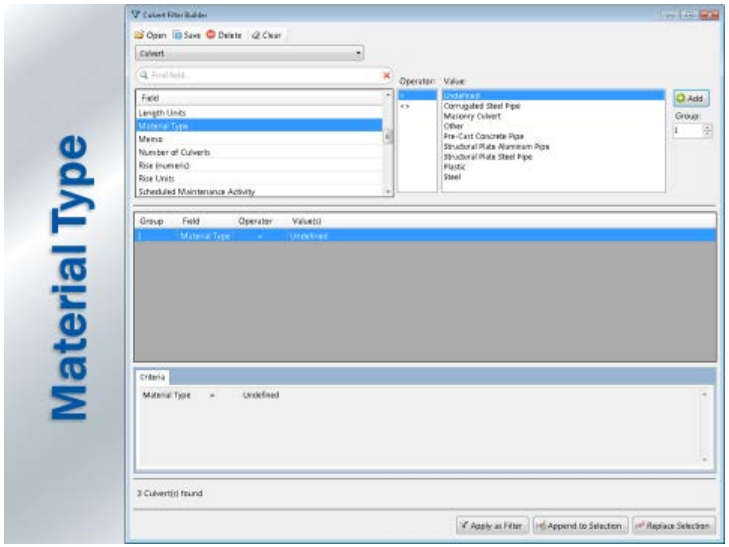
Length

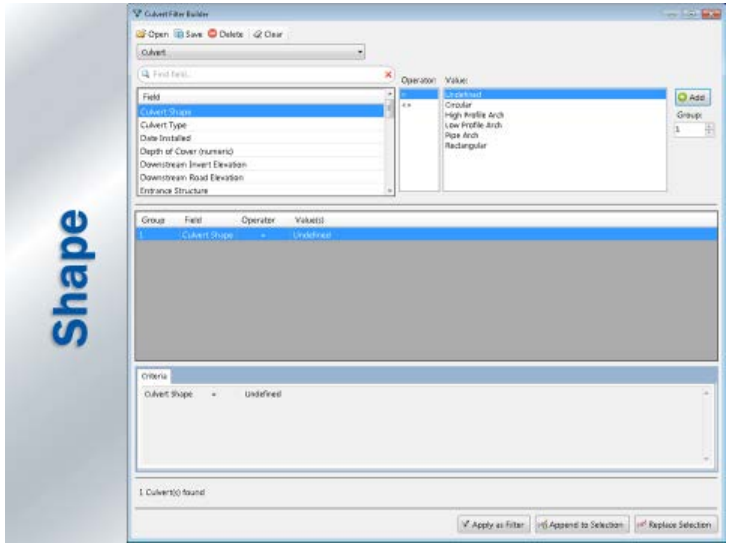


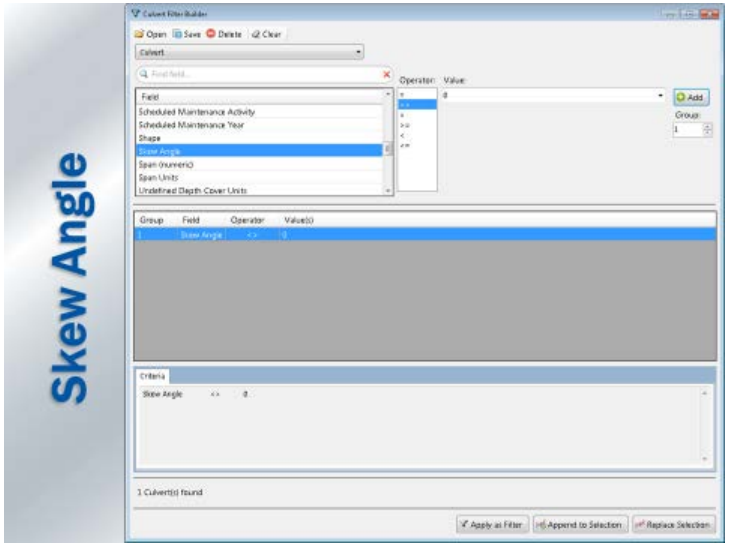

Width

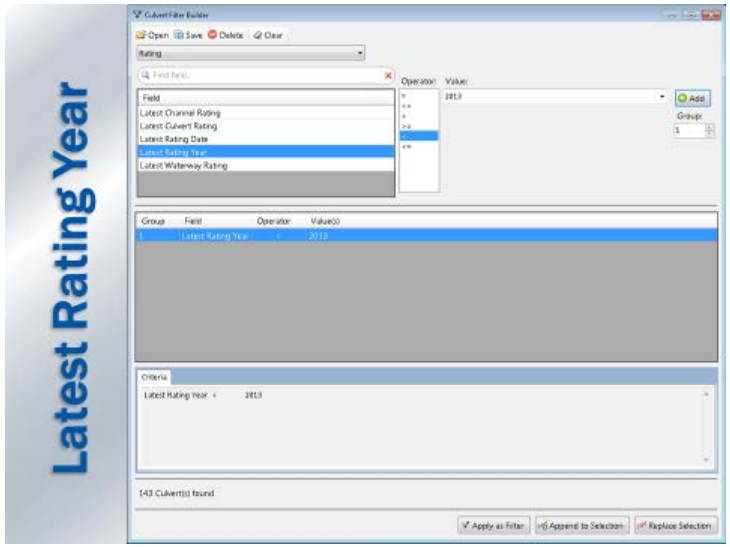

Height/Diameter

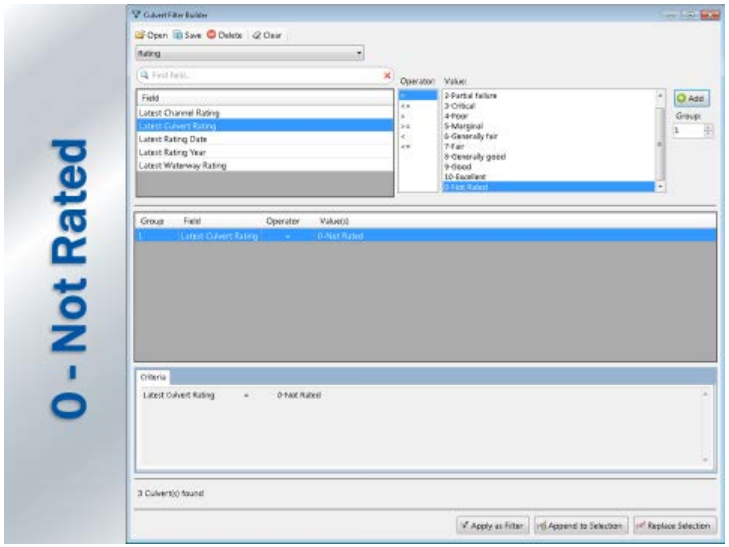

Depth of Cover

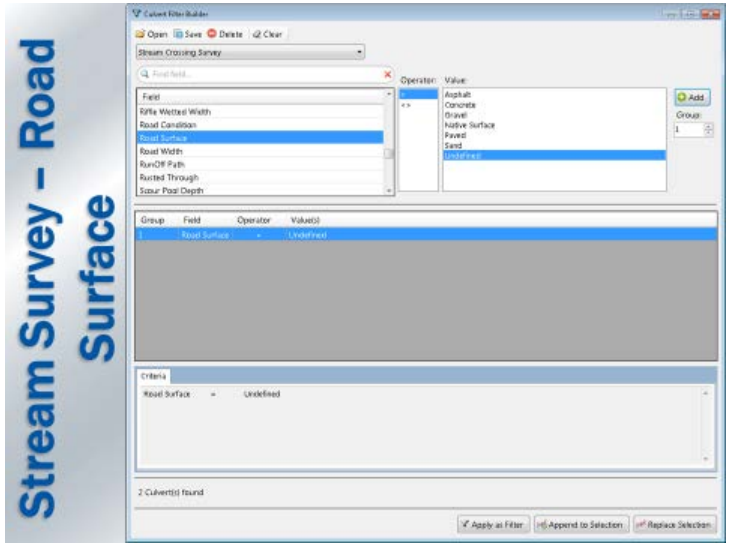

Material Type

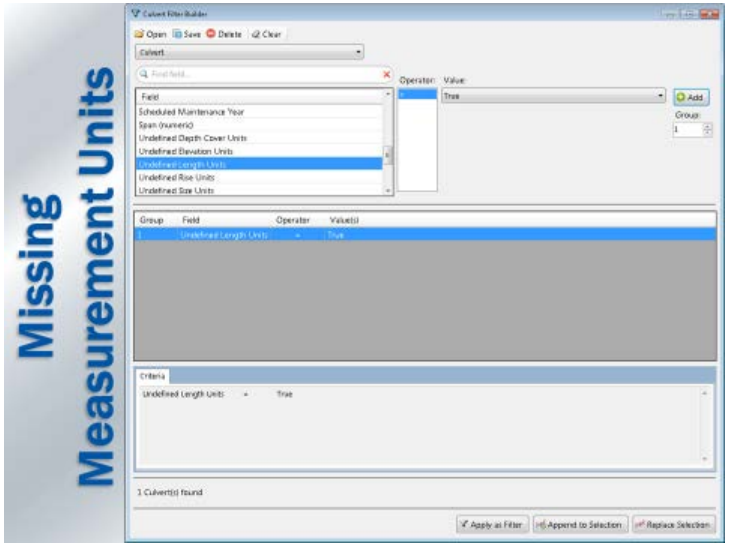

Shape

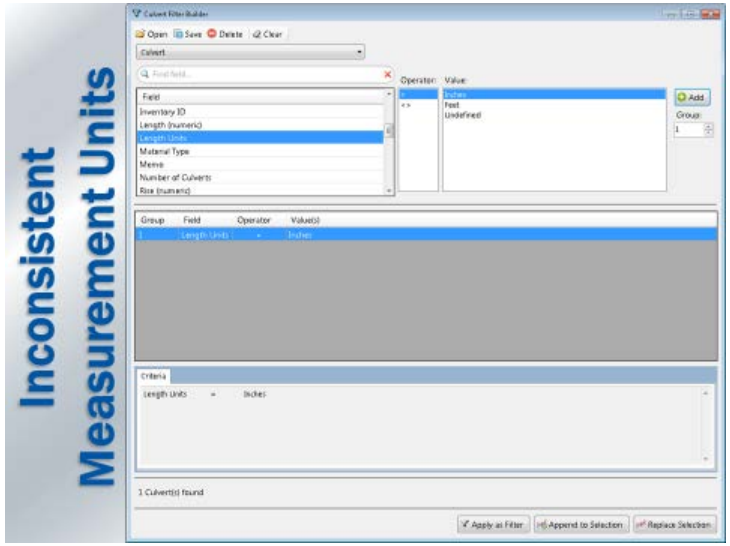

Skew Angle


Latest Rating Year


0 - Not Rated


Stream Survey – Road Surface


Missing Measurement Units


Inconsistent Measurement Units

METHOD FOR REPORTING
COLLECTION AREA

Reporting Collected Mileage

- Must be reportable by collection day
- Must be in electronic geo-located format

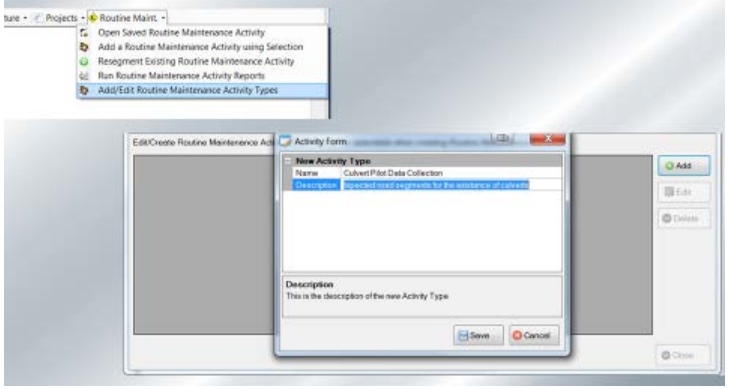
Brainstorming Options

- Track area on paper when collecting and then:
  - Create a Routine Maintenance project
  - Create a Filter from a map select
  - Use other GIS program to create map
- Define a User-Defined field in the Road Module and collect that field while out in the LDC

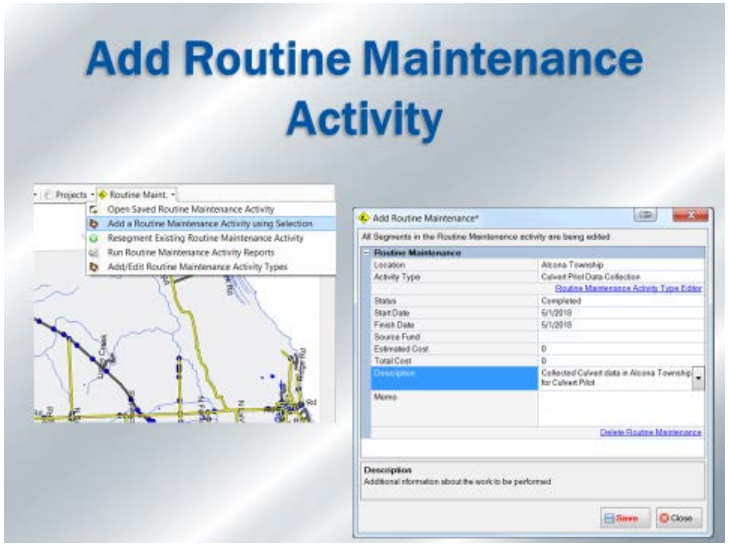
Routine Maintenance Option

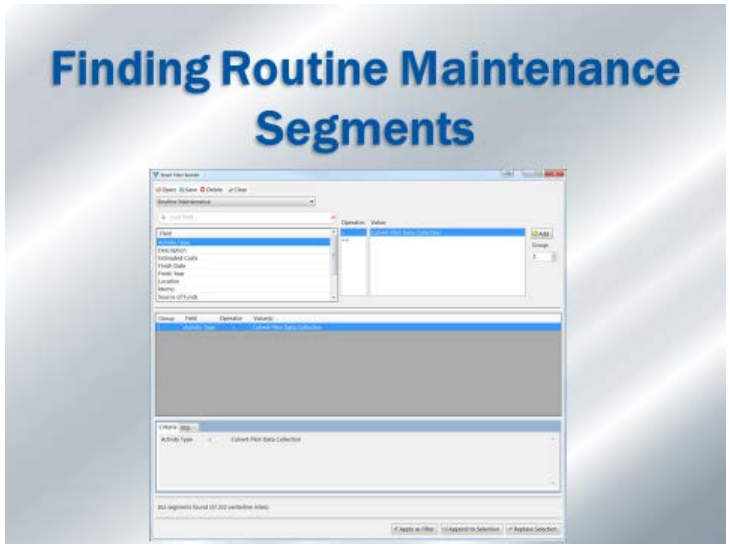
- While collecting Culvert data, highlight printed map to mark area
- Then use printed map as a guide to select road segments in Roadsoft
- Create a Routine Maintenance project for the selected segments

Add Routine Maintenance Type



Select Inspected Roads on the map
Alcona Township


Add Routine Maintenance Activity
Projects
Routine Maint.
Open Saved Routine Maintenance Activity
Add a Routine Maintenance Activity using Selection
Resegment Existing Routine Maintenance Activity
Run Routine Maintenance Activity Reports
Add/Edit Routine Maintenance Activity Types
Add Routine Maintenance*
All Segments in the Routine Maintenance activity are being edited
Routine Maintenance
Location
Alcona Township
Activity Type
Culvert Pilot Data Collection
Routine Maintenance Activity Type Editor
Status
Completed
Start Date
5/1/2010
Finish Date
5/1/2010
Source Fund
Estimated Cost
0
Total Cost
0
Description
Collected Culvert data in Alcona Township for Culvert Pilot
Memo
Delete Routine Maintenance
Description
Additional information about the work to be performed
Save
Close


Finding Routine Maintenance Segments

SHARING DATA

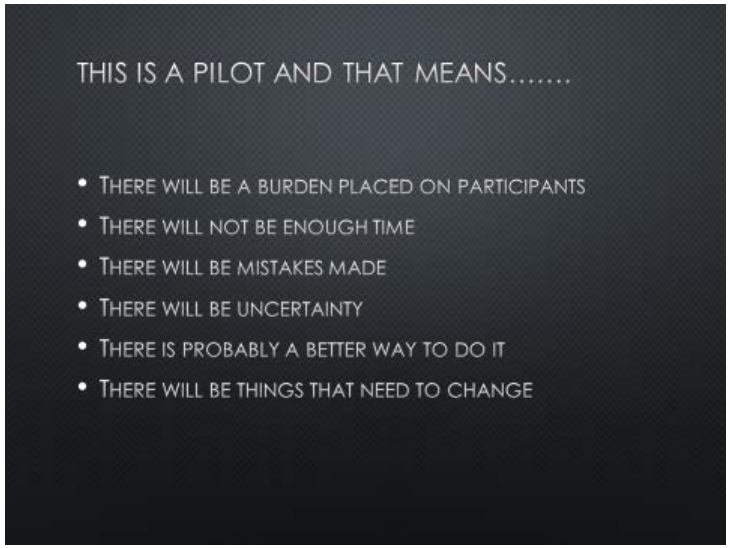
COMING SOON

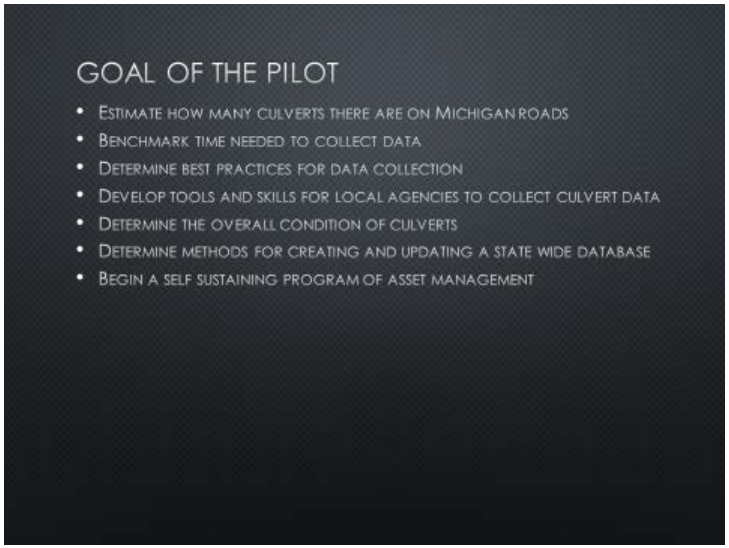
- Data sharing is not currently available in Roadsoft
- However, a future release will provide a method of creating two files for sharing:
  - An XML file of Culvert data
  - A file of your examined set of Roads if tracked
- Additional information will be provided

Upcoming Trainings

- Culvert Data Collection using Roadsoft
  - Wednesday, April 25
    - 10:00-12:00 EDT
  - Tuesday, May 1
    - 1:00-3:00 EDT
- Culvert Ratings & Measurements
  - Thursday, April 26
    - 10:00-12:00 EDT
  - -Wednesday, May 2
    - 1:00-3:00 EDT

APPENDIX J: CONDITION EVALUATION WEBINAR SLIDES





PILOT BACKGROUND

- Received supplement funding from legislature in budget allocation in January 2018
- Funding needed to be spent by end of FY18 (September 30, 2018)
- Intended to fit in with Governor's utility initiative and respective pilots
- Local analog to MDOT culvert collection

CULVERT - DEFINED

Culverts for the purposes of this pilot are defined as linear drainage conduits underneath a public roadway that are not considered "bridges" by the Federal Highway Administration (FHWA).

In general, the FHWA considers a "bridge" as having a combined span of more than twenty feet, which would include listing on the National Bridge Inventory.

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 (manholes, catch basins etc.).

Only culverts found within Public Act 51 Certified Roads are eligible for collection as part of this data collection effort; culverts found beneath private driveways or commercial drives are not eligible for inclusion or reimbursement.

WHO WAS SELECTED FOR THE PILOT?

- All agencies that responded to the survey are eligible to participate in the pilot project
- Agencies were organized into "rounds" based on their survey Reponses (Tier) and geographical proximity to other responding agencies
  - Round 1 – all tier 3 agencies, and all other agencies that fell within the overall RPO boundary of response "hotspots"
  - Round 2 – all other agencies that responded to the survey
  - Round 3 – Volunteers that have stepped up after the fact and wish to participate with no funding

ROUND 1 COLLECTION FUNDING

Counties
- $10,000 in reimbursable start up/mobilization
- $30* per centerline mile of road where all culverts are collected

Cities
- $5,000 in reimbursable start up/mobilization
- $30* per centerline mile of road where all culverts are collected

* Agencies will be reimbursed for centerline miles checked, regardless of presence of culverts

ROUND 2 COLLECTION FUNDING

Counties
- $10,000 in reimbursable start up/mobilization
- $XX* per centerline mile of road where all culverts are collected

Cities
- $5,000 in reimbursable start up/mobilization
- $XX* per centerline mile of road where all culverts are collected

* per-mile funding will be dependent on overall agency participation and the amount of data that is collected, not to exceed round 1 levels

ROUND 3 VOLUNTEER COLLECTION

- Agencies that wish to participate in the training and data collection process with no funding
- Good opportunity to get a head start on a potential future statewide culvert data collection effort

START-UP FUNDS – APPROPRIATE USE

Acceptable
- Training time and expenses
- Staff time before or during collection related to the pilot
- Equipment purchase for collection effort
  - Laptop
  - Tablet
  - GPS unit
  - Laser level
  - Laser tape
  - Camera
  - PFD or other safety gear
  - Waders / hip boots
  - Other justifiable equipment or accessories required

Not Acceptable
- Non-project associate equipment
- Vehicle purchase

Direct questions about eligible expenses to Roger Belknap, TAMC Coordinator

Funding will be processed through your RPO or MPO

BASIS OF PAYMENT FOR SUBMITTED DATA

- Per Mile payment for collecting all culverts on the system you own
- Payment for road mileage without culverts that were field checked
- Capped at Act 51 certified mileage level
- Data must be turned in to TAMC by July 30, 2018

TAMC 2018 CULVERT DATA COLLECTION PILOT PROJECT - KEY DATES

- Culvert pilot survey of local agencies: March 6-14, 2018
- Notification Letters sent to all agencies: April 13, 2018
- Training & Meetings
  - Kick-off informational webinar: April 19, 2018
  - Inventory collection webinar: April 25, 10:00 am
  - Condition evaluation webinar: April 26, 10:00 am
  - Repeat - Inventory collection webinar : May 1, 1:00 pm
  - Repeat - Condition evaluation webinar: may 2, 1:00 pm
- Agency commitment to the project by may 14, 2018
- CTT technical assistance provided for participating agencies
- Agency data submittal deadline: **July 30, 2018**
- End of work on project, submittal of final report: **September 30, 2018**

PROJECT DELIVERABLES

Must submit:

1. Inventory data for all culverts in the collection area
2. Condition assessment for all culverts in the collection area (Agencies who are just starting collection for the first time, and do not have an existing inventory may forego condition assessment to focus on locating culverts)
3. Network export of the collected area including centerline miles collected
4. Daily Data Benchmarking Logs (round 1 required, round 2 & 3 optional)
5. Invoicing details for RPO/MPO, Summary of data collection activities (Employee, # of Hours, Dates);

BENCHMARKING DATA LOGS

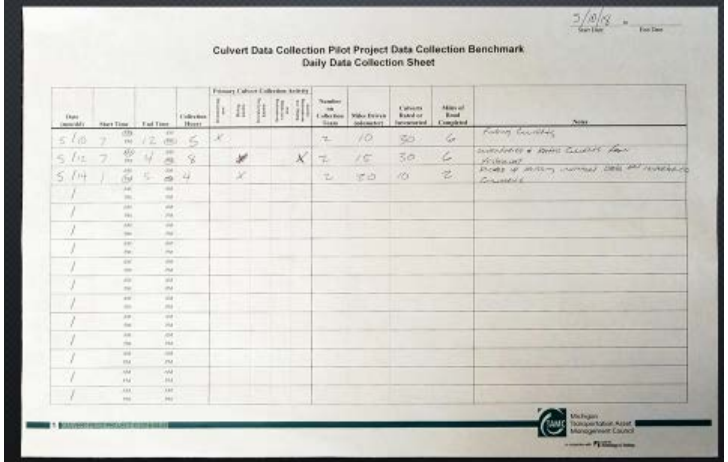
Goal

- Develop cost/time per mile to collect inventory
- Develop cost/time per mile to collect condition assessments
- Differentiate between starting new and filling in gaps

Daily Data Sheet

- Field time dedicated to collecting data
- Number of miles of road covered (collected all culvert data)
- Number of culverts inventoried or condition assessed
- Number of miles driven over the collection period (odometer)
- Number of people on collection team

DATA COLLECTION BENCHMARKING



Culvert Data Collection Pilot Project Data Collection Benchmark
Daily Data Collection Sheet

SAFETY

FOLLOW YOUR AGENCY'S SAFETY PROTOCOL/RULES

ADVICE:

- LIGHT BAR
- CLASS 2 HIGH VISIBILITY VESTS
- FLOTATION / RESCUE DEVICE
- TEAM COLLECTION

HAZARDS:

- TRAFFIC
- HIGH STREAM FLOW
- CONFINED SPACES
- ROADSIDE METHAMPHETAMINE WASTE

HTTPS://VIMEO.COM/240236689?REF=FM-V-SHARE

HTTP://WWW.MICHIGAN.GOV/MDOT/0,4616,7-151-9621_11041_14408-29269--,00.HTML

TECHNICAL SUPPORT / CONTACTS

CENTER FOR TECHNOLOGY & TRAINING AT MICHIGAN TECH UNIVERSITY

- CHRIS GILBERTSON CGGILBER@MTU.EDU – OVERALL PILOT TECHNICAL QUESTIONS, CONDITION ASSESSMENT
- SCOTT BERSHING SJBERSHI@MTU.EDU – EQUIPMENT OR PROCEDURES PROBLEMS, GENERAL QUESTIONS
- MARY CRANE MCRANE@MTU.EDU – ROADSOFT QUESTIONS SPECIFIC TO THE PILOT

CENTER FOR SHARED SOLUTIONS

- MARK HOLMES HOLMESM3@MICHIGAN.GOV – UPLOAD AND FINAL SUBMITTAL QUESTIONS

TAMC

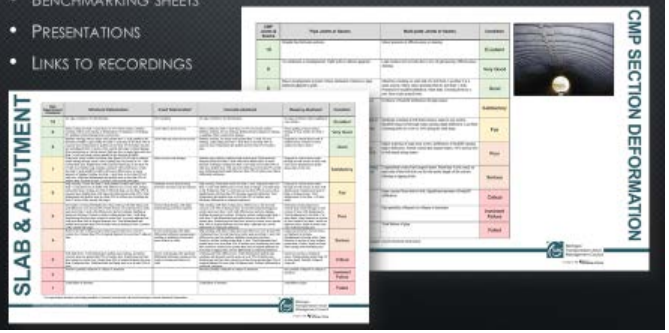
- REBECCA CURTIS, MDOT CURTISR4@MICHIGAN.GOV – OVERALL PILOT DIRECTION QUESTIONS
- JOANNA JOHNSON, KALAMAZOO COUNTY JJOHNSON@KALAMAZOOCOUNTYROADS.COM – OVERALL PILOT DIRECTION QUESTIONS

MDOT

- POLY KENT KENTP@MICHIGAN.GOV – FINANCIAL / REIMBURSEMENT QUESTIONS
- ROGER BELKNAP BELKNAPR@MICHIGAN.GOV – FINANCIAL / REIMBURSEMENT QUESTIONS

RESOURCES

- CSS IS SETTING UP A WEBSITE HTTPS://WWW.MICHIGAN.GOV/TAMC/
- DOCUMENTS WILL BE AVAILABLE THERE
- FAQ'S
- BENCHMARKING SHEETS
- PRESENTATIONS
- LINKS TO RECORDINGS



NEXT STEPS FROM TAMC

- DATA SUBMITTED WILL BE SEAMED INTO A STATEWIDE CULVERT DATABASE BY CSS
- FINAL REPORT FROM THIS EFFORT WILL INFORM TAMC AND POTENTIALLY THE WATER ASSET MANAGEMENT COUNSEL (WAMC)
- HELP ASSESS THE FEASIBILITY OF FURTHER COLLECTION EFFORTS

RECOMMENDED EQUIPMENT

- Rugged Tablet
  - Roadsoft LDC
  - Compass App (skew angle)
  - Camera
- Laser Distance Measure
  - Culvert Length
- Laser Auto Level & Grade Rod
  - Depth of Cover
- Metal Detector
- Probe Rod / Shovel
- Chipping hammer
- Tape Measure
- PPE
- Flashlight
- Magnet

NOTES ON TABLET USAGE

- May need to setup GPS for compatibility with data collector

NOTES ON AUTO-LEVEL

- Turn off before moving
  - Locks and prevents internal damage to the auto-leveling mechanism

INVENTORY DATA COLLECTION

- *Inventory ID*
- *GPS Coordinates*
- Material Type
- Asset Collection Date
- Shape
- Skew Angle
- *Photographs (Optional)*
- Length
- Width
- Height/diameter
- Depth of Cover
- Roadway Surface Type
- Culvert Rating

INVENTORY ID

- Automatically generated by Roadsoft

GPS COORDINATES

- Latitude and longitude of the culvert, measured at the middle of the road overtop the structure and recorded in decimal degrees

ASSET COLLECTION DATE

- Date at which the condition ratings were collected

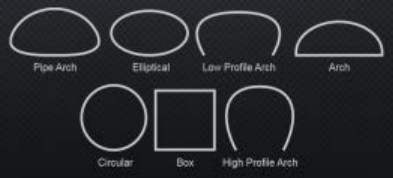
MATERIAL TYPE

The primary material of the culvert structure:

- Undefined
- Aluminum Box Culvert
- Aluminum Long Span Structure
- Cast-in-place Concrete Culvert
- Corrugated Aluminum Pipe
- Corrugated Steel Box Culvert
- Corrugated Steel Pipe
- Long Span Corrugated Steel Structure
- Masonry Culvert
- Other
- Pre-Cast Concrete Pipe
- Structural Plate Aluminum Pipe
- Structural Plate Steel Pipe
- None
- Plastic
- Timber
- Steel
- Aluminum
- Concrete

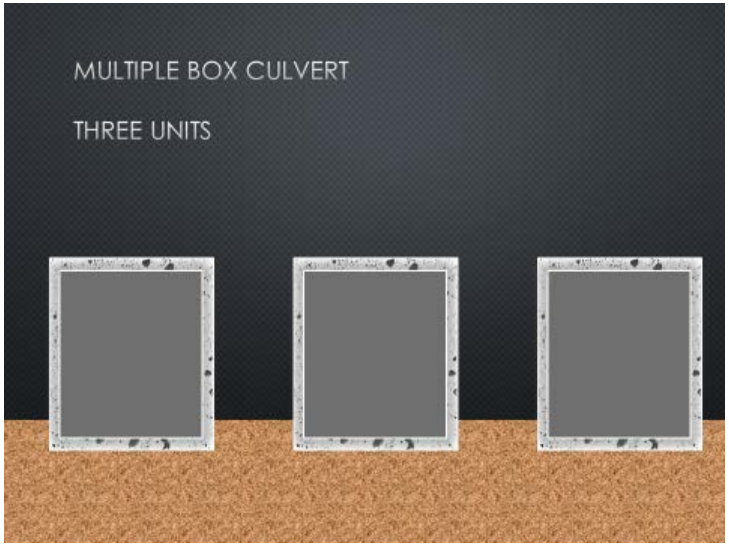
SHAPE

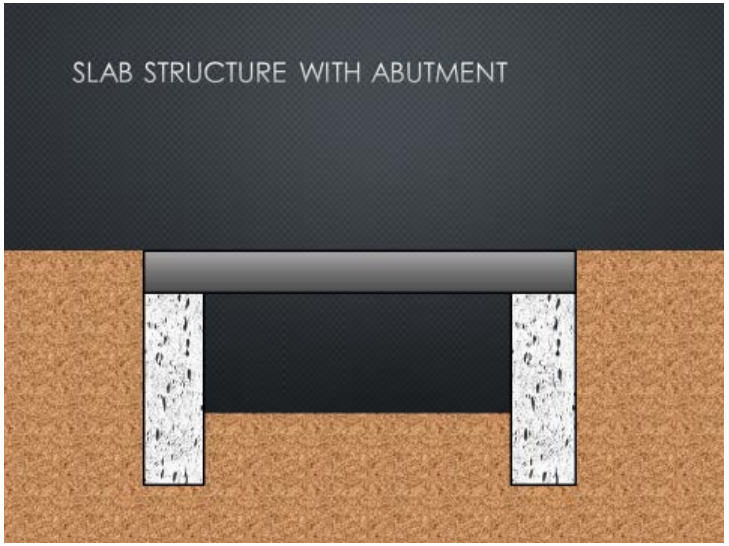
- Undefined
- Arch
- Circular
- High Profile Arch
- Horizontal Ellipse
- Low Profile Arch
- Other
- Pear
- Pipe Arch
- Rectangular
- Underpass
- Vertical Ellipse
- Box
- Multi-cell box
- 3-sided
- Slab/superstructure & abutment

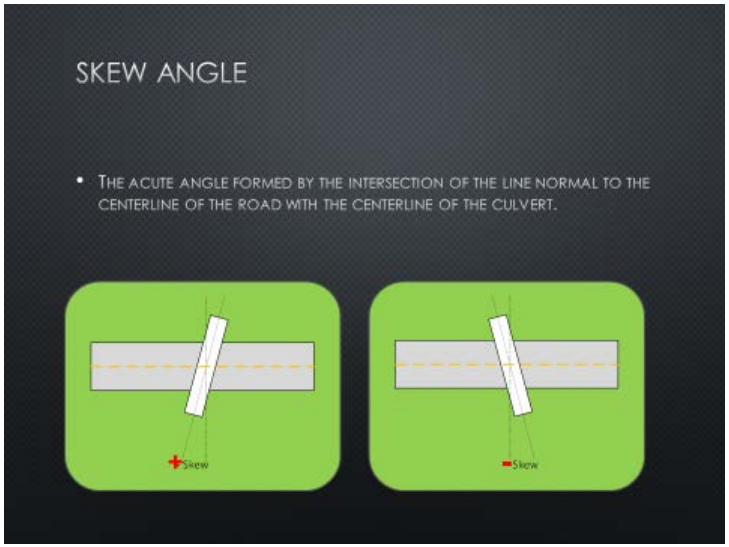


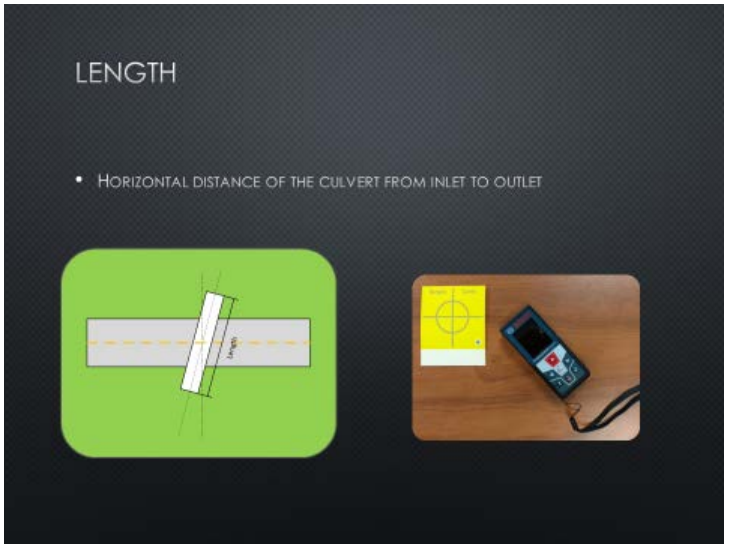
MULTI CELL BOX CULVERT

ONE UNIT – SHARES COMMON MEMBERS


MULTIPLE BOX CULVERT
THREE UNITS


SLAB STRUCTURE WITH ABUTMENT


SKEW ANGLE
• THE ACUTE ANGLE FORMED BY THE INTERSECTION OF THE LINE NORMAL TO THE CENTERLINE OF THE ROAD WITH THE CENTERLINE OF THE CULVERT.
+Skew
-Skew

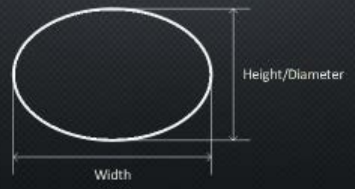

LENGTH
• HORIZONTAL DISTANCE OF THE CULVERT FROM INLET TO OUTLET

WIDTH

THE ORIGINAL DISTANCE OF THE CULVERT OPENING (PERPENDICULAR TO THE LENGTH)

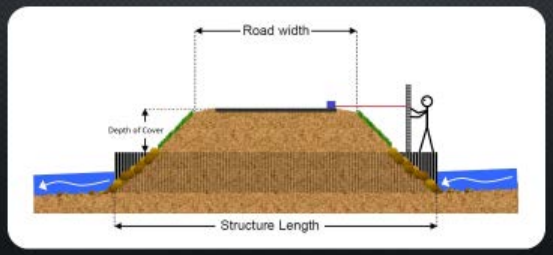
HEIGHT/DIAMETER

THE ORIGINAL HEIGHT OF THE CULVERT OPENING



DEPTH OF COVER

- THE DEPTH OF SOIL FROM THE ROADWAY TO THE PEAK OF THE CULVERT STRUCTURE



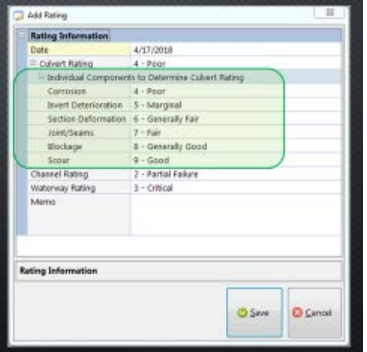
ROADWAY SURFACE TYPE

THE ROAD SURFACE TYPE IS NOT DISPLAYED IN THE CULVERT MODULE BUT CAN BE AVAILABLE FOR THE EXPORT DIRECTLY FROM THE ROAD MODULE IF IT HAS BEEN ENTERED THERE.

- IT CANNOT CURRENTLY BE DIRECTLY ENTERED IN TO THE CULVERT MODULE UNLESS YOU CREATE A STREAM CROSSING SURVEY AND ENTER IT IN THE ROAD INFORMATION FOR THE SURVEY.

CULVERT RATING

- AN OVERALL CULVERT RATING ENTERED INTO THE STATE-WIDE DATABASE
- GENERALLY REPRESENTS THE WEAKEST LINK
  - CAN BE OVERRIDDEN BY INSPECTOR FOR SITE-SPECIFIC CIRCUMSTANCES
  - PLEASE ADD COMMENT IF RATING DIFFERENT THAN THE LOWEST OF THE 6 ELEMENT RATINGS



PHOTOGRAPHS (OPTIONAL)

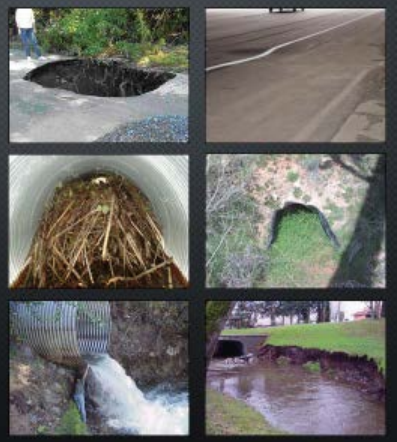
PRIMARY PHOTOS:

- 2 FROM EACH END (4 TOTAL)
  - ONE LOOKING AT THE INLET/OUTLET AND SOME SURROUNDINGS
  - ONE LOOKING INTO THE CULVERT

PHOTOGRAPHS CONTINUED

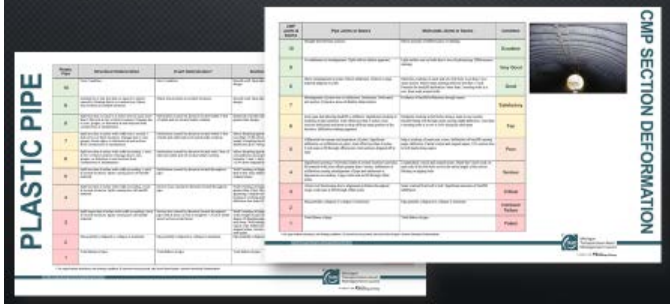
SECONDARY PHOTOS:

- AT THE DISCRETION OF THE INSPECTOR
  - ROAD SURFACE
  - BLOCKAGE
  - SCOUR
  - ETC.



CONDITION ASSESSMENT RESOURCES

- CONDITION ASSESSMENT CHEAT SHEET WILL BE AVAILABLE ON PROJECT WEBSITE (EARLY NEXT WEEK)
- CONDITION ASSESSMENT GUIDE WILL BE COMPETE SOON, WHICH COVERS WEBINAR MATERIAL (ON WEBSITE IN A WEEK OR SO)
- OHIO GUIDE GIVES BACKGROUND DISCUSSION THAT IS HELPFUL



CONDITION ASSESSMENT

- FOLLOWS INTENT OF FHWA CULVERT INSPECTION MANUAL (1986)
- CLOSELY MIRRORS OHIO DOT UPDATED FHWA METHOD (2017)
- RATING SPECIFICS FOR EACH ELEMENT VARY BY MATERIAL AND CULVERT TYPE
- INDIVIDUAL RATING FOR THE FOLLOWING ELEMENTS:
  - STRUCTURAL DETERIORATION
  - INVERT DETERIORATION
  - SECTION DEFORMATION
  - JOINTS/SEAMS
  - BLOCKAGE
  - SCOUR

CONDITION ASSESSMENT

- 10 (TOP) TO 1 (BOTTOM) SCALE FOR SIX INDIVIDUAL RATING ELEMENTS
- ALL INDIVIDUAL ELEMENT RATING GET LOGGED BUT LOWEST IS RECORDED AS CONDITION SCORE
- ELEMENT RATING CRITERIA ARE INCLUSIVE FOR THE LOWEST RATING (DON'T NEED ALL FACTORS)

4	Extensive heavy rust and scaling throughout. Perforations throughout invert with an area less than 25% of invert area. Severe undermining with slight differential settlement causing minor cracking or spalling in footing and minor distress in walls

INVERT DETERIORATION

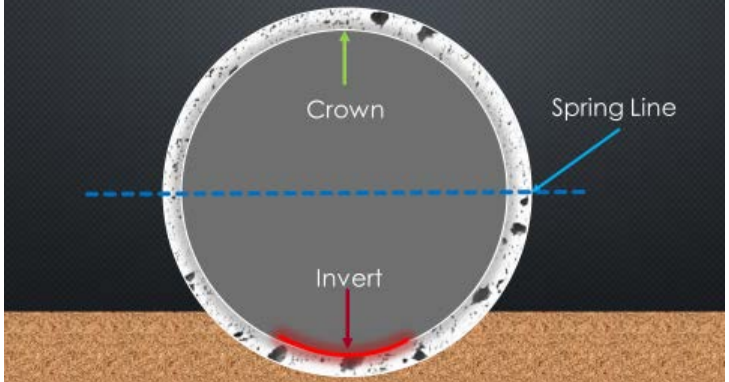
CORRUGATED METAL PIPE

PLASTIC PIPE

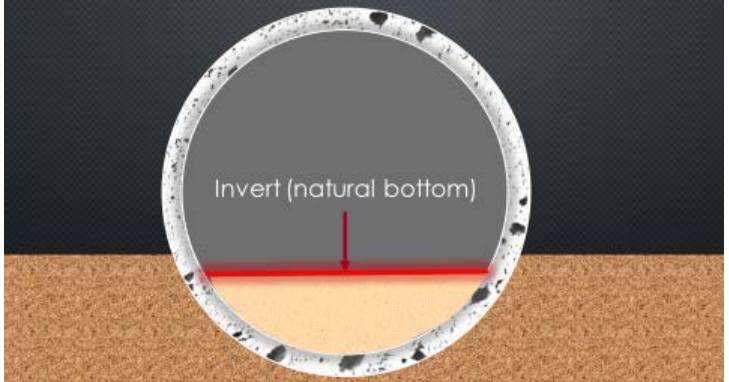
CONCRETE PIPE (LINED MASONRY, TIMBER AND SLAB/ABUTMENT)

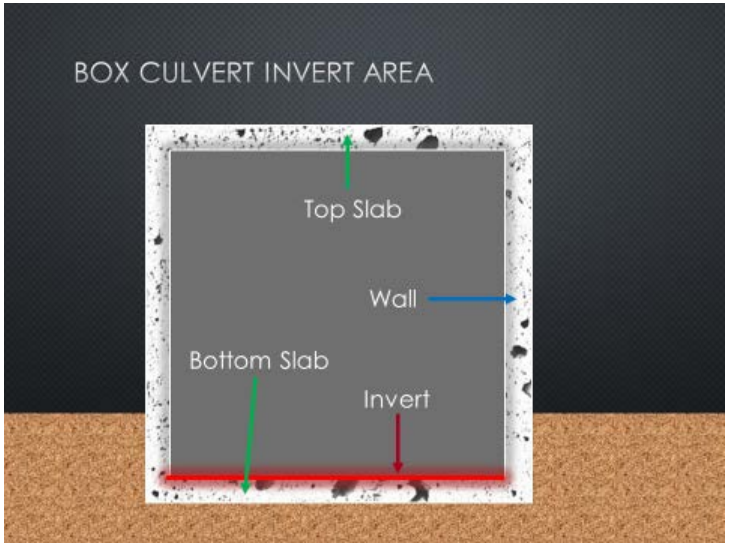
NATURAL BOTTOM (ANY MATERIAL)

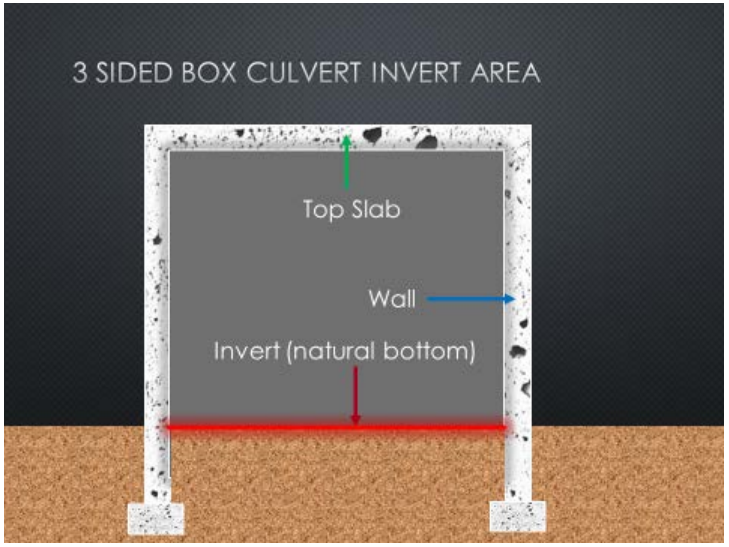
CIRCULAR PIPE INVERT AREA

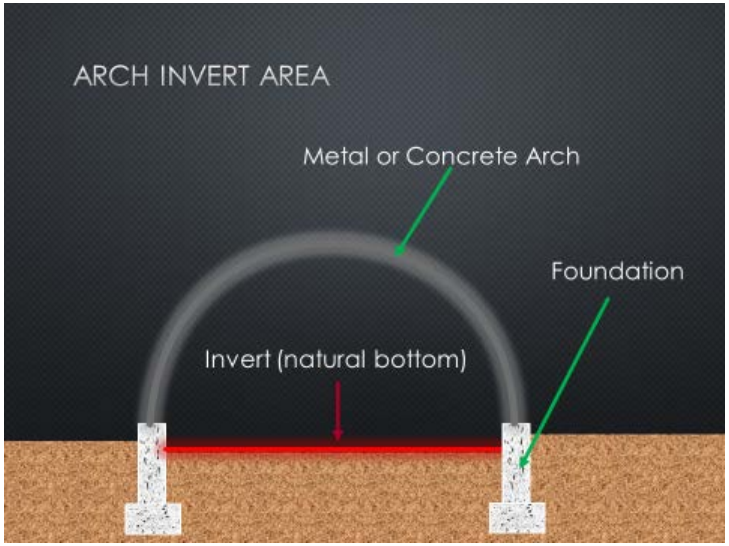


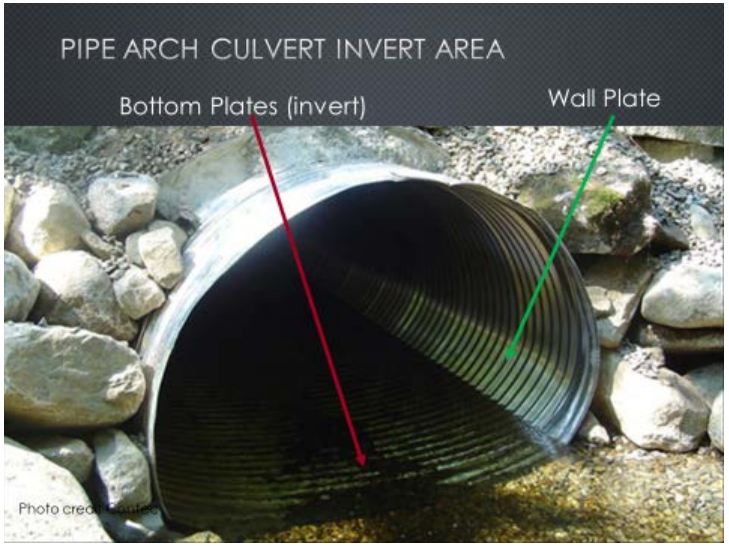
AOP DESIGN CIRCULAR PIPE INVERT AREA




BOX CULVERT INVERT AREA
Top Slab
Wall
Bottom Slab
Invert


3 SIDED BOX CULVERT INVERT AREA
Top Slab
Wall
Invert (natural bottom)


ARCH INVERT AREA
Metal or Concrete Arch
Foundation
Invert (natural bottom)


PIPE ARCH CULVERT INVERT AREA
Bottom Plates (invert)
Wall Plate

CMP INVERT DETERIORATION EXAMPLE 1

CMP	Closed Bottom Invert Deterioration
10	New condition; galvanizing intact; no corrosion.
9	Discoloration of surface. Galvanizing partially gone along invert. No layers of rust.
8	Discoloration of surface. Galvanizing gone along invert but no layers of rust. Minor section loss at ends of pipe not located beneath roadway.
7	Galvanizing gone along invert with layers of rust. Moderate section loss at ends of pipe not located beneath roadway. Moderate section loss: Less than 4% of invert area.
6	Heavy rust and scale throughout. Heavy section loss with perforations in invert not located under the roadway. Heavy section loss: Up to 10% of invert area.
5	Extensive heavy rust and scaling throughout. Perforations throughout invert with an area less than 20% of invert area. Overall thin metal, which allows for an easy puncture with chipping hammer.
4	Extensive heavy rust and scaling throughout. Perforations throughout invert with an area less than 25% of invert area.
3	Perforations throughout invert with an area greater than 25% of invert area.
2	Pipe partially collapsed.
1	Total failure of pipe.

CMP INVERT DETERIORATION EXAMPLE 2

CMP	Closed Bottom Invert Deterioration
10	New condition; galvanizing intact; no corrosion.
9	Discoloration of surface. Galvanizing partially gone along invert. No layers of rust.
8	Discoloration of surface. Galvanizing gone along invert but no layers of rust. Minor section loss at ends of pipe not located beneath roadway.
7	Galvanizing gone along invert with layers of rust. Moderate section loss at ends of pipe not located beneath roadway. Moderate section loss: Less than 4% of invert area.
6	Heavy rust and scale throughout. Heavy section loss with perforations in invert not located under the roadway. Heavy section loss: Up to 10% of invert area.
5	Extensive heavy rust and scaling throughout. Perforations throughout invert with an area less than 20% of invert area. Overall thin metal, which allows for an easy puncture with chipping hammer.
4	Extensive heavy rust and scaling throughout. Perforations throughout invert with an area less than 25% of invert area.
3	Perforations throughout invert with an area greater than 25% of invert area.
2	Pipe partially collapsed.
1	Total failure of pipe.

CMP INVERT DETERIORATION EXAMPLE 3

CMP	Closed Bottom Invert Deterioration
10	New condition; galvanizing intact; no corrosion.
9	Discoloration of surface. Galvanizing partially gone along invert. No layers of rust.
8	Discoloration of surface. Galvanizing gone along invert but no layers of rust. Minor section loss at ends of pipe not located beneath roadway.
7	Galvanizing gone along invert with layers of rust. Moderate section loss at ends of pipe not located beneath roadway. Moderate section loss: Less than 4% of invert area.
6	Heavy rust and scale throughout. Heavy section loss with perforations in invert not located under the roadway. Heavy section loss: Up to 10% of invert area.
5	Extensive heavy rust and scaling throughout. Perforations throughout invert with an area less than 20% of invert area. Overall thin metal, which allows for an easy puncture with chipping hammer.
4	Extensive heavy rust and scaling throughout. Perforations throughout invert with an area less than 25% of invert area.
3	Perforations throughout invert with an area greater than 25% of invert area.
2	Pipe partially collapsed.
1	Total failure of pipe.

PLASTIC PIPE INVERT DETERIORATION EXAMPLE 1

Plastic Pipe	Invert Deterioration
10	New Condition.
9	Minor discoloration at isolated locations.
8	Perforations caused by abrasion located within 5 feet of outlet and not located under roadway.
7	Perforations caused by abrasion located within 5 feet of inlet and outlet and not located under roadway.
6	Substantial perforations caused by abrasion located within 5 feet of inlet and outlet and not located under roadway.
5	Perforations caused by abrasion located throughout pipe.
4	Section loses caused by abrasion located throughout pipe.
3	Section loss caused by abrasion located throughout pipe with at least a 2 foot in length by ½ foot in width invert section eroded away.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

CONCRETE PIPE INVERT DETERIORATION EXAMPLE 1

6

Concrete Pipe	Structural Deterioration
10	New Condition. Superficial and isolated damage from construction.
9	Hairline cracking without rust staining or delamination(s). Surface in good condition.
8	Hairline cracking: Less than 1/16th inch wide parallel to traffic without rust staining. Light scaling: Less than 1/8th inch deep with less than 10% of exposed area. Delaminated or Spalled areas: Less than 1% of surface area. Note: cast-in-place box culverts may have a single large crack less than 3/16th inch on each surface parallel traffic direction.
7	Hairline and map cracking: Cracks less than 1/8th inch parallel to traffic with minor efflorescence or minor amounts of leakage. Scaling: Less than 1/16th inch deep or 20% of exposed area. Spalled areas with exposed reinforcing: Less than 6%. Total delaminated and spalled areas less than 8% of surface area.
6	Map cracking with hairline cracks less than 1/8th inch parallel to traffic or less than 1/16th inch transverse to traffic with efflorescence, or rust stains, or leakage or oil. Scaling 1/16th inch deep on less than 30% of surface area. Spalled areas with exposed reinforcing on less than 10% of surface area. Total delaminated and spalled areas less than 18% of surface area.
5	Transverse cracks open greater than 1/8th inch with efflorescence and rust staining. Spalling at numerous locations. Extensive surface scaling on invert greater than 1/2 inch. Extensive cracking with cracks open more than 1/8th inch with efflorescence. Spalling has caused exposure of heavily corroded reinforcing steel on bottom or top of slab. Extensive surface scaling on invert greater than 1/16th inch or approximately 30% of culvert invert.
4	Extensive cracking with spalling, delaminations, and slight differential movement. Scaling has exposed all surfaces of the reinforcing steel in bottom and top slab or invert with approximately 30% loss of wall thickness at invert. Concrete very soft.
3	Full depth holes. Extensive cracking greater than 1/2 inch. Spalled areas with exposed reinforcing greater than 25%. Over 50% of the surface area is delaminated, spalled, or punky. Reinforcing steel bars have extensive section loss and bar perimeter is completely exposed.
2	Culvert partially collapsed or collapse is imminent.
1	The culvert is collapsed.

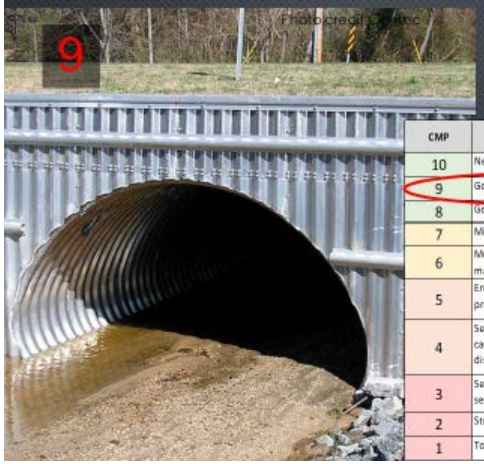
CONCRETE PIPE INVERT DETERIORATION EXAMPLE 2

2

Concrete Pipe	Structural Deterioration
10	New Condition. Superficial and isolated damage from construction.
9	Hairline cracking without rust staining or delamination(s). Surface in good condition.
8	Hairline cracking: Less than 1/16th inch wide parallel to traffic without rust staining. Light scaling: Less than 1/8th inch deep with less than 10% of exposed area. Delaminated or Spalled areas: Less than 1% of surface area. Note: cast-in-place box culverts may have a single large crack less than 3/16th inch on each surface parallel traffic direction.
7	Hairline and map cracking: Cracks less than 1/8th inch parallel to traffic with minor efflorescence or minor amounts of leakage. Scaling: Less than 1/16th inch deep or 20% of exposed area. Spalled areas with exposed reinforcing: Less than 6%. Total delaminated and spalled areas less than 8% of surface area.
6	Map cracking with hairline cracks less than 1/8th inch parallel to traffic or less than 1/16th inch transverse to traffic with efflorescence, or rust stains, or leakage or oil. Scaling 1/16th inch deep on less than 30% of surface area. Spalled areas with exposed reinforcing on less than 10% of surface area. Total delaminated and spalled areas less than 18% of surface area.
5	Transverse cracks open greater than 1/8th inch with efflorescence and rust staining. Spalling at numerous locations. Extensive surface scaling on invert greater than 1/2 inch. Extensive cracking with cracks open more than 1/8th inch with efflorescence. Spalling has caused exposure of heavily corroded reinforcing steel on bottom or top of slab. Extensive surface scaling on invert greater than 1/16th inch or approximately 30% of culvert invert.
4	Extensive cracking with spalling, delaminations, and slight differential movement. Scaling has exposed all surfaces of the reinforcing steel in bottom and top slab or invert with approximately 30% loss of wall thickness at invert. Concrete very soft.
3	Full depth holes. Extensive cracking greater than 1/2 inch. Spalled areas with exposed reinforcing greater than 25%. Over 50% of the surface area is delaminated, spalled, or punky. Reinforcing steel bars have extensive section loss and bar perimeter is completely exposed.
2	Culvert partially collapsed or collapse is imminent.
1	The culvert is collapsed.

NATURAL BOTTOM INVERT DETERIORATION EXAMPLE 1

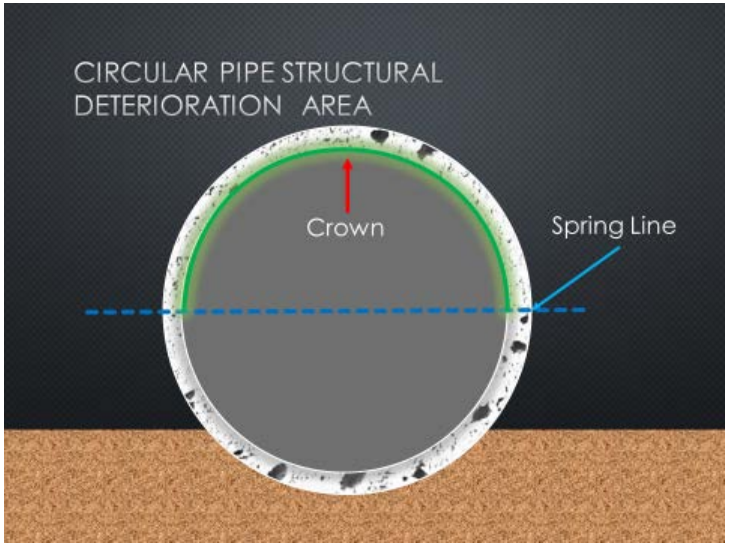
9

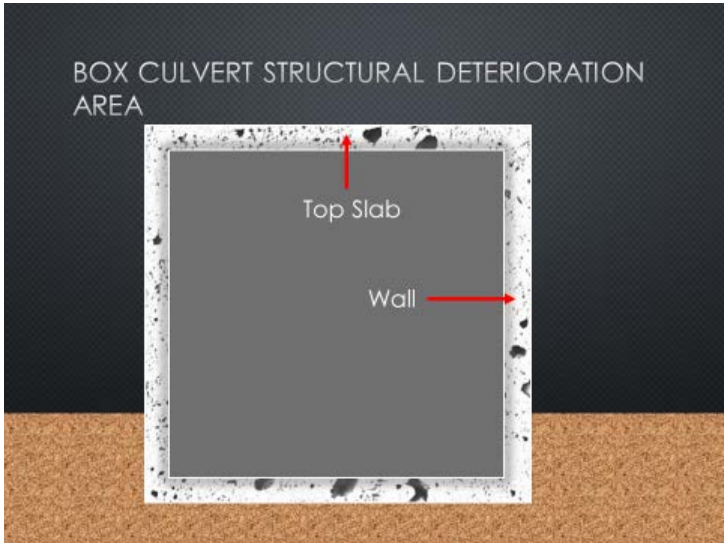


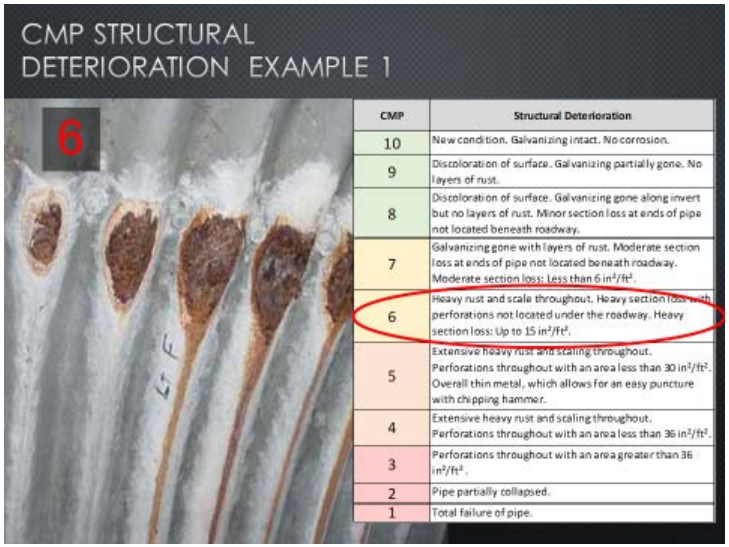
CMP	Open Bottom Invert Deterioration
10	New condition
9	Good with no invert erosion
8	Good with only minor invert erosion
7	Minor erosion near footings
6	Moderate erosion along footing; protective measures may be required
5	Erosion along footing with slight undermining, protection required
4	Severe undermining with slight differential settlement causing minor cracking or spalling in footing and minor distress in walls
3	Severe undermining with significant differential settlement causing severe cracks in footing and distress
2	Structure partially collapsed or collapse is imminent.
1	Total failure of structure.

STRUCTURAL DETERIORATION

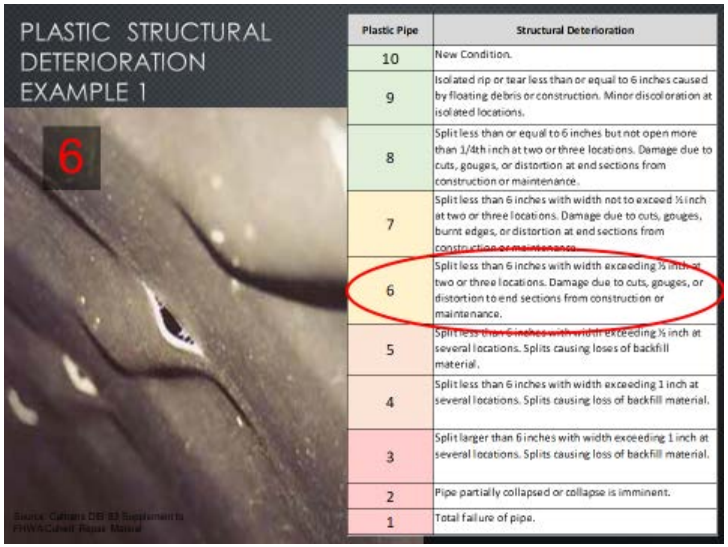
CORRUGATED METAL PIPE
PLASTIC PIPE
CONCRETE PIPE
MASONRY
TIMBER
SLAB/ABUTMENT





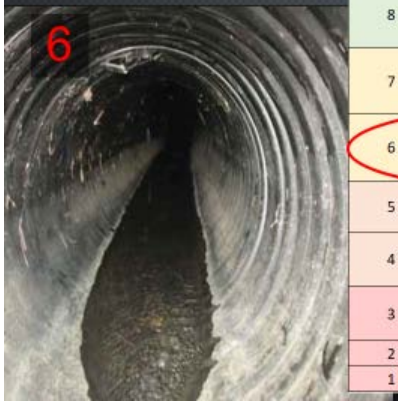


CMP	Structural Deterioration
10	New condition. Galvanizing intact. No corrosion.
9	Discoloration of surface. Galvanizing partially gone. No layers of rust.
8	Discoloration of surface. Galvanizing gone along invert but no layers of rust. Minor section loss at ends of pipe not located beneath roadway.
7	Galvanizing gone with layers of rust. Moderate section loss at ends of pipe not located beneath roadway. Moderate section loss: Less than 6 in^2/ft^2.
6	Heavy rust and scale throughout. Heavy section loss with perforations not located under the roadway. Heavy section loss: Up to 15 in^2/ft^2.
5	Extensive heavy rust and scaling throughout. Perforations throughout with an area less than 30 in^2/ft^2. Overall thin metal, which allows for an easy puncture with chipping hammer.
4	Extensive heavy rust and scaling throughout. Perforations throughout with an area less than 36 in^2/ft^2.
3	Perforations throughout with an area greater than 36 in^2/ft^2.
2	Pipe partially collapsed.
1	Total failure of pipe.



Plastic Pipe	Structural Deterioration
10	New Condition.
9	Isolated rip or tear less than or equal to 6 inches caused by floating debris or construction. Minor discoloration at isolated locations.
8	Split less than or equal to 6 inches but not open more than 1/4th inch at two or three locations. Damage due to cuts, gouges, or distortion at end sections from construction or maintenance.
7	Split less than 6 inches with width not to exceed ½ inch at two or three locations. Damage due to cuts, gouges, burnt edges, or distortion at end sections from construction or maintenance.
6	Split less than 6 inches with width exceeding ½ inch at two or three locations. Damage due to cuts, gouges, or distortion to end sections from construction or maintenance.
5	Split less than 6 inches with width exceeding ½ inch at several locations. Splits causing loses of backfill material.
4	Split less than 6 inches with width exceeding 1 inch at several locations. Splits causing loss of backfill material.
3	Split larger than 6 inches with width exceeding 1 inch at several locations. Splits causing loss of backfill material.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

PLASTIC STRUCTURAL DETERIORATION EXAMPLE 2



Plastic Pipe	Structural Deterioration
10	New Condition.
9	Isolated rip or tear less than or equal to 6 inches caused by floating debris or construction. Minor discoloration at isolated locations.
8	Split less than or equal to 6 inches but not open more than 1/4th inch at two or three locations. Damage due to cuts, gouges, or distortion at end sections from construction or maintenance.
7	Split less than 6 inches with width not to exceed ½ inch at two or three locations. Damage due to cuts, gouges, burnt edges, or distortion at end sections from construction or maintenance.
6	Split less than 6 inches with width exceeding ½ inch at two or three locations. Damage due to cuts, gouges, or distortion to end sections from construction or maintenance.
5	Split less than 6 inches with width exceeding ½ inch at several locations. Splits causing loses of backfill material.
4	Split less than 6 inches with width exceeding 1 inch at several locations. Splits causing loss of backfill material.
3	Split larger than 6 inches with width exceeding 1 inch at several locations. Splits causing loss of backfill material.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

CONCRETE STRUCTURAL DETERIORATION EXAMPLE 1

Concrete Pipe	Structural Deterioration
10	New Condition. Superficial and isolated damage from construction.
9	Hairline cracking without rust staining or delamination(s). Surface in good condition.
8	Hairline cracking. Less than 1/16th inch wide parallel to traffic without rust staining. Light scaling. Less than 1/8th inch deep with less than 10% of exposed area. Delaminated or Spalled areas: less than 2% of surface area. Note: cast-in-place box culverts may have a single large crack less than 1/16th inch on each surface parallel traffic direction.
7	Hairline and map cracking. Cracks less than 1/8th inch parallel to traffic with minor efflorescence or minor amounts of leakage. Scaling: less than 1/4th inch deep or 20% of exposed area, spalled areas with exposed reinforcing: less than 5%. Total delaminated and spalled areas less than 5% of surface area.
6	Map cracking with hairline cracks less than 1/8th inch parallel to traffic or less than 1/16th inch transverse to traffic with efflorescence, or rust stains, or leakage or sl. scaling to 1/4th inch deep or less than 20% of surface area. Spalled areas with exposed reinforcing or less than 10% of surface area. Total delaminated and spalled areas less than 10% of surface area.
5	Transverse cracks open greater than 1/8th inch with efflorescence and rust staining. Spalling at numerous locations. Extensive surface scaling on invert greater than 1/2 inch. Extensive cracking with cracks open more than 1/8th inch with efflorescence. Spalling has caused exposure of heavily corroded reinforcing steel on bottom or top of slab. Extensive surface scaling on invert greater than 1/2th inch or aggregate visible throughout invert.
4	Extensive cracking with spalling, delaminations, and slight differential movement. Spalling has exposed all surfaces of the reinforcing steel in bottom and top slab or invert with approximately 30% loss of wall thickness at invert. Concrete very soft.
3	Full depth failure of [illegible] greater than 1/2 inch. Spalled areas with exposed reinforcing greater than 25%. Over 50% of the surface area is delaminated, spalled, or punky. Reinforcing steel bars have extensive section loss and bar perimeter is completely exposed.
2	Culvert partially collapsed or collapse is imminent.
1	The culvert is collapsed.

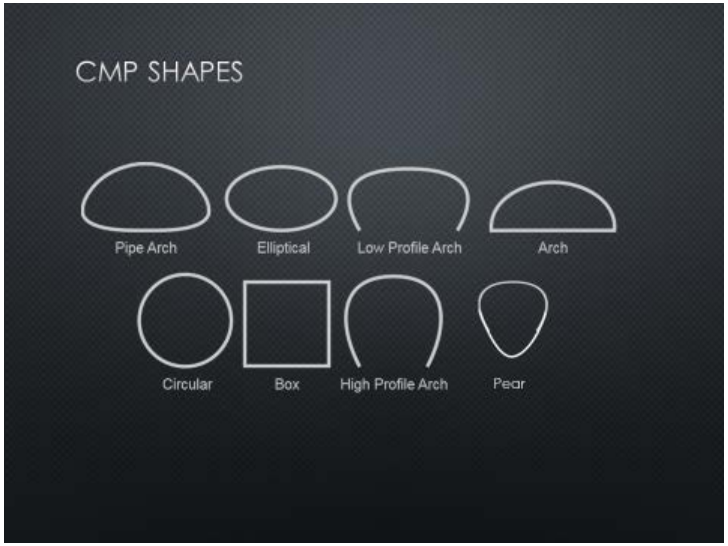
MASONRY STRUCTURAL DETERIORATION EXAMPLE 1

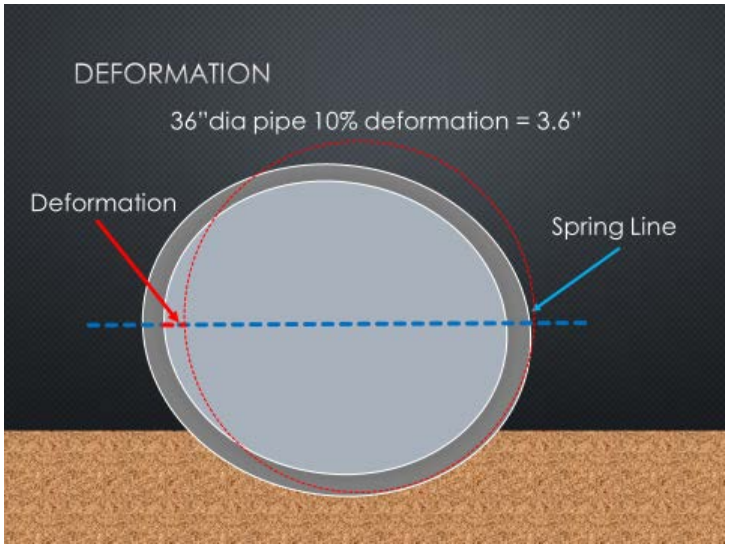
Masonry	Structural Deterioration
10	New Condition
9	No cracking. No missing or dislocated masonry. Surface in great condition.
8	Surface deterioration at isolated locations.
7	Minor cracking in masonry units
6	Minor cracking. Slight dislocation of masonry units. Large areas of surface scaling. Split or cracked stones.
5	Extensive cracking. Significant dislocation of masonry units. Large areas of surface scaling. Split or cracked stones.
4	Severe cracking with spalling. Delamination(s). Slight differential movement. Individual lower masonry units of structure missing or crushed.
3	Cracking very severe with significant spalling, delamination, and differential movement. Individual masonry units in lower part of structure missing or crushed. Individual masonry units in top of culvert missing or crushed.
2	Structure partially collapsed or collapse is imminent.
1	Total failure of structure.

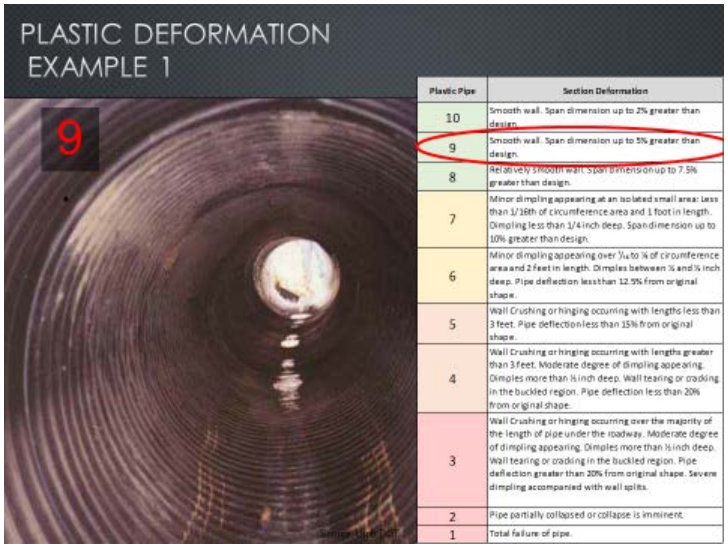
TIMBER STRUCTURAL DETERIORATION EXAMPLE 1

Timber	Structural Deterioration
10	New condition
9	No evidence of decay or abrasion/wear. Connections are in place and functioning as intended.
8	Little to no evidence of decay. Minor abrasion/wearing. Connections are in place and functioning as intended. No issues with structural members. Checks/cracks penetrate <5% of the member thickness. Member does not have splits or shakes.
7	Some evidence of decay, moderate abrasion/wearing, negligible section loss in structural members. Affects less than 10% of member section. Loose fasteners but the connection is in place and functioning as intended. Checks/Cracks penetrate 5-50% of the member thickness and not in tension zone.
6	Some evidence of decay, moderate abrasion/wearing, negligible section loss in structural members. Affects less than 10% of member section. Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended. Checks/Cracks penetrate 5-50% of the member thickness and not in tension zone. Member has splits/shakes with length less than member depth.
5	Decay and section loss affects 10% or more of the member but does not warrant structural review. Loose fasteners or pack rust without distortion is present but the connection is in place and functioning as intended. Checks/cracks penetrate >50% of member thickness or >5% in tension zone. Member has splits/shakes with length greater than member depth.
4	Decay and section loss affects 10% or more of the member but does not warrant structural review. Missing bolts, rivets, broken welds, fasteners, or pack rust with distortion but does not warrant structural review. Checks/cracks penetrate >50% of member thickness or >5% in tension zone. Member has splits/shakes with length greater than member depth and have not been arrested.
3	The condition warrants a structural review to determine the effect on strength, or serviceability of the element OR a structural review has been completed and the defects impact strength or serviceability.
2	Structure partially collapsed or collapse is imminent.
1	Total failure of structure.

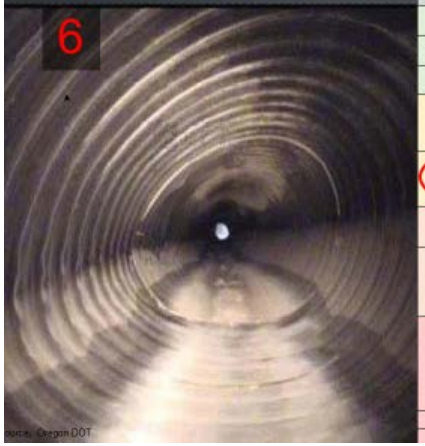
SECTION DEFORMATION
CORRUGATED METAL PIPE (BY EACH SHAPE TYPE)
PLASTIC PIPE


CMP SHAPES
Pipe Arch
Elliptical
Low Profile Arch
Arch
Circular
Box
High Profile Arch
Pear


DEFORMATION
36"dia pipe 10% deformation = 3.6"
Deformation
Spring Line


PLASTIC DEFORMATION
EXAMPLE 1
9
Plastic Pipe
Section Deformation
10
Smooth wall. Span dimension up to 2% greater than design.
9
Smooth wall. Span dimension up to 5% greater than design.
8
Relatively smooth wall. Span dimension up to 7.5% greater than design.
7
Minor dimpling appearing at an isolated small area: less than 1/18th of circumference area and 1 foot in length. Dimpling less than 1/4 inch deep. Span dimension up to 10% greater than design.
6
Minor dimpling appearing over 1/18 to 1/4 of circumference area and 2 feet in length. Dimples between ¼ and ½ inch deep. Pipe deflection less than 12.5% from original shape.
5
Wall Crushing or hinging occurring with lengths less than 3 feet. Pipe deflection less than 15% from original shape.
4
Wall Crushing or hinging occurring with lengths greater than 3 feet. Moderate degree of dimpling appearing. Dimples more than ½ inch deep. Wall tearing or cracking in the buckled region. Pipe deflection less than 20% from original shape.
3
Wall Crushing or hinging occurring over the majority of the length of pipe under the roadway. Moderate degree of dimpling appearing. Dimples more than ½ inch deep. Wall tearing or cracking in the buckled region. Pipe deflection greater than 20% from original shape. Severe dimpling accompanied with wall splits.
2
Pipe partially collapsed or collapse is imminent.
1
Total failure of pipe.

PLASTIC DEFORMATION EXAMPLE 2



Plastic Pipe	Section Deformation
10	Smooth wall. Span dimension up to 2% greater than design.
9	Smooth wall. Span dimension up to 5% greater than design.
8	Relatively smooth wall. Span dimension up to 7.5% greater than design.
7	Minor dimpling appearing at an isolated small area: Less than 1/16th of circumference area and 1 foot in length. Dimpling less than 1/4 inch deep. Span dimension up to 10% greater than design.
6	Minor dimpling appearing over 1/16 to ¼ of circumference area and 2 feet in length. Dimples between ¼ and ½ inch deep. Pipe deflection less than 12.5% from original shape.
5	Wall Crushing or hinging occurring with lengths less than 3 feet. Pipe deflection less than 15% from original shape.
4	Wall Crushing or hinging occurring with lengths greater than 3 feet. Moderate degree of dimpling appearing. Dimples more than ½ inch deep. Wall tearing or cracking in the buckled region. Pipe deflection less than 20% from original shape.
3	Wall Crushing or hinging occurring over the majority of the length of pipe under the roadway. Moderate degree of dimpling appearing. Dimples more than ½ inch deep. Wall tearing or cracking in the buckled region. Pipe deflection greater than 20% from original shape. Severe dimpling accompanied with wall splits.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

PLASTIC DEFORMATION EXAMPLE 3

Plastic Pipe	Section Deformation
10	Smooth wall. Span dimension up to 2% greater than design.
9	Smooth wall. Span dimension up to 5% greater than design.
8	Relatively smooth wall. Span dimension up to 7.5% greater than design.
7	Minor dimpling appearing at an isolated small area: Less than 1/16th of circumference area and 1 foot in length. Dimpling less than 1/4 inch deep. Span dimension up to 10% greater than design.
6	Minor dimpling appearing over 1/16 to ¼ of circumference area and 2 feet in length. Dimples between ¼ and ½ inch deep. Pipe deflection less than 12.5% from original shape.
5	Wall Crushing or hinging occurring with lengths less than 3 feet. Pipe deflection less than 15% from original shape.
4	Wall Crushing or hinging occurring with lengths greater than 3 feet. Moderate degree of dimpling appearing. Dimples more than ½ inch deep. Wall tearing or cracking in the buckled region. Pipe deflection less than 20% from original shape.
3	Wall Crushing or hinging occurring over the majority of the length of pipe under the roadway. Moderate degree of dimpling appearing. Dimples more than ½ inch deep. Wall tearing or cracking in the buckled region. Pipe deflection greater than 20% from original shape. Severe dimpling accompanied with wall splits.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

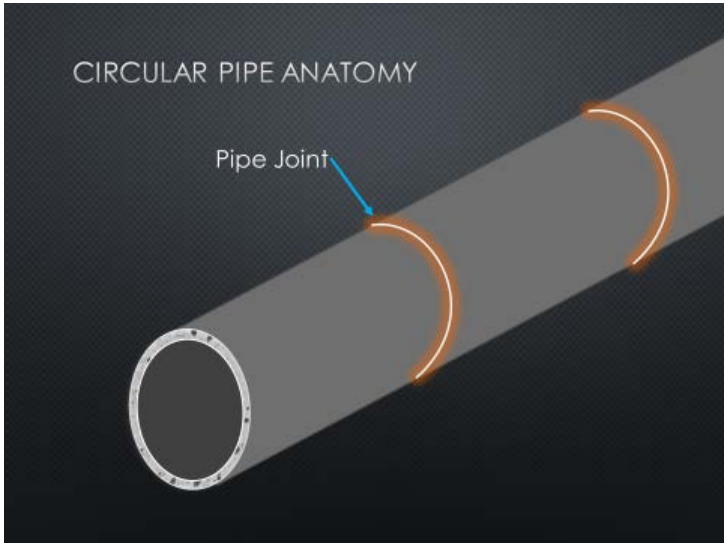
CMP DEFORMATION EXAMPLE 1

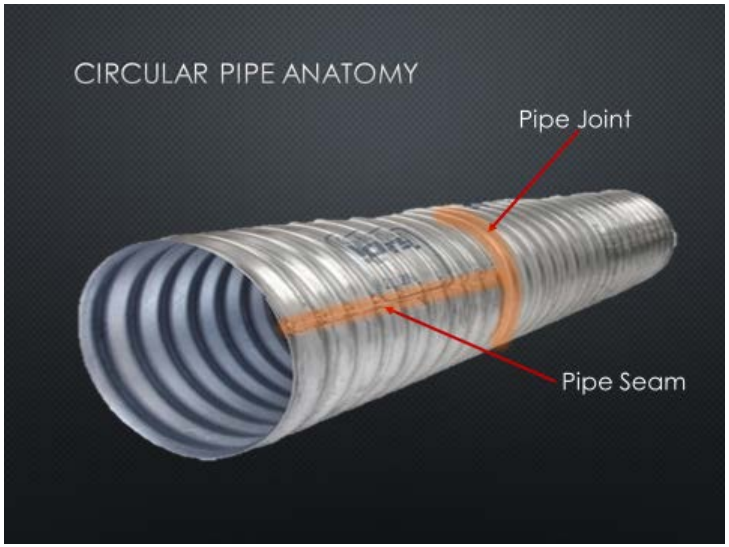
CMP Shape	Low Profile Long Span*
10	New Condition
9	Good appearance, smooth symmetrical curvature. Top arc mid-ordinate: within 11 percent of original design. Horizontal span: within 5 percent of original design.
8	Generally good; curvature is smooth and symmetrical. Top arc mid-ordinate: within 11 percent to 15 percent of original design. Horizontal span: within 5 percent of original design.
7	Smooth curvature, shape is non-symmetrical. Top arc mid-ordinate: within 15 percent of original design. Horizontal span: more than +/- 5 percent of design.
6	Generally fair; significant distortion and deflection in one section; half top of arcs beginning to flatten; mid-ordinate of half top arc 20 percent less than original design. Top arc mid-ordinate: within 15 to 20 percent of original design. Horizontal span: more than +/- 5 percent of original design.
5	Marginal, significant distortion and deflection throughout; mid-ordinate of half top arc less than 80 percent of original design. Top arc mid-ordinate: within 15 to 20 percent of design. Horizontal span: more than +/- 5 percent of design.
4	Poor, extreme distortion and deflection in one section and ordinate of half top arc 50 to 70 percent less than design. Top arc mid-ordinate: 20 to 30 percent less than original design. Horizontal span: more than +/- 5 percent of original design.
3	Critical, extreme distortion and end deflection throughout; mid-ordinate of half top arc more than 70 percent less than design. Top arc mid-ordinate: more than 30 percent of original design. Horizontal span: more than +/- 5 percent of design.
2	Severe due to partial collapse; top arc curvature flat or reverse curved.
1	Completely collapsed

CMP DEFORMATION EXAMPLE 2

CMP Shape	Round / Vertical Elongated Pipes
10	New Condition
9	Good, smooth curvature in barrel. Horizontal diameter (span) dimension within 10% of original design.
8	Generally good, top half of pipe smooth but minor flattening of bottom. Horizontal diameter (span) dimension within 10% of original design.
7	Fair, top half has smooth curvature but bottom half has flattened significantly. Horizontal diameter (span) dimension within 10% of original design.
6	Generally fair, significant distortion at isolated locations in top half and extreme flattening of the invert. Horizontal diameter (span) dimension 10% to 15% greater than original design.
5	Marginal significant distortion throughout length of pipe, lower third may be kinked. Horizontal diameter (span) dimension 10% to 15% greater than original design.
4	Poor with extreme deflection at isolated locations, flattening of the crown, crown radius 20 to 30 feet. Horizontal diameter (span) dimension in excess of 15% greater than original design.
3	Critical, extreme distortion and deflection throughout pipe, flattening of the crown, crown radius over 30 feet. Horizontal diameter (span) dimension more than 20% greater than original design.
2	Partially collapsed with crown in reverse curvature.
1	Structure collapsed

JOINTS / SEAMS
Corrugated Metal (Pipes and Multi-plate)
Concrete Pipe
Plastic Pipe
Masonry
Timber


CIRCULAR PIPE ANATOMY
Pipe Joint


CIRCULAR PIPE ANATOMY
Pipe Joint
Pipe Seam

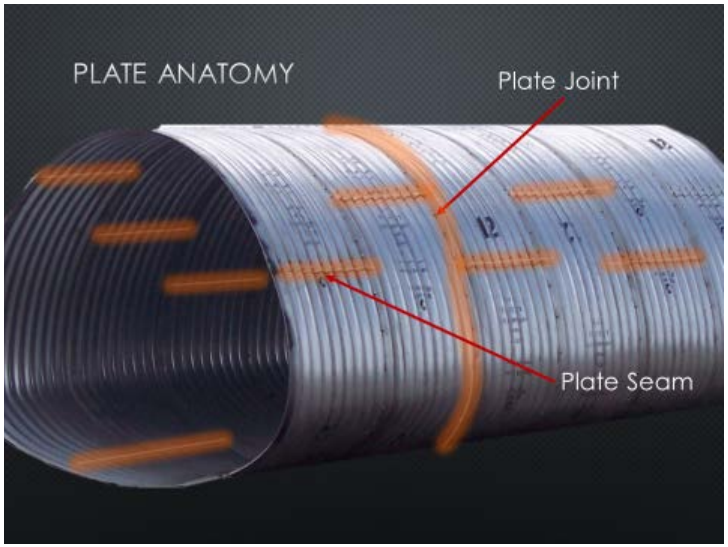


PLATE ANATOMY
Plate Joint
Plate Seam

CMP JOINTS/SEAMS EXAMPLE

5

CMP	Pipe Joints or Seams
10	Straight line between sections.
9	No settlement or misalignment. Tight with no defects apparent.
8	Minor misalignment at joints. Minor settlement. Distress to pipe material adjacent to joint.
7	Misalignment of joints but no infiltration. Settlement. Dislocated end section. Extensive areas of shallow deterioration.
6	Joint open and allowing backfill to infiltrate. Significant cracking or buckling of pipe material. Joint offset less than 3 inches. End sections dislocated and about to drop off from main portion of the structure. Infiltration staining apparent.
5	Differential movement and separation of joints. Significant infiltration or exfiltration at joints. Joint offset less than 4 inches. Voids seen in fill through offset joints. End sections dropped off at inlet.
4	Significant openings. Dislocated joints at several locations exposing fill material with joint offsets greater than 4 inches. Infiltration or exfiltration causing misalignment of pipe and settlement or depressions in roadway. Large voids seen in fill through offset joints.
3	Culvert not functioning due to alignment problems throughout. Large voids seen in fill through offset joints.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

CMP JOINTS/SEAMS EXAMPLE

8

CMP	Multi-plate Joints or Seams
10	Minor amounts of efflorescence or staining.
9	Light surface rust on bolts due to loss of galvanizing. Efflorescence staining.
8	Metal has cracking on each side of a bolt hole: less than 3 in a seam section. Minor seam openings that are less than ¼ inch. Potential for backfill infiltration. More than 2 missing bolts in a row. Rust scale around bolts.
7	Evidence of backfill infiltration through seams.
6	Moderate cracking at bolt holes along a seam in one section. Backfill being lost through seam causing slight deflection. Less than 6 missing bolts in a row or 20% along the total seam.
5	Major cracking of seam near crown. Infiltration of backfill causing major deflection. Partial cocked and cusped seams. 10% section loss to bolt heads along seams.
4	Longitudinal cocked and cusped seams. Metal has 3 inch crack on each side of the bolt hole run for the entire length of the culvert. Missing or tipping bolts.
3	Seam cracked from bolt to bolt. Significant amounts of backfill infiltration.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

CONCRETE PIPE JOINTS/SEAMS EXAMPLE

3

Concrete Pipe	Joints/Seams
10	Straight line between sections.
9	No settlement or misalignment. Tight with no defects apparent.
8	Minor misalignment at joints. Minor settlement. Distress to pipe material adjacent to joint.
7	Misalignment of joints but no infiltration. Settlement. Dislocated end section. Extensive areas of shallow deterioration. Minor cracking.
6	Joint open and allowing backfill to infiltrate. Significant cracking, spalling, or buckling of pipe material. Joint offset less than 3 inches. End sections dislocated and about to drop off from main portion of the structure. Infiltration staining apparent.
5	Differential movement and separation of joints. Significant infiltration or exfiltration at joints. Joint offset less than 4 inches. Voids seen in fill through offset joints. End sections dropped off at inlet.
4	Significant openings. Dislocated joints at several locations exposing fill material with joint offsets greater than 4 inches. Infiltration or exfiltration causing misalignment of pipe and settlement or depressions in roadway. Large voids seen in fill through offset joints.
3	Culvert not functioning due to alignment problems throughout. Large voids seen in fill through offset joints.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

PLASTIC PIPE JOINTS/SEAMS EXAMPLE

7

Plastic Pipe	Joints/Seams
10	Straight line between sections.
9	No settlement or misalignment. Tight with no defects apparent.
8	Minor misalignment at joints. Minor settlement. Distress to pipe material adjacent to joint.
7	Misalignment of joints but no infiltration. Settlement. Dislocated end section. Extensive areas of shallow deterioration. Minor cracking.
6	Joint open and allowing backfill to infiltrate. Significant cracking or buckling of pipe material. Joint offset less than 3 inches. End sections dislocated and about to drop off from main portion of the structure. Infiltration staining apparent.
5	Differential movement and separation of joints. Significant infiltration or exfiltration at joints. Joint offset less than 4 inches. Voids seen in fill through offset joints. End sections dropped off at inlet.
4	Significant openings. Dislocated joints at several locations exposing fill material with joint offsets greater than 4 inches. Infiltration or exfiltration causing misalignment of pipe and settlement or depressions in roadway. Large voids seen in fill through offset joints.
3	Culvert not functioning due to alignment problems throughout. Large voids seen in fill through offset joints.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

MASONRY JOINTS/SEAMS EXAMPLE

6

Masonry	Joints/Seams
10	Straight line between sections.
9	No settlement or misalignment. Tight with no defects apparent.
8	Minor misalignment at joints. Minor settlement. Distress to pipe material adjacent to joint. Shallow mortar deterioration at isolated locations.
7	Misalignment of joints but no infiltration. Settlement. Dislocated end section. Extensive areas of shallow deterioration. Missing mortar at isolated locations. Minor cracking.
6	Joint open and allowing backfill to infiltrate. Significant cracking, spalling, or buckling of pipe material. Joint offset less than 3 inches. End sections dislocated and about to drop off from main portion of the structure. Mortar generally deteriorated. Loose or missing mortar at isolated locations. Infiltration staining apparent.
5	Differential movement and separation of joints. Significant infiltration or exfiltration at joints. Joint offset less than 4 inches. Voids seen in fill through offset joints. End sections dropped off at inlet. Mortar severely deteriorated. Significant loss of mortar. Significant
4	Significant openings. Dislocated joints at several locations exposing fill material with joint offsets greater than 4 inches. Infiltration or exfiltration causing misalignment of pipe and settlement or depressions in roadway. Large voids seen in fill through offset joints. Extensive areas of missing mortar for masonry structures.
3	Culvert not functioning due to alignment problems throughout. Large voids seen in fill through offset joints.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

TIMBER JOINTS/SEAMS EXAMPLE

7

Timber	Joints/Seams
10	Straight line between sections.
9	No settlement or misalignment. Tight with no defects apparent.
8	Minor misalignment at joints. Minor settlement. Distress to pipe material adjacent to joint.
7	Misalignment of joints but no infiltration. Settlement. Dislocated end section. Extensive areas of shallow deterioration.
6	Joint open and allowing backfill to infiltrate. Significant deterioration or buckling of pipe material. Joint offset less than 3 inches. End sections dislocated and about to drop off from main portion of the structure. Infiltration staining apparent.
5	Differential movement and separation of joints. Significant infiltration or exfiltration at joints. Joint offset less than 4 inches. Voids seen in fill through offset joints. End sections dropped off at inlet.
4	Significant openings. Dislocated joints at several locations exposing fill material with joint offsets greater than 4 inches. Infiltration or exfiltration causing misalignment of pipe and settlement or depressions in roadway. Large voids seen in fill through offset joints.
3	Culvert not functioning due to alignment problems throughout. Large voids seen in fill through offset joints.
2	Pipe partially collapsed or collapse is imminent.
1	Total failure of pipe.

BLOCKAGE

APPLICABLE TO ALL CULVERT TYPES

BLOCKAGE EXAMPLE 1

8

Code	Blockage
10	No blockage. Designed condition.
9	Minor amounts of sediment build-up with no appreciable loss of opening.
8	Culvert waterway blockage is less than 5% of the cross sectional area of the opening. Bank and channel have minor amounts of drift.
7	Culvert waterway blockage is less than 10% of the cross sectional area of the opening. Sediment buildup causing flow through 1 of 2 pipes. Silt and Gravel buildup restricts half of the channel. Tree or bush growing in the channel. Fence placed at inlet or outlet. Rock dams in culvert.
6	Culvert waterway blockage is less than 30% of the cross sectional area of the opening. Tree or bush growing in channel. Fence placed at inlet or outlet. Rock dams in culvert.
5	Culvert waterway blockage is less than 40% of the cross sectional area of the opening. Occasional overtopping of roadway. Large deposits of debris are in the waterway.
4	Culvert waterway blockage is less than 80% of the cross sectional area of the opening. Overtopping of roadway with significant traffic delays.
3	Culvert waterway blockage is 80% or greater of the cross sectional area of the opening. Frequent overtopping of roadway with significant traffic delays.
2	Culvert waterway completely blocked and causing water to pool. Road closed because of channel failure.
1	Total failure of pipe.

BLOCKAGE EXAMPLE 2

5

Code	Blockage
10	No blockage. Designed condition.
9	Minor amounts of sediment build-up with no appreciable loss of opening.
8	Culvert waterway blockage is less than 5% of the cross sectional area of the opening. Bank and channel have minor amounts of drift.
7	Culvert waterway blockage is less than 10% of the cross sectional area of the opening. Sediment buildup causing flow through 1 of 2 pipes. Silt and Gravel buildup restricts half of the channel. Tree or bush growing in the channel. Fence placed at inlet or outlet. Rock dams in culvert.
6	Culvert waterway blockage is less than 30% of the cross sectional area of the opening. Tree or bush growing in channel. Fence placed at inlet or outlet. Rock dams in culvert.
5	Culvert waterway blockage is less than 40% of the cross sectional area of the opening. Occasional overtopping of roadway. Large deposits of debris are in the waterway.
4	Culvert waterway blockage is less than 80% of the cross sectional area of the opening. Overtopping of roadway with significant traffic delays.
3	Culvert waterway blockage is 80% or greater of the cross sectional area of the opening. Frequent overtopping of roadway with significant traffic delays.
2	Culvert waterway completely blocked and causing water to pool. Road closed because of channel failure.
1	Total failure of pipe.

BLOCKAGE EXAMPLE 3

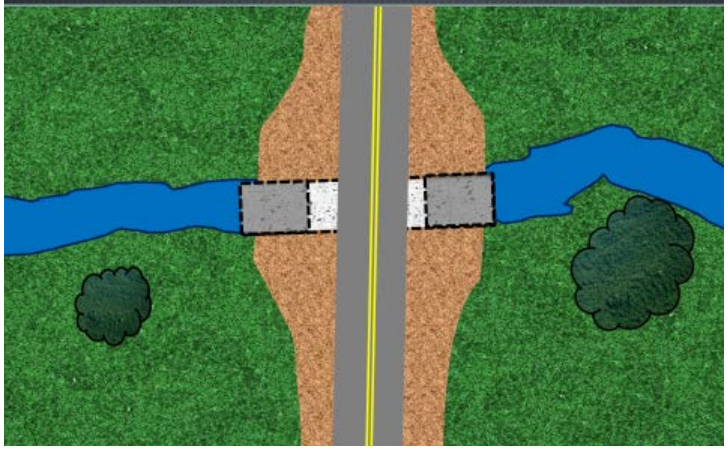
4

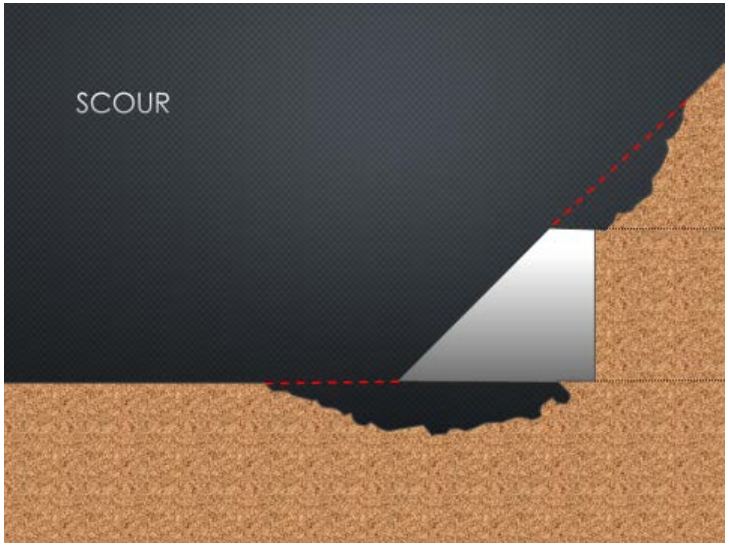
Code	Blockage
10	No blockage. Designed condition.
9	Minor amounts of sediment build-up with no appreciable loss of opening.
8	Culvert waterway blockage is less than 5% of the cross sectional area of the opening. Bank and channel have minor amounts of drift.
7	Culvert waterway blockage is less than 10% of the cross sectional area of the opening. Sediment buildup causing flow through 1 of 2 pipes. Silt and Gravel buildup restricts half of the channel. Tree or bush growing in the channel. Fence placed at inlet or outlet. Rock dams in culvert.
6	Culvert waterway blockage is less than 30% of the cross sectional area of the opening. Tree or bush growing in channel. Fence placed at inlet or outlet. Rock dams in culvert.
5	Culvert waterway blockage is less than 40% of the cross sectional area of the opening. Occasional overtopping of roadway. Large deposits of debris are in the waterway.
4	Culvert waterway blockage is less than 80% of the cross sectional area of the opening. Overtopping of roadway with significant traffic delays.
3	Culvert waterway blockage is 80% or greater of the cross sectional area of the opening. Frequent overtopping of roadway with significant traffic delays.
2	Culvert waterway completely blocked and causing water to pool. Road closed because of channel failure.
1	Total failure of pipe.

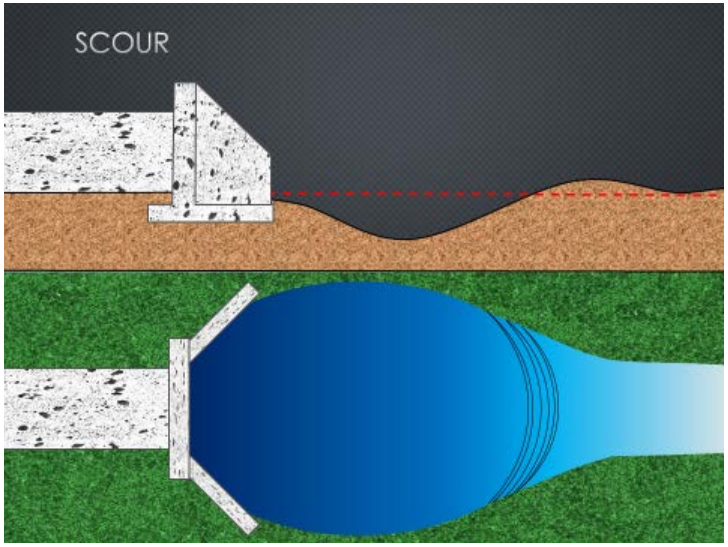
SCOUR

APPLICABLE TO ALL CULVERT TYPES

CULVERT EXTENSIONS



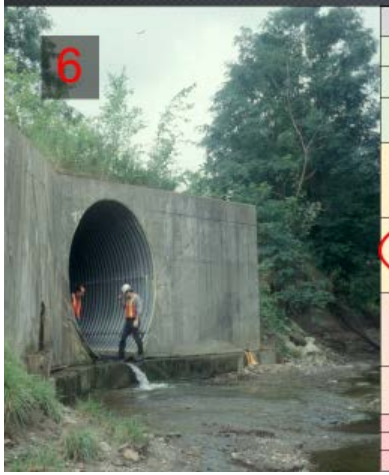




SCOUR EXAMPLE 1

Code	Scour
10	No evidence of scour at either inlet or outlet of culvert.
9	Minor scour holes developing at inlet or outlet. Scour protection placed.
8	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.
7	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.
6	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.
5	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.
4	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.
3	Streambed degradation causing severe settlement.
2	Culvert closed because of channel failure.
1	Total failure of culvert because of channel failure.

SCOUR EXAMPLE 2



Code	Scour
10	No evidence of scour at either inlet or outlet of culvert.
9	Minor scour holes developing at inlet or outlet. Scour protection placed.
8	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.
7	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.
6	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.
5	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.
4	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.
3	Streambed degradation causing severe settlement.
2	Culvert closed because of channel failure.
1	Total failure of culvert because of channel failure.

SCOUR EXAMPLE 3

5

Code	Scour
10	No evidence of scour at either inlet or outlet of culvert.
9	Minor scour holes developing at inlet or outlet. Scour protection placed.
8	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.
7	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.
6	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.
5	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.
4	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.
3	Streambed degradation causing severe settlement.
2	Culvert closed because of channel failure.
1	Total failure of culvert because of channel failure.

SCOUR EXAMPLE 4

3

Code	Scour
10	No evidence of scour at either inlet or outlet of culvert.
9	Minor scour holes developing at inlet or outlet. Scour protection placed.
8	Minor scour holes developing at inlet or outlet. Top of footings is exposed. Probing indicates soft material in scour hole.
7	Minor scour holes, 1 foot or less deep, developing at inlet or outlet. Footings along the side are exposed less than 6 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.
6	Minor scour holes, 2 feet or less deep, developing at inlet or outlet. Footings along the side are exposed less than 12 inches. Damage to scour counter measures. Probing indicates soft material in scour hole.
5	Significant scour holes, 3 feet or less deep, developing at inlet or outlet. Does not appear to be undermining cutoff walls or headwalls. Bottom of footing is exposed. Major stream erosion behind headwall that threatens to undermine culvert.
4	Major scour holes, 3 feet or deeper, at inlet or outlet undermining cutoff walls or headwalls. Footing is undermined.
3	Streambed degradation causing severe settlement.
2	Culvert closed because of channel failure.
1	Total failure of culvert because of channel failure.

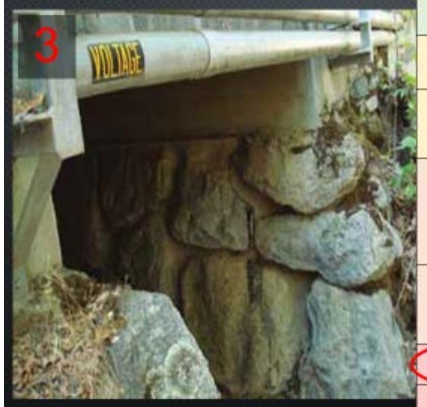
SLAB/SUPERSTRUCTURE & ABUTMENTS

6

Slab/Superstructure & Abutment	Slab
10	No signs of distress. No deceleration.
9	Minor spalling less than ½ inch deep over 5% of deck surface. Hairline cracking without rust staining or delamination. No dampness. No leakage. No spalling. Isolated damage from construction.
8	Hairline cracking with cracking in each grid greater than 1/16 inch parallel to the direction of traffic. Light scaling less than ¼ inch deep or less than 10% of exposed area. Delaminated or spalled areas less than 2% of surface area (not including the first 12 inches of the outside slab edges), isolated damage from construction or vehicle impact. Slab may have a single large crack less than ½ inch or isolated surface parallel to the direction of traffic.
7	Transverse cracks evident on bottom side. Spaced 10'-20' with or without cracks leaking through voids. Some spalling may be present on 2% - 10% of total deck area. Spalled areas with exposed reinforcing on less than 5% of slab area. Hairline map cracking, sometimes with exposed areas. Cracks less than ¼ inch parallel to traffic with minor efflorescence or minor amount of leakage. Scaling less than ¼ inch deep, or less than 20% of slab area. Additional delaminated and spalled areas on less than 10% of surface area (exclude the first 12 inches of the outside slab edges.
6	Map cracking. Cracks less than ¼ inch parallel to traffic and cracks less than 1/16 inch transverse to traffic with efflorescence or rust stain. Leakage and exposed rebar. Scaling less than 3/16th inch deep on less than 30% of exposed area. Spalled areas with exposed reinforcing less than 10%. Total delaminated and spalled areas less than 20% of surface area excluding the first 12 inches of the outside slab edges.
5	Map cracking with dark damp areas and efflorescence over at least 30% of deck bottom. Several transverse cracks open more than ¼ inch with efflorescence and rust staining. Spalling at numerous locations. Extensive surface scaling greater than ¼ inch deep. Reinforcing steel bars have extensive section loss. 4 or more adjacent bars with more than 10% of original diameter lost. Total delaminated and spalled areas greater than 25% of surface area excluding the first 12 inches of the outside slab edges.
4	Refer to the above rating except reinforcing steel bars have extensive section loss. Greater than 20% of original diameter for more than 5 adjacent bars.
3	Full depth holes. Total delaminated, spalled, map cracking, and patchy concrete areas are greater than 50% of surface area. Reinforcing steel bars have extensive section loss. Greater than 30% of original diameter for more than 10 adjacent bars. Additional dark and damp areas over at least 50% of deck.
2	Slab partially collapsed or collapse is imminent.
1	Total failure of Slab.

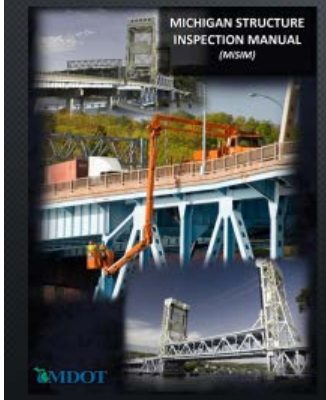
SLAB/SUPERSTRUCTURE & ABUTMENTS EXAMPLE 1

3



Slab/Superstructure & Abutment	Masonry Abutment
10	No signs of distress. Minor spalling of stone surface.
9	Minor spalling of stone surface. Scaling of stone surface less than ½ inch.
8	Diagonal or vertical shear crack in isolated stones. Fracture of stone surface less than 2 inches.
7	Diagonal or vertical shear cracks through several courses of stone with some minor displacement. Spalls along edge of seat area.
6	Diagonal or vertical shear cracks through several courses of stone with displacement. Displacement may be bulge or leaning stones. Total displacement is less than ½ of stone depth.
5	Settlement causing diagonal or vertical shear cracks through several courses of stone with displacement. Total displacement is less than ½ of stone depth. Large fractures or erosion of stone surfaces less than 5 inches on adjacent stones. Spalls on beam seats cause reduced bearing area.
4	Large unsound areas. Several stones are displaced or missing. Misalignment of mortar joints. Large fractures or erosion of stone surfaces greater than 5 inches. Spalls on beam seats causing reduced bearing area.
3	Numerous missing or displaced stones. Displacements greater than 1/3 of stone depth. Partially collapsed wingwall.
2	Partially collapsed abutment.
1	Total failure of abutment.

SLAB/SUPERSTRUCTURE & ABUTMENTS



- These structure types, though less than 20', could be evaluated similar to bridges using the Michigan Structure Inspection Manual

COMBINED CULVERT RATING

- New entries will be entered as subcategories under Culvert Rating
  - One entry for each of the 6 elements requiring rating
  - The lowest of these will auto-populate the overall culvert rating
  - Overall rating can be overwritten at the discretion of the evaluator
  - Individual element ratings will be saved in memo field to allow for future comparison and maintenance needs evaluation

REFERENCES

Arnoult, JD. 1986. Culvert Inspection Manual. Federal Highway Administration (FHWA). IP-86-2. [Available from: https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=31&id=57]

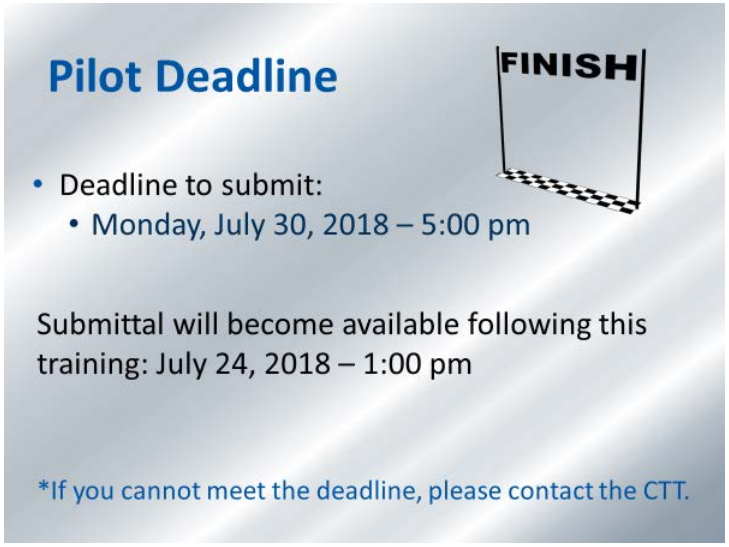
Hunt JH, Zerges SM, Roberts BC, Bergendahl B. 2010. Culvert Assessment and Decision-Making Procedures Manual For Federal Lands Highway, First Edition. Federal Highway Administration (FHWA). CFL/TD-10-005.p. B.1-B.74. [Available from: https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=208&id=166]

MDOT. 2017. Michigan Structure Inspection Manual (MiSIM). Michigan Department of Transportation (MDOT). [Available from: https://www.michigan.gov/mdot/0,4616,7-151-9625_24768_24773-326737--,00.html]

ODOT. 2017. Culvert Inspection Manual. Ohio Department of Transportation (ODOT). p. 29-67. [Available from: http://www.dot.state.oh.us/Divisions/Engineering/Hydraulics/Culvert%20Management/Pages/Culvert-Management.aspx]

WisDOT. 2018. Bridge Inspection Field Manual. Wisconsin Department of Transportation (WisDOT). p. 48-57. [Available from: http://wisconsindot.gov/Pages/doing-bus/eng-consultants/cnslt-rsrces/strct/Inspection-manual.aspx]

APPENDIX K: CULVERT PILOT DATA SUBMITTAL WEBINAR SLIDES



Topics for Today

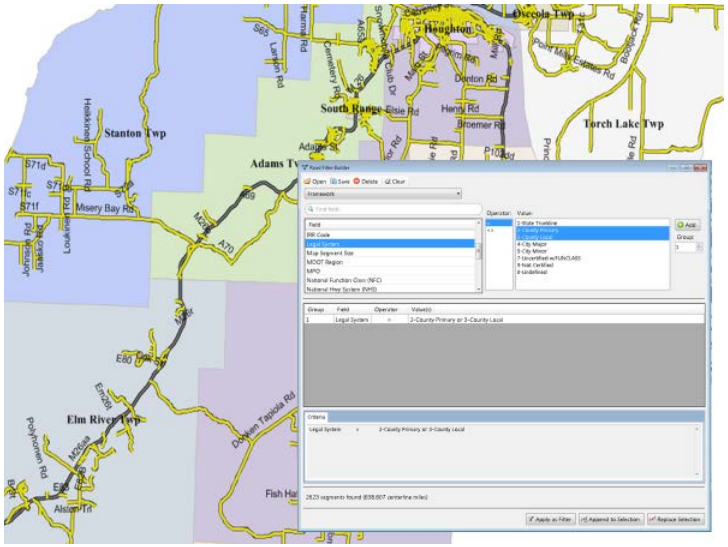
- Culvert Data Submittal
  - Validation
  - Submittal
- Collection Area
  - Mapping Collection Area
  - Submittal

Roadsoft 2018.7

- Available today
- TAMC menu includes two new menu options:
  - ➢Upload Culvert Data file for the Council…
  - ➢Upload Collection Area (roads) File for the Council…

Where to collect Culvert Data?

- Culverts on which Roads?
  - On all but State Trunkline roads



Culvert Definition

- Two open ends
- Less than 20 ft span
- 12” or bigger
- Not driveway culvert

Data Fields to be collected

- Inventory ID
- GPS Coordinates
- Material Type
- Asset Collection Date (Rating Date)
- Shape
- Skew Angle
- Photographs (optional)
- Length (and unit)
- Width (and unit)
- Height/Diameter (and unit)
- Depth of Cover (and unit)
- Roadway Surface Type
- Culvert Rating

Material Types

- Plastic
- Steel
- Timber
- Aluminum
- Concrete

*Other Roadsoft types will also be accepted

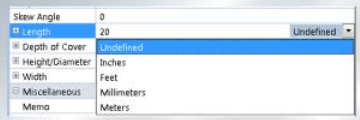
Culvert Shapes

- Box
- Multi-Cell Box
- 3-Sided
- Slab/Superstructure & Abutment
- Circular
- Elliptical
- Arch

*Other Roadsoft types will also be accepted

Units of Measurement

- Be sure to choose units associated with measured fields
  - Length
  - Width
  - Height/Diameter
  - Depth of Cover

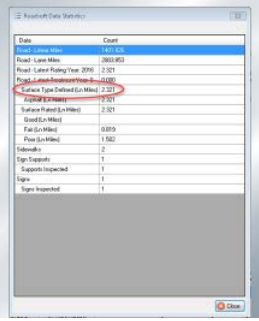


- Less than 6 feet? Use inches…

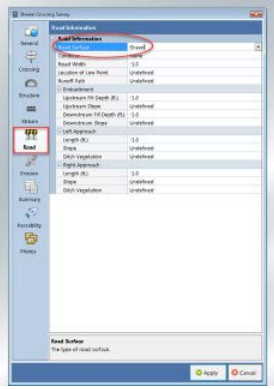
Roadway Surface Type

- If your agency has done PASER ratings on all of your roads, you will not need to collect surface type

Roadsoft Data Statistics
(Asset Management Menu)



Stream Crossing Survey: Road – Road Surface



Where to Enter Collection Fields

Generated for you:
- Inventory ID
- GPS Coordinates

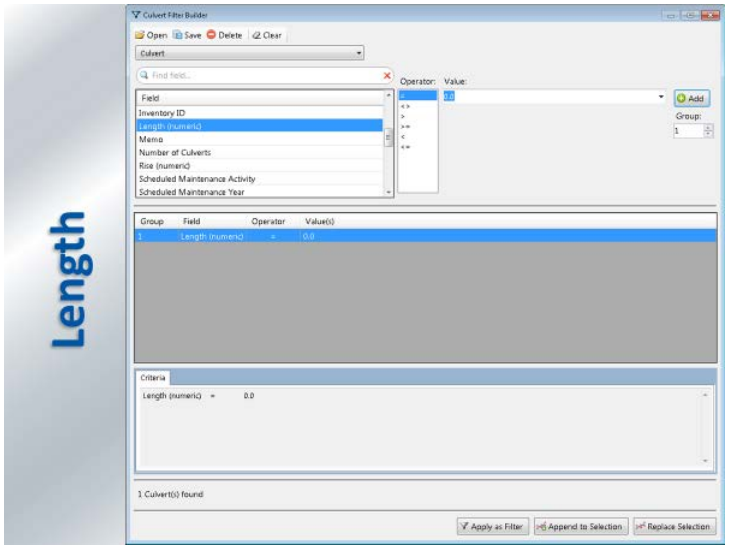
Culvert Tab:
- Material Type
- Shape
- Skew Angle
- Length
- Width
- Height/Diameter
- Depth of Cover

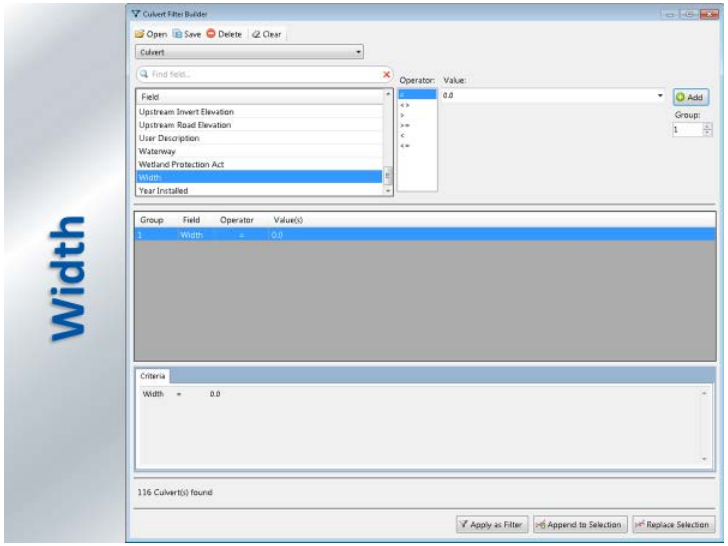
Ratings Tab:
- Asset Collection Date (Rating Date)
- Culvert Rating

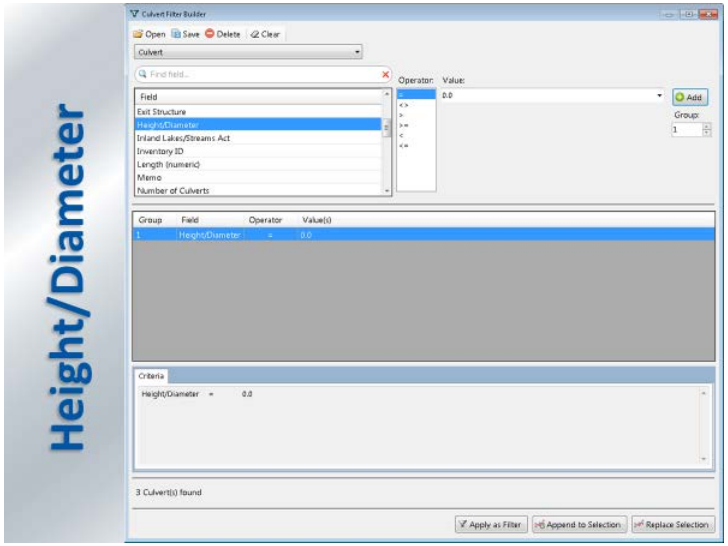
Stream Surveys Tab: Road:
- Roadway Surface Type (or Road Module if collected)

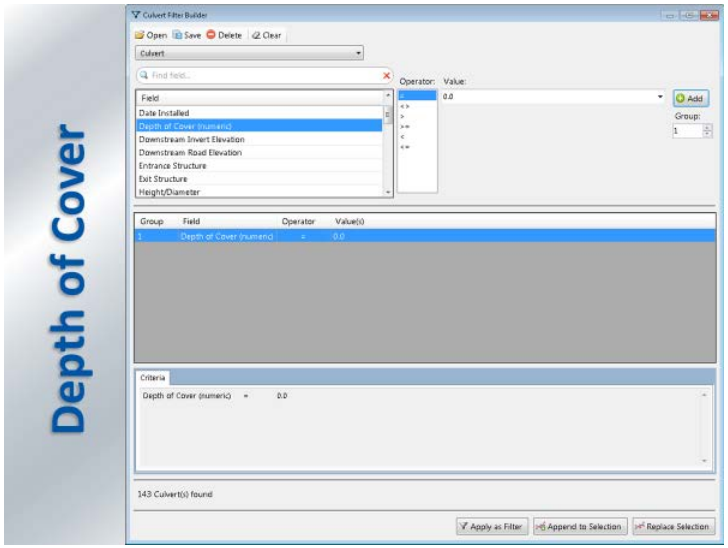
Documents:
- Photographs (optional)

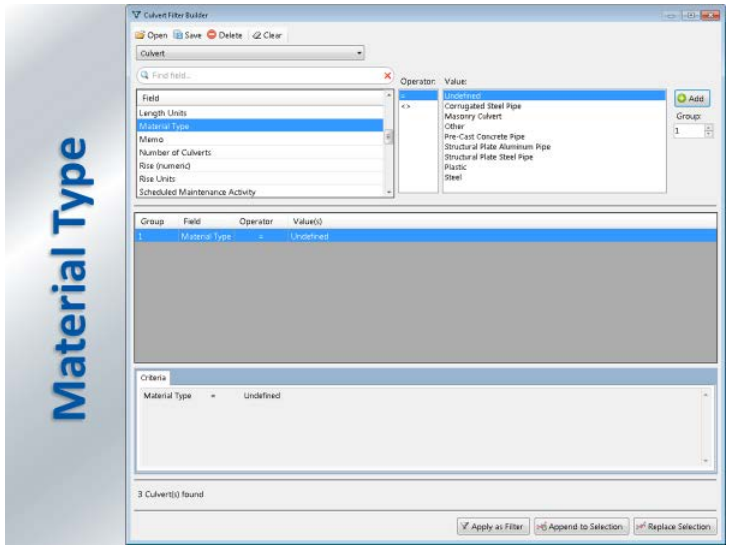
DATA VALIDATION SUGGESTIONS

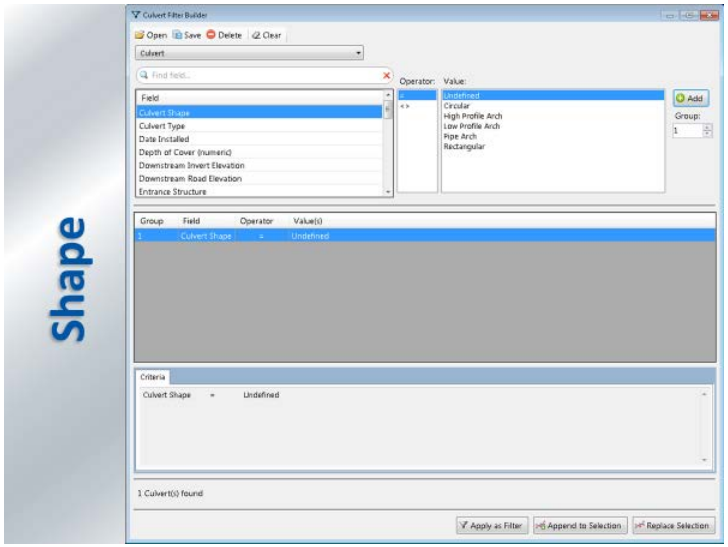

Length
Culvert Filter Builder
Open
Save
Delete
Clear
Culvert
Find field...
Field
Inventory ID
Length (numeric)
Memo
Number of Culverts
Rise (numeric)
Scheduled Maintenance Activity
Scheduled Maintenance Year
Operator:
Value:
Add
Group:
Group
Field
Operator
Value(s)
Criteria
1 Culvert(s) found
Apply as Filter
Append to Selection
Replace Selection

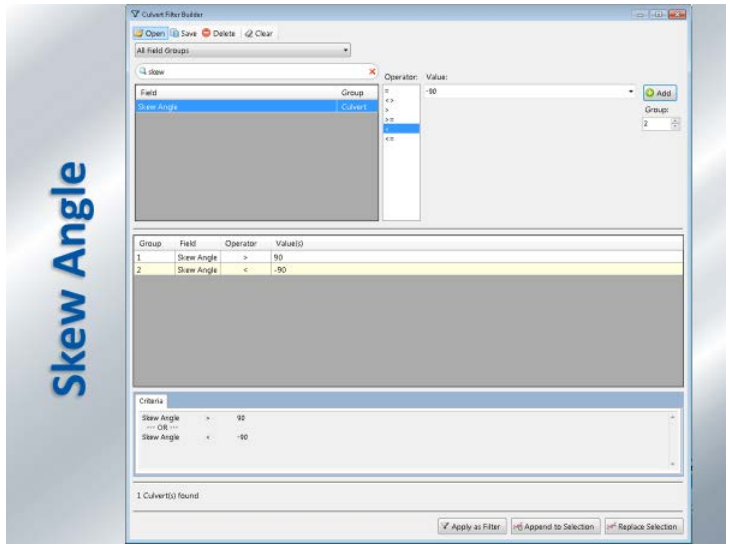

Width
Culvert Filter Builder
Open
Save
Delete
Clear
Culvert
Find field...
Field
Upstream Invert Elevation
Upstream Road Elevation
User Description
Waterway
Wetland Protection Act
Width
Year Installed
Operator:
Value:
Add
Group:
Group
Field
Operator
Value(s)
Criteria
116 Culvert(s) found
Apply as Filter
Append to Selection
Replace Selection

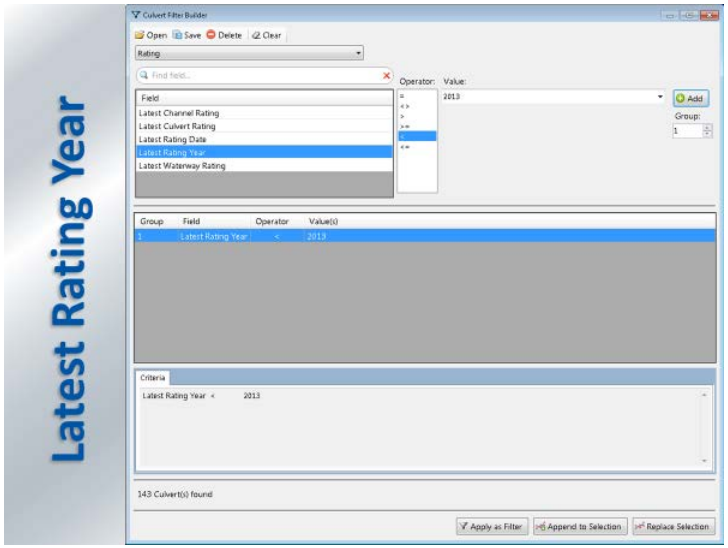

Height/Diameter
Culvert Filter Builder
Open
Save
Delete
Clear
Culvert
Find field...
Field
Exit Structure
Height/Diameter
Inland Lakes/Streams Act
Inventory ID
Length (numeric)
Memo
Number of Culverts
Operator:
Value:
Add
Group:
Group
Field
Operator
Value(s)
Criteria
3 Culvert(s) found
Apply as Filter
Append to Selection
Replace Selection

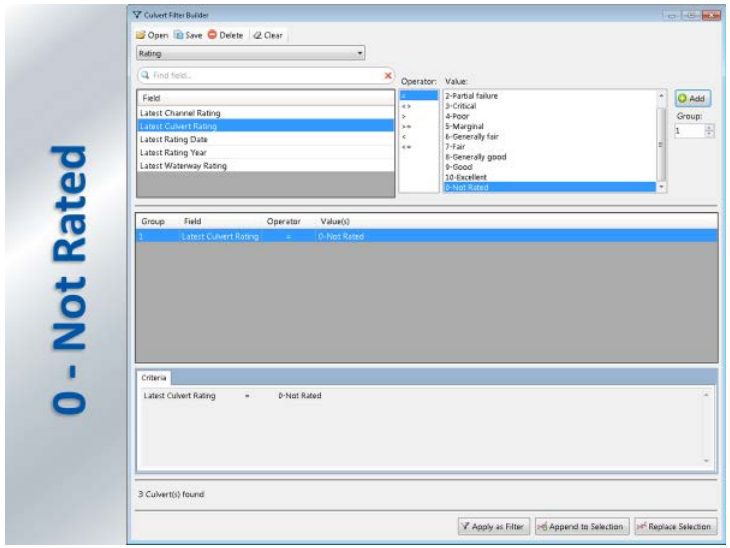

Depth of Cover

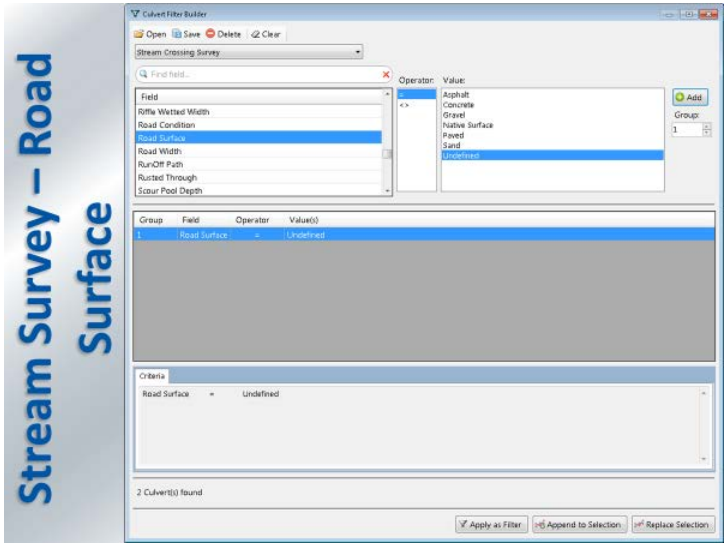

Material Type

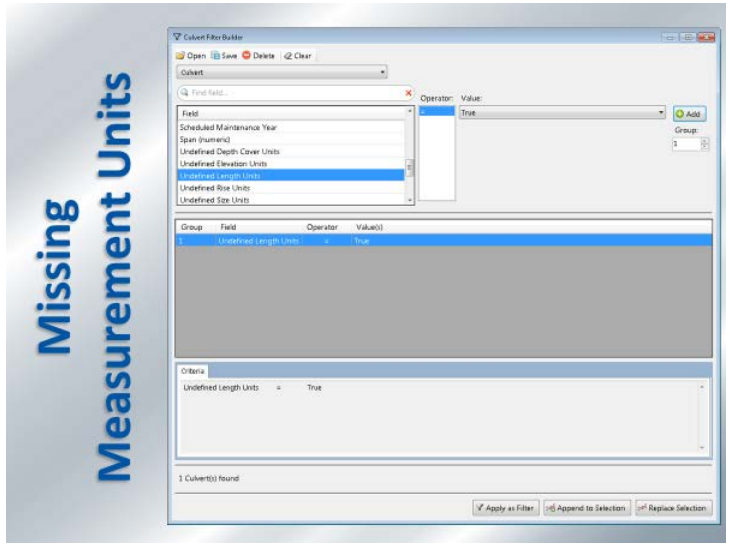

Shape


Skew Angle

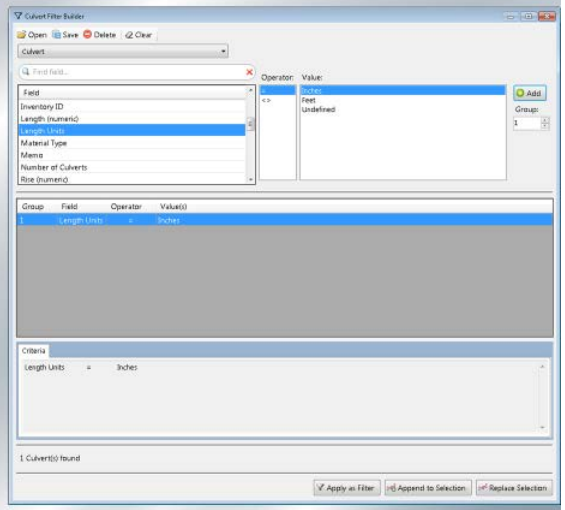

Latest Rating Year


0 - Not Rated


Stream Survey – Road Surface


Missing Measurement Units

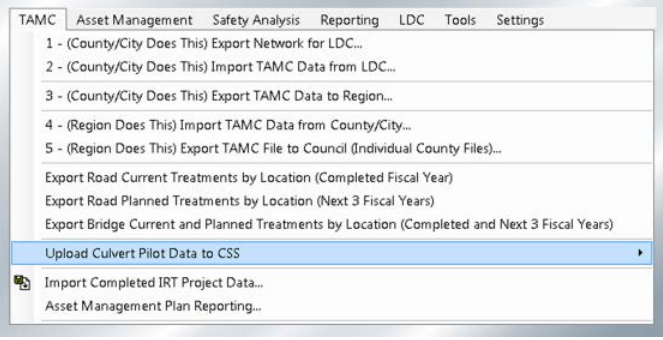
Inconsistent Measurement Units



SUBMITTING CULVERT DATA

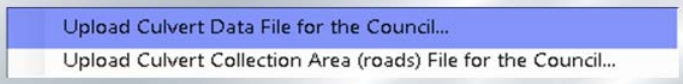
TAMC Menu

- Upload Culvert Pilot Data to CSS



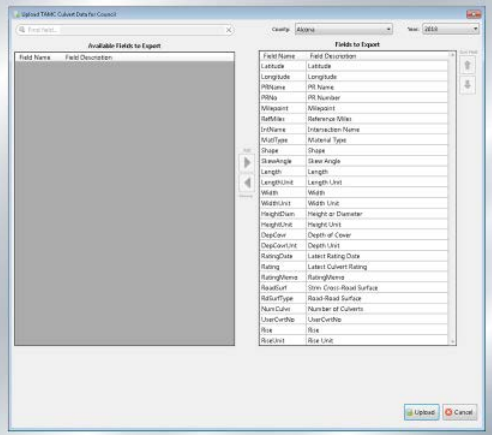
Uploading Culverts

- Culvert Data:
  - ➢Upload Culvert Data File for the Council

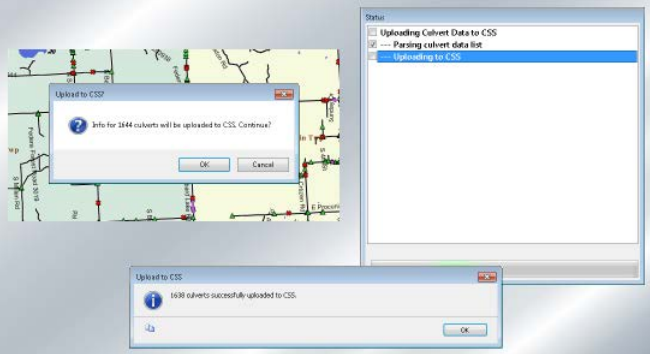


*Uploads data for ALL Culverts

Upload Form



Messages



Problems with transfer?

- Contact the CTT for assistance

METHOD FOR REPORTING COLLECTION AREA

Reporting Collected Mileage

- Must be reportable by collection day
- Must be in electronic geo-located format

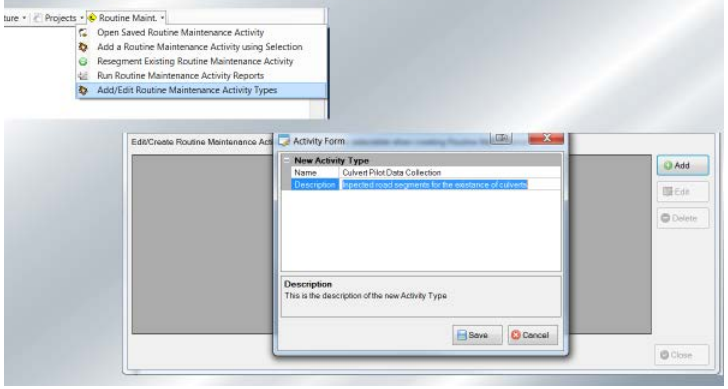
Brainstorming Options

- Track area on paper when collecting and then:
  - Create a Routine Maintenance project
  - Create a Filter from a map selection
  - Use other GIS program to create map
- Define a User-Defined field in the Road Module and collect that field while out in the LDC

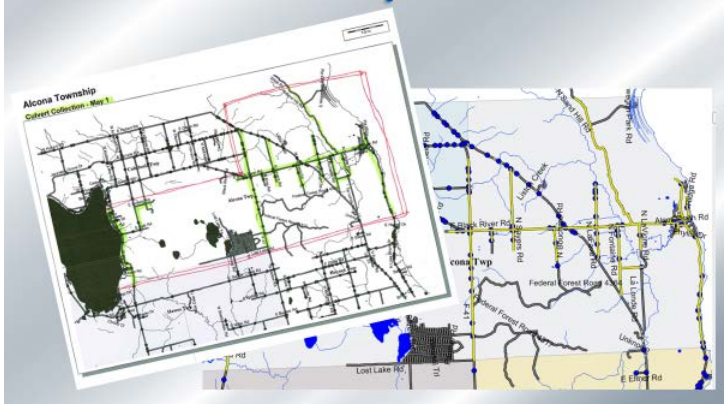
Routine Maintenance Option

- While collecting Culvert data, highlight printed map to mark area
- Then use printed map as a guide to select road segments in Roadsoft
- Create a Routine Maintenance project for the selected segments

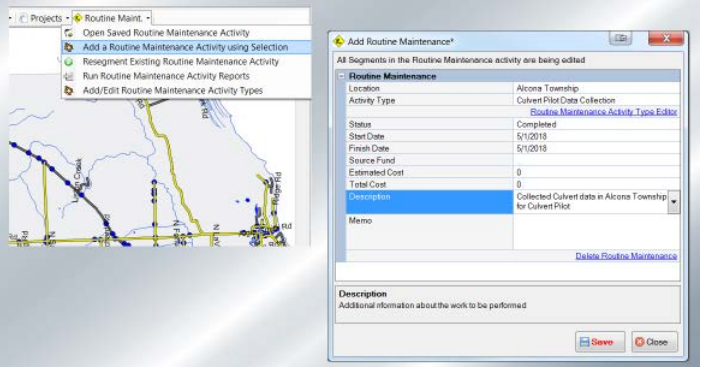
Add Routine Maintenance Type



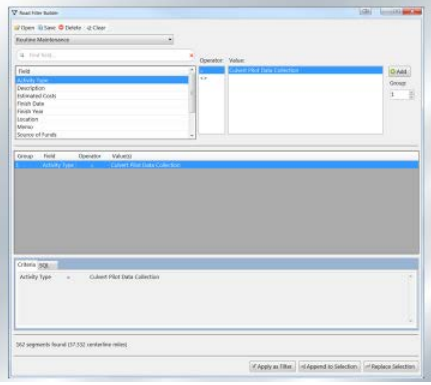
Select Inspected Roads on the map



Add Routine Maintenance Activity



Finding Routine Maintenance Segments

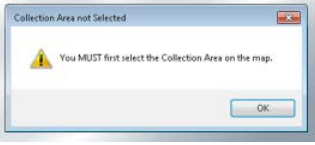


SUBMITTING COLLECTION AREA

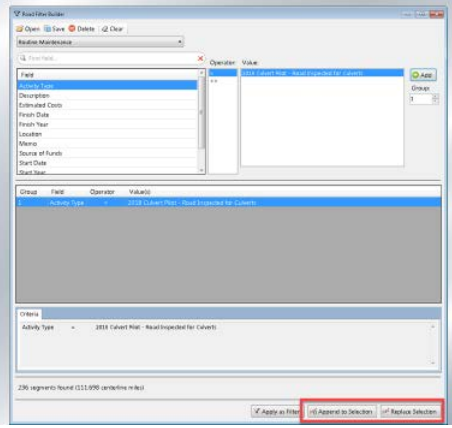
Making selection on map

- Make the ROAD layer the active layer and make the segments selected using some method…

*Your collection area MUST be selected on the map before you use the menu item.

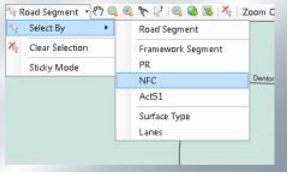


Routine Maintenance

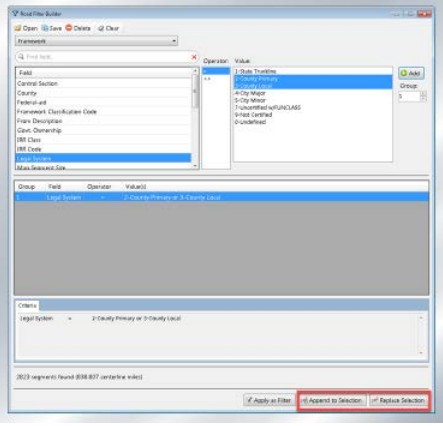


Manual Selection

- Use Select By to set mode
- Add Segments: Ctrl-Click or Shift-Click (or sticky-mode)
- Remove Segments: Alt-Click
- Save Selection as Filter



Filter Selection

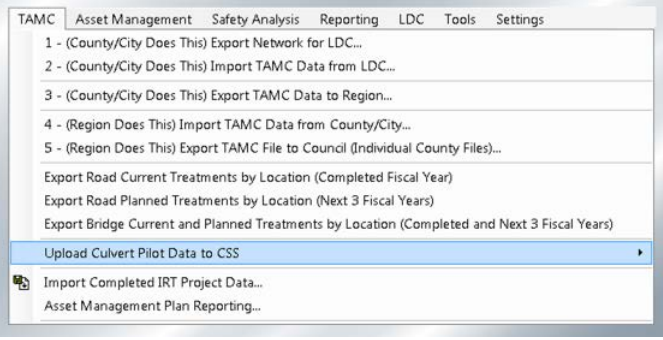


Multiple Saved Filters

- Open one and Apply to the map with Replace Selection
- Open others and Apply to the map with Append to Selection

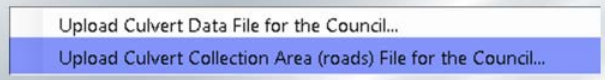
TAMC Menu

- Upload Culvert Pilot Data to CSS



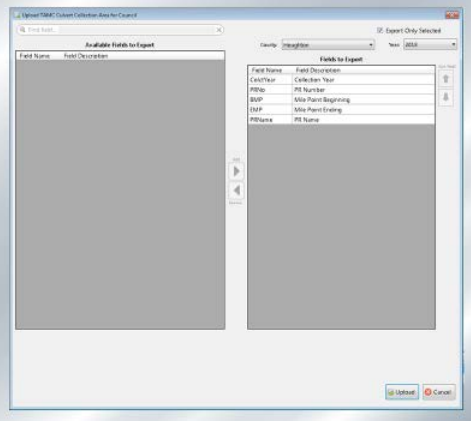
Uploading Collection Area

- Collection Area (Selected Roads):
  - ➢Upload Culvert Collection Area (roads) File for the Council

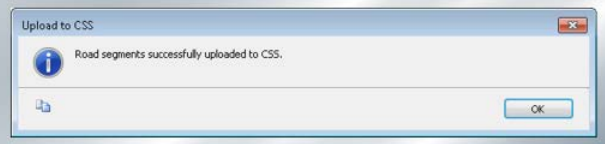


*Uploads only selected roads

Upload Form



Messages



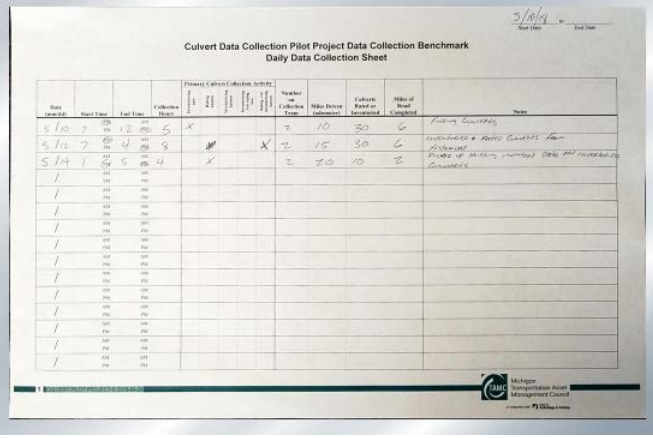
Problems with transfer?

- Contact the CTT for assistance

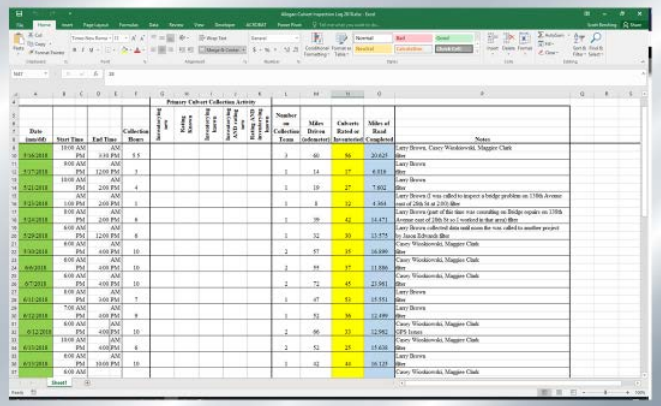
Other Data Submission

- Culvert Data for Non-Roadsoft Users
  - GIS project export, shapefile, or spreadsheet containing lat & long, as well as all other required data fields emailed to **bersh@mtu.edu**
- Daily Logs
  - Electronic or scanned copies of handwritten logs emailed to **bersh@mtu.edu**
- Mileage Logs for Non-Roadsoft Users
  - Highlighted maps, GIS Maps, etc emailed to **bersh@mtu.edu**

Daily Logs

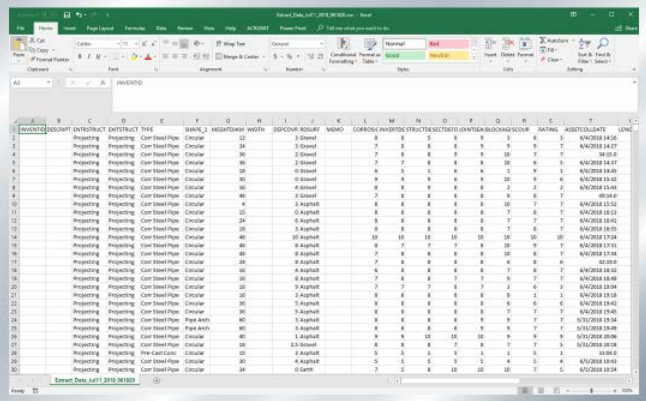

Culvert Data Collection Pilot Project Data Collection Benchmark
Daily Data Collection Sheet

Daily Logs



Non-Roadsoft User Culvert Data

Non-Roadsoft User Culvert Data



Non-Roadsoft User Mileage

Next Steps

- CTT will create a follow-up survey for participating agencies.
- CTT will work with the Michigan Department of Technology, Management and Budget and assist TAMC with compiling and disseminating data.
- CTT will work with the TAMC Bridge Committee to complete a final report summarizing the pilot, noting observations & lessons learned, and highlighting best practices, by September 30, 2018.

Questions?

APPENDIX L: REGIONAL CULVERT MAPS

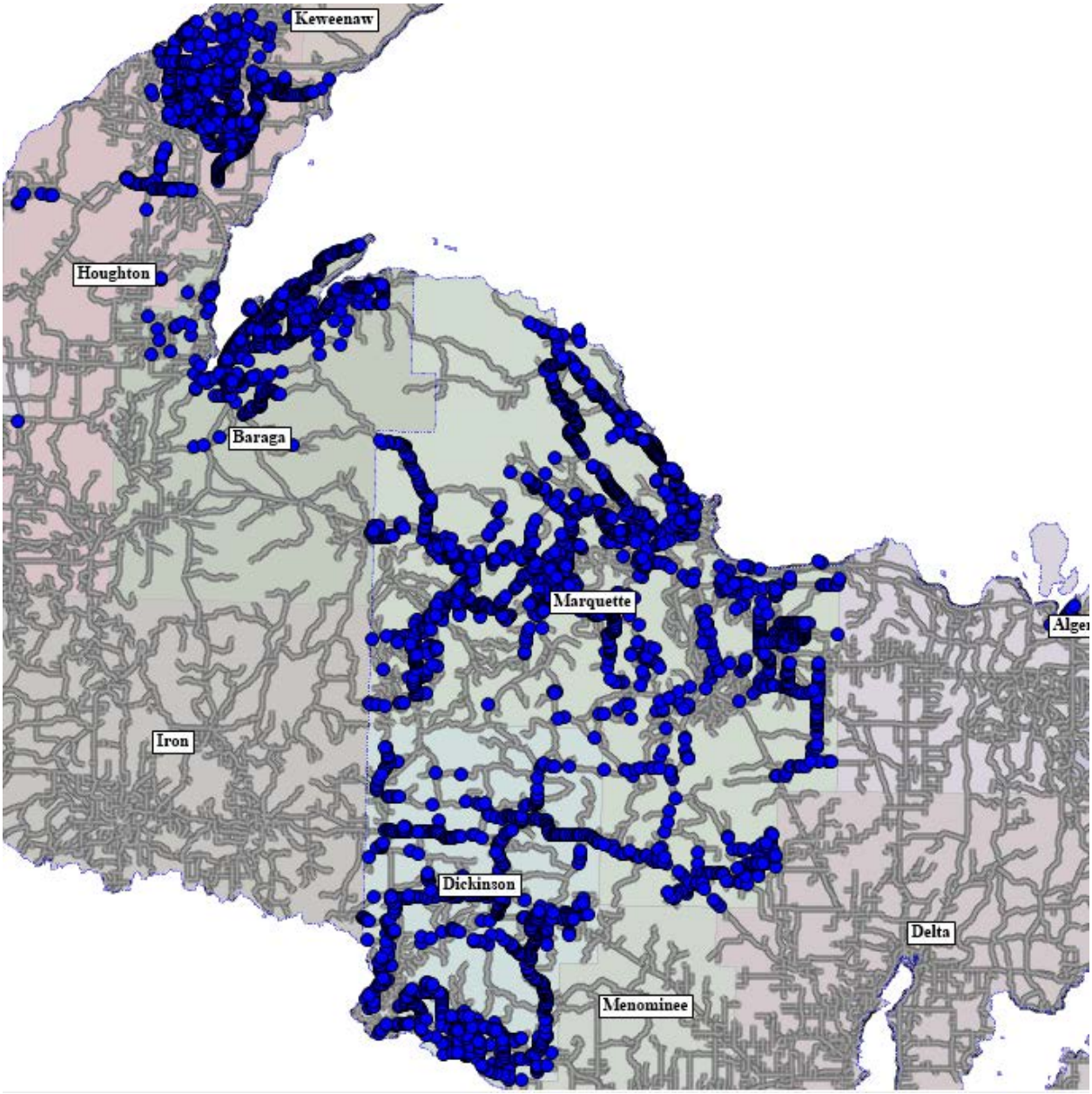


Figure 18: Western and central upper peninsula regional culvert data

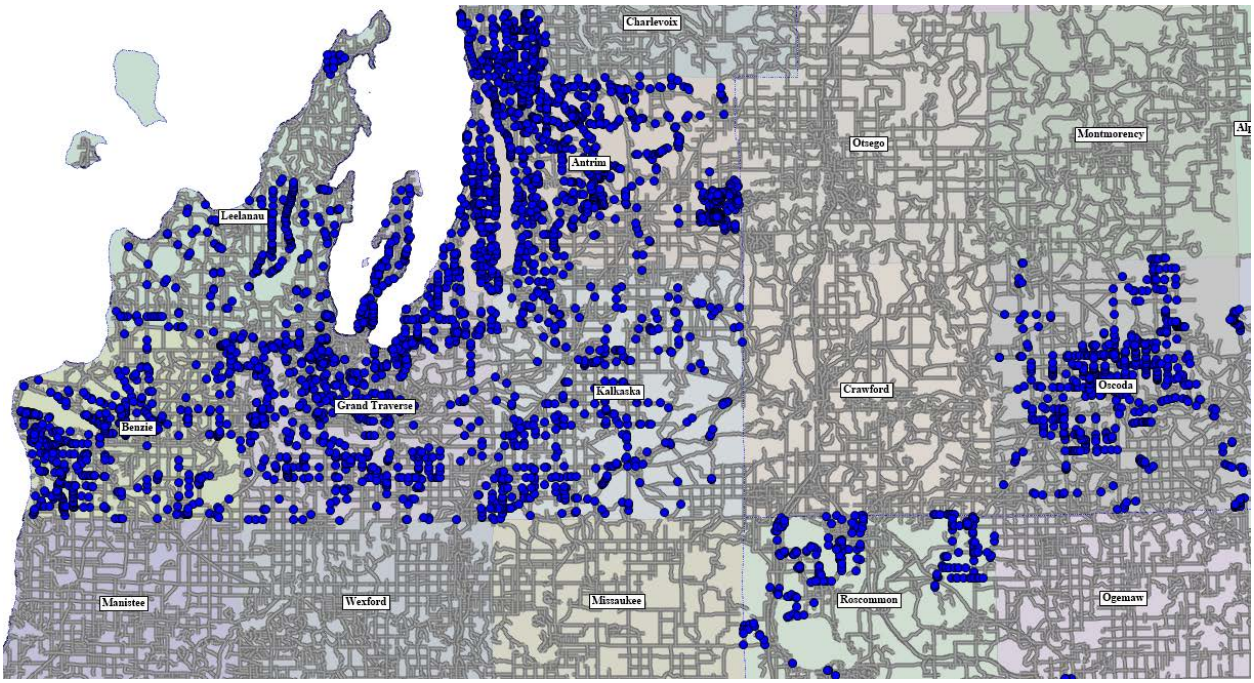


Figure 19: Northern lower peninsula regional culvert data

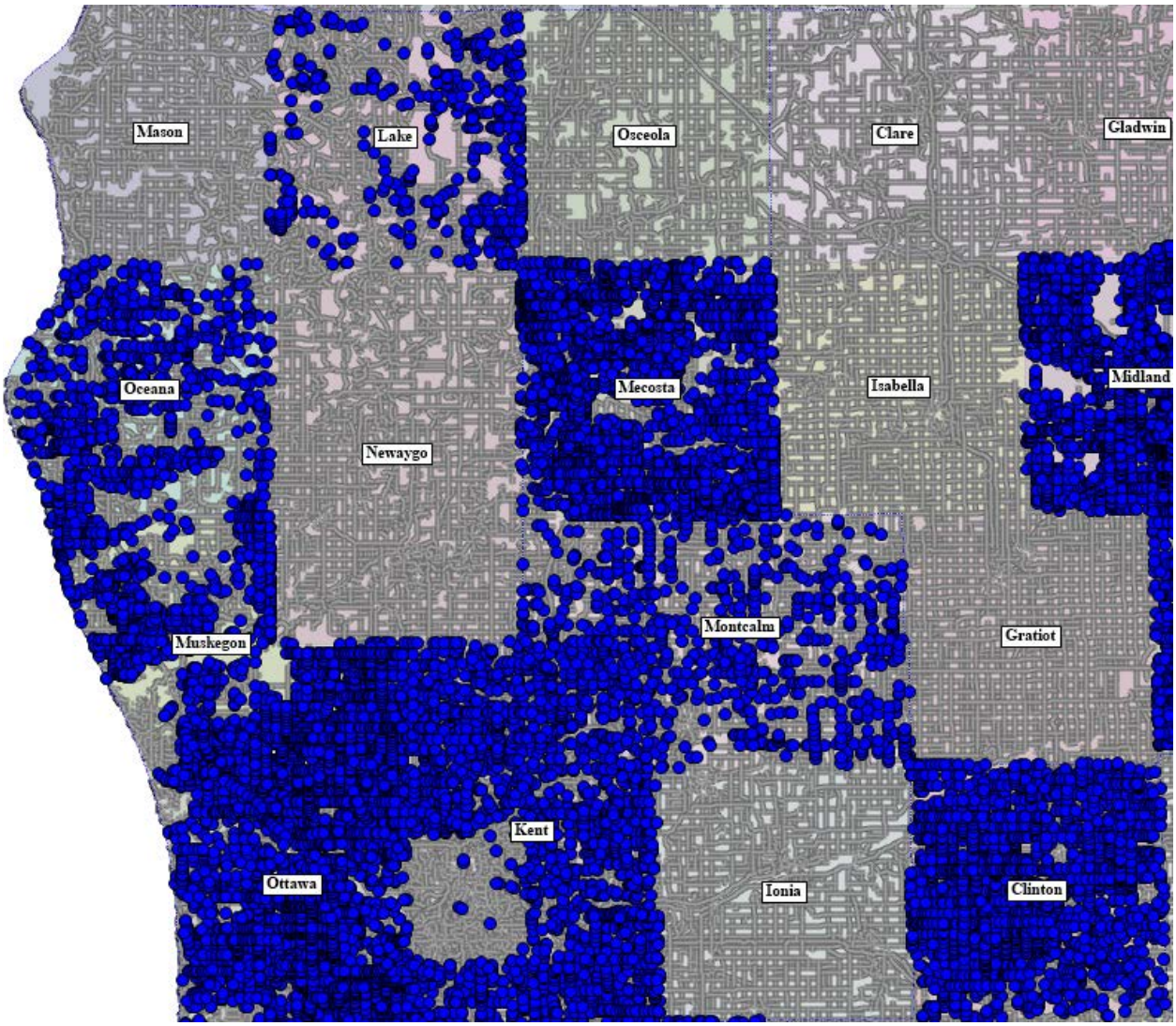


Figure 20: Western lower peninsula regional culvert data

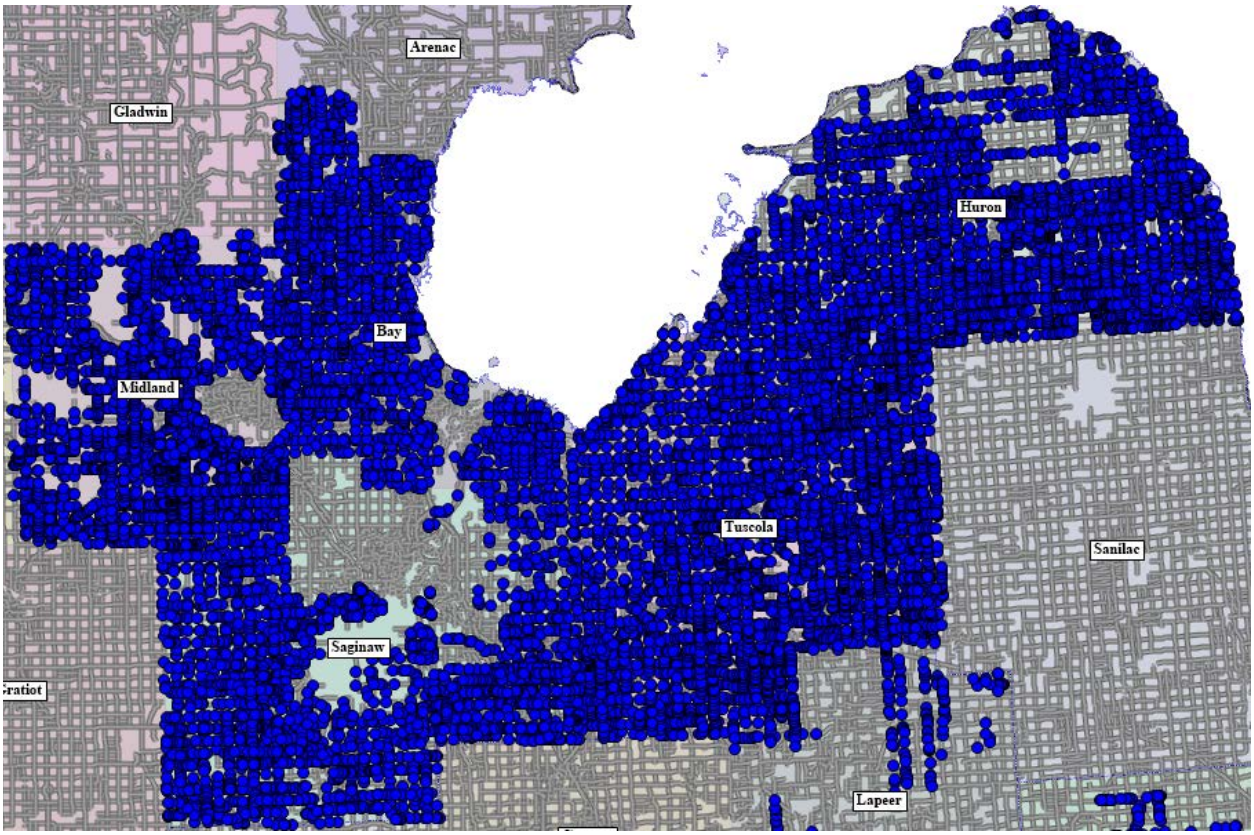


Figure 21: Eastern lower peninsula regional culvert data

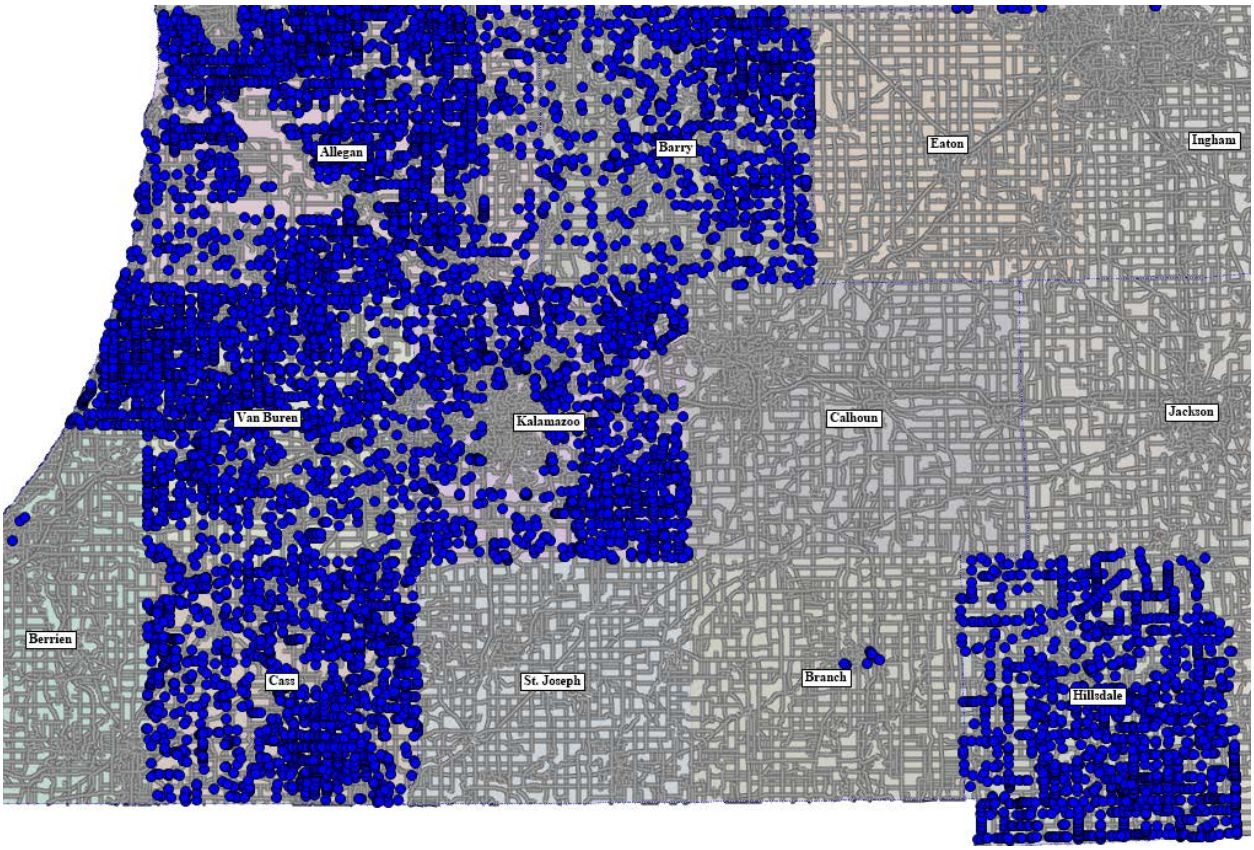


Figure 22: Southwestern lower peninsula regional culvert data

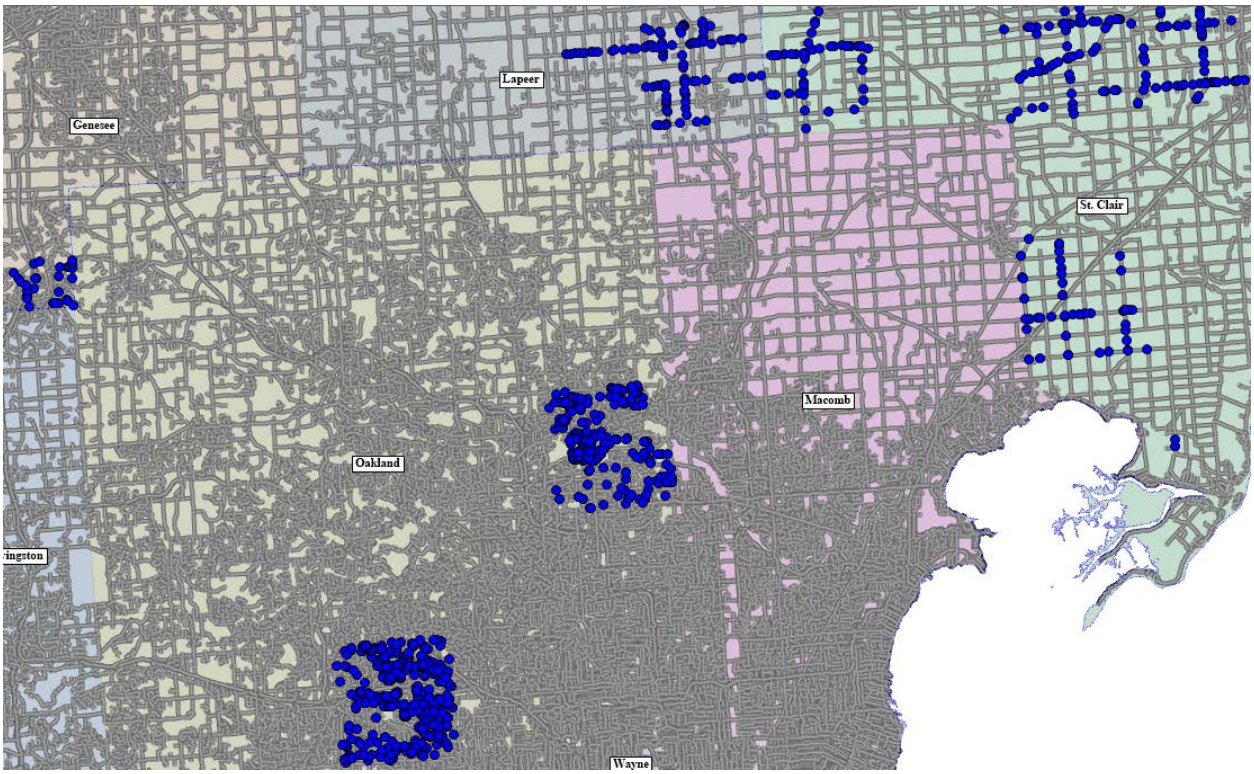


Figure 23: Southeastern lower peninsula regional culvert data

APPENDIX M: FOLLOW-UP SURVEY

TAMC Michigan Local Agency Culvert Data Collection Pilot Project Follow-Up Survey

Thank you for participating in the Transportation Asset Management Council's (TAMC) 2018 Michigan Local Agency Culvert Inventory Pilot Project. We realize that this project had an extremely short timeframe and tight deadlines, and we appreciate the amount of effort it took for your agency to participate.

Now that the data submittal deadline has passed, we're hoping you'll be able to take a few minutes to participate in another survey asking about your experiences and to provide feedback and suggestions for potential future culvert-related data collection activities. This information will be used in the final report on the project and to determine best practices and recommend procedures for the future across the State.

We sincerely appreciate all your efforts in asset management and thank you in advance for your participation.

Sincerely,

Rebecca Curtis, TAMC Bridge Committee Chair

1) Which of the following best describes your culvert inventory and condition evaluation program prior to participating in the pilot:
    a. Culverts had not been inventoried or condition evaluated.
    b. A portion of agency culverts had been inventoried, but none or very few have had their condition evaluated on a routine basis (at least once every 5 years).
    c. Most culverts had been inventoried and their condition evaluated on a routine basis (at least once every 5 years).
2) How many culverts have been inventoried as part of this pilot?
    a. What percentage of the culverts in your jurisdiction do you feel this represents? (Note: enter 100% if you believe every culvert is included in your inventory data)
3) What culvert characteristics did you record?
    a. Inventory ID
    b. GPS Coordinates
    c. Material Type
    d. Asset Collection Date
    e. Shape
    f. Skew Angle
    g. Length
    h. Span (width)
    i. Rise (height/diameter)
    j. Depth of Cover

k. Roadway Surface Type
l. Culvert Rating
m. Photographs
n. Other –

4) Which of these characteristics do you feel are important, or do you plan to continue to record in the future?
    a. Inventory ID
    b. GPS Coordinates
    c. Material Type
    d. Asset Collection Date
    e. Shape
    f. Skew Angle
    g. Length
    h. Span (width)
    i. Rise (height/diameter)
    j. Depth of Cover
    k. Roadway Surface Type
    l. Culvert Rating
    m. Photographs
    n. Other –
5) How did you organize and store your culvert inventory data?
    a. Roadsoft
        i. If Not
        ii. Do you use Roadsoft for other road asset data collection?
            1. If so, please specify why Roadsoft wasn't used for this pilot (this will help with future development of the software)?
    b. ArcGIS (or similar)
        i. Other
    c. Other
6) How frequently do you plan to evaluate the condition of your culverts?
    a. Will the frequency vary depending on culvert size, material, condition of roadway above, or other properties?
7) How do you plan to use the data you've collected as part of this pilot?
8) If you collected both inventory and condition data, did you do it at the same time?
        a. Yes:
            i. Please describe the procedures you used to collect the data at the same time.
            ii. Please describe the tools you used to collect the data at the same time.
            iii. Do you have any recommendations for tools for inventory or condition evaluation that helped with collecting data at the same time, based on your agency's experience with the pilot?

b. NO:
    i. Please describe the procedures you used to collect the data.
    ii. Please describe the tools you used to collect the data.
    iii. Do you have any recommendations for tools for inventory or condition evaluation based on your agency's experience with the pilot?

9) Do you have an estimate of time it took to collect the data for each culvert? Location, physical attributes, condition, etc?
10) Do you have an estimate on the cost to collect the data for each culvert? Location, physical attributes, condition, etc?
11) Do you have any feedback on personnel necessary to collect the data for the pilot project - did you use 1,2 or more persons?
12) What time of the year would you recommend for future data collections?
13) What procedures did you use to collect inventory and condition data?
14) If you did not complete your inventory, do you have plans to do so outside of the project?
15) If you did not complete your condition assessments, do you have plans to do so outside of this project?
16) Did you or your crew experience anything odd/surprises/something worth sharing (ie – critters, other unexpected things)?
17) Please share any other comments regarding the TAMC 2018 Michigan Local Agency Culvert Inventory Pilot Project or your agency's current culvert inventory and condition evaluation program.
18) Would you be willing to be interviewed over the phone for more information and details regarding your responses to this survey?
19) Agency –
20) Name –
21) Email –
22) Phone number –

Any further narrative or comments can be sent via email to Scott Bershing at the Center for Technology & Training at bersh@mtu.edu.

APPENDIX N: SAMPLE CULVERT ASSET MANAGEMENT DOCUMENT

Purpose: This section should discuss the motivation behind creating and implementing a culvert management program. Possible motivations include maximizing useful service lives of culverts, implementing proactive maintenance over reactive replacement or rehabilitation, using funding in the most cost-effective manner, etc. An example is provided below:

The ___ County Road Commission (_CRC) seeks to implement a cost-effective program of preventive maintenance to maximize the useful service life of the local culverts under its jurisdiction.

The agency recognizes that limited funds are available for improving the culvert network. Preventive maintenance is a more effective use of these funds than the costly alternative of major rehabilitation or replacement, and we seek to identify those culverts that will benefit from a planned maintenance program.

Goal: This section should summarize the broad, overall goal of the culvert management system. An example is provided below:

The goal of the culvert management system is the preservation of the County's culvert network in a cost effective manner.

Objectives: This section should discuss measurable outcomes specifically leading to the achievement of the stated goals. Possible objectives could include establishing the current condition of your agency's culverts, implementing preventative maintenance techniques and rehabilitating / replacing deteriorated culverts, identifying funding sources, prioritizing action in a cost efficient manner, having all culverts above a certain condition rating, etc. An example is provided below:

The _CRC's objectives in implementing a culvert management program include:

- *Establishing the current condition of culverts;*
- *Developing a "mix of fixes" that will:*
  - *Program regular scheduled maintenance actions to impede deterioration of culverts in satisfactory or above condition;*
  - *Implement selective corrective repairs or rehabilitation to degraded culvert elements to restore functionality;*
  - *Identify and program those eligible culverts in need of replacement;*
- *Identifying available funding sources;*
  - *Dedicated County resources;*
  - *Maximize opportunity to obtain other funding;*
- *Prioritizing the programmed actions within available funding limitations;*
- *Having 80% of culverts rated as satisfactory to excellent and less than 10% classified as serious to failed within 10 years.*

Performance Measure: This section should discuss specific metrics for determining the success of a culvert management system. An overarching metric for performance is the increase in service life at a certain condition state. Some methods of measuring this performance rely on knowledge of how long culverts will perform at a certain condition rating; this knowledge comes from tracking past performance or relying on estimates. If your agency does not have knowledge of the average service lives of different culvert materials an alternative performance metric could more simply be the increase in condition rating by certain maintenance actions, annual changes in the number of culverts rated at a certain condition level, or some combination of all of these metrics. An example is provided below:

Several metrics will be used to assess the effectiveness of the culvert management plan. _CRC will monitor and report the annual change in the number of its culverts rated satisfactory to excellent (7 or higher) and the annual change in the number of serious to failed culverts. A tracking graph will be used to monitor progress toward an objective of having 80% of the County's culverts rated satisfactory to excellent and less than 10% classified as serious to failed.

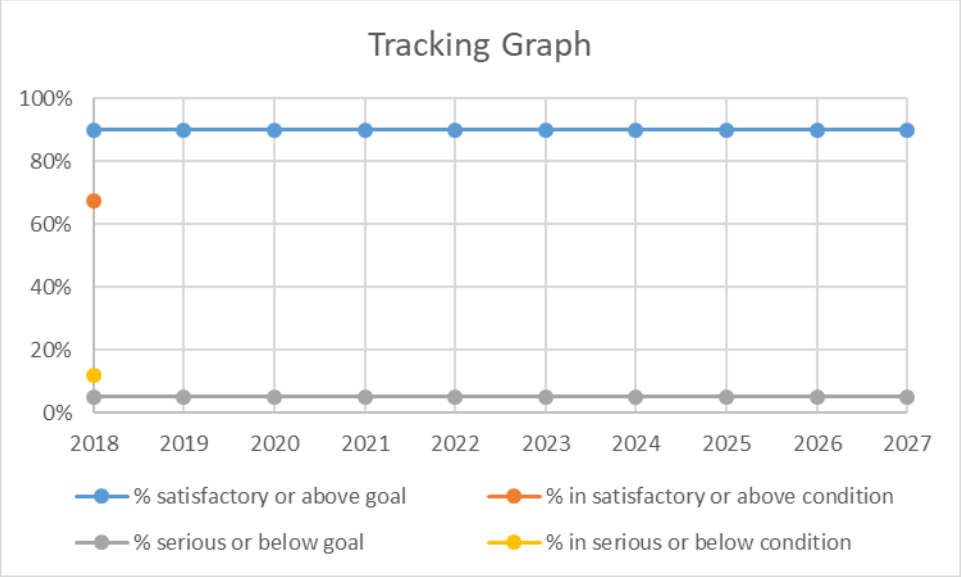


Figure 24: Tracking Graph

The preservation plan is intended to extend the period of time that culverts remain in condition states satisfactory to excellent, thereby increasing their useful service life and reducing future maintenance costs. Based on past inspection records and condition ratings, the _CRC will establish a baseline of past performance by determining the average period of time that a culvert remains in satisfactory to excellent condition. The performance measure will be the increased average amount of time at the satisfactory to excellent condition state after implementation of the preservation strategy when compared to the base line time before the implementation.

Culvert Assets & Condition Analysis: This section should outline general information about your agency's culvert inventory and condition ratings. Consider a breakdown of culverts by material type, structure type, or other relevant features and list percentages of culverts in each condition rating in accordance with your agency's goals. Compare your inventory with the statewide inventory and draw conclusions about the relative state of your culverts. Attach full inventory data as an Appendix to the document if there is too much data to be presented in the body of the report. Include proposed maintenance actions in the appendix as well if there have been actions proposed. An example is provided below:

_ CRC is responsible for 420 culverts. Detailed inventory data, condition ratings, and proposed preventive maintenance actions for each culvert are contained in tables in the appendices. The culvert inventory and condition evaluation data was obtained from the Michigan Local Agency Culvert Inventory & Condition Evaluation Pilot in accordance with FHWA specifications. A summary and distribution of the culvert population is presented in the following table:

Table 1. _CRC Culvert Inventory and Condition Ratings

Culvert Type	# of culverts	2018 Condition Rating									
		1	2	3	4	5	6	7	8	9	10
CMP	153	3	5	10	2	9	19	33	46	26	3
Concrete	189	0	7	8	5	14	39	43	49	19	2
Plastic	59	1	4	1	2	0	9	20	15	8	4
Masonry	3	0	0	0	0	0	2	0	1	0	0
Timber	1	0	0	0	0	0	0	0	1	0	0
Slab & Abutment	15	0	0	0	2	0	0	2	10	0	1
		1.0%	3.8%	4.5%	2.6%	5.5%	16.4%	23.3%	29.0%	12.6%	2.4%
		Serious or Lower						Satisfactory or Better			
		11.9%						67.4%			

Of the _CRC's 420 structures, 153 are corrugated metal pipe (CMP), 189 are concrete, 59 are plastic, 3 are masonry, 1 is timber, and 15 are slab and abutment. The distribution of overall condition is: 11.9% are at a serious to failed condition state, 88.1% are at a satisfactory or better condition state. Statewide, MDOT's statistics for local agency culverts show that 9.0% are at a serious to failed condition state and 91.0% are at a satisfactory to excellent condition state, indicating that _CRC has a greater percentage of serious to failed culverts compared to the statewide average for local agencies.

Certain culverts rated in serious or lower condition require replacement or major rehabilitation. Many of the remaining culverts require one-time preventive maintenance actions to repair defects and restore the structure to a higher condition rating. Most culverts are included in a scheduled maintenance plan with appropriate maintenance actions programmed for groups of culverts of similar material and type, bundled by location.

Risk Management: This section should discuss risks associated with culverts and propose a plan to help mitigate these risks such as the establishment of a regular inspection program and an

operations and maintenance program. Details of these programs should be discussed as well as they relate to risk mitigation. An example is provided below:

The _CRC recognizes that potential risks associated with culverts generally fall into several categories:

- *Personal injury and property damage resulting from a culvert collapse or partial failure;*
- *Loss of access to a region or individual properties resulting from culvert closures, restricted load postings, or extended outages for rehabilitation and repair activities; and*
- *Delays, congestion, and inconvenience due to serviceability issues, such as poor quality riding surface, development of sinkholes, etc.*

The _CRC addresses these risks by implementing a regular culvert inspection program and a preservation program of preventive maintenance. _CRC administers the biennial inspection of its culverts in accordance with the FHWA suggestions. The inspection reports document the condition of _CRC's culverts and are evaluated to identify new defects and monitor advancing deterioration. A summary inspection report is then generated and identifies items requiring follow-up special inspection actions and recommends culvert-by-culvert maintenance activities.

The preservation program identifies actions in the operations and maintenance plan that are preventive or are responsive to specific culvert conditions. The actions are prioritized to correct critical structural safety and traffic issues first, then to address other needs based on the operational importance of each culvert and the long term preservation of the network. The inspection results are used to modify and update the operations and maintenance plan annually.

Preservation Strategy: This section should discuss specific actions for improving / maintaining culvert condition and should discuss the priority of each action. Many agencies employ a "Mix-of-Fixes" strategy that incorporates replacement, rehabilitation (R&R), preventive maintenance, and scheduled maintenance simultaneously to address numerous types of culvert concerns. An example is provided below:

_CRC's culvert management system employs a balanced "Mix of Fixes" strategy made up of Replacement, Rehabilitation, Preventive Maintenance, and Scheduled Maintenance. The aim of this plan is to address culverts of critical concern by targeting the poorest rated elements, and improve the overall condition of the culvert network to satisfactory to excellent condition.

***Replacement** involves complete structure replacement, and is intended to improve critical to failed culverts to an excellent condition rating.*

Rehabilitation *is undertaken to extend the service life of existing culverts. The work will restore deficient culverts. Rehabilitation actions are intended to improve serious to fair condition culverts to an improved condition state.*

Preventive Maintenance *work will improve and extend the service life of fair or poor condition culverts. Preventive Maintenance projects are directed at limited culvert elements that are rated in fair or poor condition with the intent of improving these elements to a satisfactory or greater condition rating. Most preventive maintenance projects will be one-time actions in response to a condition state need. Routine preventive work will be performed by the County's in-house maintenance crews, while the larger more complex work will be contracted.*

_CRC's Scheduled Maintenance program is an integral part of the Preservation Plan, and is intended to extend the service life of satisfactory to excellent structures by preserving the culverts in their current condition for a longer period of time. Scheduled maintenance is proactive and not condition driven. In-house maintenance crews will perform much of this work.

The "Mix of Fixes" strategy combines long-term replacement, medium-term rehabilitation, and short-term preventive maintenance with a regular program of scheduled maintenance. Implementing this balanced mixture, as described in the Operations and Maintenance Plan below, will increase the number of culverts improved each year and preserve the overall health of _CRC's culvert network.

Implementation of the Strategy: This section should discuss how your agency plans to implement its developed strategy. This includes discussion of specific maintenance actions, and references to your agency's specific culvert inventory needs. An example is provided below:

_CRC's implementation of a culvert management system strategy begins with an annual review of the current condition of each of the County's culverts using biennual inspection data and the inspector's work recommendations from the Roadsoft inspection records. The inspection inventory and condition data are consolidated in a spreadsheet for _CRC's culverts in the appendix. Preventive maintenance needs are determined for each culvert and the corresponding actions are identified and assembled on a spreadsheet, sorted by culvert material and type in the appendix along with inspection follow-up actions.

The preservation actions are selected in accordance with criteria contained in the table below. These criteria are based on research into other agencies effective actions. _CRC has modified the selection criteria slightly to better address its local culvert network.

Table 2. Preservation Actions (NOTE: use this list as an example ONLY)

Action	Culvert Selection Criteria	Expected Improved
Replacement		
Total Replacement	Overall condition rating < 4, rehabilitation exceeds cost of replacement or does not add as much benefit	10
Structural Segment Replacement	Structural deterioration rating < 5, rehabilitation exceeds cost of replacement or does not add as much benefit	9
Headwall Replacement	Scour rating < 5, if headwall already present, rehabilitation exceeds cost of replacement or does not add as much	9
Embankment Replacement	Scour rating < 4, excessive loss of embankment that cannot be rehabilitated	9
Rehabilitation		
Invert Paving	Invert deterioration rating < 3, CMP material, replacement exceeds cost of rehabilitation	9
Concrete Crack Sealing w/ fiberglass plastic mortar (FPM)	Invert or structural deterioration rating < 4, concrete material, replacement exceeds cost of rehabilitation	8
Slip lining with PVC	Invert deterioration rating < 4, replacement exceeds cost of rehabilitation	7
Preventative Maintenance		
Concrete crack sealing with mortar	Invert or structural deterioration rating < 7, concrete material	7
Bolt replacement	Structural deterioration rating < 7, bolts are reason for deterioration rating	7
Full painting	Invert or structural deterioration rating < 5, CMP material	8
Scheduled Maintenance		
Debris clearing	Blockage rating < 9	9
Spot Painting	Invert or structural deterioration rating < 7, CMP material	7
Vegetation Control	Blockage rating < 9, vegetation is a cause of blockage	9

Cost Estimate: This section should briefly discuss how cost estimates are generated for each preservative action. Discuss specific documents and references used to establish cost estimates. An example is provided below:

> *_CRC computes the estimated cost of each typical preservation action using unit prices based on previous culvert work performed within the county. The cost of items of varying complexity, such as maintenance of traffic, staged construction, scour countermeasures, etc., are computed on a culvert-by-culvert basis. The cost estimates are reviewed and updated annually.*

Operations and Maintenance Plan – Annual Activities / _-Year Program: This section should discuss the specific culverts from your inventory that will undergo preservative action within a specified time frame. Different plans can be made for different objectives such as one plan for restoration actions and another for preservative actions. Standard time frames for operations and maintenance plans are often five or ten years, although varying time frames can be specified based on short- and long-term goals. The subsections will discuss the criteria for selecting these specific culverts and forecast anticipated costs. An example is provided below:

> *A primary objective of _CRC's preservation plan is improvement of the 142 culverts rated fair or lower to a rating of satisfactory or higher within ten years through a program of replacement, rehabilitation, and preventive maintenance actions. The work has been prioritized considering each individual culvert's needs, its criticality, present cost of improvements, and impact of deferral (cost increase due to increased degradation). A corresponding five-year program incorporates comprehensive annual scheduled maintenance activities designed to preserve culverts currently rated satisfactory or higher with the objective of extending their useful service life.*

Project Prioritization Criteria: This section discusses the methods used to determine which projects should be performed first. Describe how your agency plans to perform projects in the most logical, cost-efficient manner. A tabulated breakdown of prioritizing criteria may be considered if warranted for your agency's specific prioritization method. An example is provided below:

> *_CRC uses a risk-based model for project prioritization based on the condition and criticality of a culvert. Criticality is determined from specific criteria including:*
>
> - *Availability, length, and cost of detour routes in event of culvert failure*
> - *Average daily traffic passing over culvert*
> - *Replacement cost in event of culvert failure*
> - *Culvert failure's impact on local ecosystem, including fish and other aquatic organism passage*
> - *Potential for property loss and personal injury resulting from failure*
> - *Cost increase due to maintenance deferral and continued deterioration*

A culvert's criticality is assigned a rating on a 1-10 scale on a culvert-by-culvert basis based on this criterion, with 10 being least critical and 1 being most critical. A culverts criticality rating is then multiplied by its condition rating to achieve an overall score representing culvert risk. Culverts with the lowest scores are considered high risk culverts and are generally prioritized first. Culverts with the highest scores are considered low risk culverts and are generally prioritized last. Risk is estimated on an annual basis based on changing condition ratings and criticality criteria.

_-Year Annual Cost Projection: This section should be formatted as a table displaying costs for specific projects broken down by year performed and preventive action performed. An example is provided below:

Table 3. 5-Year Cost Estimate (NOTE: Shortened for brevity, use this list as an example ONLY)

Culvert ID	**Year**				
	2019	**2020**	**2021**	**2022**	**2023**
Replacement					
Subtotal					
Rehabilitation					
Subtotal					
Preventative Maintenance					
Subtotal					
Scheduled Maintenance (Non-culvert specific)					
Subtotal					
Annual Totals					
Annual Total					

Identify Funding Sources: This section should identify funding sources to carry out the proposed culvert management program, including dedicated country resources and outside funding opportunities, such as state or federal grant programs. Reference specific projects in which funding has been acquired. An example is provided below:

> *Projects for the replacement of culverts 1648 and 1670, and the rehabilitation of 1711 have been programmed and funded. The _CRC applied for MDOT local aid funding in 2018 for the replacement of culverts 1675 and 1678 in the 2020 & 2021 program years, respectively. Other replacement and rehabilitation projects will be submitted for funding in subsequent program years. The preventive maintenance projects shown for 2019 will be funded through a County appropriation of $75,000 for culvert preservation. Projects submitted to the local aid program that are not selected for funding will be added to the County program. The scheduled maintenance and minor repairs will be performed by the County's in-house maintenance forces and funded through the County's annual operating budget.*

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