

City of Alexandria, Virginia  
Department of Transportation and Environmental Services

**Task Order G19-07**  
**Investigation of Sewer Pipelines in Stream Areas**

# **TECHNICAL MEMORANDUM**

**DRAFT**

October 2021





**SECTION 1 PROJECT BACKGROUND .....1-1**

**SECTION 2 INVESTIGATION AND ASSESSMENT METHODOLOGY .....2-1**

2.1 Condition Assessment of Sewer Pipelines.....2-1

2.2 Asset condition From Internal CCTV Inspection .....2-1

2.3 Likelihood of failure (Based on Review of Internal Pipe Condition).....2-2

2.4 Consequence of Failure .....2-3

2.5 Percent Remaining Useful Life.....2-6

2.6 Condition Assessment In Stream Areas .....2-7

2.7 Likelihood of Failure (Based on External Conditions) .....2-7

**SECTION 3 CCTV INSPECTION DATA REVIEW FINDINGS.....3-1**

3.1 CCTV Inspection Data .....3-1

3.2 Summary of Findings From CCTV Data .....3-1

**SECTION 4 FIELD INSPECTIONS.....4-1**

4.1 Field Inspection Process .....4-1

4.2 Summary of Field Inspection Findings .....4-1

4.2.1 Holmes Run .....4-2

4.2.2 Lucky Run .....4-5

4.2.3 Taylor Run .....4-6

4.2.4 Tributary to Backlick Run .....4-12

4.2.5 Timber Branch .....4-13

4.2.6 Tributary to Taylor Run .....4-15

**SECTION 5 ASSESSMENT ANALYSIS.....5-1**

5.1 Results of Calculation of Likelihood of Failure and Consequence of Failure .....5-1

**SECTION 6 FINDINGS AND RECOMMENDATIONS .....6-1**

6.1 Reinspection and Reassessment.....6-4

**SECTION 7 REFERENCES.....7-1**



List of Tables

Table 2-1:	Example Table of Consequences Failure.....	2-4
Table 2-2:	Example of the CoF calculation for Taylor Run 000520SEWP is provided below. ....	2-5
Table 2-3:	Estimated Useful Life for Pipe Materials.....	2-7
Table 3-1:	Sewer Segments with PACP Structural Quick Scores above 3000.....	3-1
Table 4-1:	Summary of Sewer Segments with External Risk Factor Greater than 3.....	4-1
Table 5-1:	Summary of Assets with Likelihood of Failure (LoF) Greater than 3.....	5-1
Table 6-1:	Prioritized List of Stream Area Pipeline Segments.....	6-1
Table 6-2:	Summary of Pipe Segments with Missing CCTV Data.....	6-3

List of Figures

Figure 2-1:	PACP Quick Rating Example.....	2-2
Figure 2-2:	Example Asset Risk Assessment Graph.....	2-3
Figure 2-3:	Percent remaining physical life determination.....	2-6
Figure 4-1:	Location of Exposed and Undermined Sewer Crossing on Holmes Run.....	4-2
Figure 4-2:	Looking East along the Crossing (002618SEWP) with Close-up.....	4-3
Figure 4-3:	Looking North (upstream on Holmes Run) at MH 002476SSMH and exposed 002639SEWP.....	4-4
Figure 4-4:	Looking West (downstream on tributary) along exposed 002639SEWP towards 002476SSMH.....	4-4
Figure 4-5:	Location of Exposed Sewer Segment in Lucky Run 009524SEWP.....	4-5
Figure 4-6:	Exposed Sewer Segments in Lucky Run along eroded streambank 009524SEWP.....	4-6
Figure 4-7:	Location of exposed side sewer crossing 000040SEWP along Taylor Run.....	4-7
Figure 4-8:	Exposed side sewer crossing 000040SEWP immediately downstream of storm water outfall.....	4-7
Figure 4-9:	Location of Exposed Sewer Crossing 009478SEWP on Taylor Run.....	4-8
Figure 4-10:	Exposed Sewer Crossing 009478SEWP with supports.....	4-9
Figure 4-11:	Severely Eroded Streambank upstream of crossing 009478SEWP.....	4-9
Figure 4-12:	Location of Exposed side sewer crossing 09121SEWP.....	4-10
Figure 4-13:	Exposed side sewer 009121SEWP on Taylor Run with damaged joints.....	4-11
Figure 4-14:	Location of streambank collapse downstream of 002316SSMH.....	4-12
Figure 4-15:	Streambank collapse at 002316SSMH.....	4-13
Figure 4-16:	Streambank collapse looking upstream.....	4-13
Figure 4-17:	Location of exposed sewer 006374SEWP.....	4-13
Figure 4-18:	Exposed sewer 006374SEWP in Timber Branch.....	4-14
Figure 4-19:	Location of exposed 000709SEWP in Tributary to Taylor Run.....	4-15
Figure 4-20:	Exposed RCP Sewer 00709SEWP beneath pedestrian bridge in Tributary to Taylor Run.....	4-16

List of Appendices

Appendix A	Calculation Results Of Likelihood Of Failure And Consequence Of Failure
Appendix B	Percent Remaining Physical Life Calculation
Appendix C	Table Of External Risk Factor For Failure



## SECTION 1 PROJECT BACKGROUND

The City of Alexandria (the City) retained Greeley and Hansen to assist with providing a collection system Capacity, Management, Operations and Maintenance (CMOM) evaluation and then developing and implementing a CMOM Program that was tailored to the needs of the City.

This task builds on the following previous tasks performed by Greeley and Hansen:

- 1.) A Documents Review Task to identify and review relevant City records to assess the City's current programs and practices. The records review formed a baseline for the subsequent tasks and development of the City's CMOM Program.
- 2.) Field Observation of Work Practices and Staff Interviews were conducted to evaluate existing City practices as compared to the following components identified within the United States Environmental Protection Agency (USEPA) guidance for developing a CMOM program:
  - System Capacity Assurance
  - System Management
  - System Operation
  - Equipment and Collection System Maintenance.

The full findings and recommendations from these initial tasks were documented in the Data Review, Field Observations, and Work Practices Memorandum.

Based on that memorandum's findings/gap analysis (Strength, Challenges, Opportunities and Threats), the City decided to implement early action items to address key issues identified in the gap analysis immediately, and in parallel, developed a CMOM Program Strategy.

Investigation of Sewer Pipelines in Stream Areas was one of the selected early action items. Sewer assets adjacent to or crossing streams are subject to erosion. If sewers become exposed, they are at risk of breakage, especially during storm events when high stream flows and storm debris can impact the exposed sewer pipelines. To begin addressing these findings from earlier investigations, the City, utilized the contractor, Insight, to conduct Closed Circuit Television (CCTV) inspections of the sewer lines in streams areas to gather information on the internal condition of these sewer assets in environmentally sensitive areas.

The City's goals are to: 1) Implement a methodical analysis which allows the City to prioritize sewer pipeline rehabilitation projects and manage risks in environmentally sensitive areas, and 2) proactively maintain sewer assets in stream areas for cost effective repair and rehabilitation and to avoid costly emergency response to sewer pipeline failures.

The City's Sanitary Infrastructure Division tasked Greeley and Hansen with the current investigation to complete the effort. The previously gathered CCTV data was reviewed and field visits to the stream areas were conducted to assess the external condition of sewer assets in stream areas. The information gathered



was used to evaluate and analyze the need to rehabilitate or replace sewer lines in stream areas as well as the potential need to armor the sewer assets and/or stabilize the stream to protect the sewer assets. A prioritized list of sewer assets to move into planning and design was prepared and is discussed in Section 6 Findings and Recommendations.



## **SECTION 2 INVESTIGATION AND ASSESSMENT METHODOLOGY**

As discussed above, the goal of the methodology described below is to develop a prioritized list of assets for rehabilitation.

### **2.1 CONDITION ASSESSMENT OF SEWER PIPELINES**

The internal condition of sewer pipelines in stream areas was investigated by reviewing data associated with 135 sewer segments and associated CCTV inspection data provided by the City and performing condition assessments of the sewer segments. The CCTV inspection data collected from the City's ongoing initiative of CCTV investigation of sewer pipelines in stream areas includes:

- CCTV inspection videos
- PACP survey reports
- NASSCO compliant condition assessment database, if available

The CCTV videos were reviewed to identify the defects on sewer pipelines, and make sure the defects were correctly coded, and PACP quick scores were correctly assigned to each sewer asset.

Following the review and update of CCTV inspection data, all the information gathered as part of the PACP CCTV inspections was used to develop a condition assessment report for the sewers inspected. The standard methodology recommended by NASSCO was applied to develop a risk-based condition assessment of sewer pipelines to provide the basis for the identification of a prioritized list of sewer rehabilitation projects. The risk-based condition assessment summarized the following characteristics of sewer assets:

- Asset condition
- Probability of failure
- Consequence of failure
- Remaining useful life

### **2.2 ASSET CONDITION FROM INTERNAL CCTV INSPECTION**

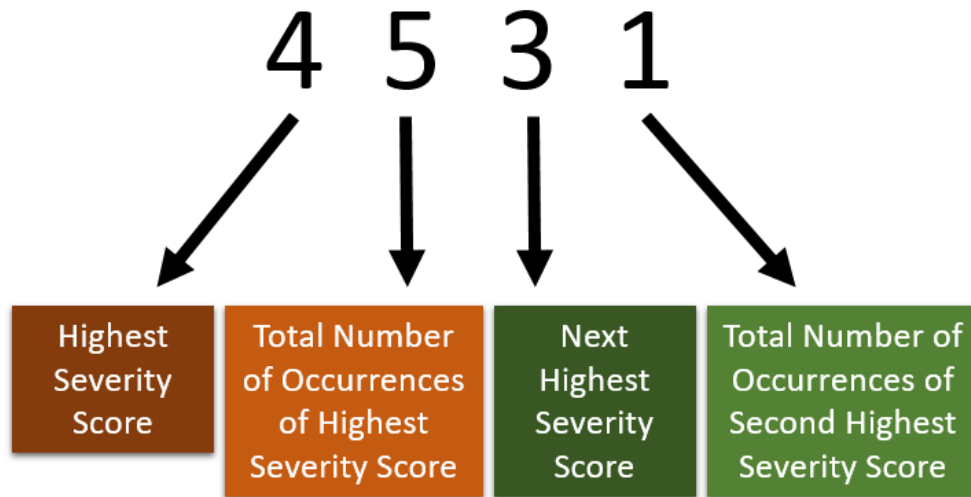
All defects of an asset surveyed via CCTV inspection were summarized, and the general condition of an asset was summarized by a PACP quick score, an overall pipe rating, and a pipe rating index. Each defect is either categorized as Structural or O&M and has a score from 1-5. The PACP Quick Rating (aka QuickScore) can be calculated for each pipe based on all of the defects observed during the inspection. Figure 2-1 shows an example of a pipe with five (5) defects with a severity rating of four (4) and one (1) defect with a severity rating of three (3). The first number represents the highest severity; in this example, no defects with a severity rating of five (5) are present in this pipe. These QuickScores can be calculated for Structural and O&M related defects independently, and/or calculated using the total number of defects.

For the purpose of this sewer investigation the focus was on defects with high severity that might possibly result in pipe failure due to the deteriorated structural integrity. As a result, the PACP quick score was



selected in collaboration with City staff as the primary indicator of asset condition. The significant defects are summarized in recommendations for the asset. These findings were submitted separately in electronic format to the City in four CCTV Review Submittal packages. Findings are summarized in Section 3.

Figure 2-1: PACP Quick Rating Example



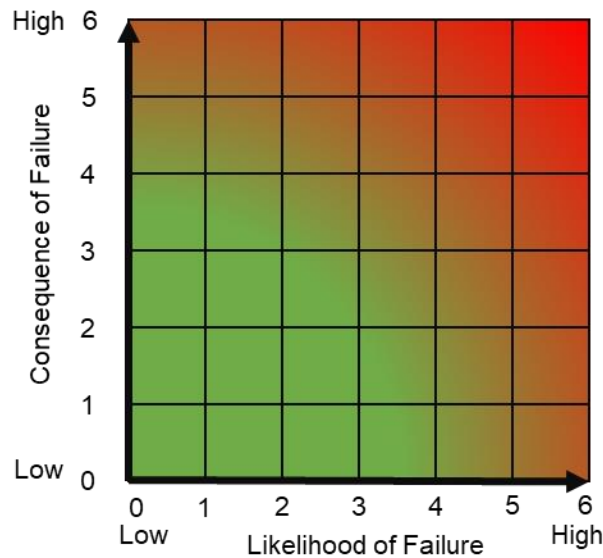
### 2.3 LIKELIHOOD OF FAILURE (BASED ON REVIEW OF INTERNAL PIPE CONDITION)

The probability of failure was calculated per NASSCO's guidance on determining the Likelihood of Failure (LoF) of a sewer asset based on its physical condition based on the CCTV review of the internal pipe condition. The LoF is determined by dividing the first two numbers of PACP quick score by 10 and

- If no condition assessment data is available, the LoF is 0, and
- If condition assessment is available and there are no defects, 1.0 is added to the result of the division and the LoF is 1.0, and
- There are no more than nine occurrences of the highest condition grade, then example  $LoF = 32/10 = 3.2$
- If the second character is a letter (indicating more than 9 occurrences), that letter is replaced by the number zero, and 1.0 is added to the result of the division.



Figure 2-2: Example Asset Risk Assessment Graph



The LoF was determined for each sewer pipeline asset. The structural quick score was used to calculate LoF because structural integrity is the focus of this project. O&M quick score was not used for this purpose. The maximum LoF determined by this method is 6.0.

## 2.4 CONSEQUENCE OF FAILURE

The consequence of failure was determined per NASSCO’s guidance on determining the Consequence of Failure (CoF) of a sewer asset based on the combination of direct and indirect impact on the vicinity and community due to a potential asset failure. The process of determining CoF investigates multiple considerations associated with potential impacts using a Triple Bottom Line criterion that includes measurements from economic, social and environmental aspects. Major CoF considerations recommended by NASSCO include:

- Diameter
- Depth
- Relative network position of pipe
- Class of road
- Distance from water body
- Distance from important customer
- Accessibility of pipe

The challenge of determining CoF is to understand all the considerations required by the nature of the project, and to assign weights to different aspects of impacts based on goals and priorities of the project. The major category of considerations recommended by NASSCO was utilized and the following matrix (Table 2-1) shows the basis for the computation of CoF.





Table 2-1: Example Table of Consequences Failure

	<b>Economic</b>	<b>Social</b>	<b>Environmental</b>
<b>Weighting Factor</b>	<b>0.25</b>	<b>0.10</b>	<b>0.65</b>
<b>Network Position</b>			
Diameter			
Depth			
Relative network position of pipe*			
<b>Location of Pipe</b>			
Class of road			
<b>Proximity to Sensitive Environment</b>			
Distance from water body			
Distance from Resource Protection Area			
<b>Serves Important Customer</b>			
Distance from upstream significant customer			
<b>Accessibility</b>			
Accessibility of pipe			

\*Note: Relative network position is indicative of number pipes discharging to the pipe and magnitude of customers served.

This approach and the weighting factors were discussed and confirmed with the City as part of the collaborative Work Plan development at the start of project.

Some of the considerations can be determined based on the information collected from the field, including Diameter, Depth, Class of road, Distance from water body, and Accessibility of pipe.

To determine the Relative network position of pipe and the Distance from important customer that required complex network analysis is challenging. The Relative network position of pipe is interpreted as the number of all upstream pipes of a pipe asset, and Distance from important customer is interpreted as the total pipe lengths of the shortest route from the important customer to a pipe asset. An iterative approach utilizing ArcGIS Network Analyst (an ArcGIS Pro and ArcMap extension) was developed and used to complete the network analysis. As recommend by NASSCO Schools and Hospitals were considered important Customers.

Process for Determining the Relative Network Position of Pipe

1. Create a geometric network based on the City’s sanitary sewer shapefile and stored in a geodatabase. The geometric network is used as the network reference in following network analysis.
2. Identify the stem and branches of the interested set of pipes to be analyzed at an overview, and record the IDs of all key manholes (the end node of each branch and the stem).
3. Create a shapefile for each of the key manholes (one shapefile for one manhole).



4. Use the “Trace Upstream” function from the Network Analyst to identify relative network position. This function will return the selection of all upstream pipes from a certain manhole. The shapefiles of the key manholes created in Step 3 will be used as “Flag” for the function, and the “Trace Task Type” should be set as “Find Upstream Accumulation”. As a result, each call of the function will return a selection of all upstream pipes from a key manhole. Record the number of pipes and repeat calling this function until all key manholes are resolved.
5. The upstream pipe numbers for key manholes are put into a spreadsheet as necessary references to figure out the Relative network position of pipe for each pipe asset.

Process for Determining Distance from Important Customer

1. The NASSCO recommends including School and Hospital as important customers. All schools and hospital are identified from the City’s parcel shapefile.
2. During Step 4 of Determine Relative Network Position of Pipe, observe if the selection of upstream pipes intersects or passes around the important customer parcels. Identify if the pipe serving important customers connected with the key manhole. If connection is verified, record the downstream manhole ID of the service pipe.
3. Create a shapefile for each pair of manholes (service manhole for important customer and key manhole)
4. Use the “Trace Upstream” function from the Network Analyst to determine the shortest route from a pipe asset to an important customer. The shapefiles of manhole pairs created in Step 3 will be used as “Flag” for the function, and the “Trace Task Type” should be set as “Find Path”. As a result, each call of the function will return a selection of all pipes between the two manholes at the shortest path.
5. Based on the returned selection of Step 4, add selection of connected pipes and check the update of total lengths of pipes. Repeat the step until all pipe assets are resolved.

Table 2-2: Example of the CoF calculation for Taylor Run 000520SEWP is provided below.

	Investigation Results	Economic	Social	Environmental
<b>Weighting Factor</b>		<b>0.25</b>	<b>0.10</b>	<b>0.65</b>
<b>Network Position</b>				
Diameter	18 inches	4	4	
Depth	13.5 feet	3		
Relative network position of pipe*	416 upstream sewers	6	6	
<b>Location of Pipe</b>				
Class of road	Major Local	3	3	
<b>Proximity to Sensitive Environment</b>				
Distance from water body	<25 feet			6
Distance from Resource Protection Area				
<b>Serves Important Customer</b>				
Distance from upstream significant customer	4,327 feet		5	



	Investigation Results	Economic	Social	Environmental
<b>Weighting Factor</b>		<b>0.25</b>	<b>0.10</b>	<b>0.65</b>
<b>Accessibility</b>				
Accessibility of pipe	On Right-of-Way with traffic control	2		
<b>Subtotals</b>		3.6	4.5	6
<b>Total Score</b>		5.25		

Excel spreadsheets were developed to calculate both the LoF and CoF for each pipeline segment and are included in Appendix A.

## 2.5 PERCENT REMAINING USEFUL LIFE

The percent remaining useful life was calculated for the sewer assets prioritized by the LoF and CoF calculations/ ratings using the formula from EPA Fundamentals of Asset Management (presentation series) as shown below.

Figure 2-3: Percent remaining physical life determination

**Example: simple determination of “% remaining physical life”**

- Calculate physical life consumed
 
$$\% \text{ physical life consumed} = \frac{\text{Life to date}}{\text{Estimated useful life}}$$
- Determine % remaining physical life
 
$$\% \text{ remaining physical life} = 1.0 - \% \text{ physical life consumed}$$

Example calculation - % remaining physical life  
Asset acquired 1992; current year 2012; useful life 25 years

$$20\% \text{ remaining physical life} = 1.0 - (20 \text{ yr. LTD} / 25 \text{ yr. EUL})$$


---

Fundamentals of Asset Management 13

To determine the asset acquired (installed) date, the City’s GIS Parcel viewer was used to determine the year built for a sample of the homes or buildings serviced by the sewer system in each stream area. The estimated useful life for the pipe materials found in use in the stream areas was determined from a literature search was conducted and are noted in the reference section. The percent remaining physical life calculation are included in Appendix B. Percent remaining physical life for the prioritized assets are summarized in Section 6.



Table 2-3: Estimated Useful Life for Pipe Materials

Pipe Material	Abbreviation	Range from Literature (years)	Value used in calculation (years)
Cast Iron Pipe	CP	100-150	100
Ductile Iron Pipe	DI	100	100
Cured in Place Pipe	XXX	50-100	100
Reinforced Concrete Pipe	RCP	50-100*	100

\*Useful life is impacted by bedding placement during construction

## 2.6 CONDITION ASSESSMENT IN STREAM AREAS

A general condition assessment of the external pipe and stream areas at 153 sewer segment locations was performed by field inspections to evaluate if stream restoration or armoring is potentially needed to protect sewer assets. The field inspections on stream areas at sewer locations estimate the cover depth of the sewer, assessed the exterior condition of manholes, and evaluate the impact of stream on the sewer.

The results of the sewer location checks include the following:

- Estimated Depth of cover: buried, (noted if aerial)
- Material and condition of pipe and manholes
- Status of encasement or armoring if any
- External impacts on sewer assets: such as downed trees, exposed due to erosion, manhole within streams

All the information collected during field inspections was recorded in separate field site investigation sheets dedicated to each sewer and manhole asset along with photographs of each site. Field investigation packages were submitted in electronic format. Findings are summarized in Section 4.

## 2.7 LIKELIHOOD OF FAILURE (BASED ON EXTERNAL CONDITIONS)

To assist in developing a prioritized list of stream area sewer pipeline segments recommended to be developed into rehabilitation projects, the condition of the stream area at the location of the sewer asset and the impact of any erosion was rated on a scale of 1 to 6 as documented in the scale below:

1. No sign of erosion. Or protective armoring in place (rocks or concrete encasement)
2. Mild streambank erosion/degradation
3. Partially exposed but CIPP Lined
4. Streambank erosion/degradation and fully exposed but CIPP Lined
5. Fully exposed and undermined, not encased but CIPP lined
6. Fully exposed and undermined, not encased and NOT CIPP lined

A table showing the external rating of each sewer segment investigated in the field is included in Appendix C.



## SECTION 3 CCTV INSPECTION DATA REVIEW FINDINGS

### 3.1 CCTV INSPECTION DATA

The City of Alexandria Department of Transportation and Environmental Services (T&ES) provided all CCTV inspection data for the investigation. The CCTV inspections were performed and the associated data sheets were prepared by the City’s CCTV contractor, Insight, during the period April 3, 2018 to March 1, 2019.

As discussed in Section 2, Greeley and Hansen reviewed and analyzed the CCTV videos and data. These findings were submitted separately in electronic format to the City in four CCTV Review Submittal packages. A summary of the findings is presented in the following Section 3.2.

### 3.2 SUMMARY OF FINDINGS FROM CCTV DATA

During the review of the CCTV inspection data, it was found that 19 sewer segments had PACP Structural Quick Scores above 3000. Table 3-1 summarizes these findings.

Table 3-1: Sewer Segments with PACP Structural Quick Scores above 3000

Stream Area	Facility ID	Upstream MH	Pipe Material	Diameter (Inch)	Mainline Length (Feet)	PACP Structural Quick Score
Holmes Run	001804SEWP	007604SSMH	RCP	10	103.0	5141
Lucky Run	001146SEWP	000566SSMH	RCP	15	508.0	3100
Taylor Run	009120SEWP	007492SSMH	XXX	8	147.0	3124
Taylor Run	009177SEWP	007540SSMH	XXX	18	346.0	3100
Timber Branch	006372SEWP	006414SSMH	CP	10	108.0	3221
Timber Branch	006658SEWP	006561SSMH	CP	10	132.0	4133
Timber Branch	006872SEWP	006556SSMH	RCP	15	137.0	3122
Timber Branch	007187SEWP	006636SSMH	CP	10	157.0	3123*
Timber Branch	007530SEWP	006627SSMH	CP	10	82.0	4121*
Timber Branch	007544SEWP	006669SSMH	XXX	15	255.0	3100
Timber Branch	009471SEWP	006679SSMH	XXX	15	464.7	5100
Tributary to Backlick Run	002692SEWP	002329SSMH	RCP	15	430.0	5441
Tributary to Cameron Run	500022SEWP	500012SSMH	XXX	10	149.0	3400*
Tributary to Holmes Run	000876SEWP	001181SSMH	CP	10	328.0	3100
Tributary to Holmes Run	000906SEWP	001106SSMH	RCP	10	63.7	5223*
Tributary to Holmes Run	002552SEWP	002226SSMH	RCP	18	300.7	3100



**TECHNICAL MEMORANDUM**

Draft | October 2021

Stream Area	Facility ID	Upstream MH	Pipe Material	Diameter (Inch)	Mainline Length (Feet)	PACP Structural Quick Score
Tributary to Hooffs Run	003836SEWP	003621SSMH	XXX	10	189.0	3825
Tributary to Taylor Run	000150SEWP	000483SSMH	XXX	12	215.0	3100
Tributary to Taylor Run	000151SEWP	000484SSMH	CP	10	61.2	3121

\*= revised score based on Greeley and Hansen review of CCTV video



## SECTION 4 FIELD INSPECTIONS

### 4.1 FIELD INSPECTION PROCESS

As detailed in Section 2, each stream area segment was walked to review the external condition of the sewer assets. Manhole lids were opened and briefly inspected to gage depth of sewer lines if survey data was not available. Field quality assurance field checks were also performed. Field site investigation packages documenting each site including photographs were submitted separately to the City.

### 4.2 SUMMARY OF FIELD INSPECTION FINDINGS

The field inspections revealed that there are sewers that are exposed due to stream erosion. Table 4-1 summarizes the sewer segments with an external risk factor for than 3 and indicates with if the segment has been lined which would assist in mitigating risks until a rehabilitation project is completed.

Table 4-1: Summary of Sewer Segments with External Risk Factor Greater than 3

Stream Name	Facility ID	Pipe Shape	Pipe Material	Height (Inch)	Mainline Length (Feet)	External Risk Factor	Comments
Holmes Run	002024SEWP	Circular	XXX	10	111.0	3	Bell exposed near one manhole and fractured encasement
Holmes Run	002524SEWP	Circular	*	10	*	3	Concrete breaking away in spots exposing pipe that appears to be CIPP
Holmes Run	002618SEWP	Circular	CP or DIP	12	110.9	6	Pipe exposed, encasement cracked and broken, not CIPP lined, only first couple feet were CCTVed
Holmes Run	002639SEWP	Circular	RCP	12	*	6	Pipe exposed, partial undermined armor or no armor, no CCTV data
Lucky Run	009524SEWP	Circular	XXX	12	140.0	5	Pipe exposed in streambank
Taylor Run	000040SEWP	Circular	XXX	10	98.2	5	Exposed cast iron sewer
Taylor Run	009121SEWP	Circular	XXX	10	148.0	5	Exposed with broken bells at joints
Taylor Run	009478SEWP	Circular	XXX	15	260.0	5	Exposed DIP crossing
Timber Branch	006374SEWP	Circular	CP	12	100.0	6	Aerial cast Iron pipe exposed, erosion around supports
Timber Branch	006379SEWP	Circular	XXX	12	227.0	3	US MH in middle of stream
Timber Branch	006933SEWP	Circular	XXX	10	45.1	3	DS MH in middle of stream
Timber Branch	006935SEWP	Circular	XXX	15	62.0	3	DS MH in middle of stream
Tributary to Backlick Run	002759SEWP	Circular	RCP	15	191.6	3	Streambank collapsing by DS MH



Stream Name	Facility ID	Pipe Shape	Pipe Material	Height (Inch)	Mainline Length (Feet)	External Risk Factor	Comments
Tributary to Holmes Run	001041SEWP	Circular	XXX	12	255.0	3	Partially exposed sewer crossing and stream bank erosion close to manhole
Tributary to Taylor Run	000709SEWP	Circular	XXX	12	268.7	3	Partially exposed sewer crossing
Tributary to Taylor Run	009162SEWP	Circular	*	10	*	3	Partially exposed sewer crossing

\*No CCTV data

Crossings of the highest concern based on best professional judgement of the field reviews are discussed below.

#### 4.2.1 Holmes Run

At the location of Holmes Run Sewer Crossing 002618SEWP and the downstream segment 002639SEWP shown in Figure 4-1, pipe segments have become exposed due to stream erosion from Holmes Run and the small tributary stream the enters Holmes Run from the east adjacent to 002476SSMH.

Figure 4-1: Location of Exposed and Undermined Sewer Crossing on Holmes Run







Figure 4-2: Looking East along the Crossing (002618SEWP) with Close-up



The concrete armoring over 002618SEWP (12-inch dia.) has become broken and cracked exposing the ductile iron pipe as shown in Figure 4-2. The downstream segment 002639SEWP has been undermined by erosive forces and at the streams' junction a channel has been created behind manhole 002476SSMH as shown in Figure 4-3. Figure 4-4 shows that segment 002639SEWP is also exposed further downstream where the streambank of the small tributary has been eroded away.



Figure 4-3: Looking North (upstream on Holmes Run) at MH 002476SSMH and exposed 002639SEWP



Figure 4-4: Looking West (downstream on tributary) along exposed 002639SEWP towards 002476SSMH





## 4.2.2 Lucky Run

Lucky Run has experienced severe erosion of its stream banks exposing approximately 25 feet of sewer segment 009524SEWP which runs parallel to the stream. The location of the sewer segment is shown in Figure 4-5. A portion of the exposed segment and the deep erosion into the streambank is shown in Figure 4-6. The CCTV review of segment indicates that the City has been proactive in lining the sewer to stabilize and prevent joint deflection. The City, as part of its Stormwater Division’s stream restoration efforts, has prepared a design to restore the stream. A review of the “Lucky Run Stream Restoration and Pond Rehabilitation” Final Design drawings dated May 1, 2019 prepared by URS and Wetland Studies and Solutions Inc. indicates that the design once constructed will protect this sewer asset.

Figure 4-5: Location of Exposed Sewer Segment in Lucky Run 009524SEWP





Figure 4-6: Exposed Sewer Segments in Lucky Run along eroded streambank 009524SEWP



### 4.2.3 Taylor Run

An 18-inch sewer line runs parallel to Taylor Run and crosses it in one location and continues to run parallel along the opposite bank. Additionally, neighborhood side sewers connect into the 18-inch sewer line. The stream is severely eroded with steep banks. The connecting side sewer (000040SEWP), which is located immediately downstream of a storm water outfall, is exposed. The location of the sewer segment is shown in Figure 4-7. The exposed sewer is shown in Figure 4-8.



Figure 4-7: Location of exposed side sewer crossing 000040SEWP along Taylor Run



Figure 4-8: Exposed side sewer crossing 000040SEWP immediately downstream of storm water outfall





The 18-inch crossing 009478SEWP is also exposed and has been repaired as a supported aerial ductile iron pipe crossing. See Figure 4-9 for the location. See Figure 4-10 and Figure 4-11 for photographs of the sewer crossing.

Figure 4-9: Location of Exposed Sewer Crossing 009478SEWP on Taylor Run



The City is currently designing a stream restoration project along the stream reach which extends 1,900 linear feet from the inflowing 72-inch culvert located behind the Chinquapin Park Recreation Center at the intersection of King Street and Chinquapin Drive downstream to the twin bridge culverts which carry Taylor Run underneath the overflow parking lot access road of the First Baptist Church of Alexandria, Virginia. The planned project would protect the exposed sewers in Taylor Run discussed above.



Figure 4-10: Exposed Sewer Crossing  
009478SEWP with supports



Figure 4-11: Severely Eroded Streambank  
upstream of crossing 009478SEWP





Figure 4-12: Location of Exposed side sewer crossing 09121SEWP



In addition to being exposed, side sewer 009121SEWP on Taylor Run has damaged joints. See Figure 4-12 for the location and Figure 4-13 for a photograph of the exposed pipe.





Figure 4-13: Exposed side sewer 009121SEWP on Taylor Run with damaged joints





#### 4.2.4 Tributary to Backlick Run

Figure 4-14: Location of streambank collapse downstream of 002316SSMH



At manhole 002316SSMH the stream bank is collapsing. See Figure 4-14 for the location of this asset and Figure 4-15 and Figure 4-16 for photographs of the condition of the stream bank.



Figure 4-15: Streambank collapse at 002316SSMH



Figure 4-16: Streambank collapse looking upstream



#### 4.2.5 Timber Branch

Figure 4-17: Location of exposed sewer 006374SEWP





Figure 4-18: Exposed sewer 006374SEWP in Timber Branch



Exposed sewer 006374SEWP is above the streambed. The location of the sewer segment is shown in Figure 4-17. The exposed sewer is shown in Figure 4-18.



#### 4.2.6 Tributary to Taylor Run

Figure 4-19: Location of exposed 000709SEWP in Tributary to Taylor Run



Exposed sewer 000709SEWP is located under a pedestrian bridge. The location of the sewer segment is shown in Figure 4-19. The exposed sewer is shown in Figure 4-20.



Figure 4-20: Exposed RCP Sewer 00709SEWP beneath pedestrian bridge in Tributary to Taylor Run





## SECTION 5 ASSESSMENT ANALYSIS

### 5.1 RESULTS OF CALCULATION OF LIKELIHOOD OF FAILURE AND CONSEQUENCE OF FAILURE

As detailed in Section 2, the Likelihood of Failure (based on the internal condition) and the Consequence of Failure were calculated for each pipe asset. The excel files for the calculations by stream area have been transmitted to the City separately and are included on a CD included in Appendix A.

The majority pipe segments investigated have a consequence of failure of approximately 4 or greater putting them into the orange to red area of the risk graph because they are in close proximity to streams and the weighting selected for the environmental factor for these sensitive areas during Work Plan development.

The standard LoF based on internal condition of the pipeline is below 3.0 for the majority of pipe segments. This is partially due the proactive effort of the City to CIPP line many of the assets in stream areas to reduce infiltration and inflow as well as asset renewal. A summary of the 21 sewer segments with a Likelihood of Failure of 3.0 and above are noted in Table 5-1.

Table 5-1: Summary of Assets with Likelihood of Failure (LoF) Greater than 3

Stream Area	Sewer ID	PACP Structural Quick Score	Dia. (Inch)	Depth (Feet)	Relative Network Position of Pipe	Distance from water body (Feet)	Distance from Important Customer (Feet)	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
Holmes Run	001804SEWP	5141	10	18.6	29	< 25 ft.	Not connected	5.1	4.65
Lucky Run	001146SEWP	3100	15	3.0	66	< 25 ft.	Not connected	3.1	4.95
Taylor Run	007134SEWP	2C00	15	15.9	127	< 25 ft.	2593	3.0	5.22
Taylor Run	009120SEWP	3124	8	6.2	1	< 25 ft.	Not connected	3.1	4.47
Taylor Run	009177SEWP	3100	18	5.4	151	< 25 ft.	3689	3.1	4.95
Timber Branch	006372SEWP	3221	10	7.0	2	25 - 50 ft.	Not connected	3.2	3.90
Timber Branch	006658SEWP	4133	10	9.1	2	< 25 ft.	Not connected	4.1	4.55
Timber Branch	006872SEWP	3122	15	13.8	287	25 - 50 ft.	2942	3.1	4.53
Timber Branch	007187SEWP	3123	10	10.8	11	< 25 ft.	Not connected	3.1	4.67



**TECHNICAL MEMORANDUM**

Draft | October 2021

Stream Area	Sewer ID	PACP Structural Quick Score	Dia. (Inch)	Depth (Feet)	Relative Network Position of Pipe	Distance from water body (Feet)	Distance from Important Customer (Feet)	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
Timber Branch	007530SEWP	4121	10	12.7	8	< 25 ft.	Not connected	4.1	4.60
Timber Branch	007544SEWP	3100	15	4.8	309	< 25 ft.	3737	3.1	5.15
Timber Branch	009471SEWP	5100	15	6.3	325	25 - 50 ft.	4516	5.1	4.47
Trib. to Back Lick Run	002692SEWP	5441	15	5.2	80	< 25 ft.	Not connected	5.4	4.88
Trib. To Cameron Run	500022SEWP	3400	10	6.5	168	< 25 ft.	Not connected	3.4	4.92
Trib. to Holmes Run	000876SEWP	3100	10	14.0	24	< 25 ft.	Not connected	3.1	5.10
Trib. to Holmes Run	000906SEWP	5223	10	7.9	6	< 25 ft.	Not connected	5.2	4.57
Trib. to Holmes Run	002552SEWP	3100	18	6.8	36	< 25 ft.	Not connected	3.1	4.72
Trib. To Hooff's Run	003836SEWP	3825	10	7.5	12	< 25 ft.	Not connected	3.8	4.65
Trib. To Taylor Run	000150SEWP	3100	12	5.0	81	< 25 ft.	Not connected	3.1	4.72
Trib. To Taylor Run	000151SEWP	3121	10	5.0	7	< 25 ft.	Not connected	3.1	4.65





## SECTION 6 FINDINGS AND RECOMMENDATIONS

Based on the investigations and analysis discussed, above, a prioritized list of stream area sewer pipeline segments is recommended to be considered for rehabilitation projects based on calculated risks, and observations. The Prioritized List presented in Table 6-1 highlights the risk factor in bold (external or internal LoF) that generated the prioritized status. Crossings of the highest concern based on best professional judgement of the field reviews are discussed in detail in Sections 4.2.1 to 4.2.6. Of particular concern, are the adjacent Holmes Run Pipe segments 002618SEWP and 002639SEWP discussed in Section 4.2.1. It is recommended that these two assets move immediately into planning for rehabilitation.

Table 6-1: Prioritized List of Stream Area Pipeline Segments

Stream Area	Sewer ID	Pipe Material	Diameter (Inch)	Percent Remaining Physical Life (%)	External Risk Factor	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
Holmes Run	001804SEWP	RCP	10	43%	1	<b>5.1</b>	4.65
Holmes Run	002024SEWP	XXX	10	>75%*	<b>3</b>	1	4.75
Holmes Run	002524SEWP	**	10	33%	<b>3</b>	**	4.82
Holmes Run	002618SEWP	CP or DIP	12	44%	<b>6</b>	**	4.88
Holmes Run	002639SEWP	RCP	12	33%	<b>6</b>	**	4.95
Lucky Run	001146SEWP	RCP	15	45%	1	<b>3.1</b>	4.95
Lucky Run	009524SEWP	XXX	12	>75%	<b>5</b>	1	5.20
Taylor Run	000040SEWP	XXX	10	>75%	<b>5</b>	2.1	4.80
Taylor Run	007134SEWP	XXX	15	>75%	1	<b>3.0</b>	5.22
Taylor Run	009120SEWP	XXX	8	>75%	1	<b>3.1</b>	4.47
Taylor Run	009121SEWP	XXX	10	>75%	<b>5</b>	2.5	4.42
Taylor Run	009177SEWP	XXX	18	>75%	1	<b>3.1</b>	4.95
Taylor Run	009478SEWP	XXX	15	>75%	<b>5</b>	1	5.32
Timber Branch	006372SEWP	CP	10	36%	1	<b>3.2</b>	3.90



**TECHNICAL MEMORANDUM**

Draft | October 2021

Stream Area	Sewer ID	Pipe Material	Diameter (Inch)	Percent Remaining Physical Life (%)	External Risk Factor	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
Timber Branch	006374SEWP	CP	12	36%	<b>6</b>	2.1	4.63
Timber Branch	006379SEWP	XXX	12	>75%*	<b>3</b>	2.2	5.07
Timber Branch	006658SEWP	CP	10	36%	1	<b>4.1</b>	4.55
Timber Branch	006872SEWP	RCP	15	36%	1	<b>3.1</b>	4.53
Timber Branch	006933SEWP	XXX	10	>75%*	<b>3</b>	1	4.80
Timber Branch	006935SEWP	XXX	15	>75%*	<b>3</b>	1	5.25
Timber Branch	007187SEWP	CP	10	36%	1	<b>3.1</b>	4.67
Timber Branch	007530SEWP	CP	10	36%	1	<b>4.1</b>	4.60
Timber Branch	007544SEWP	XXX	15	>75%*	1	<b>3.1</b>	5.15
Timber Branch	009471SEWP	XXX	15	>75%*	1	<b>5.1</b>	4.47
Trib. to Back Lick Run	002692SEWP	RCP	15	44%	1	<b>5.4</b>	4.88
Trib. to Back Lick Run	002759SEWP	RCP	15	44%	<b>3</b>	1	5.32
Trib. To Cameron Run	500022SEWP	XXX	10	>75%*	1	<b>3.4</b>	4.92
Trib. to Holmes Run	000876SEWP	CP	10	40%	1	<b>3.1</b>	5.10
Trib. to Holmes Run	000906SEWP	RCP	10	40%	1	<b>5.2</b>	4.57
Trib. to Holmes Run	001041SEWP	XXX	12	>75%*	<b>3</b>	1	5.03
Trib. to Holmes Run	002552SEWP	RCP	18	43	1	<b>3.1</b>	4.72



**TECHNICAL MEMORANDUM**

Draft | October 2021

Stream Area	Sewer ID	Pipe Material	Diameter (Inch)	Percent Remaining Physical Life (%)	External Risk Factor	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
Trib. To Hooff's Run	003836SEWP	XXX	10	>75%*	1	<b>3.8</b>	4.65
Trib. To Taylor Run	000150SEWP	XXX	12	>75%*	1	<b>3.1</b>	4.72
Trib. To Taylor Run	000151SEWP	CP	10	33%	1	<b>3.1</b>	4.65
Trib. To Taylor Run	000709SEWP	XXX	12	>75%*	<b>3</b>	<b>1</b>	4.77
Trib. To Taylor Run	009162SEWP	**	10	42%	<b>3</b>	<b>**</b>	4.63

\*The City began relining sewers in the early 2000s which has extended their estimated useful life, based on this timeframe for lining installation >75% is estimated.

\*\* CCTV data not available.

Note that the final technical memorandum and final prioritized list will be prepared once the remaining stream area sewers are CCTV inspected and the CCTV data reviewed. **The City previously estimated that approximately 20 sewers currently remain uninspected and approximately 14 sewers have incomplete inspections and is currently working to obtain this information. Based on data provided to Greeley and Hansen to date, there are 24 segments missing CCTV data which are summarized in Table 6-2 below.** Data on these segments will be provided to Greeley and Hansen by the City once it is available.

Table 6-2: Summary of Pipe Segments with Missing CCTV Data

Stream	Facility ID	Upstream MH	Downstream MH
Lucky Run	000311SEWP	000628SSMH	000629SSMH
Lucky Run	003431SEWP	003138SSMH	003178SSMH
Holmes Run	002524SEWP	002128SSMH	002131SSMH
Holmes Run	002639SEWP	002479SSMH	002476SSMH
Taylor Run	000754SEWP	000460SSMH	000461SSMH
Taylor Run	000794SEWP	000042SSMH	000041SSMH
Taylor Run	006666SEWP	007531SSMH	006571SSMH
Taylor Run	009098SEWP	000041SSMH	007530SSMH
Taylor Run	009237SEWP	007546SSMH	007494SSMH
Taylor Run	009253SEWP	007582SSMH	007586SSMH
Taylor Run	009254SEWP	007587SSMH	007586SSMH
Taylor Run	009255SEWP	007586SSMH	007588SSMH
Taylor Run	009256SEWP	007588SSMH	007585SSMH
Taylor Run	009257SEWP	007585SSMH	007584SSMH



Stream	Facility ID	Upstream MH	Downstream MH
Taylor Run	009258SEWP	N/A	007585SSMH
Timber Branch	006234SEWP	006261SSMH	006421SSMH
Timber Branch	006868SEWP	006551SSMH	006555SSMH
Timber Branch	006871SEWP	006555SSMH	006556SSMH
Tributary to Backlick Run	002771SEWP	002344SSMH	002343SSMH
Tributary to Cameron Run	001707SEWP	007613SSMH	001349SSMH
Tributary to Holmes Run	001028SEWP	001354SSMH	001202SSMH
Tributary to Holmes Run	002133SEWP	500002SSMH	002216SSMH
Tributary to Holmes Run	002241SEWP	001581SSMH	001580SSMH
Tributary to Taylor Run	009162SEWP	007528SSMH	000547SSMH

Services for CCTV review of these assets, analysis and an update of the Revised Technical Memorandum to a Final Memorandum will be provided through a separate Task Order.

In addition, two sewer segments within railway corridors were not able to be accessed during this phase of the investigation:

- 009290SEWP
- 001707SEWP

Discussions with the CSX rail company indicate that an inspector from the rail agency must coordinate and participate in the inspection of sewer assets in the railway corridors for safety. They also indicated there is a fee of \$1,500 required for the railway inspector service.

It is recommended that the assets on railway right of ways be completed as part of the next task order to finalize the memorandum.

### 6.1 REINSPECTION AND REASSESSMENT

While the sewers in the tables above are recommended for rehabilitation or inspection, there are also other sewers in this project that were not recommended for either because they did not have significant defects. As a general rule of thumb sewers with a QuickScore of 3 should be inspected within the next 5 years (short term inspection schedule) and sewers with a QuickScore of 2 or 1 should be reinspected in the next 5-10 years (long term inspection schedule). However, because all of these sewers are located in or near streams they have a higher consequence of failure when compared to a typical sewer in the right-of-way that this rule of thumb applies to. Therefore, the following schedule is recommended:

- For sewers with a QuickScore of 3, reinspect and reassess within the next 3 years
- For sewers with a QuickScore of 2 or 1, reinspect and reassess within the next 3 – 6 years.

By placing all of the pipes in stream areas on a shorter term rehabilitation and reassessment schedule, the City can be proactive in avoiding potential infrastructure and environmental issues.



## **SECTION 7 REFERENCES**

1. Data Review, Field Observations and Work Practices Memorandum, July 2018, Greeley and Hansen
2. CMOM Program Strategy, December 2019, Greeley and Hansen
3. Lucky Run Stream Restoration and Pond Rehabilitation Final Design, May 2019, URS Corporation and Wetland Studies and Solutions, Inc.
4. Taylor Run Stream Restoration 60% Design Submittal, January 2020, URS Corporation and Wetland Studies and Solutions, Inc.



# APPENDIX A    CALCULATION RESULTS OF LIKELIHOOD OF FAILURE AND CONSEQUENCE OF FAILURE

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by: Xuhui Zeng, Greeley and Hansen  
Checked by: Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - **If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary**

Stream Crossing:	Holmes Run
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
001804SEWP	007604SSMH	002474SSMH	5141	10	18.6	29	Unpaved	< 25 ft.	Not connected	On Right-of-Way - no traffic control	5.1	4.65
002024SEWP	002136SSMH	002135SSMH	0000	10	5.1	28	Unpaved	< 25 ft.	0	On public lands without vehicle access	1.0	4.75
002618SEWP	002499SSMH	002476SSMH	N/A	12	2.7	132	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	0.0	4.88
002524SEWP	002128SSMH	002131SSMH	N/A	10	3.1	41	Unpaved	< 25 ft.	0	On public lands without vehicle access	0.0	4.82
002639SEWP	002479SSMH	002476SSMH	N/A	15	2.3	133	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	0.0	4.95

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
 Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by:  
 Checked by:

Xuhui Zeng, Greeley and Hansen  
 Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - **If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary**

Stream Crossing:	Hooffs Run
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
009653SEWP	007898SSMH	003625SSMH	2A00	27	1.8	303	Arterial/Building/Pool	< 25 ft.	2298	On Right-of-Way - no traffic control	3.0	5.32



**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by: Xuhui Zeng, Greeley and Hansen  
Checked by: Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary

Stream Crossing:	Lucky Run
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
000312SEWP	000629SSMH	007751SSMH	0000	10	4.3	14	Highway/Waterway	< 25 ft.	Not connected	On public lands with vehicle access	1.0	4.92
000318SEWP	000641SSMH	000694SSMH	2311	10	21.7	17	Minor Local	25 - 50 ft.	Not connected	On public lands with vehicle access	2.3	4.17
001146SEWP	000566SSMH	000758SSMH	3100	15	3.0	66	Arterial/Building/Pool	< 25 ft.	Not connected	On Right-of-Way - with traffic control	3.1	4.95
001318SEWP	000694SSMH	000609SSMH	0000	10	9.0	18	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.65
001345SEWP	000758SSMH	000562SSMH	0000	15	5.9	69	Arterial/Building/Pool	< 25 ft.	Not connected	On Right-of-Way - with traffic control	1.0	4.95
001407SEWP	000785SSMH	000758SSMH	0000	10	3.0	3	Unpaved	< 25 ft.	Not connected	On Right-of-Way - with traffic control	1.0	4.42
002417SEWP	003178SSMH	003180SSMH	0000	10	10.4	129	Unpaved	< 25 ft.	Not connected	On public lands with vehicle access	1.0	4.88
009523SEWP	003180SSMH	007751SSMH	0000	12	4.7	130	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.82
009524SEWP	007764SSMH	007763SSMH	0000	12	3.1	147	Highway/Waterway	< 25 ft.	Not connected	On public lands without vehicle access	1.0	5.20
009525SEWP	007751SSMH	007764SSMH	0000	12	4.3	146	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.82
009526SEWP	007763SSMH	000609SSMH	0000	12	5.2	148	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.82
000311SEWP	000628SSMH	000629SSMH	N/A	10	11.9	13	Minor Local	25 - 50 ft.	Not connected	On public lands with vehicle access	0.0	4.07
003431SEWP	003138SSMH	003178SSMH	N/A	12	23.6	118	Highway/Waterway	< 25 ft.	Not connected	On public lands with vehicle access	0.0	5.27

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by:  
Checked by:

Xuhui Zeng, Greeley and Hansen  
Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - **If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary**

Stream Crossing:	Old Cameron Run Ch
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
002750SEWP	003608SSMH	003267SSMH		18	9.4	31	Arterial/Building/Pool	< 25 ft.	Not connected	On Right-of-Way - no traffic control	0.0	4.95

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by:  
Checked by:

Xuhui Zeng, Greeley and Hansen  
Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary

Stream Crossing:	Taylor Run
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
000040SEWP	000047SSMH	000041SSMH	2100	10	3.0	32	Collector	< 25 ft.	Not connected	On Right-of-Way - with traffic control	2.1	4.80
000041SEWP	000040SSMH	000042SSMH	2200	18	3.0	85	Major Local	< 25 ft.	260	On public lands without vehicle access	2.2	5.13
000155SEWP	000471SSMH	000461SSMH	0000	18	7.3	162	Minor Local	< 25 ft.	4033	On Right-of-Way - no traffic control	1.0	5.07
000520SEWP	000375SSMH	000373SSMH	0000	18	13.5	416	Major Local	< 25 ft.	4327	On Right-of-Way - with traffic control	1.0	5.25
000755SEWP	000482SSMH	000461SSMH	0000	12	9.8	103	Minor Local	< 25 ft.	1201	On Right-of-Way - with traffic control	1.0	4.90
000961SEWP	006587SSMH	000467SSMH	0000	18	9.7	144	Minor Local	25 - 50 ft.	3324	On Right-of-Way - no traffic control	1.0	4.35
007134SEWP	006570SSMH	006586SSMH	2C00	15	15.9	127	Unpaved	< 25 ft.	2593	On private lands without vehicle access	3.0	5.22
007135SEWP	006586SSMH	006587SSMH	2300	15	9.3	128	Minor Local	< 25 ft.	2874	On Right-of-Way - no traffic control	2.3	5.00
009107SEWP	007494SSMH	007495SSMH	0000	18	6.0	333	Minor Local	< 25 ft.	1887	On Right-of-Way - with traffic control	1.0	5.13
009120SEWP	007492SSMH	007495SSMH	3124	8	6.2	1	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	3.1	4.47
009121SEWP	007493SSMH	007492SSMH	2500	10	7.4	0	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	2.5	4.42
009164SEWP	007530SSMH	007529SSMH	0000	15	3.0	121	Unpaved	< 25 ft.	1436	On public lands without vehicle access	1.0	5.03
009166SEWP	006571SSMH	007532SSMH	0000	15	3.0	125	Arterial/Building/Pool	25 - 50 ft.	2169	On public lands with vehicle access	1.0	4.63
009167SEWP	007532SSMH	006570SSMH	0000	15	12.8	126	Arterial/Building/Pool	< 25 ft.	2481	On public lands with vehicle access	1.0	5.38
009176SEWP	000467SSMH	007540SSMH	0000	18	8.9	150	Minor Local	< 25 ft.	3468	On Right-of-Way - no traffic control	1.0	5.00
009177SEWP	007540SSMH	000471SSMH	3100	18	5.4	151	Minor Local	< 25 ft.	3689	On Right-of-Way - no traffic control	3.1	4.95
009178SEWP	000461SSMH	007541SSMH	0000	18	7.3	330	Minor Local	< 25 ft.	1590	On Right-of-Way - with traffic control	1.0	5.13
009179SEWP	007541SSMH	007494SSMH	0000	18	2.9	331	Minor Local	< 25 ft.	1686	On Right-of-Way - with traffic control	1.0	5.07
009182SEWP	007542SSMH	000460SSMH	0000	10	10.5	37	Minor Local	25 - 50 ft.	Not connected	On Right-of-Way - with traffic control	1.0	4.10
009477SEWP	007529SSMH	007756SSMH	0000	15	3.0	122	Unpaved	< 25 ft.	1590	On public lands without vehicle access	1.0	5.03
009478SEWP	007756SSMH	007531SSMH	0000	15	3.0	123	Arterial/Building/Pool	< 25 ft.	1752	On public lands without vehicle access	1.0	5.32
001117SEWP	000426SSMH	006587SSMH	N/A	8	13.4	14	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	0.0	4.55
000754SEWP	000460SSMH	000461SSMH	N/A	10	10.3	62	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	0.0	4.75
000794SEWP	000042SSMH	000041SSMH	N/A	15	3.0	86	Collector	< 25 ft.	658	On Right-of-Way - with traffic control	0.0	5.10
006666SEWP	007531SSMH	006571SSMH	N/A	18	3.0	124	Collector	25 - 50 ft.	2013	On public lands without vehicle access	0.0	4.60
009098SEWP	000041SSMH	007530SSMH	N/A	15	3.0	120	Collector	< 25 ft.	959	On public lands without vehicle access	0.0	5.20
009237SEWP	007546SSMH	007494SSMH	N/A	N/A	2.2	0	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	0.0	4.28
009253SEWP	007582SSMH	007586SSMH	N/A	18	3.0	503	Unpaved	< 25 ft.	5047	On private lands without vehicle access	0.0	5.13
009254SEWP	007587SSMH	007586SSMH	N/A	15	7.2	247	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	0.0	5.07
009255SEWP	007586SSMH	007588SSMH	N/A	24	3.0	752	Unpaved	< 25 ft.	5145	On private lands without vehicle access	0.0	5.20

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by:  
Checked by:

Xuhui Zeng, Greeley and Hansen  
Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary

Stream Crossing:	Timber Branch
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
006265SEWP	006639SSMH	007605SSMH	0000	12	10.3	229	Minor Local	25 - 50 ft.	1671	On Right-of-Way - with traffic control	1.0	4.45
006371SEWP	006413SSMH	006415SSMH	0000	12	7.2	10	Minor Local	25 - 50 ft.	Not connected	On Right-of-Way - with traffic control	1.0	3.90
006372SEWP	006414SSMH	006415SSMH	3221	10	7.0	2	Minor Local	25 - 50 ft.	Not connected	On Right-of-Way - with traffic control	3.2	3.90
006374SEWP	006415SSMH	006638SSMH	2100	12	9.3	12	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	2.1	4.63
006375SEWP	006417SSMH	006416SSMH	0000	12	6.3	226	Minor Local	< 25 ft.	1309	On Right-of-Way - with traffic control	1.0	5.05
006376SEWP	006416SSMH	006639SSMH	0000	15	9.5	228	Minor Local	25 - 50 ft.	1327	On Right-of-Way - with traffic control	1.0	4.47
006378SEWP	006419SSMH	006417SSMH	0000	12	8.0	225	Minor Local	25 - 50 ft.	1108	On Right-of-Way - with traffic control	1.0	4.40
006379SEWP	006397SSMH	006419SSMH	2200	12	8.2	223	Minor Local	< 25 ft.	883	On Right-of-Way - with traffic control	2.2	5.07
006658SEWP	006561SSMH	006687SSMH	4133	10	9.1	2	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	4.1	4.55
006872SEWP	006556SSMH	006557SSMH	3122	15	13.8	287	Minor Local	25 - 50 ft.	2942	On Right-of-Way - with traffic control	3.1	4.53
006873SEWP	006633SSMH	006556SSMH	1200	10	8.7	16	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	1.2	4.63
006932SEWP	006302SSMH	007606SSMH	2100	12	8.0	164	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	2.1	4.92
006933SEWP	006396SSMH	006397SSMH	0000	10	5.7	36	Collector	< 25 ft.	Not connected	On Right-of-Way - with traffic control	1.0	4.80
006935SEWP	006421SSMH	006397SSMH	0000	15	3.2	185	Collector	< 25 ft.	819	On Right-of-Way - with traffic control	1.0	5.25
006990SEWP	006637SSMH	006551SSMH	0000	12	10.4	255	Minor Local	50 - 75 ft.	2469	On Right-of-Way - with traffic control	1.0	1.20
007074SEWP	006557SSMH	006626SSMH	2100	15	14.0	293	Minor Local	25 - 50 ft.	3076	On Right-of-Way - with traffic control	2.1	4.57
007078SEWP	006626SSMH	006668SSMH	0000	15	8.3	303	Unpaved	25 - 50 ft.	3208	On private lands without vehicle access	1.0	4.55
007187SEWP	006636SSMH	006555SSMH	3123	10	10.8	11	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	3.1	4.67
007193SEWP	006709SSMH	006687SSMH	0000	10	8.4	3	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	1.0	4.55
007194SEWP	006686SSMH	006710SSMH	2200	15	10.3	327	Minor Local	25 - 50 ft.	5010	On Right-of-Way - with traffic control	2.2	4.50
007195SEWP	006681SSMH	006709SSMH	0000	10	7.1	4	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	1.0	4.55
007299SEWP	006833SSMH	006834SSMH	0000	12	7.5	332	Minor Local	25 - 50 ft.	5350	On Right-of-Way - with traffic control	1.0	4.38
007530SEWP	006627SSMH	006626SSMH	4121	10	12.7	8	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	4.1	4.60
007536SEWP	006661SSMH	006668SSMH	0000	10	6.4	3	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.50
007543SEWP	006668SSMH	006669SSMH	2100	15	3.0	308	Unpaved	25 - 50 ft.	3533	On private lands without vehicle access	2.1	4.50
007544SEWP	006669SSMH	006670SSMH	3100	15	4.8	309	Unpaved	< 25 ft.	3737	On private lands without vehicle access	3.1	5.15
007545SEWP	006670SSMH	006671SSMH	0000	15	6.0	310	Unpaved	< 25 ft.	3992	On private lands without vehicle access	1.0	5.20

Stream Crossing:	Timber Branch
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
007552SEWP	006678SSMH	006679SSMH	0000	10	9.1	12	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	1.0	4.63
007554SEWP	006671SSMH	006679SSMH	0000	15	7.5	311	Arterial/Building/Pool	< 25 ft.	4363	On public lands with vehicle access	1.0	5.40
007569SEWP	006687SSMH	006832SSMH	2200	10	8.1	8	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	2.2	4.55
007572SEWP	006710SSMH	006833SSMH	0000	15	8.7	331	Minor Local	25 - 50 ft.	5049	On Right-of-Way - with traffic control	1.0	4.45
009283SEWP	007606SSMH	007607SSMH	2100	12	4.9	164	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	2.1	4.95
009284SEWP	007607SSMH	006421SSMH	0000	12	3.8	165	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.82
009286SEWP	007605SSMH	006638SSMH	0000	12	11.0	230	Minor Local	25 - 50 ft.	1934	On Right-of-Way - with traffic control	1.0	4.45
009471SEWP	006679SSMH	007749SSMH	5100	15	6.3	325	Minor Local	25 - 50 ft.	4516	On Right-of-Way - with traffic control	5.1	4.47
009472SEWP	007749SSMH	006686SSMH	0000	15	6.8	326	Minor Local	25 - 50 ft.	4586	On Right-of-Way - with traffic control	1.0	4.47
009501SEWP	006638SSMH	007793SSMH	0000	12	7.1	244	Minor Local	25 - 50 ft.	1969	On Right-of-Way - with traffic control	1.0	4.40
009502SEWP	007793SSMH	006637SSMH	0000	12	6.5	254	Minor Local	25 - 50 ft.	2099	On Right-of-Way - with traffic control	1.0	4.40
006234SEWP	006261SSMH	006421SSMH	N/A	12	3.0	18	Major Local	< 25 ft.	600	On Right-of-Way - with traffic control	0.0	4.80
006868SEWP	006551SSMH	006555SSMH	N/A	12	11.0	260	Minor Local	25 - 50 ft.	2549	On Right-of-Way - with traffic control	0.0	4.45
006871SEWP	006555SSMH	006556SSMH	N/A	15	12.2	273	Minor Local	< 25 ft.	2764	On Right-of-Way - with traffic control	0.0	5.17

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by:  
Checked by:

Xuhui Zeng, Greeley and Hansen  
Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary

Stream Crossing:	Trib. to Backlick
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
001505SEWP	002335SSMH	002319SSMH	2500	15	3.0	2	Major Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	2.5	4.65
002692SEWP	002329SSMH	002330SSMH	5441	15	5.2	80	Major Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	5.4	4.88
002756SEWP	002330SSMH	002331SSMH	0000	15	5.3	109	Arterial/Building/Pool	< 25 ft.	Not connected	On public lands with vehicle access	1.0	5.07
002757SEWP	002331SSMH	002332SSMH	0000	15	9.0	110	Arterial/Building/Pool	< 25 ft.	Not connected	On public lands with vehicle access	1.0	5.13
002758SEWP	002332SSMH	002333SSMH	0000	15	10.8	164	Arterial/Building/Pool	< 25 ft.	Not connected	On public lands with vehicle access	1.0	5.32
002759SEWP	002333SSMH	002316SSMH	0000	15	10.2	165	Arterial/Building/Pool	< 25 ft.	Not connected	On public lands with vehicle access	1.0	5.32
002760SEWP	002336SSMH	002335SSMH	0000	15	3.0	1	Major Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.60
002761SEWP	002337SSMH	002336SSMH	0000	10	4.8	0	Major Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.45
002887SEWP	008015SSMH	002332SSMH	0000	12	7.6	52	Minor Local	< 25 ft.	Not connected	On public lands with vehicle access	1.0	4.75
002768SEWP	002319SSMH	002344SSMH	N/A	15	3.0	5	Arterial/Building/Pool	< 25 ft.	Not connected	On public lands with vehicle access	0.0	4.85
002888SEWP	003059SSMH	002330SSMH	N/A	10	3.9	27	Major Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	0.0	4.65
002771SEWP	002344SSMH	002343SSMH	N/A	10	3.0	6	Arterial/Building/Pool	< 25 ft.	Not connected	On private lands without vehicle access	0.0	4.88

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by: Xuhui Zeng, Greeley and Hansen  
Checked by: Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - **If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary**

Stream Crossing:	Trib. to Cameron Run
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
000208SEWP	000912SSMH	000979SSMH	0000	10	10.2	91	Unpaved	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.70
009290SEWP	001307SSMH	007613SSMH	0000	10	3.0	20			1034		1.0	0.55
500022SEWP	500012SSMH	500013SSMH	3400	10	6.5	168	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	3.4	4.92
001707SEWP	007613SSMH	001349SSMH	N/A	10	3.0	21			1094		0.0	0.55

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
 Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by: Xuhui Zeng, Greeley and Hansen  
 Checked by: Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - **If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary**

Stream Crossing:	Trib. to Four Mile Run
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
009350SEWP	004620SSMH	004916SSMH	N/A	36	3.0	199	Unpaved	< 25 ft.	7301	On public lands with vehicle access	0.0	5.17



**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by: Xuhui Zeng, Greeley and Hansen  
Checked by: Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary

Stream Crossing:	Trib to Holmes Run
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
000202SEWP	001355SSMH	001375SSMH	0000	12	5.7	85	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.75
000876SEWP	001181SSMH	001182SSMH	3100	10	14.0	24	Arterial/Building/Pool	< 25 ft.	Not connected	On private lands without vehicle access	3.1	5.10
000906SEWP	001106SSMH	007644SSMH	5223	10	7.9	6	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	5.2	4.57
001026SEWP	001353SSMH	001352SSMH	0000	12	5.1	164	Unpaved	< 25 ft.	1619	On public lands without vehicle access	1.0	5.03
001027SEWP	001202SSMH	001353SSMH	0000	12	3.9	163	Unpaved	< 25 ft.	1353	On public lands without vehicle access	1.0	5.03
001032SEWP	000555SSMH	007644SSMH	0000	12	18.4	77	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.95
001041SEWP	001352SSMH	007885SSMH	0000	12	4.3	165	Unpaved	< 25 ft.	1840	On public lands without vehicle access	1.0	5.03
001636SEWP	001422SSMH	001375SSMH	0000	10	19.5	74	Unpaved	< 25 ft.	738	On public lands without vehicle access	1.0	5.10
001667SEWP	002224SSMH	002232SSMH	0000	18	6.3	39	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	1.0	4.85
001668SEWP	002227SSMH	002228SSMH	0000	15	7.1	34	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	1.0	4.85
001670SEWP	002223SSMH	002224SSMH	0000	18	9.8	38	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	1.0	4.85
001671SEWP	002225SSMH	002223SSMH	0000	18	6.4	37	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	1.0	4.85
001678SEWP	002228SSMH	002226SSMH	0000	15	6.8	35	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	1.0	4.85
002133SEWP	500002SSMH	002216SSMH	N/A	10	6.9	0	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	0.0	4.42
002552SEWP	002226SSMH	002225SSMH	3100	18	6.8	36	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	3.1	4.72
002554SEWP	002231SSMH	002482SSMH	0000	18	4.1	41	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	1.0	4.80
002559SEWP	002229SSMH	002227SSMH	0000	15	6.0	33	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	1.0	4.85
009091SEWP	007479SSMH	007481SSMH	3123	15	5.0	29	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	3.1	4.72
009092SEWP	007481SSMH	007482SSMH	2100	15	3.0	30	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	2.1	4.72
009093SEWP	007482SSMH	007483SSMH	0000	15	3.0	31	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	1.0	4.80
009094SEWP	007483SSMH	002229SSMH	0000	15	6.0	32	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.80
009323SEWP	001106SSMH	001355SSMH	0000	12	4.2	84	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.75
009630SEWP	007885SSMH	001358SSMH	4121	12	9.3	166	Unpaved	< 25 ft.	2140	On public lands without vehicle access	4.1	5.07
500017SEWP	500009SSMH	001581SSMH	0000	18	3.0	427	Minor Local	< 25 ft.	Not connected	On private lands without vehicle access	1.0	5.10
000201SEWP	001375SSMH	001354SSMH	N/A	12	3.0	161	Unpaved	< 25 ft.	1012	On public lands without vehicle access	0.0	5.03
002553SEWP	002232SSMH	002231SSMH	N/A	15	4.1	40	Unpaved	< 25 ft.	Not connected	On private lands without vehicle access	0.0	4.80
001028SEWP	001354SSMH	001202SSMH	N/A	12	5.5	162	Unpaved	< 25 ft.	1218	On public lands without vehicle access	0.0	5.03
002241SEWP	001581SSMH	001580SSMH	N/A	18	11.7	428	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	0.0	5.07

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by: Xuhui Zeng, Greeley and Hansen  
Checked by: Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - **If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary**

Stream Crossing:	Trib. to Hooffs Run
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
003836SEWP	003621SSMH	003622SSMH	3825	10	7.5	12	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	3.8	4.65

**TO G19-07: Investigation of Sewer Pipelines in Stream Areas  
Calculator of Likelihood of Failure (LoF) and Consequences of Failure (CoF)**

Developed by: Xuhui Zeng, Greeley and Hansen  
Checked by: Angela Essner, Greeley and Hansen

**Notes:**

1. Green cells for input (asset information and project information).
2. Orange cells for output (LoF and CoF).
3. Grey cells marked as unavailable data.
4. After entering all necessary information, click on buttons ("Calculate LoF" and "Calculate CoF") to calculate LoF and CoF for all assets.
5. Hidden columns from P to Y are intermediate outputs for QA/QC, including the CoF factor assigned to each item and average CoF for Economic, Social and Environmental considerations.
6. Calculation of LoF:
  - Take the first two numbers and divided by 10
  - If the second number is a character, replace the character with 0 and add 1 to the first number.
  - If PACP quick score is not available, LoF = 0
  - If PACP quick score is 0000, LoF = 1
7. Calculation of CoF:
  - $CoF_{Economic} = (CoF_{Diameter} + CoF_{Depth} + CoF_{Position} + CoF_{RoadClass} + CoF_{Accessibility}) / 5$
  - $CoF_{Social} = (CoF_{Diameter} + CoF_{Position} + CoF_{RoadClass} + CoF_{CustomerDistance}) / 4$
  - $CoF_{Environmental} = CoF_{WaterDistance}$
  - $CoF = CoF_{Economic} * Economic\_Factor + CoF_{Social} * Social\_Factor + CoF_{Environmental} * Environmental\_Factor$
  - If the Depth of a manhole is not available, it is set default at 3.0 feet, which is the average depth of frost line and the minimum depth of sanitary

Stream Crossing:	Trib. to Taylor Run
Economic Factor:	0.25
Social Factor:	0.1
Environmental Factor:	0.65

Sewer ID	Upstream Manhole	Downstream Manhole	PACP Structural Quick Score	Diameter (Inch)	Depth (Feet)	Relative Network Position of Pipe	Class of Road	Distance from water body (Feet)	Distance from Important Customer (Feet)	Accessibility of Pipe	Likelihood of Failure (LoF)	Consequence of Failure (CoF)
000150SEWP	000483SSMH	000482SSMH	3100	12	5.0	81	Minor Local	< 25 ft.	Not connected	On Right-of-Way - with traffic control	3.1	4.72
000151SEWP	000484SSMH	000483SSMH	3121	10	5.0	7	Minor Local	< 25 ft.	Not connected	On private lands without vehicle access	3.1	4.65
000709SEWP	000538SSMH	000547SSMH	0000	12	4.1	54	Unpaved	< 25 ft.	Not connected	Behind build structures and no vehicle access	1.0	4.77
000719SEWP	000520SSMH	000521SSMH	0000	12	6.7	38	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.65
000725SEWP	000521SSMH	000527SSMH	0000	12	3.0	39	Unpaved	< 25 ft.	Not connected	Behind build structures and no vehicle access	1.0	4.77
000726SEWP	000527SSMH	000528SSMH	0000	12	7.0	40	Unpaved	< 25 ft.	Not connected	Behind build structures and no vehicle access	1.0	4.82
000727SEWP	000528SSMH	000537SSMH	0000	12	7.0	41	Unpaved	< 25 ft.	Not connected	Behind build structures and no vehicle access	1.0	4.82
000731SEWP	000531SSMH	000538SSMH	0000	10	5.8	10	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.45
009109SEWP	000547SSMH	007499SSMH	0000	12	4.1	65	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.67
009168SEWP	007499SSMH	007533SSMH	0000	12	4.1	66	Unpaved	< 25 ft.	Not connected	On public lands without vehicle access	1.0	4.67
009169SEWP	007533SSMH	000878SSMH	0000	12	5.0	67	Unpaved	50 - 75 ft.	Not connected	On public lands without vehicle access	1.0	3.38
009234SEWP	000878SSMH	007537SSMH	0000	12	3.0	69	Unpaved	< 25 ft.	Not connected	Behind build structures and no vehicle access	1.0	4.77
009236SEWP	007538SSMH	000483SSMH	0000	12	5.0	72	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.67
009479SEWP	007535SSMH	007757SSMH	0000	10	3.0	70	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.60
009480SEWP	007757SSMH	007538SSMH	0000	12	3.0	71	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	1.0	4.67
001293SEWP	000537SSMH	000538SSMH	N/A	12	3.0	42	Minor Local	< 25 ft.	Not connected	On Right-of-Way - no traffic control	0.0	4.60
009162SEWP	007528SSMH	000547SSMH	N/A	10	3.1	9	Unpaved	< 25 ft.	Not connected	Behind build structures and no vehicle access	0.0	4.63



# APPENDIX B PERCENT REMAINING PHYSICAL LIFE CALCULATION

**Appendix B**  
**City of Alexandria Investigation of Sewer Pipelines in Stream Areas**

**Calculation of Percent Remaining Physical Life for Prioritized Stream Area Pipeline Segments\***

Stream	Address	Year Built	Current Year	Estimated Useful Life	% Remaining Physical Life	Sewer
Holmes Run	5909 Jewell Ct	1954	2021	100	33%	002024SEWP
Holmes Run	5904 Kelley Ct	1954	2021	100	33%	002524SEWP, 002639SEWP
Holmes Run	5400 N. Morgan St.	1965	2021	100	44%	002618SEWP
Holmes Run	435 N. Armistead	1965	2021	100	44%	002618SEWP
Holmes Run	420 N. Van Dorn	1964	2021	100	43%	001804SEWP
Lucky Run	2206 N. Pickett St.	1966	2021	100	45%	(Stonegate Scenic Easement)
Lucky Run	4706 W. Braddock Ave.	1968	2021	100	47%	Open ditch area between roads Beauregard
Old Cameron Run Channel	2034 Eisenhower Ave	1982	2021	100	61%	02750SEWP
	2111 Eisenhower Ave	1984				02750SEWP
	2121 Eisenhower Ave	1985				02750SEWP
Taylor Run	3305 King St.	1950	2021	100	29%	000040SEWP, 09121SEWP
	3115 King St.	1950				
	3137 King St.	1950				
Timber Branch	670 W. Timber Branch Parkway	1957	2021	100	36%	Timber Branch Subshed
	818 W. Timber Branch Parkway	1957				
	621 E. Timber Branch Parkway	1961				
	813 E. Timber Branch Parkway	1959				
Tributary to Backlick	500 S Pickett St	1977				002692SEWP
	600 S Pickett St	1967				002692SEWP
	801 S Pickett St	1965	2021	100	44%	002692SEWP
Tributary to Cameron Run	6 Ft Williams Parkway	1959				500022SEWP
	3739 Duke St.	1950	2021	100	29%	500022SEWP
	3524 SAYLOR PL	1961	2021	100	40%	000208SEWP
	3520 SAYLOR PL	1961				000208SEWP
	247 NORMANDY HILL DR	1962	2021	100	41%	009290SEWP, 001707SEWP
Tributary to Four Mile Run	Sometime After 1954 when Common Interceptor was built	1954	2021	100	33%	009350SEWP
Tributary to Holmes Run	4400 WHEELER AV (Apt. complex)	1962	2021	100	41%	500017SEWP, 002241SEWP
		1964	2021	100	43%	002554SEWP, 002553SEWP, 001667SEWP, 001670SEWP, 001671SEWP, 002552SEWP, 001678SEWP, 001668SEWP, 0002559SEWP
	5075 POLK AV	1960	2021	100	39%	002133SEWP
	5614 HARDING AV	1968	2021	100	47%	0016336SEWP, 000201SEWP, 001028SEWP
	1900 N BEAUREGARD ST	1979	2021	100	58%	000876SEWP
Tributary to Taylor Run	1647 Francis Hammond Parkway	1954	2021	100	33%	000151SEWP
	1659 Francis Hammond Parkway	1954				000151SEWP
	1231 Kingston AV	1963	2021	100	42%	009162SEWP
	1301 Kingston AV	1963				009162SEWP

\*Compiled by AEY from City of Alexandria GIS Parcel Viewer to obtain year built data for a sampling of homes and buildings serviced by the sewer systems in each stream area.



# APPENDIX C TABLE OF EXTERNAL RISK FACTOR FOR FAILURE

## Appendix C

### External Risk Factor for Failure for Field Inspected Pipe Segments

No.	Stream Name	FacilityID	Pipe Shape	Pipe Material	Height (Inch)	Mainline Length (Feet)	External Risk Factor	Comments
1	Holmes Run	001804SEWP	Circular	RCP	10	103.0	1	
2	Holmes Run	002024SEWP	Circular	XXX	10	111.0	3	Bell exposed near one manhole and fractured encasement
3	Holmes Run	002524SEWP	Circular	*	*	*	3	Concrete breaking away in spots exposing pipe that appears to be CIPP
4	Holmes Run	002618SEWP	Circular	CP or DIP	12	110.9	6	Pipe exposed, encasement cracked, not CIPP lined, only first couple ft were CCTVed
5	Holmes Run	002639SEWP	Circular	RCP	12		6	Pipe exposed, partial undermined armor or no armor, no CCTV data
6	Hooffs Run	009653SEWP	Circular	PVC	27	252.7	1	
7	Lucky Run	000311SEWP	Circular	*	*	*	1	
8	Lucky Run	000312SEWP	Circular	PVC	10	54.2	1	
9	Lucky Run	000318SEWP	Circular	RCP	10	121.9	1	
10	Lucky Run	001146SEWP	Circular	RCP	15	508.0	1	
11	Lucky Run	001318SEWP	Circular	RCP	10	63.7	1	
12	Lucky Run	001345SEWP	Circular	RCP	15	701.3	1	
13	Lucky Run	001407SEWP	Circular	RCP	10	209.9	1	
14	Lucky Run	002417SEWP	Circular	PVC	10	25.2	1	
15	Lucky Run	003431SEWP	Circular	*	*	*	1	
16	Lucky Run	009523SEWP	Circular	XXX	12	117.0	1	
17	Lucky Run	009524SEWP	Circular	XXX	12	140.0	5	
18	Lucky Run	009525SEWP	Circular	XXX	12	131.2	1	
19	Lucky Run	009526SEWP	Circular	XXX	12	435.5	1	
20	Old Cameron Run Channel	002750SEWP	Oval	RCP	18	235.3	1	
21	Taylor Run	000040SEWP	Circular	XXX	10	98.2	5	Exposed cast iron sewer
22	Taylor Run	000041SEWP	Circular	XXX	18	391.0	1	
23	Taylor Run	000155SEWP	Circular	XXX	18	255.7	1	
24	Taylor Run	000520SEWP	Circular	RCP	18	157.8	1	
25	Taylor Run	000754SEWP	Circular	*	*	*	1	
26	Taylor Run	000755SEWP	Circular	XXX	12	390.0	1	
27	Taylor Run	000794SEWP	Circular	*	*	*	2	
28	Taylor Run	000961SEWP	Circular	XXX	18	141.5	1	
29	Taylor Run	001117SEWP	Circular	XXX	8	67.9	1	
30	Taylor Run	006666SEWP	Circular	*	*	*	1	
31	Taylor Run	007134SEWP	Circular	XXX	15	286.8	1	
32	Taylor Run	007135SEWP	Circular	XXX	15	449.0	1	
33	Taylor Run	009098SEWP	Circular	*	*	*	2	Eroded bank
34	Taylor Run	009107SEWP	Circular	XXX	18	548.0	1	
35	Taylor Run	009120SEWP	Circular	XXX	8	147.0	1	
36	Taylor Run	009121SEWP	Circular	XXX	10	148.0	5	Exposed with broken bells at joints
37	Taylor Run	009164SEWP	Circular	XXX	15	154.0	2	
38	Taylor Run	009166SEWP	Circular	XXX	15	141.0	1	
39	Taylor Run	009167SEWP	Circular	XXX	15	110.1	1	
40	Taylor Run	009176SEWP	Circular	XXX	18	223.1	1	
41	Taylor Run	009177SEWP	Circular	XXX	18	346.0	1	
42	Taylor Run	009178SEWP	Circular	XXX	18	97.8	1	
43	Taylor Run	009179SEWP	Circular	XXX	18	120.0	1	
44	Taylor Run	009182SEWP	Circular	XXX	10	150.0	1	
45	Taylor Run	009237SEWP	Circular	*	*	*	2	Gabion up stream of MH beginning to erode
46	Taylor Run	009253SEWP	Circular	*	*	*	1	
47	Taylor Run	009254SEWP	Circular	*	*	*	1	
48	Taylor Run	009255SEWP	Circular	*	*	*	1	
49	Taylor Run	009477SEWP	Circular	XXX	15	164.0	1	
50	Taylor Run	009478SEWP	Circular	XXX	15	260.0	5	Exposed DIP crossing
51	Timber Branch	006234SEWP	Circular	*	*	*	1	
52	Timber Branch	006265SEWP	Circular	XXX	12	262.1	1	

## Appendix C

### External Risk Factor for Failure for Field Inspected Pipe Segments

No.	Stream Name	FacilityID	Pipe Shape	Pipe Material	Height (Inch)	Mainline Length (Feet)	External Risk Factor	Comments
53	Timber Branch	006371SEWP	Circular	XXX	12	92.0	1	
54	Timber Branch	006372SEWP	Circular	CP	10	108.0	1	
55	Timber Branch	006374SEWP	Circular	CP	12	100.0	6	Aerial cast iron pipe exposed, erosion around supports
56	Timber Branch	006375SEWP	Circular	XXX	12	18.0	1	
57	Timber Branch	006376SEWP	Circular	XXX	15	346.0	1	
58	Timber Branch	006378SEWP	Circular	XXX	12	202.0	1	
59	Timber Branch	006379SEWP	Circular	XXX	12	227.0	3	
60	Timber Branch	006658SEWP	Circular	CP	10	132.0	1	
61	Timber Branch	006868SEWP	Circular	*	*	*	1	
62	Timber Branch	006871SEWP	Circular	*	*	*	2	Bank steep and eroded close to impacting support of road
63	Timber Branch	006872SEWP	Circular	RCP	15	137.0	1	
64	Timber Branch	006873SEWP	Circular	CP	10	60.0	1	
65	Timber Branch	006932SEWP	Circular	XXX	12	153.0	1	
66	Timber Branch	006933SEWP	Circular	XXX	10	45.1	3	
67	Timber Branch	006935SEWP	Circular	XXX	15	62.0	3	
68	Timber Branch	006990SEWP	Circular	XXX	12	77.0	1	
69	Timber Branch	007074SEWP	Circular	XXX	15	128.0	1	
70	Timber Branch	007078SEWP	Circular	XXX	15	325.0	1	
71	Timber Branch	007187SEWP	Circular	CP	10	157.0	1	
72	Timber Branch	007193SEWP	Circular	CP	10	30.3	1	
73	Timber Branch	007194SEWP	Circular	RCP	15	39.1	1	
74	Timber Branch	007195SEWP	Circular	XXX	10	83.2	1	
75	Timber Branch	007299SEWP	Circular	RCP	12	118.0	1	
76	Timber Branch	007530SEWP	Circular	CP	10	82.0	1	
77	Timber Branch	007536SEWP	Circular	XXX	10	211.5	1	
78	Timber Branch	007543SEWP	Circular	XXX	15	454.0	1	
79	Timber Branch	007544SEWP	Circular	XXX	15	255.0	1	
80	Timber Branch	007545SEWP	Circular	XXX	15	375.0	1	
81	Timber Branch	007552SEWP	Circular	XXX	10	182.0	1	
82	Timber Branch	007554SEWP	Circular	XXX	15	156.1	1	
83	Timber Branch	007569SEWP	Circular	XXX	10	382.5	1	
84	Timber Branch	007572SEWP	Circular	RCP	15	297.0	1	
85	Timber Branch	009283SEWP	Circular	XXX	12	215.0	2	Some undercutting near down stream manhole
86	Timber Branch	009284SEWP	Circular	XXX	12	126.0	2	Some undercutting near US stream manhole
87	Timber Branch	009286SEWP	Circular	XXX	12	37.0	1	
88	Timber Branch	009471SEWP	Circular	XXX	15	464.7	1	
89	Timber Branch	009472SEWP	Circular	RCP	15	54.0	1	
90	Timber Branch	009501SEWP	Circular	CP	12	134.0	1	
91	Timber Branch	009502SEWP	Circular	XXX	12	371.0	1	
92	Tributary to Backlick Run	001505SEWP	Circular	RCP	15	32.0	1	
93	Tributary to Backlick Run	002692SEWP	Circular	RCP	15	430.0	1	
94	Tributary to Backlick Run	002756SEWP	Circular	RCP	15	7.5	1	
95	Tributary to Backlick Run	002757SEWP	Circular	RCP	15	48.0	1	
96	Tributary to Backlick Run	002758SEWP	Circular	RCP	15	256.7	1	
97	Tributary to Backlick Run	002759SEWP	Circular	RCP	15	191.6	3	Streambank collapsing by DS MH
98	Tributary to Backlick Run	002760SEWP	Circular	RCP	15	39.0	1	
99	Tributary to Backlick Run	002761SEWP	Circular	CP	10	200.0	1	
100	Tributary to Backlick Run	002768SEWP	Circular	RCP	15	354.5	1	
101	Tributary to Backlick Run	002771SEWP	Circular	*	*	*	1	
102	Tributary to Backlick Run	002887SEWP	Circular	CP	12	204.0	1	
103	Tributary to Backlick Run	002888SEWP	Circular	CP	10	310.0	1	
104	Tributary to Cameron Run	000208SEWP	Circular	XXX	10	371.0	1	
105	Tributary to Cameron Run	009290SEWP	Circular	FRP	10	59.1		No Access located within CSX ROW
106	Tributary to Cameron Run	001707SEWP	Circular	*	*	*		No access under CSX railway and No CCTV
107	Tributary to Cameron Run	500022SEWP	Circular	XXX	10	149.0	1	
108	Tributary to Four Mile Run	009350SEWP	Circular	RCP	36	277.8	1	
109	Tributary to Holmes Run	000201SEWP	Circular	XXX	12	206.8	1	
110	Tributary to Holmes Run	000202SEWP	Circular	XXX	12	278.2	1	



## Appendix C

### External Risk Factor for Failure for Field Inspected Pipe Segments

No.	Stream Name	FacilityID	Pipe Shape	Pipe Material	Height (Inch)	Mainline Length (Feet)	External Risk Factor	Comments
111	Tributary to Holmes Run	000876SEWP	Circular	CP	10	328.0	1	
112	Tributary to Holmes Run	000906SEWP	Circular	RCP	10	63.7	1	
113	Tributary to Holmes Run	001026SEWP	Circular	XXX	12	221.0	2	stream bank erosion close to manholes
114	Tributary to Holmes Run	001027SEWP	Circular	XXX	12	268.0	2	stream bank erosion close to manholes
115	Tributary to Holmes Run	001028SEWP	Circular	*	*	*	2	stream bank erosion close to DS manhole
116	Tributary to Holmes Run	001032SEWP	Circular	XXX	12	151.6	1	
117	Tributary to Holmes Run	001041SEWP	Circular	XXX	12	255.0	3	Partially exposed sewer crossing and stream bank erosion close to manhole
118	Tributary to Holmes Run	001636SEWP	Circular	XXX	10	274.0	1	
119	Tributary to Holmes Run	001667SEWP	Circular	RCP	18	85.1	1	
120	Tributary to Holmes Run	001668SEWP	Circular	RCP	15	268.0	1	
121	Tributary to Holmes Run	001670SEWP	Circular	RCP	18	125.3	1	
122	Tributary to Holmes Run	001671SEWP	Circular	RCP	18	205.7	1	
123	Tributary to Holmes Run	001677SEWP	Circular	RCP	18	85.1	1	
124	Tributary to Holmes Run	001678SEWP	Circular	RCP	15	307.1	1	
125	Tributary to Holmes Run	002133SEWP	Circular	*	*	*	1	
126	Tributary to Holmes Run	002241SEWP	Circular	*	*	*	1	
127	Tributary to Holmes Run	002552SEWP	Circular	RCP	18	300.7	1	
128	Tributary to Holmes Run	002553SEWP	Circular	RCP	15	420.4	2	Erosion at stream bank, DS MH in stream
129	Tributary to Holmes Run	002554SEWP	Circular	RCP	18	188.0	2	Erosion at stream bank, US MH in stream
130	Tributary to Holmes Run	002599SEWP	Circular	RCP	15	231.2	1	
131	Tributary to Holmes Run	009091SEWP	Circular	RCP	15	218.2	1	
132	Tributary to Holmes Run	009092SEWP	Circular	RCP	15	264.0	1	
133	Tributary to Holmes Run	009093SEWP	Circular	RCP	15	90.0	1	
134	Tributary to Holmes Run	009094SEWP	Circular	RCP	15	150.2	1	
135	Tributary to Holmes Run	009323SEWP	Circular	XXX	12	248.3	1	
136	Tributary to Holmes Run	009630SEWP	Circular	XXX	12	359.2	1	
137	Tributary to Holmes Run	500017SEWP	Circular	RCP	18	275.8	1	
138	Tributary to Hooff's Run	003836SEWP	Circular	XXX	10	189.0	1	
139	Tributary to Taylor Run	000150SEWP	Circular	XXX	12	215.0	1	
140	Tributary to Taylor Run	000151SEWP	Circular	CP	10	61.2	1	
141	Tributary to Taylor Run	000709SEWP	Circular	XXX	12	268.7	3	Partially exposed sewer crossing
142	Tributary to Taylor Run	000719SEWP	Circular	XXX	12	130.1	1	
143	Tributary to Taylor Run	000725SEWP	Circular	XXX	12	186.5	1	
144	Tributary to Taylor Run	000726SEWP	Circular	XXX	12	184.1	1	
145	Tributary to Taylor Run	000727SEWP	Circular	XXX	12	319.4	1	
146	Tributary to Taylor Run	000731SEWP	Circular	XXX	10	75.1	1	
147	Tributary to Taylor Run	001293SEWP	Circular	XXX	12	156.8	1	
148	Tributary to Taylor Run	009109SEWP	Circular	XXX	12	192.6	1	
149	Tributary to Taylor Run	009162SEWP	Circular	*	*	*	3	Partially exposed sewer crossing
150	Tributary to Taylor Run	009168SEWP	Circular	XXX	12	361.6	1	
151	Tributary to Taylor Run	009169SEWP	Circular	XXX	12	263.0	1	
152	Tributary to Taylor Run	009234SEWP	Circular	XXX	12	52.1	1	
153	Tributary to Taylor Run	009236SEWP	Circular	XXX	12	385.4	1	
154	Tributary to Taylor Run	009479SEWP	Circular	XXX	12	55.6	1	
155	Tributary to Taylor Run	009480SEWP	Circular	XXX	12	260.3	1	

\* = No CCTV data available



**GREELEY AND HANSEN**

5301 Shawnee Road, Suite 400  
Alexandria, VA 22312  
1.800.837.9779