

New Scanning Technology Defers Expensive Culvert Rehabilitation

Managing buried infrastructure has increasingly become a priority for asset owners across North America. Much of today's highway infrastructure was deployed decades ago and have reached or passed their designed life expectancy and are scheduled for rehabilitation or replacement. To assist in the identification of soil voids, which potentially lead to critical culvert failures, the Ontario Ministry of Transportation (MTO) hosted a pilot to test a new scanning technology.

In 2017, [Transport Canada](#) approached the ministry proposing a partnership that included an infrastructure inspection firm called [Inversa](#), an engineering company headquartered in New Brunswick, that provides unique condition assessment tools. The proposed partnership offered an opportunity to test and verify newly developed inspection technology that detects the presence of soil voids behind buried corrugated metal pipe culverts.

The ministry recognized the advantages of the partnership to confirm the structural integrity of Ontario's extensive network of buried infrastructure, and to assess the validity of historic ministry culvert inspection data.

For the pilot project, the ministry provided access to over 150 corrugated metal pipes (CMP) that were identified for rehabilitation. Eighty-one of the 150 available culverts were scanned for the pilot, thus validating the accuracy of the scanning technology.

Thousands of culverts traverse beneath Ontario highways. Traditionally, ministry culvert replacements are included in the planning of capital highway projects or are replaced independently when required. Numerous rehabilitation measures that enhance structural integrity extending a culvert's service life. However, when soil voids exist behind culvert walls, water flow can further remove soil from around a rehabilitated culvert, compromising its structural integrity. Detecting the extent of soil voids is key to ensuring that rehabilitation is successful.



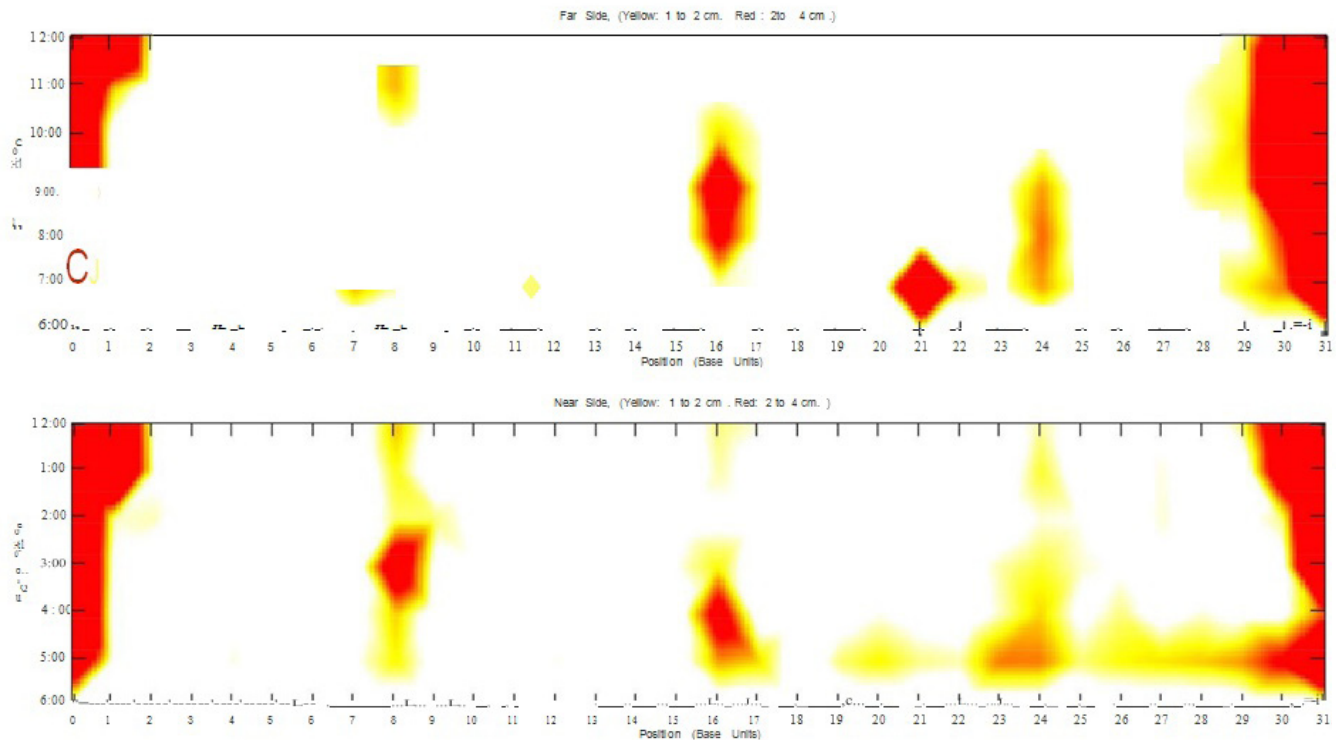
A culvert inspection technician uses the hand-held wand to identify soil voids.

What is a Culvert Failure?

A culvert is a conduit, typically embedded underground, that enables water to flow unobstructed beneath the highway from one side of the road to the other. They are often constructed of corrugated metal, concrete or other materials, and rely on soil compaction to support structural integrity.

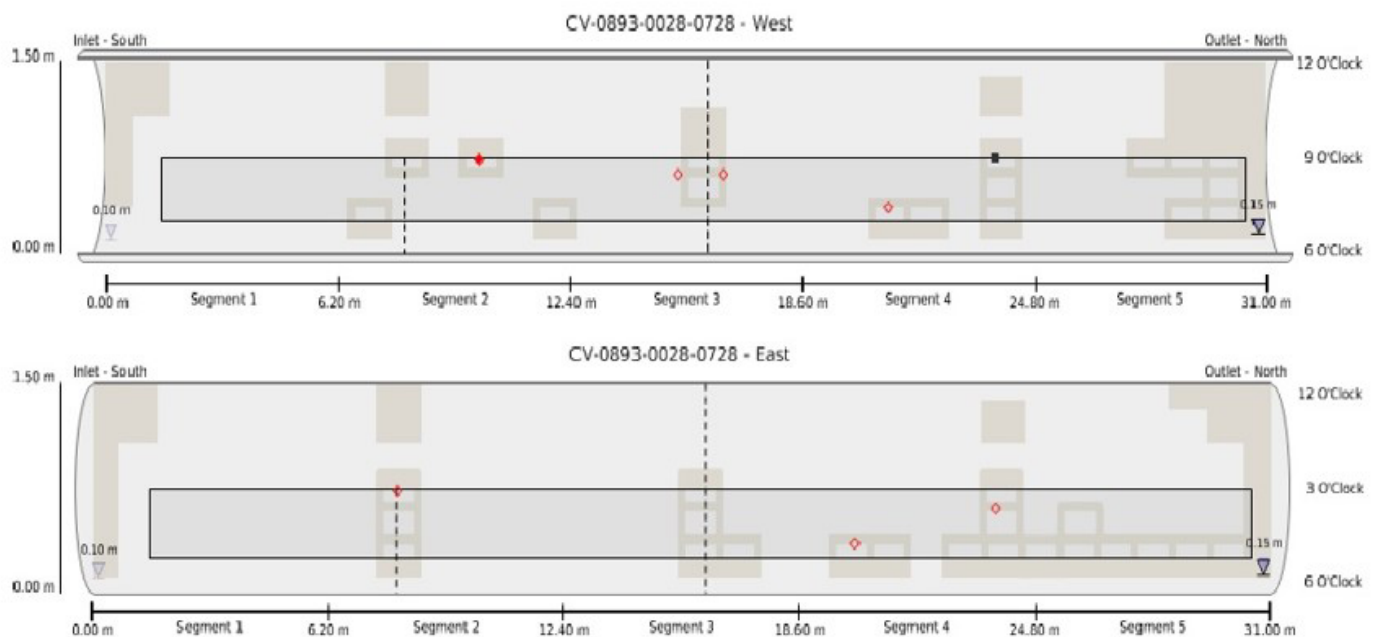
The structural integrity of a culvert is compromised when soil voids occur or when soil erodes or collapses around the outside wall of a culvert. Severe soil voids can result in catastrophic culvert failures that often lead to inconvenient and expensive road closures. >

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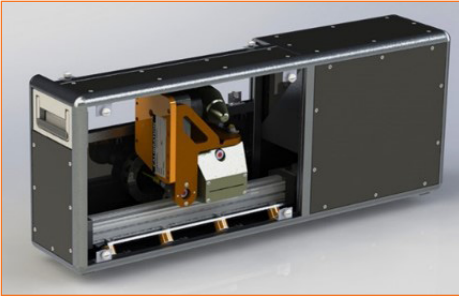
Above: A heat map of a ministry culvert: white, indicates good soil compaction; yellow, areas that require monitoring or further inspection; and, red, indicates soil voids.*

Below: Resulting pipe map developed from the culvert scan of a ministry asset showing visual indicators of culvert anomalies.*

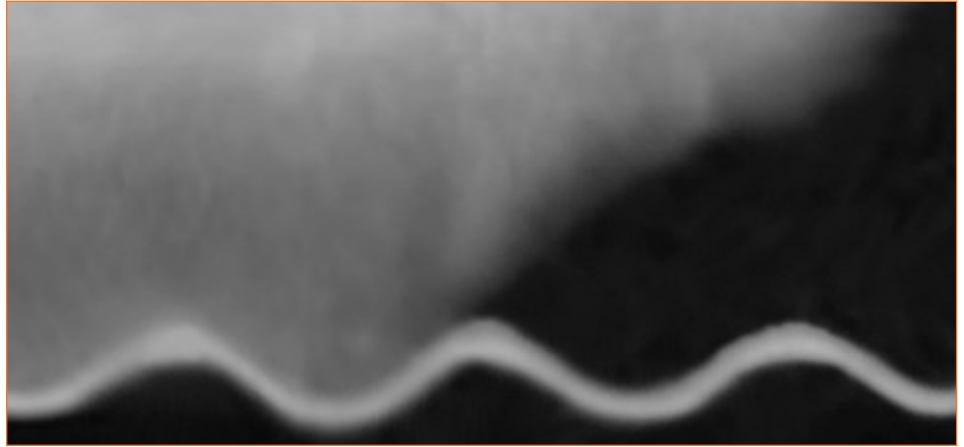


Acoustic Anomalies are designated as rectangles and are assigned an ID number. The X and Y position is recorded and displayed in the table for the corresponding pipe segment.

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*Inversa's BCT™ technology is based on medical CT (CAT scan) and allows the imaging of materials such as steel, composites, soil and plastics for diagnostic purposes. The unit is roughly the size of a suitcase and weighs approximately seventy pounds.**



*Diagnostic imaging of CMP identifies an area of soil void. This image shows the CMP wall (wavy white line at the bottom) with good supporting soil on the top left of the image and a transition to a soil void on the right of the image, shown in black.**

Culvert Inspections

For many years, culverts have been inspected visually and by conducting acoustic "knock tests". A knock test requires an inspector to tap on culvert walls listening for changes in acoustics to identify hollow voids behind culvert walls. Subjective and speculative, the acoustic method lacks descriptive evidence for the condition of the supporting soil. Also, knock tests identify the quantity, not the magnitude, of suspected voids.

During the pilot, a unique new condition assessment tool, a lightweight scanning wand called the Single Side Handheld Radiation Probe, was deployed to assess soil integrity behind Ontario's culvert walls. The wand is a unique infrastructure condition assessment tool, capable of non-destructively mapping culvert wall soil compaction more reliably than current visual or acoustic inspection methods.

The wand takes the guess work out of soil void detection and is used in conjunction with tablet software that collects and stores all culvert scanning data. The wand

can be operated by any technician and requires only a micro-curies strength isotope (ionizing radiation) for operation. It is spectral calibrated to generate heat maps of each inspected culvert which displays soil void sizes within one-third of a centimeter.

Generated heat maps represent the length of a culvert, using clock positioning at every meter, to show soil compaction behind the culvert. Areas shown in red are flagged for more detailed investigation using Backscatter Computed Tomography (BCT™) technology for further imaging.

Taking the Guesswork out of Culvert Soil Voids

BCT™ technology operates similarly to hospital MRI and CT scan technology by providing digital images of soil integrity behind culvert walls. It differs from conventional medical radiography because it has the unique ability to examine infrastructure from a single side, providing a tomographic, or cross-sectional "slice" view of a culvert regardless of its physical size. BCT™

is used to scan through almost any material. This technology must be used by licensed technicians.

Over the past ten years, BCT™ technology has been developed, tested and implemented. It has been used to scan culverts owned by Canadian provinces, U.S. Departments of Transportation, and the Army Corp of Engineers.

BCT™ In Action

Each BCT™ diagnostic scan transfers data to an on-site laptop, building a digital image of the soil densities behind the culvert wall, in roughly six minutes.

The BCT™ culvert scan is mapped with GPS coordinates building a pipe map the length of the culvert, also using clock positioning at every meter. This pipe map provides visual indicators of physical culvert defects that may contribute to loss of soil compaction. >

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Site specific inspection data is transferred to a software application, where it may be viewed and categorized. Categories for a culvert's physical condition include:

- culvert blockage
- head walls
- topside
- joints
- cracks
- waterway
- fine soil loss
- rocks
- corrosion

Each category features optimal, repeatable data and is accompanied by condition photos for reporting purposes. The collected data is used to generate tailored infrastructure condition reports.

Unexpected Results for Ministry Assets

The pilot project results surprised the ministry - of the 81 culverts previously identified for rehabilitation, only 13 require maintenance activities, 11 require rehabilitation and just two were identified for full replacement. The remaining 56 culverts were verified for continued monitoring only. The data verifies that many expensive rehabilitation projects may be deferred allowing the ministry to more effectively plan resource investment and allocation.

MTO and the Ontario Structural Inspection Manual (OSIM) defect scale ratings were applied to the pilot project findings and confirmed the condition of supporting soils and structural integrity for each of the scanned Ontario culverts. The scans conclusively established more accurate Ontario culvert data that can be integrated with the ministry's existing asset management systems.

The culvert inspection at Highway 406 provided a good case study for the scanning technology. Visually, the culvert appeared to be nearing the point for

rehabilitation or replacement but scanning results revealed that the culvert had several years of service life left and should remain on the ministry's list of monitored culverts.

Verification of soil conditions for Ontario culverts defers the expense of planned rehabilitation projects, the associated highway traffic management, and the disruption of roadside vegetation root systems which prevent culvert failures by keeping soils in place.

The data collected scanning Ontario's culverts leaves nothing to interpretation. By understanding the true structural condition of buried culverts, the ministry has a conclusive view of asset integrity.

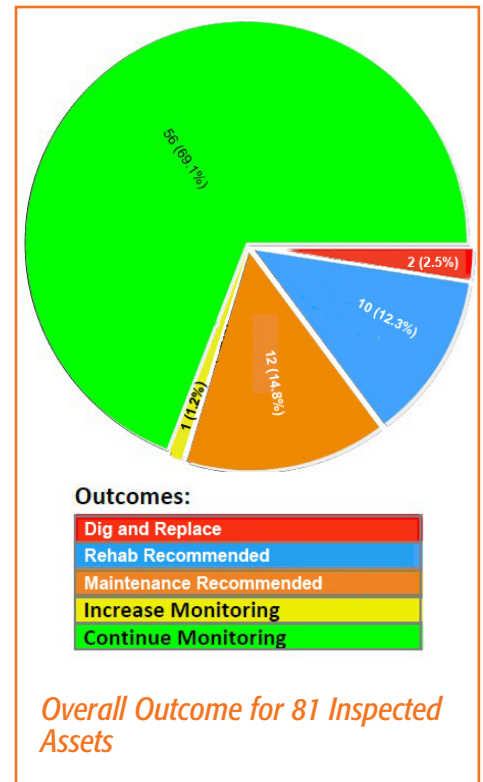
Overall Outcome for 81 Inspected Assets

- Excellent: 7
- Good: 30
- Fair: 29
- Poor: 15

Strategic Planning and Spending

Thousands of culverts traverse beneath Ontario highways. Traditionally, ministry culvert replacements are included in the planning of capital highway projects or are replaced independently when required. Numerous rehabilitation measures that enhance structural integrity extending a culvert's service life. However, when soil voids exist behind culvert walls, water flow can further remove soil from around a rehabilitated culvert, compromising its structural integrity. Detecting the extent of soil voids is key to ensuring that rehabilitation is successful.

With conclusive data on each of the 81 culverts, the ministry may now make strategic investment decisions related to



the prioritization or deferment of culvert rehabilitation or replacement. Optimized decision-making results in a reduction in unnecessary rehabilitation costs and stabilizes highway safety.

Environment and Climate Changes

The intensity and frequency of recent weather events demonstrate changes in our environment and climate. Storms present a significant strain on infrastructure and can lead to infrastructure failures which are extremely harmful to the environment and watercourses, often resulting in lengthy and traumatic impacts on fish and other wildlife habitat.

In many cases, failures can be avoided by identifying the assets most at risk of failure and developing a rehabilitation strategy. Replacing assets disrupts watercourses more dramatically than trenchless rehabilitation. >

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To show the scale of this culvert, a technician stands on the right embankment as inspectors scan near the end of a 106m culvert under Ontario's Highway 406, in St. Catharines, Ontario.

The resulting new infrastructure data is customized specifically for the Ontario's Ministry of Transportation. As we experience more severe weather, which often affects culvert capacities, data can be used in conjunction with emergency management system planning or with critical climate change data.

Conclusion and Potential Savings for the People of Ontario

To put the scanning results into perspective, to dig and replace the ten Ontario culverts recommended for rehabilitation it would cost approximately \$16 million. Furthermore, it would cost approximately \$125 million to replace all 81 culverts inspected during the pilot project. In the coming years, failures may continue to escalate, which will further



A monitor on the embankment at a culvert site, receives data from the BCT™ scan to build a visual image of soil integrity, shown on the right. It takes six minutes for a scanned culvert wall image to transmit to the on-site computer monitor.

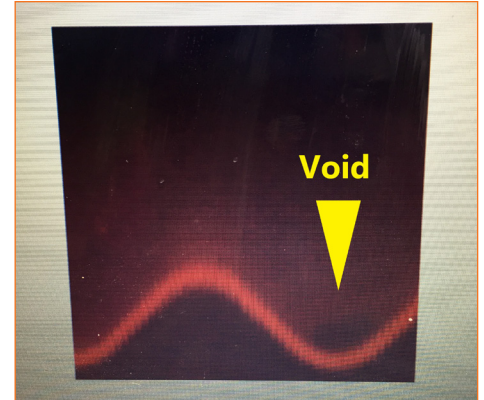
strain budgets and operational planning. Fortunately, through innovation many of these risks can be mitigated.

The ministry considers the pilot project a success for all partners, based on the following results.

- Corroboration from BCT™ scans validated the precision of the new hand-held inspection wand
- The accuracy of MTO's historic culvert inspection data was verified
- Premature rehabilitation for 56 culverts was deferred

The pilot project included on-site scanning work and the collection of in-depth structural imaging and data, to establish a baseline for ministry assets. The baseline data can assist ministry inspection staff with future condition comparisons. Consecutive inspections can provide asset deterioration trends.

The ministry will continue to explore opportunities to establish a condition



The image of the Highway 406 culvert scan reveals a slight void - it is displayed as a darker shadow in the right dip of the corrugated pipe.

baseline for all Ontario culvert infrastructure, and to develop a data collection process to better identify asset deterioration trends.

There is also potential for using BCT™ scanning technology to eliminate the guess work related to bridge deck inspections. BCT™ has the capability to scan through asphalt or concrete to identify delamination or deterioration of bridge decks, eliminating invasive inspection methods like core sampling. •

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