Office of the Auditor General of Ontario

Value-for-Money Audit:

Inspection and Maintenance of the Province's Bridges and Culverts

December 2021

Ministry of Transportation

Inspection and Maintenance of the Province's Bridges and Culverts

1.0 Summary

As part of its mandate to deliver a safe highway network that promotes mobility for people and goods, the Ministry of Transportation (Ministry) is responsible for inspecting, maintaining and repairing approximately 3,000 bridges and 2,000 large culverts (tunnels carrying a stream or open drain under a road) located on provincial highways and in northern areas of the province. Under the *Public Transportation and Highway Improvement Act, 1990,* the province's bridges must be inspected every two calendar years by or under the direction of a professional engineer using the Ontario Structure Inspection Manual (OSIM). Regular visual inspections are done to ensure that bridges are kept safe and in good repair, and to identify safety hazards and repair and maintenance needs; enhanced and emergency inspections may be done when serious deterioration or damage is suspected.

The first and most prominent safety factor of a bridge is its design and construction. Bridge inspection is put in place to assess the level of depreciation of the bridge for capital maintenance planning for rehabilitation of the bridge and to identify immediate safety concerns to be addressed. The depreciation of the bridge does not equate to a reduction in safety. If a safety issue is identified upon inspection, a repair crew is called immediately to fix the problem. At the time of our audit, 89% of Ontario provincial bridges were in good condition, meeting the province's goal of 85% of bridges being in good condition at all times. As well, 10% of bridges were assessed to be in fair condition and 1% of bridges were assessed to be in poor condition. The 1% of bridges that are identified as in poor condition is not an indication of any safety concern but rather indicates that capital maintenance to rehabilitate the bridge is needed within a year.

The Ministry does not have dedicated bridge inspectors. Rather, each of the province's five road network regions has an office staffed with Ministry structural engineers; about half of the inspectors who conduct two-year inspections are Ministry staff and the rest are contractors.

The Ministry's Bridge Management System (BMS) supports the OSIM inspection and management process. Data for the BMS is entered by the inspectors at the time of inspection, and the system calculates the Bridge Condition Index (BCI). The condition data and inventory information are uploaded into the Asset Management System, an analytical tool that generates individual bridge rehabilitation needs and expenditure requirements for capital planning. The expert engineer we contracted to assist us with

our audit conducted an independent inspection of 15 bridges across the province and recorded virtually the same BCI results as Ministry inspectors, with minor variances.

Since 2007/08, the Ministry of Transportation and the Ministry of Northern Development, Mines, Natural Resources and Forestry have budgeted over $7.5 billion on the maintenance, operation and expansion of Ontario's network of transportation structures, mainly bridges and culverts. Annual funding for these structures increased by over 700%, from $93 million in 2007/08 to $754 million in 2021/22.

Our audit found that although the OSIM is widely used across Canada for bridge inspection, the OSIM does not provide a uniform inspection approach for all structures in Ontario, and it lacks a standard flood response protocol for structures affected by floods or at risk from flooding. Also, when guiding inspectors in how to record the material condition of a structure, the OSIM does not use quantitative measurements of the degradation between excellent and good, and instead uses less precise qualitative descriptions.

The OSIM inspection tables used to assess the elements of a structure also cannot flag or describe those elements that are considered critical to a bridge's safety. Therefore, the deterioration or poor condition of a bridge element as assessed by the BCI may not predict the likelihood of failure of the bridge or even of the element itself. In addition, the BCI may not capture the actual repair and maintenance needs of these elements. As a result, Ministry staff calculate a modified BCI value for each bridge in order to assess its priority for repair.

We also found that although the Ministry has performed inspections on every bridge every two years, as required, there are issues with the quality of these inspections. While the Ministry performs audit inspections and provides recommendations to the regions to correct errors, it does not follow up to ensure that its recommendations are being addressed.

The following are some of our most significant findings:

- **Some inspectors perform six or more inspections per day, contrary to the OSIM and Ministry guidance.** The OSIM stipulates that all visual inspections should involve an element-by-element assessment of material defects and that an inspector should plan to spend approximately two to three hours on a typical bridge site in order to have enough time to adequately assess the condition of all elements. The Ministry has not been assessing the reasonableness of the number of inspections being completed in a day for either consultant inspectors or its own inspectors.
- **The Ministry cannot verify how much time has been spent inspecting some bridges, since some inspection photos do not include required time stamps.** Following our 2009 audit on Bridge Inspection and Maintenance, the Ministry's Bridge Office instructed Ministry engineers on how to assess consultants' work, including that they ensure photographs submitted with their inspections have both the date and the time printed on them. When this practice is not enforced, the Ministry cannot verify that a consultant has spent enough time to conduct a thorough inspection of a bridge.
- **Consultant inspection files were missing information or contained errors.** We examined 173 inspection reports submitted by consultants and found errors and omissions that could impact the data the Ministry uses to prioritize bridge maintenance and rehabilitation. Specifically, we found 10 instances where the condition of different portions of the bridge was incorrectly measured or recorded, and 31 inspections where a significant change in the bridge's calculated condition was not accompanied by an explanation.
- **Technology is not being used to improve efficiencies and cost-effectiveness, and resolve accessibility issues in inspections.** Some elements of a bridge are physically inaccessible to inspectors for close observation during regular inspections, because they are under the bridge, underground, underwater or very high up. Our 2009 audit on Bridge Inspection and

Maintenance noted that, facing challenges to access, some inspectors were leaving some elements uninspected or estimating their condition from a distance or without seeing them. Such practices increase the risk of inaccurate assessments. Although technologies that could improve inspections are in use elsewhere, these technologies had not been incorporated in the Ministry's inspections at the time of our audit.

- **The Ministry's bridge audit inspection program highlights problems with inspection accuracy that are not being resolved.** The bridge audit inspection program was implemented to ensure that structures are inspected in compliance with the OSIM. Our Office obtained the audit inspection reports for the five years 2015–2019 and found that auditors have been making some of the same recommendations to the regions year after year. Notably, that regions should be reminded of the importance of correcting information that affects accuracy of BCI values. The Ministry has not taken action to ensure that its auditors' recommendations are being addressed.
- **The Ministry lacks a robust training program for its in-house and consultant inspectors.** Inspectors are required to attend the Ministry's OSIM inspection workshop/webinar every two years to ensure they are aware of recent inspection issues and updates to the Bridge Management System, inspection techniques, specifications, safety regulations, Ministry directives or standards. Our review found that the inspection program lacks rigour and testing, and does not provide information on quality assurance procedures that Ministry staff should know. The Ministry has not provided a fieldwork training component to consultants since 2014 and to in-house inspectors since 2018.
- **The Ministry's Structure Rehabilitation Manual is outdated.** This manual, used for planning rehabilitation work on bridges and culverts and their structural components, was last updated in 2007. Since then, there have been major changes in practice to all stages of rehabilitation work. The Ministry issues interim policy memos to provide updated guidance, but has not incorporated them into a revised manual to standardize guidance and simplify access to updates.
- **The Ministry cannot accurately plan capital work for its culverts, as BCI ratings do not accurately reflect the actual condition of the culverts**. While BCI ratings are a good indicator of the deterioration of bridges, where visual inspection can effectively forecast rate of deterioration, BCI ratings are not representative of the true condition of culverts. As a result, the deterioration models used by the Ministry show more rapid deterioration than is actually the case. As a consequence, the Ministry may order work on culverts prematurely. To correct for these ratings, Ministry staff apply judgment when needed to adjust the BCI and may ignore the data until the Ministry's structural engineers point out that culverts need work for other reasons, often when they become functionally deficient.
- **The Ministry is unaware if maintenance and repair work is done in a timely manner by the regions.** The regions do not track as required the completion of maintenance work identified by inspectors and do not submit confirmation to the Ministry when work has been completed. The Ministry's Head Office informed us that it does not follow up with the regions to confirm that they are tracking and conducting maintenance work in a timely manner. It does not receive the regions' maintenance tracking spreadsheets or keep track of their completed work.

This report contains 10 recommendations, with 22 action items, to address our audit findings.

Overall Conclusion

Our audit concluded that the Ministry performs inspections every two years on every bridge it is responsible for, as required. However, the Ministry could improve its inspection process, as the inspectors are currently left to make subjective assessments that can ultimately impact capital planning and bridge maintenance decisions. As well, follow-up work is not performed to confirm that recommendations made by inspectors for identified maintenance work are carried out on a timely basis. Also, technology is not being used to best effect to improve efficiencies and cost-effectiveness, and to resolve accessibility issues in inspections.

The Ontario Structure Inspection Manual does not provide a uniform inspection approach for all structures in Ontario, it lacks a protocol for structures affected by floods or at risk from flooding, and it does not quantify the degradation of material condition from excellent to good, leaving inspectors to make subjective assessments and rely on imprecise descriptions.

As well, the Ministry cannot accurately plan capital work for its culverts, as Bridge Condition Index ratings do not accurately reflect the actual condition of culverts.

We noted that the Ministry lacks a robust training and testing program for its in-house and consultant inspectors to ensure they are aware of recent inspection issues and updates to the Bridge Management System, inspection techniques, specifications, safety regulations, and Ministry directives or standards.

OVERALL MINISTRY RESPONSE

The Ministry of Transportation (Ministry) wishes to thank the Auditor General for her detailed review and recommendations regarding the practices pertaining to bridge inspections. The Ministry takes its obligation to maintain Ontario's bridges seriously. Keeping bridges in safe condition and in a state of good repair supports the mandate of providing reliable mobility for people and goods in Ontario. Over the past five years, 673 bridges were rehabilitated or replaced. Over the past 10 years, the percentage of bridges rated as "good" increased from 71% to 89%.

Ontario is considered a North American leader in terms of bridge management and bridge safety. The inspection manual methods employed by Ontario are also used by half the provinces in Canada. By law, bridge engineers inspect every bridge every two years using prescribed procedures to adequately maintain bridges to ensure they are safe and in a state of good repair, and to gather information for the management of the Ministry's structural assets. Over the past decade, the Ministry has improved the inspection process, including adopting the recently implemented Bridge Management System. Concurrently, with significant investments in highway infrastructure, the overall condition of Ontario's bridges has improved significantly. The Ministry will take action to further improve the bridge management processes as identified in the Auditor's report.

2.0 Background

2.1 Ministry Responsible for Bridges and Structural Culverts on Provincial Highways

Ontario's provincial and municipal road network includes about 13,000 bridges, structures that typically carry a road or path across a river, ravine, road or other obstacle. Regular inspections and maintenance of these bridges is required to ensure that they remain safe and are kept in a state of good repair.

The Ministry of Transportation (Ministry) is responsible for inspection and maintenance (which includes repairs) of approximately 3,000 bridges located on provincial highways, as well as approximately 150 bridges located in northern areas of the province that are not part of a municipality. Municipalities are responsible for the remaining 10,000 bridges located on municipal roads.

The Ministry is also responsible for the inspection and maintenance of approximately 2,000 structural culverts located on provincial highways. Culverts are structures that form an opening through soil carrying a stream or open drain under a road, and structural culverts refers to culverts with a span of 3 metres or greater (large culverts).

Under the *Public Transportation and Highway Improvement Act, 1990*, municipal bridges, like provincial ones, must be inspected every two years by a professional engineer and kept in state of good repair. Municipalities are responsible for ensuring their bridges are inspected and maintained.

2.2 Provincial Bridge Inventory and Five Road Network Regions

Bridge inspection and maintenance is part of the Ministry's broader road network management responsibilities which include highway maintenance and expansion. To manage the provincial road network, the Ministry has divided the province into five regions. **Figure 1** shows the number of bridges in each region and the location of each Ministry Regional Office.

The Ministry does not have dedicated bridge inspectors. Rather, each region has an office staffed with Ministry structural engineers who are responsible for managing the broader provincial road network, of which one component is bridge inspection and maintenance.

In addition to the five regional offices, the Ministry operates a head office in St. Catharines. The Head Office establishes and updates policies and standards centrally with regard to bridge inspection and maintenance, and conducts training of bridge inspectors, reinspection audits (reinspection), and capital investment planning.

Figure 1: Number of Bridges in Five Ontario Regions, December 31, 2020

Source of data: Ministry of Transportation

Region Name	Regional Office Location	# of Bridges	% of Total
Central	Toronto	1,181	40
Eastern	Kingston	499	17
Northeastern	North Bay	600	20
Northwestern	Thunder Bay	222	7
West	London	486	16
Total		**2,988**	**100**

2.3 Bridges Must Be Inspected Every Two Years Using the Ontario Structure Inspection Manual

According to Ontario Regulation 104/97, under the *Public Transportation and Highway Improvement Act,* bridges in Ontario must be inspected every two calendar years by or under the direction of a professional engineer using the Ontario Structure Inspection Manual (OSIM). The Ministry conducts two main types of bridge inspections: regular and enhanced. Regular inspections are done to ensure that bridges are kept safe and in good repair, and to identify safety hazards and repair and maintenance needs. An enhanced inspection may be ordered by an inspector who identifies deterioration that warrants a more thorough inspection. (**Section 2.4** discusses regular and enhanced inspections.) The Ministry also conducts unscheduled emergency bridge inspections in response to events that may damage a bridge, such as floods, earthquakes and vehicle accidents.

The Ministry uses the information gathered from inspections to prioritize bridge repairs, maintenance work, and replacement of elements and structures. According to the OSIM, inspectors must assess all required bridge components, record their condition and make recommendations for necessary repairs or additional enhanced investigations. The OSIM groups the various components of a bridge (points to be observed—for example, pavement, railing systems and barrier systems on walls) into "elements" (for example, retaining walls) for inspection purposes.

The Ministry published the first edition of the OSIM in 1985, with major revisions in 2000. It has been adopted in five other Canadian provinces, as shown in **Figure 2.**

The Ministry updates the OSIM when it becomes aware that a critical revision needs to be made or when it receives an appropriate number of comments requesting changes from Ministry inspectors and from attendees at the Bridge Inspection Workshops it holds every two years (see **Section 4.3.1**). The Ministry's Structures Office (formerly the Bridge Office) takes responsibility for the updates. The changes are then

Figure 2: Bridge Inspection Manuals Used in Canadian Provinces and Territories

Prepared by the Office of the Auditor General of Ontario

Province/ Territory	Manual
ON	Ontario Structure Inspection Manual (OSIM)
SK	OSIM
MB	OSIM
NB	OSIM
PE	OSIM
NS	OSIM
QC	Manuel d'inspection des structures— Instructions techniques
YT	Bridge inspection manuals
NW	Bridge inspection manuals
BC	Bridge inspection manuals
AB	Bridge Inspection and Maintenance System

Note: Some provinces use the OSIM with companion memos/amendments focusing on the unique structure types in the province.

endorsed by the Bridge Committee, and ultimately approved by the Director, Standards and Contracts Branch (formerly Highway Standards Branch). Once the revised OSIM is approved and published, the Structures Office sends the manual to the Regional Offices for distribution to regional staff and to the Ministry of Transportation Library for posting online. The Ministry revised and updated the OSIM in 2003, 2008 and 2018.

In 2009, our Office engaged a structural engineering expert who advised us that the Ministry had established comprehensive standards for bridge inspection in the OSIM, and if the standards are followed, the required inspection procedures effectively enable structural deficiencies to be identified.

2.4 Regular and Enhanced Bridge Inspections

Since regular inspections must be conducted every two years, the Ministry conducts about 1,500 bridge inspections annually (half of the provincial bridge inventory). According to the OSIM, A regular inspection of a typical bridge, such as the one shown in **Figure 3**, should take about two to three hours. For larger, more complex or smaller bridges, the inspection time will vary. Typically, inspections are performed by one engineer inspector and one assistant.

The main purpose of a regular inspection is to visually determine what percentage of the surface area (in square metres) of each bridge element is in either good, fair or poor condition and to identify the type, severity and extent of deterioration of each element.

For example, the asphalt surface on the bridge deck top in the photograph shown in **Figure 4** is about 65% in good condition (meaning, no visible cracks in asphalt) and 20% in fair condition, (meaning, there are small to large asphalt cracks). The OSIM provides detailed technical guidance on how the condition of each element should be assessed.

Regular inspections help to identify any public safety hazards that may require immediate repairs, load restrictions or bridge/lane closures.

Bridge inspections usually do not require road or lane closures because inspectors are not required to approach each bridge component in order to inspect it from close up. Instead, inspectors can approach on

Figure 3: A Typical Highway Bridge in Ontario's Provincial Network

Source of data: Ministry of Transportation

Figure 4: Asphalt Surface on a Bridge Deck Top Showing Deterioration

Source of data: Ministry of Transportation

Figure 5: Bridgemaster Used to Assist with Enhanced Bridge Inspections

Source of data: Ministry of Transportation

foot or use binoculars to inspect some components from a distance, such as the bridge soffit, bearings or pier caps. Inspectors are required to take photographs of inspected components.

If an inspector identifies deterioration on a specific bridge or an element that warrants a more thorough inspection, an enhanced inspection may be recommended. Once an enhanced inspection has been performed, additional enhanced inspections must be performed on that bridge at least every six years; the interval changes depending on the type and extent of deterioration, and the importance of the element to the stability of the bridge. Typically, this type of inspection is used for bridges over 30 years old that are in poor condition.

During an enhanced inspection, the engineer is required to be within arm's reach to inspect all bridge elements. Special equipment such as the Bridgemaster unit shown in **Figure 5** is used to assist with the inspection. Also, for in-depth investigations, special equipment such as ground-penetrating radar is used to "look inside" the elements to see the extent of deterioration.

Enhanced inspections can take several hours or even days and usually are conducted by several inspectors/engineers. They also often require shoulder, lane and/or possibly road closures.

2.5 Bridge Maintenance and Rehabilitation

Bridge work falls under the Ministry's policies and procedures for procuring engineering services. Broadly, there are four levels of bridge work, distinguished by cost, complexity and frequency. These occur at different intervals over the 75-year life cycle of a bridge:

- **Routine bridge maintenance—**Maintenance contractors wash bridges each spring to remove winter sand and salt, and also plow and monitor bridges during the winter.
- **Bridge maintenance to extend useful life—**Repairing concrete, re-coating steel components and lubricating bridge bearings are performed as needed to extend the useful life of the bridge.
- **Bridge rehabilitation—**Major rehabilitation includes replacement of surfaces showing wear, concrete repairs to the entire structure and overlay or replacement of the deck. Substantial rehabilitation is expected when a bridge reaches 30 years of use, and additional lesser rehabilitation work may be required at 15-year increments throughout the life of the bridge.
- **Bridge replacement—**Once a bridge is 75 years old, it has reached the end of its useful life. At this

point a decision is made either to conduct major work to extend the bridge's useful life or to replace the bridge.

2.6 From Calculating the Bridge Condition Index to Requesting Capital Funding

Bridge work is scheduled on the basis of a bridge's assessed condition using the Bridge Condition Index (BCI), funding, an engineering review of urgency, and combining bridge and pavement projects. The Ministry's Bridge Management System contains the inventory of all structures it has responsibility for, including bridges and large culverts, and their condition. This includes the condition of the various elements of a structure observed during the visual inspection and their associated replacement values. The information is used to calculate the overall BCI.

The condition data and inventory information from the Bridge Management System are downloaded for use in the Asset Management System (AMS) and in the Bridge Priority Tool. Both of these systems have a built-in deterioration model that estimates the long-term bridge rehabilitation needs based on the age of the structure, the condition level to which it is allowed to deteriorate, changes in traffic and local conditions, and the quality and timeliness of maintenance during the structure's life.

This chain of assessments and calculations begins with the inspector's visual examination using the OSIM guidelines, and relies on the inspector to estimate various values, as explained in **Section 2.6.2.** However, if some inspections are done with insufficient care or if there are differences due to inspectors' judgment in how they measure the condition of various bridge elements, then the basic data entered into the calculation of the condition of the bridges can be inaccurate and/or not comparable. In turn, this faulty data would affect the stream of calculations that flow from it, including the final evaluation of the condition and needs of Ontario's inventory of bridges.

2.6.1 What Is the Bridge Management System?

To manage the inventory of provincial bridges, the Ministry uses the Bridge Management System (BMS), a web-based program implemented in 2018 to store inventory and inspection data on structures the Ministry owns and maintains. The current BMS replaced an older system whose deficiencies were noted in our Office's 2009 audit of Bridge Inspection and Maintenance. Inspectors log into the BMS and input the observations from their inspections. The BMS contains physical and historical information for each bridge and culvert spanning over 3 metres, such as age, type, location, length, number of spans, area of each bridge element, the results of each inspection and the condition that each element is assessed to be in, from poor to excellent. The bridge's condition is recorded in the BMS, including the condition of its elements and their replacement value.

In addition to inspection data, the BMS database contains basic inventory data, work history data, and documents such as photographs from inspections, reports and engineering drawings. There are over 2 million records in the system with more than 500,000 inspection photos, 70,000 engineering drawings and 12,200 reports.

As inspectors enter inspection data into the BMS, the system calculates the Bridge Condition Index (BCI). The condition data and inventory information from the BMS populate the Asset Management System (AMS), an analytical tool used to generate individual bridge rehabilitation needs and expenditure requirements for capital planning.

2.6.2 How Is BCI Calculated by the BMS?

The OSIM lists over 15 element groups and over 50 individual elements. Depending on the type of bridge and era of the design, different bridges have a different number of components (that is, points to be observed). Each bridge typically has at least 20 elements, but only 12 impact the BCI calculation, as shown in **Appendix 1.**

The BCI was developed as a means of combining inspection information into a single value to give an indication of the overall condition of the bridge. It is calculated using asset management principles based on the remaining economic worth of the bridge. The greater an element's deterioration in condition, the lower its economic value. The BCI is a weighted average of all elements (since all elements are not of equal value to the bridge) and all "condition states" (since each condition state represents a different degree of loss of value of the element).

The inspector simply records, per element, one of the four condition states—*excellent, good, fair* or *poor*—as shown in **Figure 6.** These states have precise engineering definitions that depend on the element and material type. The bridge's BCI rating begins at 100, when the bridge is in new condition, and theoretically becomes 0 if all elements reach a poor condition. In practice, though, it is impossible for the BCI to reach 0 since rehabilitation work is performed on the bridge before all elements are allowed to reach poor condition.

Each element is inspected in accordance with the OSIM, and the inspector selects a value to record for each of the four condition states and notes all the maintenance work that is needed. At each biennial or enhanced component-level bridge inspection, the inspector records the type, severity and extent of deterioration of each major structural element, such as decks, girders, joints, bearings and pier caps. Minor elements such as wearing surfaces, coatings and drainage systems are recorded separately. **Appendix 2** demonstrates how the weighting of each bridge element in the BCI is determined by its replacement value in the Ministry's price index.

If different portions of a bridge element are in different conditions, then the inspector visually estimates the dimensions of each portion to provide a breakdown. For example, if the bridge barrier is 100 m² and different portions of the barrier are in different condition, then the inspector differentiates between those portions, which could potentially be 65 m² in one assessed condition, 25 m² in another condition and 10 m² in still another condition.

Most inspectors record their observations on a paper form and enter the data into the web-based BMS when they have access to their computer. The data they enter records the dimensions of each element of the bridge and the assessment value of that element—for example, 20% of the bridge deck: poor condition; 50%: fair condition; 20%: good condition; and 10%: excellent condition. The BMS uses this data to calculate BCI as a single value, a measure of a bridge's overall structural condition and its remaining economic value. Bridges with a BCI of 70 or above are generally considered to be in good condition.

The BCI is used to plan maintenance and repair work. Bridge inspection assesses the level of depreciation of the bridge for capital maintenance planning for rehabilitation of the bridge and to identify immediate safety concerns to be addressed. However, the depreciation of the bridge does not equate to a reduction in safety. If a safety issue is identified upon inspection, a repair crew is called immediately to fix the problem. The first and most prominent safety factor of a bridge is its design and construction. In 2020/21, 89% of Ontario's provincial bridges were in good condition, meeting the 85% provincial target, 10% of bridges were assessed to be in fair condition and 1% of bridges were assessed to be in poor condition, as shown in **Figure 7.** The 1% of bridges that are identified as in poor condition is not an indication of any safety concern but rather indicates that capital maintenance to rehabilitate the bridge is needed within a year.

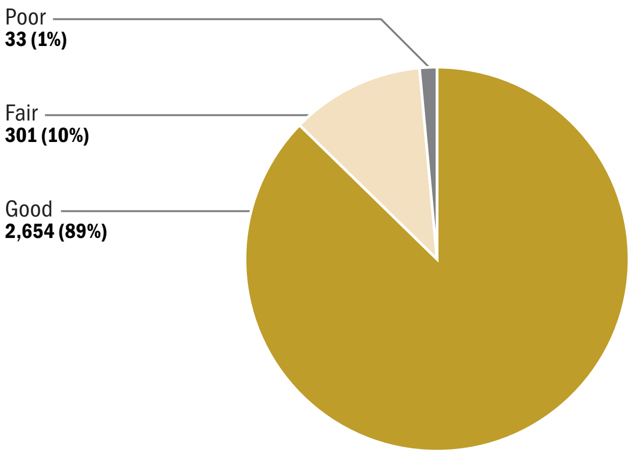
Figure 6: Weighting of Bridge Elements by Condition State Used in Calculating the Bridge Condition Index

Prepared by the Office of the Auditor General of Ontario

Condition State	Weight Factor
Excellent	1.00
Good	0.75
Fair	0.40
Poor	0.00

Figure 7: Number and Percentage of Ontario Provincial Bridges by Condition as at December 31, 2020

Source of data: Ministry of Transportation



The final product of the inspection process is an OSIM Inspection Report (the record of inspection) that can be retrieved by the Ministry's Bridge Office management as needed or by future inspectors of the same bridge as a reference point.

The responsible Ministry engineer then reviews the inspection report and signs off on it. As one last check, the Regional Coordinator reviews the inspection report for completeness and sends it back to the inspector, either to finalize and submit it, or to revise it and possibly do more inspection work. A finalized and submitted report can no longer be changed and becomes an official record of inspection.

BCI and other inspection data from the BMS are then transferred to the AMS analytical tool. Before it acquired the AMS system, the Ministry extracted BMS data and conducted capital planning analysis on the Excel-based Bridge Priority Tool.

2.6.3 Data Analysis for Capital Planning

Bridge Priority Index: Determining "Now Need" and Short-Term (One-to-Five-Year) Needs

The BCI provides only a starting point for prioritization of bridge projects, as it gives only an indication of the overall condition of the bridge based on the economic value of individual elements and the extent of their deterioration. The BCI is not sensitive to the fact that some elements are more critical than others for a bridge's overall structural integrity and for the safety of bridge users (see **Section 4.1.2**). Therefore, Ministry staff calculate a Priority Index for each bridge (shown in **Figure 8**) by modifying the BCI value, upon examining the condition of five critical bridge elements:

1. deck top;
2. deck soffit;
3. barrier wall;
4. expansion joints; and
5. concrete/steel beams.

Each of these critical elements is assigned a "now need threshold" (the percentage of the element that is in poor condition and should be repaired within a year) and a weight (the importance of the element in relation to the entire structure). These five elements alone can lower the BCI by as much as 20 points. As a result, a bridge may have high overall BCI score, but if these five elements are poor it will be assessed as high priority for repair. In contrast, if a bridge has an overall low BCI but these five critical elements are in fair or good condition, it will be a lower priority in the queue.

Figure 8: Maintenance Schedules for Bridges and Large Culverts as Indicated by Bridge Priority Index (BPI) Ratings

Prepared by the Office of the Auditor General of Ontario

BPI Rating	Maintenance Schedule
Good: 70 –100	Maintenance is not usually required within the next five years.
Fair: 60–70	Maintenance work is usually scheduled within the next five years. This is the ideal time to schedule major bridge repairs from the point of view of capital planning.
Poor: <60	Maintenance work is usually scheduled within one year (bridge should be rehabilitated during the next construction season).

Bridges with a Priority Index of less than 70 are considered to be on the zero-to-five-year rehabilitation list; bridges with a Priority Index of less than 60 are considered to be a "now need," which means they should be rehabilitated during the next construction season.

Other adjustments are also made to the BCI based on data that is not considered in calculating the BCI, such as the age of the bridge, type of bridge and last major rehabilitation date.

Bridge Priority Tool and Asset Management System (AMS)

From 2006 to 2015, the Bridge Priority Tool (an Excel spreadsheet) was used to import the data produced by the BCI into a deterioration model to determine when a bridge would need major rehabilitation work or replacement, and to calculate the cost of the capital work. This type of planning can extend up to 25 years ahead.

In 2007, the Ministry procured a Pavement Management System (PMS), a decision-support tool for management that analyzes pavement condition data to identify the rehabilitation needs for pavements.

In 2016, the Ministry asked the PMS vendor to incorporate the functions of the Bridge Priority Tool into the PMS, which resulted in the system being renamed the AMS. The enhanced AMS retains the functions of the old Bridge Priority Tool (for example, adjusting BCI based on "now need" of the five critical elements, age of the bridge, etc.), but is a more powerful tool that can analyze variables such as traffic levels, increasing or decreasing population in the region, weather, impact of remoteness of the area on construction crews and on cost of material, and other geomatics data, as well as short- and long-term budgets. These enhancements were meant to give the AMS the capability to produce the optimal capital workplan for the whole provincial bridge inventory, serving the province's goal of 85% of bridges being in good condition at all times. The new tool also allows bridge work and road work, including work on pavements, traffic signals, drainage, etc., to be bundled efficiently to minimize construction costs, traffic disruptions and public inconvenience.

The AMS also estimates the cost of future bridge repairs and rehabilitation. The province's regions use the AMS rankings to develop a five-year capital work plan for repair and rehabilitation. These regional plans become part of the larger provincial work plan.

The Ministry relies on the AMS rankings and its staff's judgment to make annual funding requests for bridge repair and maintenance to the Treasury Board, basing its highway needs calculations and funding requests on meeting specific performance measures for pavement and bridge condition.

Once funding approval is received (with a five-to-10-year outlook), funds are provided to regional program delivery offices. The Asset Management Branch of the Ministry works with Regional Offices to develop and deliver multi-year capital rehabilitation programs and report on their progress to the Ministry Head Office, which in turn reports to the Treasury Board.

2.7 Approximately Half of Bridge Inspections Are Conducted by Engineering Consultants

Each year just over half of all bridge inspections are outsourced to private engineering firms and the remaining inspections are conducted by Ministry staff. Consultants must submit their inspection reports to the regional office for review before they are finalized and entered into the Ministry's database.

The percentage of inspections conducted by consultants in each of the five regions varies significantly, from 6% in West Region to almost 80% in Central Region. The variation by region is due to the number of bridges and culverts in each region as compared to the number of in-house inspectors. **Figure 9** shows the percentage of inspections in each region that were conducted by consultants and Ministry staff during 2019 and 2020.

Figure 9: Bridge Inspections in Each Region Conducted by Consultants and by Ministry of Transportation Staff, 2019 and 2020

Source of data: Ministry of Transportation

	West Region		Central Region		Eastern Region		Northeastern Region		Northwestern Region		
	#	%	#	%	#	%	#	%	#	%	Total
Ministry staff	435	94%	244	21%	288	62%	158	27%	106	49%	1,231
Consultants	28	6%	903	79%	176	38%	417	73%	112	51%	1,636
Total	**463**		**1,147**		**464**		**575**		**218**		**2,867**

2.8 Over $7.5 Billion Budgeted in the Past 15 Years to Maintain, Operate and Expand Province's Network of Transportation Structures

Since 2007/08, the Ministry of Transportation and the Ministry of Northern Development, Mines, Natural Resources and Forestry have budgeted over $7.5 billion on the maintenance, operation and expansion of Ontario's network of transportation structures, mainly comprising bridges and culverts. As shown in **Figure 10**, funding for these structures increased by over 700%, from $93 million in 2007/08 to $754 million in 2021/22.

Bridge inspection and maintenance is not a discrete program, but rather comprises part of the Ministry's responsibilities in overseeing the provincial road network. The Ministry thus does not report bridge-related costs separately; they are included in the overall budget for planning, inspecting, repairing and rehabilitating the provincial highway network.

3.0 Audit Objective and Scope

Our audit objective was to assess whether the Ministry of Transportation (Ministry) had cost-effective and efficient processes and systems in place to:

- conduct required bridge and culvert inspections; and
- complete bridge and culvert maintenance, repair, rehabilitation and replacement work on a timely basis and with due regard for public safety.

In planning for our work, we identified the audit criteria (see **Appendix 3**) we would use to address our audit objective. These criteria were established based on a review of applicable legislation, policies and procedures, internal and external studies, and best practices. Senior management reviewed and agreed with the suitability of our objective and associated criteria. Municipalities are responsible for ensuring their bridges are inspected and maintained.

We conducted our audit within the period December 2019 and September 2021. We obtained written representation from Ministry management that, effective November 16, 2021, they had provided us with all the information they were aware of that could significantly affect the findings or the conclusion of this report.

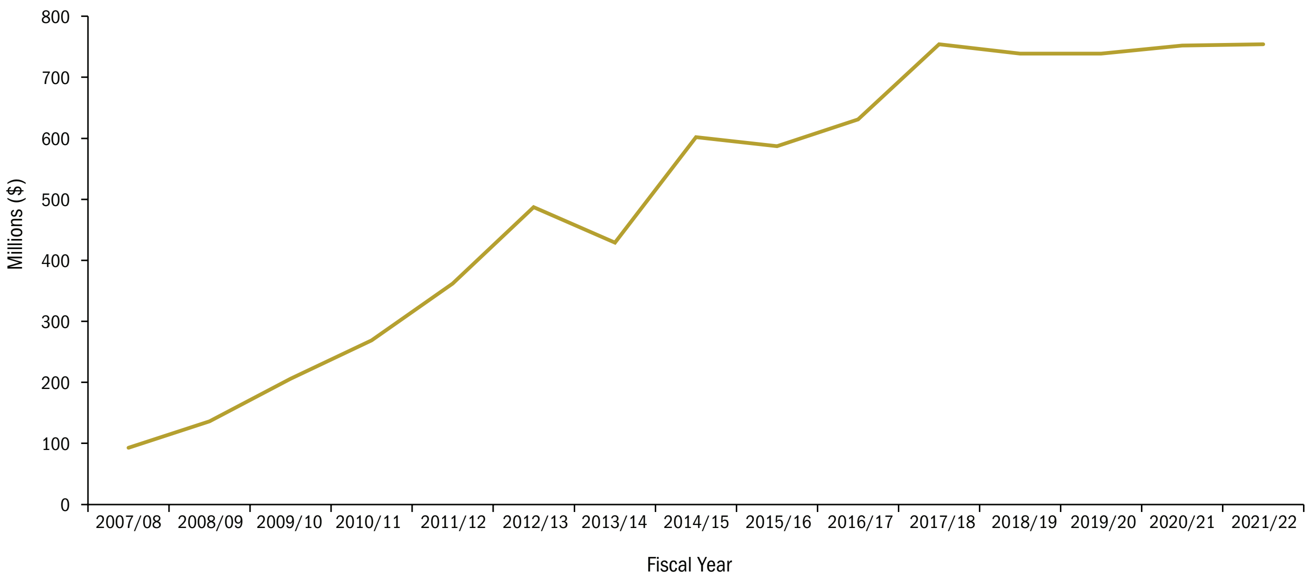
Our audit work was initially conducted in person, at the Ministry's Head Office in St. Catharines, and the Central Region office in Toronto. Following the Province's announcement of a state of emergency due to COVID-19 in March 2020, we shifted to conducting remote work in the West and Northeastern Regions.

We interviewed staff, examined documentation, reviewed the results of bridge inspections, and researched bridge management practices followed in other jurisdictions. We also accompanied Ministry staff on bridge inspections to gain an understanding of the inspection process and the challenges that inspectors face.

We conducted jurisdictional research and met with representatives from 407 ETR privatized highway company to find comparisons to Ontario's structural inspection practices. We also interviewed researchers

Figure 10: Year-Over-Year Trend in Provincial Highway Structures Funding, 2007/08–2021/22

Source of data: Ministry of Transportation



from the University of Waterloo to learn about the use of technology in assisting and enhancing the effectiveness of bridge inspections.

In the course of our audit, we hired a structural engineer to review the Ministry's bridge inspection standards, manuals and practices, and to re-inspect 15 provincial bridges using the Ministry's Inspection Manual to obtain an independent assessment of the condition of these bridges.

We conducted our work and reported on the results of our examination in accordance with the applicable Canadian Standards on Assurance Engagements—Direct Engagements issued by the Auditing and Assurance Standards Board of the Chartered Professional Accountants of Canada. This included obtaining a reasonable level of assurance.

The Office of the Auditor General of Ontario applies the Canadian Standards of Quality Control and, as a result, maintains a comprehensive quality control system that includes documented policies and procedures with respect to compliance with rules of professional conduct, professional standards and applicable legal and regulatory requirements.

We have complied with the independence and other ethical requirements of the Code of Professional Conduct of the Chartered Professional Accountants of Ontario, which are founded on fundamental principles of integrity, objectivity, professional competence and due care, confidentiality and professional behaviour.

4.0 Detailed Audit Observations

4.1 Quality of Inspection Manual and Standards

Bridges in Ontario must be inspected in accordance with the Ontario Structure Inspection Manual (OSIM). Ontario Regulation 104/97 under the *Public Transportation and Highway Improvement Act,* states that the structural integrity, safety and condition of every bridge is to be determined by performing at least one inspection every two years under the direction of a professional engineer in accordance with the OSIM. We found that the Ministry of Transportation (Ministry) has these inspections performed every two years on every bridge it is responsible for.

The Introduction to the OSIM states that its purpose is to provide a uniform inspection approach for all structures in Ontario. As the inspection data that is collected is used to assess the structures' safety and plan their maintenance or replacement, it is important that the OSIM gives inspectors clear and comprehensive guidance and minimize inspectors' subjectivity. However, our audit found a number of issues with respect to the OSIM, including that the OSIM is not clear on guidance on recording the transition of the condition of structures, which results in less precise quantitative assessments (see **Section 4.1.1**); it does not differentiate between elements based on how critical they are to a bridge (see **Section 4.1.2**); and it does not include a standard flood response protocol for assessing, monitoring and inspecting provincial structures affected by floods or at risk from flooding (see **Section 4.1.3**).

4.1.1 Guidance on Recording Material Conditions of Structures Uses Qualitative Descriptions Rather Than Quantitative Measurements

As described in **Section 2.6.2**, the OSIM guides inspectors in how they should calculate the overall material condition of a bridge, stated as the Bridge Condition Index (BCI). An inspector first assigns point values to the elements that make up the bridge, based on data gathered through observing defects in those elements; this gives a listing of "condition states" for these elements (excellent, good, fair or poor). The structural engineering expert we retained observed that when guiding inspectors in how to record the material condition of a structure, the OSIM does not adequately quantify the degradation of material condition from "excellent" to "good" over time. Instead, it describes the condition in qualitative terms. Our expert noted that the descriptors in the OSIM are "vague," leaving various inspectors and jurisdictions to interpret the OSIM requirement and to develop their own degradation curve in accordance with their interpretations. The Ministry's Bridge Office noted a similar issue in its examination of factors that can skew inspection results, when it reported on its 2018 and 2019 audits of bridge inspections; see **Section 4.2.6.**

Our expert also pointed out that although the OSIM is now a fully searchable PDF document, its layout remains confusing to new inspectors. As well, while the OSIM element tables are generally sufficient for documentation of each bridge element, the table format has not changed through many iterations of OSIM and could be improved substantially to provide clearer documentation, easier transfer of field data to bridge management databases and better flagging of issues and recommended follow-up inspection work. Some of its photographs used to specify bridge components and material deficiencies need to be updated. However, on a positive note, our expert found that the relationship between the severity of observed material defects and a bridge element's material condition has been made more explicit in the OSIM.

Our structural engineering expert's additional comments on the 2018 version of the OSIM are presented in **Appendix 4.**

4.1.2 Inspection Manual Does Not Differentiate Critical from Non-critical Elements

The OSIM inspection tables used in assessing the elements of a structure do not include any facility for flagging and detailing those elements that are considered critical or potentially vulnerable.

This is important because, while the OSIM is widely used across Canada for bridge inspection, it does not incorporate all the information that is relevant to the safety of a bridge in calculating the BCI. As described in **Section 2.6**, the BCI is a calculation of a bridge's assessed condition to assess its depreciation, and to provide information relating to its long-term management needs. Engineers understand that some elements of a bridge that are less critical or non-critical to its overall structural integrity can exhibit severe deterioration without compromising the bridge's structural integrity and safety. Their deterioration or poor condition as assessed by the

BCI may not predict the likelihood of failure of the bridge, or even of the element itself. An example of this is an abutment wall that has become delaminated—that is, whose concrete surface has separated or begun to flake.

In contrast, other elements are critical, meaning that their failure could cause the failure of the whole structure. The BCI, which provides a single measure of a bridge's overall condition, is not always an effective indicator for identifying the actual repair and maintenance needs of these elements. Even when a bridge is in new condition, if a critical element has been under-designed, such as a slender column or an under-reinforced cantilever slab, it may fail. In addition, critical elements that cannot be inspected easily (or at all) can also lead to a major failure or collapse. Bridges with progressive cascading failure mechanisms, where the failure of one element can set off a chain reaction of element failures, can also fail suddenly if one link in the chain becomes compromised, regardless of the structure's overall condition.

As noted in **Section 2.6.3**, Ministry staff calculate a Priority Index for each bridge by modifying the BCI value (shown in **Figure 8**), upon examining the condition of five critical bridge elements:

1. deck top;
2. deck soffit;
3. barrier wall;
4. expansion joints; and
5. concrete/steel beams.

As a result, a bridge may have high overall BCI score, but if these five elements are poor it will be assessed as high priority for repair. In contrast, if a bridge has an overall low BCI but the five critical elements are in fair or good condition, its repair will be scheduled in line with other lower priority bridges.

RECOMMENDATION 1

To improve the guidance given to bridge inspectors and to provide a more uniform inspection approach across the province that yields a more accurate assessment of its structures, we recommend that the Ministry of Transportation:

- update the Ontario Structure Inspection Manual (OSIM) to provide clarity and guidance on how inspectors can quantify the degradation of a structure's material condition from excellent to good, for the calculation of the overall material condition of a bridge; and
- incorporate in the OSIM inspection tables that are used in assessing the elements of a structure the ability to identify and summarize the elements that are critical to the structure's integrity.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the recommendations that clarity and guidance are important with respect to the OSIM. The Ministry strives to ensure that the procedures in place for bridge inspection requirements are modern, clear and concise, and achieve the goals of the inspection. To achieve this, the Ministry is continually reviewing and improving its bridge inspection procedures to enhance consistency.

The Ministry will review the OSIM over the next 24 months to provide clearer guidance to inspectors with respect to differentiating conditions and describing the progression of a bridge element from one condition state to another. By their nature, some aspects of condition assessment will continue to be subject to the expertise and judgment of the inspecting engineer, but the revisions should provide greater consistency across inspections.

Certain elements of the bridge are more critical to the structure's overall integrity. This depends on the element, the structure type, the site conditions and the material. Improved guidance will be added to the OSIM to assist inspectors in differentiating the assessment of elements that may be critical to the integrity of the structure.

4.1.3 Ministry Has No Manual for Flood Assessment, Monitoring, Inspection and Management of Bridges and Culverts

Flooding can happen at any time of year when the volume of water in a river or stream exceeds the capacity of the channel through which it flows. Floods in Ontario are typically caused by melting snow, ice jams, high lake levels, heavy rains and thunderstorms. Flash floods can occur in heavy rainstorms or when a storm drain is plugged—often with little or no warning—such as the widespread flooding in June 2017 along much of the Grand River. Flooding and water damage to bridges can cause the failure of the entire structure or some of its components, as with the 2018 failure of a bearing seat in the South Saugeen River Bridge. As a result of the damage to this substructure element supporting the bridge's load-bearing beams, Ministry staff had to close the bridge and a portion of Highway 89 to allow the repair to be completed.

Ontario has not developed a standard flood response protocol for assessing, monitoring and inspecting provincial structures affected by floods or at risk from flooding. As a result, Ministry staff and contractors lack guidelines for performing these tasks uniformly across the province's five regions, meaning that safety standards may differ across the province.

The Ministry's Area Maintenance Contract personnel are responsible for completing regular patrols of the Ministry's structures, which include walk-around inspections in the spring when rising water levels due to spring runoff are of concern. Ministry field staff and bridge co-ordinators also monitor water levels as required. However, not all regions have the experience of dealing with the threat of major flooding events. Climate change has increased the frequency of extreme weather events such as high-intensity rainstorms and 100-year storm events, even in regions that have little experience of flooding.

RECOMMENDATION 2

To reduce the risk posed to the province's bridges, culverts and roadways by the potential for more frequent and intense floods and extreme weather events, we recommend that the Ministry of Transportation:

- develop a standard flood response protocol for assessing, monitoring and inspecting provincial structures affected by floods, or at risk from flooding; and
- create a flood inspection manual for structures that are at risk from flooding, and review and update it periodically.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the recommendation that a flood response protocol be developed.

Bridge engineers, through their formal and ongoing education, have the expertise to assess the many factors that would affect the safety and performance of a bridge. This includes measuring material degradation and soil support stability that are affected by events such as a unique, unexpected flooding event.

To enhance consistency, the Ministry is currently developing an emergency response guideline to describe inspection procedures and protocols pertaining to a number of extraordinary events, such as extreme flooding events, vehicle fires, etc. We anticipate having this guide implemented by the end of 2023.

In the interim, the Ministry will issue guidance in the form of a memo to engineers in order to have a consistent and robust response protocol for flood events within six months.

4.2 Quality of Inspections

4.2.1 Some Inspectors Perform Six or More Inspections Per Day, Contrary to OSIM and Ministry Guidance

The OSIM specifies that all visual inspections should involve an element-by-element assessment of material defects and bridge maintenance needs. In order to adequately assess the condition of all elements, the OSIM stipulates that the inspector should plan to spend approximately two to three hours on a typical bridge site, although the time may vary depending on bridge type and age.

We reviewed a number of inspections conducted in 2018 and 2019 in Central, Northeastern and West regions and found that more than a dozen inspectors, both consultants and Ministry inspectors, had performed six or more inspections on the same day.

Of these, we selected eight inspectors who had conducted six or more bridge inspections in a day. We then extracted photographs from the inspection reports prepared by these eight inspectors. We estimated the duration of these inspections by finding the difference between the time the earliest photograph was taken via the photo time stamp and the time the latest photograph was taken.

Our review determined that these eight inspectors from three different engineering firms had spent less than one hour inspecting each bridge. Moreover, we found instances where the time elapsed between the first and last photograph taken of the bridge was less than 20 minutes.

We similarly highlighted this issue in our 2009 audit of Bridge Inspection and Maintenance. There, we noted several instances where an inspector performed more than 10 inspections in a single day. We recommended that the Ministry take steps to confirm that thorough inspections are being done, including assessing the reasonableness of the number of inspections that are performed by an inspector in a single day.

A hurried or careless inspection increases the risk that serious deficiencies will be missed. It may result in an inaccurate condition rating for a bridge, which in turn can affect the Ministry's ability to correctly prioritize maintenance and rehabilitation work (discussed in **Section 4.2.6**), and could even jeopardize the safety of bridge users. Yet, in spite of the OSIM protocol and our 2009 audit recommendation, the Ministry has not been assessing the quality of its inspections or considering how many inspections it is reasonable to complete in a day, for either its consultants or its own inspectors. We noted, however, that the Ministry has the information at hand to conduct such an assessment, as much of the inspection data available to the Ministry gives a clear indication of the time spent on inspections.

4.2.2 Ministry Cannot Verify Time Spent Inspecting Some Bridges, as Their Inspection Photos Do Not Include Required Time Stamps

Following our 2009 value-for-money audit on Bridge Inspection and Maintenance, the Ministry's Bridge Office provided instructions in September 2009 to Ministry engineers on how to assess consultants' work, including that they ensure that the photographs submitted with their inspections have both the date and the time printed on them. Nevertheless, this audit found that photos still do not always include the required time stamps. Specifically, seven of 28 consultant bridge inspectors hired by the Ministry in 2018 and 2019 submitted photographs that did not have time stamps (hours and minutes), which prevents us and the Ministry from determining the amount of time consultants spent on the bridges they inspected.

We also found that photographs from two inspectors did not include the date, meaning that the Ministry would not be able to verify the duration of the inspection, the date of the inspection, and whether the inspection was conducted within the dates specified in the contract. Finally, we found that one inspector did not submit any photographs at all as part of his inspection report, making it impossible to determine whether the inspector visited the bridge site.

By not enforcing the practice of time stamping, the Ministry cannot verify that a consultant has spent sufficient time to conduct a thorough inspection of a bridge and to record accurate and useful inspection data.

4.2.3 Consultant Inspection Files Were Missing Information or Contained Errors

We examined 173 electronic inspection reports from 2018 and 2019 submitted by consultants, and found errors and omissions that could impact the data the Ministry uses to prioritize bridge maintenance and rehabilitation. In our review we found:

- 10 inspection reports where the condition of different portions of the bridge was incorrectly measured and recorded. In these cases, the inspector entered an area (in square meters) for an element that was larger than its true size. Each element of a bridge, such as the bridge deck, has a measured surface area. The inspector determines how much of each element is in excellent, good, fair or poor condition to calculate the overall condition of the bridge. If these measurements or condition ratings are inaccurate, the overall condition of the bridge will also be recorded inaccurately, which can impact its planned maintenance and rehabilitation. We reviewed the Bridge Management System in May 2020 and found that these errors were not corrected.
- 11 inspections where the consultant did not provide enough photographic documentation to support the inspection results. Omitting photographs of the defects observed limits the Ministry's ability to review and confirm the results of the inspection. The OSIM requires inspectors to submit sufficient photographs to thoroughly document their inspection of each bridge.
- 31 inspections where a substantive change in the bridge's calculated condition was not accompanied by a sufficiently detailed explanation for such a significant change. The Ministry classifies a substantive change in the bridge's calculated condition as a decrease of 5% or an increase of 3% in the two-year inspection interval, and it requires that a substantive change in the bridge's calculated condition between inspections be accompanied by an explanation for the change. This allows the Ministry to more accurately track the condition of the structure and determine whether any follow-up action is required to maintain its structural integrity. It also gives the Ministry a tool to monitor the accuracy of the inspections completed by different inspectors and at different sites.

RECOMMENDATION 3

So that bridge inspections are documented and are being performed in accordance with legislation, and so that accurate and thorough bridge inspection data is captured for decision-making, we recommend that the Ministry of Transportation (Ministry):

- implement practices that will enforce the guidance in the OSIM on the length of time an inspection should take, and regularly review the number of inspections completed per day by inspectors to assess their reasonableness and to take corrective action where it is necessary;
- communicate to all bridge inspectors the requirement to date- and time-stamp all photographs taken during an inspection;
- assess the feasibility of using current camera technology to assist in instantaneously uploading photos that are automatically date- and time-stamped; and
- enforce its quality assurance process for its regional offices to verify that the information that is being observed and documented in the

inspection files is accurately recorded in the Ministry's systems.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the recommendation and expects bridge inspections to be thorough and accurate so that the data being captured helps to inform evidence-based decision-making and that, where appropriate, technology is used to enhance the inspection process.

The Ministry's focus is on the outcomes of its bridge inspection protocols, including that all elements of the bridge are adequately inspected on a regular basis. The timing that is outlined in the OSIM is a reference point and only one measure relating to the quality of an inspection. Inspection time estimates were included in the OSIM in 2008 to help guide those engineering consultants who were bidding on the work to better understand the Ministry' expectations. As a reference point, they were not a strict requirement as there can be significant differences in bridges and their associated conditions.

A better measure of whether or not adequate care and time has been spent on any single inspection is through improved supervision. To ensure that inspectors spend adequate time to perform a thorough inspection, the Ministry will review and update the 2009 Quality Assurance memo relating to inspection oversight. The Ministry anticipates issuing a comprehensive updated memo and having it implemented within the next 24 months.

As part of quality assurance, the need for time recording of photographs will also be added to the next bridge inspection oversight training session before the start of the next inspection cycle.

The Ministry is in the process of deploying and testing a version of the Bridge Management System (BMS) suitable for tablets, which will allow photographs to be automatically uploaded into the system. Testing was delayed as a result of the COVID pandemic and will take approximately 12–18 months.

In addition to updating the Quality Assurance processes, the Ministry will require that Ministry supervisors and engineers report that the quality assurance measures have been performed every year. Ministry staff will be reminded at the next inspection oversight training to verify that the information being observed is accurately recorded in the BMS.

4.2.4 Technology Could Be Used to Improve Efficiency and Resolve Accessibility Issues in Inspections

Some elements of a bridge are inaccessible to inspectors for close observation because they are under the bridge, underground, underwater or very high up. Regular inspections of elements such as the soffit, beams/girders or bearings may not even be possible.

Our 2009 audit of the Bridge Inspection and Maintenance Program noted that having only limited access to bridges means that inspectors are forced to leave some elements uninspected, or to estimate their condition from a distance or without seeing them, which increases the risk of inaccurate assessments. When estimation is involved, different inspectors can arrive at different assessments of the same bridge components because of their own individual judgment.

Some components located under a bridge can be inspected with equipment such as the Bridgemaster (**Figure 6**), although this equipment is expensive to rent and its use may require closing lanes or roads and disrupting traffic.

We have found numerous studies and confirmed with faculty at the University of Waterloo that improvements made since our last audit in drone, sensor and software technologies for performing inspections could help resolve accessibility issues and improve the accuracy and consistency of condition assessments by removing human judgment from the equation. Transportation ministries and private companies in other jurisdictions are already deploying drone technology. For instance, the Minnesota Department of Transportation and the US Federal Highway Administration are planning on utilizing flying drones to assist in conducting bridge inspections. To improve its dam inspections, Hydro-Québec uses underwater drones, and also estimates the annual savings from doing so to be over $2 million.

In 2020, the Ministry commissioned York University to conduct a study on the practicality and advantages of applying existing flying drone hardware, sensor and software technologies for performing inspections. The study found that drone technology can assist inspectors, especially in inspecting inaccessible components and components that would require shutting down roads and disrupting traffic. The Ministry has also engaged private companies to demonstrate the benefits of underwater drone technology for inspections at water depths that would be hazardous for human divers. However, we noted that these technologies had not been incorporated in inspections at the time of our audit.

RECOMMENDATION 4

In order to achieve cost-efficiencies and resolve accessibility issues in bridge inspections, we recommend that the Ministry of Transportation:

- prepare a business case for incorporating new technology in the inspection process; and
- if possible, incorporate new technology such as drones to assist with the inspection process.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the recommendations and will be undertaking research and preparing business cases as appropriate for the incorporation of new technologies into our standard inspection procedures.

The Ministry continually considers and researches new and innovative approaches for all areas of its activities, including bridge inspections.

The Ministry has reviewed information on the use of drones, both aerial and submersible, for bridge and culvert inspections, as well as having had several service provider presentations. Further research, jurisdictional scans and testing of how these technologies may be able to supplement normal bridge inspections will be conducted. Ministry staff are in regular contact with their peers in other jurisdictions, including through the Transportation Association of Canada (TAC), to stay abreast of innovations and changes. This includes the use of drones in other jurisdictions. As part of this research, the Ministry will conduct some trial inspections using new technology to get first-hand experience in their use and develop policies on their continued use following the trial.

4.3 Compiling and Recording Inspection Data for the Capital Planning Process

4.3.1 Accuracy of Onsite Inspections Impacts the Calculations on Which the Ministry Bases Safety and Capital Planning Decisions

The Ministry's capital planning can be directly impacted by subjective inspections of structures and inaccurate recording of data in its system. Consequential decisions on planning for the repair and maintenance of structures are based on small differences in the BCI—a single value measure of a bridge's overall condition and economic value that does not consider how critical individual elements are to a structure's integrity. We noted that an inspector's capacity for objectivity and their level of care at the point of the visual inspection, along with the accuracy in recording the results of the inspection, impacts the entire chain of calculations and the decisions based on the values generated. The BCI values are input into the Ministry's Asset Management System, the capital planning tool; if these are inaccurate the capital planning tool would generate a sub-optimal capital plan, impacting the provincial budget and financial planning. If BCI values are too low, then the Ministry may forecast funding in advance of the bridge rehabilitation work or replace the asset too soon. If, on the other hand, BCI values are too high, rehabilitation or replacement funding may not be predicted to match the optimal time.

4.3.2 Ministry's Bridge Audit Inspection Program Highlights Problems with Inspection Accuracy

The Ministry implemented a program to audit bridge inspections in 2006 to ensure that structures in the provincial inventory are inspected in compliance with the OSIM. Each year, approximately 50 structures (10 bridges in each road network region) are selected and inspected independently by the Bridge Office.

Our Office obtained the audit inspection reports for the five years from 2015 to 2019; the 2020 audit inspections were cancelled due to the COVID-19 pandemic. These reports compare inspectors' methods and measurements, and look at how closely BCI values calculated by the inspectors compare with the BCI values the Ministry auditors arrive at during their inspection. The Bridge Office's completed reports are then sent to the five road network regions; the regions are custodians of their own inspection data and are responsible for correcting errors or discrepancies found in these reports.

In all of the reports we reviewed, we noted that the Ministry found deviations and consistently recommended almost word for word: "Regions should be reminded of the importance of correcting inventory, components and quantity information that affects accuracy of BCI values."

When we asked the Ministry to explain why its Bridge Office needed to repeat this recommendation each year, it gave us the following explanations:

- Errors the Bridge Office audit inspection finds are not system errors but human errors. Some are errors contained in inspection reports that were reviewed and considered complete by regional staff.
- Sometimes inaccurate dimensions were input in the Bridge Management System for a bridge under audit, possibly because the bridge may have been altered in a rehabilitation, and the new dimensions were not yet entered in the system, causing differences between the BCI assessed by inspectors and the BCI assessed by Bridge Office auditors.
- The Bridge Office does not follow up on its recommendations to correct the bridge data, as the regions are custodians of the data and are responsible for making any required changes.

We also noted that for 2018 and 2019, the Bridge Office included an examination of factors that can skew the inspection results. One such factor is an aging bridge in transition from excellent to good condition—the Bridge Office audit found that "inspectors have different judgements" when differentiating between these two condition states and recommended that inspectors recognize that age-based transitions are "a guideline" but that they should base their condition ratings on their actual observations.

4.3.3 Bridge Audit Inspection Program Has Minimal Impact on Regional Offices' Inspections

We found that the Ministry performs audit inspections and provides recommendations to the regions without taking follow-up action to ensure that its recommendations are being followed. As a result, errors remain uncorrected and the Bridge Office auditors have been making some of the same recommendations to the regions year after year.

We selected a sample of inspections to verify whether the changes to the element quantities that were recommended in the 2017 and 2018 Bridge Office audit inspection reports were actually made in the Bridge Management System by the regional staff. We found that the noted incorrect quantities were not corrected in the Bridge Management System for any of the samples we reviewed.

RECOMMENDATION 5

So that the Ministry of Transportation (Ministry) bases its safety and capital planning decisions for the province's bridges on reliable and accurate inspection data, we recommend that the Ministry:

- update inspection and data entry practices where they are seen to be outdated or open to error; and
- have its Bridge Office inspection auditors follow up on their recommendations to the province's road network regions and ensure that errors its auditors have found in data that affects the accuracy of the Bridge Condition Index values are corrected, or that documentation exists demonstrating that no corrections are needed.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the recommendation with respect to the accuracy of the data being input into the Bridge Management System (BMS), which then drives evidence-based decision-making. The Ministry acquired a new BMS in 2018 and has been making additional enhancements since its implementation and will continue to do so going forward, using this and other recommendations as a tool for enhancements.

Enhancements include alerting the inspector if there are large changes in the Bridge Condition Index (BCI), which then requires the inspector to review data and/or justify why the large change has occurred; it also includes the ability to store information about inspector health and safety documents and bridge clearance information. Data integrity checks have been added in a few key locations to ensure validity of data.

The Ministry will review the software to determine if additional data integrity checks can be incorporated. The consultant oversight process will be strengthened to incorporate data verification.

For the audit inspections performed by the Bridge Office, a memo detailing the audit requirements and scope, including post-audit actions and follow-up, has been prepared and will be implemented prior to the start of the next inspection cycle.

4.4 Training and Oversight of Inspectors

4.4.1 Ministry Lacks a Robust Training and Testing Program for Its In-House and Consultant Inspectors

The Ministry does not provide adequate training to its in-house and consultant inspectors so that they conduct inspections in a consistent manner and produce accurate and complete information for bridge management and capital planning purposes. The OSIM states that each element of a bridge is to be inspected in a systematic fashion. Given that the Ministry's network of 3,000 bridges and 2,000 culverts is inspected by several different engineers, inconsistent assessments due to subjective judgment, poor-quality observations and inaccurate recording of data could result in unreliable BCI data being used to plan bridge maintenance and capital planning.

We noted that in-house and consultant inspectors are required to attend the OSIM inspection workshop/webinar organized by the Ministry every two years to ensure they are aware of recent inspection issues and updates to the Bridge Management System, inspection techniques, specifications, safety regulations, Ministry directives or standards.

We reviewed the last five Ministry workshops/webinars from 2012 and 2020 and found that the Ministry's program lacks rigour and testing to confirm that inspectors understand the OSIM and the inspection data they need to record. For example, we noted that until 2012, as part of its training program, the Ministry would take all in-house and consultant inspectors to bridges to conduct on-site inspections. This practical component was done to help inspectors with consistency and accuracy of their inspections. The Ministry has not provided this practical component to its consultants since 2014, and it has not provided it to in-house inspectors since 2018. Our research of other jurisdictions in Canada found that, unlike Ontario, Quebec's transportation ministry requires its inspectors to take part in on-the-job field training. We noted in particular that, since 2018, rather than focusing on on-the-job training, the Ministry has been focused on providing instruction to inspectors on data entry into the Bridge Management System in order to address data accuracy issues.

We also reviewed the training material provided to inspectors from 2010 to 2021 and found no information about the quality assurance procedures for inspections that inspectors should know. The Ministry developed the quality assurance procedures in 2009 as a response to our 2009 audit, to improve the quality of its inspections; however, it confirmed that more than 10 years after they were developed, the quality assurance memo and procedures may not be known by all Ministry inspectors, including new staff.

We also noted that the Ministry does not test in-house and consultant attendees' knowledge of the training material at the completion of the training. Certificates of training completion are automatically issued. Testing attendees at the end of the training ensures that attending inspectors pay attention and retain the information presented to them. In comparison, the transportation ministry of Alberta tests its inspectors as part of their certification process. After we identified this lack of testing in 2020, the Ministry acted upon our finding and incorporated a quiz at the end of its OSIM inspection workshop in April 2021. However, this quiz has yet to be implemented as an ongoing instrument to test trainees at the completion of their training.

We reviewed the Ministry's audit reports of its own reinspection of bridges and noted that the Ministry has recommended that consultant training could be made more rigorous to address the inconsistencies in inspection results that repeat year after year. The Ministry's audit reports recommend that technical guidance be provided to consultants prior to and during their work.

RECOMMENDATION 6

To improve quality of its bridge inspections, we recommend that the Ministry of Transportation (Ministry):

- reinstate the practical field inspection component of the Ontario Structure Inspection Manual (OSIM) training;
- include quality assurance procedures for inspections as part of the future OSIM inspection training curriculum for Ministry staff; and
- finalize the testing approach and test the inspectors as part of its certification process at the end of the OSIM training workshop.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the Auditor's observations with respect to the importance of training and quality assurance procedures for bridge inspections. The expertise, experience and skill of the inspector is very important to achieve the safety and asset management goals of the bridge inspection. The Ministry began training bridge inspectors in 2004. The format of the course has changed over time as inspectors gained additional knowledge of the OSIM methods.

The Ministry will review the OSIM inspection training program to ensure that appropriate practical training is provided to inspectors while respecting safety concerns. This training would be reviewed in advance of bridge inspectors doing work for the Ministry to ensure their training is current immediately.

In addition to a practical component, specific training will be provided to Ministry staff to reinforce the importance of proper oversight of consultant inspectors.

The Ministry will also incorporate testing into the next training workshop, scheduled for 2022.

4.4.2 Regions Do Not Follow Internal Policy Memos Issued by the Ministry

Regional Staff Do Not Always Perform Required Quality Checks to Ensure Bridge Inspections Are Conducted According to the OSIM Standards

Regional structural engineers and project managers did not always oversee and conduct quality checks of inspectors' work to ensure that their inspections followed the OSIM standards and Ministry requirements.

To ensure consultant inspectors deliver high-quality work, in 2009 the Ministry's Head Office issued a memo to the regions outlining oversight and quality checks the regions are required to do to ensure consultants conduct their inspections according to the OSIM standards, as stated in their contracts. Without these quality assurance checks, the Ministry cannot verify the accuracy, completeness and consistency of the data produced during bridge inspections.

We sampled four contracts that include hundreds of bridge inspection assignments that the Ministry awarded to consultant firms and checked if quality assurance checks were done. We found that:

- In three of the four contracts, we found that regions did not provide feedback to consultants on their performance, as required by the quality assurance policy. Consultant inspectors are supposed to complete at least 10 inspections so that regional staff can review their work and give them feedback for improvement before April 30 of each year. These reviews are done to catch improper inspection practices and inadequate documentation early, before consultants repeat the same errors many times over. We found that when contracts are awarded later than the Ministry's deadline of April 1, consultants may not have completed 10 inspections in time for regional staff to review their inspection reports and provide feedback. One region informed us that it did not complete this quality assurance task because its staff were familiar with the consultants' work from previous contracts.
- In three of the four contracts we sampled, our testing confirmed that regional staff did not visit 3% to 5% of bridge sites inspected by consultants, as its policy requires, to ensure that consultants were conducting inspections in the manner required by the quality assurance policy.
- In all four contracts we sampled, we found that regional staff did not reinspect 3% to 5% of bridges in order to compare results to consultant inspections, as required by the quality assurance policy. Staff from one region informed us that they were not aware that they were supposed to complete these quality assurance tasks.

RECOMMENDATION 7

To ensure that its regional staff are aware of and follow its quality assurance requirements and other internal policies, the Ministry of Transportation (Ministry) should:

- communicate the quality assurance requirements that are required to be performed by regions for consultant inspections through the biennial workshops held for Ministry staff; and
- audit a sample of contracts to ensure that regions are performing the quality assurance checks.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the Auditor's recommendation with respect to quality assurance requirements. As a part of a broader initiative, the Ministry has been consolidating standards, specifications, manuals and memos into a single location for easier access by staff. This work has already begun with the Technical Publications website. Additional document categories are being added to the system.

In addition to this, OSIM inspection training for Ministry staff will include a component on oversight of consultant inspection starting with the next workshop in 2022.

Reviewing consultant work is a necessary task to ensure a quality bridge inspection is obtained. The Structure Office will audit a sample of bridge inspections to validate that the quality assurance checks have been undertaken. The Ministry anticipates beginning this work within the next 12 months.

4.5 Risk of Inconsistent Rehabilitation Practices Due to Ministry's Use of Outdated Structure Rehabilitation Manual

The Structure Rehabilitation Manual is the main document used by the Ministry and its engineers for planning rehabilitation work on its bridges and culverts and their structural components. The manual is divided into four parts that reflect the following steps of structure rehabilitation:

1. Condition Surveys
2. Rehabilitation Selection—describes methods of rehabilitation and shows how the information collected in the condition surveys is used to select the most appropriate method of rehabilitation for each different type of structural component
3. Contract Preparation
4. Construction—summarizes the construction procedures used for each of the rehabilitation or repair methods included in the manual

The manual was last updated in April 2007. Since then, there have been major changes in practice to all four stages of the rehabilitation work. For example, Part I–**Section 1.3** of the manual describes the history of protective treatments for structures in Ontario. Historic context is important in understanding the performance and deterioration of structures over time and potential impacts on repairs and rehabilitation treatments. The current version of the manual covers the protective treatments in use in Ontario from the 1950s to the early 2000s. The section does not capture treatment strategies that have emerged since the last publication and that now are part of the current standard.

As another example, some of the information in Part 4–Guidance to Designers, requires updates and supplements. We noted that the Ministry is aware of this and has been issuing numerous interim policy memos to provide updated guidance to designers who rely on the Structure Rehabilitation Manual. One such policy memo contains the guideline for condition surveys to investigate the condition of rebar at the base of certain barrier walls, which is not explicitly covered in the manual itself.

A risk exists that designers will miss some of these policy memos or neglect to incorporate their guidance into their practice. As a result, the manual is not meeting its intended purpose, which is to facilitate consistent practice and quality control.

Incorporating the Ministry's policy memos into an updated manual would help reduce inconsistencies in practice and improve the clarity of the manual's guidance to engineers. It would also reduce the risk that engineers might miss the supplementary information the Ministry has been issuing in memo form. Publishing a new edition of the Structure Rehabilitation Manual would also give the Ministry the opportunity to add new information that may be relevant to bridge rehabilitation.

RECOMMENDATION 8

To ensure that construction methods used in the repair and rehabilitation of bridges are up to date and are applied consistently across the province, we recommend that the Ministry of Transportation update its Structure Rehabilitation Manual to incorporate all of the interim policy memos it has issued since its last update, and assess if any other relevant information should be included.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the recommendation. Where required, memoranda are released in lieu of updating the Structure Rehabilitation Manual and other manuals in order to implement new requirements more quickly than waiting for a review of the entire manual. The contents of the memos and the lessons learned during their implementation are then incorporated into the respective manuals and guidelines when they are updated.

The Ministry has issued eight updates specific to bridge rehabilitation since the last manual update.

The Ministry will review the practices of other jurisdictions and advanced techniques and incorporate these and all recent policy memos into an updated Structure Rehabilitation Manual. This is anticipated within 24 months.

4.6 Inspection and Maintenance of Culverts

4.6.1 Ministry Cannot Accurately Plan Capital Work for Culverts as BCI Ratings Do Not Accurately Reflect the Actual Condition of the Culverts

The Ministry's Bridge Management System (BMS) contains the inventory of its bridges and large culverts and their condition (see **Section 2.6.1**). This includes the condition of the various elements of a structure observed during the visual inspection and their associated replacement values. The information is used to calculate the overall Bridge Condition Index (BCI). The condition data and inventory information from the Bridge Management System are downloaded for use in the Asset Management System.

The Asset Management System uses deterioration models to "deteriorate" a culvert's condition (BCI) by 0.5% to 2% per year, accelerating depending on age, and calculates treatments for each level of deterioration. Once the BCI falls below 60, the culvert is assessed to be in poor condition, and maintenance work (rehabilitation or replacement) is usually scheduled within one year. Culverts are expected to reach 60 BCI at the 25-year mark, at which point the Ministry would schedule rehabilitation work within one year.

Ministry staff have noted that while BCI is a good indicator of deterioration of a bridge, where visual inspection of the components can effectively forecast its rate of deterioration, BCI deterioration ratings are not representative of the condition of culverts. A Ministry analysis found little correlation between a culvert's age and its true condition; as well, a culvert may have a very poor appearance without needing work.

We noted, through our review of an internal memo sent to senior management in the Ministry, that Ministry staff who conducted culvert inspections from 2010 to 2015 have found that the Ministry's guidelines and schedules for maintenance and rehabilitation work, as described in **Figure 8**, may not be applicable to culverts:

- Culverts rated in poor condition (BCI <60) may not actually require rehabilitation or replacement within one year, as the guidelines stipulate.
- Culverts rated in fair condition (BCI 60–70) may not actually need rehabilitation or repair within five years, as stipulated by the guidelines.

This means that the deterioration models used by the Ministry and coded into the new AMS for planning capital work show more rapid deterioration than the actual deterioration observed by inspection staff. As a result, without accurate measures of its culverts' current condition or forecasting of their future condition, the Ministry cannot accurately plan and budget long-term capital work required for the culverts. In particular, there is a risk that the Ministry may order work on culverts prematurely when their actual condition does not require rehabilitation or replacement.

To correct for the BCI ratings when applied to culverts, Ministry engineers apply judgment when needed to adjust the BCI. They informed us that they may ignore the data until the Ministry's structural engineers point out that large culverts need work for other reasons, often when they become functionally deficient.

We have also noted that despite knowing the limitations of BCI for capital planning for culverts, the Ministry uses BCI data for public reporting. For example, Ontario's strategic investment plan, *Ontario's Long-Term Infrastructure Plan 2017*, states that 65% of large culverts are in good condition, 24% fair and 11% poor.

4.6.2 Lack of Performance Targets for Large Culverts to Benchmark Against

The Ministry sets performance targets for its large asset groups, which helps it allocate funds for long- and short-term maintenance and repairs. For example, the Ministry sets a "good condition" performance target for pavements of 67%. This means maintaining 67% of pavements in good enough condition so as not to require any work for six or more years and maintaining 33% of pavements in fair condition, where work is expected to be needed within five years. Ontario's long-term target for bridges is for 85% to be in good condition. On average, bridges in Ontario require major rehabilitation every 30 to 35 years and replacement after 60 to 70 years.

The Ministry makes annual funding requests for these assets based on various scenarios in which the funding is linked to the ability of the bridges and pavements respectively to meet the performance targets of 85% and 67% good condition.

We noted that the Ministry does not have a performance target for large culverts, even though this asset is valued at $5 billion. As result, there is no benchmark against which to compare the Ministry's performance in maintaining and repairing culverts.

Many jurisdictions have such performance targets for culverts. For example, the Township of Enniskillen in Ontario sets a target of 100% for maintaining its large culverts in better than poor condition. The Ontario Township of Russell's target is to maintain the average condition of its culverts at fair or good. The US Federal Highway Administration sets 10% as the upper limit for all National Highway System bridges and culverts classified in poor condition. California's target for having its culverts in good or fair condition is 90%.

RECOMMENDATION 9

To improve the accuracy and usefulness of its data on the condition of large culverts, we recommend that the Ministry of Transportation:

- review and update the existing rating system to better represent the actual condition of large culverts;
- review and update the deterioration model for large culverts used in the Asset Management System to predict future repair needs; and
- develop performance targets for large culverts, measure the culverts against the targets, and report on their condition publicly.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the Auditor's recommendation that the rating system and performance targets for large culverts be reviewed.

The Ministry has focused its efforts on the asset management of pavements and bridges, as they represent the largest expenditures for the overall maintenance and renewal of the highway network. After having developed these bridge tools to an advanced level, the Structures Office will now begin to focus on the larger culverts.

The Ministry will review the rating system for culverts to reflect the condition of large culverts more accurately.

The Ministry will also review the deterioration models used for culverts of all types and materials. The asset management of large culverts will be reviewed to determine if changes should be made to better anticipate future repair needs.

The Ministry will also review and develop performance targets for large culverts and measure culverts against the targets to properly reflect the condition of culverts of all materials and report on their condition publicly.

4.7 Regional Tracking of Recommended Maintenance Work

In 2017, the Ministry reaffirmed to the regions its policy requiring all maintenance needs to be recorded on an inspection form and forwarded to the maintenance crews of the responsible region for action, with high-priority items flagged to be completed first. When maintenance work is completed, the region is to record confirmation on the maintenance tracking spreadsheet that the required work has been performed.

We noted that the regions were not required to submit confirmation to the Ministry that the maintenance work has been completed. As a result, the Ministry's Head Office is unaware if maintenance work is done in a timely manner.

A maintenance tracking spreadsheet, with needed work identified during the two-year inspections and recommended time frames, must be used. Regional offices are to indicate work completed and its date; the spreadsheet has a column for them to add further comments. They must also enter the priority of the maintenance needs so that the work is scheduled accordingly. Notice of completion of the work is sent by email within the region.

We obtained maintenance tracking spreadsheets from 2017 to 2020 from three of the five regions and found that these regions did not always record the procedures for acting on maintenance recommendations resulting from the biennial inspections. One region's spreadsheet with work dates completed from one bridge co-ordinator could not be located for one of the years. For two regions, we could not determine whether all recommended maintenance work, regardless of priority level, was actually done because the completed work dates were not always recorded. For one region none of the maintenance work on any spreadsheet was given priority levels as required by the 2017 procedures document. For two regions that did track their completed work, we could not determine whether the work was done in a timely manner because dates were not specified.

Since the regions do not track the completion of maintenance work as required, it cannot be confirmed that their maintenance work is being completed in a timely manner.

We asked the Ministry's Head Office whether it followed up with the regions to confirm they are tracking and conducting maintenance work in a timely manner in accordance with the 2017 memo. The Head Office informed us that it does not receive the regions' maintenance tracking spreadsheets and does not monitor the completed work because the regions are responsible for tracking and managing their maintenance work.

RECOMMENDATION 10

To validate that regions are tracking the maintenance needs of the province's bridges and completing maintenance work in a timely manner going forward, the Ministry of Transportation Head Office should obtain the information from the regions or through the Bridge Management System and ensure that maintenance work is completed on a priority basis.

MINISTRY RESPONSE

The Ministry of Transportation (Ministry) agrees with the recommendation. The Ministry has developed a spreadsheet tracking system for ensuring that maintenance work is performed. With the release of the new Bridge Management System in 2018, this functionality was not yet incorporated. The entire tracking along with prioritizing and tracking work is now performed within the system subsequent to this audit.

The Structures Office will now also review the maintenance accomplishments and create reports on the work performed and ensure the appropriate action was taken.

Appendix 1: Ontario Structure Inspection Manual (OSIM) Element Groups and Elements

Source of data: Ministry of Transportation

Element # and Group	# of Elements within the Group	Elements Impacting BCI	Replacement (Initial) Cost ($)	Impacts BCI?	Weight of Impact on BCI (%)	This Element Group Includes a Critical Element for Priority Index
1. Piers	3	3	2,800	Yes	21.4	No
2. Abutments	4	4	2,600	Yes	19.8	No
3. Joints	3	2	2,101	Yes	16.0	Yes
4. Decks	7	6	1,085	Yes	8.3	Yes
5. Trusses/arches	4	3	900	Yes	6.9	Yes
6. Retaining walls	4	3	750	Yes	5.7	No
7. Barriers	4	4	600	Yes	4.6	Yes
8. Beams/main longitudinal components (MLE)	6	3	600	Yes	4.6	Yes
9. Approaches	5	4	231	Yes	1.8	No
10. Coating	2	2	205	Yes	1.6	No
11. Sidewalk/curb	2	2	190	Yes	1.4	No
12. Culverts (only for culverts)	3	3	1,050	Yes (only culverts)	8.0	No
13. Accessories	4	0	0	No	0.0	No
14. Bracing	1	0	0	No	0.0	No
15. Embankments and streams	3	0	0	No	0.0	No
16. Foundation (non-observable component)	1	0	0	No	0.0	No
Total	**56**	**39**	**13,112**		**100.0**	

Note: BCI = Bridge Condition Index.

Appendix 2: Example of Bridge Condition Index (BCI) Calculation

Prepared by the Office of the Auditor General of Ontario

Element and Element #	A Total Quantity (m^2)	B Unit Replacement Cost ($/$m^2$)	C = A x B Total Replacement Value (TRV) ($)	Excellent (1.0) (m^2)	Good (0.75) (m^2)	Fair (0.4) (m^2)	Poor (0) (m^2)	Current Element Value (CEV) ($)
4 Deck top	1,000	120	120,000	500	100	200	200	78,600*
4 Soffit	1,000	120	120,000	500	100	200	200	78,600
8 Beams	600	200	120,000			300	300	24,000
2 Abutments	100	900	90,000		50	50		51,750
1 Piers	100	900	90,000		50	50		51,750
7 Barrier	200	200	40,000		120	80		24,400
Total			**580,000**					**309,100**

Note: The BCI for this bridge is: 100 * (309,100 / 580,000) = 53

* Calculations:
Total Equivalent Value (TEV): 120 * 1,000 = 120,000
Current Element Value (CEV): (1.0 x 120 x 500 + 0.75 * 120 * 100 + 0.4 x 120 * 200 + 0.0 x 120 * 200) = 60,000 + 9,000 + 9,600 + 0 = 78,600

Appendix 3: Audit Criteria

Prepared by the Office of the Auditor General of Ontario

1. Cost-effective processes and systems are in place to ensure that complete bridge inventory and inspection information is accurately collected, recorded, reviewed and maintained.
2. Cost-effective oversight and training processes are in place to ensure bridge inspections are conducted in accordance with required standards.
3. Timely and cost-effective bridge inspection processes are in place to identify bridge safety concerns, and repair, maintenance and replacement needs.
4. Cost-effective and efficient processes are in place to ensure bridge repair and maintenance work is prioritized and completed with due regard for public safety and economy, and that this work is completed on a timely basis.
5. Human and financial resources are used efficiently and cost effectively to fulfill mandated responsibilities.
6. Performance indicators are in place to measure the effectiveness of the bridge inspection and maintenance program. Results are used to take timely corrective actions.

Appendix 4: Selected Details of Structural Engineering Expert's Assessment of the Ontario Structure Inspection Manual, 2018

Source of data: Cambrium Infrastructure Solutions, Bridge Inspection Audit—2020

- The Ontario Structure Inspection Manual (OSIM) has improved somewhat in the 2018 edition. The fonts have been cleaned up and the OSIM is now a fully searchable PDF document.
- The photographs in the OSIM have not been updated, including the low-quality pictures generated from photocopies of old black-and-white photos. For future editions, these photos should be replaced with more recent examples in full colour.
- The general layout has not changed for many editions. Some of the layout seems confusing. For example, the sections concerning Signs and Live Loads appear to be out of place. The OSIM does not present up front a coherent organizing principle built around a step-by-step guide for preparing the inspection forms and conducting the inspection of a bridge and its elements. The process of inspection requires the user to flip back and forth through the manual. New inspectors find the manual to be confusing.
- OSIM should explicitly clarify that the regulatory requirement for inspection every two (2) calendar years does not mean every 24 months. Over time, inspections undertaken every 2 calendar years will produce an average inspection interval of approximately 24 months.
- The relationship between defect severity and material condition has been made more explicit through the addition of the Combined State Tables (2008) as well as the new colour-coded matrices for Concrete and Asphalt. If the colour-coded matrices were expanded to a full page each for every material, these could potentially contain sufficient information to fully supplant some or all of the cumbersome State Tables and Combined State Tables.
- The degradation of material condition from Excellent to Good is currently described in words and the description is vague. Various inspectors and jurisdictions use various mathematical depictions and interpretations of this. Future editions of OSIM should provide a proper degradation graph to eliminate the current ambiguity.
- The OSIM does not provide a sufficiently detailed list of situations where the environment applicable to various elements should be considered as Benign, Moderate or Severe. Additionally, the use of the word "Severe" to describe the environment can lead to confusion with the use of the word "Severe" to describe material defects. The term "Severe" should be changed to "Aggressive" to describe environments with high susceptibility to salt splash and salt exposure.
- The OSIM element inspection tables are cumbersome in their presentation. The table organization appears to date back to a time before computer usage became widespread. The OSIM element tables are generally sufficient for documentation of each bridge element. However, the table format has not changed through many iterations of OSIM and could be improved substantially to provide clearer documentation, easier transfer of field data to bridge management databases and better flagging of issues and recommended follow-up inspection work. Further, the table format results in OSIM reports that are unnecessarily long. As an alternative, many consultants and jurisdictions have created custom element tables in a format compatible with modern data processing.
- The usability of the element inspection tables could be further enhanced by provide references to the appropriate place in the manual for each item of data.
- There is also no coherent reference for many of the data fields in the element inspection tables. Currently, the inspector must work through the myriad example photos and diagrams to try to find a suitable diagram describing the relevant data fields, e.g., Element Type. This shortcoming has been addressed by various Bridge Management System (BMS) software packages and inspection applications which include pre-populated picklists and drop-down tables to ensure data consistency and compliance. Some consultants have distilled this pick-list data into printed data entry manuals to supplement OSIM. In order to provide more universal data compliance, future editions of OSIM should include such lists in the manual.

- While OSIM indicates that Enhanced Inspection should typically be done for structures that are over 30 years old with critical components in poor condition, the OSIM inspection tables do not include any facility for flagging and summarizing those elements that are considered critical or potentially vulnerable.
- The Appraisal Indices (Fatigue, Seismic, Scour, etc.) are not explained in any meaningful manner within OSIM.
- OSIM could benefit from a companion "Case Book" with various situation/interpretation scenarios to help guide inspectors through typical and less typical situations encountered during OSIM inspections. This could take the form of "Case Memos" issued by MTO as situations are reported, with the memos continuously compiled into a document available for download.

Office of the Auditor General of Ontario

20 Dundas Street West, Suite 1530
Toronto, Ontario
M5G 2C2

www.auditor.on.ca

ISSN 1911-7078 (Online)
ISBN 978-1-4868-5647-3
(PDF, 2021 ed.)