Louisville and Jefferson County Metropolitan Sewer District Continuous Sewer System Assessment Protocol

Safe, clean waterways

Louisville & Jefferson County Metropolitan Sewer District
Continuous Sewer System Assessment Protocol

Revision Date:

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msd
Safe, clean waterways

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CHANGE LOG

SECTION	SUMMARY OF CHANGES
Section 1: Continuous Sewer System Assessment Protocol	Updated references from Amended Consent Decree (ACD) to Second Amended Consent Decree (2ACD).
Section 2: System and Organizational Framework	Updated statistics and addressed Bullitt and Oldham County SCAP basins. Updated references from Amended Consent Decree (ACD) to Second Amended Consent Decree (2ACD). Updated organizational information. Updated web and network locations. Updated software references. Added reference to Manhole Assessment and Certification Program (MACP). Added links to System Capacity Assurance Protocol (SCAP), Infor Public Sector (IPS), GraniteNet Web Solutions, and NASSCO PACP Software..
Section 3: Inspection	Added discussion of AI coding. Added reference to MACP. Added discussion of ad hoc manhole inspections.
Section 4: Assessment	None
Section 5: Implementation	Updated references from Amended Consent Decree (ACD) to Second Amended Consent Decree (2ACD).
Section 6: Reporting	Updated references from Amended Consent Decree (ACD) to Second Amended Consent Decree (2ACD). Updated frequencies to reflect current reporting requirements.
Section 7: Updates, Availability and Training	Updated organizational information. Updated web and network locations.
Appendix A NASSCO PACP Standards	Updated to reference MACP..
Appendix B NASSCO Certified Software	Removed. Included as a link in Section 2.
Appendix C NASSCO PACP QAQC	Removed. Included as a link in Section 3.
Appendix B MSD Manhole Inspection Form and Codes	Renumbered from Appendix D.
Appendix C NASSCO PACP Grading System	Renumbered from Appendix E.
Appendix D NASSCO PACP Based Risk Management	Renumbered from Appendix F.
Appendix E Basis for Development of Probability of Failure Curves and Tables for MSD's Application with Hansen's Advanced Asset Management Module	Renumbered from Appendix G.
Appendix F Consequence of Failure Index	Renumbered from Appendix H.

Section 1: Continuous Sewer System Assessment Protocol

1.1. Purpose

The Louisville and Jefferson County Metropolitan Sewer District (MSD) conducts a wide-ranging sewer condition evaluation to comply with its Second Amended Consent Decree (2ACD) as well as the Capacity, Management, Operations and Maintenance (CMOM) and Nine Minimum Control (NMC) programs. The Continuous Sewer System Assessment (CSSA) program, Emergency Evaluation and Escalation Program (EEEP), Infrastructure Rehabilitation Program (IRP), and Gravity Line Preventive Maintenance (GLPM) program address certain aspects of Paragraph 37b., "CMOM (Capacity, Management, Operations and Maintenance) Programs Self-Assessment" and Paragraph 37a. "Nine Minimum Controls (NMC)" from the 2ACD.

The primary objective of the CSSA is to develop and implement maintenance and rehabilitation recommendations that reduce sewer overflows and improve the capacity, structural integrity and functionality of existing assets.

1.2. Goals

The goal of the CSSA is to address sanitary sewer overflows (SSOs) and maintain or increase the functionality of existing assets.

1.3. Acronyms

2ACD	Second Amended Consent Decree
AWAM	Associate in Water Asset Management
CCTV	Closed Circuit Television
CHEMG	Chemical Grease Control
CHEMR	Chemical Root Control
CIP	Capital Improvement Program
CIPP	Cured-In-Place Pipe
CMOM	Capacity Management, Operations and Maintenance
COF	Consequence of Failure
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CSSA	Continuous Sewer System Assessment
CTAM	Certification of Training in Asset Management
EEEP	Emergency Evaluation and Escalation Program
GIS	Geographic Information Systems
GLPM	Gravity Line Preventive Maintenance
I/I	Infiltration and Inflow
ICA	Interceptor Condition and Assessment

IPS	Infor Public Sector
IRP	Infrastructure Rehabilitation Program
ITCP	Inspector Training Certification Program
LACP	Lateral Assessment and Certification Program
LASA	Linear Assets Support Administration
LF	Linear Feet
LIDAR	Light Detection and Ranging
LOF	Likelihood of Failure
LOJIC	Louisville and Jefferson County Information Consortium
MACP	Manhole Assessment and Certification Program
MSD	Louisville and Jefferson County Metropolitan Sewer District
NASSCO	National Association of Sewer Service Companies
NMC	Nine Minimum Controls
PACP	Pipeline Assessment and Certification Program
PLOF	Predicted Likelihood of Failure
POTW	Publicly Owned Treatment Works
PSC	Property Service Connection
PWAM	Professional in Water Asset Management
RCAM	Regulatory Compliance and Asset Management
SCAP	System Capacity Assurance Plan
SL-RAT	Sewer Line Rapid Assessment Tool
SSES	Sanitary Sewer Evaluation Study
SSO	Sanitary Sewer Overflow
SSS	Separate Sanitary System
TISCIT	Total Integrated Sonar & CCTV Inspection Technique
WQTC	Water Quality Treatment Center
WUS	Waters of the US

Section 2: System and Organizational Framework

2.1. MSD Wastewater Collection, Transmission and Treatment System

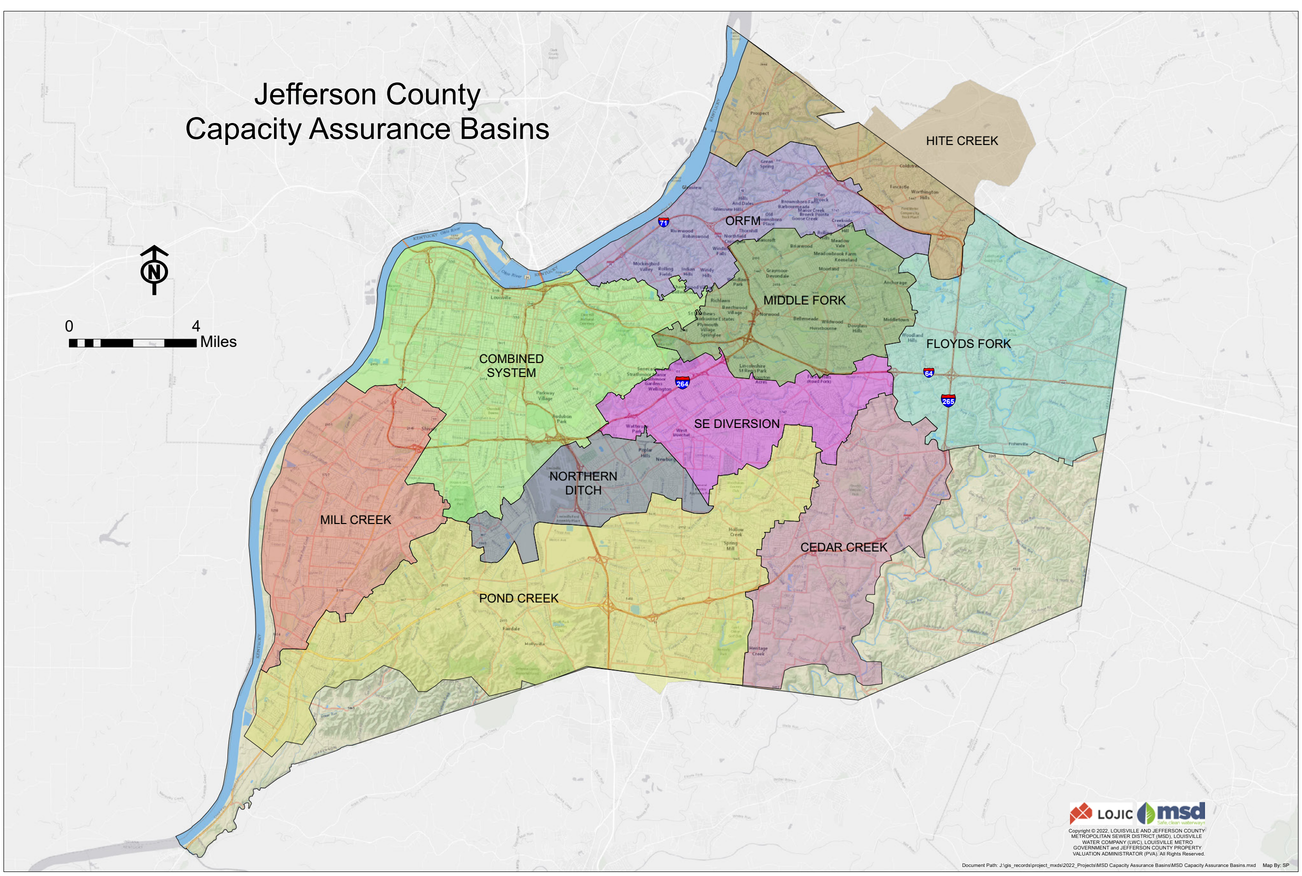
MSD is responsible for the operation and maintenance of the sewer system within the public right-of-way and dedicated easements in Jefferson County, Kentucky, in addition to areas in Bullitt and Oldham Counties. The sanitary sewer collection system includes over 3,600 miles of sewers ranging from 6 inches to 27.5 feet in diameter, built between the mid-1800's and present day. The construction materials consist of brick, iron, polyvinyl chloride, clay, vitrified clay, and reinforced concrete. There are over 86,000 combined and separate sanitary manholes in the system constructed of reinforced concrete and brick materials. MSD also operates and maintains over 68,000 catch basins and yard drains, over 300 sanitary pump stations, 16 flood pump stations, and 20 water quality treatment centers (WQTCs).

The system is divided into 10 basins in Jefferson County, based on receiving WQTC and major infrastructure sewersheds, as shown in **Figure 2.1.** These basins are used to track capacity credits, as documented in MSD's **System Capacity Assurance Plan** (SCAP). Basins in Bullitt and Oldham Counties are based on receiving WQTC.

2.1.1. Collection System

MSD owns and operates a system that transports wastewater by both gravity and force main systems. The gravity system collects wastewater at the property service connection (PSC) from the point of discharge from homes and businesses, and conveys it through a series of manholes, collector sewers, and interceptors to a

Figure 2.1. Jefferson County SCAP Basins



permitted Publicly Owned Treatment Works (POTW) before being discharged to the Waters of the United States (WUS).

2.1.2. Transmission and Treatment System

Wastewater is conveyed to MSD's network of treatment facilities, which are permitted by the Kentucky Department of Environmental Protection under the Kentucky Pollutant Discharge Elimination System. The treatment process provides the means to achieve beneficial reuse of wastewater biosolids, while treating the wastewater to a level that allows for sustained recreational and commercial uses, as well as natural habitats for aquatic wildlife. The MSD network includes both combined sewer system (CSS) and sanitary sewer system (SSS) treatment, employing a variety of activated sludge treatment processes that have received national awards for operational excellence.

2.2. Program Framework

The CSSA, EEEP, IRP and GLPM programs require a defined approach to prioritize, perform, and track the inspection, cleaning, rehabilitation, replacement, and maintenance of sewer assets on a scheduled cycle. While the programs are prescribed under CMOM, they are also intended to improve compliance with NMC 1 and 2, which require the proper operation, regular maintenance, and maximum use of MSD's CSS to prevent dry weather combined sewer overflows (CSOs) and reduce wet weather CSOs to the extent possible.

Assets are put into groups based on location and diameter. Once the inspection of an asset group is complete, the data is evaluated through a pipe condition assessment process and appropriate maintenance and rehabilitation actions are taken. The inspection activities are carried out under MSD's CSSA program, while immediate repairs are addressed by the EEEP, rehabilitation activities are addressed by the IRP, and recurring maintenance activities are addressed by the GLPM. The process workflow for the programs is outlined in **Figure 2.2.** Progress is updated annually in the 2ACD annual report.

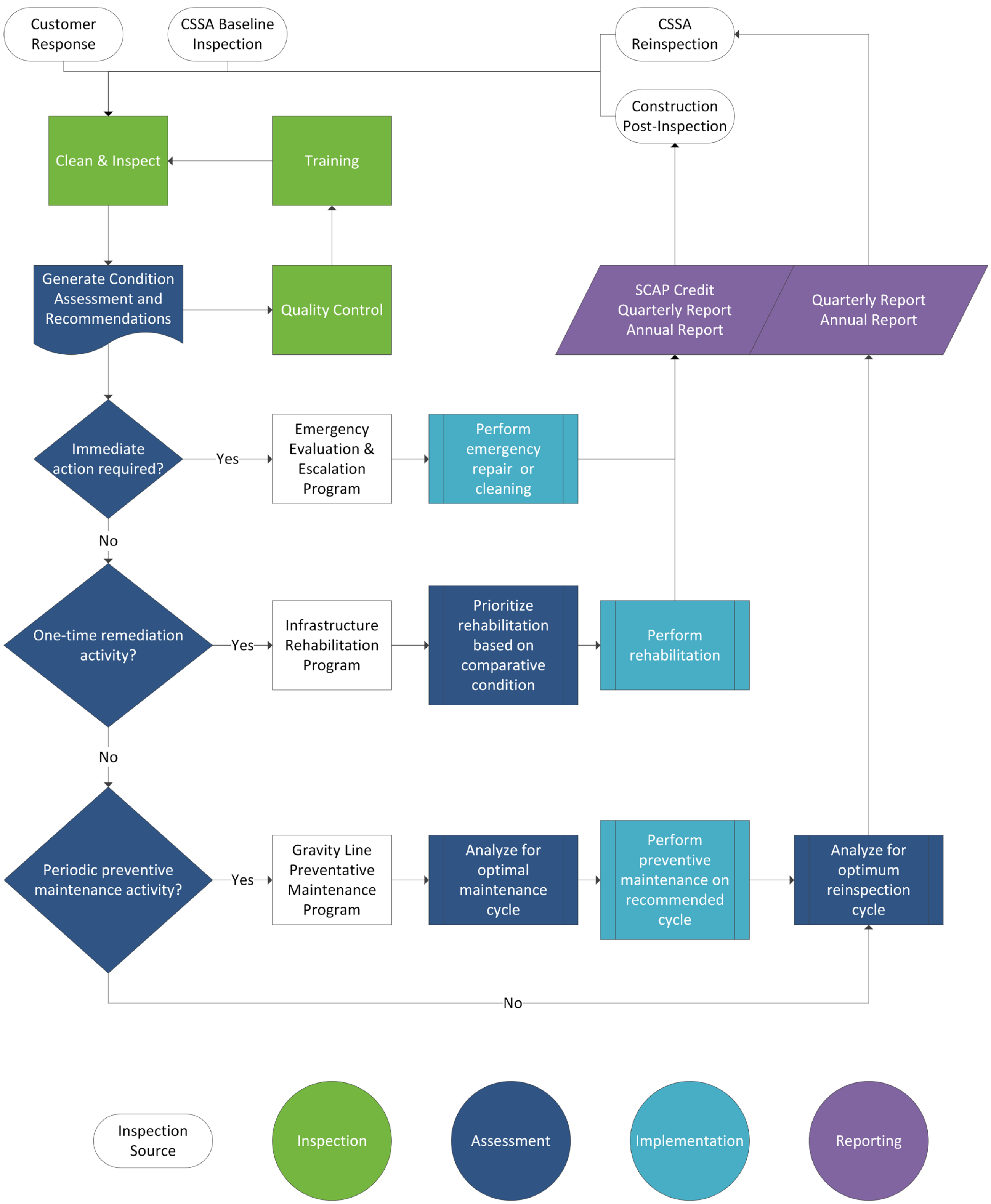
The IRP, a subsidiary program of the CSSA, pertains to sewer lines identified through inspections and data analysis as having structural or significant maintenance issues. This program recommends a rehabilitation method to restore asset integrity, assigns work to available resources, tracks progress, and documents the work performed on designated segments.

The GLPM, formerly the Blockage Abatement Program, is another subsidiary program of the CSSA. This program encompasses sewer lines identified through inspections and data analysis as having recurring maintenance needs due to root blockages, sedimentation, or oil and grease deposits. Additionally, this program tracks the segments with operational defects, sets up recurring work orders, assigns work to available resources, tracks progress, and documents the work performed.

To proactively address current and upcoming infrastructure issues, a detailed decision framework has been developed including inspecting, assessing, implementing, and reporting in a continuous cycle, as illustrated in **Figure 2.2**.

- **Inspecting** includes mainline and manhole inspections, including gravity lines and force mains, as well as flow monitoring in mains and at pump stations.
- **Assessing** includes evaluation of inspection data for major defects or issues, recommending remediation activities as needed, and prioritizing activities based on likelihood and consequence of failure.
- **Implementing** includes infrastructure rehabilitation and replacement as well as proactive maintenance activities like periodic cleaning.
- **Reporting** includes post-construction inspection and monitoring as well as calculation of credits in accordance with the approved SCAP procedure.

Figure 2.2. CSSA Protocol Workflow



The team that works to execute the protocol consists of MSD staff from a variety of departments, including the Regulatory Compliance & GIS and Technical Services departments in the Engineering Division, and the Drainage Maintenance & CSO/NMC, Linear Assets Support, and Sanitary departments in the Operations Division.

2.3. Information Management

Infor Public Sector (IPS) computerized maintenance management system, formerly known as Hansen, houses the entire master asset inventory of MSD's sewer and drainage infrastructure. All work performed on pipes, manholes, and other infrastructure, including detailed inspections and preventive maintenance activities, are managed in this system.

The data gathered from inspections, or from documenting work performed under the program, is imported into IPS using various import tools or manually entered into the system by staff or consultants.

Inspections are performed using coding defined in the Pipeline Assessment and Certification Program (PACP) and Manhole Assessment and Certification Program (MACP) defect coding standards, developed by the National Association of Sewer Service Companies (NASSCO). Info regarding these standards may be found in **Appendix A**.

Mainline inspections are recorded using NASSCO-certified PACP software. MSD currently uses **GraniteNet Web Solutions** to perform and manage inspections. Contractors may use any NASSCO-certified PACP software. Information regarding the certification requirements and a list of certified software vendors may be found on the webpage **NASSCO PACP Software**.

Deliverables for inspections conducted prior to implementing GraniteNet, including reports, videos and photos, are archived on the network at **T:\TVI CSSA\NEZTEK**. Inspections conduction since the implementation can be accessed in GraniteNet.

Section 3: Inspection

Areas may be selected for an in-depth Interceptor Condition Assessment (ICA) or Sanitary Sewer Evaluation Study (SSES).These studies can include CCTV, sonar, laser profiling, manhole, and wet weather inspections. Other areas may include only CCTV, acoustic, and manhole inspections.

3.1. Mainline Inspections

Sewer conditions are assessed by performing CCTV and LIDAR/SONAR inspections and by coding defects using PACP defect codes. Defects are assigned a severity rating ranging from 1 to 5, with 5 being the most severe and 1 being the least severe. Defect reports are available in IPS and PACP defect codes can be found in **Appendix A**. Common PACP defects, along with their associated severity rating, are given in **Table 3.1**. CCTV inspections may be coded using artificial intelligence processing.

Table 3.1. PACP/MACP Defect Severity

GROUP	DESCRIPTOR	CRITERIA	SEVERITY
Crack	Circumferential		1
	Longitudinal		2
	Multiple		3
Fracture	Circumferential		2
	Longitudinal		3
	Multiple		4
Pipe Failures	Broken	Soil Visible	5
	Hole	Soil Visible	5
Collapse	Pipe		5
Deformed	Pipe	<=10%	4
		> 10%	5
Joint	Offset	Med	1
		Large	2
	Separated	Med	1
		Large	2
Surface Damage Chemical	Roughness Increased	C	1
	Surface Spelling	C	2
	Aggregate Visible	C	3
	Aggregate Missing	C	4
	Reinforcement Visible	C	5
Deposits Attached	Encrustation, Grease, or Ragging	<=10%	2
		<=20%	3
		<=30%	4
		> 30%	5
Infiltration	Weeper		2
	Dripper		3
	Runner		4
	Gusher		5

Table 3.2. Target frequency - Inspection

SCHEDULE PERIOD (YEARS)		CONSEQUENCE OF FAILURE (COF)				
		1	2	3	4	5
LIKELIHOOD OF FAILURE (LOF)	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

For segments that are 6 to 12 inches in diameter and have a severity rating of 2 or less according to the most recent PACP data, acoustic inspections are used to assess defects in segments and pre-screen for additional CCTV. Sewer Line Rapid Assessment Tools (SL-RAT) emit an acoustic signal through a sewer segment from the transmitting device to the receiving device that are both inserted into the manholes on either end of the segment. A score is obtained ranging from 0 to 10, with 0 being a complete blockage and 10 being no blockage within the segment. If a score of 6 or less is received, the segment is flushed and retested. If the segment continues to score less than 6 after cleaning, it is referred for CCTV.

3.1.1. Routine Mainline Inspection

From FY08 through FY18, MSD committed to performing a baseline inspection of its gravity mainlines through SSES and ICA projects, as well as by SCAP sub-basin. Based on a risk register developed from the initial inspections, MSD has developed the inspection schedule shown in **Table 3.2**. The most critical and vulnerable infrastructure is on an annual inspection schedule and less critical infrastructure is on a schedule ranging from 5 to 20 years. Development of the risk register is discussed further in **Section 4**. Interceptors are assigned for inspection as a single project per interceptor, and the inspection schedule is based on the interceptor segment with the highest risk rating. SCAP sub-basins are similarly assigned for inspection as a single project with schedule based on the segment within the sub-basin with the highest risk.

3.1.2. Post-Construction Inspection

Rehabilitation construction contracts require post-construction CCTV and coding to confirm defects have been addressed, to identify any rehabilitation construction issues, and to reset defect scores used in the recommendation development.

3.1.3. New Asset Inspection

MSD requires inspections of newly constructed mainlines as they are brought into the system, as well as inspections of any newly-acquired gravity infrastructure.

3.1.4. Quality Control / Quality Assurance

Mainline inspection data captured via CCTV may be coded using artificial intelligence processing, which receives a 100% review by a certified PACP coder. Other inspection data is captured via CCTV is QA/QC'ed following NASSCO recommended standards, available on the webpage **NASSCO PACP Quality Assurance**. Videos and detailed observations for CCTV inspection may require additional work following QA/QC review until passing final acceptance criteria.

3.2. Manhole Inspections

Manhole asset information is field verified, including measurements and materials, and corrected in IPS as required. Structural condition is evaluated for each manhole component, including the cover, frame, rings, cone, wall, bench, channel and steps, as well as for each pipe connection. Characteristics and condition assessments are described in the inspection information. Infiltration and inflow (I/I) are rated for each component. Additional

Table 3.3. MSD Manhole Defect Severity

GROUP	DESCRIPTOR	CRITERIA	SEVERITY
Structural Condition Codes	Minor	Misaligned	1
		Slight Separation	
	Moderate	Light Deterioration	2
		Severe Separation	
	Heavy	Leaking	3
		Medium Deterioration	
		Poor Fitting	
		Roots	
	Severe	Broken	4
		Cracks	
		Heavy Deterioration	
		Material Missing	
		Multiple	
I/I Quantity Codes	Minor	Evidence I/I	1
	Moderate	Light I/I Seen Occurring	2
	Heavy	Medium I/I Seen Occurring	3
	Severe	Heavy I/I Seen Occurring	4

information regarding structural defects or I/I presence may be included in the comments. Photos are taken of the inspection to document conditions.

MSD currently uses the MACP standard. Defect reports are available in IPS and MACP defect codes can be found in **Appendix A**. Common MACP defects, along with their associated severity rating, are given in **Table 3.1**. Manhole conditions were previously assessed using a manhole inspection form and defect codes generated by MSD, available in **Appendix B**, which was created before NASSCO developed its MACP coding standard. MSD manhole inspection codes are identified with associated severity ratings in **Table 3.3**.

3.2.1. Routine Manhole Inspection

From FY08 through FY18, MSD committed to performing a baseline inspection of its gravity mainlines. Manholes were inspected as a part of ICA and SSES projects and where projects were planned under the IRP to address known problems in the system. MSD currently inspects manholes formally and proactively only when a main has been identified for rehabilitation under the IRP. As a part of the mainline inspection, MSD also inspects and refers manholes for repair when defects are noted. A formal inspection is not documented, but repairs are documented through work orders in IPS.

3.2.2. New Asset Inspection

MSD requires inspections of newly constructed manholes as they are brought into the system, as well as inspections of any newly-acquired gravity infrastructure.

3.3. Service Line Inspections

MSD currently inspects service lines proactively only when a main has been identified for rehabilitation under the IRP. The public portion of the lateral is inspected for defects that may interfere with cured-in-place lining and repairs are made as needed prior to rehabilitation. MSD also inspects service lines when an issue has been identified (e.g., backup), and, when appropriate, assigns the lateral for rehabilitation.

3.4. Strengths and Limitations

Asset inspections inherently have strengths and limitations. A brief discussion of the strengths and limitations are included below.

3.4.1. Strengths

- Visual assessment of field conditions
- Ability to see underground assets
- Ability to assess severity with quantifiable severity codes
- Establishing a system-wide condition of assets
- Awareness of asset conditions
- Verifying asset locations
- Ability to map defects
- Standardized data
- Allows regulatory compliance
- Proactive use of resources, facilitates remediation prior to failure

3.4.2. Limitations

- Inspection machinery has certain limitations due to the information collection device
- Length of the cable
- Speed of video collection
- Camera angles, pipe deviation angles or changes in pipe slope inhibiting collection of asset condition
- Abandoned or Incomplete surveys
- Omitted or erroneous defects
- Full assessment can only be conducted with complete surveys
- Flow conditions greater than 50% of pipe limits visual inspection
- Limited pipe visibility due to extensive amounts of roots or obstructions
- Consistency and quality of defect coding
- Variance in defect coding due to human interpretation
- Access to assets or difficulty locating assets, i.e. buried manholes or limited road access
- Weather conditions

Section 4: Assessment

4.1. Data Gathering and Evaluation

Once an inspection has been performed, asset evaluation can begin. The evaluation process includes gathering asset inspection data, evaluation of asset condition, quantifying asset defects, generating initial recommendations for rehabilitation, maintenance and reinspection, and review of initial recommendations for final recommendation.

Data is gathered and prepared to quantify defects and make initial determination of rehabilitation and maintenance projects. A Microsoft Access database joins sewer infrastructure defects, asset information and work order history stored in IPS with geographic details stored in LOJIC. The data is then processed through a series of queries. The queries calculate ratings and indexes for each asset which are used to make recommendations. Recommended activities can vary from scheduled reinspection at a later date to complete replacement.

4.2. Recommendation Development

4.2.1. Pipe Evaluation and Initial Recommendations

Pipe ratings and indexes are calculated using the NASSCO PACP Condition Grading System, available in **Appendix C**. Ratings are the sum of the defect severity scores assigned to each pipe segment, and indexes are the average of the defect severity scores assigned to each pipe segment. Ratings and indexes are calculated for overall defects, structural defects including corrosion, and O&M defects per the NASSCO guidance. MSD has also developed additional ratings and indexes to identify specific defects, such as infiltration and FOG, or to prescribe specific maintenance activities, such as root cutting or point repair.

Initial pipe recommendations are based on indexes and ratings. Recommended activities are described in **Table 4.1**. To aid in the evaluation process, a pipe decision matrix is described in **Figure 4.1**.

4.2.2. Manhole Evaluation and Initial Recommendations

Manhole ratings and indexes are calculated using the NASSCO PACP Condition Grading System, available in **Appendix C**, for MACP inspections or based on MSD's internal grading system for MSD inspections. Ratings are the sum of the defect severity scores assigned to each component of the manhole and are calculated for each component. Indexes are the sum of the structural or infiltration codes for all components of the manhole, and are calculated for the entire manhole structure.

Initial manhole recommendations are based on indexes, ratings, and proximity to the 100-year floodplain. Recommended activities are described in **Table 4.2**. To aid in the evaluation process, a manhole assessment flow chart is described in **Figure 4.2**.

4.2.3. Final Recommendations

After the initial recommendations are generated, the assets that have work order history subsequent to the most recent inspection are reviewed to determine if any of the following work orders addressed the initial problem identified in the inspection. An additional review is conducted of pipes recommended for point repairs to determine if it is feasible and more economical to repair the pipe with CIPP alone. In those cases, the pipe is recommended for CIPP and all lateral connections are added to the recommendation for rehabilitation. Site specific information and sewer knowledge can redirect remediation recommendations. Financial and spatial factors are considered in selecting rehabilitation alternatives.

4.3. Cost Estimate

Cost estimates are calculated based on final recommendations using average costs when available from previous bid data. This data is maintained within the workbook template used to process recommendations and updated as necessary.

Table 4.1. Mainline Maintenance and Rehabilitation Activities

METHOD	DESCRIPTION	BENEFITS	DRAWBACKS
Replace Pipe	Full pipe replacement is recommended on review when there is a high frequency of defects with high severity codes and when rehabilitation is not applicable.	Reduction of I/I New materials New expected life of sewer infrastructure Functional pipe	Potential high construction and restoration costs Maintaining existing sewer flows Construction access Disturb neighborhood/ businesses
Cured-In -Place Pipe	CIPP is to pull a liner through a pipe and then add heat to cure and adhere the liner to the existing pipe thus creating a new pipe inside of the existing pipe.	Reduction of I/I New life expectancy of pipe Minimal surface restoration costs Minimal disturbance of surrounding areas Lateral line connections and joints sealed Provides structural support	Access point to pipe could cause installation issues Results are temperature dependent Slightly reduces the diameter of the pipe Cost increases as size of liner increases
Pipe Point Repair	A point repair includes rehabilitation to a single location to address concerns such as holes, infiltration, and joint concerns. For pipe point repairs, a single point repair is usually less than 8 linear feet of a pipe. Work could include multiple point repairs along one pipe segment and or manhole.	Reduction of I/I Repaired point of defect	Potential difficulty in reaching defect Potential difficulty in making repair Potential high construction and restoration costs Maintaining existing sewer flows Construction access Disturb neighborhood/ businesses
PM Cleaning	Cleaning sewer entails flushing out the line to remove sediment, rocks and other obstructions of flow. Removal of heavy materials such as rocks or debris.	Restores hydraulic capacity to pipe	Inadvertently damage pipe Access Maintaining existing flows Removal and disposal of material

Table 4.1. Mainline Maintenance and Rehabilitation Activities

METHOD	DESCRIPTION	BENEFITS	DRAWBACKS
Heavy Cleaning (includes root cutting)	Heavy cleaning includes large obstacles. Removal of heavy materials such as rocks, roots or debris.	Restores hydraulic capacity to pipe Typically needed for further assessment	Inadvertently damage pipe Potential damage structure Access Maintaining existing flows Removal and disposal of material
Chemical Root Treatment (CHEMR)	Can enter through cracks, joints or other openings. Root obstructions can decrease the hydraulic capacity of the pipe and limits the ability to complete a full inspection. It may also have adverse impacts on structural integrity.	Restores hydraulic capacity to pipe Typically needed for further assessment	Roots grow back Removal and disposal of material
Chemical Grease Treatment (CHEMG)	Used when fats, oils and grease have deposited in a pipe to restore hydraulic capacity.	Restores hydraulic capacity to pipe Typically needed for further assessment	Source not addressed

Figure 4.1. Pipe Assessment Flow Chart

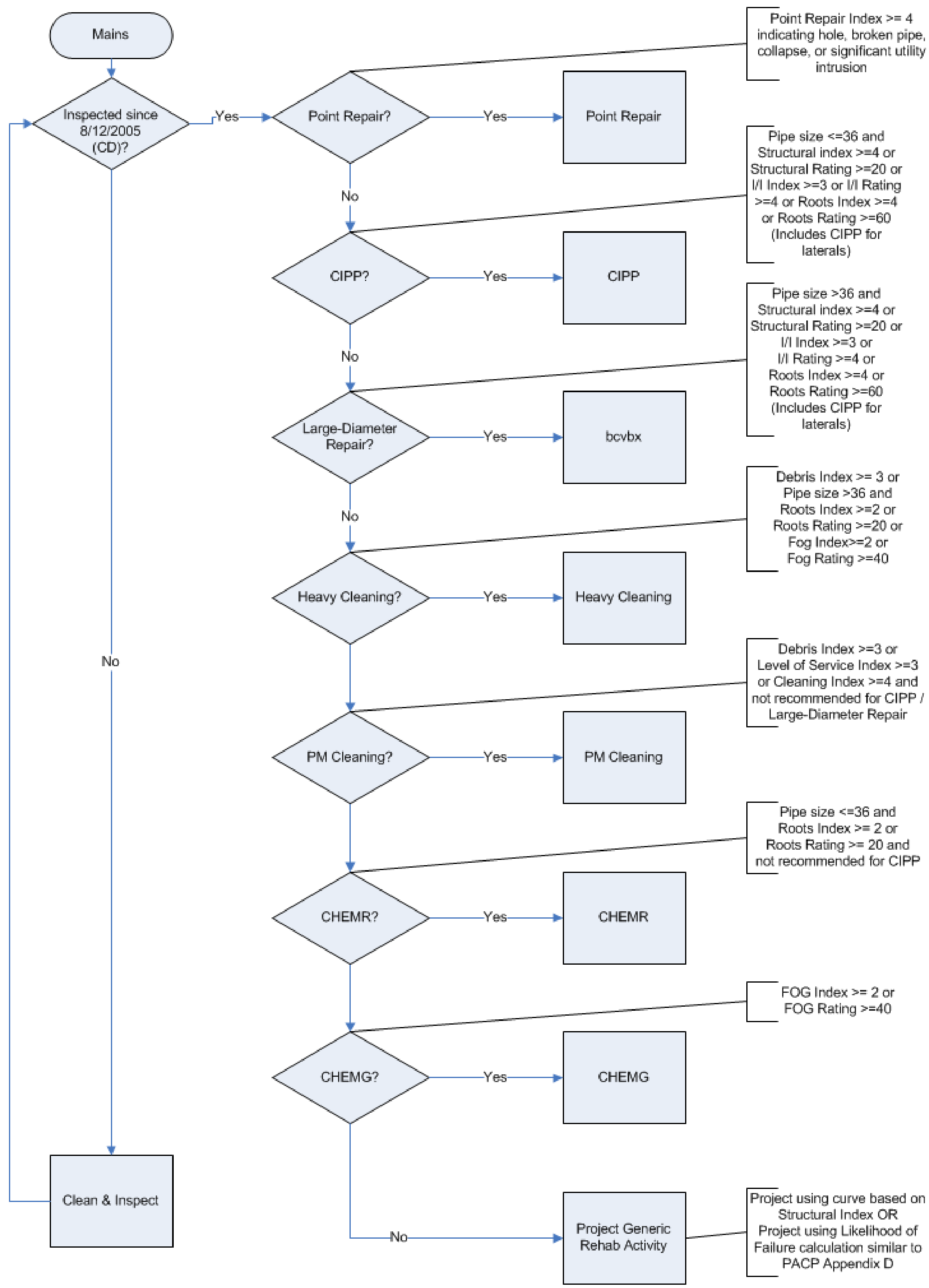
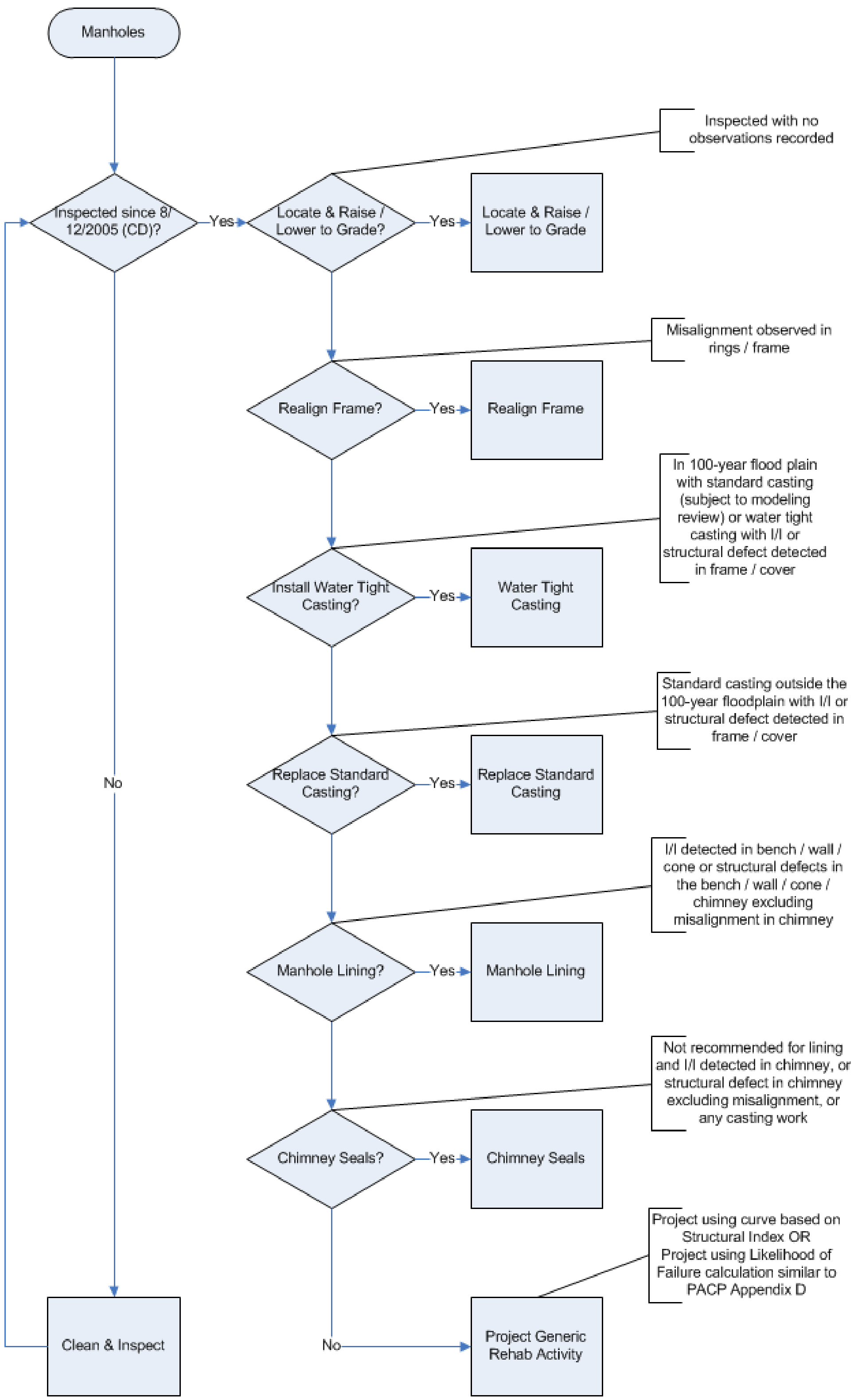


Table 4.2. Manhole Maintenance and Rehabilitation Activities

METHOD	DESCRIPTION	BENEFITS	DRAWBACKS
Realign Manhole Frame	After time, the soils around a manhole or outside forces can cause the manhole frame to become misaligned. When the frame is out of alignment it can be difficult to gain manhole access or determine structural condition of the manhole. Also, I/I can enter through the misaligned frame. The rehabilitation may include a chimney seal.	Structural condition is improved Reduction of I/I Improved access	Access could be a challenge Potential high restoration costs
Install Manhole Chimney Seal	The chimney is the top portion of the manhole. A chimney seal is either a mechanical or chemical seal of all the upper components of the manhole (frame, rings, cone). Chimney seal extensions may also be required.	Reduction of I/I Flexibility restores integrity Simple construction	Access could cause installation issues Maintenance issues
Replace Manhole Frame and Cover	The manhole frame and cover replacement includes new installation and is recommended when there is damage to the existing frame and cover.	Reduction of I/I Restores access to manhole Provides structural support to manhole	Access could be a challenge Potential high restoration costs
Install Manhole Watertight Cover	Water tight covers are recommended for manhole locations which may be inundated, such as floodplains, drainage channels, etc.	Reduction of I/I	Access could cause installation issues Maintenance issues Potential high restoration costs
Line Manhole	Lining a manhole includes applying a coating. Lining a manhole is recommended when there is a presence of I/I.	Reduction of I/I Life expectancy of manhole extended Provides structural support to manhole	Access to manhole Temperature dependent
Replace Manhole	Structural conditions beyond rehabilitation or point repair	Reduction of I/I Life of manhole extended	Costly alternative Potential high construction and restoration costs Maintaining existing sewer flows Construction access Disturb neighborhood/ businesses

Figure 4.2. Manhole Assessment Flow Chart



4.4. System Capacity Assurance Plan Credits

The estimated System Capacity Assurance Plan (SCAP) credits for a repair are calculated with the recommendation tool using the same logic as documented in the SCAP manual. As the work is not yet completed, the credits are calculated based on asset dimensions, location and the recommended activity.

4.5. Prioritization and Risk Management

MSD has developed a risk register for gravity sewer mains based on the likelihood of failure (LOF) and the consequence of failure (COF) at the segment level, similar to the process described in NASSCO's PACP-Based Risk Management, available in **Appendix D**. NASSCO describes risk as the product of likelihood and consequence of failure, as quantified in the following equation:

Risk = Likelihood of Failure (LOF) × Consequence of Failure (COF)

4.5.1. Likelihood of Failure

LOF is the first half of the risk equation. NASSCO recommends the use of the PACP Quick Rating to develop a calculated LOF for sewer mains; however, MSD recognizes that failure may be caused by structural or maintenance defects in an asset, that failure due to a structural issue may be on a different timeline than failure due to a maintenance issue, and that the solutions for each type of issue may be unique. As such, MSD has elected to evaluate LOF separately for structural and O&M issues based on solution – infrastructure rehabilitation, hydraulic cleaning, and root control.

For sewer mains, MSD utilizes the sewer main indexes, calculated as described in **Appendix C**, to determine the current likelihood of failure for sewer mains. For structural failure, MSD uses the structural index. MSD also uses the O&M index to determine the current likelihood of maintenance failure for sewer mains.

Similarly for sewer manholes, MSD uses the sewer manhole indexes, calculated as described in **Appendix C**, to determine the current likelihood of failure for sewer manholes.

MSD previously presented a methodology in the technical memo, provided in **Appendix E**, to predict likelihood of failure based on current knowledge of the system. Based on this approach, MSD additionally utilizes matrices developed by the National Research Council (NRC) of Canada of Markovian transition probabilities by pipe type and age to interpolate the predicted likelihood of failure (PLOF) ten years after the current inspection for each pipe segment. This analysis assists MSD in identifying prioritizing pipe segments for infrastructure rehabilitation that are not yet in failure mode.

LOF and structural PLOF are measured on a scale of 1 to 5.

4.5.2. Consequence of Failure

COF is the second half of the risk equation. COF may be developed in a number of ways, utilizing a number of variables that are important to a specific agency. MSD has developed a COF index that is based on the work of the Wet Weather Team, available in **Appendix F**.

The team's stakeholder consensus values were initially scaled and weighted against a series of qualitative and quantitative descriptors that describe the severity of the impact of an event on the value in question. For instance, one of the Public Health Enhancement descriptors indicated that the Wet Weather Team found minimal potential for surface cave-in due to failure was described as a negligible COF, while a surface cave-in in the right of way was described as a severe COF.

MSD reviewed the quantitative and qualitative descriptors, compared with potential sources of quantitative data, and developed a quantitative COF model based on depth, diameter, condition knowledge, potential for cave-ins, land use, and wastewater characteristics based on upstream pretreatment requirements as COF indicators. The score for each indicator is weighted and the COF is measured on a scale of one through five.

Table 4.3. Risk Register

SCHEDULE PERIOD (YEARS)		CONSEQUENCE OF FAILURE (COF)				
		1	2	3	4	5
LIKELIHOOD OF FAILURE (LOF)	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

4.5.3. Risk Register

As previously stated, MSD calculates the risk of failure as

$$\text{Risk} = \text{Likelihood of Failure (LOF)} \times \text{Consequence of Failure (COF)}$$

The product of the five-point scales can range from one through 25, and the resulting risk score for each pipe segment can be plotted as shown in **Table 4.3**

MSD has utilized this matrix to schedule the target inspection frequency as discussed in **Section 3** and to develop a target schedule for structural rehabilitation under the IRP and target routine inspection, hydraulic cleaning, and mechanical cleaning frequency under the GLPM, as discussed in detail in **Section 5**.

4.6. Strengths and Limitations

Performing asset evaluations inherently has strengths and limitations. A brief discussion of the strengths and limitations are included below.

4.6.1. Strengths

- Identifies asset rehabilitation needs in a consistent manner
- Holistic approach to evaluation of assets
- Defines remediation priorities
- Recommends activities according to guidelines
- Spatial understanding of infrastructure rehabilitation priorities
- Multi-faceted evaluation of available LOJIC data, video, condition assessments and maintenance records

4.6.2. Limitations

- Incomplete data (for example assets not located, surveys abandoned, etc.)
- Evaluate only available data
- Lateral lines are not included
- Cannot quantify all risk factors (site accessibility, other field/construction constraints, private sewer customer impacts, etc.)
- Utility locations unknown for construction/contracting

Section 5: Implementation

After the evaluation phase, the recommended rehabilitation and maintenance activities are implemented.

5.1. Emergency Evaluation and Escalation Program

The purpose of the Emergency Evaluation and Escalation Program (EEEP) is to prevent major structural failures and maintain public safety by repairing gravity sanitary collections system assets that are near failure mode.

Evaluation for emergency action is required in the event that an inspection indicates that an asset is in imminent danger of structural failure as reported by a trained inspector performing an inspection, and represents an immediate threat to public health and safety. In the event that a failing asset is identified, MSD Operations inspection staff are required to notify their supervisor and inspection contractors are required to notify MSD Engineering staff. Operations Management and Engineering staff evaluate the situation to determine the appropriate course of action and timeframe to address the problem identified.

Depending on the scope and timeframe of the necessary solution, the project is escalated to an emergency repair project completed by Operations staff, escalated to an emergency project managed by Engineering staff and completed by a contractor, prioritized as a near-term planned project through the Capital Improvement Program (CIP), or referred to the IRP as a project of the highest priority.

5.2. Infrastructure Rehabilitation Program

The purpose of the IRP is to mitigate overflows and other public safety concerns by rehabilitating gravity sanitary collections system assets to support consent decree projects, right-size proposed new infrastructure and reduce risk.

The IRP includes rehabilitation of sewer mains and laterals through lining, generally using cured-in-place pipe for laterals and sewer mains under 36 inches, and other lining methods for larger pipe. Point repairs are performed when they are more economical than non-intrusive methods or when lining is not possible or secondary to the repair.

The IRP also includes epoxy lining for manhole rehabilitation, and casting adjustments and replacements as needed to ensure safe and reliable access to the system.

The IRP includes pipe and manhole replacement as a last resort when other low-impact repair methods are not possible.

5.2.1. Priority

MSD responds to immediate needs identified through the EEEP and referred to the IRP as the highest priority.

MSD is currently under consent decree to abate combined and sanitary sewer overflows, and utilizes IRP projects as a supplement to projects mandated by the 2ACD to reduce infiltration and achieve post-construction compliance with 2ACD requirements. Projects to support 2ACD objectives are given the next highest priority.

MSD also utilizes the IRP to address structural and infiltration issues to right-size capacity additions and upgrades when flow monitoring and modeling indicates rehabilitation may positively impact the project. Projects that support hydraulic capacity of new and existing infrastructure are given the next highest priority.

MSD Engineering and Operations staff and contractors refer assets to Engineering for inclusion in the IRP program when a planned or reactive inspection indicates an issue exists in the asset that could be addressed by rehabilitation. Additionally, when an inspection is attempted on a sewer main that cannot be completed because the manhole is buried or unlocatable, it is referred to the IRP to provide access. Referred projects are given the next highest priority.

Table 5.1. Target Schedule - Infrastructure Rehabilitation

SCHEDULE PERIOD (YEARS)		CONSEQUENCE OF FAILURE (COF)				
		1	2	3	4	5
LIKELIHOOD OF FAILURE (LOF)	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Table 5.2. Target Schedule - Routine Hydraulic Cleaning

SCHEDULE PERIOD (YEARS)		CONSEQUENCE OF FAILURE (COF)				
		1	2	3	4	5
LIKELIHOOD OF FAILURE (LOF)	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Finally, MSD schedules assets for the IRP based on the risk register developed from ongoing inspections, as shown in Table 5.1, with the most vulnerable infrastructure targeted for rehabilitation as soon as possible, and a longer rehabilitation schedule for less vulnerable susceptible assets. Development of the risk register was addressed in Section 4. The schedule is updated at least annually as new inspections are performed.

5.3. Gravity Line Preventive Maintenance Program

The purpose of the Gravity Line Preventive Maintenance Program (GLPM) is to mitigate overflows and other public safety concerns by performing preventive maintenance activities related to gravity sanitary collections system assets.

MSD utilizes routine hydraulic cleaning (flushing), routine mechanical cleaning (primarily root cutting), chemical root treatment, and chemical grease treatment to reduce the probability of overflows occurring due to maintenance issues in the gravity collection system and manages these activities through GLPM.

5.3.1. Routine Hydraulic Cleaning

Routine hydraulic cleaning, or sewer flushing, is utilized to prevent overflows due to debris accumulation in the sewer main. MSD initially included assets in the routine hydraulic cleaning program based on institutional knowledge and referral from inspectors and other Operations staff for problems like sewers with flat slopes.

PACP guidelines include cleaning sewer mains prior to inspection where practical, therefore, most sewer mains will be cleaned on inspection per the target frequency as discussed in Section 3. Other mains require more frequent cleaning to maintain level of service. After the baseline condition data were collected through FY18, the system was assessed and sewers that had not been targeted for the IRP, but had observations of significant debris, history of repeated discharges on associated manholes or laterals, or history of repeated cleaning requests, were added to the program in FY19. The target cleaning schedule is included in Table 5.2, developed through the risk register as discussed in Section 4. The schedule is updated at least annually as new inspections are performed, and staff may refer sewer mains to the program as needed based on observation.

Table 5.3. Target Schedule - Chemical Grease Control

SCHEDULE PERIOD (YEARS)		CONSEQUENCE OF FAILURE (COF)				
		1	2	3	4	5
LIKELIHOOD OF FAILURE (LOF)	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

5.3.2. Chemical Root Control

MSD initially included assets in the chemical root control (CHEMR) program based on institutional knowledge and referral from inspectors and other Operations staff. Assets are now included based on recommendations derived from inspection data. CHEMR is most effective on sewers less than 36” in diameter with observations of fine roots.

The target treatment schedule is on a three-year cycle to coincide with the warranty period for chemical root control products. The schedule is updated at least annually as new inspections are performed, and staff may refer sewer mains to the program as needed based on observation.

5.3.3. Chemical Grease Control

MSD included assets in areas with recurring grease-related issues in a FOG quality control inspection activity called PMTV. These assets were jointly inspected on a routine basis by LASA staff, tasked with physically performing the CCTV inspection, and Industrial Waste staff, tasked with identifying point sources of FOG in the system to address through Industrial Waste processes. The PMTV program has been discontinued; however, LASA staff continue to refer grease issues to Industrial Waste for further investigation to identify sources.

MSD concurrently investigated and piloted the use of chemical grease control (CHEMG) treatment applied through hydraulic cleaning to dissolve FOG in the main and prevent buildup which could lead to a discharge. Initially CHEMG was applied in pilot areas to test efficacy; it was subsequently included in areas where Operations was assigned a second-attempt inspection area to capture baseline condition.

After the baseline condition data were collected through FY18, the system was assessed and sewers under 36” in diameter with observations of significant grease were added to the program in FY19. The target cleaning schedule is included in **Table 5.3**, developed through the risk register as discussed in **Section 4**. The schedule is updated at least annually as new inspections are performed, and staff may refer sewer mains to the program as needed based on observation.

5.3.4. Routine Mechanical Cleaning

Routine mechanical cleaning may consist of root cutting or debris removal by a mechanized means, and can be utilized to prevent overflows due to roots and heavy debris accumulation in the sewer main. MSD initially included assets in a routine mechanical cleaning program for root cutting based on institutional knowledge and referral from inspectors and other Operations staff for problems like repeated discharges due to roots in the main. This activity was discontinued in 2009 due to the concern that repeated mechanical cleaning may cause more structural damage to a sewer main than other procedures. The activity was replaced by chemical root control to control fine roots, infrastructure rehabilitation to address more serious issues caused by roots, and routine hydraulic cleaning to address debris accumulation.

5.4. Implementation Capabilities and Responsibilities

MSD staff has the capability of performing some maintenance and rehabilitation projects to maintain operations of sewer infrastructure. The scope and limitations of the Operations Division are linked to the scale of the rehabilitation project and deadline for construction completion. Guidelines to Operations Division work capabilities are outlined below. All other repairs are bid and managed by the Engineering Division.

Operations Division Rehabilitation & Maintenance Capabilities

- Install pipe up to 13 feet in depth
- Replace pipe or point repair up to 20 LF
- Install CIPP with diameters up to 6 inches (public laterals)
- Install CIPP point repair up to 15 inches in diameter, up to 6 LF
- Make repairs in areas having relatively easy access to rehabilitation site, within right of way or in close proximity to roadway access
- Repair manholes, chimney rings and repairs above the cone of manhole
- Install watertight lids
- Perform medium cleaning activities (Grease Removal, Flush/Vactor Lines, Root Cutting)
- Perform CCTV inspections of gravity mains accessible by crawler

Maintenance work orders are produced per the recommendations of the evaluation. Ongoing sewer cleaning and maintenance activities are assigned to Operations and contracted as workloads require. If maintenance, rehabilitation or repair activities are outside of the capabilities of Operations, they are packaged for bid. If a rehabilitation project is planned for bid, maintenance activities are included in the bid package for the study area.

Project work is tracked by work orders in IPS reflecting maintenance and rehabilitation work completed.

Section 6: Reporting

6.1. Regulatory Reporting

Each year, activities performed under the GLPM are reported in the appropriate section of MSD's 2ACD Annual Report. Annual reports are due by the September 30 following the end of the fiscal year.

The Annual Reports are sent electronically to the following recipients:

EPA – Dennis Sayre sayre.dennis@epa.gov

Kentucky Division of Water – Bryan Parker bryan.parker@ky.gov

Department of Justice – eescdcopy.enrd@usdoj.gov

6.2. System Capacity Assurance Plan Credit Calculation and Reporting

MSD's SCAP provides direction for calculating and reporting SCAP credits for activities performed under the IRP.

6.3. Asset Updates

At least annually, a report is generated to identify assets that have been renewed through the IRP and update the appropriate fields in IPS and GIS to reflect the update. A workflow has been established for resolving sanitary errata to have related assets and inspections updated.

6.4. Data Retention and Trending

MSD tracks the information related to maintenance and rehabilitation of assets in IPS in the form of work orders. Information is tracked on individual assets such as manholes, sewer mains, and sewer service lines. The type of information tracked includes but is not limited to the maintenance activity performed, and the quantity of the asset maintained or renewed, if applicable. MSD utilizes this information to conduct a periodic review of system-wide maintenance activities compared with overflows to document trends in overflow reduction as part of the CMOM program. The information from the discharge program is used to update the protocol on an as-needed basis.

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Section 7: Updates, Availability and Training

7.1. Review and Updates to the Protocol

The protocol will be reviewed periodically, not less than every three (3) years. When changes are made, MSD will update the procedures, work instructions and training as necessary.

7.1.1. Responsibility

The Regulatory Compliance and Asset Management (RCAM) Manager in the Engineering Division is responsible for leading and scheduling a periodic review of the protocol with applicable personnel. The review team should include but is not limited the staff listed in **Table 7.1**

7.1.2. Scope

Proposed modifications to the CSSA and associated procedures are coordinated, reviewed, approved and distributed by the Regulatory Compliance and Asset Management Manager or designated staff. This review is inclusive of the required personnel necessary for a full evaluation of the documents regarding changes in procedure, efficiency, technology improvements and regulatory changes.

7.2. Distribution and Availability of Protocol

The original document is stored on the network at **M:\Engineering\GISLOG\10 - CD Asset Management\InDesign Documents**.

When changes are made to the protocol, a new master copy of the document is scanned into MSD's eB system and made available to MSD personnel. Historical documents are archived and only the most current version will remain available to MSD personnel.

7.3. Training

7.3.1. NASSCO PACP, MACP and LACP Training

MSD requires staff performing inspections, performing assessments, performing construction inspections under the IRP, or documenting or reporting work performed to be trained and certified in PACP, and recommends them to be certified in MACP and LACP. NASSCO provides certified trainers for initial certification. NASSCO requires recertification every 3 years, which may be completed in person or online. NASSCO maintains an online database of certified individuals, available on the webpage **NASSCO Certified Professionals Directory**.

7.3.2. NASSCO Inspector Training Certification Program

MSD encourages staff performing assessments or performing construction inspections under the IRP to be trained and certified through NASSCO's Inspector Training Certification Program (ITCP). NASSCO provides certified trainers for certification. NASSCO requires recertification every 10 years. NASSCO maintains an online database of certified individuals, available on the webpage **NASSCO Certified Professionals Directory**.

Table 7.1. Responsible Staff

DIVISION	DEPARTMENT	TITLE
Engineering	Regulatory Compliance & GIS	Regulatory Compliance & Asset Management Manager
Engineering	Technical Services	Engineering Manager - Collections System & Construction
Operations	Linear Assets Support	Linear Assets Support Manager
Operations	Sanitary	Wastewater Manager

7.3.3. Asset Management Training

MSD encourages staff performing assessments to be trained and certified in asset management. The Trenchless Technology Center at Louisiana Tech hosts the Certification of Training in Asset Management (CTAM), and certifies graduates as Associate in Water Asset Management (AWAM) or Professional in Water Asset Management (PWAM), depending on their years of experience with asset management. Both certifications require continuing education to be documented annually. More information about the program may be found on the **CTAM web page**

7.3.4. Procedure Training

Staff executing the procedures to implement the protocol receive on-the-job training. When the protocol or the associated procedures or work instructions are updated, staff receive updated training.

7.3.5. Equipment Training

All staff involved in performing field work under the protocol receive training in accordance with their job classification and job function along with equipment manufacturer and MSD operational and safety requirements.

Appendix A NASSCO PACP Standard

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Appendix B - Color Coded Chart

NASSCO'S PIPELINE ASSESSMENT CERTIFICATION PROGRAM® (PACP®)

Section 4 — Structural Defect Coding

C CRACK 4-3
CL Longitudinal
CC Circumferential
CM Multiple
CS Spiral
CH Hinge (2, 3, 4)

F FRACTURE 4-9
FL Longitudinal
FC Circumferential
FM Multiple
FS Spiral
FH Hinge (2, 3, 4)

B BROKEN 4-17
BSV Soil Visible
BVV Void Visible

H HOLE 4-21
HSV Soil Visible
HVV Void Visible

D DEFORMED (Rigid) 4-26
DR Deformed Rigid
No modifiers used.

D DEFORMED (Flexible) 4-26
DFBR Bulging Round
DFBI Bulging Inv.Curv
DFC Creasing
DFE Elliptical

D DEFORMED (Brick) 4-26
DTBR Bulging Round
DTBI Bulging Inv Curv

X COLLAPSE 4-37
X Collapse
No descriptors and no modifiers used.

J JOINT 4-45
JOS Offset Small
JOM Offset Medium
JOL Offset Large

J JOINT 4-45
JOSD Offset Small Defect
JOMD Offset Medium Defect
JOLD Offset Large Defect

J JOINT 4-45
JSS Separation Small
JSM Separation Med.
JSL Separation Large

J JOINT 4-45
JAS Angular Small
JAM Angular Medium
JAL Angular Large

S SURFACE DAMAGE 4-51
SRI Roughness Increased
SAV Aggregate Visible
SAP Aggregate Projecting
SAM Aggregate Missing

S SURFACE DAMAGE 4-52
SRV Reinforcement Visible
SRP Reinforcemt Projecting
SRC Reinforcemt Corroded
SMW Missing Wall

S SURFACE DAMAGE 4-52
SSS Surface Spalling
SSC Surface Spalling Coating
SCP Chemical Attack
SZ Other

LF LINING FEATURES 4-67
LFAC Abdn'd Connection
LFAS Annular Space
LFB Blistered Lining
LFCS Service Cut Shifted

LF LINING FEATURES 4-67
LFD Detached
LFDC Discoloration
LFDE Defective End
LFDL Delamination

LF LINING FEATURES 4-67
LFOC Overcut Service
LFRS Resin Slug
LFUC Undercut Service
LFW Wrinkled
LFZ Other

WF WELD FAILURE 4-85
WFC Circumferential
WFL Longitudinal
WFM Multiple
WFS Spiral
WFZ Other

RP POINT REPAIR 4-89
RPL Liner
RPLD Liner Defective
RPP Patch
RPPD Patch Defective

RP POINT REPAIR 4-89
RPR Replacement
RPRD Replmt. Defective
RPZ Other
RPZD Other Defective

BRICKWORK 4-97
DB Displaced
MB Missing
DI Dropped Invert

BRICKWORK 4-97
MMS Mortar Missing Small
MMM Mortar Missing Med
MML Mortar Missing Large

Appendix B - Color Coded Chart

NASCO'S PIPELINE ASSESSMENT CERTIFICATION PROGRAM® (PACP)®

Section 5 — Operation and Maintenance

D DEPOSITS (Attached) 5-3
- DAE Encrustation
- DAGS Grease
- DAR Ragging
- DAZ Other

D DEPOSITS (Settled) 5-4
- DSF Fine
- DSGV Gravel
- DSC Hard/Compact
- DSZ Other

D DEPOSITS (Ingress) 5-4
- DNF Fine (silt/sand)
- DNGV Gravel
- DNZ Other

R ROOT (Fine) 5-11
- RFB Barrel
- RFL Lateral
- RFC Connection
- RFJ Joint

R ROOTS (Medium) 5-12
- RMB Barrel
- RML Lateral
- RMC Connection
- RMJ Joint

R ROOTS (Ball) 5-12
- RBB Barrel
- RBL Lateral
- RBC Connection
- RBJ Joint

R ROOTS (Tap) 5-12
- RTB Barrel
- RTL Lateral
- RTC Connection
- RTJ Joint

I INFILTRATION 5-20
- IS Stain
- ISB Barrel
- ISC Connection
- ISJ Joint
- ISL Lateral

I INFILTRATION 5-20
- IW Weeper
- IWB Barrel
- IWC Connection
- IWJ Joint
- IWL Lateral

I INFILTRATION 5-20
- ID Dripper
- IDB Barrel
- IDC Connection
- IDJ Joint
- IDL Lateral

I INFILTRATION 5-21
- IR Runner
- IRB Barrel
- IRC Connection
- IRJ Joint
- IRL Lateral

I INFILTRATION 5-21
- IG Gusher
- IGB Barrel
- IGC Connection
- IGJ Joint
- IGL Lateral

OB OBSTACLES OBSTRUCTIONS 5-31
- OBB Brick or Masonry
- OBC Object Through Connection
- OBI Object Intruding Through Wall

OB OBSTACLES OBSTRUCTIONS 5-31
- OBJ Object in Joint
- OBM Pipe Material in Invert
- OBN Construction Debris
- OBP External Pipe Cable

OB OBSTACLES OBSTRUCTIONS 5-32
- OBR Rocks
- OBS Built in Structure
- OBZ Other

V VERMIN 5-45
- VR Rat
- VC Cockroach
- VZ Other

G GROUT TEST & SEAL 5-50
- GTP Grout Test Passed
- GTPJ Joint
- GTPL Lateral
- GTF Grout Test Failed
- GTFJ Joint
- GTFL Lateral

G GROUT TEST & SEAL 5-50
- GTU Grout Test Unable
- GTUJ Joint
- GTUL Lateral
- GRT Grout Test Location

Section 6 — Construction Features

T TAP 6-3
- TB Break-In/Hammer
- TBI Intruding
- TBD Defective
- TBC Capped
- TBA Activity
- TBB Abandoned

T TAP 6-3
- TF Factory Made
- TFI Intruding
- TFD Defective
- TFC Capped
- TFA Activity
- TFB Abandoned

T TAP 6-4
- TR Rehabilitated
- TRI Intruding
- TRD Defective
- TRC Capped
- TRA Activity
- TRB Abandoned

T TAP 6-4
- TS Saddle
- TSI Intruding
- TSD Defective
- TSC Capped
- TSA Activity
- TSB Abandoned

IS INTRUDING SEALING MATERIAL 6-15
- ISSR Sealing Ring
- ISSRB Broken
- ISSRH Hanging
- ISSRL Loose
- ISGT Grout
- ISZ Other

L LINE (of sewer) 6-21
- LD Down
- LL Left
- LLD Left Down
- LLU Left Up

L LINE (of sewer) 6-21
- LR Right
- LRD Right Down
- LRU Right Up
- LU Up

A ACCESS POINT 6-25
- ACB Catch Basin
- ACO Cleanout
- ACOM Mainline
- ACOP Property
- ACOH House

A ACCESS POINT 6-25
- ADP Discharge Point
- AEP End of Pipe
- AJB Junction Box
- AM Meter
- AMH Manhole

A ACCESS POINT 6-26
- AOC Other Structure
- ATC Tee Connection
- AWA Wastewater Access
- AWW Wetwell
- AZ Other

Section 7 — Miscellaneous Features

M MISCELLANEOUS FEATURES 7-1
- MCU Camera Underwater
- MGO General Observation
- MGP General Photograph
- MJL Joint Length

M MISCELLANEOUS FEATURES 7-2
- MLC Lining Change
- MMC Material Change
- MSC Shape/Size Change
- MSA Survey Abandoned
- MWL Water Level

M MISCELLANEOUS FEATURES 7-3
- MWLS Water Level Sag
- MWM Water Mark
- MY Dye Test
- MYV Dye Visible
- MYN Not Visible

Pipeline Assessment Certification Program
V on 7.0.0 May 2015

B-2

Appendix B - Color Coded Chart

NASSCO'S PIPELINE ASSESSMENT CERTIFICATION PROGRAM® (PACP)®

Section 2 — Header Form Fields

14 Weather 2-5
- 1 = Dry
- 2 = Heavy Rain
- 3 = Light Rain
- 4 = Snow
- 5 = Dry Weather/Wet Ground

15 Pre-Cleaning 2-5
- H = Heavy Cleaning
- L = Light Cleaning (Jetting)
- N = No Pre-Cleaning
- X = Not Known
- Z = Other

17 Flow Control 2-6
- B = Bypassed
- D = Dewatered Using Jetter
- L = Lift Station
- N = Not Controlled
- P = Plugged

18 Purpose 2-7
- A = Maintenance
- B = Infiltration/Inflow Invest
- C = Post-Rehabilitation
- D = Pre-Rehabilitation
- E = Pre-Acceptance
- F = Routine Assessment

18 Purpose 2-7
- G = Capital Improvement Program Assessment
- H = Resurvey
- I = SSES
- R = Pre-Existing Video
- X = Not Known

19 Direction 2-7
- D = Downstream
- U = Upstream

28 Location Code 2-11
- A = Primary Major Arterial Road
- B = Secondary Road
- C = Local/Rural Street
- D = Easement/Right-of-Way
- E = Woods

28 Location Code 2-11
- F = Sidewalk
- G = Parking Lot
- H = Alley
- I = Ditch
- J = Building
- K = Creek (or any waterway)

28 Location Code 2-11
- L = Railway
- M = Airport
- N = Levee/Floodwall
- O = Dam
- P = Levee Pump Station
- Y = Yard
- Z = Other

30 Pipe Use 2-12
- CB = Combined Pipe
- DP = Dam Pipe
- FM = Force Main
- LG = Levee Gravity Pipe
- LP = Levee Pressure Pipe

30 Pipe Use 2-12
- PR = Process Pipe
- SS = Sanitary Sewage Pipe
- SW = Stormwater Pipe
- XX = Not Known
- ZZ = Other

33 Shape 2-13 E-1
- A = Arched
- B = Barrel
- C = Circular
- E = Egg-Shaped
- H = Horseshoe
- O = Oval (elliptical)

33 Shape 2-13 E-1
- R = Rectangular
- S = Square
- T = Trapezoidal
- U = U-Shaped with Flat Top
- Z = Other

34 Material 2-14 E-4
- ABS = Acrylonitrile Butadiene Styrene
- AC = Asbestos Cement
- BR = Brick
- CAS = Cast Iron
- CLC = Clay-Lined Concrete
- CMP = Corrugated Metal Pipe

34 Material 2-14 E-4
- CP = Concrete Pipe
- CSB = Conc. Segments Bolted
- CSU = Conc. Segments Unbolted
- CT = Clay Tile
- DIP = Ductile Iron Pipe

34 Material 2-14 E-4
- FRP = Fiberglass Reinforced Pipe
- OB = Orangeburg/Pitch Fiber
- PCCP = Pre-Stressed Concrete Cylinder Pipe
- PCP = Polymer Concrete Pipe
- PE = Polyethylene

34 Material 2-14 E-4
- PP = Polypropylene
- PSC = Plastic/Steel Composite
- PVC = Polyvinyl Chloride
- RCP = Reinf. Concrete Pipe
- RMP = Reinf. Plastic Pipe
- SB = Segmented Block

34 Material 2-14 E-4
- SP = Steel Pipe
- VCP = Vitrified Clay Pipe
- WD = Wood
- XXX = Not Known
- ZZZ = Other

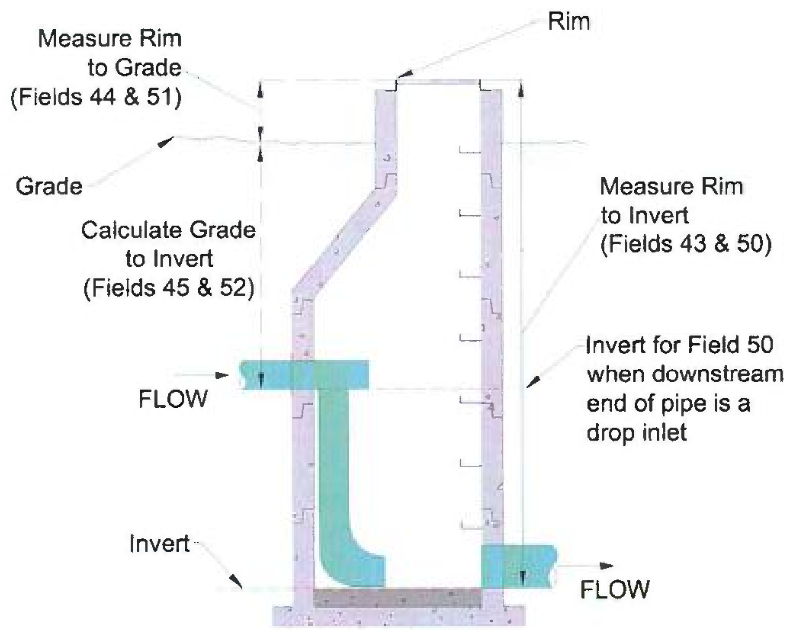
35 Lining Method 2-15 E-17
- CIP = Cured-In-Place Pipe
- FF = Fold and Form
- FP = Formed-In-Place Liner
- GP = Grout-In-Place Liner
- GRC = Glass Reinf. Cement
- N = None
- SC = Continuous Slip Liner

35 Lining Method 2-15 E-17
- SE = Sectional Slip Liner
- SL = Spray Liner
- SN = Segmented Panel
- SP = Segmented Pipe
- SW = Spiral Wound
- XX = Not Known
- ZZ = Other

36 Coating Method 2-16 E-23
- CT = Coal Tar
- CM = Cement Mortar
- EP = Epoxy
- PE = Polyethylene

36 Coating Method 2-16 E-23
- PO = Polyurethane
- PU = Polyurea
- PVC = Polyvinyl Chloride
- XX = Not Known
- ZZ = Other

Appendix B - Color Coded Chart



APPENDIX B MSD MANHOLE INSPECTION FORM AND CODES

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MSD
Metropolitan Sewer District

Manhole Inspection Form

Manhole ID:		Location:	
Installed:	Record #:		
Map #:	Coordinates:	X:	Y:

Asset Information ***Please Field Verify***

Manhole Type					
Surface Cover					
Depth of Manhole					
Cover Diameter					
Barrel Diameter					
Metered?					
Drop Manhole?					

Manhole Inspection Data

Started Date	
Completed Date	
Completed By	
Project ID	
Crew Leader	
Weather	Wet Dry
Flow Depth	
Ability to Quantify	
Ponding? Y / N	Problem? Y / N
Surcharge Evidence?	Y / N Depth:
Debris/Silt Buildup?	Y / N Depth:

	Condition	Test	Size	I&I Quantity
Cover				
Frame				
Rings				
Cone				
Wall				
Bench				
Channel				
Base				
Steps				

In/Out Mains

Pipe	From ID	To ID	In/Out	Length	Diameter	Pipe Type	Condition
1)							
2)							
3)							
4)							
5)							

Comments

Page 1 of 1

Asset Codes

Manhole Type

CODE	DESCRIPT
B	BURIED MANHOLE
BD	BRICK DAM
CB	CATCH BASIN
CDS	CDS UNIT
COP	CLEANOUT PIT
CSO	COMBINED SEWER OVERFLOW
DG	DIVERSION GATE
DMH	DROP MANHOLE
FLM	FLOW MONITOR
HT	HOLDING TANK
JB	JUNCTION BOX
OUT	CSO OUTFALL
PIM	POINT OF INTERSECTION MANHOLE
R	REGULATOR
SI	SIPHON INLET
SIB	SIPHON BREAKER
SRG	SURGE TANK
VV	VALVE VAULT
WER	WEIR MANHOLE
WW	WET WELL

Surface Cover

CODE	DESCRIPT
A	ASPHALT
AB	ASPHALT & CONCRETE STREET
AQ	ASPHALT STREET & GRASS SURFACE
B	BRICK
C	CONCRETE
CR	SHELL STREET & GRAVEL SURFACE
D	SIDEWALK
E	TREES/SHRUBS
F	CLOSE TO FENCE
G	GRASS
H	SHELL
I	UNMOVABLE BUILDING
J	OVERHEAD UTILITIES
K	RAILROAD
L	HIGHWAY
M	PIPE ABOVE GROUND
O	OTHER -- SEE COMMENT
P	GROWN UP AREA
R	GRAVEL
T	LANDSCAPED AREA
U	UNDER PHYSICAL OBJECT
X	PAVED STREET WITH CRACKS

Cover Type

CODE	DESCRIPT
1	LOCK DOWN W/ HEX KEY
2	TWO HOLE
4	FOUR HOLE
A	MULTI-HOLE
B	BOLTED
C	CONCRETE
D	SIDE SLOTS-SOLID
E	CONCEALED PICKHOLES
F	OTHER
I	SURFACE DRAINAGE
J	PLATEN
K	OVERSIZED PICK HOLES
N	WATER TIGHT SEAL
O	OTHER -- SEE COMMENTS
P	PLASTIC W/ CONCRETE FILL
S	SOLID
V	VENTED

Frame Type

CODE	DESCRIPT
1	CAST IRON
2	CAST IRON W/ INTERNAL SEAL
3	CONCRETE
4	CONCRETE W/ INTERNAL SEAL
5	OTHER -- SEE COMMENTS
6	CONCRETE W/ EXTERNAL SEAL
7	PLASTIC

Material

CODE	DESCRIPT
B	BURIED MANHOLE
BD	BRICK DAM
CB	CATCH BASIN
CDS	CDS UNIT
COP	CLEANOUT PIT
CSO	COMBINED SEWER OVERFLOW
DG	DIVERSION GATE
DMH	DROP MANHOLE
FLM	FLOW MONITOR
HT	HOLDING TANK
JB	JUNCTION BOX
OUT	CSO OUTFALL
PIM	POINT OF INTERSECTION MANHOLE
R	REGULATOR
SI	SIPHON INLET
SIB	SIPHON BREAKER
SRG	SURGE TANK
VV	VALVE VAULT
WER	WEIR MANHOLE
WW	WET WELL

Inspection Data Codes

Ability to Quantify

CODE	DESCRIPTION
A	VERY DIFFICULT
B	POOR
C	GOOD
D	EXCELLENT

Condition

CODE	DESCRIPTION
A	SATISFACTORY
C	CRACKS
E	MEDIUM DETERIORATION
G	SEVERE SEPARATION
H	BROKEN
I	MISALIGNED
J	LIGHT DETERIORATION
K	HEAVY DETERIORATION
L	LEAKNG
M	MATERIAL MISSING
N	NO PROBLEM
P	POOR FITTING
R	ROOTS
S	SLIGHT SEPARATION
Z	MULTIPLE DEFECTS - SEE COMMENTS

I&I Quantity

CODE	DESCRIPTION
A	LIGHT I/I SEEN OCCURRING
B	MEDIUM I/I SEEN OCCURRING
C	HEAVY I/I SEEN OCCURRING
D	EVIDENCE I/I
N	NONE OBSERVED

Inspection Test Method

CODE	DESCRIPTION
CODES NOT USED	CONDITON EVALUATION
	EXFILTRATION
	GROUNDWATER INFILTRATION
	SMOKE TEST
	STORM FLOOD DYE TEST
	SURFACE FLOOD DYE TEST
	VACUUM
	VISUAL -- ABOVE
	VISUAL - ENTRY

Appendix C NASSCO PACP Grading System

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PACP® Condition Grading System

Using the PACP Code Matrix, each PACP code is assigned a condition grade ranging from 1 to 5. Grades are assigned based on the significance of the defect, extent of damage, percentage of restriction to flow capacity or the amount of wall loss due to deterioration.

Note

The PACP Condition Grading System alone is inadequate for determining if a pipe segment should be rehabilitated or replaced. Many other factors in addition to the internal condition of the segment should be considered. The fact that a segment has significant grade 4 or grade 5 defects does not necessarily mean the pipe segment should be immediately rehabilitated, thus ***PACP does not replace the judgment of professional engineers****. Recent experience by PACP users has shown that pipe segments with serious defects, such as hinge failures, may remain largely unchanged for many decades if no deterioration factors such as surcharging, roots or groundwater are present.*

Condition Grades

Condition Grades are assigned for two defect categories, structural and operation and maintenance (O&M). Grades and definitions are listed below:

5 – Most significant defect grade

4 – Significant defect grade

3 – Moderate defect grade

2 – Minor to moderate defect grade

1 – Minor defect grade

The PACP Condition Grading System results are entirely dependent on the quality of the PACP defect coding. Errors in the coding will directly result in errors in the grading. Coding should be accomplished based on proper PACP guidelines and not based on condition grades. All utilities, engineers and contractors should make sure the data they are using was coded by experienced technicians, who have successfully demonstrated their competence using PACP through a formal or informal apprenticeship program. PACP data from inexperienced technicians should be checked and corrected as needed. Errors found in coding should be corrected and brought to the attention of the technician.

Pipe Rating System

The PACP Condition Grading System provides a framework within which to calculate several pipe rating numbers which is useful for ranking line segments based on severity of observed defects and conditions. The pipe ratings are based upon the number of occurrences for each condition grade within individual line segments and are separately calculated for structural defects and Operation and Maintenance (O&M) defects. PACP's Pipe Grading System provides three ways to express pipe segment conditions – Quick Rating, Overall Pipe Rating and Pipe Rating Index.

Grading Continuous Pipe Defects

The PACP Continuous Defect feature enables special coding when long or repeated portions of a pipe are affected by the same defect. Since a long or "repeated" defect is obviously more severe than a "point" defect, a mechanism is provided to translate these continuous defects into an equivalent number of point defects.

The equivalent number of point defects contained in a continuous defect is calculated by dividing the length of the continuous defect by 5 for the Imperial System and by 1.5 for the International Metric System of units (SI). The quotient is then rounded to the nearest whole number. For example, a 19.7 foot (6 m) continuous defect, grade 3, should be equivalent to four Grade 3 defects. See proper calculations for both systems below:

$$Equivalent\ Point\ Defects = \frac{Length\ (ft)}{5} = \frac{Lenth\ (m)}{1.5}$$

Examples:

$$\frac{19.7\ ft}{5\ {}^{ft}/_{Defect}} = 3.94 \approx 4\ Defects$$

$$\frac{6\ m}{1.5\ {}^{m}/_{Defect}} = 4\ Defects$$

> **Note**
>
> *Fractions of the quotient are rounded to the nearest whole number (i.e. ≤0.49 is rounded down, and ≥ 0.5 is rounded up).*

Appendix C - PACP Condition Grading System

PACP Quick Rating

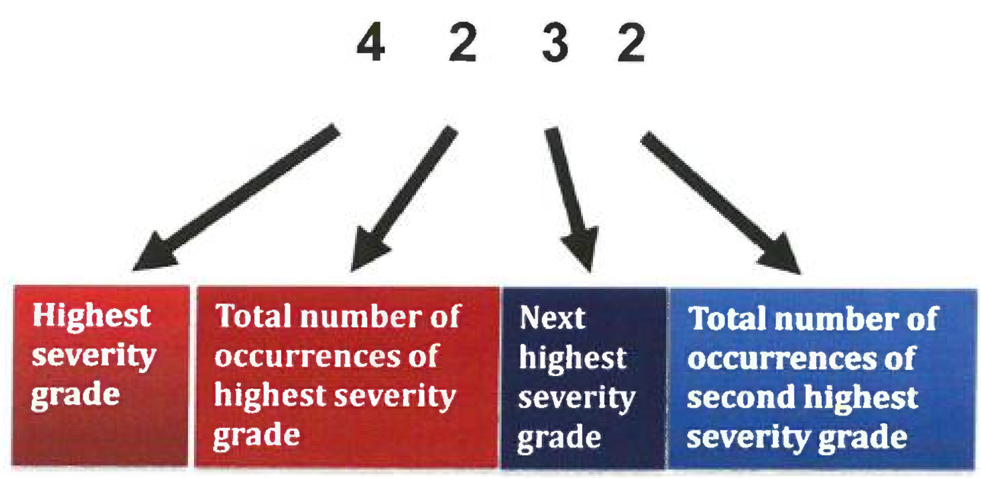
The PACP Quick Rating is a shorthand way of expressing the number of occurrences for the two highest severity grades. The quick rating is a four character score compiled as follows:

First Character: Highest severity grade occurring along the pipe length.

Second Character: Total number of occurrences of that highest severity grade. If the total number exceeds 9, then alphabetic characters are used as follows:
10 to 14 = A, 15 to 19 = B and 20 to 24 = C, etc.

Third Character. Second highest severity grade occurring along the pipe length.

Fourth Character: Total number of the second highest severity grade occurrences. If the total number exceeds 9, then alphabetic characters are used as follows:
10 to 14 = A, 15 to 19 = B and 20 to 24 = C, etc.



For example: 4B27

This immediately shows no grade 5 defects or grade 3 defects were observed. However, fifteen to nineteen grade 4 defects and seven grade 2 defects were found.

Another example: 3224

Two grade 3 defects and four grade 2 defects were observed in the pipe, however, no grade 5 or grade 4 defects were found.

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If a pipe segment only has defects of one grade, the first two characters are the grade and the quantity of defects, and the last two characters are 00 (denoting no other defect grades). For example, a segment with two grade 4 defects and no other defects would have a rating of 4200. A pipe segment with no defects would have a rating of 0000 (all zeros). This does not imply that grade 0 exists.

The PACP Quick Rating provides a means to summarize the number and severity of the most significant defects found within a pipe segment. As with the other pipe ratings, the quick rating is separately calculated for Structural (QSR) and O&M (QMR) coded defects, and may be combined into an Overall Quick Rating (QOR).

Segment Grade Scores (SG):

Each pipe segment will have a separate Segment Grade Score for each of the five condition grades. These scores are calculated by multiplying each condition grade number by its number of occurrences in the individual pipe segment.

$$SG_N = \textit{number of grade N defects} \times \textit{condition grade N}$$

For example, a pipe has the following defects and condition grades:

Structural	O&M
6 defects, grade 5	2 defects, grade 3
2 defects, grade 3	4 defects, grade 2
4 defects, grade2	

The segment grade scores for the structural and O&M ratings are:

Cond.	Defects		Segment Grade	
Grade	Structural	O&M	Structural	O&M
5	6	0	$SG_5 = (6\,x\,5) = 30$	$SG_5 = (0\,x\,5) = 0$
4	0	0	$SG_4 = 0$	$SG_4 = 0$
3	2	2	$SG_3 = 6$	$SG_3 = 6$
2	4	4	$SG_2 = 8$	$SG_2 = 8$
1	0	0	$SG_1 = 0$	$SG_1 = 0$

Note

If a pipe segment had no defects of a particular grade, then the Segment Grade Score for that grade would be zero (0).

Overall Pipe Rating (OR):

The five individual Segment Grade Scores are be added together to calculate the Overall Pipe Rating. Structural pipe ratings are calculated using only structural defect grades, while O&M pipe ratings are calculated using only O&M defect grades. This total score should be viewed with caution, since a high Overall Pipe Rating score may indicate a high number of low severity defects, a low number of high severity defects or a balance of high and low defect grades.

$$OR = SG_1 + SG_2 + SG_3 + SG_4 + SG_5$$

For example, from the previous example the following ratings are calculated:

Condition Grade	Defects		Segment Grade	
	Structural	O&M	Structural	O&M
5	6	0	30	0
4	0	0	0	0
3	2	2	6	6
2	4	4	8	8
1	0	0	0	0
Total Defects =	**12**	**6**		
		Overall Rating =	**44**	**14**

Pipe Rating Index (RI)

The Pipe Rating Index is an indicator of overall defect severity within the line segment. This index is calculated by dividing the overall pipe rating by the total number of defects. Pipe Rating Indexes are separately calculated for Structural and O&M. Note: since this calculated index score simply represents an average of the segment grade scores, it does not indicate whether there are many or few defects with high or low condition grade numbers. A pipe segment with zero condition grade defects would have a Pipe Rating Index of zero (0).

$$RI = \left(\frac{Overall\ Rating}{Total\ number\ of\ defects}\right)$$

For example, from the previous example the following ratings are calculated:

$$RI_{Structural} = \frac{44}{12} = 3.7\ , and, RI_{O\&M} = \frac{14}{6} = 2.3$$

Condition Grade	Defects		Segment Grade	
	Structural	O&M	Structural	O&M
5	6	0	30	0
4	0	0	0	0
3	2	2	6	6
2	4	4	8	8
1	0	0	0	0
Total Defects =	**12**	**6**		
		Overall Rating =	**44**	**14**
		Rating Index =	**3.7**	**2.3**

While all of these rating methods have benefits and each could be adapted, the Overall Quick Rating (QOR) provides the highest condition grade within the ratings. The highest condition grade is not always apparent in the RI or OR. Therefore, the Overal Quick Rating (QOR) is used in determining the likelihood of failure component of risk discussed in subsequent sections of this Appendix.

Safe, clean waterways

Appendix C - PACP Condition Grading System

Following is a sample sheet with pipe rating examples, calculations and explanations.

	A	B	C	D	E	F	G
1			Condition Grades	Number of Defects		Segment Grade	
2				Structural	O&M	Structural	O&M
						(C)x(D)	(C)x(E)
3	Point Defects		5	3	5	15	25
4			4	5	0	20	0
5			3	2	4	6	12
6			2	3	5	6	10
7			1	1	3	1	3
8	Continuous Defects	Length (ft)					
				(B)/5	(B)/5	(C)x(D)	(C)x(E)
9	S01-F01 *(Struc.)*	29	3	6	-	18	-
10	S02-F02 *(Struc.)*	21	2	4	-	8	-
11	S03-F03 *(Struc.)*	16	5	3	-	15	-
12	S04-F04 *(O&M)*	15	3	-	3	-	9
13	S05-F05 *(O&M)*	16	1	-	3	-	3
				Σ(D)	Σ(E)		
14	**Total Defects =**			**27**	**23**		
						Σ(F)	Σ(G)
15	**Overall Rating =**					**89**	**62**
						(F15)/(D14)	(G15)/(E14)
16	**Rating Index =**					**3.3**	**2.7**
	Quick Rating =			**5645**	**5537**		
	Overall Quick Rating =			**5A45**			

Manhole Rating System:

The MACP Condition Grading System provides a framework within which to calculate several manhole rating numbers which is useful for ranking manholes based on severity of observed defects and conditions. The manhole ratings are based upon the number of occurrences for each condition grade within components of individual manholes and are separately calculated for structural defects and O&M defects. The MACP Manhole Rating System provides three ways to express manhole conditions – Quick Rating, Overall Pipe Rating and Pipe Rating Index.

Grading Continuous Manhole Defects

The MACP "Continuous Defect" feature enables special coding when long or repeated portions of a pipe are affected by the same defect. Since a long or "repeated" defect is obviously more severe than a "point" defect, a mechanism is provided to translate these continuous defects into an equivalent number of point defects.

The equivalent number of point defects contained in a continuous defect, is calculated by dividing the length of the continuous defect by 1 for the Imperial system and 0.3 for the International (Metric) System of units (SI). The quotient is then rounded to the nearest whole number. As an example, a 2.7 foot (0.82 m) continuous defect, grade 3, should be equivalent to three Grade 3 defects. See proper calculations for both systems below:

$$\boldsymbol{Equivalent\ Point\ Defects} = \frac{\boldsymbol{Length\ (ft)}}{\mathbf{1}} = \frac{\boldsymbol{Lenth\ (m)}}{\mathbf{0.3}}$$

Examples:

$$\frac{\mathbf{2.7}\ \boldsymbol{ft}}{\mathbf{1}\ {}^{\boldsymbol{ft}}/_{\boldsymbol{Defect}}} = \mathbf{2.7} \approx \mathbf{3}\ \boldsymbol{Defects}$$

$$\frac{0.82\ m}{0.3\ {}^{m}/_{Defect}} = 2.7 \approx \mathbf{3}\ Defects$$

> **Note**
>
> *The Equivalent Point Defects number that is calculated is rounded to the nearest whole number (i.e. ≤0.49 is rounded down, and ≥ 0.5 is rounded up).*

MACP Quick Rating

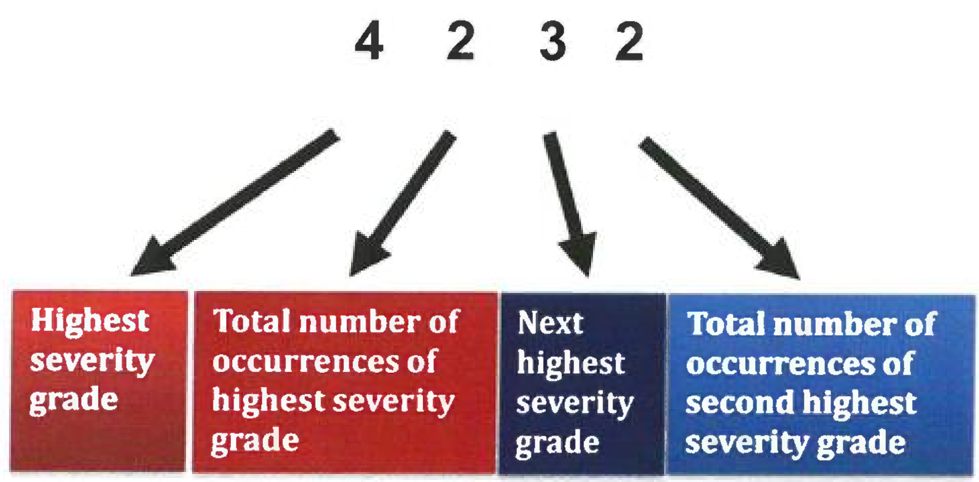
The MACP Quick Rating is a shorthand way of expressing the number of occurrences for the two highest severity grades within a manhole. The Quick Rating is a four character score compiled as follows:

First Character: Highest severity grade occurring in the manhole.

Second Character: Total number of occurrences of that highest severity grade. If the total number exceeds 9, then alphabetic characters are used as follows: 10 to 14 = A; 15 to 19 = B; 20 to 24 = C; etc.

Third Character: Second highest severity grade occurring in the manhole.

Fourth Character: Total number of the second highest severity grade occurrences. If the total number exceeds 9, then alphabetic characters are used as follows: 10 to 14 = A; 15 to 19 = B; 20 to 24 = C; etc.



For example: 4A24
This immediately shows that no grade 5 defects or grade 3 defects were found in this manhole. However, 10 to 14 grade 4 defects and four grade 2 defects were found.

Another example: 3224

Two grade 3 defects and four grade 2 defects were observed in this manhole. However, no grade 5 or grade 4 defects were found.

If a manhole only has defects of one grade, the first two characters are the grade and the quantity of defects, and the last two characters are 00 (denoting no other defect grades). For example, a manhole with two grade 4 defects and no other defects would have a rating of 4200. A manhole with no defects would have a rating of 0000 (all zeros); this does not imply that grade 0 exists.

The MACP Quick Rating provides a means to summarize the number and severity of the most significant defects found within a manhole. As with the other manhole ratings, the Quick Rating is separately calculated for Structural (QSR) and O&M (QMR) coded defects, and may be combined into an Overall Quick Rating (QOR).

Manhole Grade Scores (MG):

Each manhole will have a separate Manhole Grade Score for each of the five Condition Grades. These scores are calculated by multiplying each Condition Grade number by its number of occurrences in the individual manhole.

$$MG_N = number\ of\ grade\ N\ defects\ \times condition\ grade\ N$$

For example, a manhole has the following defects and condition grades:

Structural
6 defects, grade 5
2 defects, grade 3
4 defects, grade 2

O&M
2 defects, grade 3
4 defects, grade 2

The manhole grade scores for the structural and O&M ratings are:

Cond. Grade	Defects		Segment Grade	
	Structural	O&M	Structural	O&M
5	6	0	$MG_5 = (6\ x\ 5) = 30$	$MG_5 = (0\ x\ 5) = 0$
4	0	0	$MG_4 = 0$	$MG_4 = 0$
3	2	2	$MG_3 = 6$	$MG_3 = 6$
2	4	4	$MG_2 = 8$	$MG_2 = 8$
1	0	0	$MG_1 = 0$	$MG_1 = 0$

Note

If a manhole had no defects of a particular grade, then the Manhole Grade Score for that grade would be zero (0).

Overall Manhole Rating (OMR)

The five individual Manhole Grade Scores are added together to calculate the Overall Manhole Rating. Structural Manhole Ratings are calculated using only Structural Defect grades, while O&M Manhole Ratings are calculated using only O&M Defect grades. This total score should be viewed with caution since a high Overall Manhole Rating score may indicate a high number of low severity defects, a low number of high severity defects, or a balance of high and low defect grades.

$$OMR = MG_1 + MG_2 + MG_3 + MG_4 + MG_5$$

For example, from the previous example the following ratings are calculated:

Condition Grade	Defects		Manhole Grade	
	Structural	O&M	Structural	O&M
5	6	0	30	0
4	0	0	0	0
3	2	2	6	6
2	4	4	8	8
1	0	0	0	0
Total Defects =	**12**	**6**		
		Overall Manhole Rating =	**44**	**14**

Manhole Rating Index (MRI)

The Manhole Rating Index in an indicator of overall defect severity within the manhole. This Index is calculated by dividing the Overall Manhole Rating by the total number of defects. Manhole Rating Indices are separately calculated for Structural and O&M. Since this calculated Index score simply represents an average of the Manhole Grade Scores, it **DOES NOT** indicate whether there are many or few defects with high or low Condition Grade numbers. A manhole with zero condition grade defects would have a Manhole Rating Index of zero (0).

$$MRI = \left(\frac{Overall\ Rating}{Total\ Number\ of\ Defects}\right)$$

Using the defect information from the previous example, the following ratings are calculated:

$$MRI_{Structural} = \frac{44}{12} = 3.7\ , and, MRI_{O\&M} = \frac{14}{6} = 2.3$$

Condition Grade	Defects		Segment Grade	
	Structural	O&M	Structural	O&M
5	6	0	30	0
4	0	0	0	0
3	2	2	6	6
2	4	4	8	8
1	0	0	0	0
Total Defects =	**12**	**6**		
		Overall Rating =	**44**	**14**
		Rating Index =	**3.7**	**2.3**

While all of these rating methods have benefit and each could be adapted, the Overall Quick Rating (QOR) provides the highest condition grade within the ratings. The highest condition grade is not always apparent in the MRI or OMR. Therefore, the Overall Quick Rating is used to determine the Likelihood of Failure component of risk discussed in the following Appendix.

Appendix C - PACP Condition Grading System

A sample sheet with Manhole Rating examples, calculations, and explanations is presented here:

	A	B	C	D	E	F	G
1			Condition Grades	Number of Defects		Manhole Grade	
2				Structural	O&M	Structural	O&M
						(C)x(D)	(C)x(E)
3	Point Defects		5	3	5	15	25
4			4	5	0	20	0
5			3	2	4	6	12
6			2	3	5	6	10
7			1	1	3	1	3
8	Continuous Defects	Length (ft)					
				(B)/1	(B)/1	(C)x(D)	(C)x(E)
9	S01-F01 *(Struc.)*	6	3	6	-	18	-
10	S02-F02 *(Struc.)*	5	2	5	-	10	-
11	S03-F03 *(Struc.)*	6	5	6	-	30	-
12	S04-F04 *(O&M)*	5	3	-	5	-	15
13	S05-F05 *(O&M)*	4	1	-	4	-	4
				Σ(D)	Σ(E)		
14	**Total Defects =**			**17**	**9**		
						Σ(F)	Σ(G)
15	**Overall Rating =**					**58**	**19**
						(F15)/(D14)	(G15)/(E14)
16	**Rating Index =**					**3.4**	**2.1**
	Quick Rating =			**5345**	**5534**		
	Overall Quick Rating =			**5845**			

Condition Code Matrix

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Appendix C - PACP Condition Grading System

Categories of Pipe Types

In PACP Version 7.0.0., new columns were added in the Condition Grade Table for three different categories of pipe types: sewer, stormwater and levee. This was done to allow users to quickly and accurately identify which grades applied most appropriately to the system, that they are coding. The following explains what is included under each of the three new headings.

Sewer: This category is intended to apply to any pipe that carries sanitary waste ultimately to the local treatment facility. This includes residential sewer pipes (both laterals and mainlines), industrial sewer pipes, as well as combined systems that carry a combination of both sanitary and stormwater waste streams.

Stormwater: This category is intended to apply to any pipe that carries drainage flow that comes from precipitation, or flow that results from elevated water tables. These piping networks often carry flows to detention ponds or holding structures or to direct discharge points at a local waterway. They do not typically carry flow to a treatment facility, and they do not carry comingled wastewater and stormwater flows.

Levee: This category is intended to apply to any pipe that carries water to or from a dam, levee or floodwall impoundment. This includes toe drains that typically run parallel levees and floodwalls and dump into gravity sewers that penetrate through or run under the levees.These toe drains are also referred to as laterals. For dams, there are often seepage collector drains that empty into the outlet (often open channel) from the dam's conduit. These seepage collector drains are also referred to as laterals.

Appendix C - PACP Condition Grading System

PACP/LACP Condition Grades

Structural Defect Codes

Description	Code	Structural Grade		O&M Grade
		Sewer/Combined/ Stormwater	Levee/Dam	
CRACK				
Crack Longitudinal	CL	2	3	
Crack Circumferential	CC	1	1	
Crack Multiple	CM	3	3	
Crack Spiral	CS	2	3	
Crack Hinge 2	CH2	2	5	
Crack Hinge 3	CH3	3	5	
Crack Hinge 4	CH4	4	5	
FRACTURE				
Fracture Longitudinal	FL	3	4	
Fracture Circumferential	FC	2	4	
Fracture Multiple	FM	4	4	
Fracture Spiral	FS	3	4	
Fracture Hinge 2	FH2	3	5	
Fracture Hinge 3	FH3	4	5	
Fracture Hinge 4	FH4	4	5	
BROKEN				
Broken	B	4	5	
Broken Soil Visible	BSV	5	5	
Broken Void Visible	BVV	5	5	
HOLE				
Hole	H	< 2 clock pos → 4 ≥ 2 clock pos → 5	5	

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Appendix C - PACP Condition Grading System

Description	Code	Structural Grade		O&M Grade
		Sewer/Combined/ Stormwater	Levee/Dam	
Hole Soil Visible	HSV	5	5	
Hole Void Visible	HVV	5	5	
DEFORMED				
Deformed Rigid	DR	≤ 5% → 4 > 5% → 5	≤ 5% → 4 > 5% → 5	
Deformed Flexible Bulging Round	DFBR	≤ 10% → 4 >10% → 5	≤ 5% → 2 >5% to ≤ 10% → 3 >10% to ≤ 20% → 4 >20% to ≤ 40% → 5	
Deformed Flexible Bulging Inverse Curvature	DFBI	5	≤ 10% → 4 > 10% → 5	
Deformed Flexible Creasing	DFC	5	4	
Deformed Flexible Elliptical	DFE	3	≤ 5% → 2 >5% to ≤ 10% → 3 >10% to ≤ 20% → 4 >20% to ≤ 40% → 5	
Deformed Brick Bulging Round	DTBR	≤ 5% → 4 > 5% → 5	≤ 10% → 4 > 10% → 5	
Deformed Brick Bulging Inverse Curvature	DTBI	5	≤ 10% → 4 > 10% → 5	
COLLAPSE				
Collapse	X	5	5	
JOINT				
Joint Offset Small (Displaced)	JOS	NA	4	
Joint Offset Medium	JOM	3	5	
Joint Offset Medium Defective	JOMD	3	5	4
Joint Offset Large	JOL	4	5	
Joint Offset Large Defective	JOLD	4	5	5
Joint Separated Small (Open)	JSS	-	5	
Joint Separated Medium	JSM	3	5	

Appendix C - PACP Condition Grading System

Description	Code	Structural Grade		O&M Grade
		Sewer/Combined/ Stormwater	Levee/Dam	
Joint Separated Large	JSL	4	5	
Joint Angular Small	JAS	-	4	
Joint Angular Medium	JAM	3	5	
Joint Angular Large	JAL	4	5	
SURFACE DAMAGE				
Surface Damage Roughness Increased	SRI	1	1	
Surface Damage Aggregate Visible	SAV	2	3	
Surface Damage Aggregate Projecting	SAP	3	3	
Surface Damage Aggregate Missing	SAM	4	3	
Surface Damage Reinforcement Visible	SRV	4	4	
Surface Damage Reinforcement Projecting	SRP	5	4	
Surface Damage Reinforcement Corroded	SRC	5	5	
Surface Damage Missing Wall	SMW	5	5	
Surface Damage Surface Spalling	SSS	2	3	
Surface Damage Spalling of Coating	SSC	1	1	
Surface Damage Corrosion	SCP	3	4	
Surface Damage Other	SZ	-	-	
LINING FEATURE				
Lining Feature Abandoned Connection	LFAC	-	-	
Lining Feature Annular Space	LFAS	3	3	
Lining Feature Blistered	LFB	3	3	
Lining Feature Service Cut Shifted	LFCS	3	3	
Lining Feature Detached	LFD	3	3	
Lining Feature Discoloration	LFDC	3	1	
Lining Feature Defective End	LFDE	3	3	
Lining Feature Delamination	LFDL	3	3	
Lining Feature Overcut Service	LFOC	3	3	
Lining Feature Resin Slug	LFRS	3	3	
Lining Feature Undercut Service	LFUC	3	3	

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Appendix C - PACP Condition Grading System

Description	Code	Structural Grade		O&M Grade
		Sewer/Combined/ Stormwater	Levee/Dam	
Lining Feature Wrinkled	LFW	3	3	
Lining Feature Other	LFZ	-	-	
WELD FAILURE				
Weld Failure Circumferential	WFC	2	4	
Weld Failure Longitudinal	WFL	2	4	
Weld Failure Multiple	WFM	3	5	
Weld Failure Spiral	WFS	2	4	
Weld Failure Other	WFZ	-	-	
POINT REPAIR				
Point Repair Liner	RPL	-	-	
Point Repair Liner Defective	RPLD	4	4	
Point Repair Patch	RPP	-	3	
Point Repair Patch Defective	RPPD	4	4	
Point Repair Replacement	RPR	-	3	
Point Repair Replacement Defective	RPRD	4	4	
Point Repair Other	RPZ	-	3	
Point Repair Other Defective	RPZD	4*	4	
BRICKWORK				
Displaced Brick	DB	3	3	
Missing Brick	MB	4	4	
Dropped Invert	DI	5	5	
Missing Mortar Small	MMS	2	3	
Missing Mortar Medium	MMM	3	4	
Missing Mortar Large	MML	3	5	

Operation and Maintenance Codes

Description	Code	Structural Grade	O&M Grade	
			Sewer/Combined/ Stormwater	Levee
Deposits Attached Encrustation	DAE		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Deposits Attached Grease	DAGS		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Deposits Attached Ragging	DAR		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Deposits Attached Other	DAZ		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Deposits Settled Hard/Compacted	DSC		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Deposits Settled Fine	DSF		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Deposits Settled Gravel	DSGV		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5

Appendix C - PACP Condition Grading System

Description	Code	Structural Grade	O&M Grade	
			Sewer/Combined/ Stormwater	Levee
Deposits Settled Other	DSZ		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Deposits Ingress Fine	DNF		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Deposits Ingress Gravel	DNGV		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Deposits Ingress Other	DNZ		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Roots Fine Barrel	RFB		2	2
Roots Fine Lateral	RFL		1	2
Roots Fine Connection	RFC		1	2
Roots Fine Joint	RFJ		1	2
Roots Tap Barrel	RTB		3	3
Roots Tap Lateral	RTL		2	3
Roots Tap Connection	RTC		2	3
Roots Tap Joint	RTJ		2	3
Roots Medium Barrel	RMB		4	4
Roots Medium Lateral	RML		3	4
Roots Medium Connection	RMC		3	4
Roots Medium Joint	RMJ		3	4
Roots Ball Barrel	RBB		5	4

Appendix C - PACP Condition Grading System

Description	Code	Structural Grade	O&M Grade	
			Sewer/Combined/ Stormwater	Levee
Roots Ball Lateral	RBL		4	4
Roots Ball Connection	RBC		4	4
Roots Ball Joint	RBJ		4	4
Infiltration Weeper	IW		2	2
Infiltration Weeper Barrel	IWB		2	2
Infiltration Weeper Lateral	IWL		2	2
Infiltration Weeper Connection	IWC		2	2
Infiltration Weeper Joint	IWJ		2	2
Infiltration Dripper	ID		3	3
Infiltration Dripper Barrel	IDB		3	3
Infiltration Dripper Lateral	IDL		3	3
Infiltration Dripper Connection	IDC		3	3
Infiltration Dripper Joint	IDJ		3	3
Infiltration Runner	IR		4	4
Infiltration Runner Barrel	IRB		4	4
Infiltration Runner Lateral	IRL		4	4
Infiltration Runner Connection	IRC		4	4
Infiltration Runner Joint	IRJ		4	4
Infiltration Gusher	IG		5	5
Infiltration Gusher Barrel	IGB		5	5
Infiltration Gusher Lateral	IGL		5	5
Infiltration Gusher Connection	IGC		5	5
Infiltration Gusher Joint	IGJ		5	5
Infiltration Stain	IS		1	1
Infiltration Stain Barrel	ISB		1	1
Infiltration Stain Lateral	ISL		1	1
Infiltration Stain Connection	ISC		1	1
Infiltration Stain Joint	ISJ		1	1

Appendix C - PACP Condition Grading System

Description	Code	Structural Grade	O&M Grade	
			Sewer/Combined/ Stormwater	Levee
Obstruction Brick or Masonry	OBB		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Obstruction Pipe Material in Invert	OBM		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Obstruction Intruding Through Wall	OBI		5	5
Obstruction Wedged in Joint	OBJ		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Obstruction Through Connection	OBC		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Obstruction External Pipe or Cable	OBP		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Obstruction Built into Structure	OBS		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Obstruction Construction Debris	OBN		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5

Appendix C - PACP Condition Grading System

Description	Code	Structural Grade	O&M Grade	
			Sewer/Combined/ Stormwater	Levee
Obstacle/Obstruction Rocks	OBR		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Obstacle/Obstruction Other Objects	OBZ		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Vermin Rat	VR		2	2
Vermin Cockroach	VC		1	1
Vermin Other	VZ		1	1
Grout Test Pass Joint	GTPJ		-	-
Grout Test Pass Lateral	GTPL		-	-
Grout Test Fail Joint	GTFJ		-	-
Grout Test Fail Lateral	GTFL		-	-
Grout Test Unable to Test Joint	GTUJ		-	-
Grout Test Unable to Test Lateral	GTUL		-	-
Grout at a Location (Not a Joint)	GRT		-	-

Construction Features Codes

Description	Code	Structural Grade	O&M Grade	
			Sewer/Combined/Stormwater	Levee
Tap Factory Defective	TFD		3	4
Tap Factory Intruding*	TFI		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	3
Tap Factory Capped	TFC		-	-
Tap Factory Activity	TFA		-	-
Tap Factory Abandoned	TFB		-	-
Tap Break-In/Hammer	TB		-	-
Tap Break-In/Hammer Defective	TBD		3	4
Tap Break-In/Hammer Intruding*	TBI		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	3
Tap Break-In/Hammer Capped	TBC		-	-
Tap Break-In/Hammer Activity	TBA		-	-
Tap Break-In/Hammer Abandoned	TBB		-	-
Tap Saddle	TS		-	-
Tap Saddle Defective	TSD		3	4
Tap Saddle Intruding*	TSI		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	3
Tap Saddle Capped	TSC		-	-
Tap Saddle Activity	TSA		-	-
Tap Saddle Abandoned	TSB		-	-

Appendix C - PACP Condition Grading System

Description	Code	Structural Grade	O&M Grade	
			Sewer/Combined/Stormwater	Levee
Tap Rehabilitated Defective	TRD		3	4
Tap Rehabilitated Intruding*	TRI		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	3
Tap Rehabilitated Capped	TRC		-	-
Tap Rehabilitated Activity	TRA		-	-
Tap Rehabilitated Abandoned	TRB		-	-
Intruding Sealing Material Sealing Ring	ISSR		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Intruding Seal Material Sealing Ring Hanging	ISSRH		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Intruding Seal Material Sealing Ring Broken	ISSRB		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Intruding Seal Material Sealing Loose, Poorly Fitting	ISSRL		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Intruding Sealing Material Grout	ISGT		≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5

Appendix C - PACP Condition Grading System

Description	Code	Structural Grade	O&M Grade	
			Sewer/Combined/Stormwater	Levee
Intruding Sealing Material Other	ISZ		≤ 10% → 2 >10% to ≤ 20%→3 >20% to ≤ 30%→4 >30% → 5	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Line Left**	LL		≤ 10% → 1 >10% to ≤ 20%→2 >20% → 4	1
Line Left/Up**	LLU		≤ 10% → 1 >10% to ≤ 20%→2 >20% → 4	1
Line Left/Down**	LLD		≤ 10% → 1 >10% to ≤ 20%→2 >20% → 4	1
Line Right**	LR		≤ 10% → 1 >10% to ≤ 20%→2 >20% → 4	1
Line Right/Up**	LRU		≤ 10% → 1 >10% to ≤ 20%→2 >20% → 4	1
Line Right/Down**	LRD		≤ 10% → 1 >10% to ≤ 20%→2 >20% → 4	1
Line Up**	LU		≤ 10% → 1 >10% to ≤ 20%→2 >20% → 4	1
Line Down**	LD		≤ 10% → 1 >10% to ≤ 20%→2 >20% → 4	1
Access Point Cleanout Mainline	ACOM		-	-
Access Point Cleanout Property	ACOP		-	-

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Appendix C - PACP Condition Grading System

Description	Code	Structural Grade	O&M Grade	
			Sewer/Combined/Stormwater	Levee
Access Point Cleanout House	ACOH		-	-
Access Point Discharge Point	ADP		-	-
Access Point Junction Box	AJB		-	-
Access Point Meter	AM		-	-
Access Point Manhole	AMH		-	-
Access Point Other Special Structure	AOC		-	-
Access Point Tee Connection	ATC		-	-
Access Point Wastewater Access	AWA		-	-
Access Point Catch Basin	ACB		-	-
Access Point End of Pipe	AEP		-	-

Hidden Formulas in Software :

*Percent = (Length of intrusion/Pipe height) x 100

**Degrees = (Percent/100) x 90

Miscellaneous Features Codes

Description	Code	Structural Grade		O&M Grade	
		Sewer/Combined/ Stormwater	Levee	Sewer/Combined/ Stormwater	Levee
Miscellaneous Camera Underwater	MCU			4	4
Miscellaneous Shape/Size Change	MSC				
Miscellaneous General Observation	MGO				
Miscellaneous General Photograph	MGP				
Miscellaneous Material Change	MMC				
Miscellaneous Lining Change	MLC				
Miscellaneous Joint Length Change	MJL				
Miscellaneous Survey Abandoned	MSA				4
Miscellaneous Water Level	MWL				
Miscellaneous Water Level Sag	MWLS	≤ 30% → 2 >30% to ≤ 50% → 3 >50% to ≤ 75% → 4 >75% → 5			
Miscellaneous Water Mark	MWM				
Miscellaneous Dye Test Visible	MYV				
Miscellaneous Dye Test Not Visible	MYN				

Appendix C - PACP Condition Grading System

MACP Condition Grades Instructions

When more than one code/text-code is allowed, select the highest grade possible from the matrix below.

Grades for manholes without vehicular traffic have the acronym NT (No-Traffic) after the grade number.

Field 25 codes: E, F, I, J, K, L, Y, Z

Grades for manholes with vehicular traffic have the acronym T (Traffic) after the grade number.

Field 25 codes: A, B, C, D, G, H, M

Field 27 is Inflow Potential from Runoff; S = Sheeting, P = Ponding, I = Inundated

Field	Description	Structural Grade	O&M Grade
		COVER	
52	Hole Number	-	If # of holes > 0, then check Field 27: If S - 3, P - 4, I - 5
55	Cover/Frame Fit	R - 4_{NT}, 5_T U - 4_{NT}, 5_T O - 5	G - 1 U - 4_{NT}, 5_T R - 4_{NT}, 5_T O - 5
56	Cover Condition	Sound - 1 Restraint Defective - 2 Cracked - 3_{NT}, 4_T Corroded – 4 Broken - 5 Missing - 5	Bolts Missing - 2 Restraint Defective – 2 Restraint Missing - 3

Appendix C - PACP Condition Grading System

58	Cover Insert Condition	Corroded - 3	Sound - 1 Poor Fitting - 3 Cracked - 3 Insert Fell 5 Leaking - 5
61	Adjustment Ring Condition	Sound - 1 Corroded – 3 Cracked - 3 Poor Installation – 3 Broken - 5	Leaking - 5
		FRAME	
68	Frame Condition	Sound - 1 Cracked - 4_{NT}, 5_{T} Broken - 5 Missing - 5 Corroded - 1	-
69	Seal Condition	Sound - 1 Offset - 3 Missing – 3 Cracked - 3_{NT},4_{T} Loose - 3_{NT}, 4_{T}	Sound - 1 Cracked - 3 Loose - 3 Offset - 3 Missing - 3
70	Frame Offset Distance	d<1 in. – 1;d<25 mm - 1 1 in.>d≥4 in. – 3 25 mm>d≥102 mm - 3 d>4 in. – 5;d>102 mm - 5	-
71	Frame Seal Inflow	-	None - 1 IS - 2 IW - 3 ID - 4 IR - 5 IG - 5
		CHIMNEY	

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76	Chimney I/I	-	None - 1 IS - 2 IW - 3 ID - 4 IR - 5 IG - 5
		PIPE CONNECTIONS	
115	Pipe Condition	-	Sound - 1 Defective - 3

Appendix C - PACP Condition Grading System

NASSCO MACP Condition Grading System
Code Matrix for the Component Defect Section

Group	Code	Structural Grade				O&M Grade			
		Chimney	Cone and Wall	Bench	Channel	Chimney	Cone and Wall	Bench	Channel
Structural Family									
Crack (C)	CC	2	2	2	2				
	CL	2	2	2	2				
	CM	3	3	3	3				
	CS	2	2	2	2				
Fracture (F)	FC	3	3	3	3				
	FL	3	3	3	3				
	FM	4	4	4	4				
	FS	3	3	3	3				
Broken (B)	B	5	5	5	5				
	BSV	5	5	5	5				
	BVV	5	5	5	5				
Hole (H)	H	2	2	2	1 clock pos → 4, ≥ 2 clock pos → 5				
	HSV	5	5	5	5				
	HVV	5	5	5	5				
Collapse (X)	X	5	5	5	5				

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Group	Code	Structural Grade				O&M Grade			
		Chimney	Cone and Wall	Bench	Channel	Chimney	Cone and Wall	Bench	Channel
Joint (J)	JOM	5	5	5	5				
	JOL	5	5	5	5				
	JSM	5	5	5	5				
	JSL	5	5	5	5				
	JAM	5	5	5	5				
	JAL	5	5	5	5				
Surface Damage	SRI	1	1	1	1				
	SSS	2	2	2	2				
	SSC	2	2	2	2				
	SAV	2	2	2	2				
	SAP	3	3	3	3				
Surface Damage (Silent)	SAM	4	4	4	4				
	SRV	5	5	5	5				
	SRP	5	5	5	5				
	SRC	5	5	5	5				
	SMW	5	5	5	5				
	SZ	-	-	-	-				
Surface Damage (Metal)	SCP	3	3	3	3				

Appendix C - PACP Condition Grading System

Group	Code	Structural Grade				O&M Grade			
		Chimney	Cone and Wall	Bench	Channel	Chimney	Cone and Wall	Bench	Channel
Lining Features (LF)	LFD	4	4	3	3				
	LFDE	3	3	3	3				
	LFB	3	3	3	3				
	LFCS	3	3	3	3				
	LFAC	-	-	-	-				
	LFOC	2	2	2	2				
	LFUC	2	2	2	2				
	LFBK	3	3	3	3				
	LFAS	3	3	3	3				
	LFBU	3	3	3	3				
	LFDC	3	2	3	3				
	LFDL	4	4	4	4				
	LFPH	4	4	4	4				
	LFRS	3	3	3	3				
	LFW	2	2	2	2				
	LFZ	-	-	-	-				
Weld Failure (WF)	WFC	2	2	2	2				
	WFL	2	2	2	2				

Appendix C - PACP Condition Grading System

Group	Code	Structural Grade				O&M Grade			
		Chimney	Cone and Wall	Bench	Channel	Chimney	Cone and Wall	Bench	Channel
	WFM	3	3	3	3				
	WFS	2	2	2	2				
Point Repair (RP)	RPLD	4	4	4	4				
	RPPD	4	4	4	4				
	RPRD	4	4	-	-				
Point Repair (RP)	RPZD	-	-	-	-				
Brickwork (Silent)	DB	3	3	3	3				
	MB	4	4	4	4				
	MMS	2	2	2	2				
	MMM	3	3	3	3				
	MML	4	4	4	4				
O&M Family									
Deposits (D)	DAE					1 < 30% 2≥30%	1 < 30% 2≥30%	1 <30% 2 ≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4
	DAGS					1	1	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4

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Group	Code	Structural Grade				O&M Grade			
		Chimney	Cone and Wall	Bench	Channel	Chimney	Cone and Wall	Bench	Channel
	DAR					1	1	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4
	DAZ					1 < 30% 2>=30%	1 < 30% 2≥30%	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4
	DSC					n/a	n/a	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4
	DSF					n/a	n/a	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4
	DSGV					n/a	n/a	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4
	DSZ					n/a	n/a	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4
	DNF					n/a	n/a	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4
Deposits (D)	DNGV					n/a	n/a	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4

Appendix C - PACP Condition Grading System

Group	Code	Structural Grade				O&M Grade			
		Chimney	Cone and Wall	Bench	Channel	Chimney	Cone and Wall	Bench	Channel
	DNZ					n/a	n/a	1<30% 2≥30%	≤ 10% → 1 >10% to ≤ 20% → 2 > 20% to ≤ 30% → 3 > 30% → 4
Roots (R)	RFB					1	1	1	2
	RFL					1	1	1	1
	RFC					1	1	1	1
	RFJ					1	1	1	1
	RTB					1	1	1	3
	RTL					1	1	1	2
	RTC					1	1	1	2
	RTJ					1	1	1	2
	RMB					1	1	1	4
	RML					1	1	1	3
	RMC					1	1	1	3
	RMJ					1	1	1	3
	RBB					2	2	2	5
	RBL					2	2	2	4
	RBC					2	2	2	4
	RBJ					2	2	2	4

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Appendix C - PACP Condition Grading System

Group	Code	Structural Grade				O&M Grade			
		Chimney	Cone and Wall	Bench	Channel	Chimney	Cone and Wall	Bench	Channel
Infiltration (I)	IS					1	1	1	1
	IW					2	2	2	2
	ID					3	3	3	3
	IR					4	4	4	4
Infiltration (I)	IG					5	5	5	5
Obstacles/ Obstructions (OB)	OBB					1<30% 2≥30	1<30% 2≥30	1<30% 2≥30	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
	OBM					1<30% 2≥30	1<30% 2≥30	1<30% 2≥30	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
	OBI					5	5	5	5
	OBJ					1<30% 2≥30	1<30% 2≥30	1<30% 2≥30	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
	OBC					1<30% 2≥30	1<30% 2≥30	1<30% 2≥30	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
	OBP					1<30% 2≥30	1<30% 2≥30	1<30% 2≥30	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
	OBS					1<30% 2≥30	1<30% 2≥30	1<30% 2≥30	≤ 10% → 2 >10% to ≤ 20% → 3

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Group	Code	Structural Grade				O&M Grade			
		Chimney	Cone and Wall	Bench	Channel	Chimney	Cone and Wall	Bench	Channel
									>20% to ≤ 30% → 4 >30% → 5
	OBN					1<30% 2≥30	1<30% 2≥30	1<30% 2≥30	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
	OBR					1<30% 2≥30	1<30% 2≥30	1<30% 2≥30	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
	OBZ					1<30% 2≥30	1<30% 2≥30	1<30% 2≥30	≤ 10% → 2 >10% to ≤ 20% → 3 >20% to ≤ 30% → 4 >30% → 5
Vermin (V)	VR					2	2	2	2
	VC					1	1	1	1
	VZ					1	1	1	1
Construction Features Family									
Intruding Sealing Material (IS)	ISSR					1	1	1	1
	ISSRH					1	1	1	1
Intruding Sealing Material (IS)	ISSRB					1	1	1	1
	ISSRL					1	1	1	1
	ISGT					1	1	1	1
	ISZ					1	1	1	1

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Appendix C - PACP Condition Grading System

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Appendix D NASSCO PACP Based Risk Management

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Appendix D – PACP Based Risk Management

Risk Management in Piping Systems

The purpose of asset management is to maintain the intended function or level of service of a system as cost effectively as possible. This is achieved by maintaining the individual components of the system, known as assets, at the lowest life cycle cost possible without negatively impacting the performance of the overall system. Managing assets in a risk-based and fact-based manner is a contemporary strategy developed as organizations began to recognize a need to affordably maintain aging infrastructure despite decreased funding, while at the same time meeting stakeholder expectations, agreeing to levels of service and complying with Federal mandates. This Appendix explains suggested procedures that can become an integral part in developing an asset management plan for utilities.

Organizations need baseline asset condition information and operations data upon which to base management decisions. An effective asset management program requires a utility to answer some basic asset questions such as the following.

- What pipes, structures and laterals do we own?
- Where are these assets located?
- What are their materials, dimensions, depth and ground cover?
- What is the condition of each asset?
- What is the remaining estimated useful life of each asset?
- What is the value of these assets?
- What customers do they serve?
- What other community assets would be affected by failure of a particular asset?
- What should be done to better maintain or rehabilitate each asset?
- What will be the repair, replacement and rehabilitation cost?
- When should it be done?
- What effect will this have upon the utility budget?
- How should all of this be communicated to stake holders?

Federal and state regulations such as CMOM and GASB34 have increased the need for utilities to competently and expediently answer these questions. To accomplish this, utilities need facts (data) regarding their pipeline assets. This data is included in maps, databases and reports, which must relate to each other and form a foundation for projects. As a standard tool in this process, the PACP survey data and condition ratings enable utilities to more efficiently prioritize, budget and schedule various operation, maintenance and rehabilitation tasks.

Appendix D – PACP Based Risk Management

This appendix introduces a risk based methodology that is compatible with the size and resources of individual utilities. It demonstrates how PACP data, along with general knowledge of the utility, can be used to develop considerable portions of an asset management plan.

Risk relates to the probability of something bad happening, or the likelihood of a negative impact occurring, and how this can be avoided. Sometimes risk is used to describe the severity of consequence(s) related to a potential failure. Asset management relates the combination of both **Likelihood of Failure** and **Consequence of Failure** to risk. Risk takes into account the asset's physical condition, as well as the impact that its failure would have on system performance and stakeholders. Mathematically, the risk from an occurrence may be expressed as the product of likelihood and consequence of failure as quantified in the following equation:

$$\boldsymbol{Risk = Likelihood\ of\ Failure\ (LoF) \times Consequence\ of\ Failure\ (CoF)}$$

Likelihood of Failure

Likelihood of Failure (LoF) refers to a calculated numerical representation that denotes the probability of failure based upon an asset's physical condition, typically determined by reviewing PACP survey reports.

The process requires the selection of a rating system that relates directly to the known pipe condition. The PACP Quick Rating can be used to establish a value for Likelihood of Failure for pipelines based on condition assessment data provided by PACP. This rating is preferred, among the other PACP pipe rating systems (See Appendix C), since its derivation is based upon the highest rating scores and is not adversely skewed by the presence of multiple low condition grade scores. The PACP Quick Rating also protects against generating low scores, since its calculation is not affected by line segment length. This rating is determined by recognizing that it is a factor of the highest grade defect observed within a particular pipe segment. It is also recognized that a pipe segment with more of these grade defects may be more likely to fail than those with only a few.

An asset's Likelihood of Failure is determined by dividing the first two numbers of the PACP Quick Rating by 10 and using the following guidelines.

If no condition assessment data is available, the LoF is 0 (zero).

If condition assessment data is available and there are no defects, 1.0 is added to the result of the division and the LoF is 1.0.

If there are no more than 9 occurrences of the highest condition grade, divide the first two numbers of the PACP Quick Rating by 10.

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.

> **Note**
>
> *This method results in a maximum 6.0 rating provided that there exists more than 9 Grade 5 defects.*

Example 1:
The asset has no condition assessment data available, therefore:

$$\mathbf{LoF} = \frac{\mathbf{0}}{\mathbf{10}} = \mathbf{0}$$

> **Note**
>
> *A LoF of zero DOES NOT indicate that there is no likelihood of failure of this asset. Instead, any rating of zero is meant to be a flag that indicates that data is missing, and should be promptly collected in order for this asset to be properly managed.*

Example 2:

The asset has an O&M Quick Rating of 0000 (no defects found), therefore: $\mathbf{LoF} = \frac{0}{10} + \mathbf{1.0} = \mathbf{1.0}$

Example 3:
The asset has an Overall Quick Rating of 3248, therefore:

$$\mathbf{LoF} = \frac{\mathbf{32}}{\mathbf{10}} = \mathbf{3.2}$$

Example 4:
The asset has an O&M Quick Rating of 5B21, therefore:

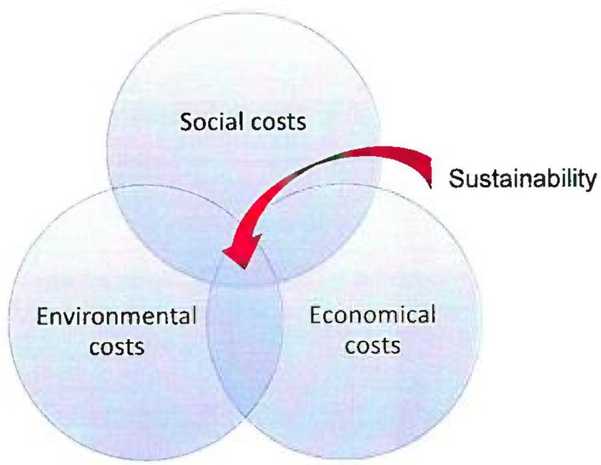
$$\mathbf{LoF} = \frac{\mathbf{50}}{\mathbf{10}} + \mathbf{1.0} = \mathbf{6.0}$$

Consequence of Failure

Pipe failure may be defined in a multitude of ways that can vary from one agency to the next. For the purposes of this Appendix, pipe failure is defined as the inability to convey flow. Consequence of Failure (CoF) is the combination of direct and indirect impact on the vicinity and community due to a potential asset failure.

In recent decades this type of impact has typically been expressed in "Triple Bottom Line "(TBL) terms – also known as People, Planet and Profit. This concept emerged in the early 1980's as a criterion for measuring economic, ecologic and societal success. The TBL expands the traditional organization's financial bottom line to view other non-traditional social and environmental factors. Consideration of these factors encourages an organization to also focus on social and environmental aspects, rather than solely upon the (more visible) economic aspects of management. This also helps an organization to consider its stakeholders.

TBL concept focuses not only upon direct Economical costs, but also on Social costs and Environmental costs. The goal is sustainability of all the assets in a balanced manner.



Economical Costs

The economical consequence of failure encompasses the impacts of direct and indirect economic losses to the affected organization and third parties due to asset failure.

Economic factors are typically expressed in dollars and include property damage, repair cost and production loss, among others. Regarding utilities, economical cost considerations may include those related to pipe material, diameter, depth and length of the pipe segments; direct or indirect interaction with other infrastructure elements, such as roads and bridges in the repair vicinity; effects of local topography on required access, and possible access restriction created by such barriers as walls and fences.

Direct consequences of failures include such costs as those for asset repairs, legal fees and fines. Indirect consequences include environmental cleanup costs and loss of business revenue to the community. In addition, consideration must be given to other external costs that are not directly measureable but result from the failure - such as loss in property value, utility credibility and increased insurance rates.

Both direct and indirect costs are considered when measuring the Economical Consequence of Failure.

Social Costs

The social consequences of failure represent the impact on society due to asset failure. These considerations may include the number of affected properties; the type of affected properties such as: hospitals, schools, parks, businesses or critical services as defined by the owner; the duration of the failure, and public image. In addition, there must be consideration for health and safety issues that may directly or indirectly create the possibility for public exposure to health-threatening problems, injuries or even fatalities.

Finally, public image and utility's credibility is extremely important due to the magnitude of its effect on the negative public exposure, criticism and legal actions the organization may face due to the failure.

Environmental Costs

The environmental consequence of failure considers the impact to ecological conditions occurring as a result of asset failure. Examples are contamination of soil, groundwater and surface water. Environmental cost considerations may include proximity to wetlands and waterways, proximity to Federal Emergency Management Agency (FEMA) flood zones, possible contamination of potable water sources and the sensitivity of nearby soils. The main consequence is the Sanitary Sewer Overflow (SSO) resulting from a failure. Also fines from consent decrees and from federal and state agencies may also result in Economic and Social costs.

Rating Methodology

Consequence of Failure is determined by considering the location and demographics of an asset. For example, a 56 inch combined trunk sewer, 100 feet downstream of a Combined Sewer Overflow (CSO) that crosses a body of water, has a higher consequence of failure, than an 8 inch sanitary sewer at the upstream end of the system that only serves one resident. Likewise, a different 56 inch sewer would have a lower consequence of failure, than another 56 inch combined trunk sewer that is installed deeper, has a higher dry weather flow and crosses under a high traffic roadway.

In order to present this concept in a useful format, these considerations should be broken into separate scoring parameters using a similar (maximum of 6) scoring system as Likelihood of Failure, so that the two components equally contribute to risk. This can be done by several methods; however, the method selected must be a result of sufficient consultation with the utility. This should include a consideration of how each of the three cost structures should be weighted, and to what extend the various components of these costs are present and important to the community.

When assigning weighting factors, one should consider how much the parameter contributes to the economic, social and environmental impacts in the event of a failure. Some parameters may impact just one of the three TBL categories, while some may have varying degrees of impacts. An example of this would be a sewer line that crosses a waterway. This clearly can impact the environmental aspect of the TBL, considering the likelihood for contamination of the stream. There may also be some social impacts with respect to an interruption in recreational use of the waterway, and economic impacts that result from penalties and fines. All of this must be thoroughly discussed with the system owner.

The following procedures should be considered as a guide regarding discussions with a utility and as a possible and reasonable scenario of a Consequence of Failure rating procedure. The utility may desire additional considerations or may not consider some of these issues pertinent.

Relative Network Position of Pipe

Some utilities are storing their data in advanced enterprise GIS databases. Typically a database will carry pipe attributes like material, diameter, upstream and downstream inverts, upstream structure, downstream structure, length along with other attributes. Others have more limited capabilities. Most utilities have some level of system mapping.

Calculation of Consequence of Failure for a pipe, due to its relative network position, could be a simple function based on just the diameter of a pipe, or the complex upstream trace function based on a number of pipes connected (discharging) to the pipe.

In general large diameter pipes are located at the downstream portion of the system, while small diameter pipes are located at the upstream portion. Consequence of Failure will be higher when a blockage or failure occurs on a large diameter pipe compared to a small diameter pipe.

Consequence of Failure may be assigned to a scale from 1 to 6 with 6 being the highest consequence and 1 being the least. We can establish six groups based on the diameter of pipes within the system. As an example, the following table may be a reasonable distribution.

Diameter	CoF Factor
Less than 8"	1
≥ 8" - < 10"	2
≥ 10" - < 15"	3
≥ 15" - < 21"	4
≥ 21" - <30"	5
≥30"	6

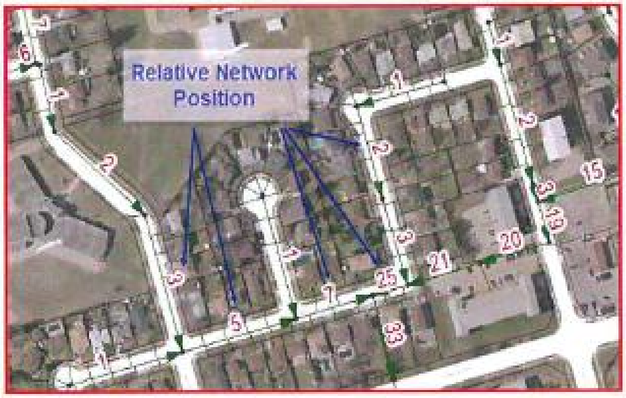
This consideration should affect both Economic and Social costs. Larger diameter pipe generally costs more to repair, replace or rehabilitate, serves more customers and can have increased environmental impact to sensitive geographical areas.

The depth of pipe will also impact the Economic cost since deeper pipe is generally more expensive to repair, resulting in a distribution such as:

Depth	CoF Factor
Less than 6'	1
≥ 6' - < 10'	2
≥ 10' - < 14'	3
≥ 14' - < 18'	4
≥ 18' - <24'	5
≥ 24'	6

Instead of diameter, relative network position of a pipe can also be used to assign a Consequence of Failure factor. This approach generally requires more sophisticated/complex maps of the system. Relative network position can be calculated as sum of relative position of all pipes discharging to an upstream structure.

This is a Social cost consideration, since the larger number of segments should relate to more customers upstream.



The six groups based on relative network position may be rated as follows:

Relative network position of pipe	CoF Factor
10 or less	1
11 -30	2
31-70	3
71-120	4
121-150	5
>150	6

A similar approach can also be used to define the Consequence of Failure factor based on the number of customers serviced by the pipe. Cumulative sum of services (lateral) connected to a pipe can be calculated by adding cumulative sum of services connected to all pipes discharging at upstream structure of a pipe, plus number of services directly connected to the pipe.

Location of Pipe

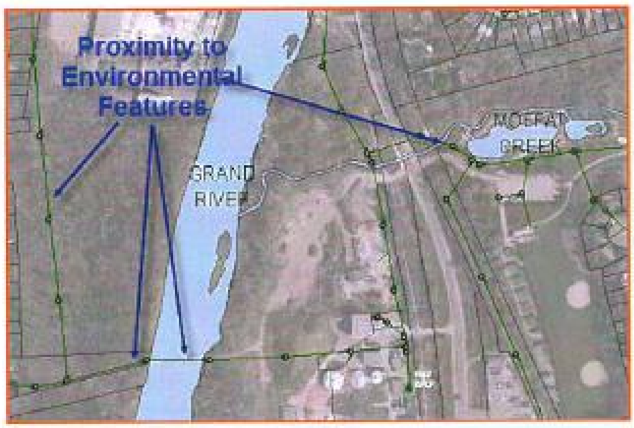
Failure of a pipe, regardless of relative network position, may have a higher consequence in terms of disruption to the community and the cost of managing emergency repairs of a pipe. Failure of a pipe on a major road causes more disruption to traffic compared to failure of a pipe on a local road. Challenging accessibility can also have a significant impact on the cost of emergency repairs.

GIS based maps with layers including street network, buildings, waterways and other datasets can be performed to assign Consequence of Failure based on, for example, the class of road the pipe is located. This is both an economic cost consideration in that pipe under more major roads generally costs more to repair, and a Social consideration due to the increased disruption of traffic. See below for a reasonable consideration.

Location of pipe (class of road)	CoF Factor
Unpaved	1
Minor Local	2
Major Local	3
Collector	4
Arterial/Building/Pool	5
Highway/Waterway	6

Proximity to Environmentally Sensitive Features

Pipes are not always installed within road right-of-way. There are various reasons to install a pipe at a close distance to environmentally sensitive features like rivers, creeks, drinking water source areas and lakes. This is, of course, is an Environmental cost consideration.



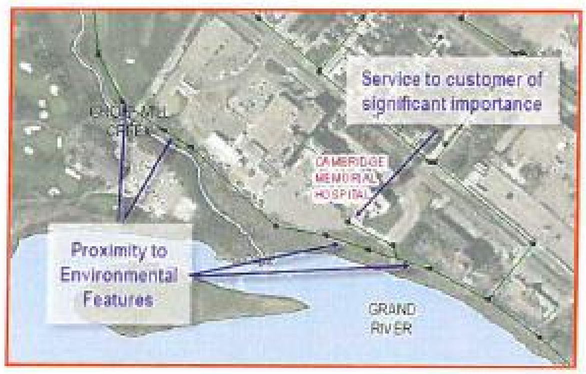
At times, these pipes are hard to access for regular maintenance and may cause significant environmental damage, when they fail. A higher Consequence of Failure factor is set, based on the distance between a pipe and an environmentally sensitive feature. This will, of course, be affected by the nature of the sensitive environment.

Distance between pipe and waterway	CoF Factor
150 LF or more	1
100 - 150 LF	2
75 - 100 LF	3
50 - 75 LF	4
25- 50 LF	5
Less than 25 LF	6

GIS algorithms/models can be set-up to assign Consequence of Failure based on calculated distance of a pipe from predefined set of environmentally sensitive features.

Service to Customer of Significant Importance

Every utility will have a set of customers who are very significant for the well-being of the community. These customers may include hospitals, schools, manufacturing facilities, and emergency services, etc., as determined by the utility. Providing uninterrupted service to these facilities may be a priority for the utility.

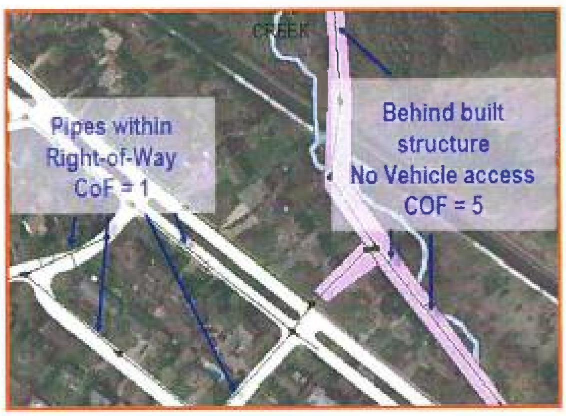


GIS based downstream trace from a service lateral of a customer can be performed to find downstream pipes servicing this customer. Based on pipe's proximity to these customers, a higher Social Consequence of Failure can be assigned.

Distance between downstream pipe to a service lateral for customer with high importance (in m)	CoF Factor
20,000 LF or more	1
15,000 - 20,000 LF	2
10,000 -15,000 LF	3
5,000 - 10,000 LF	4
1,000 - 5,000 LF	5
Less than 1,000 LF	6

Accessibility for Maintenance and Inspection

Access to manholes and pipes are very important for inspection and repairs. Large construction equipment is sometimes required to repair the failure of a pipe. Response time for a service crew may be significantly higher, if access to the pipe is difficult. The failure of such a pipe may cause significant damage to the environment, as well as private properties, due to delays in response created by difficulties in accessing the failure point. A higher Consequence of Failure should be assigned to these pipes. This will affect the economic costs, due directly to the difficulty and perhaps social costs, if the property needs to be disrupted to gain access.



Spatial pipe and utility corridor layers can be used to assign Consequence of Failure for accessibility of pipe.

Accessibility of Pipe	CoF Factor
On Right-of-Way - no traffic control	1
On Right-of-Way - with traffic control	2
On public lands with vehicle access	3
On public lands without vehicle access	4
On private lands without vehicle access	5
Behind built structures and no vehicle access	6

These suggestions should not be considered either complete or absolute. These types of factors can only be determined with considerable input from utilities and their consultants. However, these can serve as guidelines for various types of considerations.

Calculation of Overall Consequence of Failure

Each of the above factors may have a different weighting depending on the goals and priorities of a utility. An overall Consequence of Failure score is calculated as a weighted average of all individual Consequence of Failure.

For example, let's consider a hypothetical 12 inch pipe, 9 feet deep, located on a collector road, 2 miles downstream of a hospital, 40 feet from a creek with no access. In this case the utility considers environmental concerns to be more significant than economic or social, and this is reflected in the weighting factor.

The following is the type of computation that may be used. Since all systems have different characteristics and various utilities have different goals and priorities, it is not possible or practical to attempt a "one size fits all" approach.

Consequence of Failure Computation

	Economic	Social	Environmental
Weighting Factor	**1/4**	**1/4**	**1/2**
Network Position			
Diameter (12")	3	3	
Depth (9')	2		
Location of Pipe			
Collector road	4	4	
Proximity to Sensitive Environment			
40' from creek			5
Serves Important Customer			
2 miles downstream of hospital		3	
Accessibility			
Needs traffic control	2		
TOTAL	**11**	**10**	**5**
TOTAL / POSSIBLE (6*#)	11/24 = 0.458	10/18 = 0.555	5/6 = 0.833
WEIGHTED (TOTAL * Weighting Factor)	0.458 * 1/4 = 0.115	0.555 * 1/4 = 0.139	0.833 * 1/2 = 0.417
COF = SUM(of WEIGHTED)***6**	4.03		

In this example, each of the various factors were equally weighted when considering the individual Economic, Social and Environmental rates. However, these could be weighted individually (i.e. diameter considered more important than depth). Or, a utility could decide to rate each based upon the single highest rated factor in each column, or by what the utility considers the most crucial component of each. A table such as this, along with its computation and weighting methods, must be developed based upon sufficient consultation with the owner.

The Consequence of Failure value should be recorded in PACP Header Field 22, MACP Header Field 20 and LACP Header Field 21.

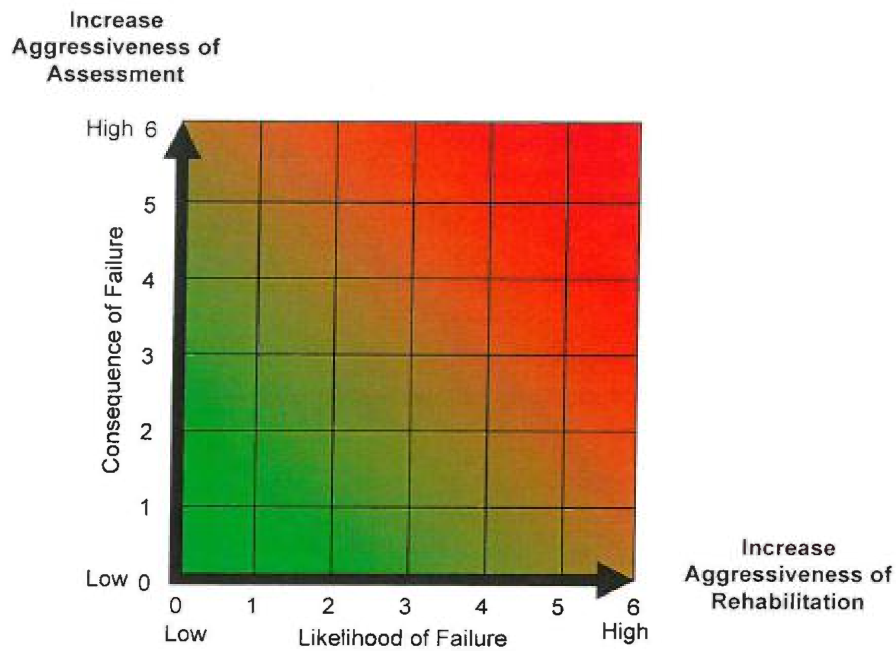
Managing Asset Risk

The overall risk associated with a failure event is a function of the likelihood of a failure event and its consequence. Not all highly probable events need the same attention, since they may not have equally high consequence (impact) to the community. Any mitigation and/or response plan shall be designed based on overall risk due to a failure event.

Upon establishing standardized definitions and a scoring system for Likelihood of Failure and Consequence of Failure, a risk matrix can be developed and plotted for review and analysis. The following figure is a schematic of a risk matrix and suggested Likelihood of Failure and Consequence of Failure categories, which is consistent with our prior discussions.

Increased Likelihood of Failure should result in more aggressive maintenance and repair. Increased Consequence of Failure should result in increased assessment. The resulting matrix can provide the basis for an economically efficient, balanced and proactive assessment, maintenance and rehabilitation program.

Appendix D – PACP Based Risk Management



This figure illustrates risk management strategy for a pipe asset based on Likelihood of Failure and its Consequence of Failure - each with a range of 0 to 6. As with most of these concepts, this should be considered a guide for a reasonable approach. There are many variations that can be made to address unique needs of an individual utility. The specific approach used for a utility must be developed with sufficient input from utility staff and must be implemented consistently throughout the utility's asset management system.

Since asset failure can result in more expensive, socially difficult and environmentally destructive consequences, increased Consequence of Failure (CoF) should lead to more aggressive assessment. Within the graph, those segments with a CoF in the darker green range may need to be cleaned and inspected less frequently. Those in the lighter green/red range should be inspected more frequently.

Pipe rehabilitation priority and methodology is directly related to the condition of the pipe which is the determining Likelihood of Failure (LoF) factor. If a pipe exhibits more severe defects, then it generally should be rehabilitated more aggressively.

However, this rehabilitation must be based upon the overall strategy and goals of the utility and in concert with CoF principals. For example, those pipes with a low CoF (say in a residential cul-de-sac) may only be scheduled for rehabilitation as total failure occurs.

In contrast, more crucial pipe (large diameter in a protected wet lands) may, for example, be scheduled for rehab, when the LoF exceeds 3.

The Asset Management Plan should clearly explain the details of the processes associated with this.

Ultimately, all of the data collected through PACP inspections and from other inventories and assessments, along with prior maintenance and rehabilitation data, will be combined to either upgrade or create a GIS data base. This database will include or provide information that answers the basic asset management questions. Perhaps the most critical portion of such a data base is that which informs a utility as to what the next action is regarding each asset. This may be an assessment such as CCTV, a maintenance activity such as cleaning a line, or a rehabilitation activity such as lining with CIPP. Each of these should also have an estimated cost and projected date (typically year).

All of this must be accomplished based upon the stated goals and priorities of the utilities and according to the generally agreed objectives of an asset management program.

The following table illustrates a typical manner such data can be used.

Appendix D – PACP Based Risk Management

Up MH	Dn MH	Street	Loc Code	Year Laid	Rehab Yr	Rehab Meth	LF	DIA	Mate rial	Observed Defects	QOR	LoF	CoF	RISK	Rehabilita -tion	Later -als	Projected Cost
A00 1	T01 2	Lake O' Odonell Rd.	Light Highway	1921	1980	Slip Line	356	10	PE			0	3	**0**		2	
A00 2	'A00 1	Easement Ball Park Rd.	Easement/ Right of Way	1921			92	10	VCP			0	3	**0**			
A00 3	A00 2	University Esmt	Easement/ Right of Way	1921	2004	Pipe Burst	188	10	PE	15% MWLS	2100	2.1	2.5	**5.3**			
A00 4	A00 3	Solace M Freeman	Easement/ Right of Way	1921	2004	Cured In Place	220	10	FRP	MWL (50%) DAGS	2100	2.1	3.0	**6.3**	Clean Line		$440
A00 5	A00 4	Solace M Freeman	Main Collector Highway	1921	2004	Cured In Place	223	10	FRP	30% MWLS, DAGS	2400	2.4	4.0	**9.6**	Clean Line		$1000
A00 6	A00 5	Alabama Esmt	Easement/ Right of Way	1921	2004	Cured In Place	410	10	FRP	DAGS, JOL stopped TV @343 ds. Reverse complet ed	4100	4.1	2.8	**11.5**	Point Repair Clean Line	2	$4,819
A00 7	A00 6	Sollace M Freeman Esmt	Easement/ ROW - 60 ft from Stream	1969			359	10	VCP	MWL (40%), FL, CM, MCU, BVV	5141	5.1	4.4	**22.4**	Pipe Burst		$18,668
B00 1	A00 7	Sollace M Freeman Esmt	Easement/ ROW - Upstream End of System	1969			253	8	VCP	MWL (20%), TFD, FM, CM	4432	4.4	2.1	**9.2**	Pipe Burst		$11,623

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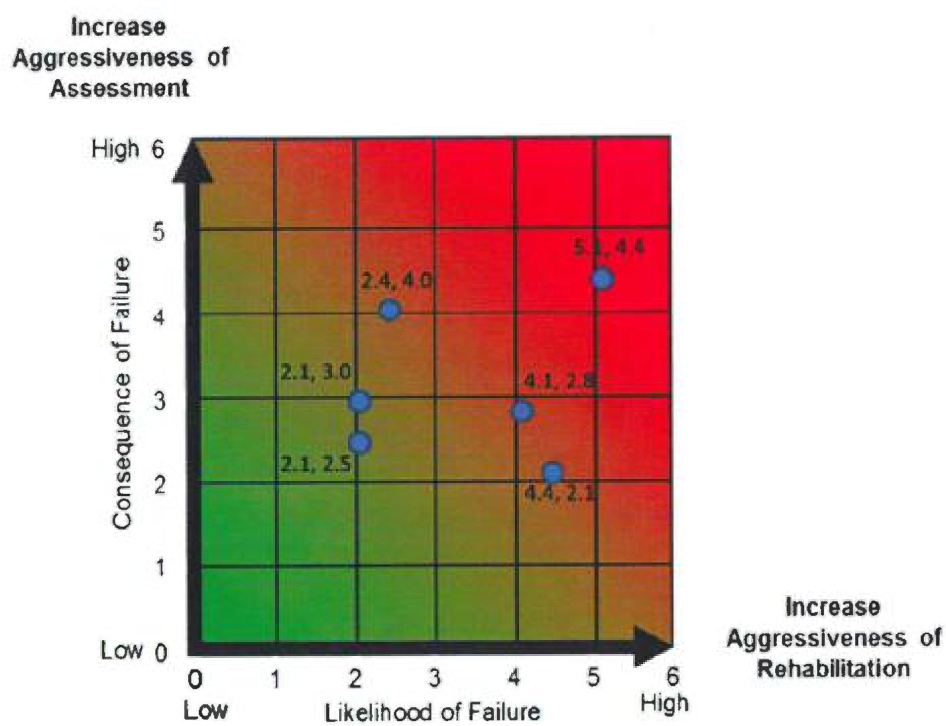
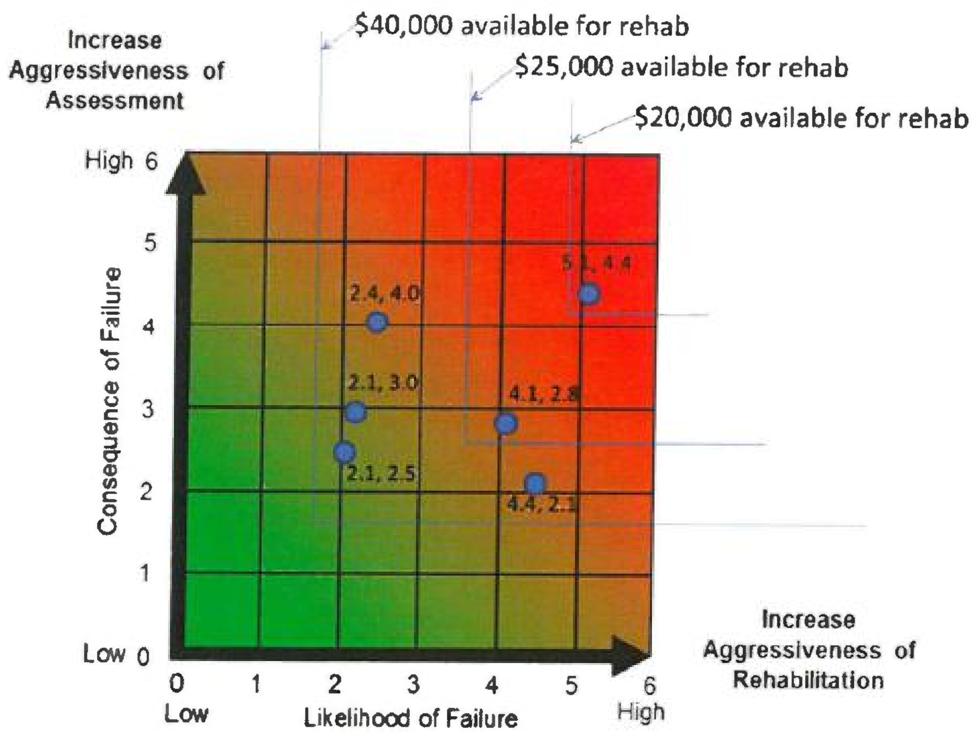
To create a visual representation of how the risk scores compare to one another, a graph of the CoF versus the LoF can be created. Using the numbers in the previous example, a graph of the scores would be as follows:



Using the rehabilitation costs estimated in the example table and starting in the upper right-hand corner (starting with the highest risk assets), the table can help to prioritize which projects should be undertaken, depending upon the budget that is available for rehabilitation projects. The lines are drawn and labeled with the amount of rehabilitation budget that would be necessary to complete all of the projects to the right and above the lines. This method of prioritizing the projects will help ensure that the utility gets the largest risk reduction for each dollar spent on rehabilitation.

Appendix D – PACP Based Risk Management



This approach can be used to systematically invest O&M dollars into assessing and rehabilitating the assets that expose the utility to the largest amount of risk. Over time and with sufficient investment, consistently applying this approach will allow utilities to reduce the amount of resources dedicated to emergency response and shift over to more strategic risk-based management of the system assets. The number of asset failures experienced each year should trend downward. When failures do occur, there should be less of a negative impact on the overall system performance. Operation and maintenance budgets should be more predictable and easier to manage (i.e. more planned activities and less emergency expenditures).

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Appendix E — Basis for Development of Probability of Failure Curves and Tables for MSD's Application with Hansen's Advanced Asset Management Module

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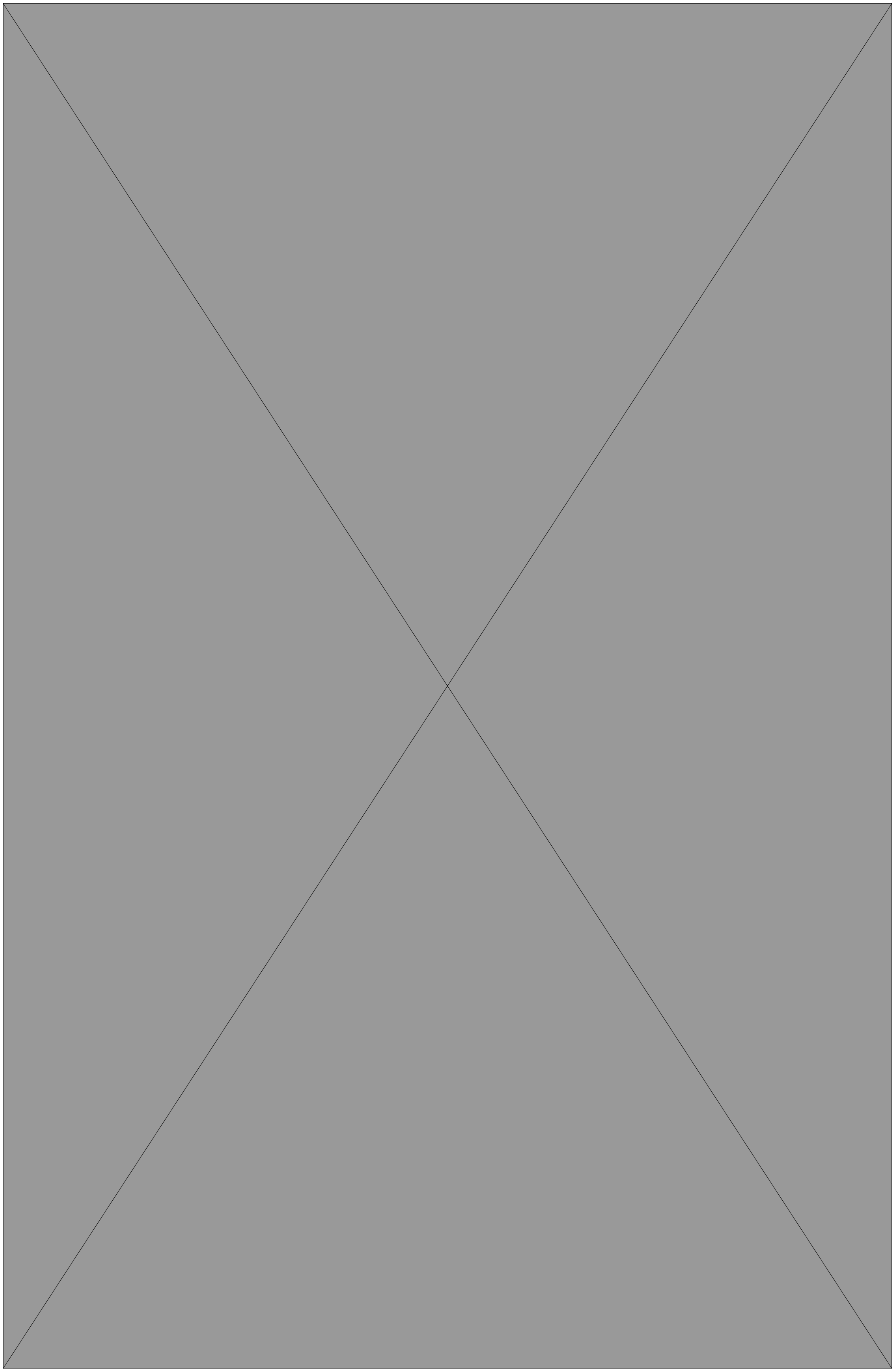


PACP Quick Rating

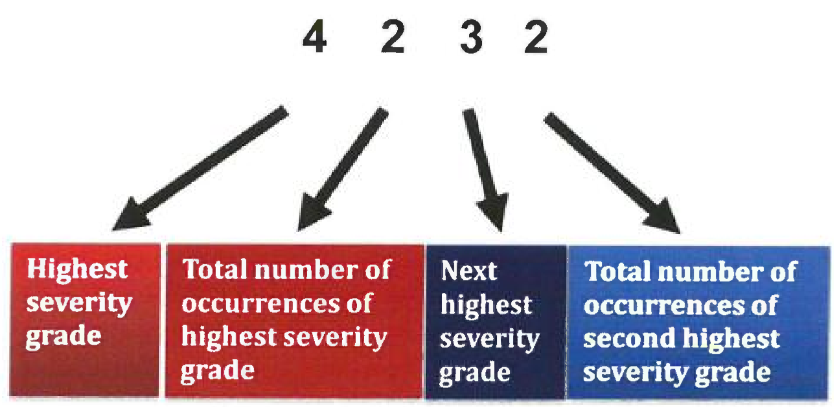
The PACP Quick Rating is a shorthand way of expressing the number of occurrences for the two highest severity grades. The quick rating is a four character score compiled as follows:

First Character: Highest severity grade occurring along the pipe length.

Second Character: Total number of occurrences of that highest severity grade. If the total number exceeds 9, then alphabetic characters are used as follows:
10 to 14 = A, 15 to 19 = B and 20 to 24 = C, etc.

Third Character Second highest severity grade occurring along the pipe length.

Fourth Character: Total number of the second highest severity grade occurrences. If the total number exceeds 9, then alphabetic characters are used as follows:
10 to 14 = A, 15 to 19 = B and 20 to 24 = C, etc.

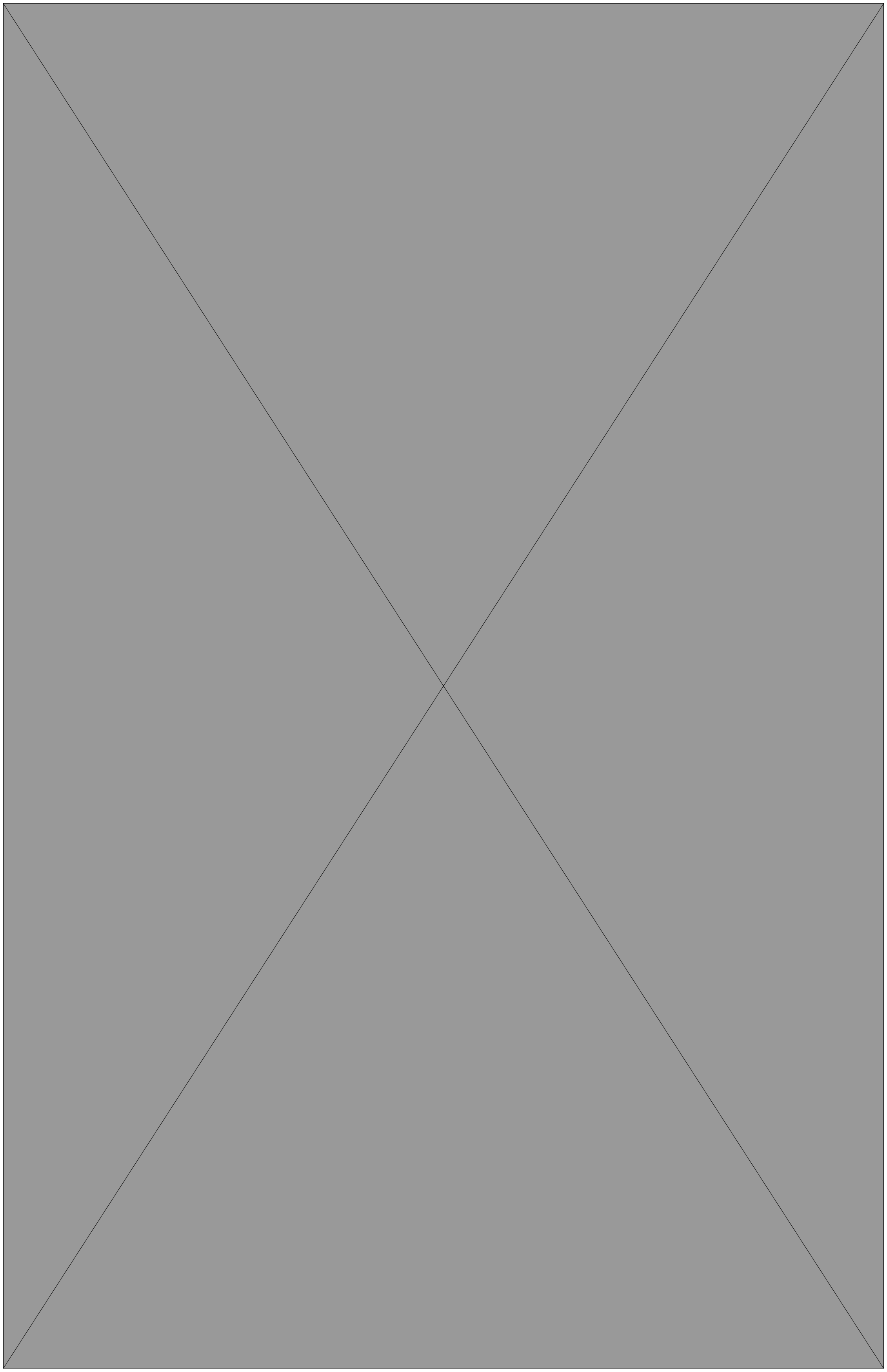


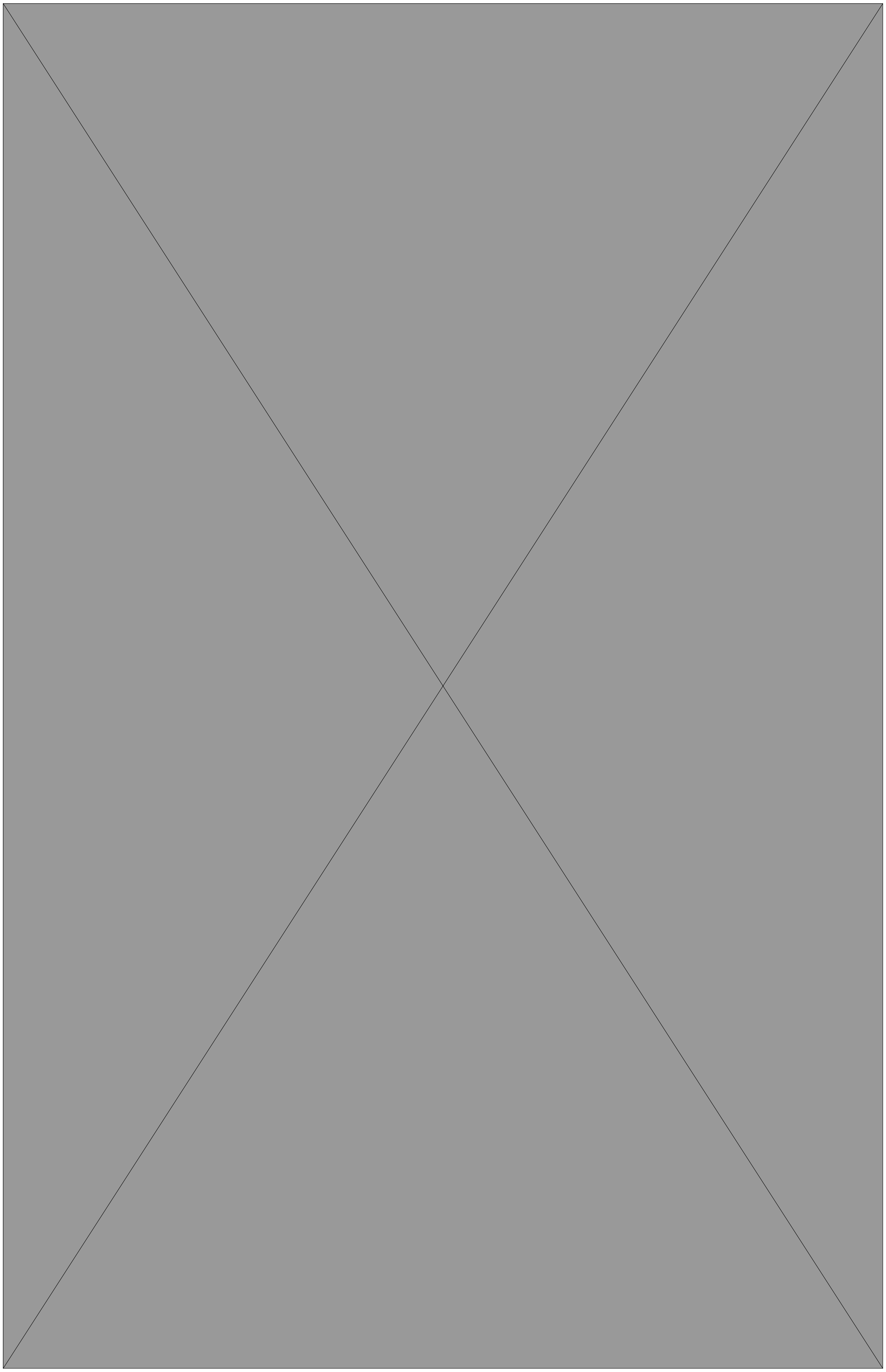
For example: 4B27

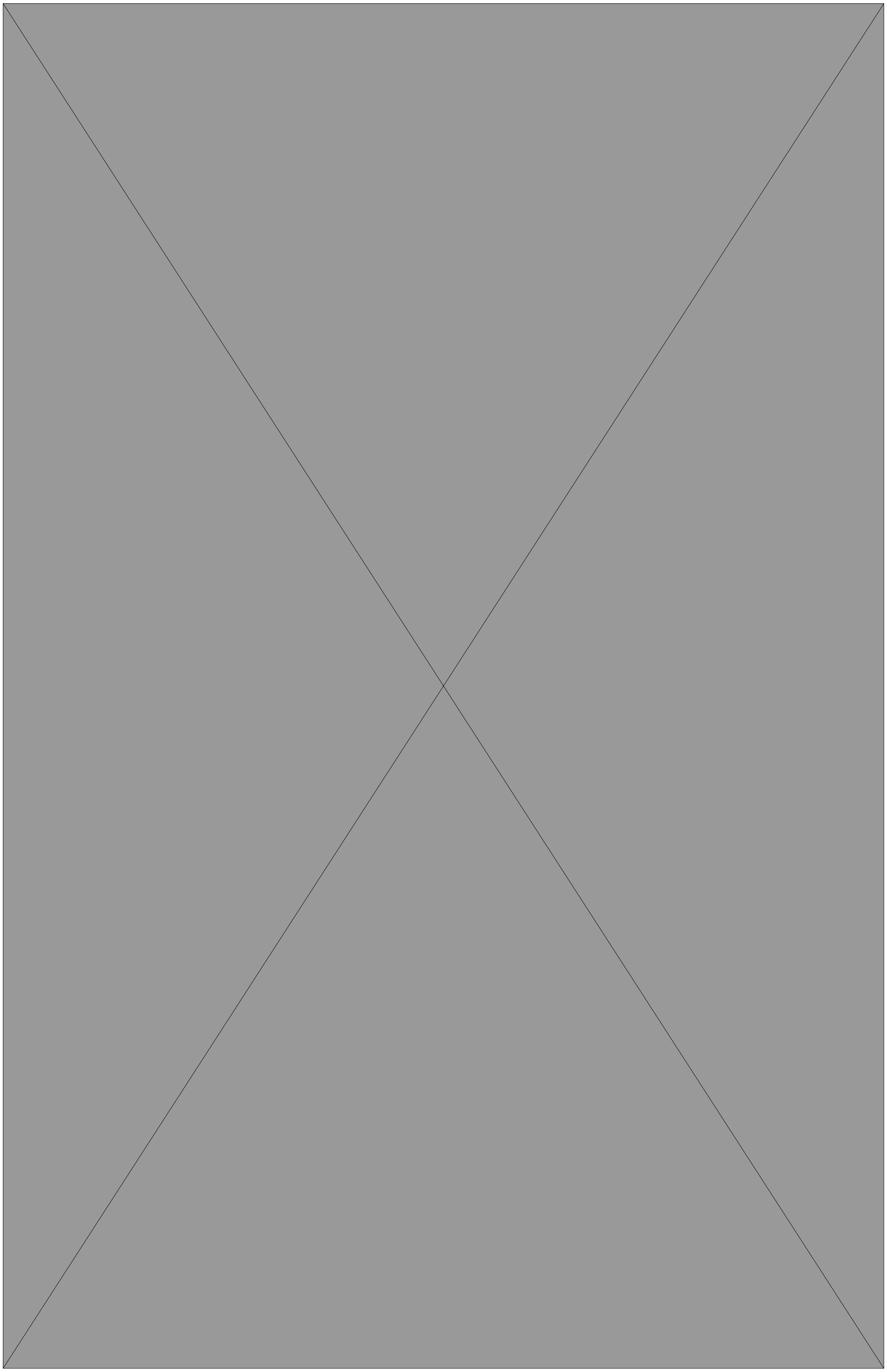
This immediately shows no grade 5 defects or grade 3 defects were observed. However, fifteen to nineteen grade 4 defects and seven grade 2 defects were found.

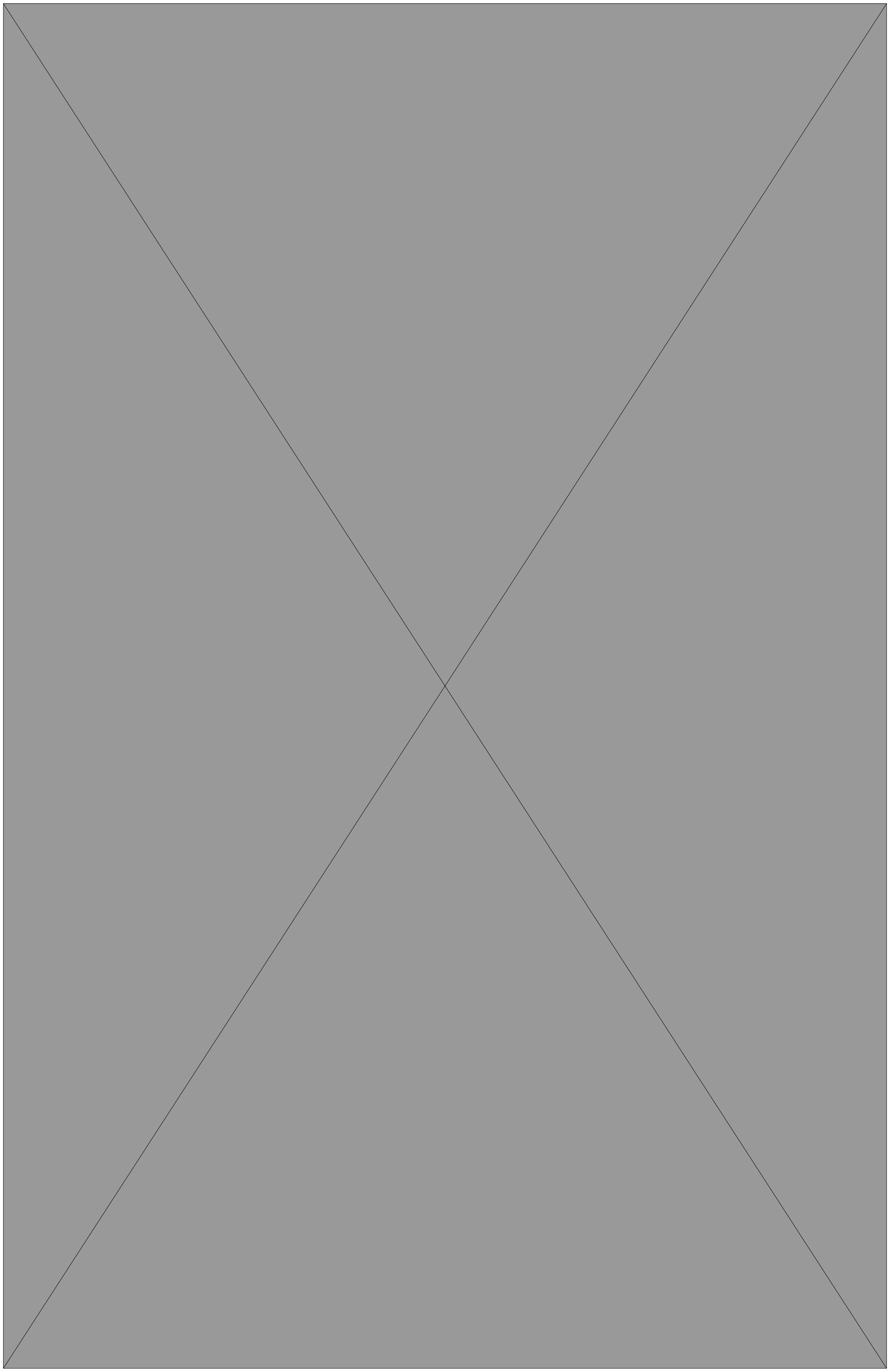
Another example: 3224

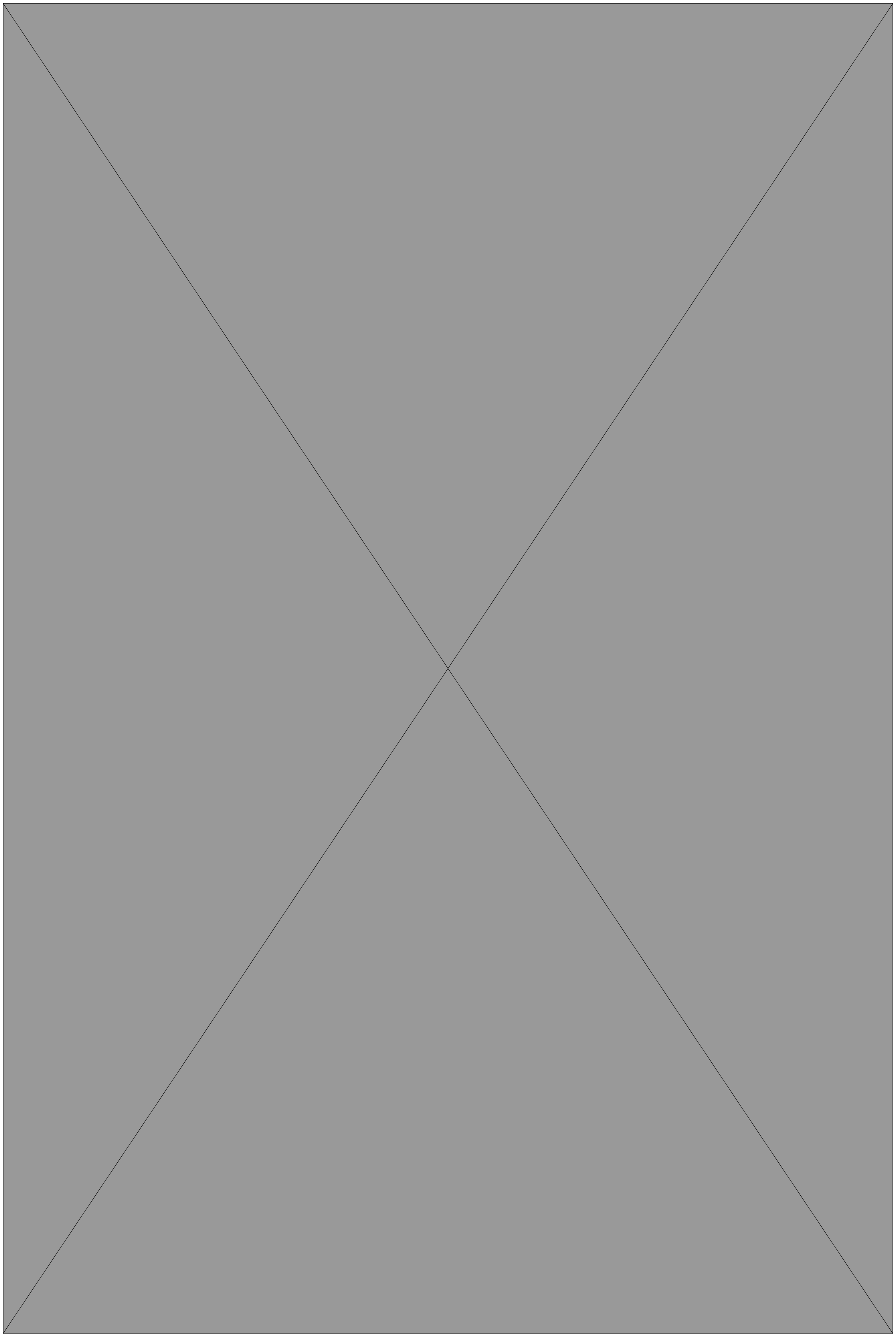
Two grade 3 defects and four grade 2 defects were observed in the pipe, however, no grade 5 or grade 4 defects were found.

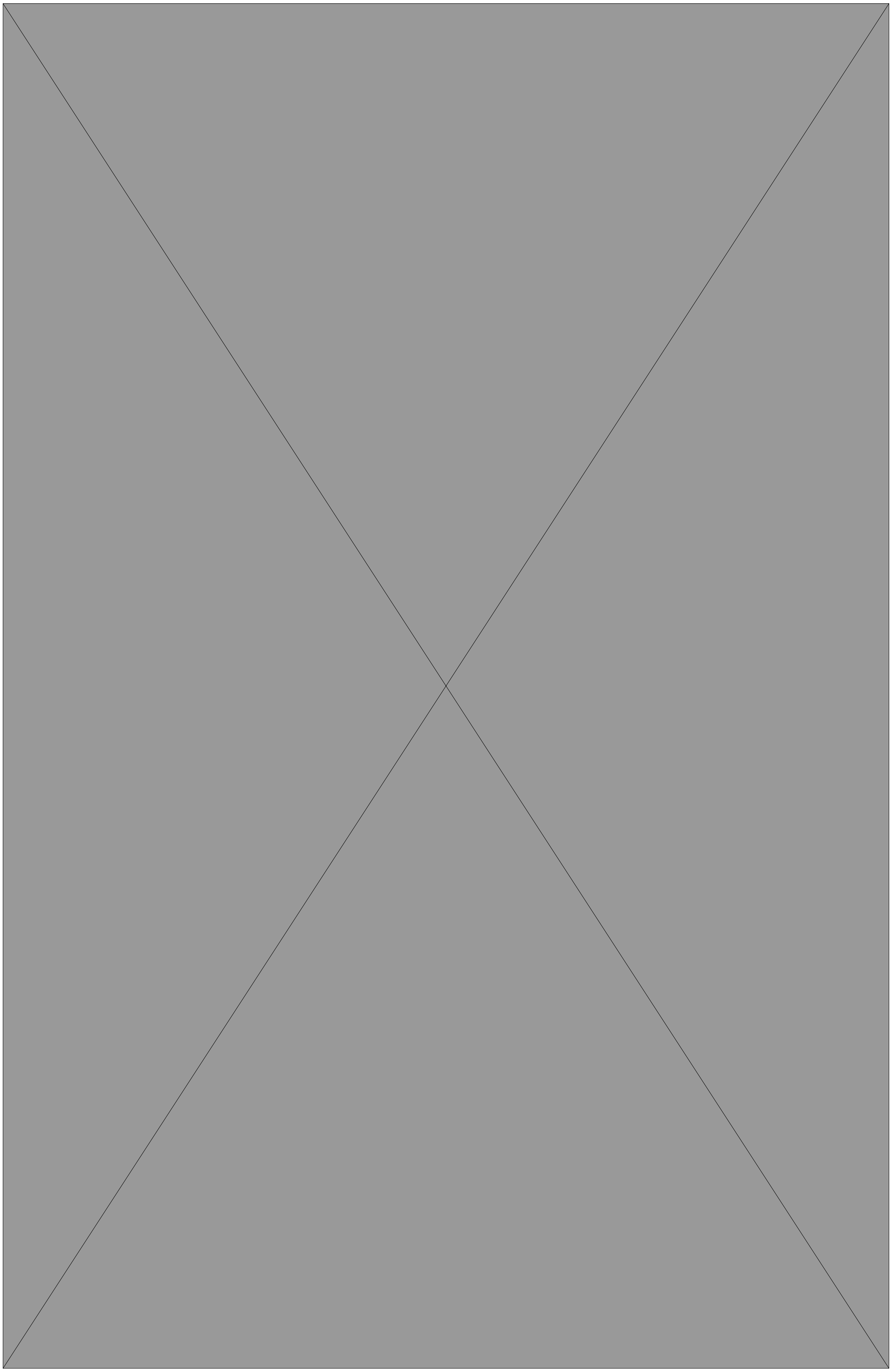


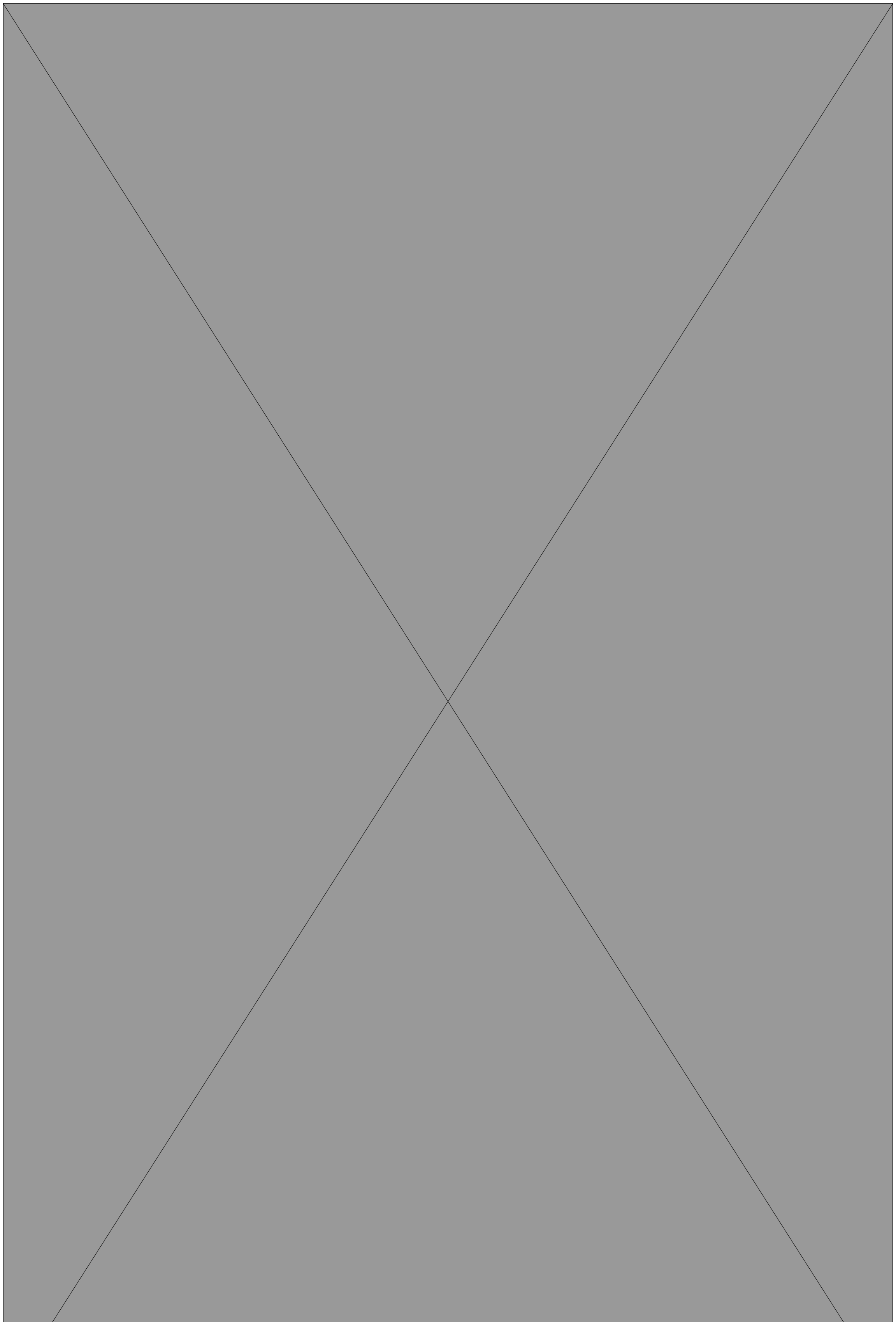


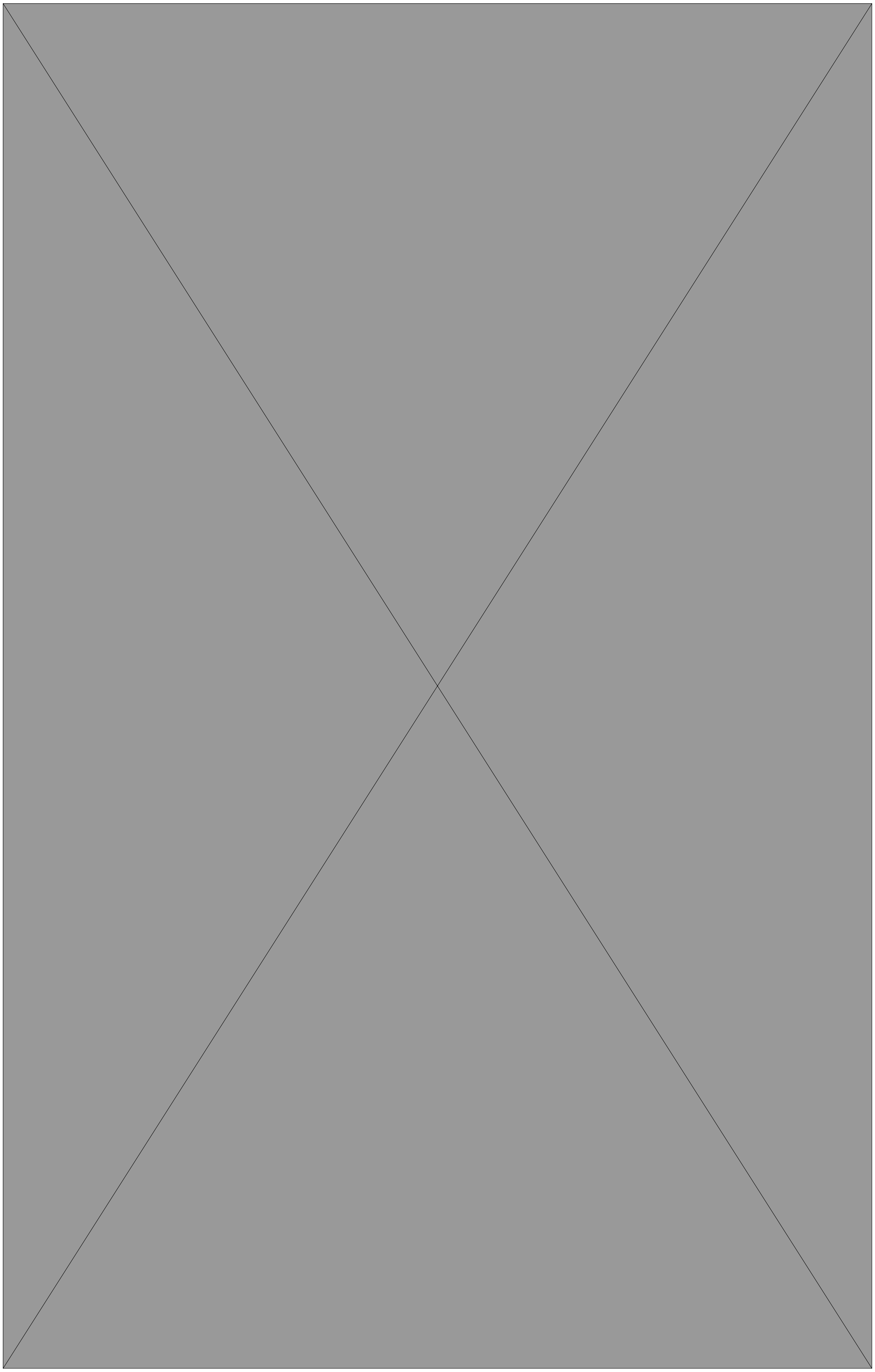


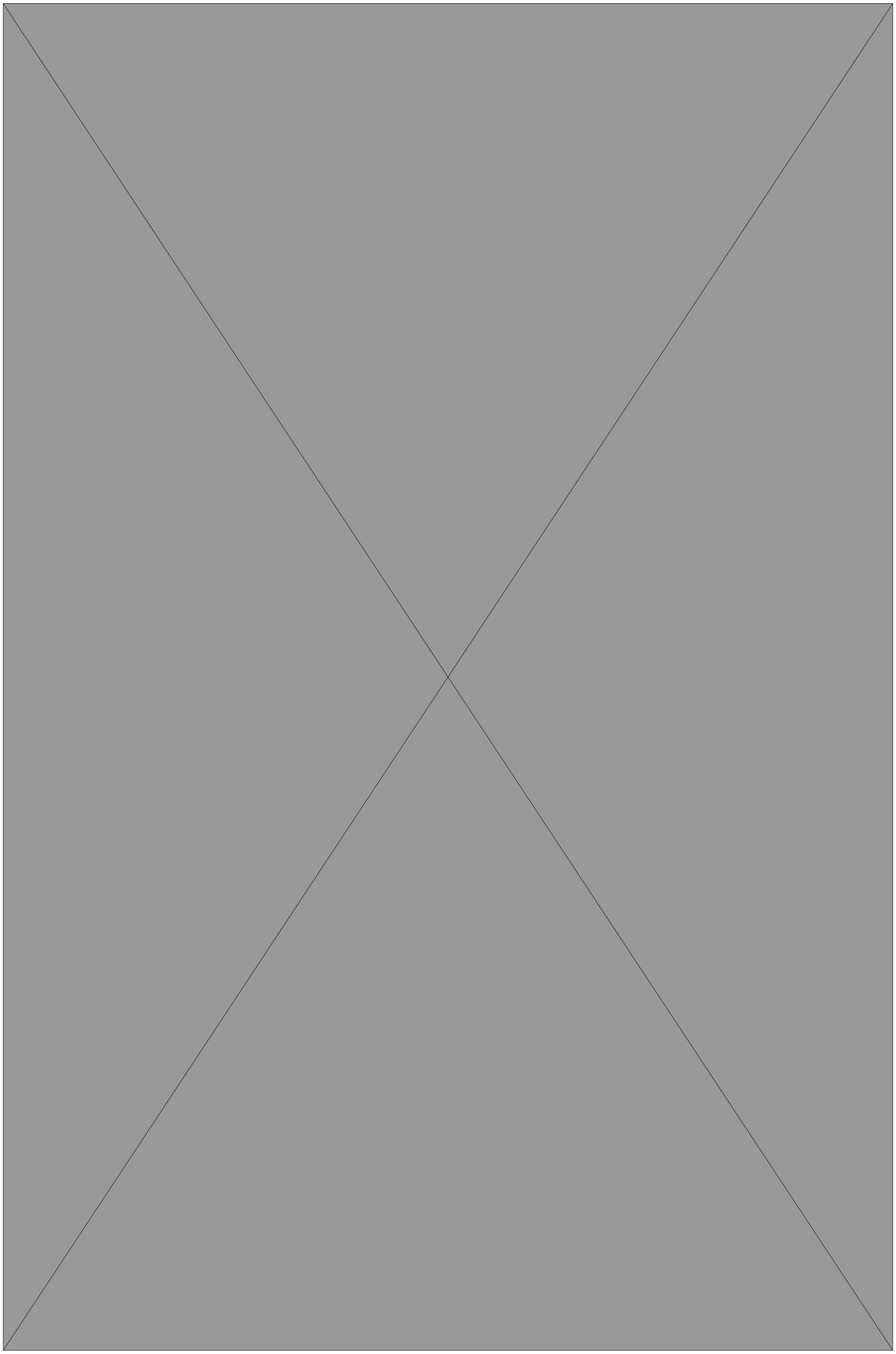


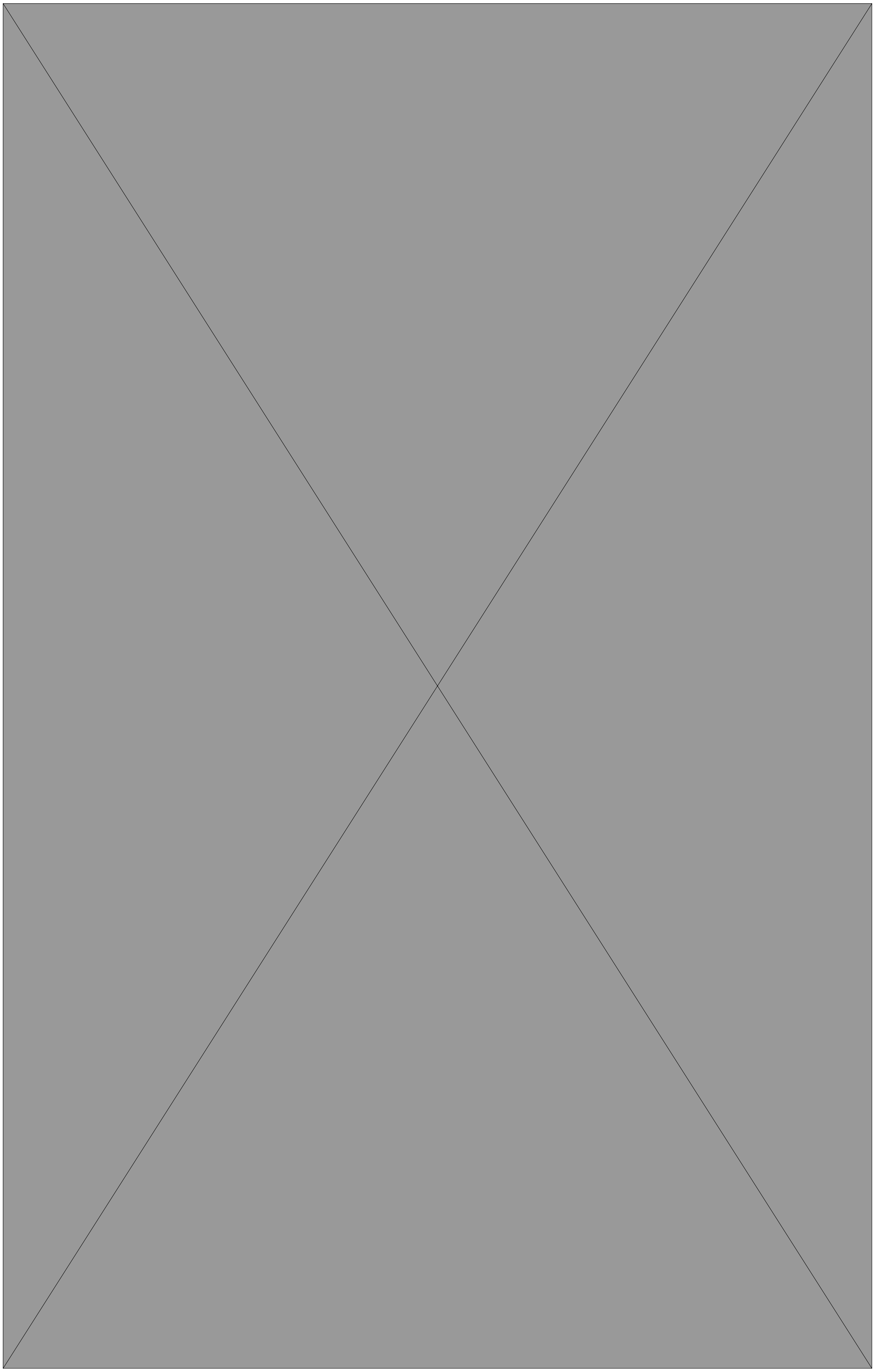


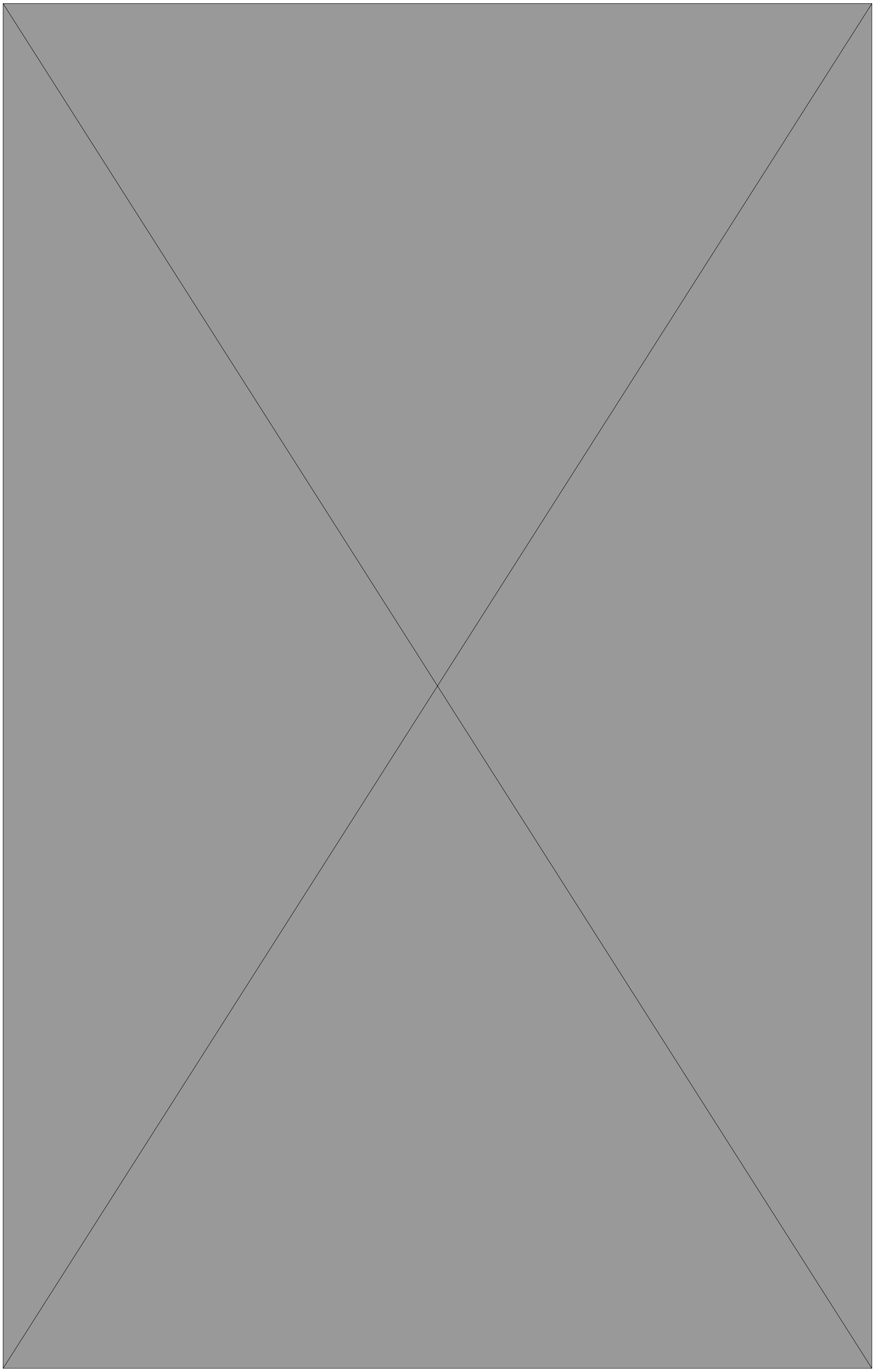


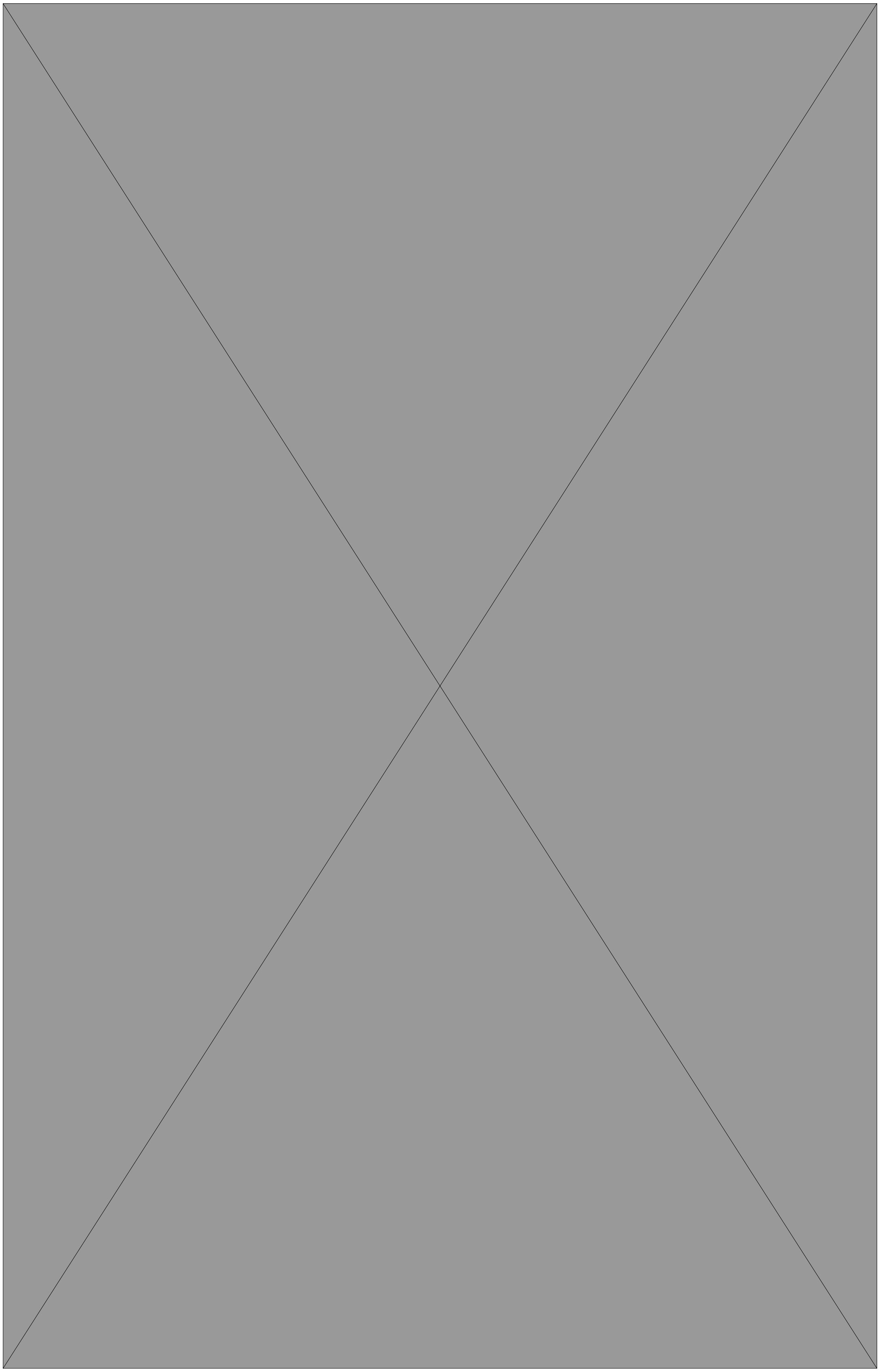


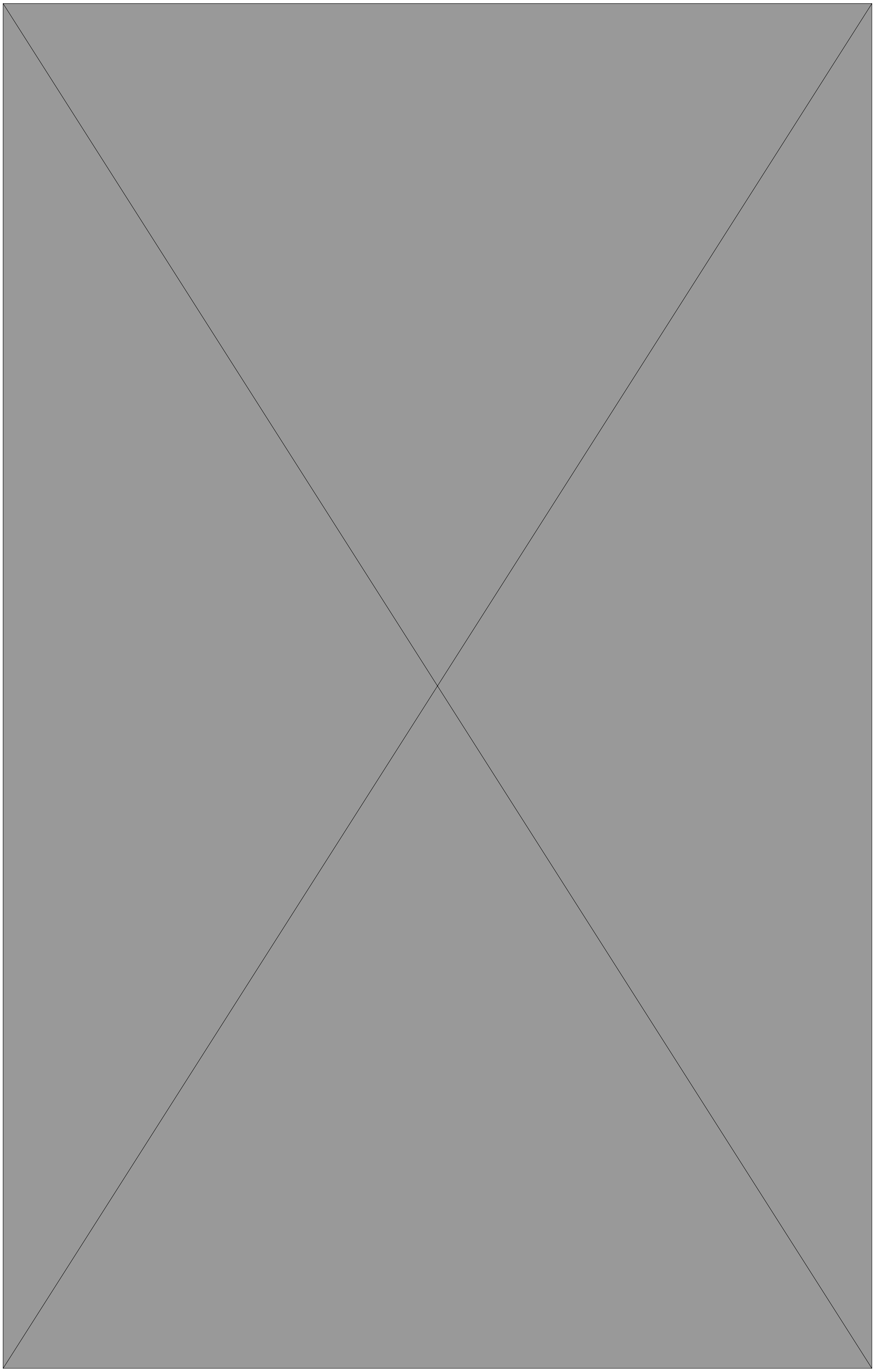


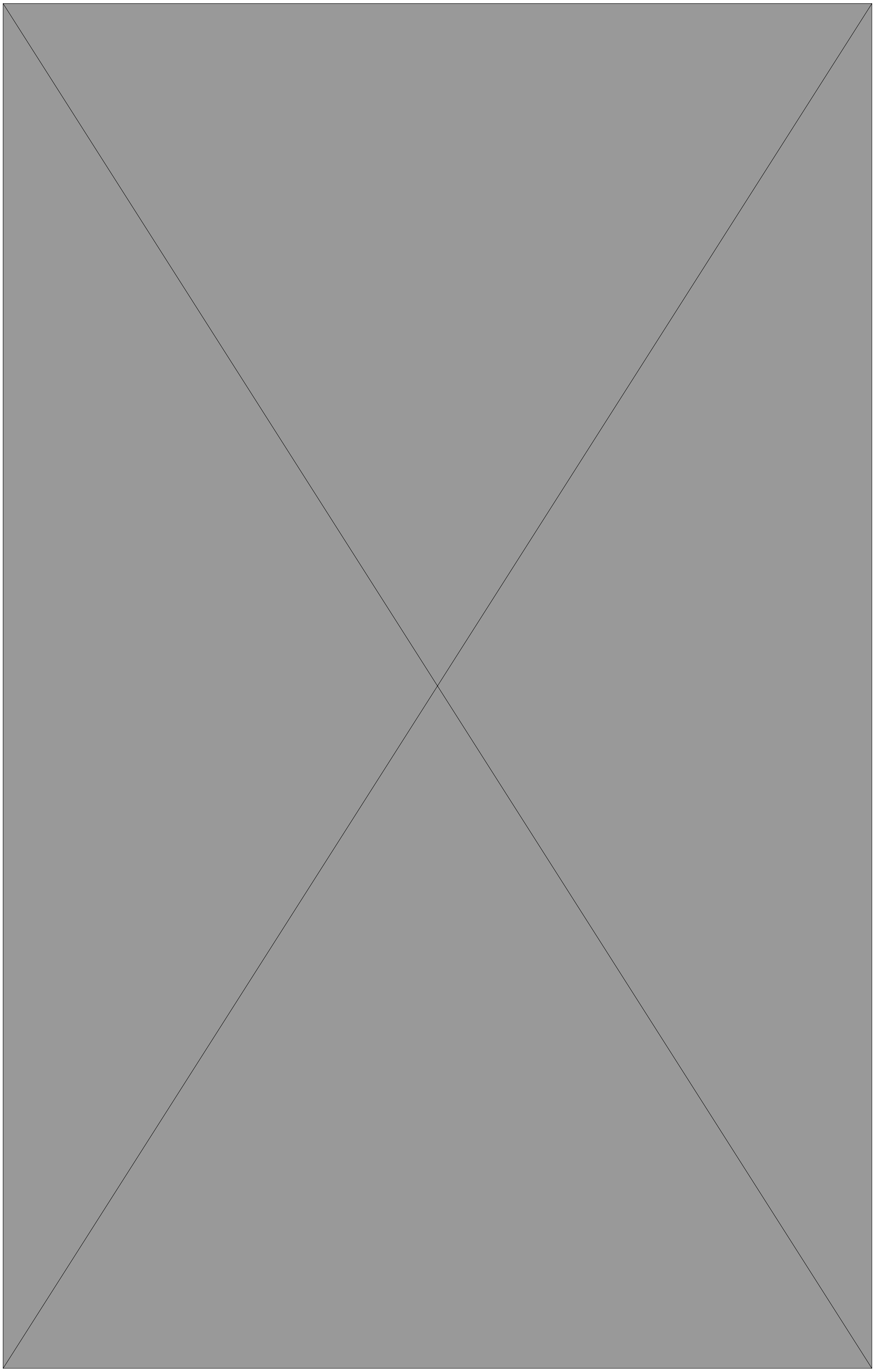


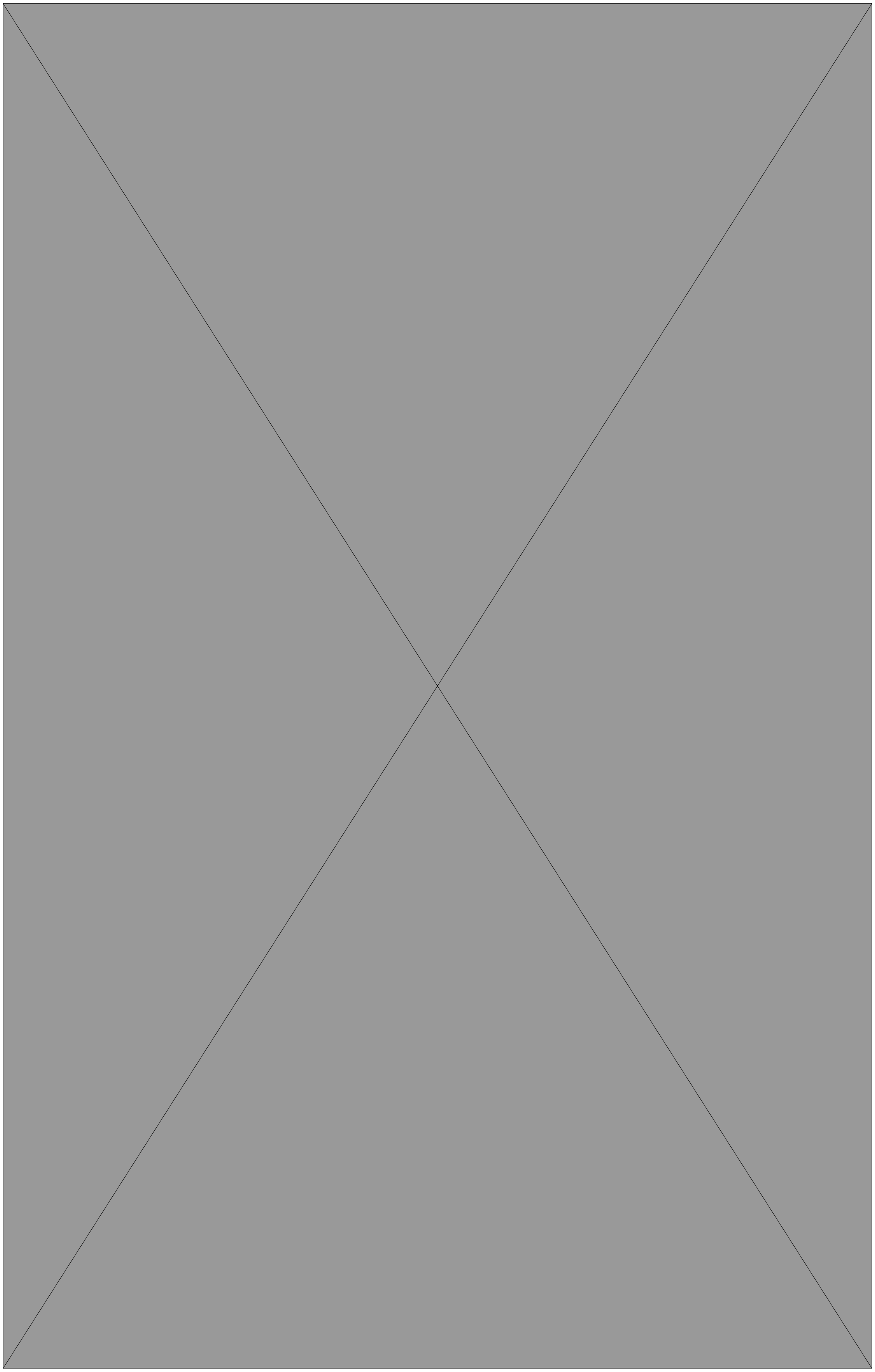


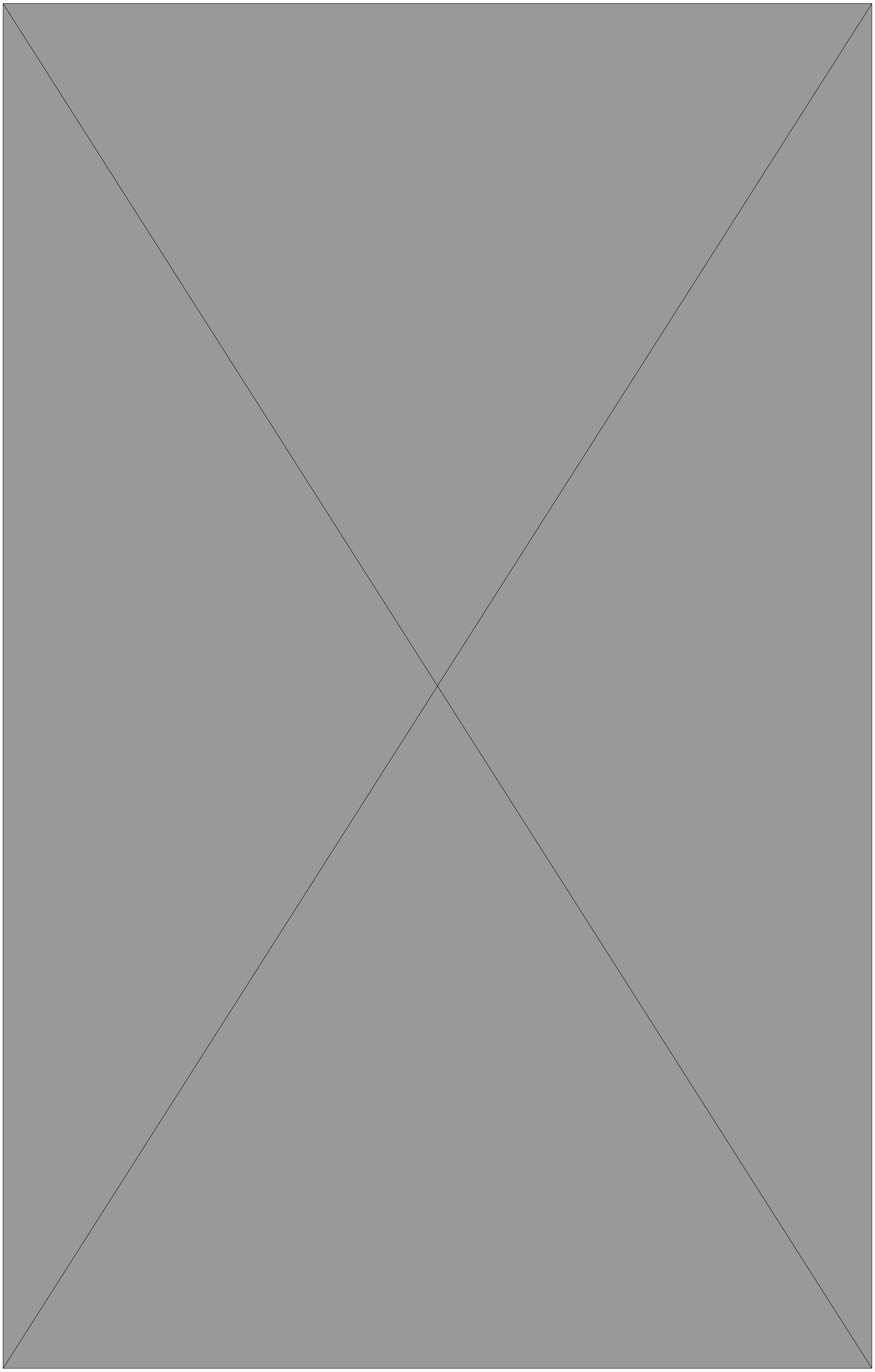


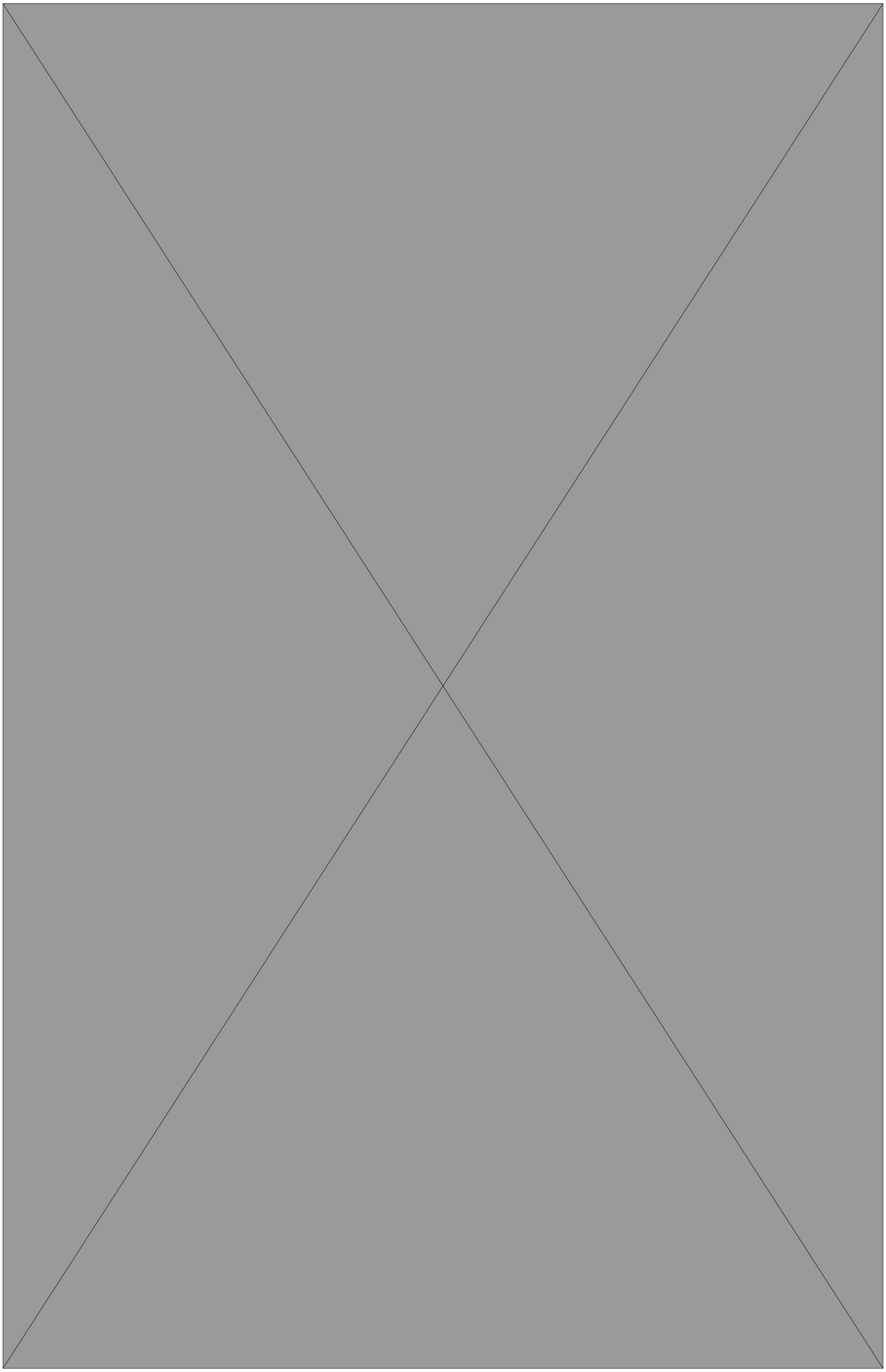












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Appendix F Consequence of Failure Index

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Consequence of Failure Index

Measurement	Data Source	Negligible	Low	Moderate	High	Severe	Null Handling	Weight
		Consequence of Failure						
Score		1	2	3	4	5		
Cave-In - Potential	SEWER[TYPE]_DET.ROADCLASS	Sewer not under road (NONE)	Sewer under low volume roads (LOCAL)	Sewer under moderate volume roads (SECCOL)	Sewer under high volume roads (PRICOL, MINART)	Sewer under high volume roads (MAJART, XWAY)	Exclude null values as 0	10
Depth	COMPSMH.DEPTH	0-<8 VF	8-<12 VF	12-<16VF	16-<20VF	>=20 VF	Exclude null values as 0	3
Diameter - Gravity	COMPSMN.PIPEDIAM, COMPSMN.UNITTYPE in (C, CI, S, T,O,E)	6-<12" diameter	12-<24" diameter	24-<36" diameter	36-<60" diameter	>=60" diameter	Exclude null values as 0	10
Diameter - Force Main	COMPSMN.PIPEDIAM, COMPSMN.UNITTYPE in (F,R)	0-<2" diameter	2<3" diameter	3-<4" diameter	4-<6" diameter	>=6" diameter	Exclude null values as 0	10
Land Use	PRCLZON.ZONIN	Undeveloped land use	Low density land use	Moderate density land use	Heavy density land use	Urban / Central Business District land use	Exclude null values as 0	10
Condition - Knowledge	NOW()-ACTCODE = SMFTVI/MHI COMPDTTM	Condition assessment within past 3 years	Condition assessment within past 4-5 years	Condition assessment within past 6-7 years	Condition assessment within past 8-9 years	Condition assessment >=10 years ago or no assessment	Include null values as 5	1
Wastewater Characteristics	Upstream pretreatment permittees	No upstream permittees	GDP upstream	Multiple GDPs upstream, but no SIUs	SIU upstream	Multiple SIUs upstream	Include null values as 1	6

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Louisville and Jefferson County Metropolitan Sewer District Continuous Sewer System Assessment Protocol

Safe, clean waterways