CITY OF OTTAWA

OTTAWA ROAD 174 AT JEANNE D'ARC PIPE COLLAPSE

ROOT CAUSE ANALYSIS REPORT

BMROSS
engineering better communities

CITY OF OTTAWA

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ROOT CAUSE ANALYSIS REPORT

December 7, 2012

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File No. 12187

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EXECUTIVE SUMMARY

On September 4, 2012 a section of steel storm drainage pipe collapsed under the southerly exit ramp of Ottawa Road 174 at Jeanne D'Arc Boulevard. The subsequent "sinkhole" in the roadway was large enough that a vehicle entered the hole and eventually lodged in the pipe.

Based on available drawings originally submitted to the Township of Gloucester, the 3600 mm dia. pipe was constructed between 1975 and 1980. In the City's asset inventory, the pipe known as STM50005, was identified as 10 gauge Corrugated Steel Pipe (CSP). The original drawing indicated that approximately 55 m was not CSP but was instead "10 Gauge, Hot Dipped Galvanized and Asphalt Coated Liner Plate". Later work established that the actual length of the liner plate section was approximately 48 metres.

The original design drawing indicated that the liner plate section was to be installed by tunneling, which is the reason liner plate was utilized rather than CSP. Tests of the material conducted on behalf of the Corrugated Steel Pipe Institute, post-failure, established that the liner plate, at the time of failure did not show any evidence that it had ever been galvanized.

A CCTV inspection on August 17, 2011 had identified that the CSP sections upstream and downstream of the liner plate section were in reasonably good condition, but the 48 m liner plate section was severely corroded. At approximately 36.5 to 38 m from the pipe entrance, two relatively large holes were observed. Significant corrosion was evident throughout. As a result of the CCTV inspection the City proceeded to immediately organize a project to re-line the corroded pipe section.

B. M. Ross and Associates Ltd (BMROSS) was retained to undertake a root cause analysis (RCA) for the incident and prepare a report. The report was to "*…include identification of industry and regulatory due diligence requirements and practices and the City's protocols and adherence to these at the time and to make recommendations regarding potential assessment protocol enhancements.*"

Extensive background information, dating from prior to the construction of the pipe, up to and including the repair of the collapse was provided to our firm by the City. In addition to the review of records and correspondence, interviews were held with City staff, representatives of the contractors involved in the project and two engineering firms.

The root cause analysis considered the impacts of construction activity within the pipe near the time of the collapse as well as activities leading up to and following the August 2011 CCTV inspection. It was concluded that the root cause of failure of the pipe beneath Ottawa Road 174 was that the structure's inherently greater risks were not identified and acted on before the pipe's structural integrity was lost.

The City of Ottawa has generally defined trunk facilities, which by design serve greater areas and are physically larger, as more critical. Trunk sanitary sewers and watermains have been given priority over storm sewers in terms of investigation effort.

Inspection by CCTV is being done regularly to improve the knowledge of the system and to determine priorities for repair and rehabilitation. At current inspection rates the entire system would be inspected approximately once every 15 years.

The City has recently adopted and is putting into practice a risk-based approach to asset investigation and investment. Improved definitions of higher risk storm sewer facilities still need to be established.

There are no legislated requirements with respect to inspection frequencies or methods for storm sewers. To establish current best practices regarding monitoring and rehabilitation for similar infrastructure our firm contacted asset management personnel at four Canadian municipalities; Calgary, Edmonton, Hamilton, and Toronto.

In our opinion the approach taken in Ottawa has not been noticeably different than the other municipalities contacted. Although the others report having risk-based approaches, how they define risk, in terms of the factors considered, is different from location to location.

In summary, based on the information obtained, we believe that, although the City did not have in place a definition of a high-risk storm sewer asset that focused on both probability and consequences of failure, its efforts to date have been similar to other jurisdictions.

Recommendations

Based on our review of the causes of the collapse of the storm sewer collector under Ottawa Road 174 just west of the Jeanne D'Arc exit, we wish to make the following recommendations:

1. The current definition of a high-risk storm sewer asset (i.e. trunk sewer) should be expanded, as envisioned by the recently adopted Comprehensive Asset Management Program, to include consideration of the probability of failure as well as the consequences of failure.

2. Those storm sewer assets designated as high risk—other than those that were assessed following the event in question—be examined as soon as possible and all these examinations be reviewed by persons qualified to assess the condition and judge the need for further action.

3. That an attempt be made to assess the quality of the information in the City's storm sewer asset inventory. Where there are weaknesses related to the inventory's source materials or as determined from observations, an effort to improve the data should be made.

4. With full consideration of safety issues, and where feasible, physical inspections be used to supplement CCTV inspections for high risk assets.

5. Procedures for scoping capital projects always include a discussion of the consequences of not proceeding quickly.

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CITY OF OTTAWA
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PIPE COLLAPSE
ROOT CAUSE ANALYSIS REPORT

1.0 INTRODUCTION

On September 4, 2012 a section of steel storm drainage pipe collapsed under the southerly exit ramp of Ottawa Road 174 at Jeanne D'Arc Boulevard. The subsequent "sinkhole" in the roadway was large enough that a vehicle entered the hole and eventually lodged in the pipe.

B. M. Ross and Associates Ltd. (BMROSS) was retained to undertake a root cause analysis (RCA) for the incident and prepare a report. The report was to "*…include identification of industry and regulatory due diligence requirements and practices and the City's protocols and adherence to these at the time and to make recommendations regarding potential assessment protocol enhancements.*" [1]

A copy of the Statement of Work is provided in Appendix A.

2.0 THE EVENT

In August 2011 the City had a closed circuit television (CCTV) inspection completed of an existing 3600 mm diameter steel pipe crossing under Ottawa Road 174 in the vicinity of the Jeanne D'Arc Boulevard exit. It was determined from the CCTV inspection that a section of the pipe was significantly corroded to the point of holes being visible in the pipe.

City staff immediately began mobilizing to undertake a rehabilitation of the pipe. They did this by expanding the scope of a project that had been initiated in July 2011 to replace the entrance headwall of the same pipe.

Subsequently, on August 14, 2012, the City awarded a construction contract to slip line the 3600 mm diameter steel pipe with a 3000 mm liner pipe and replace the existing headwall. The contractor started work on Friday, August 31, 2012, and then shut down for the Labour Day weekend.

Construction activities resumed on the morning of Tuesday, September 4, 2012 and proceeded until approximately 3:30 – 4:00 p.m. when rain began increasing the depth of

[1] City of Ottawa, "Statement of Work – Review and Analysis of September 4, 2012 Highway 174 Culvert Collapse."

flow in the storm sewer system. Shortly thereafter, at approximately 5:00 p.m., a substantial sinkhole developed within the exit ramp driving lane approximately 41 metres (m) north of the pipe headwall. Figure 2.1 shows a photograph of the sinkhole taken on September 4, 2012, hours after a car had been lodged in it.

Figure 2.1
Sinkhole in Ottawa Road 174 September 4, 2012

Photo Courtesy of City of Ottawa

3.0 THE PIPE

3.1 History

Based on available approval and as-built drawings originally submitted to the Township of Gloucester, the 3600 mm diameter storm sewer collection pipe that crosses under Ottawa Road 174 just west of the Jeanne D'Arc overpass was constructed between 1975 and 1980.[2] The works were completed as part of the development of the Convent Glen Storm Drainage Works.[3] At the time of construction, the works crossed under what was then Provincial Highway 17, which was a two lane road. In the City's asset inventory (ArcGIS database), the pipe known as STM 50005, was described with the following attributes:

[2] Cumming, Cockburn & Associates Limited, Drawing No. 3061-10 dated Nov/75 as approved by the Township of Gloucester and as-built version dated November 1980.
[3] "Engineers Report on Storm Drainage Works for the Development of the Convent Glen Community, Township of Gloucester," Cumming, Cockburn & Associates Limited, received by the Township of Gloucester, March 5, 1972.

- Location details
- Information is based on a design drawing (i.e. not as-built drawing)
- It is a trunk sewer collector
- Constructed in 1975
- Width (i.e. diameter) 3600 mm
- Material 10 gauge Corrugated Steel Pipe (CSP)
- It was located under an asphalt/concrete road
- It was not lined
- It had been CCTV inspected in 2007

Of note regarding the attributes for STM 50005 are the following points:

1. The entire pipe was identified as 10 gauge CSP. The original drawing indicated that within the 127 m length of STM 50005, approximately 55 m was not CSP but was instead "10 Gauge, Hot Dipped Galvanized and Asphalt Coated Liner Plate."[2]

   The as-built drawing, which is not referred to in the database, identified the addition of 15.2 m of CSP on the south end but made no changes to the other lengths or notes regarding the liner plate.

   A CCTV inspection of the structure in August 2011[4] established that the actual length of the liner plate section was approximately 48 m.

2. As later confirmed by staff of the City's Asset Management Branch, there was no CCTV inspection in 2007. Information provided to our firm[5] indicated that there had been a CCTV examination of the pipe in 1997.

The original design drawing indicated that the liner plate section was to be installed by tunneling, which is the reason liner plate was utilized rather than CSP. Installation by tunneling was confirmed during the repair. Tests of the material conducted on behalf of the Corrugated Steel Pipe Institute, post-failure, established that the liner plate, at the time of failure did not show any evidence that it had ever been galvanized[6]. Observations during removal of the failed section also did not identify any evidence of the proposed asphalt coating. Following the event it was established[7] that the pipe was located in a corrosive environment and upon removal it was confirmed to be severely corroded with extensive perforations.

[4] Caesar's Inspection Services "Video Inspection Report for Ottawa – Project number TV11-E1 – Report Number 7-11-128 – Storm Sewer Inspection Easement 174 to Voyageur", September 27, 2011.
[5] R.V. Anderson and Associates Ltd., "Convent Glen North Community-City of Ottawa – Storm Sewer Investigative Report", November 2006.
[6] "Metallurgical Technical Investigation Report – MTI Report No. 2012635", September 19, 2012.
[7] Brouce Services Inc. – "Hwy 174 and Jeanne D'Arc Blvd 3.6 m (12') Drainage Pipe"-DRAFT, prepared for Stantec Consulting, Sept, 2012, pp 3-5.

It is believed that following its original construction, ownership of the pipe was assumed by the Township of Gloucester and then the City of Gloucester upon its incorporation in 1981. Following amalgamation in 2001, it entered the asset inventory of the City of Ottawa.

STM 50005, as shown in figure 3.1, could be considered to be somewhat unique in that it was partially constructed of un-galvanized tunnel liner plate in a corrosive environment with conventional galvanized CSP on both ends.

Figure 3.1
Location of STM50005

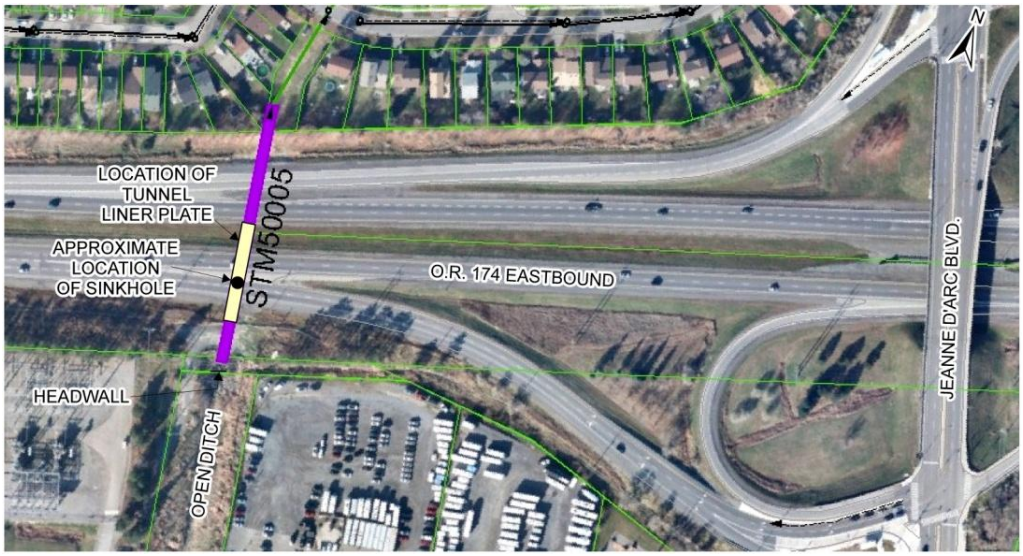

Figure 3.2 is a photograph taken in July 2012, showing the transition from CSP to liner plate. The photo was taken during the tendering period for the re-lining project by a representative of a pipe supplier for the proposed liner whose interest was the nature of the bend in the pipe.

Figure 3.2
Transition from CSP to Liner Plate – July 2012

Photo Courtesy of KWH Pipe

3.2 CCTV Inspection Observations

STM 50005 and the downstream sewers were scheduled for inspection in 2011 as part of the City's on-going review and evaluation of its sewer assets.

The CCTV inspection[4] on August 17, 2011 identified that the CSP sections upstream and downstream of the liner plate section were in reasonably good condition, but the 48 m liner plate section was severely corroded. At approximately 36.5 m to 38 m from the pipe entrance, two holes were observed. One at the 5 o'clock position, which was approximately 1.1 m^2 in area, and the other at the 8 o'clock position, which was approximately 0.9 m^2. Significant corrosion was evident throughout the liner plate section of pipe.

4.0 METHOD OF INVESTIGATION

Extensive background information, dating from prior to the construction of the pipe, up to and including the repair of the collapse was provided to our firm by the City. A list of the information reviewed is included in Appendix B.

In addition to the review of records and correspondences, interviews were held with City staff, representatives of the contractors involved in the project (Louis W. Bray Construction Limited and Clarence McDonald Excavation Ltd.) and two engineering firms, Novatech

Engineering Consultants Ltd. and Stantec Consulting. Novatech provided design services for the headwall and liner project. Stantec had been retained by the City following the collapse. Following the interviews, all interviewees were given the opportunity to clarify or add to the information that they had provided. A list of names of those interviewed is included in Appendix C.

Where it was felt necessary, BMROSS staff contacted other individuals for opinions and insights relevant to the issue.

To establish current best practices regarding monitoring and rehabilitation for similar infrastructure our firm contacted asset management personnel at several large Canadian municipalities.

As part of the investigation a timeline documenting the history of STM 50005 was developed. This timeline is included in Appendix D.

5.0 ROOT CAUSE EVALUATION

5.1 Definition

A root cause analysis (RCA) is the "identification and evaluation of the reason for non-conformance, an undesirable condition, or a problem which (when solved) restores the status quo."[8]

In practice, a traditional approach is to continually ask "why" something occurred until the original or "root" reason for the situation is determined.

5.2 Findings

Figure 5.1 provides a visual summary of the findings of the RCA. The event (the collapse of the pipe) is presented on the extreme right and causes for the event are presented right to left, moving backwards towards the root cause(s). Facts established through the investigation are presented in a shaded box. Where a cause is our "opinion", based on the investigation, it is presented in an unshaded box.

Each box is numbered and the background for the information is explained below in the corresponding text.

1. At approximately 5:00 p.m. on Tuesday, September 4, 2012, a sinkhole developed in the east driving lane of the Jeanne D'Arc Boulevard off-ramp. The centre of the sinkhole has been estimated to be approximately 41 m north of the pipe entrance. The sinkhole was a consequence of a complete loss of structural integrity and the collapse of part of the liner plate section of the pipe beneath the road.

[8] http://www.business dictionary.com/definition/root cause analysis.html.

2. On August 31 and September 4, 2012 the Contractor had been inside the pipe installing lights and removing rocks and debris. He was using a CAT 301.8 mini-excavator and a skid-steer loader. Both pieces of equipment were on rubber tracks and fit easily into the 3.6 m diameter space.

   The Contractor has indicated[9] that there was approximately 375 mm to 450 mm of material in the bottom of the pipe. He did not remove that material because it made a suitable roadway for the loader. The work on September 4, 2012, generally started at the north end of the liner plate section and worked southward. It was not concentrated in one area.

   At approximately 3:00 p.m. it began to rain and the water levels in the pipe increased. The Contractor shut down his operations and was gone from the site by approximately 4:00 p.m.

   Two possibilities exist, either the construction activities contributed to the collapse or they did not.

   2A. It is possible that the timing was just coincidence, that the Contractor's activities did not contribute.

   2B. It is also possible that vibrations from the excavator and loader, or even changes in the flow path of the water, as a result of debris removal, influenced the timing of the collapse. In our opinion, this is the more likely scenario.

   We know that the collapse of the pipe was imminent because collapse occurred. We also know that the Contractor's personnel were in the pipe throughout the day and believed it was safe. In our opinion, on the basis of the video taken August 17, 2011 alone, it would not be possible to determine when the pipe might collapse.

3. The Handbook of Steel Drainage & Highway Construction Products[10] defines the CSP sections of STM 50005 as a "soil-metal structure." The reference to "soil" is related to the fact that the condition and shape of the soil around the structure is maintained by the pipe. The pipe itself is flexible and forces created by the loads above the pipe are transferred to the surrounding soil. If voids exist, there is a potential for loss of stability and the possibility of the structural integrity being compromised.

   The tunnel liner plate section may technically not be considered a soil-metal structure but would support and rely on the soil using the same principles.

   As noted in Section 3.2, there was a CCTV inspection of the pipe[4] on August 17, 2011. The inspection identified locations at approximately 36 m to 38 m from the pipe

[9] Interview of personnel from Louis W. Bray Construction Ltd and Clarence McDonald Excavation Ltd – October 17, 2012.
[10] The Corrugated Steel Pipe Institute, "Handbook of Steel Drainage & Highway Construction Products", 2007, Page 203.

entrance and at roughly the 5:00 and 8:00 o'clock positions on the pipe, where the pipe had completely corroded.

Following the failure, one of the Contractor's personnel who was working in the structure commented that the eroded pockets behind the pipe appeared to be larger than indicated by the image in the 2011 CCTV inspection"[11]

In our opinion, the voids between the pipe wall and the native soil, combined with the highly corroded condition of the liner plate, indicate that the pipe was structurally compromised and ready to collapse. The fact that it did collapse is confirmation.

4. Upon review of the CCTV images on August 17, 2011, City staff quickly identified that the pipe was in need of rehabilitation. The video was relayed the same day from the CCTV contractor to Environmental Services Department (ESD) staff, to Asset Management Branch (AMB) and then to Design and Construction Branch – East (D&CBE). Within a day of the CCTV work, steps were taken to expand the scope of a project to replace the pipe's headwall to include re-lining of the pipe itself.

   Although, in our opinion, the images on the video were such that further assessment of the pipe was warranted immediately, no action other than activities related to the re-lining were taken. In our opinion, the appropriate immediate response would have been a visual inspection with the goal of better understanding the condition of the pipe, followed by whatever response the visual inspection determined was warranted. Consideration should have been given to ensuring that the soil erosion outside the pipe was not a concern and that further erosion did not occur.

   In our opinion, the immediate need for a more robust assessment of the pipe was not understood, identified or communicated.

5. Staff of D&CBE indicated[12] that, had they considered the condition of the pipe an "emergency," immediate steps to repair or rehabilitate would have been taken. As an example for how quickly they can mobilize for an emergency, they referred to the response taken to deal with the actual collapse.

   The reasons given for not considering the situation an emergency were the fact that the video indicated that the pipe was circular and there were no indications of any settlement of the road above. Representatives of the City and Novatech Engineering Consultants Ltd..[13, 14] both noted the roundness of the pipe and the absence of settlement, as did the Contractor's personnel who were inside the pipe on August 31 and September 4, 2012, as reasons why it appeared to be safe.

[11] From interview of staff from L. W. Bray and CME on October 17, 2012.
[12] From interview of staff from Design and Construction Branch East – October 16, 2012.
[13] Novatech Engineering Consultants Ltd., "Letter to City of Ottawa re: Youville Storm Sewer and Inlet Structure OR 174", September 11, 2012.
[14] From interview of staff from Novatech on October 17, 2012.

We would concur, on the basis of the CCTV video image in August, 2011, that considering the condition of the pipe an emergency was not warranted. However, further investigation was definitely warranted.

6. In addition to the fact that the pipe condition was not considered an emergency, we believe that there are multiple, possible and related reasons why immediate action, other than scoping a re-lining project, was not taken.

   6A. The significance of the deterioration in terms of the structural integrity of the pipe was not known. The potential for soil erosion to continue and further weaken the structure was apparently not understood.

   6B. The actual rate of corrosion and pipe deterioration was not known because there were no previous inspections to compare with the 2011 video images. No report or video were available from an inspection reported to have occurred in 1997. The City was operating on a video inspection cycle of approximately 15 years.[15]

   6C. The extent of the corrosion deterioration of the pipe was not known. Although holes had been identified during the 2011 CCTV inspection at 36.5 m and 38.0 m from the entrance, no other areas of the liner plate sections were specifically examined. Representatives of the Contractor have noted, after observing the video on October 17, 2012,[11] that upon entering the pipe in August 2012, the extent of the corrosion looked considerably more severe than was indicated by the video taken a year earlier.

   The Contractor also pointed out that upon removal the liner plate was observed to be considerably more corroded than was evident when they were working inside it.

   In addition to the above, it is our opinion that the video image does not indicate well that almost two square metres of material had disappeared from the side of the pipe.

7. In our opinion the diameter of the pipe, at 3600 mm, and the difficulty the camera had traversing the debris made it difficult for an accurate assessment of the pipe's condition to be made using CCTV inspection only.

8. In addition to the limitations of the CCTV inspection it is our opinion that the extent of deterioration was not known because there was no follow up visual inspection of the pipe.

9. No records of previous inspections existed other than a comment in a 2006 report,[5] based on a 1997 CCTV inspection, that there were no deficiencies that "require immediate action." To staff of AMB this meant that no inspection had taken place since at least 1997. The impact of this is that those reviewing the CCTV video had no benchmark from which to judge the rate of deterioration of the pipe.

[15] From interview of staff from Asset Management Branch, October 16, 2012.

10. The City undertakes five CCTV inspection contracts each year. Four of these contracts are routine inspections of storm and sanitary sewers. Each is for the inspection of approximately 70 km of sewer. The fifth contract is to do special inspections, related to specific projects or other needs. An outcome of the above is that sewers are inspected on approximately a 15 year cycle.

    When construction activity is going to take place at a location, an effort is made to CCTV inspect the adjacent sewers to determine if further work is required. In 2011, STM50005 was part of routine work in Orleans but also being done because of the proposed headwall replacement project at its entrance.

11. In addition to having a limited understanding of the extent, rate and significance of the deterioration it is our opinion that those who viewed the video did not appreciate the importance of protecting the native soil on the exterior of the pipe from erosion. As a soil-metal structure or as liner plate installed by tunneling, the stability of the structure depends on ring compression and the interaction of the steel ring with the surrounding soil. Loss of soil results in a loss of stability. When combined with the loss of pipe strength through corrosion, there is definite potential for failure.

12. It is our opinion that, although those who saw the CCTV video recognized the need for rehabilitation they did not translate what they observed into potential instability that needed to be immediately investigated further and acted on. We believe that individuals with experience in design and/or inspection of larger steel structures would have reacted differently.

13. We believe that the tunnel liner plate section of STM 50005 collapsed because the greater risks associated with this particular asset were not identified and acted on.

    In our opinion there was a risk <u>of</u> failure (i.e. probability) related to the pipe's material of construction, corrosive environment and age.

    There was also a risk <u>from</u> failure (i.e. consequences) related to the pipe's location under a busy highway and its function as a conduit for a large tributary area.

14. In our opinion these risks were not identified for three reasons:

    14A. The available record drawings were the drawings prepared for approval and As-built purposes which identified the tunneled section of the pipe as being 10 gauge liner plate, "hot dipped galvanized" with coating in the base. For reasons that are not known, a different less robust material was used but not identified. The records maintained by the City in their asset database were based on the approval drawing and therefore incorrect.

    14B. Until recently the City has not had a risk-based approach to asset management for storm sewers that would have resulted in increased observation of high risk

assets such as STM50005. This pipe was not inspected until 15 years after any previously known inspection and therefore in the latter part of the sewer inspection cycle.

14C. Related to 14B is the observation that the City treated STM 50005 like most other storm sewer assets and not as a relatively large diameter older metal pipe in a corrosive environment under a busy roadway.

5.3 Conclusions from Root Cause Analysis

In conclusion, it is our opinion that the root cause of failure of the pipe beneath Ottawa Road 174 was that the structure's inherently greater risks were not identified and acted on before the pipe's structural integrity was lost.

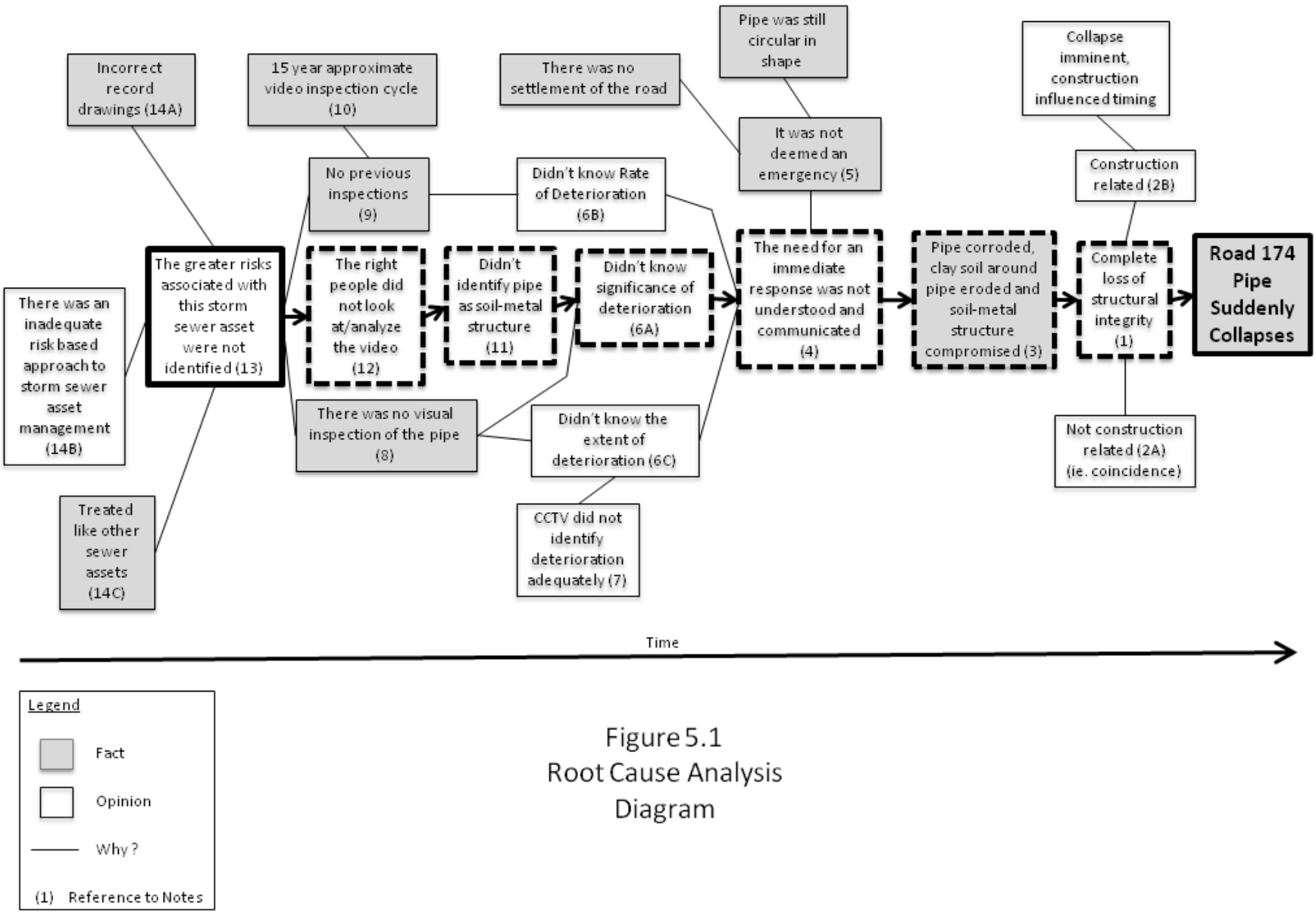

Figure 5.1
Root Cause Analysis
Diagram

6.0 ASSESSMENT OF DUE DILIGENCE AND PROCEDURES

6.1 Legislated Requirements

There are no legislated requirements with respect to inspection frequencies or methods for storm sewers. STM 50005 is included in the City's ArcGIS inventory as a trunk sewer collector and records indicate that the previous owners, the Township of Gloucester also considered this pipe to be a sewer. This classification is also consistent with practices in Hamilton and Toronto.

In Ontario, Regulation 104/97 requires that bridges and culverts having a span greater than 3 m be inspected at least once every two years. This is a fairly onerous inspection requirement and standard that in our opinion, reflects an understanding of the risk such structures pose to traffic on our roadways.

In citing this regulation, we are not suggesting that STM 50005 should have been inspected every two years. Instead, our intent is to point out that similar structures have been deemed to warrant relatively frequent inspections to reduce the risk from failure.

6.2 Best Practices

To determine current best practices our firm contacted four Canadian municipalities: Calgary, Edmonton, Hamilton, and Toronto. The first three are similar in population to Ottawa. Toronto has a similar history in terms of amalgamation of urban areas.

The approach was to determine if other municipalities had a risk-based approach to asset inspection and if they did, how would they define risk. There were also questions related to inspection frequencies and methods.

Table 6.1 summarizes our findings.

Table 6.1
Summary of Calls to Other Municipalities

Question	Calgary	Edmonton	Hamilton	Toronto
Do you have a risk based approach to sewer assets?	Has a risk based approach, driven by an asset's repair history (i.e. more repairs = more risk) Considers consequences and probability.	The City uses both a reactive (complaint driven) and proactive approach. The latter is based on asset age and "other initiatives".	Have completed a criticality study considering sewer function, size and location. Considers consequences and probability.	Yes, for local sewers and trunk sewers. Considers risks of failure and from failure.
Are sewer risks identified by diameter?	Risk is established mostly on the basis of repair history independent of diameter.	They use different programs for trunk and local sewers.	Yes, but diameter is not a controlling risk factor.	It is done based on drainage area.
Are sewer risks identified by material?	Calgary has relatively few metal sewers and generally positive repair experience.	No. Risk is based on age, previous inspections and "other initiatives".	Yes, but in Hamilton this is more applicable for forcemains.	Yes, it is a consideration. They have few metal sewers.
Are sewer risks identified by location (e.g. roadways)	A roadway location is not considered to be a specific risk factor.	High traffic volume roadways have higher frequencies of inspection.	Not necessarily. Risk is defined more by history.	Yes, but it is one of several factors.
Inspection frequency for high risk sewers	Frequency is triggered By repair history and previous inspection observations.	Larger sewers are inspected every 10 to 12 years. They are working on setting targets.	Inspection frequency is driven by previous inspections and repair history.	Toronto has inspected all trunk sanitary and combined sewers. Storm sewers are still being inspected.
Inspection frequency for all sewers	Depends on repair history and results of previous inspections. There is no defined frequency.	They are working on setting targets for all sewers.	For interceptors and major trunks the goal is 10 years but what actually happens depends on funding.	Trunk sanitary and combined sewers have a greater frequency.
Method of initial inspection	Primarily CCTV	Primarily walk-through and CCTV.	CCTV	CCTV

A review of the information provided to us indicates the following:

- Other jurisdictions typically consider risk when establishing sewer inspection frequencies.
- Probability of failure and consequences of failure are usually considered in defining risk.
- How risk is defined is quite variable. Sanitary and combined sewers would tend to have a greater risk ranking than storm sewers. Repair history and previous inspection observations are a frequently used factor and in some cases repair history is the key driver, for investigations.
- Materials, location and diameter are risk factors but not necessarily weighted more significantly than repair history.
- CCTV inspection is the most common assessment tool.

6.3 Due Diligence

Due diligence is considered to be the level of care that a reasonable person (or entity such as the City of Ottawa) exercises to avoid harm to persons or property.

In the context of STM 50005 it is necessary to determine whether or not the City undertook all reasonable steps to ensure that this pipe, and others like it, did not collapse. In our opinion the key consideration is whether the City attempted to identify storm sewer pipes that pose a greater risk of failure or a greater risk from failure.

We wish to point out the following:

- On October 10, 2012, Council approved a "Comprehensive Asset Management Program"[16] that adopts a risk-based approach to investigation and investment.
- The Asset Management Branch had, prior to 2012, identified the need for developing a "trunk sewer renewal strategy" and "sewer needs prioritization model"[17]
- Since 2006 the City has focused on CSP pipes and renewed them when warranted[18].
- Best practices for asset management are evolving quickly. This includes technologies for assessment and risk-based approaches to monitoring.

The City of Ottawa has generally defined trunk facilities, which by design serve larger areas and are physically larger, as more critical. Trunk sanitary sewers and watermains have been given priority over storm sewers in terms of investigative effort due to risks related to previous system performance issues (sewer back-up, large watermain failure).

[16] City of Ottawa, "Comprehensive Asset Management Program, 2012 State of the Asset Report" – Page 4.
[17] Asset Management Branch, "2012 Work Plan."
[18] Email communication from staff of Asset Management Branch.

Inspection by CCTV is being done regularly to improve the knowledge of the system and to determine priorities for repair and rehabilitation. At current inspection rates the entire system would be inspected approximately once every 15 years.

The City has recently adopted and is putting into practice a risk-based approach to asset investigation and investment. Improved definitions of higher risk storm sewer facilities still need to be established.

In our opinion the approach taken in Ottawa has not been noticeably different than the other municipalities contacted. Although the others report having risk-based approaches, how they define risk, in terms of the factors considered, is different from location to location.

In summary, based on the information obtained, we believe that, although the City did not have in place a definition of a high-risk storm sewer asset that focused on both probability and consequences of failure, its efforts to date have been similar to other jurisdictions.

7.0 Recommendations

Based on our review of the causes of the collapse of the storm sewer collector under Ottawa Road 174 just west of the Jeanne D'Arc exit, we wish to make the following recommendations:

6. The current definition of a high-risk storm sewer asset (i.e. trunk sewer) should be expanded, as envisioned by the recently adopted Comprehensive Asset Management Program, to include consideration of the probability of failure as well as the consequences of failure.

7. Those storm sewer assets designated as high risk—other than those that were assessed following the event in question—be examined as soon as possible and all these examinations be reviewed by persons qualified to assess the condition and judge the need for further action.

8. That an attempt be made to assess the quality of the information in the City's storm sewer asset inventory. Where there are weaknesses related to the inventory's source materials or as determined from observations, an effort to improve the data should be made.

9. With full consideration of safety issues, and where feasible, physical inspections be used to supplement CCTV inspections for high risk assets.

10. Procedures for scoping capital projects always include a discussion of the consequences of not proceeding quickly.

All of which is respectfully submitted.

B. M. ROSS AND ASSOCIATES LIMITED

Per _____
Stephen D. Burns, P. Eng.

Per _____
Bruce W. Potter, P. Eng.

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APPENDIX A

CITY OF OTTAWA
STATEMENT OF WORK

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CITY OF OTTAWA

Statement of Work

Review and Analysis of September 4, 2012

Highway 174 Culvert Collapse

1. Background

Council has identified that they wish to have the City Manager complete a thorough review of the September 4, 2012 Highway 174 culvert collapse.

It is important that all relevant information related to the 2012 Highway 174 culvert collapse is reviewed and that recommendations to prevent a re-occurrence are identified for consideration and/or implementation. The City Manager will review the findings and will bring a staff report forward for consideration by the Finance and Economic Development Committee (FEDCO) and Council in December 2012.

2. Purpose

The City of Ottawa is soliciting proposals from engineering industry professionals with direct municipal infrastructure planning, implementation and operating experience, as well as research expertise to conduct an independent peer review of the City's investigation into the causes of the September 4, 2012 collapse of a culvert located just south of the Jeanne D' Arc Boulevard off-ramp on Highway 174.

This Statement of Work is to solicit and select the most qualified proponent to:

I. Prepare a report, including visuals and a presentation that provides a concise and meaningful root cause analysis of the September 4, 2012, Highway 174 culvert collapse. The report is to include identification of industry and regulatory due diligence requirements and practices, and the City's protocols and adherence to these at the time and to make recommendations regarding potential assessment protocol enhancements.

II. Meet with the City Manager, Deputy City Manager of Planning and Infrastructure, the General Manager of Infrastructure Services, the Manager of Asset Management and complete interviews with the City staff and contractors involved in this incident and any other staff identified in the course of the review relevant to completing this review.

3. Project Scope

Complete the following:

- Draft process and timelines to complete the review.
- Meet individually with the City Manager, Deputy City Manager of Planning and Infrastructure, the General Manager of Infrastructure Services, the Manager of Asset Management and complete interviews with the City staff and contractors

involved in this incident and any other staff identified in the course of the review relevant to completing this review.

- Analyse the City's operating protocols and procedures in the context of industry norms and identify where our protocols and procedures were followed, potential assessment protocol enhancements and where omissions were made, should this be the case.
- Prepare a report, including visuals and a presentation that provides a concise and meaningful root cause analysis of the September 4, 2012, Highway 174 culvert collapse. The report is to include identification of industry and regulatory due diligence requirements and practices, and the City's protocols and adherence to these at the time and to make recommendations regarding potential assessment protocol enhancements.
- Attend Committee & Council Meetings

4. Project Deliverables

- Development of the work plan to complete the project within the assigned timelines
- Phase 1 – Background data gathering
- Phase 2 – Technical assessment and root cause analysis
  Phase 3 – Identification of potential assessment protocol enhancements (if applicable)
- Interim report in the form of a verbal or written briefing.
- Final written report.

5. Project Management

Any questions regarding this proposal are to be submitted to:

Steve Box
City Manager's Office
City of Ottawa
613-5802424 ext. 24200
Steve.Box@ottawa.ca On behalf of:

Kent Kirkpatrick
City Manager
City of Ottawa
613-580-2424 ext. 25657
Kent.Kirkpatrick@ottawa.ca

This project will require frequent communications with the vendor, primarily over the phone and email and potentially including some face-to-face meetings.

6. Anticipated Timelines

Deliverable	**Timeline**
Contract Award	October 11
Material Review	October 15-19 (22-26)
Meetings with Senior Management	October 22 – 26
Technical Assessment and Route Cause	October 29 – November 2
Interim Report	November 5 – 9
Final Report	November 12 – 16
Presented to FEDCO	December 4
Presented to Council	December 12

APPENDIX B

LIST OF DOCUMENTS REVIEWED

A) History of Structure

1. R-1076-Engineer's Report on Storm Drainage Works for the Development of Convent Glen Community
2. CCL Approval Drawings 1975 – 15 drawings
3. CCL As-built Drawing 1980 – 1 drawing
4. R-1520.A-Convent Glen North Community, Storm Sewer Investigative Report, November 2006-RVA

B) Leading up to Rehabilitation

1. Caesar's Inspection Services "Video Inspection Report for Ottawa – Project number TV11-E1 – Report Number 7-11-128 – Storm Sewer Inspection Easement 174 to Voyageur", September 27, 2011
2. Caesar's Inspection Services – Aug. 17/11 video of STM50005 - IN40482-MHST22615-D-081711.mpg
3. Youville – briefing to MOE
4. Email-Youville Headwall Lining Orient Park
5. Novatech proposal (Proposal and various PDFs)
6. Scoping Info numerous drawings and photos
7. E-SPA form-Youville Novatech
8. Grating and Overflow Work Plan
9. Revised Proposal 20110819
10. Storm Sewer Lining Work Plan
11. Youville Drive Road Culvert Slip-Lining Report
12. RVCA Final Permit and conditions
13. Soils and groundwater memo May 7/2012
14. Youville Project Briefing
15. Correspondence\Assessment- several Emails and Orleans pipe data, pipe quantities, and report
16. Ottawa Email re Slip-lining Sept. 26/11
17. Ottawa Emails re CCTV observations Aug. 17-18/11
18. Ottawa Scoping Report for Storm Outfall July 27/11

C) Construction Contract for Rehabilitation

1. Construction Schedules (Construction Administration\Schedule folder)
2. Construction Administration\Submittals folder – drawings, LWB Health and Safety Policy, Emergency Response info, Environmental Plan, Field Report, Inlet Structure Submittals, Notice of Project, Reinforcing Details, Weholite Construction & Installation Guide, Weholite Culvert Sliplining
3. Contract Award info-Contract Award\Hydro Ottawa PO
4. Tender documents and numerous documents
5. Bray Commence Work Order ISD12-2002

6. Ottawa letter to Bray -Aug. 14/12
7. E-SPA form-Youville Bray
8. Tender info – Sections A-F
9. Preliminary Construction Schedule-Aug 21/12
10. Issued for Construction ISD12-2002 – Drawings for Lining and Headwall
11. Pre-construction Meeting Notes

D) Related to Collapse

1. Bray letter (Sept. 9/12)
2. Novatech letter (Sept 11/12)
3. Project Timeline
4. Draft Sink Hole Inspection Report Oct 10 2012
5. MTI report re corrosion
6. Email-MTI report(2)
7. Ministry of Labour notes
8. Novatech Sept 4 Field Notes
9. Ottawa Highway 174 Emergency Open Pit Limit Open Pit.mpg – video
10. Ottawa Memo Culverts FINAL 2

E) City Asset Management

1. Asset Management Branch Org Chart
2. Ottawa Comprehensive Asset Management documents - 2012
3. Const Org Chart
4. IS Org Chart
5. 2012-10-10-Memo 174 Culvert Investigation
6. ISDESDUA

F) Root Cause Analysis

1. Precipitation Data July and August 2012
2. O.Reg104/94
3. Various correspondence with CSPI

G) Related to Repair

1. Numerous photos of repair
2. Novatech site notes Sept. 4/12 to Oct. 2/12

APPENDIX C

LIST OF PERSONS INTERVIEWED

LIST OF PERSONS INTERVIEWED

Design and Construction Branch

- Ziad Ghadban: Manager, Municipal Design and Construction - East
- Darryl Shurb: Program Manager, Municipal Design & Construction - East
- Steve Courtland: Senior Engineer, Infrastructure Projects

Asset Management Group

- Alain Gonthier, Manager, Asset Management Branch
- Peter McKay: Senior Engineer, Sewer & Drainage Renewal
- Gerry Taylor: Supervisor, Sewer Inspections

Stantec

- Gerald Bauer
- Susan Potyondy
- Rejean Brousseau – BSI

Louis W. Bray Construction Ltd. (LWBC) and Clarence McDonald Excavation Ltd. (CME)

- Mike Bray, President, LWBC
- Glen Dewar, General Superintendent, LWBC
- Clarence McDonald, President, CME

Novatech

- John Riddell, P.Eng., President
- Ron Cebryk, P.Eng., Sr. Project Manager
- Miro Savic, P.Eng., Project Manager
- Ted Burch, Site Inspector

APPENDIX D

TIMELINE FOR STM 50005

City of Ottawa -- Highway 174 Pipe Collapse 12187

Timeline Dec. 7/12

Year	Date	Hour	Event	Source of Info
1972	Mar. 15		Design Report for Convent Glen Storm Drainage Works submitted by CCAL to Twp. of Gloucester	Report is in Reports Folder on FTP site
1975	Nov.		Drawings for "Orleans Storm Sewer Collector are submitted to Twp. of Gloucester. Refer to Dwg's 3061-100 and 3061-101.	Drawings are in Drawings Folder on FTP site
1980	Nov.		As-built drawing for Storm Sewer Collector is prepared	
2001			Transfer of pipe to City of Ottawa from Township of Gloucester	
2011	Feb. 3		CCTV work for 2011 is identified.	Email - AMB to ESD
2011	Mar. 8		CCTV is being scheduled for Orleans area	Email - ESD to AMB
2011	June 24		Significant rainstorm damages screening facilities for pipe inlet.	Project Scoping Report of July 27/11 prepared by AMB.
2011	July 27		Project Scoping Report to replace headwall and screening is completed by AMB	Project Scoping Report of July 27/11 prepared by AMB.
2011	July 29		Meeting with Novatech re Headwall Scope	Project Timeline provided by D&CSE and Novatech Memo of Oct. 18/12.
2011	Aug. 12		Official scoping meeting between D & CSE and AMB and others - scope includes Youville Headwall and Orient Park Backwater valve (not lining)	Project Timeline provided by D&CSE
2011	Aug. 17	7:41 AM	Pipe is CCTV inspected starting at the south end	Caesar's Inspection Services Video Inspection Report 7-11-28 dated Sept. 27/11
2011	Aug. 17	3:17 PM	"Structural Issues" with RR 174 CSP identified. Corrosion and "large holes" noted.	Email - ESD to AMB
2011	Aug. 17	3:21 PM	D&CSE is advised of pipe condition	Email - AMB to D&CSE
2011	Aug. 17	4:11 PM	AMB makes request for hydraulic assessment related to slip lining. Notes pipe is "in poor/critical condition".	Email - AMB to AMB cc'd to D&CSE.
2011	Aug. 18	8:50 AM	ESD is advised that issue will be passed to D&CB for "immediate rehab" with the hope of slip lining "maybe this winter"	Email - AMB to ESD

City of Ottawa -- Highway 174 Pipe Collapse 12187

Timeline Dec. 7/12

2011	Aug. 18		D&CSE adds lining to Novatech's scope of work by telephone call.	Novatech Memo of Oct. 18/12.
2011	Aug. 19		Revised proposal from Novatech arrives (includes Sewer Lining component)	Project Timeline provided by D&CSE
2011	Sep. 8		Novatech receives PO fro City.	Novatech Memo of Oct. 18/12.
2011	Sep. 15		Novatech orders geotechnical investigation for headwall.	Novatech Memo of Oct. 18/12.
2011	Sep. 26	11:15 AM	D&CSE is advised that pipe can be slip lined.	Email - AMB to D&CSE
2011	Nov. 7		Received revised field survey for Youville Lining project.	Project Timeline provided by D&CSE
2011	Nov. 8		Decision made to advance Orient Park and have Youville Lining and Headwall to follow as a separate much larger contract. The design and construction components involved with Orient Park were fairly minor and the project was important to reduce basement flooding risk. Email from D&CSE to Novatech instructing them to have existing utilities field located.	Project Timeline provided by D&CSE
2011	Dec. 16		Email from ESD inquiring about the status of the Youville Headwall project.	Project Timeline provided by D&CSE
2012	Jan. 3		Novatech receives geotechnical report	Novatech Memo of Oct. 18/12.
2012	Jan. 27		Email from D&CSE to Novatech with general info relating to Sliplining, instruction for Novatech to contact RVCA, wish to install the Lining in the winter and to set up a meeting ASAP.	Project Timeline provided by D&CSE and Novatech Memo of Oct. 18/12.
2012	March 6		Email from D&CSE toNovatech looking for a project update.	Project Timeline provided by D&CSE
2012	March 15		Email from D&CSE to Novatech indicating that they are a little discouraged with the project progress.	Project Timeline provided by D&CSE
2012	March		"Youville Drive Road Culvert Slip-Lining Feasibility Report" is prepared	Correspondence Folder on FTP Site.
2012	Apr.25		3rd version of geotechnical report received by Novatech.	Novatech Memo of Oct. 18/12.

City of Ottawa -- Highway 174 Pipe Collapse 12187

Timeline Dec. 7/12

2012	May 12		Novatech submits 95% design submission for Youville Headwall and Lining project. Final geotechnical memo from Paterson Group is submitted for Youville Headwall.	Project Timeline provided by D&CSE
2012	June 4		Revised tender package submitted by Novatech	Project Timeline provided by D&CSE and Novatech Memo of Oct. 18/12.
2012	June 28		Headwall and Lining Tender package posted to OCA.	Project Timeline provided by D&CSE
2012	July 18		Tenders close for headwall and re-lining project.	Novatech Memo of Oct. 18/12.
2012	Aug. 14		Headwall and Lining Project is awarded to Louis W Bray Construction.	Project Timeline provided by D&CSE. Copy on FTP Site
2012	Aug. 18		Bray General Superintendent enters pipe.	Bray & CME Interview Notes
2012	Aug. 23		Pre-construction meeting held.	Novatech Memo of Oct. 18/12 and PCM notes on FTP site.
2012	Aug. 27		Commence Work Order sent to Bray	Project Timeline provided by D&CSE. Copy on FTP Site
2012	Aug. 31		CME starts installing lights in pipe and removing larger rocks at entrance near headwall.	Bray & CME Interview Notes
2012	Sept. 4	Morning	Bray and CME return to site and begin to remove debris from inside pipe.	Bray & CME Interview Notes
2012	Sept. 4	4:00 pm (+/-)	Bray and CME leave site because of rain and increasing water flows.	Bray & CME Interview Notes
2012	Sept. 4	5:00 PM (+/-)	Sinkhole develops in 174 Off Ramp.	Project Timeline provided by D&CSE