ALGORITHM DEVELOPMENT FOR SEWER PIPE SYSTEM CONDITION ASSESSMENT USING MULTI-SENSOR (MSI) TECHNOLOGY

by

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Abstract

ALGORITHM DEVELOPMENT FOR SEWER PIPE SYSTEM CONDITION

ASSESSMENT USING MULTI-SENSOR (MSI) TECHNOLOGY

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The University of Texas at Arlington, 2018

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This study investigates the performance of all the current large-diameter pipeline system of The City of Arlington (COA) sewer lines of 48 miles (24-inch inner diameter and above for rigid and flexible pipes). Proper inspection and rehabilitation plan for the city sewer pipeline system are better choice for the municipality and tax payers in terms of cost than dealing with pipe damage and collapsing problems when they happen.

The City of Arlington (COA), University of Texas at Arlington (UTA) and RedZone Robotics have established a Technology Partnership Program (TPP) to perform a condition assessment on the all COA large diameter sewers using advanced multi-sensor inspection (MSI) technology. The MSI Equipment has multi-sensor technology including Digital CCTV, Sonar, Laser sensors. As an essential part of the agreement in the TPP Program, a pipe assessment software is developed for this study by UTA team to obtain information about the sewer pipes condition from laser and sonar profiles beyond conventional pipe visual inspection. The developed software is found to be capable of calculating the debris level, deposit level, blockage level, corrosion level, sewer water level, pipe ovality as well as combining the laser and the sonar profiles and evaluate the condition of the sewer pipelines. Furthermore, a visual inspection is performed along with the laser and sonar inspection to identifies all other defects in the pipes that couldn't be

detected using MSI technology such as fractures and roots intrusion. All the field inspection is already done for all the city by UTA and COA teams and approximately 6 miles of the COA large diameter pipes have been analyzed by UTA team.

Finally, statistical models are developed for Identification of the probability of the pipe damage such as the corrosion level in ductile iron pipes and PACP structural defect score in vitrified clay pipes using few parameters such as pipe age, pipe diameter, pipe slope, pipe average flow depth and pipe average flow velocity.

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Introduction

Research Background

The sewer systems of any civilization represent a significant part that assure the transport of contaminated or dirty water away from housing communities. The first sewer pipeline appearance was in Rome around 800 B.C. and was made from stone and cement. Sewer system is either domestic or industrial that transports waste from public or private entities to treatment plants after which the material is allowed to enter any main water stream. Engineers usually design sewer pipes that have an operating velocity of 2 ft/sec to ensure proper flow of sewage material from houses to treatment plants to the body of water (Deshmukh 2012).

Sewer systems account for approximately half of the underground infrastructure in the United States (Shook and Bell, 1998). United States has over 800,000 miles of public sewer pipe lines and 500,000 miles of private lateral sewer pipe lines that connect private properties to the public sewer lines. Both of the public and private sewer lines is prone to overflows, blockages, and structural failure. The American Society of Civil Engineers (2017) rates the wastewater infrastructure as a D^+. ASCE expected that more than 56 million people will connect to centralized treatment plants by 2032, rather than private septic systems – a 23% increase in demand. A $ 270 Billion gap has been estimated by Environmental Protection Agency (EPA) for the next 25 years.

The Urban drainage and water supply systems are intended to have a long service life. Because these underground infrastructures are capital-intensive and vital components of a sustainable urban system, it is essential to maintain a certain level of infrastructures serviceability. There is always a challenge to minimize the maintenance costs and maintain the risk of failures at a tolerable level. Information on the current status of the assets can enhance proper decision-making. There are several techniques available for the assessment of sewer conditions: visual inspection by closed circuit television (CCTV), radar, acoustic techniques, sonar, laser profiling or a combination of these technologies in order to benefit from the strengths of each technology (Stanić et al., 2017).

Usually, closed circuit television (CCTV) inspection technique is used by many municipalities for inspecting their sewer pipelines. However, using only this technique would give imprecise conclusions. Also, it suffers from significant subjective and. Hence, using different sewer inspection technologies and designing a condition assessment model are essential to decrease subjectivity and errors and generate more precise and reliable results (Kaddoura 2015).

This study uses more than one inspection technology. The robot that was assigned to this project has laser profiling, sonar measurements as well as CCTV. This research is conducted to evaluate the condition of the all current large-diameter pipeline system in the city of Arlington in Texas (24-inch inner diameter and above for rigid and flexible pipes), using proven principles of material science, polymer chemistry, materials testing, and experimental data analysis. The Center for Structural Engineering Research, led by Dr. Ali Abolmaali at University of Texas at Arlington (UTA), will be responsible for analyzing and assessing the measured data of the sewer pipes and recommending if any segment in the pipe system needs to be cleaned, repaired or replaced.

ASCE has recognized the UTA-COA initiative as one of 15 challenging and Infrastructure Game Changers Projects in the nation in its 2017 Infrastructure Report Card. UTA and COA research teams have inspected over 40 miles (out of 48 miles) of the COA large diameter sewer pipes and UTA's research team has processed and analyzed approximately 15 miles so far. It was already found that some of the inspected sewer pipes need to be replaced or to be cleaned. In the past, the COA, as many municipalities over the nation, was estimating the pipes condition by using few models, and that could be far away from reality due to the different input factors to the model. By the end of this study, the COA will have enough information about its sewer pipes condition. The pipe could suddenly collapse and without showing significant warning signs as they are buried under the ground. Performing proper inspection cycles with high technical methods that could drastically limit collapses from happening. In some cases, the sewer pipe collapse could be lethal. A deputy was killed in West Side Road in San Antonio last year (San Antonio Express-News 2016).

Furthermore, sediments, solids, fat, oil, root intrusion, grease and other attached deposits are the main causes for sewer pipe blockage and can make the sewer pipe overflow. Thus, addressing the aforementioned factors that cause the pipe blockage and clean these pipes would potentially decrease the cost of water treatment by 10%. In addition to that, sewer pipe overflow could be harmful to the surrounding environment (Kaddoura 2015).

UTA's research team, through the developed software, was able to detect pipes' maximum erosion, deposits and debris levels, deposits and debris areas per section, deposits and debris volume for each pipe line segment, mean erosion, deposits and debris levels per section, percentage of deposits, debris and blockage areas of the pipe section area, and sewer water level. All of this information helps to evaluate the sewer pipe condition in the COA and take proactive actions. Maintaining pipes by taking proactive actions such as, rehabilitation, replacing and cleaning could be cost and time efficient and probably save humans life. The results of this research help the people living in the COA to have a better and healthy environment by limiting the collapse of pipes and pipes overflow. Also, the result is beneficial to COA's design engineers to enhance the design through knowing the frequent damages and flaws for each sewer pipe material type. Moreover, through the research results, the COA's geographic information system (GIS) and information technology (IT) pipe engineers will be able to enhance their models by having enough information about the city sewer pipes. In addition to all above, the study result could be utilized in the COA's hydraulic model by knowing the flow level and the blocked pipe lines at each city basin.

Research Significance

- Sewer systems account for approximately 50% of the underground infrastructure in the United States (Shook and Bell 1998).
- ASCE Assigns a Grade D+ to Nation's Infrastructure (Limited Information on Condition of Sewer Pipelines).
- Without a condition assessment for the pipe, a collapse is imminent.
- Proper inspection and rehabilitation plan are better choice for the municipality in terms of cost than dealing with pipe damage problems when they happen.
- A portion of a West Side road collapsed in San Antonio after a sewer main ruptured underground and a Deputy was killed (San Antonio Express-News 2016) (Figure 1-1).

Research Objectives

- To Develop tool(s) to evaluate the structural integrity of sewer pipelines with different materials by using the data robotic MSI inspection.

Figure 1-1 Road collapsing in San Antonio after a sewer main ruptured underground (San Antonio Express-News 2016)

- To identify the failure mechanisms and pipe condition for each pipe material from 6 miles of data obtained by inspecting 48 miles of large diameter sewer pipeline system in City of Arlington (COA).
- To identify the parameters, through measurements, which impact the pipe performance such as corrosion level, debris level, deposit level, blockage level, structural defects, roots intrusion and infiltration, etc.
- To identify the overall pipe condition and the regions that need repair or replacement. This would substantially save taxpayers in terms of cost, for instance, COA saved 17 million.
- To achieve the aforementioned objectives, the following tasks were performed:
  1. Inspection of 48 miles of COA large diameter sewer pipeline system.
  2. Using computer programming to develop a software to evaluate pipe structural integrity and condition.

3. Development of data analysis output graphs, tables and rank the worst pipes for each pipe material and for different parameters.
4. Development of statistical models to predict the damage in pipelines to prioritize the lines that need to be inspected in the future.

Performance of Sewer Pipe System

The sanitary sewer system might represent an investment of millions of dollars for a small municipality. So, it is a valuable part of each municipality's infrastructure. More than 19,000 sanitary sewer systems in the United States would have a replacement value of as much as two trillion dollars according to Environmental Protection Agency (EPA). The proper functioning of wastewater systems plays an important role for the general level of good health enjoyed in the United States. Usually, the general public do not pay much attention to the sewer sanitary system, without being aware of its design and technical workings. The system should operate effectively at a reasonable cost to ratepayers. Most municipalities sewer systems have received minimal maintenance for many years despite that their current performance of many collection systems is poor. The inherent problem "out-of-sight, out-of-mind" nature of the wastewater collection system often makes wastewater collection systems suffer from a history of inadequate investment in maintenance and repair. The lack of proper maintenance could cause a deterioration in sewers such as basement backups, overflows, cave-ins, hydraulic overloads at treatment plants, and other safety, health, and environmental problems. One of the most serious and environmentally threatening problems is sanitary sewer overflows (or SSOs). The inadequate capacity, improper management, and operation and maintenance (O&M) is mainly represented by beach closings, flooded basements, closed shellfish beds, and overloaded treatment plants (NEIWPCC 2003).

The system requires an efficient operation for 24 hours per day, but the system usually doesn't get preventive and protective maintenance programs that other public services would receive. The advantages of an efficient collection system might not be realized by most taxpayers till they face problems themselves. At that time, a regular preventive maintenance would have been a better choice for the municipality in terms of cost than dealing with these problems when they happen. Chronic sewer system overflows locations should get a special attention. The identification of these problem areas should be easy to be designated through previous records of incidents of resident complaints, drain and plumbing system backups or flooding. The causes of previous system failures could be determined by proper sewer inspections. A long-term capital improvement plan as well as the need for long-term replacement and the estimation rates of deterioration can be determined and developed by performing physical inspections. The physical inspection can be so helpful in the condition assessment of the components of the sewer system and in developing a replacement plan. There are few inspection methods to detect failure in pipes such as air testing, closed circuit television, multi-sensor inspection, smoke testing, dye water testing, and visual testing using manhole access. Structural defects or an accumulation of material in the pipe could cause blockages in gravity flow lines such as grease, sediment, collapses or tree roots. Sewer maintenance should be scheduled in locations where this is an ongoing problem more often than for the rest of the system. The age of the system, the breakdown and deterioration of the construction materials cause a deficiency in the system. However, an ongoing, well designed maintenance program will save money in the long run by correcting those deficiencies which could develop into more serious and costly future improvements (Atchison 2012).

Types of Municipal Sewer Pipes

A major concern in the water and wastewater world is infrastructure aging. The infrastructure need is estimated at $334.8 billion from January 2007 through December 2027 across the nation, according to a 2007 EPA survey. The water and wastewater infrastructure represent the largest portion of $200.8 billion. Many municipalities are facing a significant task of pipe replacement. The reason is that many pipes close to the end of their life spans, and the time to choose a replacement has arrived. Proper material choice is critical in a long-term project like pipe replacement, where life span can exceed 100 years. In this section, the most common types of municipal pipe material's strengths, weaknesses and uses for each are discussed. Figure 1-2 shows the characteristics of common wastewater piping materials (Vahidi et al., 2016).

Material	Application	Key Advantages	Key Disadvantages
Ductile Iron	High pressure available sizes of 4–54 in.	Good resistance to pressure surges	More expensive than reinforced concrete and fiberglass
Reinforced Concrete	Moderate pressure available sizes of 12–72 in.	Low corrosion rate	Relatively brittle, heavy and high transportation cost
Vitrified Clay	Low pressure for larger-diameter applications	Low thermal expansion, long life cycle, raw materials availability, corrosion resistant	High transportation cost, heavy and labor-intensive to work
PVC	Low pressure for up to 36-inch pipe sizes	Light weight, no corrosion	Suitable for small pipe sizes and low pressure only
FRP	Moderate pressure available sizes up to 72 inches	Light weight, no corrosion	Expensive
HDPE	Moderate pressure available sizes of 4–63 in.	Light weight and flexible, leak-free joints	Sensitivity to temperature changes and mechanical loading

Figure 1-2 Characteristics of common wastewater piping materials (Vahidi et al., 2016)

Ductile iron pipe

Part of the infrastructural backbone of United Sates is cast-iron pipe. It is the predecessor of ductile iron. More than 20 municipalities have pipe cast-iron pipe that's reached the 150-year old mark and more than 600 have 100-year-old working cast-iron pipe systems. Ductile iron pipes mainly used on the water side. The pipe is almost made from ferric scrap. The materials used to manufacture the pipe are 95 percent recycled. Because of that feature ductile iron pipe has earned a smart sustainable product certification. Besides ductile iron pipes, clay pipe is considered a sustainable product in the buried infrastructure industry. Ductile pipe is known by its strength, but it is susceptible to corrosion from aggressive environments caused by acids, either on the exterior from acidic soil conditions or in the interior of the pipe from acidic sewage materials. The inside of the pipe is lined with a cement mortar lining to overcome the problem in water service. It also improves the hydraulics and helps water through the pipe (West 2014).

The tensile strength of ductile iron pipes is 350 N/mm2 to 1500 N/mm2, while the cast iron pipes have a tensile strength of 150 N/mm2 to 400 N/mm2. The cast iron pipes have better elongation and higher toughness than cast iron because the graphite is presented in the form of nodules while it is presented in the form of graphite flakes in cast iron pipes. Ductile iron pipes have few advantages over cast iron pipes like, higher tensile strength, better elastic module, better ductility, making it suitable for high stress applications and where pressure surge may be experienced, higher corrosion resistance, better hydraulic flow, higher working pressure, longer lifetime and it accommodates ground movement in a better way (Thacker 2015).

Vitrified Clay Pipe

The using of vitrified clay pipes (VCP) pipe goes back to 4000 B.C. They have been used in Mesopotamia, the Minoan civilization and the Roman Empire, and has a long history of city sewer system applications. But, today’s clay pipe is not similar to those used in the United States in the 1950s and ’60s nor is it similar to aforementioned examples. The older version of the clay pipes was more porous that needed glazing on the interior and exterior, but the modern-day pipe is tighter, denser and nonporous. The pipe material itself is totally different and stronger. The joints have also advanced. Nowadays, polyester with an O-ring or a polyurethane material is used to create a factory-applied leak-free joint, while decades ago, clay pipe did not have a factory-applied joint, which meant infiltration and exfiltration along with root intrusion and loss of pipe support. Although, VCP pipe is rigid, its compression joints allow some flexibility for the ground movement. Clay pipe has an average compressive strength of 18,000 psi. Vitrified clay pipe is well-known for its resistance in highly corrosive environments, even in the presence of solvent-based chemicals and sewer gases. Only hydrofluoric acid could affect clay pipe, which is not likely to be found in sanitary sewers (West 2014).

Fiberglass Pipe

The use of fiberglass pipe was first introduced in 1948 in the oil industry. The fiberglass material consists of glass fiber reinforcement in a polyester plastic matrix and its generic name is glass reinforced plastic (GRP). Reinforced plastic mortar (RPM) pipe has a sand filler (silicate) especially for large diameter pipes to increase wall thickness and pipe stiffness economically. Nowadays, one of the best alternatives for plastic, concrete, and ductile iron pipes, for many municipalities, is fiberglass pipe. Fiberglass has a light-weight and it is corrosion-resistant. The cost of cathodic protection required with ductile iron and reinforced concrete pipe in corrosive soils could be eliminated when fiberglass pipe is used. Installation costs can be less and the installation speeds can be faster because the fiberglass pipe weighs less than other pipe alternatives. FRP (fiber reinforced plastic or fiber reinforced polymer) has polymer (plastic) matrix which has a fiber reinforcement in it. The polymer resin (plastic) matrix provides structural rigidity (shape) and compressive strength while the reinforcement fibers provide the tensile strength (Swihart 2016).

Reinforce Concrete Pipe

One of the world's most common building materials used is concrete. Reinforced concrete pipes (RCP) are used in both pressure pipe and gravity flow. RCP gravity-flow pipes are manufactured in precast plants with more than one cross section shape such as round, elliptical, arched and box, and is used in sanitary sewers, storm drains and culverts. Furthermore, RCP pipes are used in pressure pipes which is a different classification that is primarily used for potable water. RCP pipes could last for 150 years if they are well-designed and well maintained by a proper maintenance plan. RCP pipes are rigid pipes. These pipes are good candidate for low-lying or marshy environments, because the pipe system is 85 percent dependent on pipe strength and only 15 percent dependent on the soil envelope. The biggest advantage of RCP pipe is durability, strength and longevity. It also has a very good flow characteristics because it has a smooth surface. Although concrete is a durable material, it is still susceptible to H2S attacks, and it could get corroded in extremely acidic soil. Moreover, just like with any other pipe material, concrete pipe can fail due to improper installation. If it's not put in straight, it can run into cracks. RCP pipes could be cracked due to improper transportation as well (West 2014).

HDPE Pipe

High-density polyethylene pipe (HDPE) has been first used by the gas and oil industry. Because HDPE pipe is a non-corrosive pipe and its highly flexible characteristics, it became a popular choice for water and wastewater applications. Also, it has zero water loss because it has heat-fused joints. The latter characteristic is considered as an important quality as worldwide water value increase. This fusion process creates an unbreakable bond and a joint as strong as the rest of the pipe. HDPE life span is decreased because it has a low failure rate and it is also highly resistant to corrosion. It is very important for HDPE pipes to have proper planning, design, installation and inspection. HDPE pipe could last 100 years. Because of the flexibility and ductility that HDPE pipe, municipalities should consider HDPE pipe in earthquake-prone areas. A study was done by the Water Research Foundation on recent earthquakes and their implications on U.S shows that HDPE is able to handle tremendous seismic activity effectively. The study also shows that in the 2010 Chile earthquake that all the HDPE pipes were not damaged, while the rest of the water system suffered thousands of damaged pipes. The report recommends to use HDPE for in sewer pipe system in high seismic zones. HDPE sizes could vary from 1/2 to 65 inches. The use of HDPE pipes use has expanded across the world and especially in Europe. Nowadays, nearly 90 percent of new pipe installations in Europe are HDPE (West 2014).

PVC Pipe

One of the oldest synthetic materials that was discovered by scientists in the 19th century is Polyvinyl chloride. Its actual use started in World War II to insulate wiring on military ships. Decades after, PVC use highly increased, and nowadays it is frequently used for sanitary sewers system and potable water distribution lines. This pipe is often used to coat other materials that are affected by acidic conditions because it is very corrosion resistant. PVC can be softened and reformed because it is a thermoplastic. Furthermore, PVC has a fusible version that is available now, which makes it competes with HDPE in trenchless construction. A study by the Water Research Foundation, in

2008, concluded that PVC is also impermeable to gasoline which is the most common hydrocarbon contaminant. According to 2012 survey by Utah State University PVC has the lowest failure rate, amongst cast iron, ductile iron, concrete, steel and asbestos cement of only 2.6 failures per 100 miles of pipe per year. Municipalities select PVC for their sewer system since the cost of the PVC production, backfill and labor expenses are typically less expensive replacement option than other materials. Municipalities could have 70 percent savings when using the PVC material. However, some limitations should be taken into consideration when using PVC pipe such as operating pressures should not be higher than 305 psi. Also, the ambient temperature of the pipe should be less than 140 degrees. However, the latter conditions are extremely rare in sewer and water systems. Moreover, a study by American Water Works Association Research Foundation estimates the life expectancy of the PVC pipe to exceed 110 years. PVC pipe sizes ranges from 4 to 60 inches for both water and sewer applications (West 2014).

Types of Sewer Pipe Damage

One of the major rising problems in modern cities nowadays is the damage caused by the aging of sewage pipe systems. Besides aging, there are few factors that could damage the sewer pipe and might lead the pipe to collapse. According to a study in Japan in 2013, the main sewer pipe damages that are frequently occur are corrosion, crack, breakage, roots intrusion, and misalignment of connection. The top significant three types that could cause the pipe to be damaged are corrosion, crack, and breakage, that account for 55% of all the damages or defects. The latter factors are the direct cause of pipe degradation. Figure 1-3 shows the common types of the sewer pipe damage (He and Koizumi 2013).

Sinkholes could occur to all kind of sewer pipes that have damage where the water could leak into or leak out of the pipe. Water Research Center (WRC) in England has introduced the concept of sewerage system-induced sinkholes. Especially during and after a heavy rainfall, the groundwater level would increase and thereby the sewage infiltration through a damaged sewer pipe increase. This leads to loosening of the soil. At the same time, the sewerage and storm water may exfiltrate from the pipe defects. The infiltration and the exfiltration are accompanied by the discharge of soil particles, which can fluidize the adjacent soil, causing soil erosion and disturbance (Figure 1-4a, b). When the rain stops, the groundwater level starts to decrease which leads the soil particles to be dragged into the sewer pipe through the pipe defects. The latter activity could cause cavity formation (Figure 1-4c). The ground cavity gradually expands as these processes are repeated. Moreover, the expanded cavity causes the pavement to collapse and a sinkhole opens due to applied loads such as traffic loads (Figure 1-4d) (Kim et al., 2018).

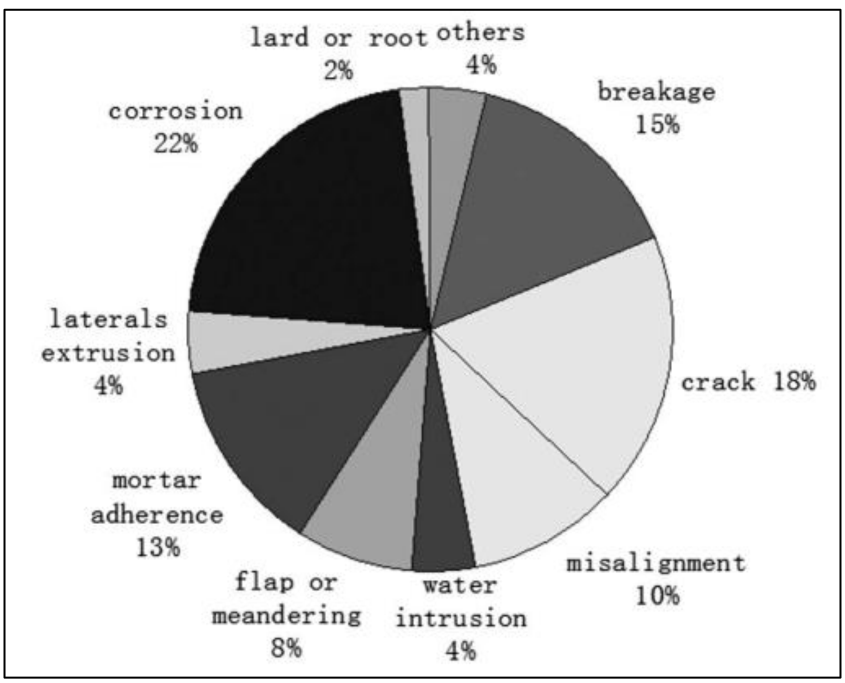


Figure 1-3 The common types of the sewer pipe damage (He and Koizumi 2013)

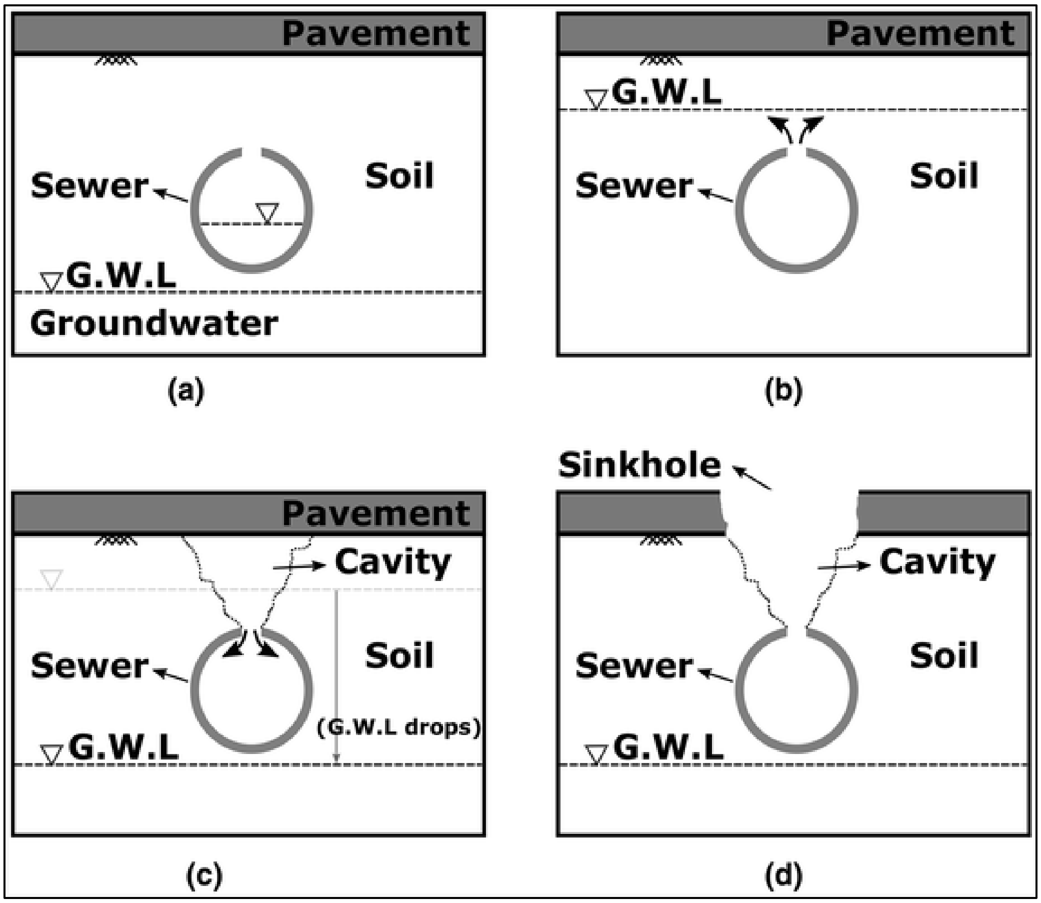
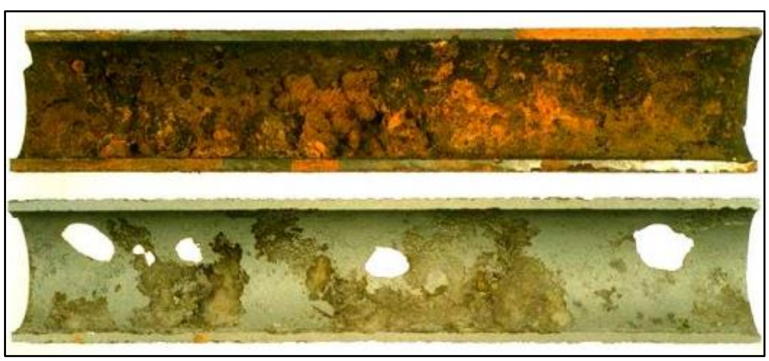


Figure 1-4 General sinkhole formation processes due to defective sewers. It shows (a) before a rainfall, (b) during a rainfall, (c) after a rainfall and (d) sinkhole opening. (Kim et al., 2018)

Types of Damage in Ductile Iron Pipe

The most common damage that ductile iron pipe could have is corrosion. The corrosion could happen to the external part of the pipe especially if the pipe in a harsh soil environment and the polyethylene encasement has flaws. These flows usually come from improper installation of the encasement or during the pipe installation. Furthermore, ductile iron pipe is also susceptible to be corroded internally especially if the internal mortar lining is damaged or eroded. Ductile iron pipe could have damages other than corrosion like longitudinal fractures or circumference fracture. However, these kinds of damages are commonly considered to be corrosion related. Figure 1-5a shows external corrosion of ductile iron pipe, while Figure 1-5b shows internal corrosion. (Gould 2016, Rajani and Kleiner 2003).

(a)



(b)

Figure 1-5 Corroded ductile iron pipe. It shows (a) external corrosion and (b) internal corrosion (Rajani and Kleiner 2003)

Types of Damage in Vitrified Clay Pipe

Vitrified clay sewer pipes defects can be classified into two main groups, structural such as longitudinal and circumferential fractures (as shown in Figure 1-6), and operational such as movable deposits or infiltration of groundwater into a leaky sewer. The last group includes root intrusions into sewer pipes as well. Root intrusion could cause partial or total flow blockages that could lead to exfiltration of wastewater through leaky pipes into the nearby soil and groundwater and, therefore, their pollution. Sewer runoffs could lead to flooding and contamination of the region. Approximately 50% of the total number of sewer blockages estimated to be attributed to sewer root intrusions. Most of the roots intrusions happen at the joints or where there is an opening occur as a result of a fracture, break or a hole in the pipe wall. Figure 1-7 shows an example of minor root intrusion and severe root intrusions for vitrified clay sewer pipe (Kuliczkowska and Parka A 2017).

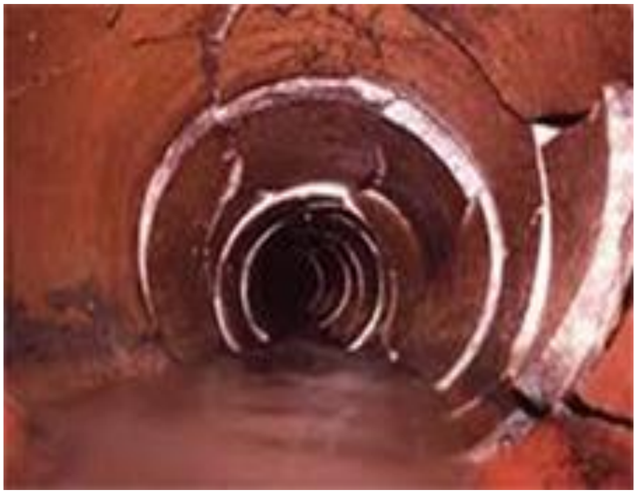
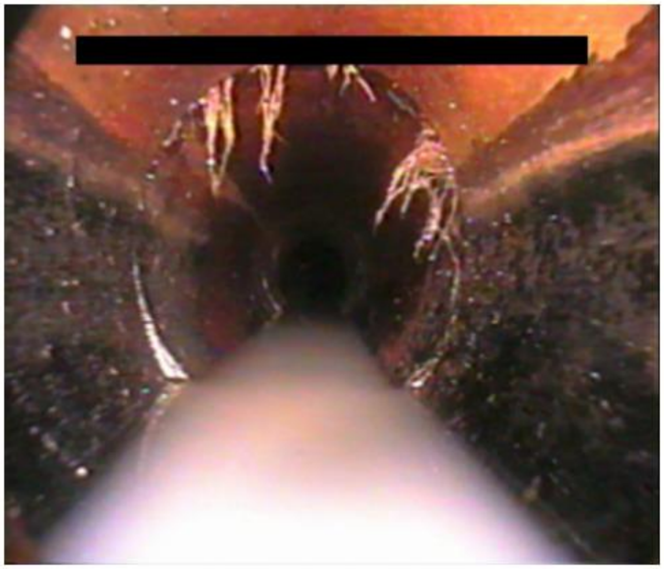


Figure 1-6 Longitudinal and circumferential fractures in vitrified clay pipes



(a)

(b)

Figure 1-7 VCP pipe root intrusion (a) minor root intrusion (b) severe root intrusion

(Kuliczkowska and Parka 2017)

Types of Damage in Reinforced Concrete Pipe

Reinforced concrete pipe is considered a rigid pipe. When a fracture happens to the pipe due to excessive loads (as shown in Figure 1-8), the pipe starts to deform. The pipe water inflow could lead to erosion voids to the surrounding soil which leads to an increase in bending moment in rigid pipe. The erosion voids cause soil movement that disturbs the backfill of the pipe and as a consequence a sinkhole could occur (Moore 2008).

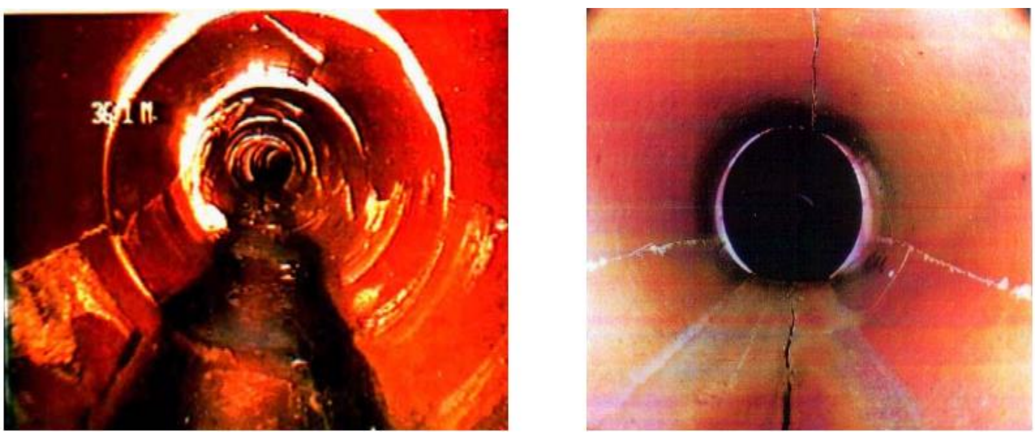


Figure 1-8 CCTV images of damaged rigid sewers showing longitudinal fractures and changes in shape (Moore 2008)

Corrosion is another common defect in reinforced concrete sewer pipes. The main reason for corrosion in these pipes is the existence of hydrogen sulfide (H_2S). H_2S commences to compose in sewer pipes as a result of the natural biological decomposition of Sulphur containing organic and inorganic substance such as proteins and sulphates. The formation of H_2S primarily happen under anaerobic environments by sulphate reducing bacteria in the slime of a matured sewer. It also could be created by bacteriological processes in the sewage. After the oxygen initially present in the sewage has been consumed by various biological processes in gravity sewers the formation of H_2S commences. Then, the anaerobic decomposition starts to occur and continues to increase. After that point, H_2S slowly escapes into the sewer atmosphere. The release of the H_2S gas increases as turbulence in the sewage stream increases. Factors like long sewage flows, low flow velocities and high sewage temperatures help the formation of H_2S. The oxidation into H_2SO by bacteria living on the moist surface of the sewer occurs, but the continued ideal conditions for the sulphate reducing bacteria prevail (Figure 1-9). Biological H_2S corrosion effect is taken place only above the surface level of the sewage stream where the sulfuric acid reacts with the lime content of cement of the reinforced concrete pipe. Biological H_2S corrosion has a bigger effect on reinforced concrete pipes which have limestone as the aggregate than on those having quartzistic aggregate. Generally, the corrosion in concrete sewer pipes could happen as fast as 3 to 6 months if these pipes have a constant presence of hydrogen sulfide in the sewer atmosphere (Steinzeug 2009).

Types of Damage in Fiberglass Pipe

Fiberglass pipe is considered a flexible pipe. Its primary structural function is distributing the imposed vertical loads to the surrounding soil. Only a small portion of imposed loads are actually carried by the flexible pipe itself. Instead, load is transferred to the surrounding bedding material. Fiberglass pipe can get cracked and damaged if the soil modulus (poor embedment) and the pipe stiffness used to calculate the pipe deflection were insufficient. Furthermore, bulges (localized deflection) frequently happen at the invert when pipe is sitting on hard subgrade. Also, invert flattening (bulge) could occur due to poor compaction in the pipe haunch (i.e. below the springline). Bulges at any location (such as haunches, springline or crown) could happen to the fiberglass pipe due to excessive compaction. These bulges cause high stress and strain concentrations. Another common failure in fiberglass pipes are at joints and fittings due to improper connection (Swihart 2016).

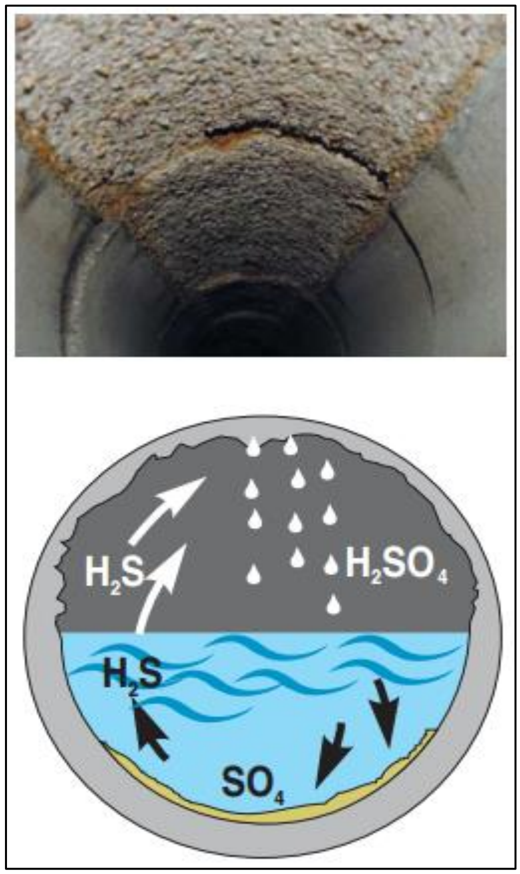


Figure 1-9 The formation of H_2S in sewer pipes (Steinzeug 2009)

Types of Damage in HDPE Pipe

HDPE pipe is a flexible pipe that deforms much easier than rigid pipes. It needs a good soil support on the pipe side to limit the pipe deflection. The three stages of creep rupture failure are shown in Figure 1-10. The stage one failure considered a purely mechanical failure mechanism due to ductile overload of the material failure mechanism. Stage one failure is a ductile bursting of the pipe with yielding of the material. Stage two failure also considered a mechanical failure mechanism but represents non-ductile slit or pinhole cracks in the pipe wall that allow leakage from the pipe. Stage three failure also represents a leakage from non-ductile cracking of the pipe wall but it is not purely mechanical. Stage three failure happens with lower stresses than Stage two failure and it occurs with some minimum level of oxidative degradation of the HDPE pipe material (Esfahani 2017).

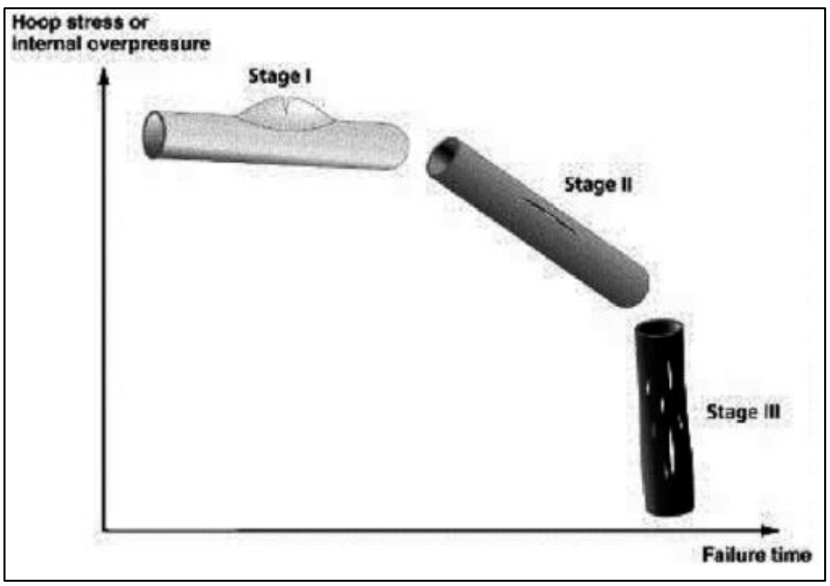


Figure 1-10 Stages of failure of HDPE pipe (Esfahani 2017)

Furthermore, incomplete joint fusion represents reduced bond strength. It indicates that the joint bond has a strength lower than the bond strength that should have under optimum heat fusion circumstances. Incomplete fusion is considered as an internal weld defect. The incomplete fusion could be presented in some welded joints that have a normal exterior appearance and it usually cannot be detected by conventional visual inspection. After the joint is placed in service, the joint could leak or fail even if the pipe passes initial pressure testing (Zakar and Budinski 2017).

Types of Damage in PVC pipe

There are two main PVC pipe degradation could happen to the pipe: photo-oxidative and thermooxidative. When PVC pipe gets exposed to extreme UV radiation from the sun, photo-oxidative degradation occurs. On the other hand, when PVC pipe is exposed to extremely high temperatures for a continuous period of time, thermo-oxidative degradation occurs. Both degradations are going through the same chemical reaction. They both release free radical formation which yields hydrochloric acid. The hydrochloric acid is considered harmful to plants and ecosystem growth. Improper handling during processing or processing in higher temperatures could lead to PVC brittleness. The pipes could also be damaged if it gets hit by tools through installation or rough handling by workers on site. PVC pipes are well known to resist corrosion, but they are not resistant to hydrocarbon compounds. A serious threat to the functionality of PVC pipes could result from improper disposal of chemicals, factory emissions, and other such pollutants in the environment. The contamination takes place in a three-step process as shown in Figure 1-11 (Deshmukh 2012).

Another type of damage that could possibly occur in PVC pipes is root intrusion. Most of the roots intrusions happen at the pipe joints or where there is an opening occur as a result of a fracture, break or a hole in the sewer pipe wall (Kuliczkowska and Parka 2017).

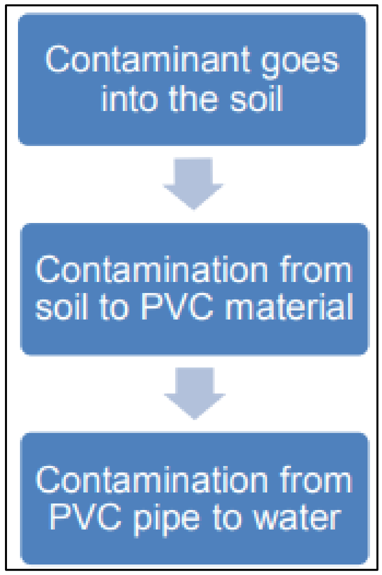


Figure 1-11 Process of contamination of PVC pipe (Deshmukh 2012)

Types of Sewer Pipe Inspections

Electro-Scan

To inspect the pipe, a voltage is applied between two electrodes. One is called the Snode and the other electrode is called surface electrode, as it is shown in Figure 1-12. Between the two electrodes, when there is no barrier, the electrical resistance is very low; however, the pipe wall's electrical resistance is high. As a result, the high electrical resistivity will prevent any leakage of the current. Any crack or hole will indicate a current's leakage (Harris and Dobson 2006).

Cracks or fractures that do not leak would provide low threshold anomalies. Figure 1-13 shows a sample result of an electro scan inspection of a pipeline. It shows the electrical current values along the distance traveled. With an accuracy of +/–40% (Kaddoura 2015).

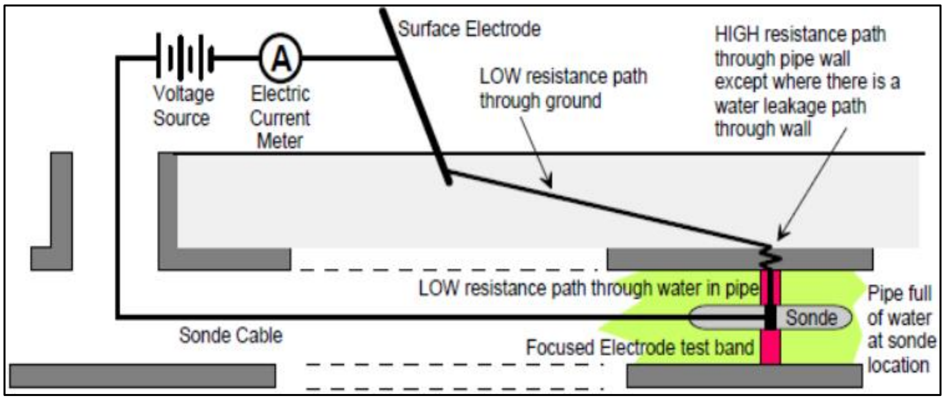


Figure 1-12 Mechanism of Electro Scan Machine (Harris and Tasello 2004)

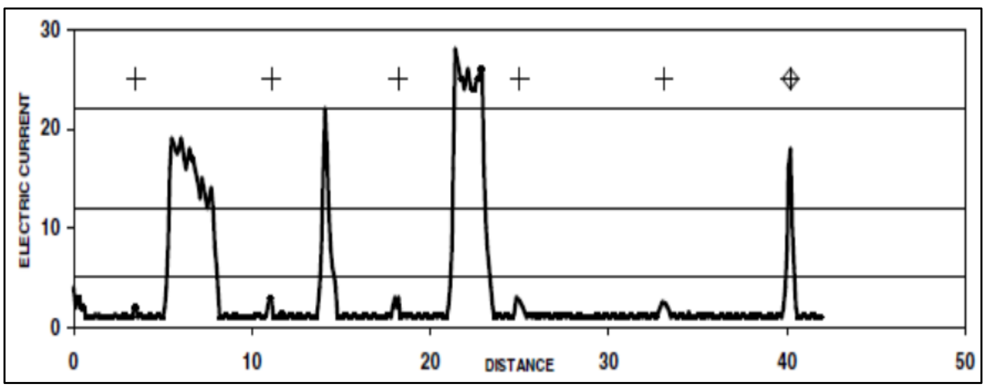
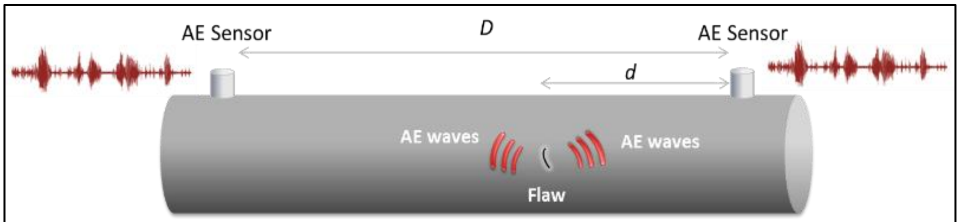


Figure 1-13 An Example of Electro Scan Current Output (Harris and Dobson 2006)

Acoustic Emission (AE)

AE method is suitable to detect damage onset and/or propagation but cannot detect existing or “silent” damage. In reinforced concrete pipes (RCP), AE is suitable to detect breaks of the steel reinforcement, crack onset, and propagation within the concrete. Other sources of emissions are friction, crack growth, turbulence, leak, and corrosion. Monitoring RCP by means of AE may not be very accurate because the method is restricted to detecting ongoing breaks, cannot detect already damaged pipes (Integrity Diagnostics 2016). Figure 1-14 illustrates AE method for pipe inspection.



$$d = \frac{1}{2}\left(D - \Delta T \cdot V\right)$$

d = distance from first hit sensor

D = distance between sensors

V = wave velocity

Figure 1-14 AE method for pipe inspection (Integrity Diagnostics 2016)

Closed-Circuit Television (CCTV)

Many municipalities across the nation are using CCTV for pipe inspection. It is the most frequently used, most cost efficient, and most effective method to inspect the internal condition of a sewer for sewer lines with diameters of 0.1-1.2 m (4 - 48 inches.) (EPA 1999). CCTV does not quantify the detected defects such as deformation, settled deposits, infiltration, and surface damage (Tuccillo et al. 2010). CCTV doesn’t detect any damage or debris below the flow line. Figure 1-15 shows how CCTV to detects damages.

Laser Profiler

The laser profiler technology is based on a ring of light, generated from a laser, around the wall of the pipeline. A camera, usually a CCTV camera, which is attached on the same crawler, detects the ring of light and stores the laser image for further analysis

(Tuccillo et al. 2010). Using CCTV alone, the operator may not observe any deflection along the pipeline while analyzing the recorded video. Utilizing laser profiler, however, would clearly present the actual condition of the pipeline. Figure 1-16 shows how the laser ring would look like in the pipe inspection. Although the laser profiler is suitable to detect corrosion (using CCTV camera) and ovality, it is unable to detect damages and debris under the water level.

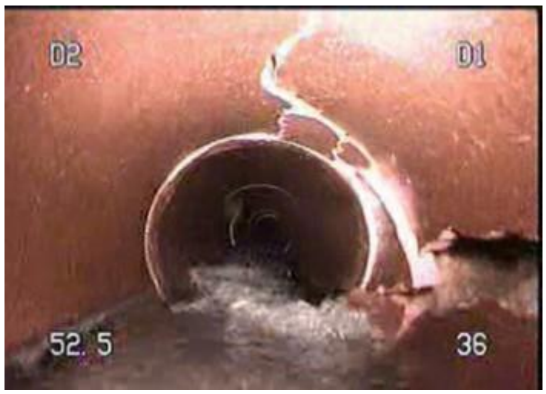


Figure 1-15 Broken and fracture-multiple are detected through CCTV

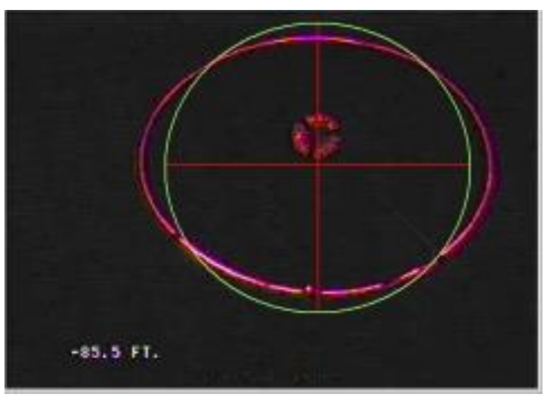


Figure 1-16 Laser ring in pipes.

Sonar

The sonar sensor is mainly utilized below the flow line to measure the volume of settled deposits. It couldn't detect fractures, root intrusion and defects above the water level (Kaddoura 2015). Figure 1-17 shows how the sonar ring would look like.

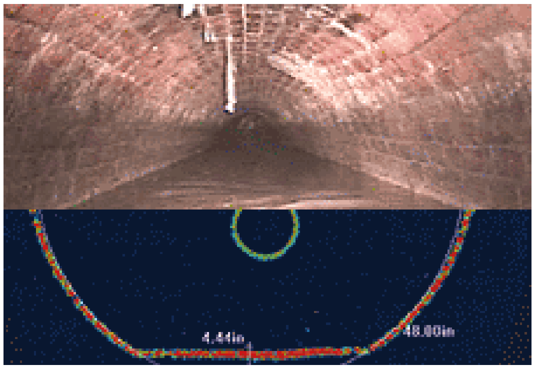


Figure 1-17 Sonar profile in pipes

Multi-Sensor Inspection (MSI)

The multi-sensor inspection equipment has entered the industry as a non-destructive evaluation (NDE) technique to evaluate the pipe condition (Redzone Robotics 2018). It effectively detects corrosion, debris and ovality. Figure 1-18 shows the sonar and laser profiles. The principle of this method is based on combining CCTV, Laser and Sonar technologies in one device to perform a complete pipe condition assessment.

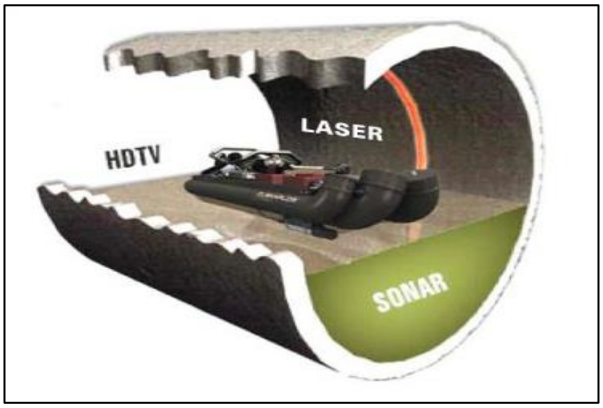


Figure 1-18 Laser and sonar profiles in pipes (Redzone Robotics 2018)

Chapter 2

Experimental Program

Technology Partnership Program (TPP)

The City of Arlington (COA), University of Texas at Arlington (UTA) and RedZone Robotics have established a Technology Partnership Program (TPP) to perform a condition assessment on the approximate 255,000 linear foot of large diameter sewers 24-inches in diameter and larger using advanced multi-sensor inspection (MSI) technology that has been pioneered by RedZone Robotics. RedZone proposed to work in collaborative effort under the TPP with the team on the project including assistance on the standard operation procedure (SOP) methods and best practices for field data collection, data post processing, data workshops for data interpretation, database findings and pipeline assessment and certification program (PACP) rating and defect coding, final reports, data integration into city of Arlington system. RedZone has been providing MSI inspections, equipment, services, data processing assessment services throughout North American in over 200 cities in the United States and Canada, and specifically millions of MSI data and processing in the State of Texas including Ft. Worth, Dallas, Houston and others. The Technology provides a cost efficient and accurate analysis of the infrastructure. RedZone's MSI Equipment has multi-sensor technologies including Digital CCTV, Sonar, Laser sensors that provide accurate and quantifiable data on erosion, ovality, debris, and other accurate engineering driven reports and capabilities. Additionally, RedZone as both the manufacturer and technology service provider have the appropriate equipment and analysis tools, software, certified technicians and training staff and tools specially designed for large diameter sewer evaluations.

RedZone's MSI Equipment Capabilities

RedZone Robotics manufactures and provides a multitude of products to capture data for the complexity of pipe. Specifically, for large diameter sewer collection systems, multi-senor platforms of robotic technology are designed to overcome the severe challenges for unique situations. RedZone Robotics MSI equipment are listed below:

- **Solo:** designed for the 8" to 12" mass of pipeline, can autonomously inspect for a 360-degree view with rapid ease and simplistic installation and removal. The process allows for quick collection of CCTV and provides an increase in time to gather more information thus eliminating waste and inefficiency. Service trucks and the drudgery of the task are eliminated for the mass quantity of pipes in this size range. Overall, this ability provides a significant reduction in cost to the municipality.
- **Mid Diameter MSI:** designed for the mid diameter pipe which range from 15" to 36" with advance capabilities which gather the full spectrum of analyst utilizing CCTV, Sonar, and Laser. An individual deployment can reach in excess of 7,000 linear feet so to avoid the difficult approach of entering every manhole that is not easily assessable. This special design can wriggle maneuvers in tightly restrictive conditions which the mid pipe can challengingly present.
- **HD Profiler:** is a floating platform for 20" to 84" pipe range with advance capabilities which gather the full spectrum of analyst utilizing CCTV, Sonar, and Laser. An individual deployment can in excess of 7,000 linear feet so to avoid the difficult approach of entering every manhole that is not easily assessable.
- **Responder Tracked:** system for 36" to 240+" has the advance capabilities for gathering the full spectrum of analyst with 360° Pan/Tilt/Zoom CCTV, 3D Laser,

Sonar, and H2S Gas detection. An individual deployment can reach in excess of 7,000 linear feet so to avoid the difficult approach of entering every manhole that is not easily accessible.

- **HDSonar Sub:** designed for fully surcharged pipe conditions between 20” to 84” using Sonar. This provides calculations of volumetric debris sediment and water level analysis.

- **Stand-Alone Sonar (SA):** was designed for fully surcharged pipe conditions using Sonar for siphons, force mains and difficult to access locations. This provides calculations of volumetric debris sediment and water level analysis. RedZone Robotics MSI equipment are shown in Figure 2-1.

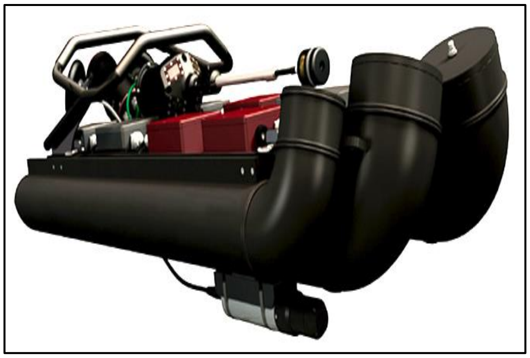
Device Used in The Research

The COA and UTA have chosen HD Profiler for the large-diameter (24-inch inner diameter and above for rigid and flexible pipes) COA sewer pipeline system inspection. The advantages of using this device for this particular study are listed below:

- Floating platform for 20” to 84” pipe range.
- Utilizing CCTV with HD camera for visual inspection and pipe coding system.
- Utilizing sonar for data measurement under the flow level.
- Utilizing laser for data measurement under the flow level.
- Provides a good accuracy and quantifiable data on erosion, ovality, debris.

(a)

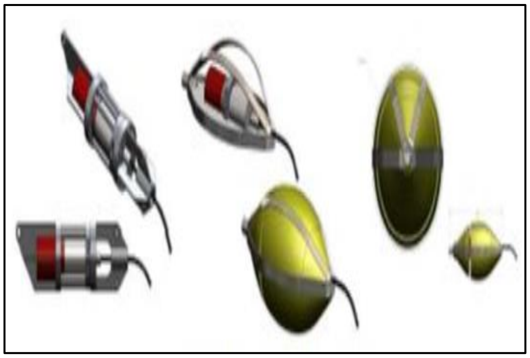
(b)



(c)

(d)

(e)



(f)

Figure 2-1 Redzone robotics MSI equipment. It shows (a) solo, (b) mid diameter MSI, (c) HD profiler, (d) responder tracked, (e) HD sonar sub and (f) stand-alone sonar (SA)

- Its parts are transferable to mid diameter MSI float (Mid Diameter MSI float can be purchased and used when there is no or shallow flow).
- An individual deployment can in excess of 7,000 linear feet so to avoid the difficult approach of entering every manhole that is not easily accessible.

The last advantage was the primary reason to select this device over option-2 (made by another company). Option-2 is not capable of inspecting more than 2,900 linear feet without an access point.

Research Training Sessions

Both City of Arlington (COA) and University of Texas at Arlington (UTA) research teams have gotten four training sessions prior to the beginning of the project. One of the COA's highest priority is safety. Thus, the City of Arlington required that both teams (COA and UTA) should have a reasonable safety training before getting into the site and measurement phase. The city has established two safety sessions for the teams to take, one is First Aid session and the second is Water Utilities Safety session.

The third training session was given by RedZone Robotics (the robot's manufacturer). This was on-site equipment training session. RedZone's team has given instruction about the usage of their device and how to do the deployments.

The forth training session was also given by RedZone Robotics. The session was about RedZone's software utilization and data processing. The latter training session, was mainly intended for UTA's research team. The topics of each session is mentioned in the following sections.

First Aid Training Session

Topics covered during this session are:

- Basic First Aid Awareness.
- Goal of First Aid Training.
- Legal Considerations.
- Emergency Actions.
- Avoiding Infectious Diseases.
- Immediate Life Threating Conditions.
- Rescue Breathing.
- Choking.
- Cardiopulmonary Resuscitation (CPR).
- Automated External Defibrillator (AED).
- Bleeding.
- Shock.
- Anaphylaxis.
- Wounds.
- Burns.
- Injuries.
- Sudden Illness.
- Heat and Cold Emergencies.
- Poisoning.
- Bites and Stings.

Water Utilities Safety Training Session

Topics covered during this session are:

- Safety Awareness.
- Personal Protective Equipment (PPE).
- Chemical Safety.
- Infectious Diseases and Infection.
- Electrical Safety.
- Excavation, Trenching and Machinery Safety.
- Confined Space Safety.
- Work Zone Traffic Control.

On-Site Equipment Training Session

Topics covered during this session are:

- Material and Tools needed.
- Connecting Robot Parts.
- Robot's Computer Pods Programming.
- Robot's Insertion, Sending and Extraction.
- Robot Parachuting.
- Robot Tagging.
- Data Extraction.
- The Usage of the Wheels.
- The Usage of the Alternative Floats.
- Equipment Cleaning.

- Bends Maneuvering.

Software Utilization and Data Processing Training Session

Topics covered during this session are:

- Field-Measurement Data Preparation.
- Fly Movie Software Training. This includes:
    - Inspected-Line Segmentation.
    - CCTV Videos Extraction.
    - Extracting Laser and Sonar Profiling to Be Processed in Profiler Software.
- Profiler Software Training. This Includes:
    - Extracting Data coordinates.
    - Laser Coordinates Alignments and Refinement.
    - Sonar Coordinates Alignments and Refinement.

Prioritization of Line Inspection

The City of Arlington has Renewal/Rehab Prioritization (RRP) model. In this model, the sewer lines are given a score based on few different factors. For each sewer line, the factor values are ascertained from GIS and MUPS. There is a look up tables that are used to derive factor points, the factor points are then weighted, and a Total Score is calculated. The score puts into consideration the following factors:

- Proximity to Waterway.
- Proximity to Parks and Schools.
- Minimum pipe diameter.

- Capacity Issues.
- Outflows.
- Pipe age.
- Pipe material.
- Visual Inspection.
- Line Incidents.
- Sewer Main Repairs.
- Work Order History.
- NASSCO Rating.
- Aerial Crossing.

The higher the Total Score for a sewer line, the greater the probability that that line needs to be renewed or rehabbed. Generally, a sewer renewal project contains all the sewer lines within a block and not just a single sewer line in here and there. For this reason, the RRP browser application groups the sewer lines by block and displays the sewer line with the highest Total Score. The pipeline inspections order takes into the consideration PRP score. Prioritization of the line inspection can be shown in Table 1.1.

Standard Operation Procedure (SOP)

The Standard Operation Procedure (SOP) includes:

- MSI Equipment Assembly and Preparation.
- Equipment Insertion, Operation and Extraction.
- Post Inspection Field review.

- Safety Considerations.
- Inspection Contingencies.
- Equipment Damage.
- Pipe Collapsing.
- The Need of Pipe Cleaning.
- Boat Capsize.
- Contact Information.
- Field Notes.

A detailed Standard Operation Procedure (SOP) is presented in Appendix B.

Table 2-1 Prioritization of the line inspection based on COA's Renewal/Rehab Prioritization (RRP)

Line	Line Avg RRP	Line Inspection priority
C	31.5	1
G	18.5	2
F	17.3	3
A	16.8	4
D	12.4	5
H	11.5	6
E	4.5	7
B	0	8

Data Collection

After the prioritization of lines, inspection cycles were established based on the PRP score of the lines to conduct the field inspection for these lines in order and to inspect some other lines in the vicinity. So, the first inspection has the highest PRP score. Some lines with lower PRP score were added to each inspection, because their location is so close to the lines with the high PRP score. The reason of doing that is to inspect more lines that are located in the same area of the lines with the high PRP score.

The data collection starts by sending the robot from a certain manhole that called the insertion manhole to another manhole in the line that called the extraction manhole to extract the robot. The latter process is called deployment. The device would go through few manholes in between the insertion and the extraction manholes during a practical deployment, as shown in Figure 2-2. The device records CCTV video, pipe laser profile and pipe sonar profile through the deployment. The laser profile represents the inner pipe perimeter shape above the sewer water level and the sonar profile represents the inner pipe perimeter shape below the sewer water level. The pipe visual inspection is conducted by watching the recorded CCTV videos to assess the pipe condition. The other pipe assessment is performed through laser and sonar data to give extra information about the pipe condition that couldn’t be detected by visual inspection process.

Device Data Extraction

After collecting data from the field measurements, laser, sonar and CCTV videos, the data are processed through more than one software to get the final results and graphs. The steps of data analysis process are shown below.

1. Data Extraction Using FlyMovie Software (Figure 2-3):

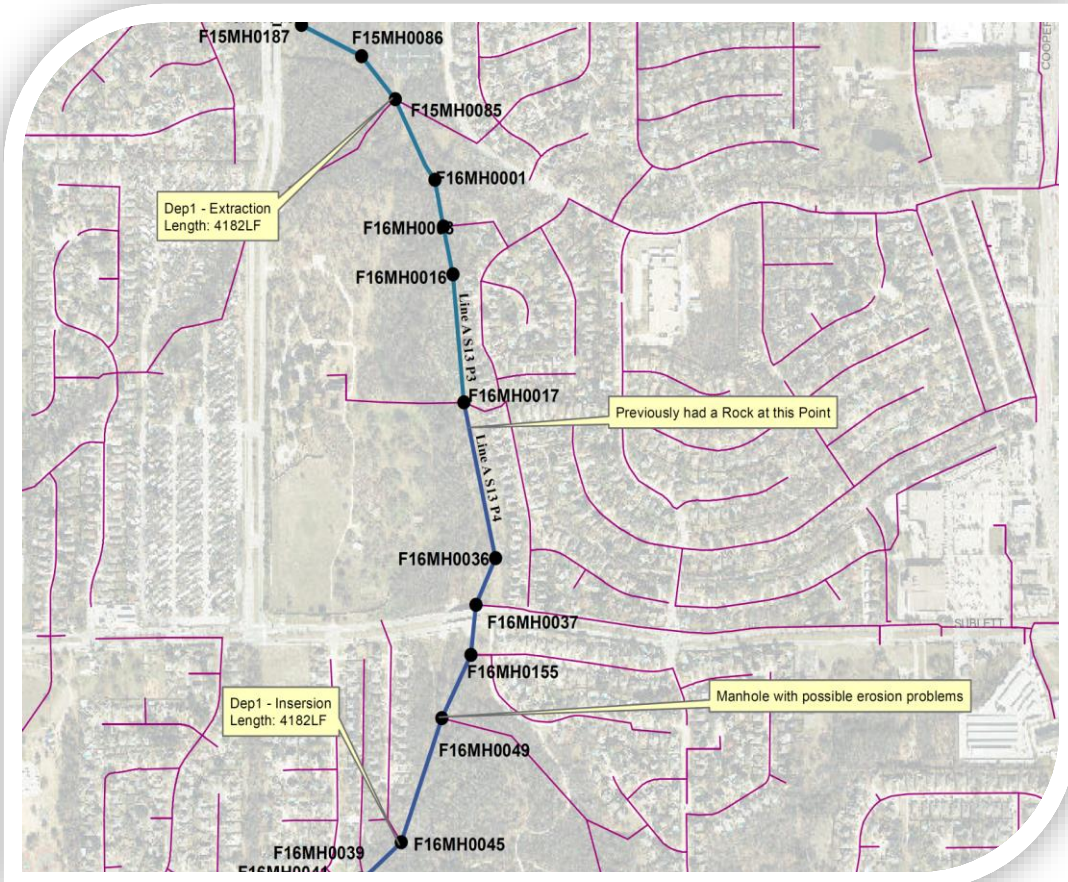


Figure 2-2 Example of an inspection deployment

a. Break down the inspected line into segments.

b. These segments represent the inspected line between each two consecutive manholes.

c. Define the asset, inspection direction, pipe size, material, and the date of the inspection.

d. Extracting Laser and Sonar Data.

e. Extracting CCTV Videos.

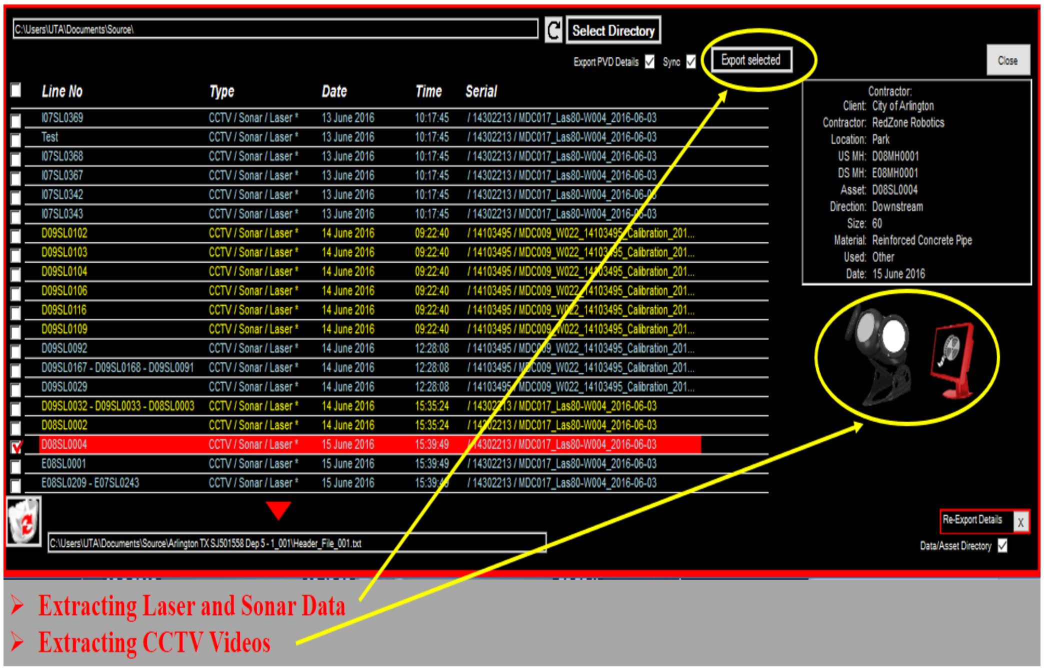


Figure 2-3 Data processing using FlyMovie software

2. Pipe Visual Inspection Using CCTV Videos:

One of the COA requirements for this study is to code pipes according to PACP (Pipeline Assessment and Certification Program). The coding system is done for CCTV videos of the related typical line (manhole to manhole). The large-diameter inspection project will use a modified PACP scoring due to limitation of coding large diameter pipe. Figure 2-4 shows a typical pipe coding system table. Figure 2-5 shows pipe visual inspection using CCTV videos. Appendix C shows the defects type and codes.

Starting a New Inspection

- Always Start Each inspection with two Codes: **AMH** and **MWL**
- **AMH** stands **A**ccess, **M**an**H**ole and signals the start of the inspection

- **MWL** stand for **M**iscellaneous, **W**ater **L**evel. Use the % to show the percent of pipe full with water.

Distance

- Used on all observations.

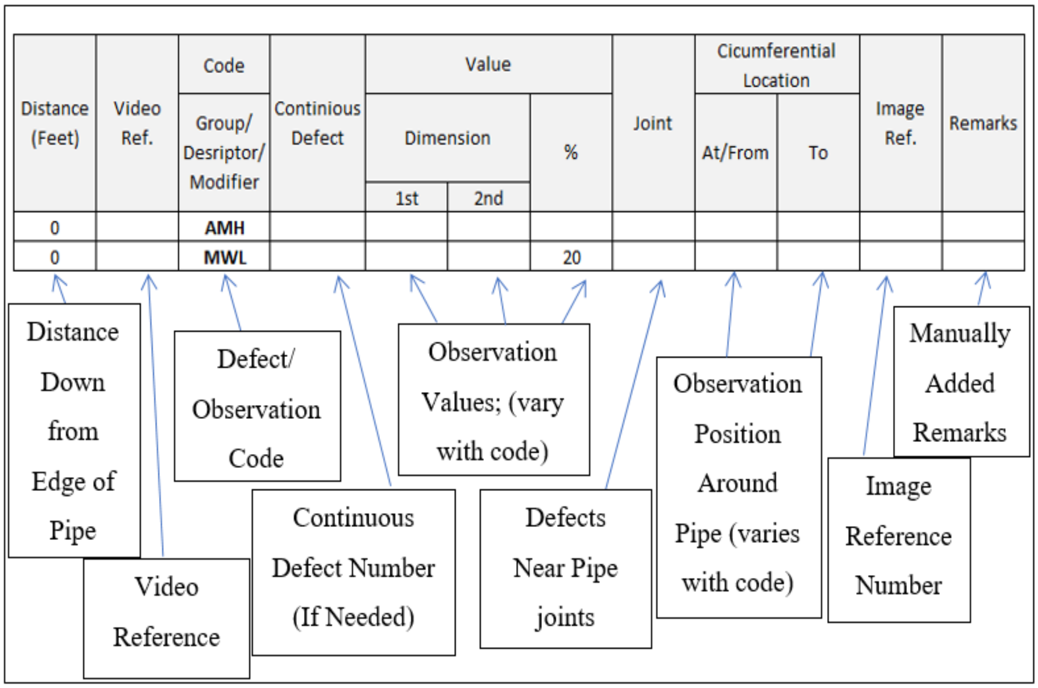


Figure 2-4 Typical pipe coding system table

1. Data Extraction Using Profiler Software:

After obtaining the laser and sonar profiles with FlyMovie software, the data is processed with Profiler software to extract the laser and sonar profile coordinates.

   a. Adjust the laser boundaries, width, sharpness and the center of the data limits (Figure 2-6).

   b. Mask the noise in data for better data capturing (Figure 2-6).

c. Adjust the recorded data to the original pipe diameter (Figure 2-7).

d. Align the coordinates of the pipe sections along the pipe length (Figure 7).

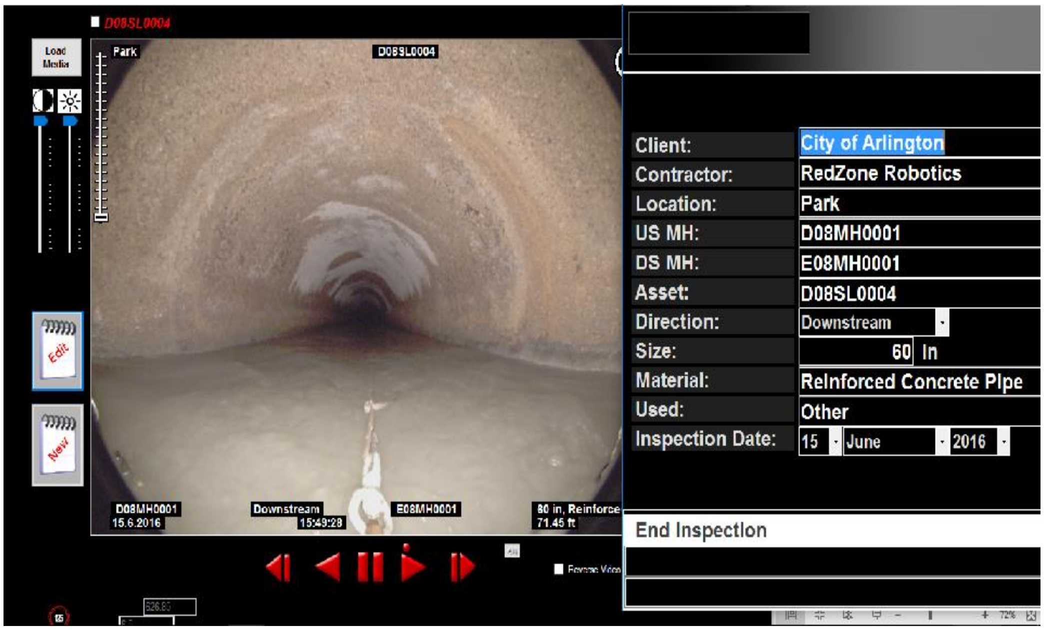


Figure 2-5 pipe visual inspection using CCTV videos

The laser and sonar coordinates are extracted from Profiler software in CSV file format, as shown in Figure 2-8. Each profile has coordinates of X and Y for every two degrees around the pipe circumference. So, every profile has 180 points, as shown in Figure 2-9. After extracting the Laser and sonar coordinates from Profiler software, the data is entered in a software developed by UTA to obtain information about the pipe condition. The developed software capabilities are explained in the following chapter.

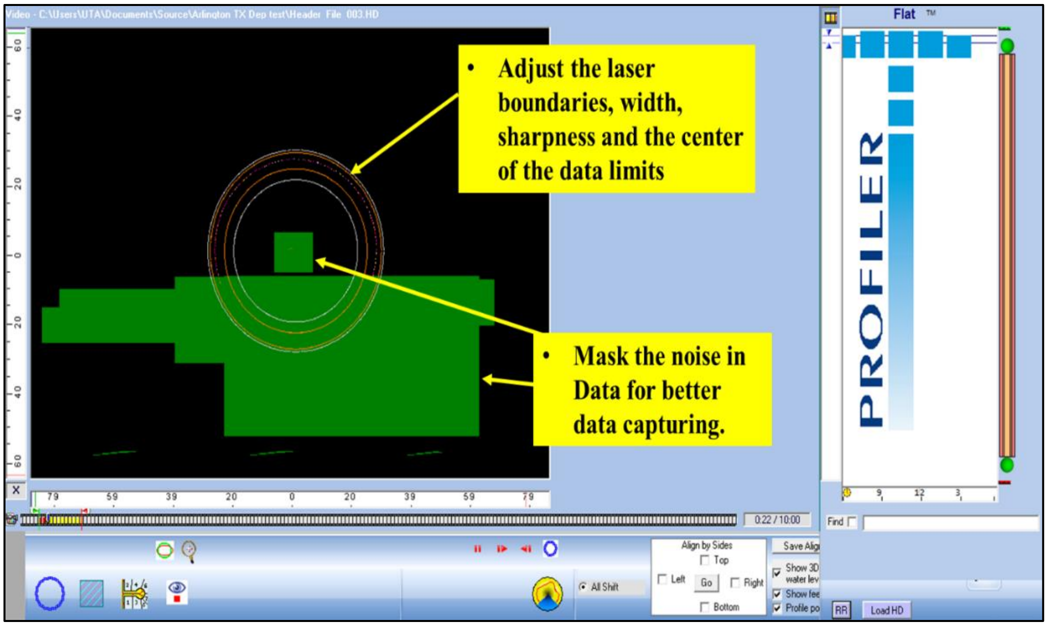


Figure 2-6 Adjusting the laser boundaries, width, sharpness, the center of the data limits and noise filtering using Profiler software

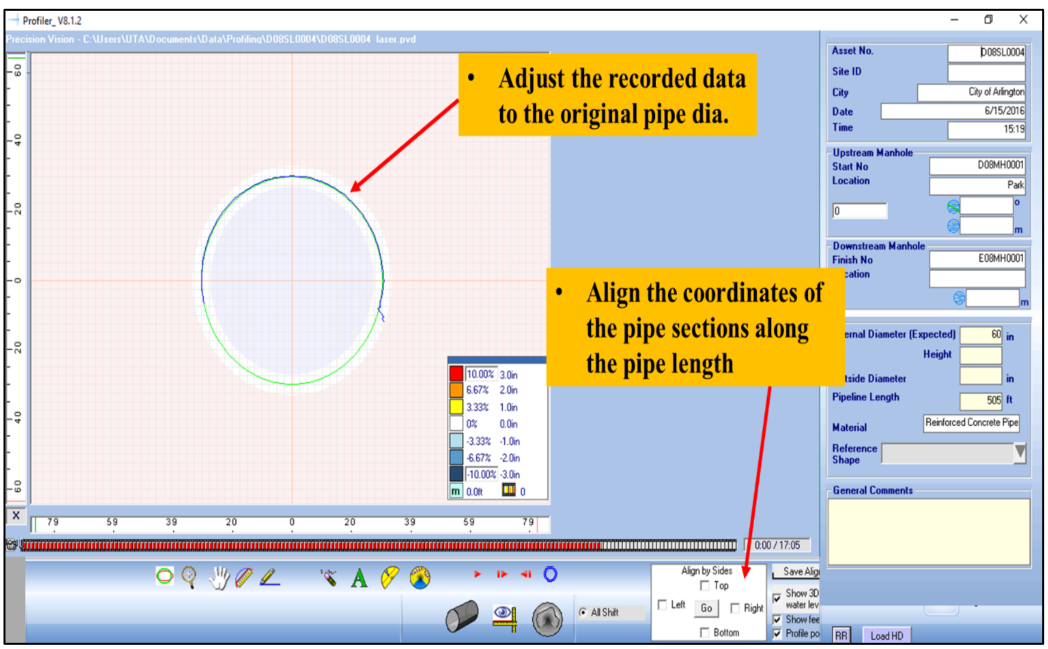


Figure 2-7 Adjusting the recorded data to the original pipe diameter and aligning the coordinates of the pipe sections along the pipe length using Profiler software.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1				WaterLev	0	0	0	0	0	0	0	0	0	0	0
2	Frame No	Distance	VideoTim		Point 1 (1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9	Point 10	Point 11
3	10	0.05	480.399	X-->	0	0	0	0	0	0	0	0	0	0	0
4				Y-->	0	0	0	0	0	0	0	0	0	0	0
5	92	3.05	486.928	X-->	0	0	0	0	0	0	0	0	0	0	0
6				Y-->	0	0	0	0	0	0	0	0	0	0	0
7	151	6.05	491.516	X-->	0	0	0	0	0	0	0	0	0	0	0
8				Y-->	0	0	0	0	0	0	0	0	0	0	0
9	201	11.3	495.457	X-->	0	0	0	0	0	0	0	0	0	0	0
10				Y-->	0	0	0	0	0	0	0	0	0	0	0
11	278	12.05	501.516	X-->	0	0	0	0	0	0	0	0	0	0	0
12				Y-->	0	0	0	0	0	0	0	0	0	0	0
13	344	15.05	506.692	X-->	0	0	0	0	0	0	0	0	0	0	0
14				Y-->	0	0	0	0	0	0	0	0	0	0	0
15	409	18.05	511.751	X-->	0	0	0	0	0	0	0	0	0	0	0
16				Y-->	0	0	0	0	0	0	0	0	0	0	0
17	475	21.1	516.927	X-->	0	0	0	0	0	0	0	0	0	0	0
18				Y-->	0	0	0	0	0	0	0	0	0	0	0
19	541	24.05	522.104	X-->	0	0	0	0	0	0	0	0	0	0	0
20				Y-->	0	0	0	0	0	0	0	0	0	0	0
21	608	27.05	527.398	X-->	0	0	0	0	0	0	0	0	0	0	0
22				Y-->	0	0	0	0	0	0	0	0	0	0	0
23	674	30.05	532.456	X-->	0	0	0	0	0	0	0	0	0	0	0

Laser Data

Figure 2-8 Example of the extracted data in CSV file format.

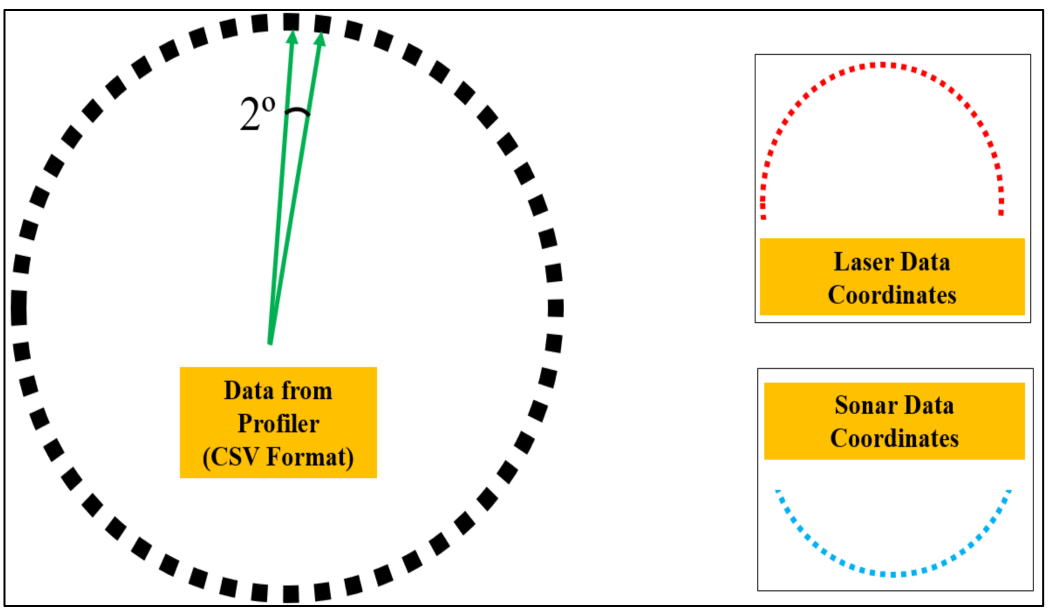


Figure 2-9 Laser and sonar profiles are represented in coordinates every two degrees.

Challenges

Field Measurement Challenges

Every inspection deployment is unique by itself. The challenges are always there for sewer lines inspection. The COA and UTA teams, after good training sessions by RedZone team, were able to successfully overcome the following inspection challenges.

Bends

Bends in lines introduce a significant challenge. There is a high probability for the float to be turned over at line bends especially if these bends are close to 90 degrees or sometimes less. Hence, increasing the float speed few feet before sharp bends and releasing the downstream tether tension is considered the best solution for the float to maneuver line bens and overcome the possibility of the float getting turned over.

Tagging

Tagging is having the equipment (the float) connected from both sides (front and back) to the upstream and downstream winches using tethers. The advantage of tagging is to pull the equipment using downstream winch if it encounters an obstruction in the pipe like a sediment, a rock, a low flow or roots.

Parachuting

Parachuting is having the equipment (the float) connected to a parachute in the front. This technique helps to increase the equipment speed when there is not enough flow level or enough flow velocity.

Low flow Level

When the level of the flow in the pipe is low, the inspection process can be a little harder to perform. The reason of that is, when there is a low flow level, the float would not be floating and rather being almost sitting in the pipe. Therefore, tagging is one of the solutions. A second solution, when there is almost no flow, is using the float wheels and the float can be dragged on those wheels using downstream winch. Furthermore, an artificial flow can be created by adding water to the upstream manhole from a close fire hydrant to raise the flow level to the extent that the float can be floating.

High Flow Level

The high flow level can be damaging to the equipment as the camera and the laser parts hit the top of the pipe. Also, these is a probability for the pipe to collapse by the latter action if the pipe in a poor condition. Another possibility of the equipment get damaged with high flow levels is being turned over at sharp bends. The best solution to that problem is to wait till the flow level gets low enough to make the deployment.

Weather

The weather condition can highly affect the inspection process. Examples of bad weather conditions are raining, storms, lightening and high temperature degree or sowing. It is always a good practice to hold off the work until the bad weather condition is gone. Sometimes, the inspection work cannot be resumed the day after, because the insertion and the extraction manholes locations would be in a muddy situation. The solution for the last case is to shift that particular deployment and choose another deployment has the insertion and the extraction manholes locations on a stiff ground.

Tether Tension

The tether tension needs to be checked out continuously throughout the whole deployment time to make sure that the tether has the appropriate tension (for both sides in case of tagging). The upstream winch tether gets slack if the float gets stuck during the deployment, while the downstream tether gets tensioned. If the latter situation happened, the run should be stopped and try to pull the equipment back and let it go again. That process, of pulling back and letting go, can be done for few times, but if the float didn't make it, the equipment should be pulled back to the nearest equipment and extracted. The obstruction can be identified later after watching the recorded video.

Camera Lenses and Laser Cleaning

It is better to clean the camera lenses as well as the laser head, whenever it is possible through manholes as they are getting splashed by the pipe flow in between the insertion and the extraction manholes, in order to collect more accurate data.

Camera Lenses Damage

The lenses of the camera are susceptible to get damaged especially when the equipment gets hit by sediments, rocks or the equipment get capsized. That could be a cause for slowing down the work as the replacing time and the calibration process might be few days.

Equipment Insertion and Extraction

The insertion of the robot and the extraction is challenging and usually need a man entry. The field team came up with a new technique to insert and extract the equipment without a man entry in most cases. The technique is simply based on using a few ropes to lower down the equipment at the upstream manhole. For the extraction, the team usually uses the tether to pull up the equipment from the downstream manhole.

Data Analysis Challenges

There are a few challenges in the data analysis process. These challenges are listed below:

- Aligning the laser and sonar coordinates.
- Combining the laser and sonar data.
- Using CCTV videos and laser to identify different pipe damages and the severity of the fractures.
- Creating algorithm and writing computer programming codes for estimating the pipe diameter.
- Creating algorithm and writing computer programming codes for estimating the deposits level and corresponding area.
- Creating algorithm and writing computer programming codes for estimating the debris level and corresponding area.
- Creating algorithm and writing computer programming codes for estimating the erosion.
- Creating algorithm and writing computer programming codes for estimating the ovality.
- Creating algorithm and writing computer programming codes for estimating Identifying and filtering the data noise.

- Creating algorithm and writing computer programming codes for estimating the pipe blockage area.
- Creating algorithm and writing computer programming codes for estimating the debris and deposits volume for a typical line.

Chapter 3

Development of Pipe Assessment Software

The pipe assessment software is developed by UTA team to obtain information about the sewer pipes condition. The developed software uses the laser and sonar coordinates that are extracted from Profiler software (as it was explained earlier). It was an essential part of the agreement in the Technology Partnership Program (TPP) to create a software by UTA to usefully get information about the sewer pipe condition beyond the visual inspection that is performed using the recorded CCTV videos. The capabilities of the developed software are discussed in the following sections in this chapter.

Combining Data, Aligning Data and Data Noise Filtering

After extracting laser and sonar data from Profiler software (as it is explained in Chapter 2), the coordinates then combined together to draw the full pipe profile. At this stage, the data of both laser and sonar are aligned for all sections along the pipe. Furthermore, data noise filtering is performed right after to get rid of the odd points resulting from reflections and bad software profile recordings.

The bad recordings happen when the Profiler software picks up some extra points for laser and sonar due to few reasons such as the chosen contrast, laser or sonar width and/or the chosen recorded zone. The developed software has the ability to significantly reduce the resulted noise.

Combining and aligning data and data noise filtering using the developed software are shown in Figure 3-1 and Figure 3-2 respectively.

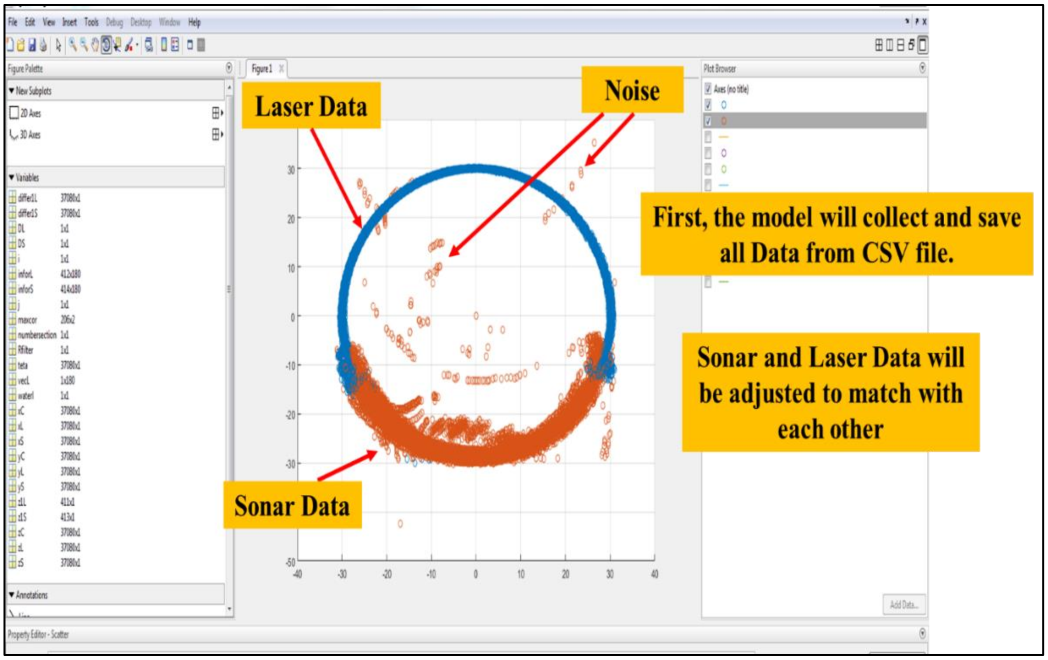


Figure 3-1 Combining and aligning data

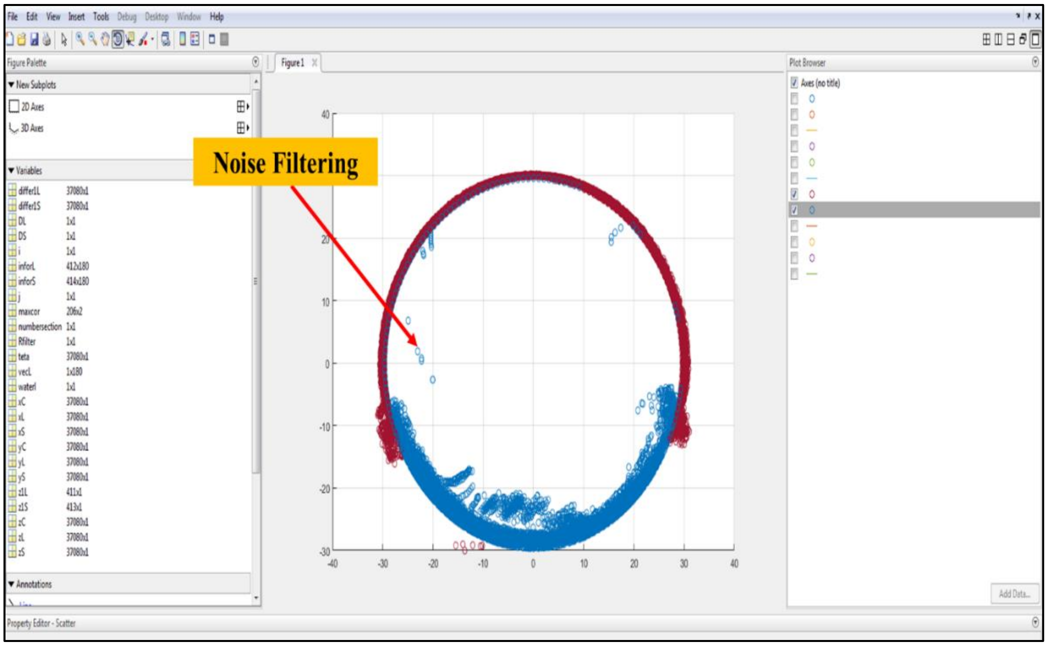


Figure 3-2 Data noise filtering

Measurement of Sewer Water Level

Knowing the sewer water level for the sewer pipes is helpful for municipalities to get an idea about the flow rate running in a particular the pipe in a certain area. It would be a good information for the municipality to improve their hydraulic model. The developed software is measuring the sewer water level in each section along the pipe length. The software is calculating the laser lowest point as well as the sonar highest point and take the highest magnitude of both values, as it shown in Figure 12.

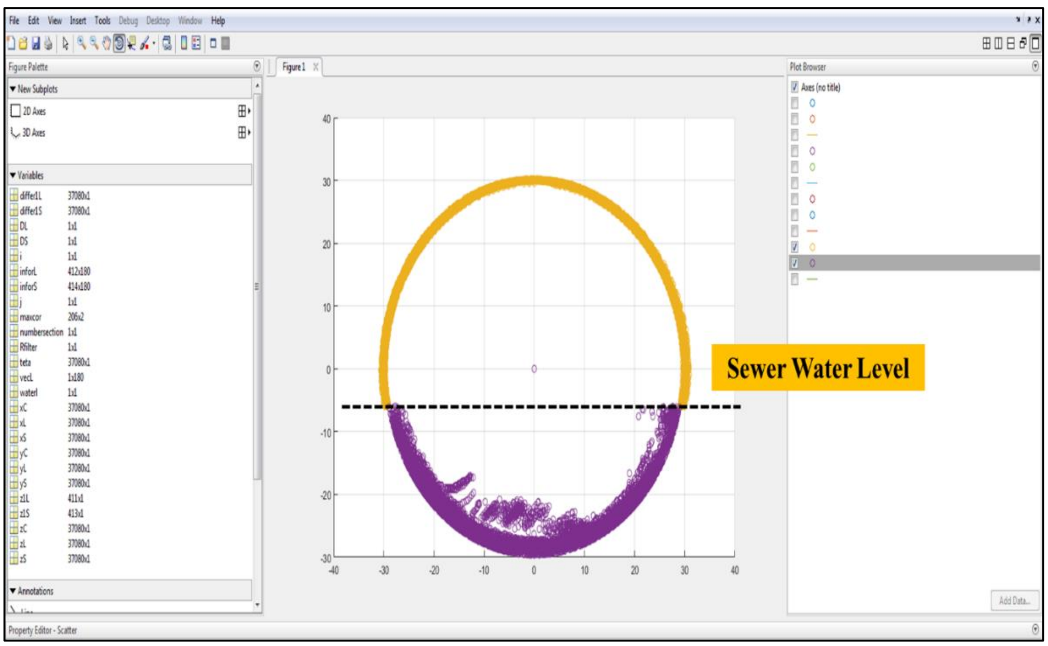


Figure 3-3 Sewer water level

Measurement of Erosion Level per Section

Measuring the erosion level per section is important for municipalities to have an idea about how much the pipe is eroded, especially if the pipe is reinforced concrete pipe. Knowing the pipe thickness is significant for estimating the pipe condition and take proactive actions to do maintenance or replacement to the pipe. Calculating the maximum and the mean erosion level per section is performed to the laser data as the erosion of the pipe wall mainly happens above the sewer water level. The maximum erosion level represents how deep the section is eroded. It helps municipalities to have an idea about which sections in the pipe line that are eroded the most. Also, the developed software calculates the mean erosion level per section. Sometimes, the maximum erosion level represents one small point in a particular section. So, having the magnitude of the mean erosion level is vital to grasp extra information about the wall loss condition at a certain section in the pipe. Representing the maximum erosion level along with the mean erosion level for each section in the pipe throughout its length would give a broader picture for municipalities about the worst sections in their sewer pipe system. Hence, a proper decision could be made by their consultants to do more realistic solutions and maintenance plans. The maximum erosion level is calculated in the developed software by measuring the farthest laser point from the original pipe diameter for each section, as shown in Figure 3-4. In addition to the maximum erosion level per section, the mean erosion level is calculated by summing all the laser points magnitudes beyond the original pipe diameter and divide that number by the numbers of these points for each section. The output of the developed software for measuring the sewer maximum and mean erosion level per section is shown in Figure 3-5. The developed software also prints all the erosion data throughout the pipe length into excel sheet table for every three feet. Example of the developed software output table for erosion data along the pipe length is shown in Table 3.1.

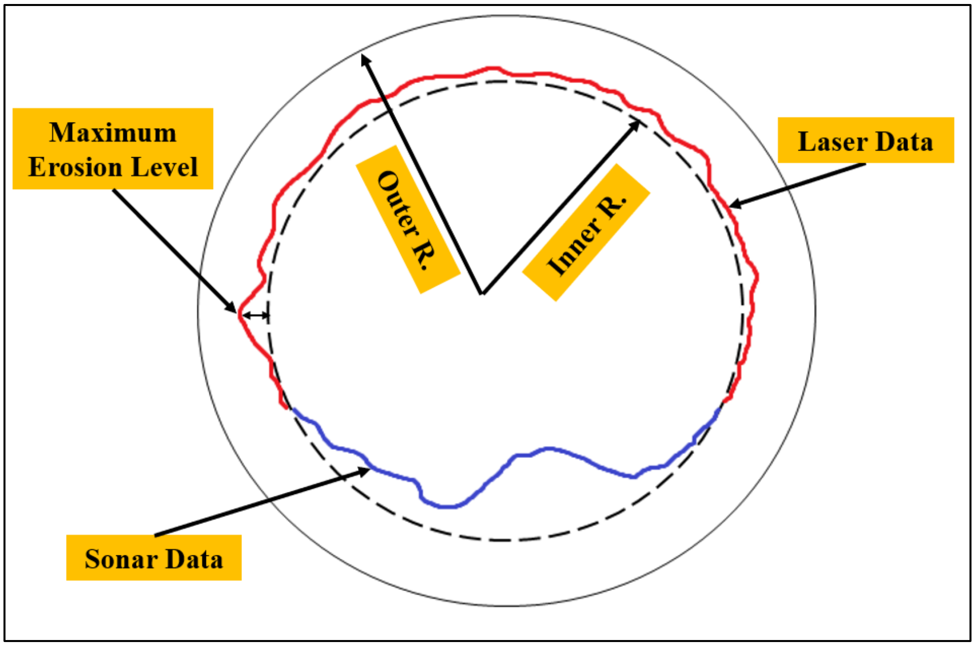


Figure 3-4 Calculation of the maximum erosion level from laser data

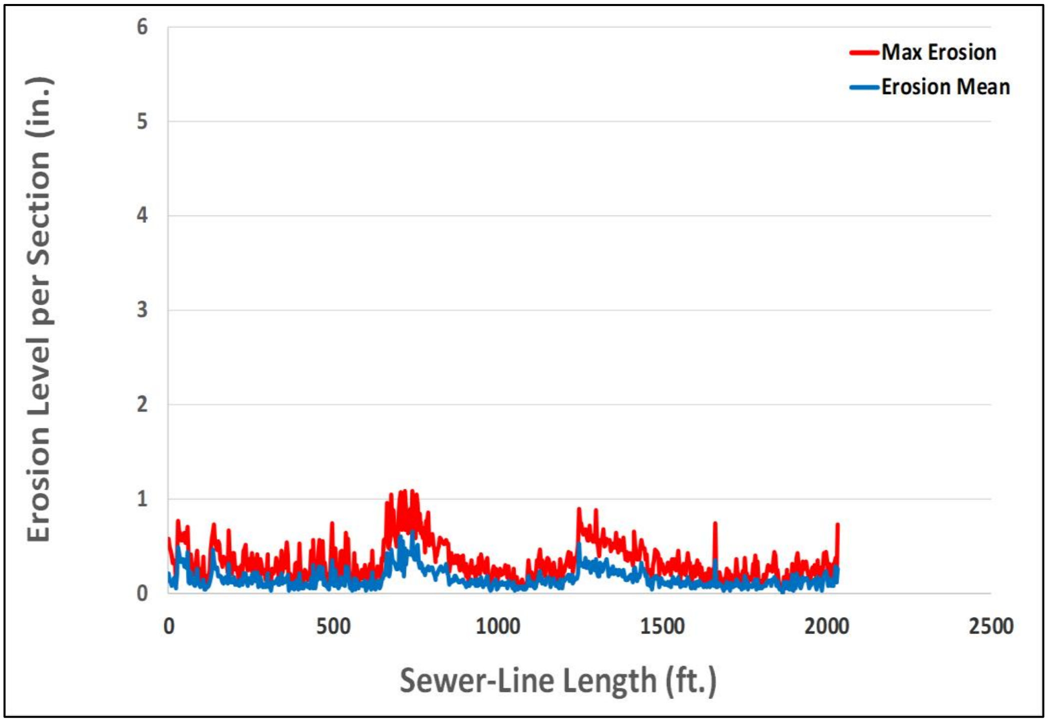


Figure 3-5 Maximum and mean erosion level per pipe section

Table 3-1 Example of the developed software output table for erosion data along the pipe length.

Maximum Erosion Per Section (in.)	**Erosion Mean Per Section (in.)**	**Sewer Line Length (ft.)**
0.36	0.11	1.00
0.39	0.13	3.05
0.17	0.07	6.05
0.27	0.12	9.05
0.14	0.07	12.05
0.11	0.05	15.05
0.23	0.09	18.05
0.13	0.06	21.05
0.12	0.09	24.05
0.15	0.08	27.05
0.10	0.03	30.05
0.08	0.04	33.05
0.11	0.06	36.05
0.28	0.18	39.05
0.14	0.09	42.05
0.16	0.08	45.10
0.20	0.10	48.05

Measurement of Debris Level per Section

Measuring the debris level per section is important for municipalities to have an idea about how much the pipe is having debris built up at the pipe bottom under the sewer water level. Knowing the pipe debris amount is significant for estimating how much the pipe is blocked by debris that hinders the sewer flow and to take proactive actions to do operations and maintenance (O&M) to the pipe. Calculating the maximum and the mean debris level per section is performed to the sonar data as the pipe debris mainly happens under the sewer water level. The maximum debris level represents how much one particular section is being choked. It helps municipalities to have an idea about which sections in the pipe line that are having the most debris. Also, the developed software calculates the mean debris level per section. Sometimes, the maximum debris level represents one small point in a particular section. So, having the magnitude of the mean debris level is vital to grasp extra information about the overall debris condition that is accumulated at the bottom of the sewer pipe at a certain section in the pipe. Representing the maximum debris level along with the mean debris level for each section in the pipe throughout its length would give a broader picture for municipalities about the worst blocked sections by debris in their sewer pipe system. Hence, a proper decision could be made by their consultants to do more realistic solutions and operation and maintenance plans. The maximum debris level is calculated in the developed software by subtracting the original pipe diameter from the sonar diameter and take the highest value for each section, as shown in Figure 3-6. In addition to the maximum debris level per section, the mean debris level is calculated by summing all the debris sonar points magnitudes and divide that number by the numbers of these points for each section. The output of the developed software for measuring the sewer maximum and mean debris level per section is shown in Figure 3-7. The developed software also prints all the debris data and the sewer water level throughout the pipe length into excel sheet table for every three feet. Example of the developed software output table for debris data and the sewer water level along the pipe length is shown in Table 3.2.

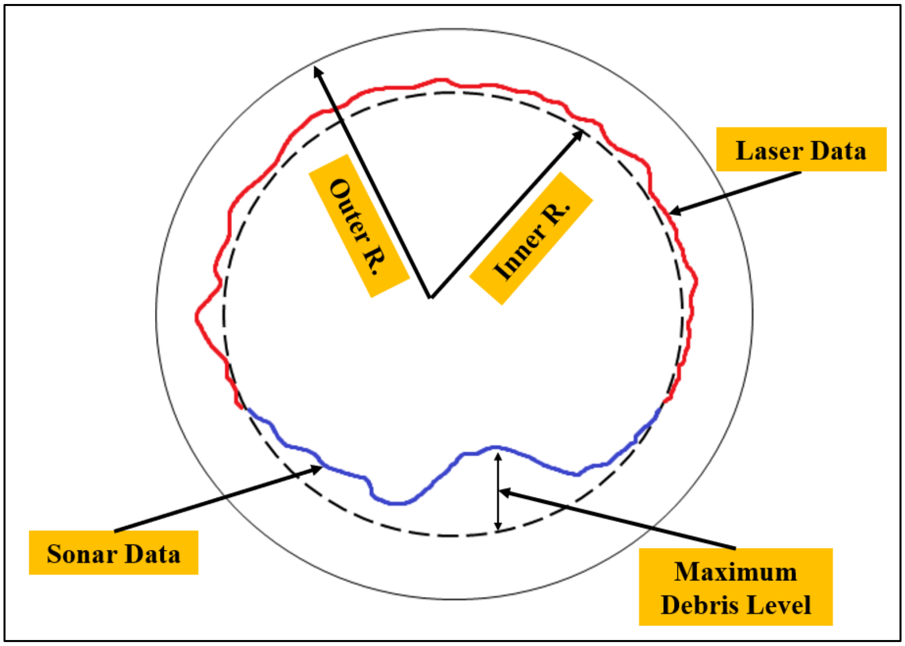


Figure 3-6 Calculation of the maximum debris level from sonar data.

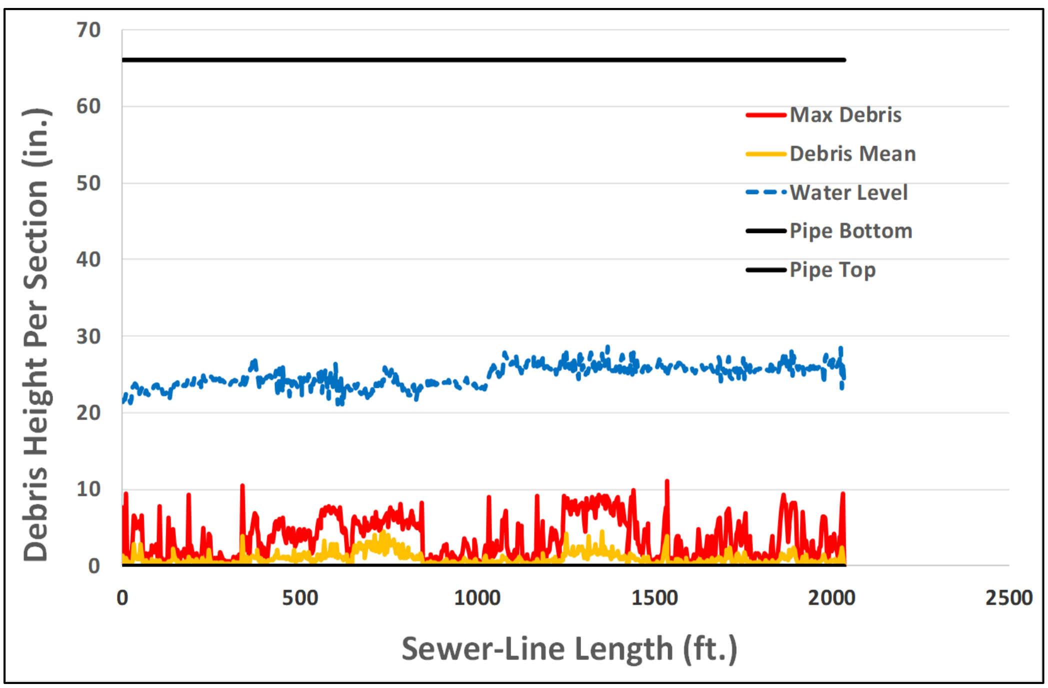


Figure 3-7 The output of the developed software for measuring the sewer maximum and mean debris level per section

Table 3-2 Example of the developed software output table for debris data and sewer water level along the pipe length.

Maximum Debris Height Per Section (in.)	Debris Mean Height Per Section (in.)	Sewer Water Level (in.)	Sewer Line Length (ft.)	Pipe Top	Pipe Bottom
1.66	0.37	5.66	1.00	32.50	0
1.80	0.54	5.11	3.40	32.50	0
0.93	0.18	5.72	6.30	32.50	0
0.41	0.26	5.40	9.70	32.50	0
1.67	0.72	4.96	12.05	32.50	0
1.41	0.58	5.34	15.40	32.50	0
1.34	0.51	5.03	18.30	32.50	0
2.03	1.18	6.46	21.20	32.50	0
3.91	1.72	6.16	24.10	32.50	0
0.26	0.32	6.31	27.95	32.50	0
2.53	0.75	5.60	30.80	32.50	0
0.08	0.05	5.00	33.70	32.50	0
0.51	0.22	5.45	36.65	32.50	0
1.37	0.49	5.76	39.50	32.50	0
2.40	0.52	5.92	42.35	32.50	0
3.94	1.32	5.77	45.25	32.50	0
0.00	0.00	5.43	48.15	32.50	0

Measurement of Debris Area per Section

The developed software calculates the debris area for every section along the pipe length. In addition to the maximum and the mean debris levels, the debris area per section gives a wider picture about the debris data and also gives a different perspective for data interpretation. The debris area per section is calculated by taking the area enclosed by four points. The four points represent two consecutive debris sonar points and two consecutive points on the original pipe circle that are having the same sequence of the chosen debris sonar points. In the same manner, the software continues to calculate all the debris areas at one section and sum them up to get the total debris area at a certain section. The concept of calculating the debris area per section is illustrated in Figure 3-8.

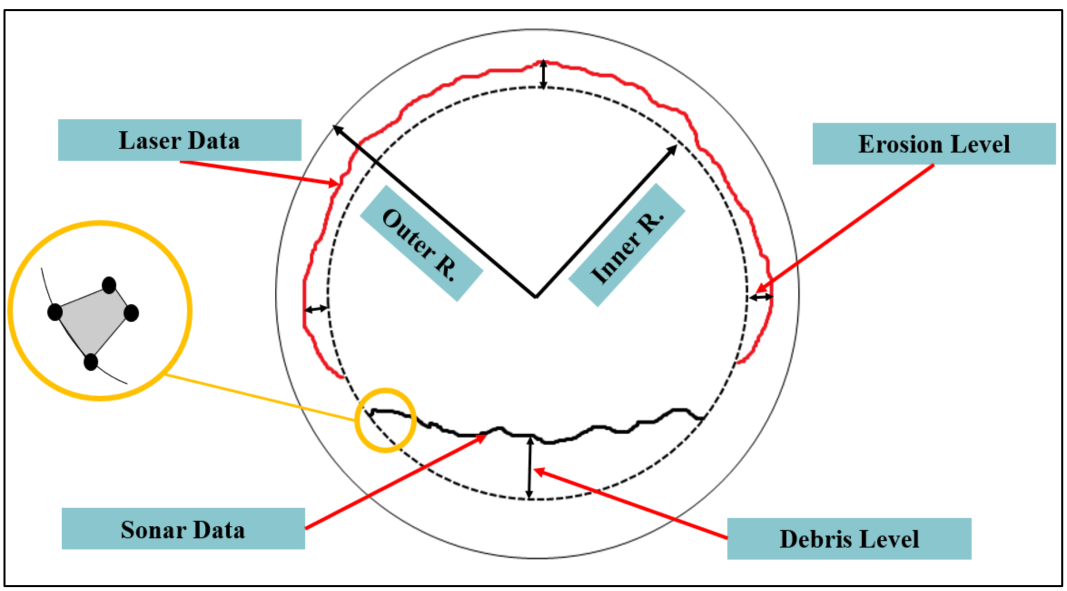


Figure 3-8 The concept of calculating the debris area per section

Moreover, the debris area output for the developed software is shown in Figure 3-9.

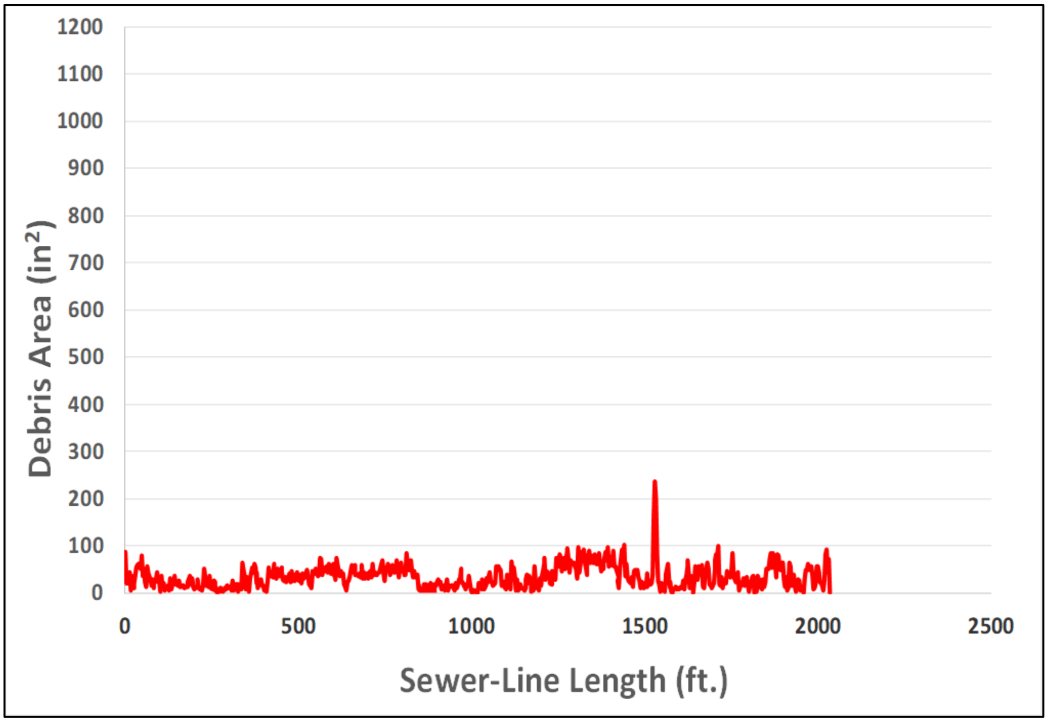


Figure 3-9 Developed software example output for the debris area

The developed software also prints all the debris area throughout the pipe length into excel sheet table for every three feet. Example of the developed software output table for debris area along the pipe length is shown in Table 3.3.

Measurement of The Percentage of Debris Area per Section

The percentage of debris area per section is simply calculated by dividing the debris area calculated in the previous section by the area of the sewer pipe section and multiplied by 100. The percentage of the debris area gives a good information for the municipalities about how much a certain section in the sewer pipe system is blocked by debris.

Table 3-3 Example of the developed software output table for debris area along the pipe length.

Debris Area (in^2)	Sewer Line Length (ft.)
1.99	1.00
4.17	3.40
1.98	6.30
1.46	9.70
3.95	12.05
2.52	15.40
4.21	18.30
7.64	21.20
12.34	24.10
2.31	27.95
7.59	30.80
0.33	33.70
0.87	36.65
6.14	39.50
6.46	42.35
8.21	45.25
0.00	48.15
3.13	52.00
5.90	54.90

Figure 3-10 shows the developed software example output for the percentage of the debris area. The developed software also prints all the percentage of deposit area per section throughout the pipe length into excel sheet table for every three feet. Example of the developed software output table for percentage of debris area per section along the pipe length is shown in Table 3.4.

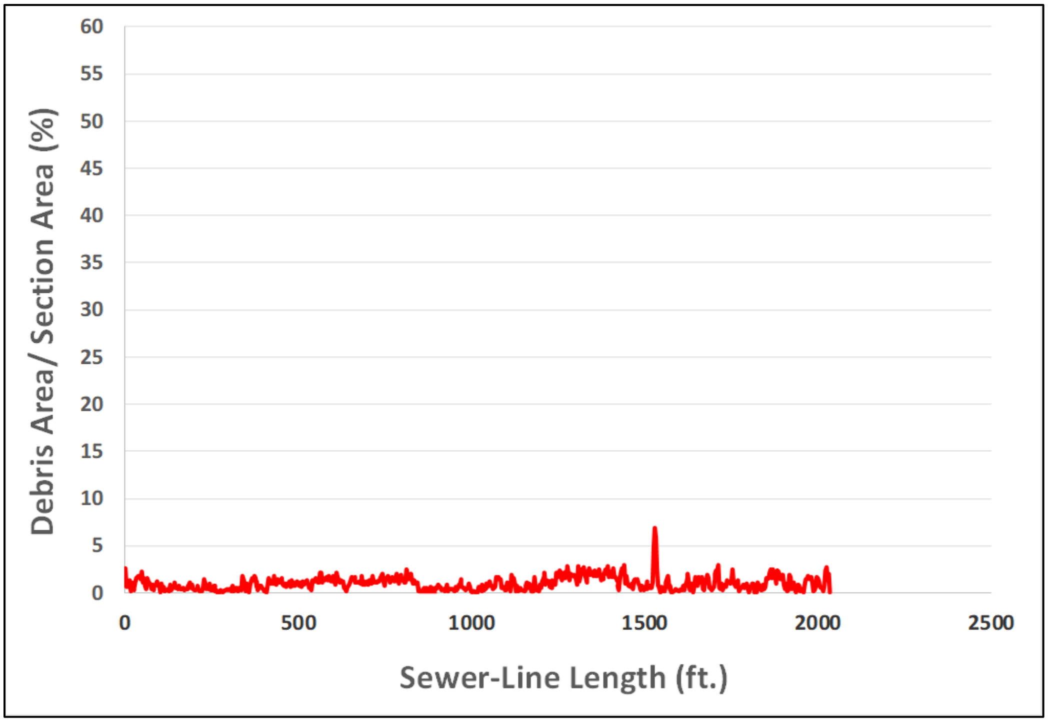


Figure 3-10 Developed software example output for the percentage of the debris area

Measurement of Debris Volume for Each Typical Line

As it was explained earlier, the typical sewer pipe line represents the pipe segment between two consecutive manholes. Knowing the debris volume for a certain line in the sewer pipe system is useful for municipalities to have an idea about how much debris volume they are expecting to clean if they want to do operation and maintenance (O&M).

Table 3-4 Example of the developed software output table for percentage of debris area per section along the pipe length

Debris Area/ Section Area (%)	**Sewer Line Length (ft.)**
0.24	1.00
0.50	3.40
0.24	6.30
0.18	9.70
0.48	12.05
0.30	15.40
0.51	18.30
0.92	21.20
1.49	24.10
0.28	27.95
0.91	30.80
0.04	33.70
0.11	36.65
0.74	39.50
0.78	42.35
0.99	45.25

The developed software calculates the debris volume for a particular line by taking the average of two consecutive debris areas for two consecutive pipe sections and multiplying the result by the distance between the two sections. Furthermore, the software continues to calculate all debris volumes between all sections throughout the pipe length and sum them up to obtain the total debris volume per each typical sewer line. Along with the deposit volume for a typical sewer line, the debris volume could be very useful for municipalities to estimate the cost of a piacular sewer pipe cleaning (performing O&M) by knowing approximately how many cubic feet are needed to be removed from the pipe.

The developed software also prints all the debris volume for the entire pipe into excel sheet table for every three feet. Example of the developed software output table for debris volume for the entire pipe is shown in Table 3.5.

Table 3-5 Example of the developed software output table debris volume for the entire line

Debris Volume Per Line (in^3)	**Debris Volume Per Line (ft^3)**
26722.14	15.5

Measurement of Deposit Level per Section

Measuring the deposit level per section is important for municipalities to have an idea about how much the pipe is having deposits attached to the pipe wall. Knowing the pipe deposit amount is significant for estimating how much the pipe is blocked by deposits and to take proactive actions to do operations and maintenance (O&M) to the pipe. Calculating the maximum and the mean deposit level per section is performed to the laser data as the pipe deposit mainly happens above the sewer water level. The maximum deposit level represents how much one particular section is being choked. It helps municipalities to have an idea about which sections in the pipe line that are having the most deposits. Also, the developed software calculates the mean deposit level per section. Sometimes, the maximum deposit level represents one small point in a particular section. So, having the magnitude of the mean deposit level is vital to grasp extra information about the overall deposit condition that is attached to the pipe wall at a certain section in the pipe. Representing the maximum deposit level along with the mean deposit level for each section in the pipe throughout its length would give a broader picture for municipalities about the worst blocked sections by deposits in their sewer pipe system. Hence, a proper decision could be made by their consultants to do more realistic solutions and operation and maintenance plans. The maximum deposit level is calculated in the developed software by subtracting the original pipe diameter from the laser diameter and take the highest value for each section, as shown in Figure 3-11. In addition to the maximum deposit level per section, the mean deposit level is calculated by summing all the deposit laser points magnitudes and divide that number by the numbers of these points for each section. The output of the developed software for measuring the sewer maximum and mean deposit level per section is shown in Figure 3-12.

The developed software also prints all the deposit data throughout the pipe length into excel sheet table for every three feet. Example of the developed software output table for deposit data along the pipe length is shown in Table 3.6.

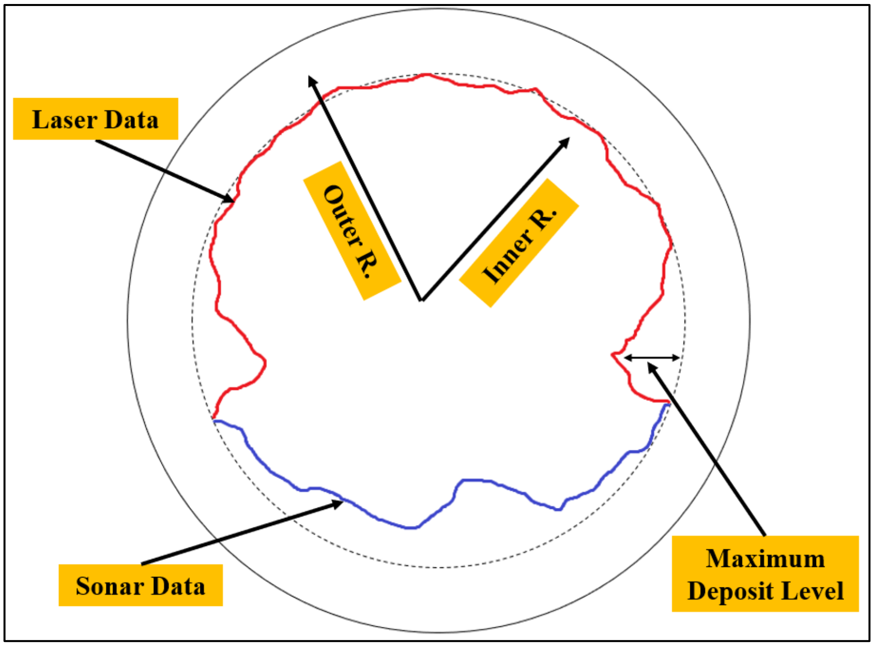


Figure 3-11 Calculation of the maximum deposit level from laser data

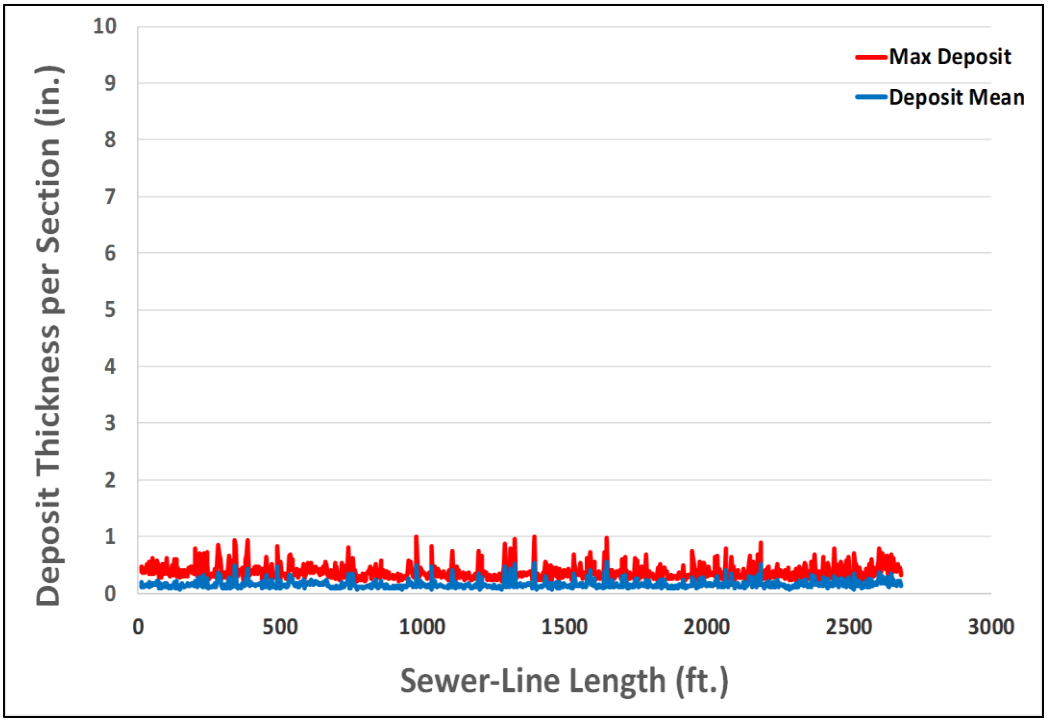


Figure 3-12 Maximum and mean deposit level per pipe section

Table 3-6 Example of the developed software output table for deposit data along the pipe length.

Maximum Deposit Thickness Per Section (in.)	**Deposit Mean Thickness Per Section (in.)**	**Sewer Line Length (ft.)**
0.75	0.25	1
0.42	0.15	3.05
0.85	0.18	6.05
0.41	0.13	9.05
0.45	0.13	12.05
0.50	0.11	15.05
0.38	0.13	18.05
0.47	0.11	21.05
0.54	0.13	24.05
0.39	0.14	27.05
0.79	0.16	30.05
0.44	0.15	33.05
0.63	0.15	36.05
0.67	0.22	39.05
0.33	0.13	42.05
0.68	0.16	45.1

Measurement of Deposit Area per Section

The developed software calculates the deposit area for every section along the pipe length. In addition to the maximum and the mean deposit levels, the deposit area per section gives a wider picture about the deposit data and also gives a different perspective for data interpretation. The deposit area per section is calculated by taking the area enclosed by four points. The four points represent two consecutive deposit laser points and two consecutive points on the original pipe circle that are having the same sequence of the chosen deposit laser points. In the same manner, the software continues to calculate all the deposits areas at one section and sum them up to get the total deposit area at a certain section. The concept of calculating the deposit area per section is the same concept that was explained in calculating the debris area, except that the laser data is taken rather than the sonar data. Moreover, the deposit area output for the developed software is shown in Figure 3-13.

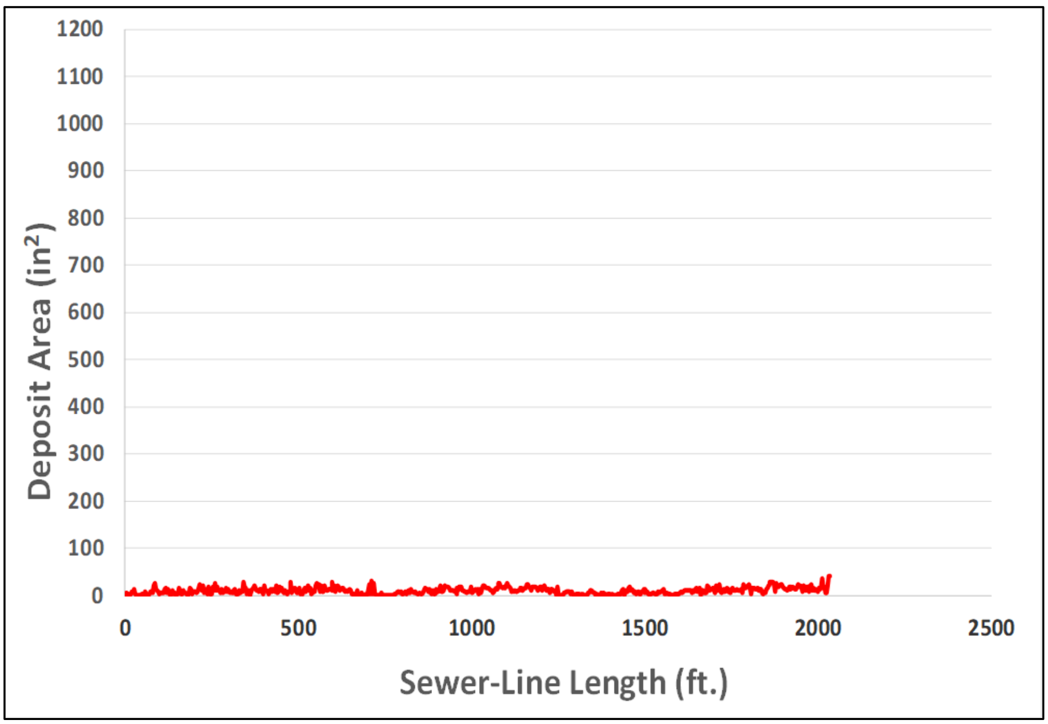


Figure 3-13 Deposit area per pipe section

The developed software also prints all the deposit area throughout the pipe length into excel sheet table for every three feet. Example of the developed software output table for deposit area along the pipe length is shown in Table 3.7.

Table 3-7 Example of the developed software output table for deposit area along the pipe length

Deposit Area (in^2)	**Sewer Line Length (ft.)**
16.37	1.00
7.99	3.05
5.45	6.05
6.36	9.05
7.46	12.05
6.76	15.05
6.87	18.05
5.28	21.05
7.10	24.05
7.71	27.05
10.46	30.05
9.04	33.05
8.54	36.05
11.89	39.05
7.15	42.05
9.09	45.10

Measurement of The Percentage of Deposit Area per Section

The percentage of deposit area per section is simply calculated by dividing the deposit area calculated in the previous section by the area of the sewer pipe section and multiplied by 100. The percentage of the deposit area gives a good information for the municipalities about how much a certain section in the sewer pipe system is blocked by deposits. Figure 3-14 shows the developed software example output for the percentage of the deposit area. The developed software also prints all the percentage of deposit area per section throughout the pipe length into excel sheet table for every three feet. Example of the developed software output table for percentage of deposit area per section along the pipe length is shown in Table 3.8.

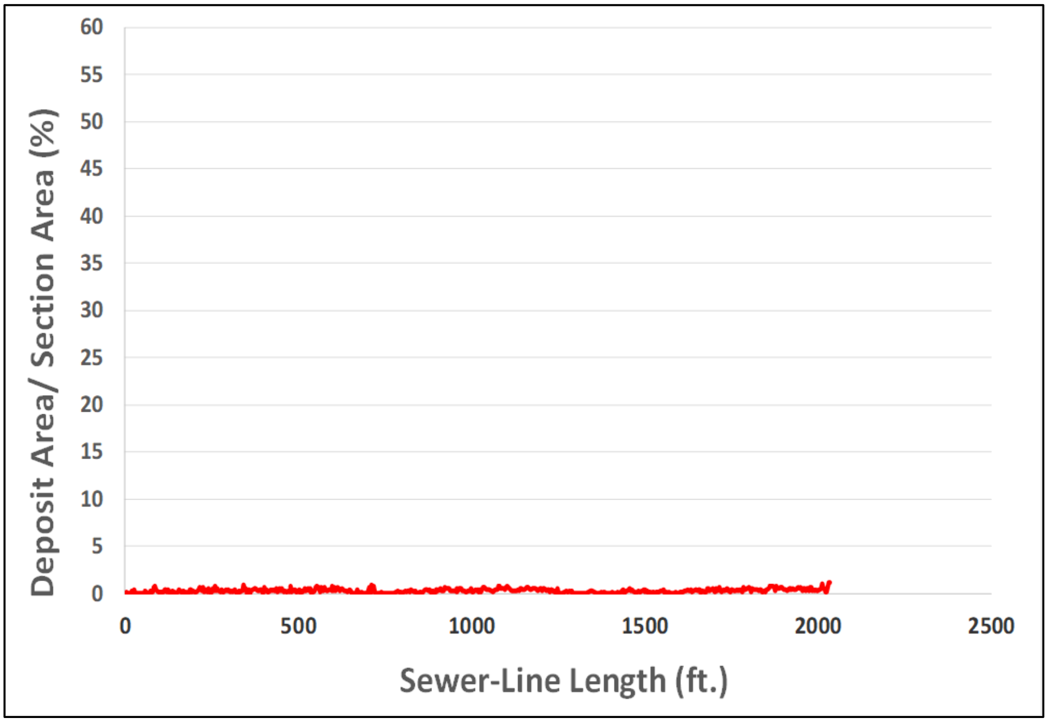


Figure 3-14 Developed software example output for the percentage of the deposit area

Table 3-8 Example of the developed software output table for percentage of deposit area per section along the pipe length

Deposit Area/ Section Area (%)	**Sewer Line Length (ft.)**
1.97	1.00
0.96	3.05
0.66	6.05
0.77	9.05
0.90	12.05
0.82	15.05
0.83	18.05
0.64	21.05
0.86	24.05
0.93	27.05
1.26	30.05
1.09	33.05
1.03	36.05
1.43	39.05
0.86	42.05
1.10	45.10
0.98	48.05
1.06	51.10

Measurement of Deposit Volume for Each Typical Line

As it was explained earlier, the typical sewer pipe line represents the pipe segment between two consecutive manholes. Knowing the deposit volume for a certain line in the sewer pipe system is useful for municipalities to have an idea about how much deposit volume they are expecting to clean if they want to do operation and maintenance (O&M). The developed software calculates the deposit volume for a particular line by taking the average of two consecutive deposit areas for two consecutive pipe sections and multiplying the result by the distance between the two sections. Furthermore, the software continues to calculate all deposit volumes between all sections throughout the pipe length and sum them up to obtain the total deposit volume per each typical sewer line. The developed software also prints all the deposit volume for the entire pipe into excel sheet table for every three feet. Example of the developed software output table for deposit volume for the entire pipe is shown in Table 3.9.

Table 3-9 Example of the developed software output table deposit volume for the entire line

Deposit Volume Per Line (in^3)
34057.9

Measurement of the percentage of Blockage Area per Section

The percentage of blockage area represents the summation of both the deposit area and the debris area for a particular pipe section and divided by the total area of the same pipe section and multiplying the result by 100. Also, the developed software output presented by the percentage of blockage area is considered very useful for municipalities to obtain good information about how much percentage of a certain pipe section in their sewer pipe system is being blocked by both deposits and debris. For all municipalities, it is easier to know which pipes in its sewer system that need operation and maintenance the most for the future maintenance plans. Furthermore, it gives more information for municipalities to know about the pipe flow capacity and to improve the municipality hydraulic model. The developed software output for the percentage of blocked area per section is shown in Figure 3-15. The developed software also prints all the percentage of blockage area per section throughout the pipe length into excel sheet table for every three feet.

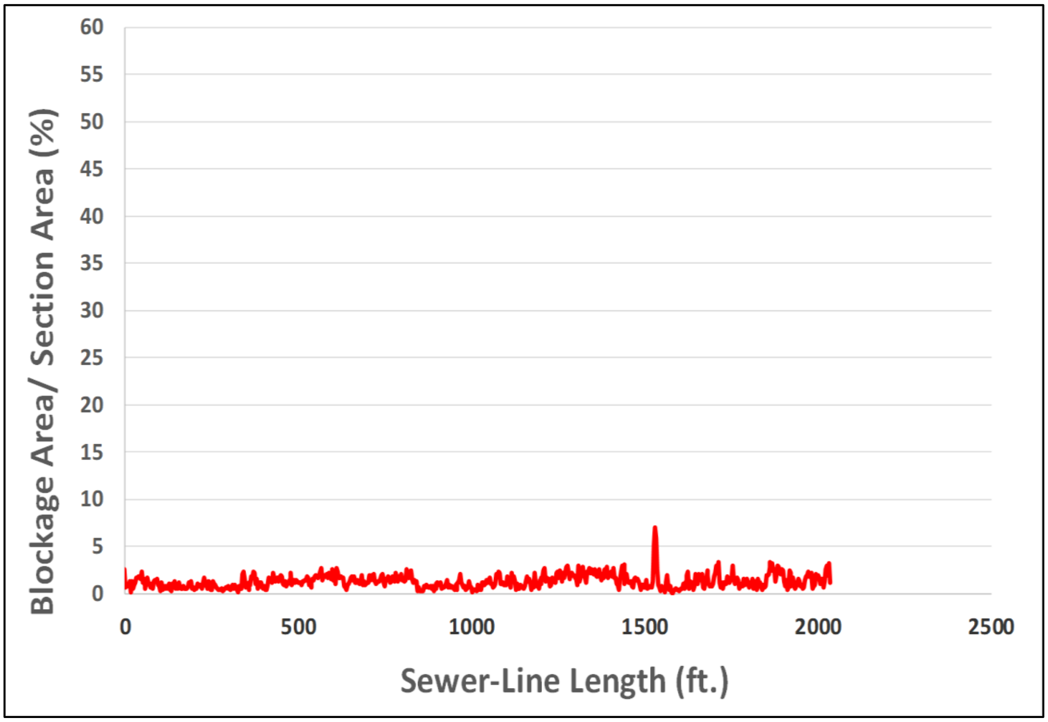


Figure 3-15 Developed software output for the percentage of blocked area per pipe section

Example of the developed software output table for percentage of blockage area per section along the pipe length is shown in Table 3.10.

Table 3-10 Example of the developed software output table for percentage of blockage area per section along the pipe length

Blockage Area/ Section Area (%)	**Sewer Line Length (ft.)**
2.21	1.00
1.47	3.05
0.90	6.05
0.94	9.05
1.37	12.05
1.12	15.05
1.33	18.05
1.56	21.05
2.34	24.05
1.21	27.05
2.18	30.05
1.13	33.05
1.13	36.05
2.17	39.05
1.64	42.05
2.09	45.10
0.98	48.05

Measurement of Section Ovality

Due to poor embedment, poor bedding or pipe over load, flexible pipes could be significantly deflected. It is significant for municipalities to have information about pipe section ovality especially for flexible pipes because they are not designed to have a significant deflection. Also, it is important to know if there is any kind of deflection or significant ovality in rigid pipe as well (like RCP pipes, VCP pipes, etc.), because in most cases it refers to a damage in the pipe that makes the deflection or make the pipe oval. These kinds of damages might be considered serious ones such as fractures that could lead the pipe to collapse. The developed software calculates the ovality by using the following formula:

$$\frac{(x\ Diameter\ \ -y\ Diameter)}{Original\ Diameter} \times 100$$

The developed software output for pipe section ovality is shown in Figure 3-16.

The developed software also prints all the ovality data throughout the pipe length into excel sheet table for every three feet. Example of the developed software output table for ovality data along the pipe length is shown in Table 3.11.

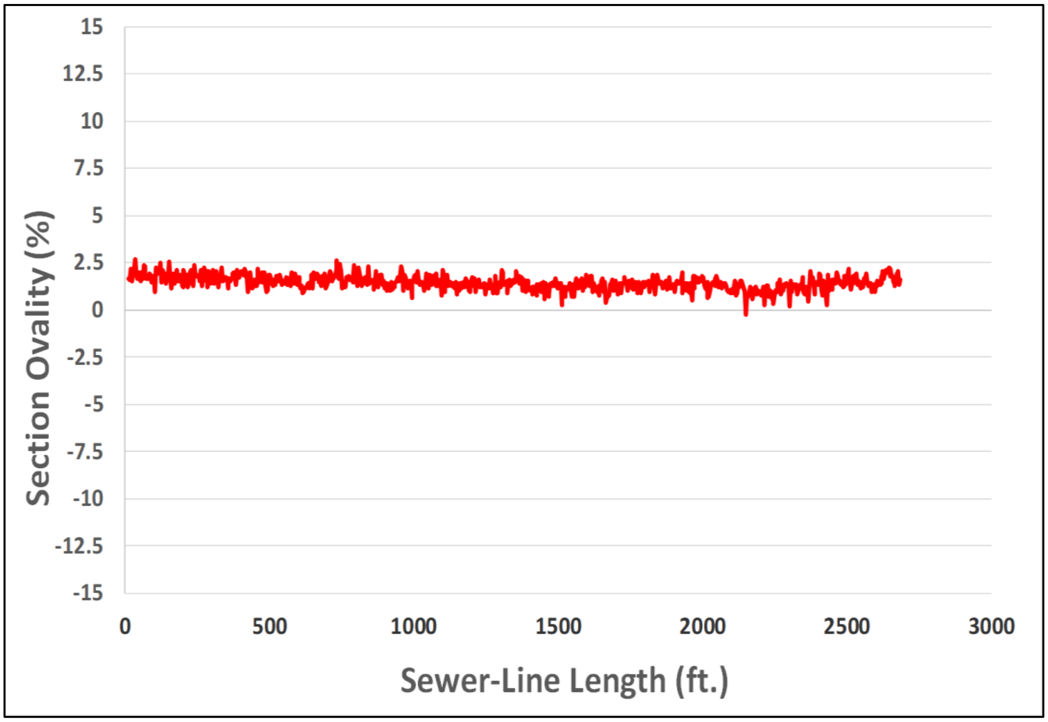


Figure 3-16 Developed software output for pipe section ovality

Table 3-11 Example of the developed software output table for ovality data along the pipe length

X - Diameter	Y - Diameter	Section Ovality (%)	Sewer Line Length (ft.)
32.29	31.66	1.94	1.00
32.53	32.14	1.20	3.05
32.55	32.60	-0.15	6.05
32.50	32.36	0.43	9.05
32.46	32.28	0.55	12.05
32.48	32.30	0.55	15.05

32.43	32.26	0.52	18.05
32.55	32.16	1.20	21.05
32.41	32.16	0.77	24.05
32.59	32.06	1.63	27.05
32.48	32.02	1.42	30.05
32.57	31.92	2.00	33.05
32.57	32.02	1.69	36.05
32.54	31.92	1.91	39.05
32.52	32.14	1.17	42.05
32.50	32.10	1.23	45.10
32.52	32.12	1.23	48.05
32.57	32.16	1.26	51.10

Algorithm Flow Charts

The developed Algorithm processes for the pipe condition assessment software are introduced in this section. The concept of the algorithm of measuring the debris level for each pipe section in sewer pipelines is presented in a flow chart as shown in Figure 3-17. Also, the concept of the algorithm of measuring the deposit level for each pipe section in sewer pipelines is presented in a flow chart as shown in Figure 3-18. Moreover, the concept of the algorithm of measuring the blockage level and the erosion level for each pipe section in sewer pipelines are presented in flow charts as shown in Figure 3-19 and Figure 3-20, respectively.

Figure 3-17 The developed algorithm flow chart for measuring the debris level

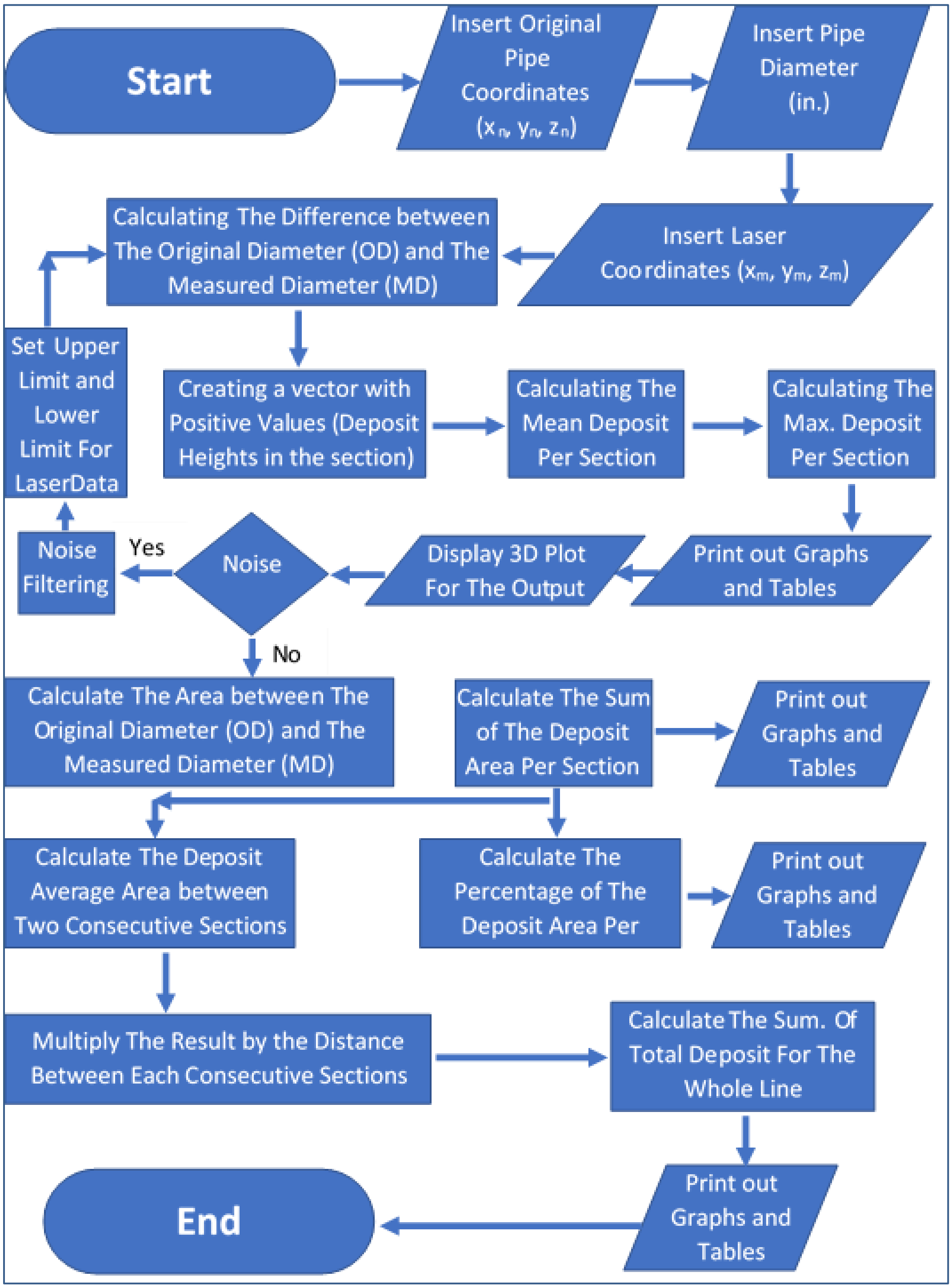


Figure 3-18 The developed algorithm flow chart for measuring the deposit level

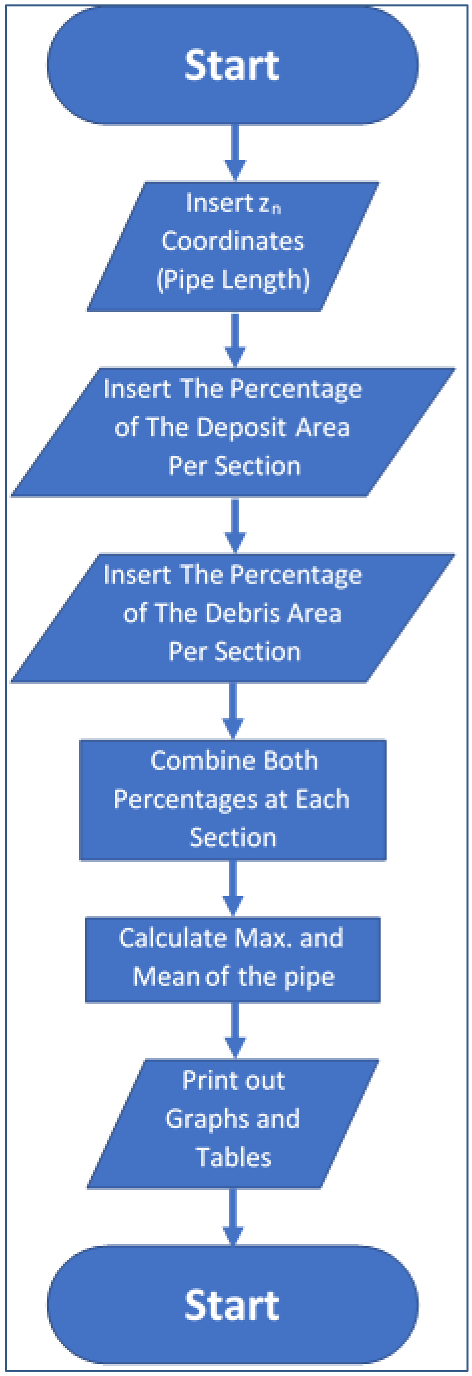


Figure 3-19 The developed algorithm flow chart for measuring the blockage level

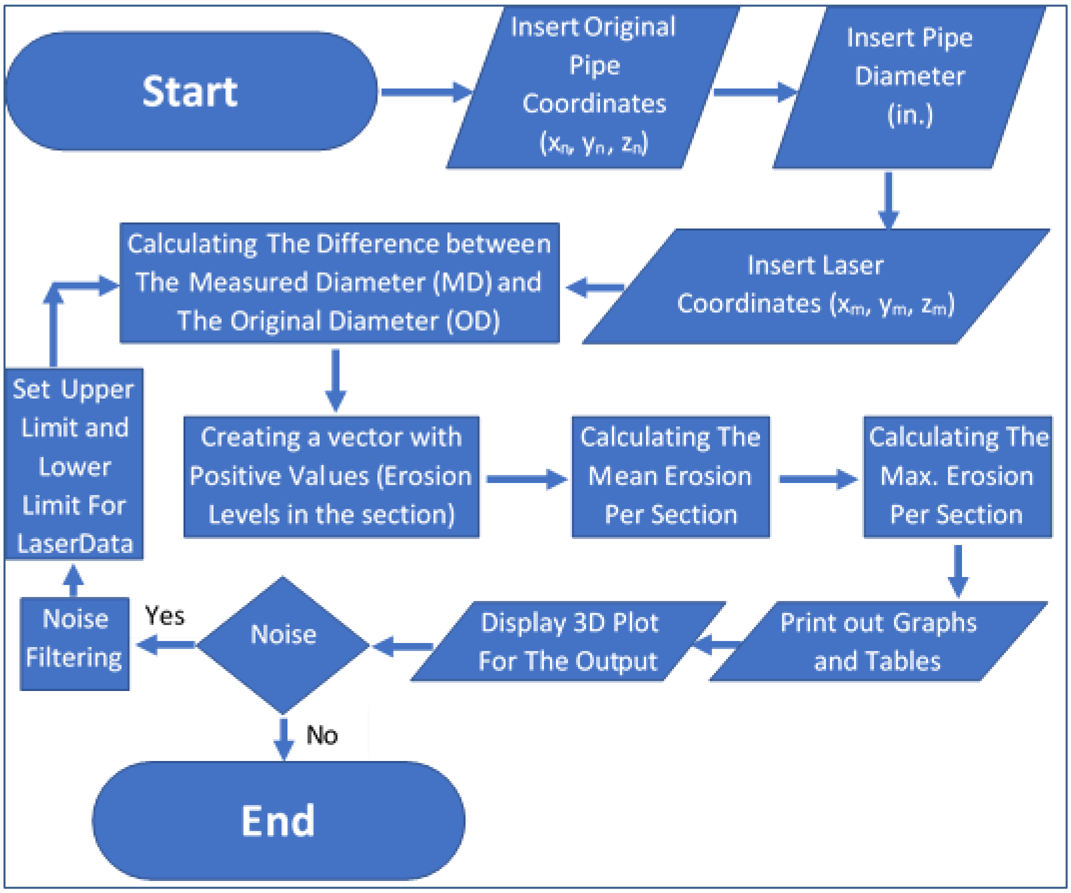


Figure 3-20 The developed algorithm flow chart for measuring the Erosion level

Chapter 4

Results and Discussion

The developed software output of the measured laser and sonar data as well as the result of the visual inspection of the large diameter (24-inch and above) sewer pipe system in the city of Arlington in Texas are presented in this chapter. The laser and sonar data output include the debris level, corrosion level, deposit level and the blockage percentage area.

Furthermore, the visual inspection results, using CCTV videos, include all the other defects that could not be detected by laser and sonar measurements such as, but not limited to, fractures and root intrusion.

The results in this chapter are representing approximately six miles of the large diameter sewer pipe system (24-inch and above) in the city of Arlington in Texas. Besides, the results also include one sewer line that has been inspected for the city of Rowlett in Texas and another sewer line that has been also inspected for the city of Ennis in Texas.

Moreover, the GIS irregularities between the inspection observations and the city's GIS data base is also introduced in this chapter. Also, the summary tables for the inspection cycles are presented.

The inspected 6 miles for the city of Arlington are divided into two inspections cycles with total of 63 sewer lines, as shown in Table 4.1 (each sewer line represents every line segment between two consecutive manholes). The asset number and the location of the lines are not shown in this research as a part of COA privacy. The maps of the two inspected cycles are presented in Figure 4-1 and Figure 4-2, respectively.

Table 4-1 Example of the developed software output table for ovality data along the pipe length

Pipe Number	GIS Pipe Material	Observed Pipe Material	GIS Pipe Diameter (in.)	Observed Pipe Diameter (in.)	Observed Pipe Length (ft.)	Distance Planned (ft.)
1	FRP	FRP	48	48.2	333	351
2	FRP	FRP	54	54	456.1	534.3
3	FRP	FRP	54	54	460	855
4	VCP	DI	36	37.1	182.55	174.1
5	DI	DI	36	36.9	470.3	350.3
6	VCP	DI	36	37.1	155.3	173.4
7	VCP	DI	36	37.1	320.3	577.3
8	DI	DI	36	37.1	56.25	58.1
9	DI	DI	24	36	19.35	12.7
10	DI	DI	30	30	729.75	722.4
11	DI	DI	30	30.7	1167.55	1151.3
12	DI	DI	30	30	993.6	1019.1
13	RCP	RCP	48	48	205.3	202
14	RCP	RCP	60	60	102.6	138
15	RCP	RCP	60	60	2688.7	2847.9
16	RCP	RCP	60	60	626	596.7
17	RCP	RCP	60	66	1220	1391.8
18	RCP	RCP	66	66	2035.55	2090.5
19	VCP	DI	36	37.2	590.3	592
20	VCP	DI	36	37.2	745.5	750
21	VCP	DI	36	37.2	353.5	376
22	VCP	VCP	27	26	514.3	519
23	VCP	VCP	27	26	493.1	495
24	VCP	VCP	27	26.2	477	483
25	VCP	VCP	27	26.5	497.8	501
26	VCP	VCP	27	26.6	490.6	418.8
27	VCP	VCP	27	27	43.9	82.1
28	VCP	VCP	27	26.6	162.3	183.5
29	PVC	PVC	30	29.5	9.5	

30	PVC	PVC	30	30	115.5	125
31	PVC	PVC	30	29.3	739	738
32	PVC	PVC	30	30	60.7	66
33	PVC	PVC	24	23.5	1141.6	1273.3
34	PVC	PVC	24	23.5	843.3	762.9
35	PVC	PVC	24	23.5	519.6	549
36	PVC	PVC	24	23.5	483.1	485
37	PVC	PVC	24	23.7	264.7	264
38	PVC	PVC	24	24	535.8	551
39	PVC	PVC	24	24	547.4	545
40	PVC	PVC	24	24	620.4	625
41	PVC	PVC	24	24	487	490
42	PVC	PVC	24	24	704.5	453.6
43	PVC	PVC	24	24	77.7	188.3
44	DI	PVC	24	24	18.3	24
45	DI	PVC	24	24	65.1	70
46	PVC	PVC	24	24	410.5	411
47	PVC	PVC	24	24	489.4	500
48	PVC	PVC	24	24	596.1	600
49	PVC	PVC	24	24	84	88
50	PVC	PVC	24	24	383.2	390
51	PVC	PVC	24	24	121.7	127
52	PVC	PVC	24	24	844.7	860
53	PVC	PVC	24	24	583	588
54	PVC	PVC	24	24	802.1	799
55	PVC	PVC	24	24	271.5	273
56	PVC	PVC	24	24	130.8	155
57	PVC	PVC	24	24	287.8	290
58	RCP	PVC	33	33	861.5	876
59	RCP	RCP	33	32.5	300.8	307
60	RCP	RCP	33	32.5	384.8	289
61	RCP	RCP	36	35.6	48.5	62.4
62	RCP	RCP	36	35.6	86.4	117.5
63	RCP	RCP	36	35.5	356.3	360

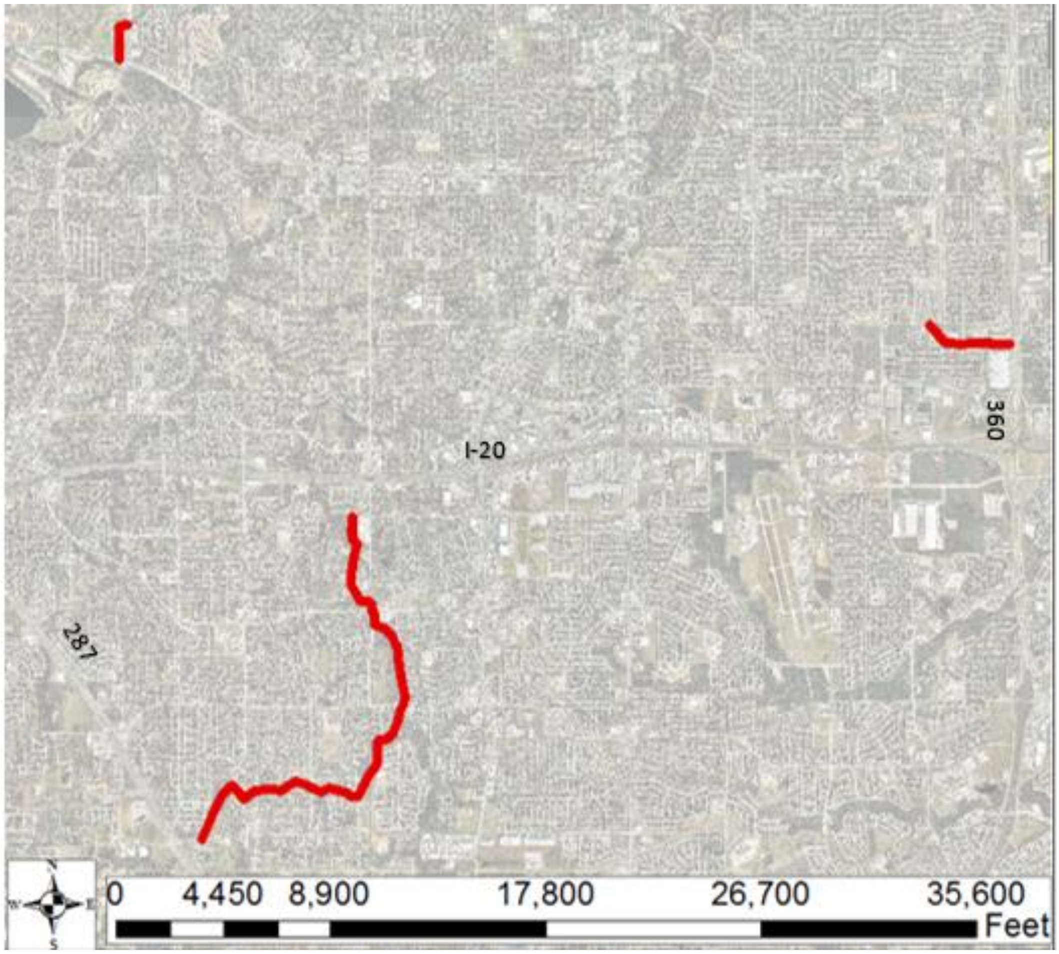


Figure 4-1 GIS map for the sewer lines inspected for the first inspection cycle

Laser and Sonar Results

The laser and sonar measurement data are so useful to estimate the sewer pipe condition. The debris level, corrosion level, deposit level and the percentage of the blockage area of a particular sewer pipe could not be inspected by using the traditional visual inspection methods such as using CCTV videos.

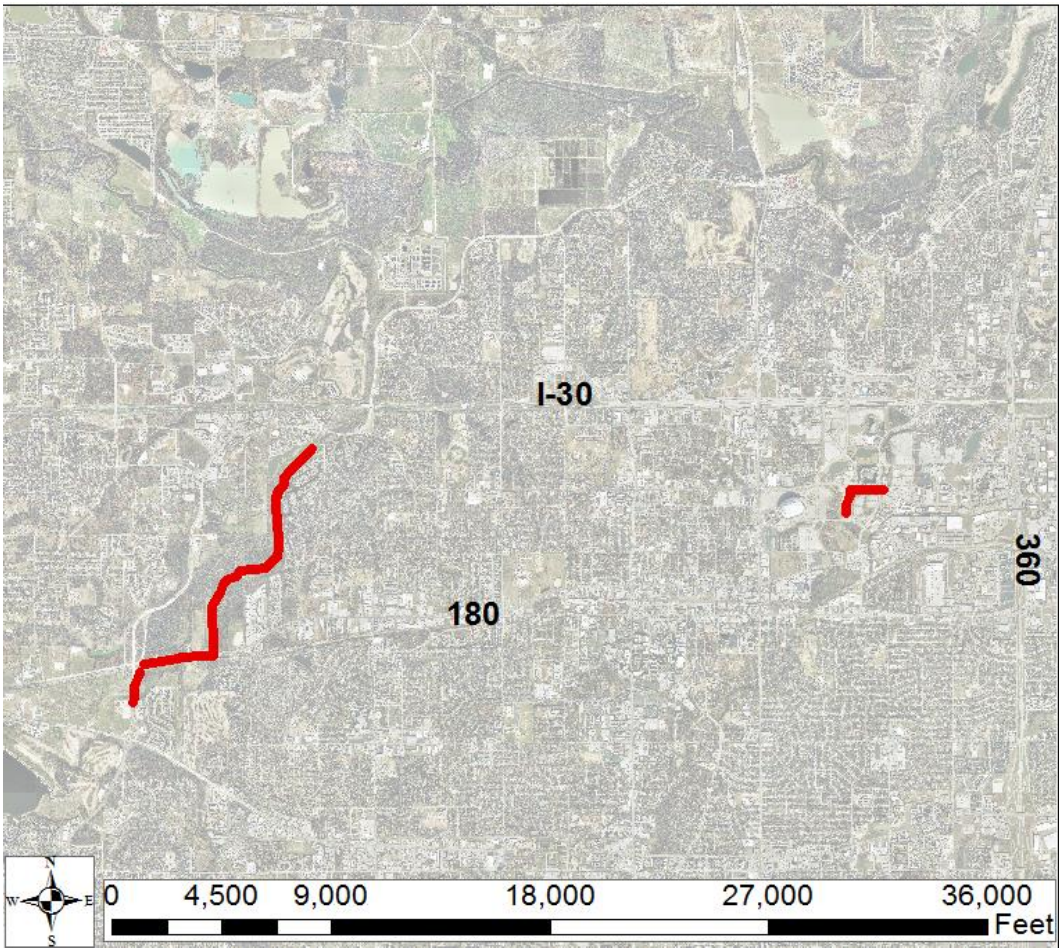


Figure 4-2 GIS map for the sewer lines inspected for the second inspection cycle

Furthermore, the output results of the laser and sonar measurements of the developed software are presented in the following sections. The results include the two inspection cycles for the city of Arlington of almost 6 miles (63 sewer lines).

Debris Level

Measuring the debris level per section is important for municipalities to have an idea about how much the pipe is having debris built up at the pipe bottom under the sewer water level. Knowing the pipe debris amount is significant for estimating how much the pipe is blocked by debris that hinders the sewer flow and to take proactive actions to do operations and maintenance (O&M) to the pipe. The debris level of the worst three sewer pipelines is introduced in this section. All the 63 sewer pipelines are ranked based on the mean of the debris level height throughout the pipeline. All other results are presented in Appendix (A).

Figures 4-3, 4-4, and 4-5 show the software output result for debris level of lines 19, 23 and 17, respectively. These lines represent the worst three sewer lines based on the mean of the debris level height. Also, the mentioned figures show the maximum debris level and the sewer water level for the same lines.

Figure 4-3 shows a maximum debris level of almost 14 inches and a maximum mean level of almost 5 inches. Furthermore, the average value of the mean debris height for the whole pipe is 1.44 inch. The latter figure also shows the height of the sewer water level.

Figure 4-4 shows a maximum debris level of a little over 10 inches and a maximum mean level of almost 2.5 inches. Moreover, the average value of the mean debris height for the whole pipe is 1 inch. The last figure also shows the height of the sewer water level for the same line.

From Figure 4-5, it can be concluded that line 17 has a maximum debris level of almost 11 inches and maximum mean level of almost 5 inches. Also, the average value of the mean debris height for the whole pipe is 0.96 inch. Figure 4-5 also shows the height of the sewer water level for line 17.

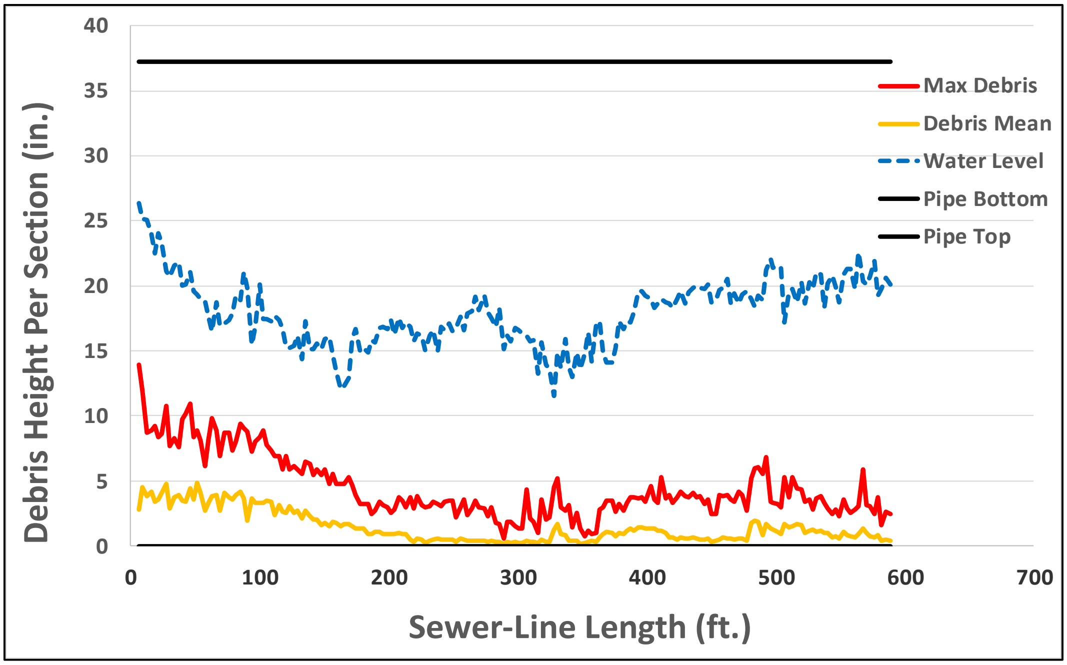


Figure 4-3 Debris level and sewer water level for line 19

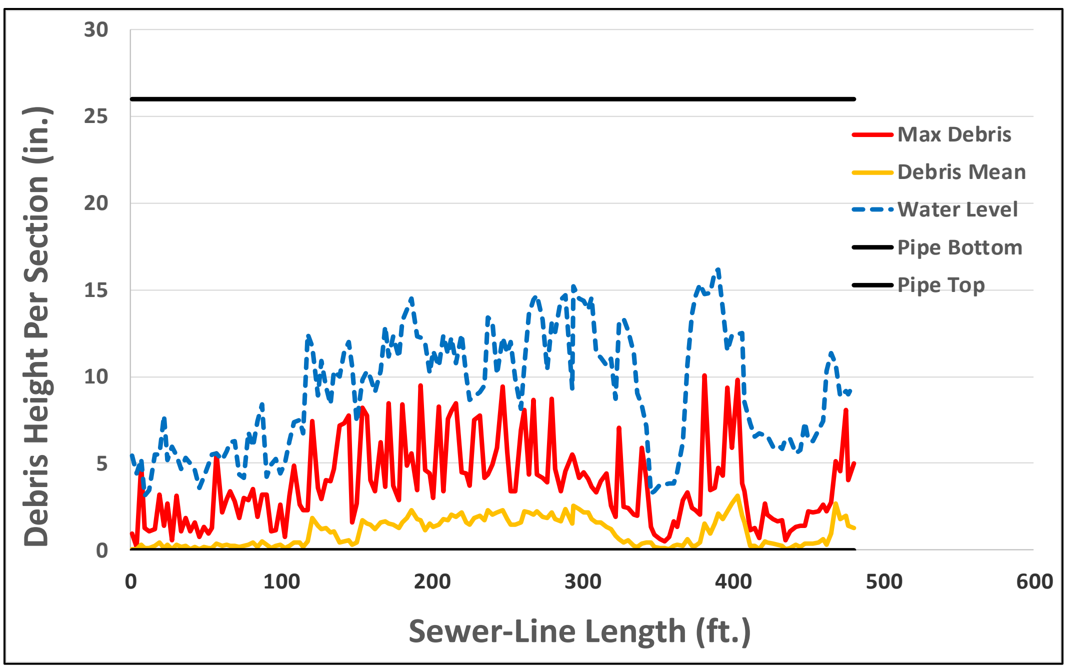


Figure 4-4 Debris level and sewer water level for line 23

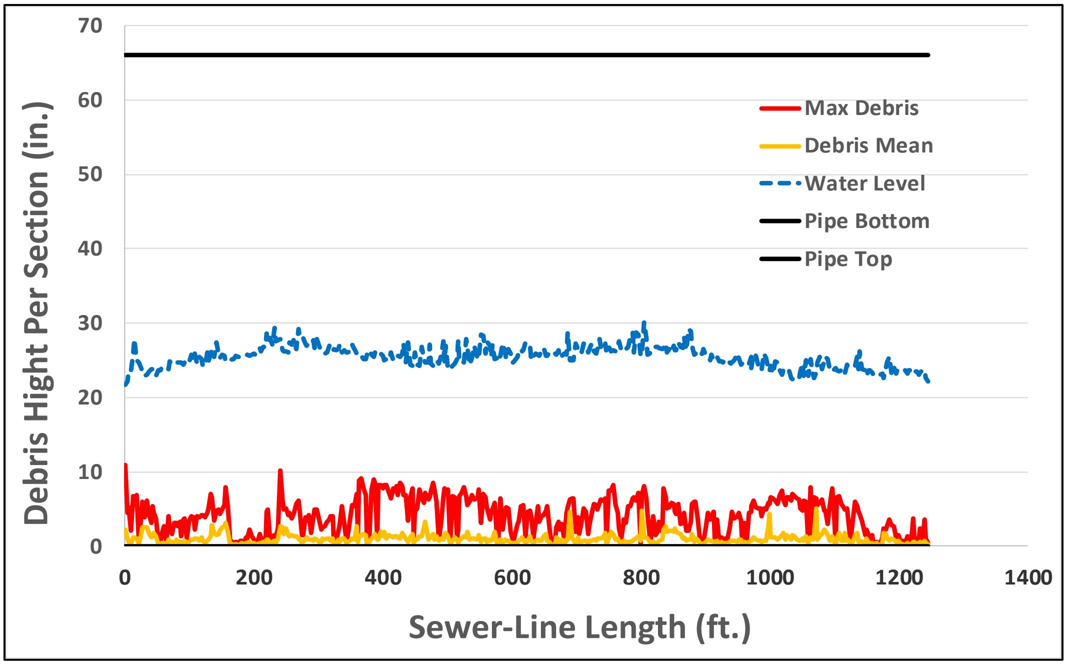


Figure 4-5 Debris level and sewer water level for line 17

Another output of the developed software for measuring the debris in a certain sewer pipeline is the percentage of debris area per section. The percentage of debris area per section is simply calculated by dividing the debris area by the area of the sewer pipe section and multiplied by 100. The percentage of the debris area gives a good information for the municipalities about how much a certain section in the sewer pipe system is blocked by debris. Figures 4-6, 4-7 and 4-8 show the percentage of debris area per section for lines 19, 23 and 17, respectively.

From Figure 4-6, it can be concluded that the maximum percentage of the debris area per cross section area is almost 18%. It also shows that the pipe (line 19) has more debris at the beginning of the pipe.

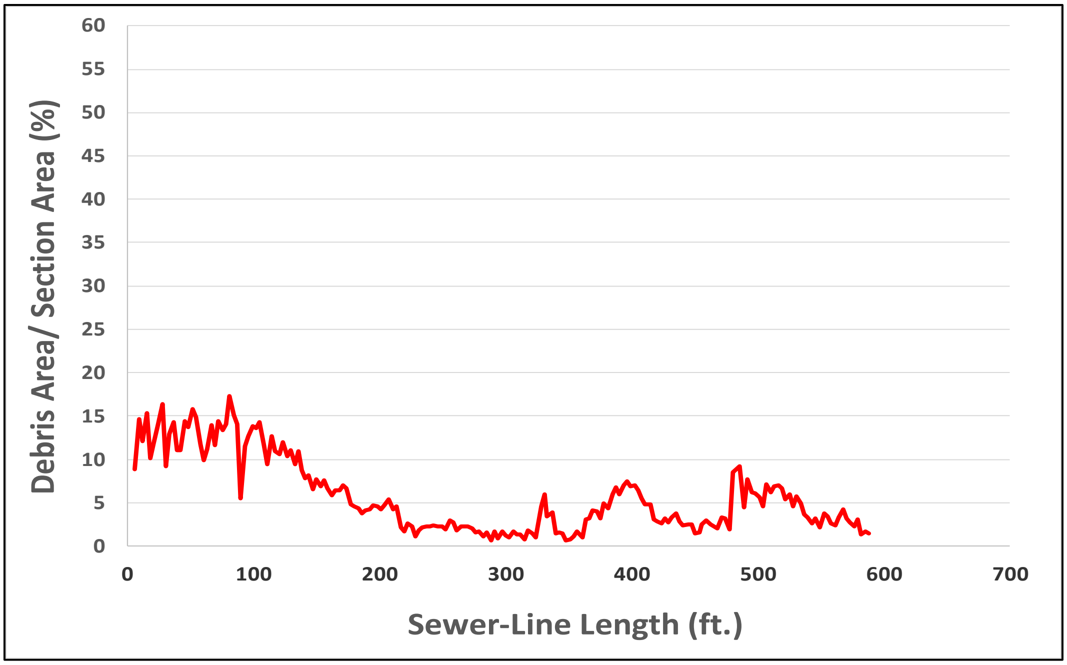


Figure 4-6 The percentage of debris area per cross section area for line 19

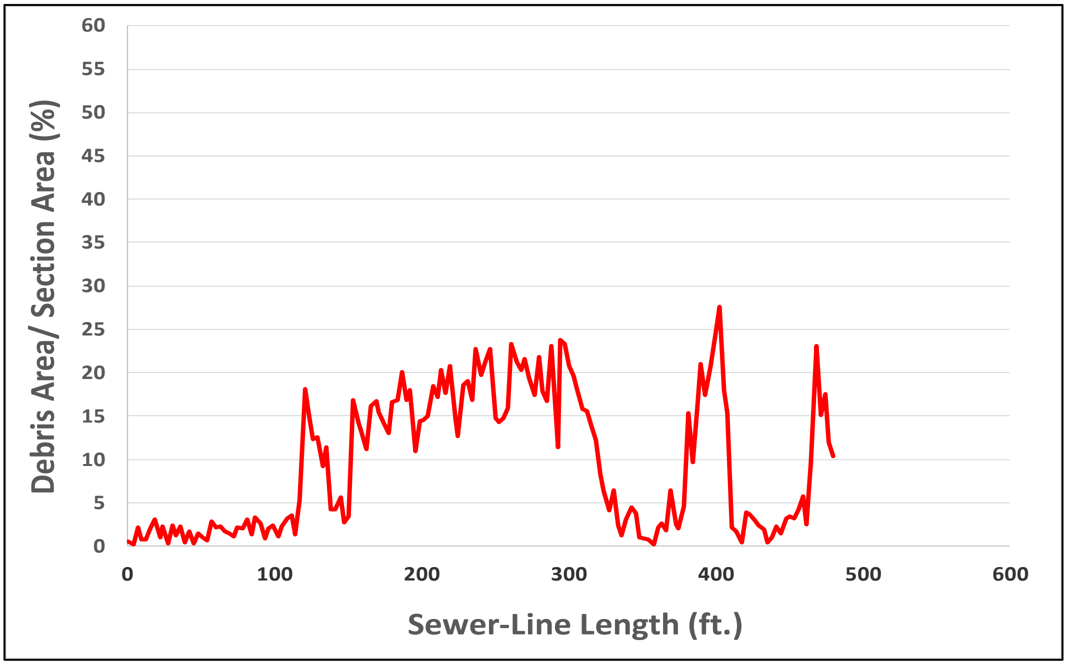


Figure 4-7 The percentage of debris area per cross section area for line 23

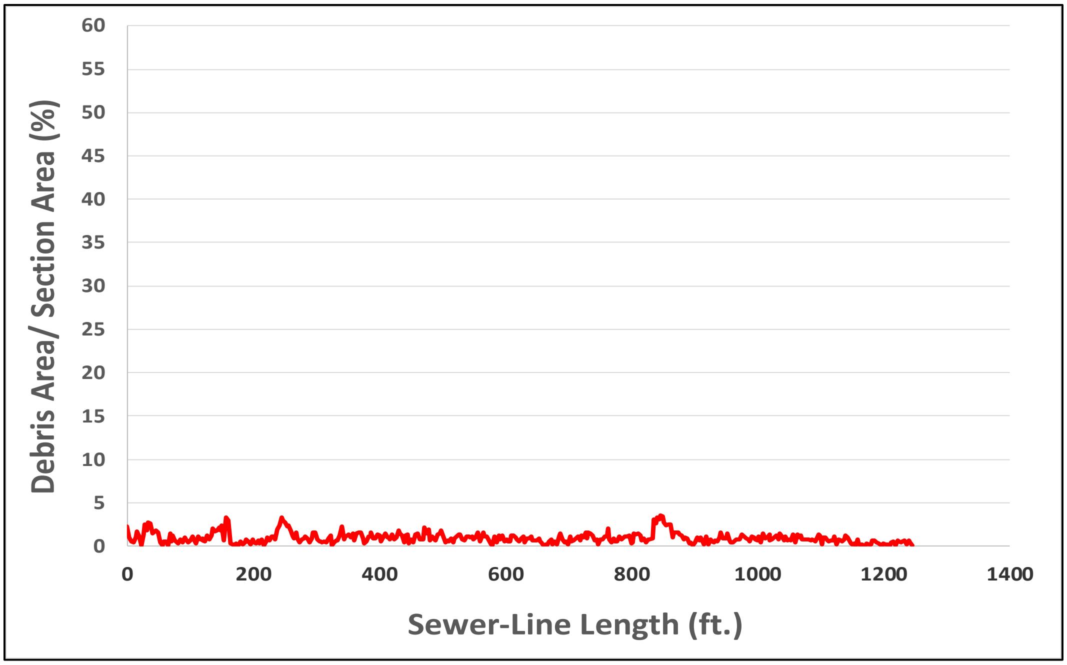


Figure 4-8 The percentage of debris area per cross section area for line 17

Furthermore, line 23 shows that it has the most percentage of the debris area per cross section amongst all lines even though it doesn't have the highest debris average level. The reason for that is because the cross-section area of the line is the least as it has 24 in. diameter (compared to line 19 of 36 in. diameter and line 23 of 66 in. diameter) so that the percentage of the debris of line 23 is showing higher than the other lines, as it clearly shown in Figure 4-7. Moreover, the latter figure also shows that the maximum percentage of the debris area is almost 27%. It also shows that the pipe is has the highest percentage in the middle and near the end of the pipe.

The percentage of the debris area per cross-section is the least for line 17, as it shown in Figure 4-8. That is because the pipe has the largest diameter of 66 in. The maximum debris percentage is almost 4%.

Another significant output of the developed software is the debris volume for each sewer line. The debris volume per 100 ft. of the pipe for the three lines is shown in Table 4.2.

Table 4-2 Debris volume per 100 ft. of the pipe

Line #	Debris Volume Per 100 Feet of pipe (ft^3)
19	63.7
23	34.2
17	22.3

Deposit Level

Measuring the deposit level per section is important for municipalities to have an idea about how much the pipe is having deposits attached to the pipe wall. Knowing the pipe deposit amount is significant for estimating how much the pipe is blocked by deposits and to take proactive actions to do operations and maintenance (O&M) to the pipe. The deposit level of the worst three sewer pipelines is introduced in this section. All the 63 sewer pipelines are ranked based on the mean of the deposit level height throughout the pipeline. All other results are presented in Appendix (A).

Figures 4-9, 4-10, and 4-11 show the software output result for deposit level of lines 17, 14 and 30, respectively. These lines represent the worst three sewer lines based on the mean of the deposit level height. Also, the mentioned figures show the maximum deposit for the same lines.

Figure 4-9 shows a maximum deposit level of almost 1.8 inch and a maximum mean level of almost 0.68 inch. Furthermore, the average value of the mean deposit height for the whole pipe is 0.33 inch.

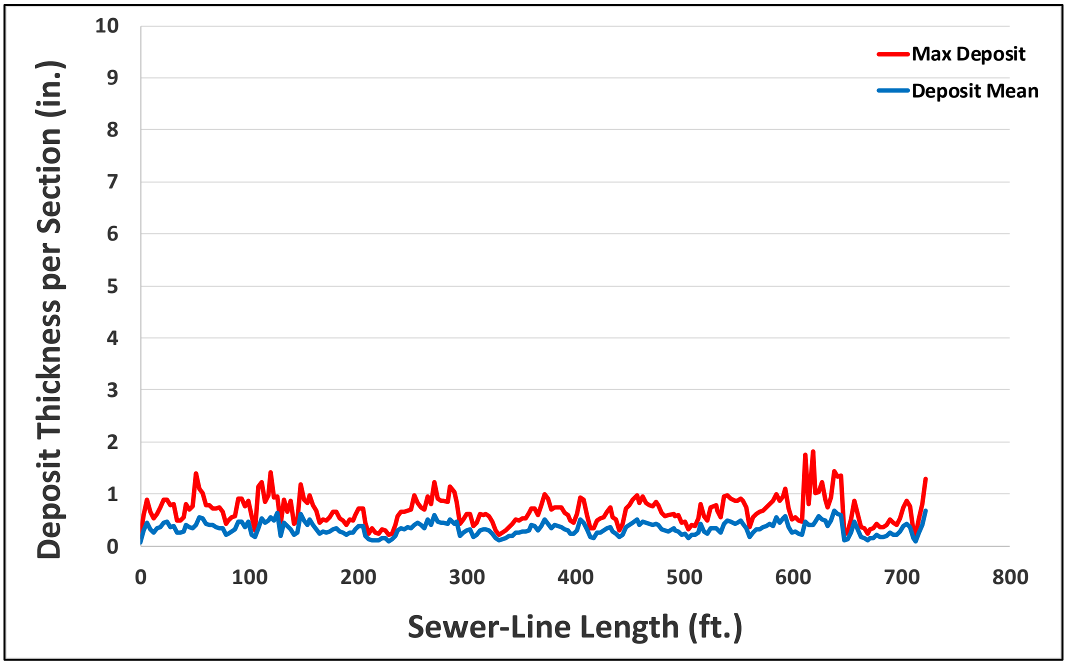


Figure 4-9 Deposit level for line 31

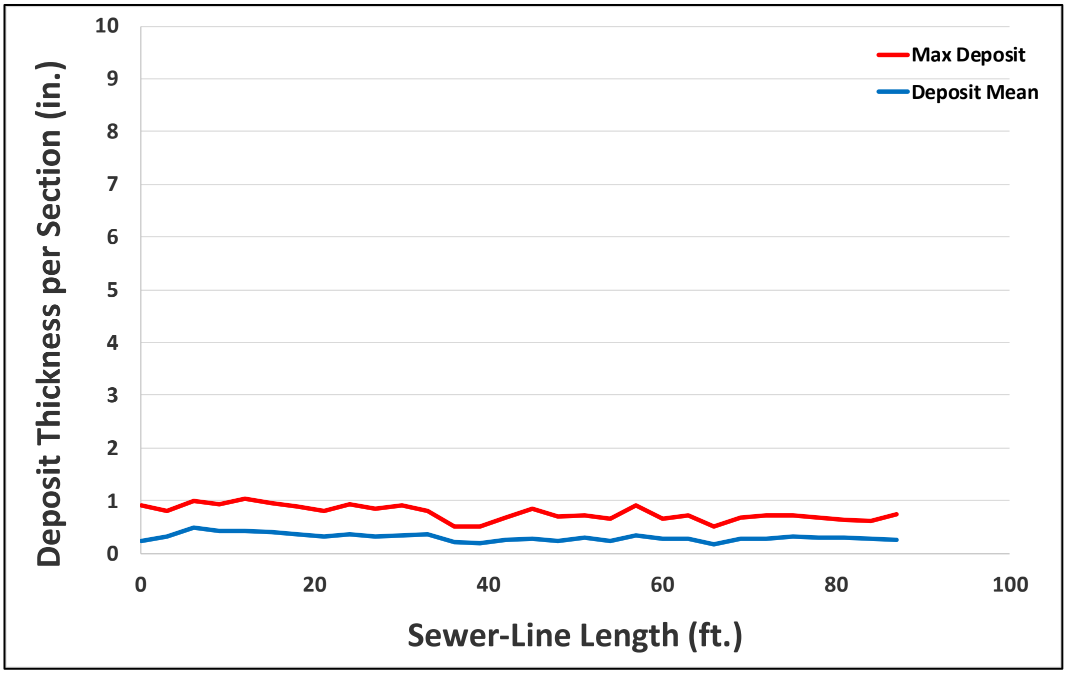


Figure 4-10 Deposit level for line 14

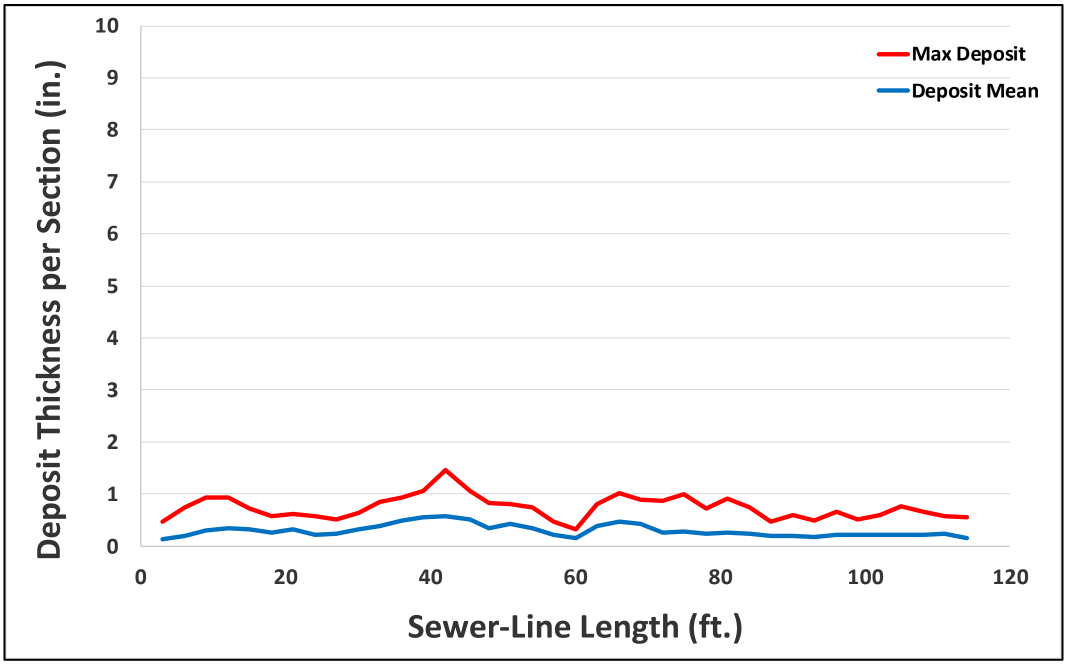


Figure 4-11 Deposit level for line 30

Figure 4-10 shows a maximum deposit level of 1.04 inch and a maximum mean level of almost 0.48 inch. Moreover, the average value of the mean deposit height for the whole pipe is 0.31 inch. From Figure 4-11, it can be concluded that line 30 has a maximum deposit level of almost 1.46 inch and maximum mean level of almost 0.57 inch. Also, the average value of the mean deposit height for the whole pipe is 0.29 inch.

Another output of the developed software for measuring the deposit in a certain sewer pipeline is the percentage of deposit area per section. The percentage of deposit area per section is simply calculated by dividing the deposit area by the area of the sewer pipe section and multiplied by 100. The percentage of the deposit area gives a good information for the municipalities about how much a certain section in the sewer pipe system is blocked by deposit. Figures 4-12, 4-13 and 4-14 show the percentage of deposit area per section for lines 31, 14 and 30, respectively.

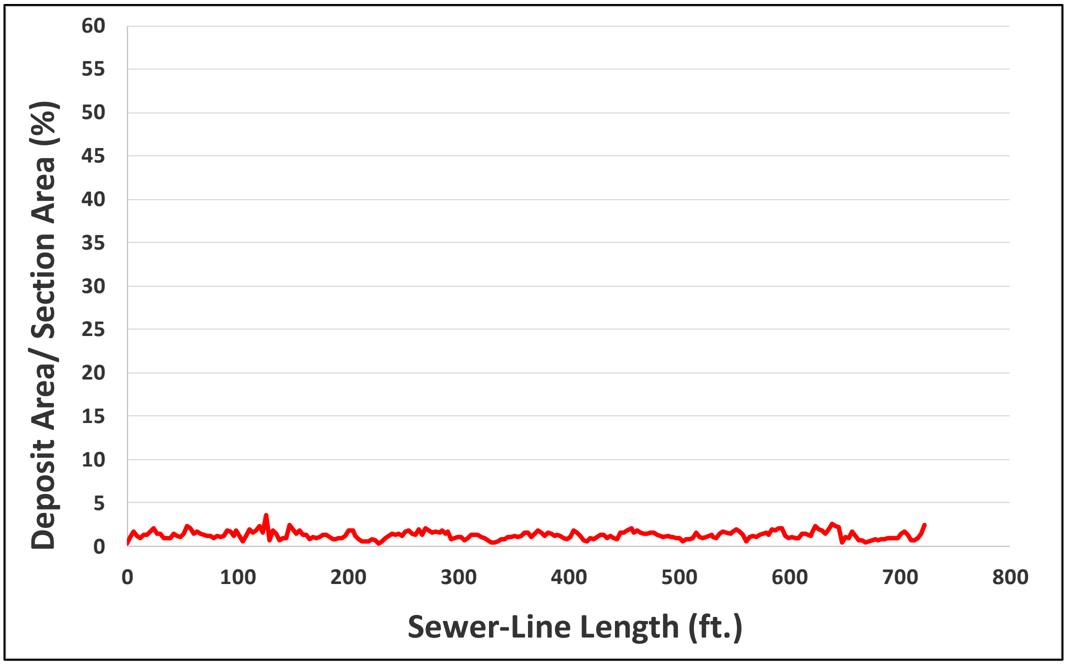


Figure 4-12 The percentage of deposit area per cross section area for line 31

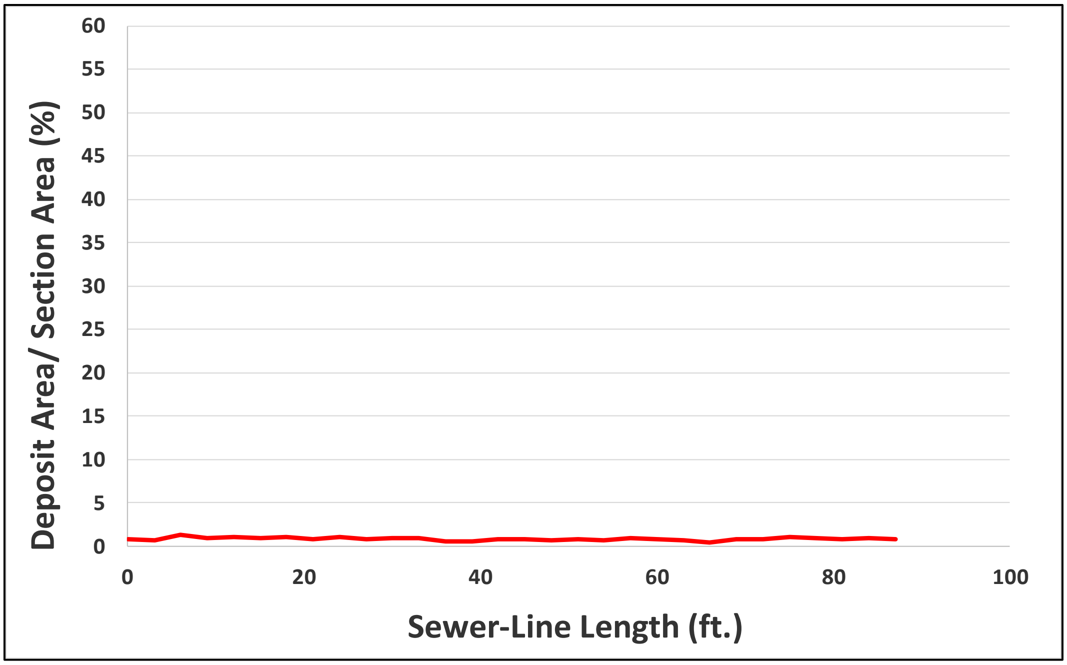


Figure 4-13 The percentage of deposit area per cross section area for line 14

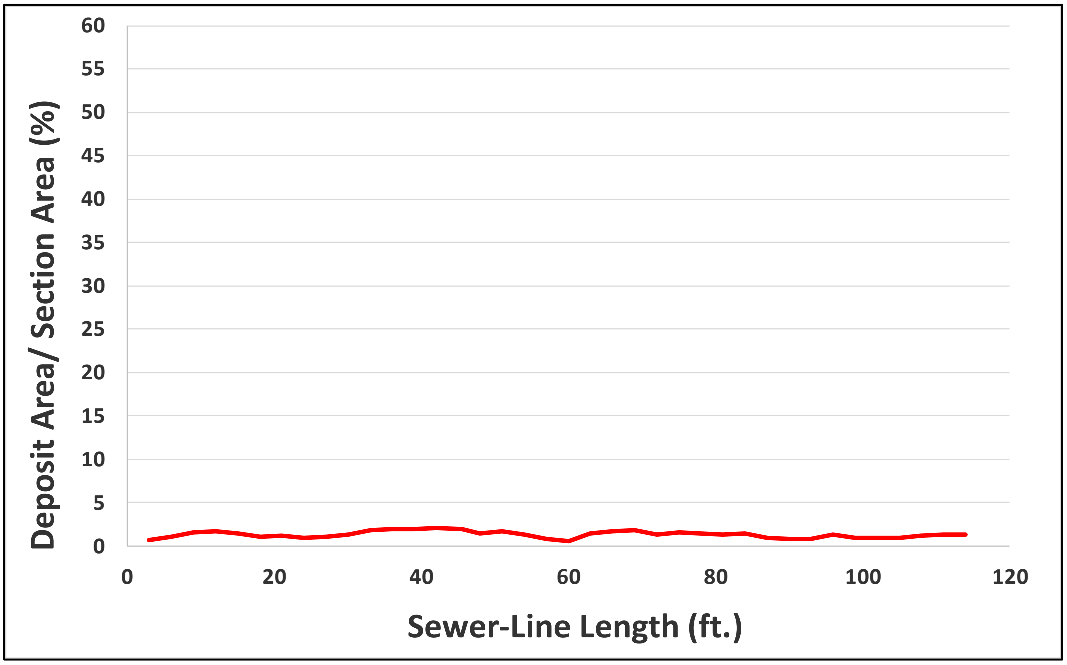


Figure 4-14 The percentage of deposit area per cross section area for line 30

From Figure 4-12, it can be concluded that the maximum percentage of the debris area per cross section area is almost 4%. Furthermore, line 14 shows that it has the least percentage of the deposit area per cross section amongst all lines. The reason for that is because the cross-section area of the line is the largest as it has 60 in. diameter (compared to lines 31 and 30 of 30 in. diameter) so that the percentage of the debris of line 14 is showing less than the other lines, as it clearly shown in Figure 4-13. Moreover, the latter figure also shows that the maximum percentage of the deposit area is almost 1.4%. The percentage of the deposit area per cross-section for line 17 is 2%, as it shown in Figure 4-14.

Another significant output of the developed software is the deposit volume for each sewer line. The deposit volume per 100 ft. of the pipe for the three lines is shown in Table 4.3.

Table 4-3 Deposit volume per 100 ft. of the pipe

Line #	Deposit Volume Per 100 Feet of pipe (in^3)
31	376327
14	125259
30	62971

Blockage Level

The percentage of blockage area represents the summation of both the deposit area and the debris area for a particular pipe section and divided by the total area of the same pipe section and multiplying the result by 100. Also, the developed software output presented by the percentage of blockage area is considered very useful for municipalities to obtain good information about how much percentage of a certain pipe section in their sewer pipe system is being blocked by both deposits and debris. For all municipalities, it is easier to know which pipes in its sewer system that need operation and maintenance the most for the future maintenance plans. Furthermore, it gives more information for municipalities to know about the pipe flow capacity and to improve the municipality hydraulic model. All the 63 sewer pipelines are ranked based on two factors the maximum percentage of the blockage area and the mean percentage area for each pipeline. The worst three sewer pipelines are introduced in this section for both maximum and mean percentage of the blockage area. All other results are presented in Appendix (A).

Figures 4-15, 4-16, and 4-17 show the software output result for the percentage blockage area per cross section area of lines 23, 24 and 26, respectively. These lines represent the worst three sewer pipelines based on the maximum of the percentage blockage area.

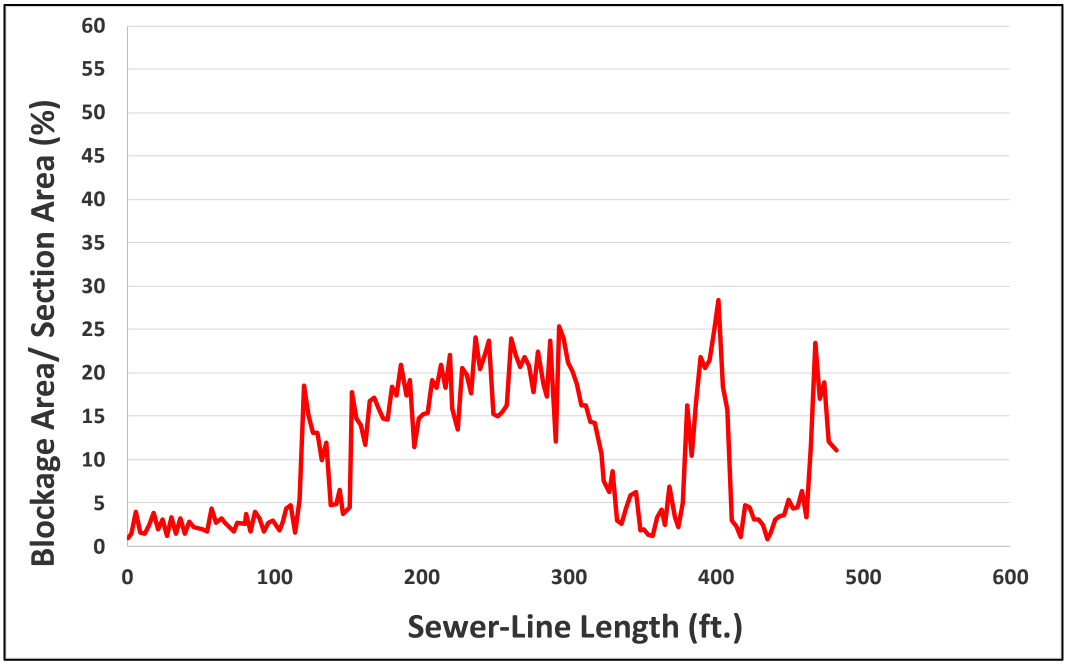


Figure 4-15 The percentage of the blockage area per cross section area for line 23

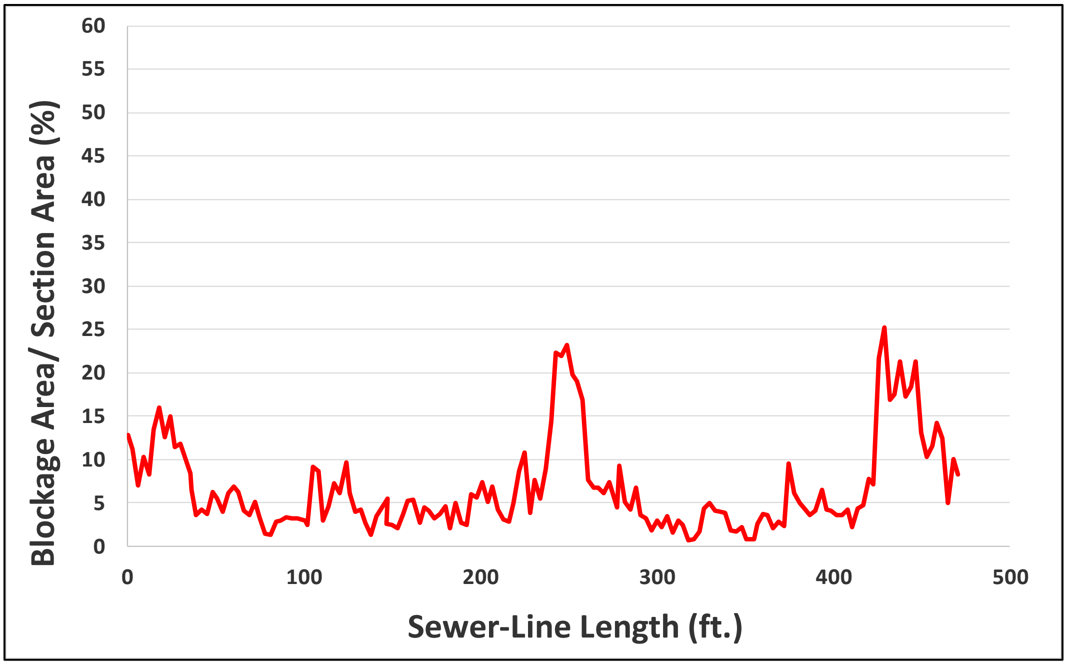


Figure 4-16 The percentage of the blockage area per cross section area for line 24

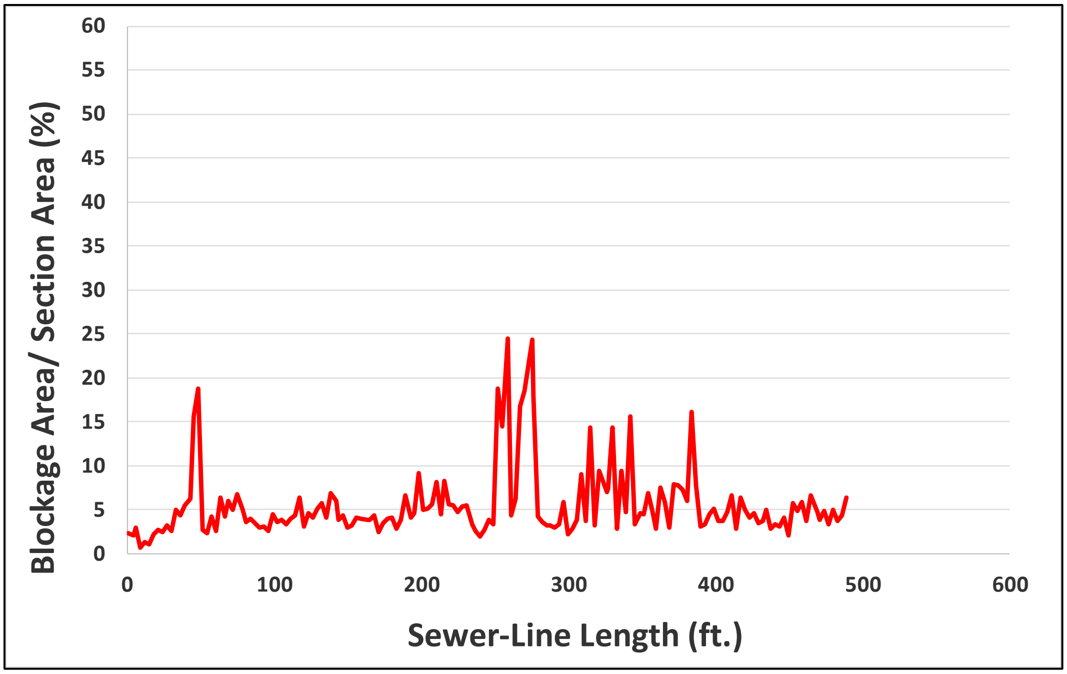


Figure 4-17 The percentage of the blockage area per cross section area for line 26

Figure 4-15 shows a maximum percentage of blockage area of almost 28%. The line is almost blocked by more than 20% by debris and deposits in the middle of the pipe and near the end as well. Furthermore, the line 23 has the highest mean percentage of the blocked area throughout the pipe length of a value of 10.3% amongst the whole 63 inspected sewer pipelines. That gives a good indication for the city decision makers for prioritization their sewer pipelines for the O&M and cleaning process.

From Figure 4-16, it can be concluded that line 24 has a maximum percentage of blockage area of almost 25%, while the mean percentage of blockage area is almost 6.5%. The latter pipeline has the second highest mean value of the percentage of the blocked area throughout the pipe length.

Moreover, line 26 has the third highest maximum percentage of the blockage area of 24.5%, as it shown in Figure 4-17, while the mean percentage of blockage area is almost 5.5%. The latter pipeline has the fourth highest mean value of the percentage of the blocked area throughout the pipe length. The third highest mean value of 6.3% of the percentage of the blocked area throughout the pipe length is found in line number 19 (Figure 4-18).

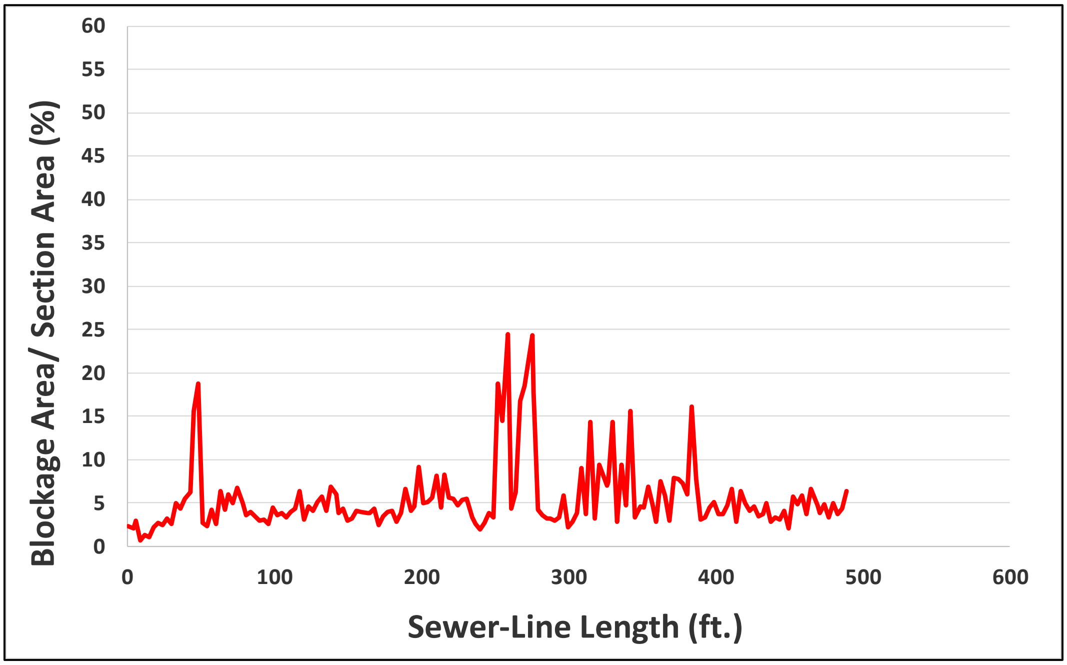


Figure 4-18 The percentage of the blockage area per cross section area for line 19

Erosion Level

Measuring the erosion level per section is important for municipalities to have an idea about the amount of the pipe loss, especially if the pipe is reinforced concrete pipe. Knowing the pipe thickness is significant for estimating the pipe condition and take proactive actions to do maintenance or replacement to the pipe. There are 11 RCP pipelines inspected amongst the all 63 inspected lines. The erosion level of the worst three sewer pipelines is introduced in this section. All the 63 sewer pipelines are ranked based on the mean of the erosion level height throughout the pipeline. All other results are presented in Appendix (A).

Figures 4-19, 4-20, and 4-21 show the software output result for erosion level of lines 13, 14 and 18, respectively. These lines represent the worst three sewer lines based on the mean of the erosion level. Also, the mentioned figures show the maximum erosion for the same lines.

Figure 4-19 shows a maximum erosion level of almost 1.1 inch and a maximum mean level of almost 0.45 inch. Furthermore, the average value of the mean erosion level for the whole pipe is 0.3 inch.

From Figure 4-20, it can be concluded that line 14 has a maximum erosion level of almost 1.1 inch and maximum mean level of almost 0.36 inch. Also, the average value of the mean erosion level for the whole pipe is 0.25 inch.

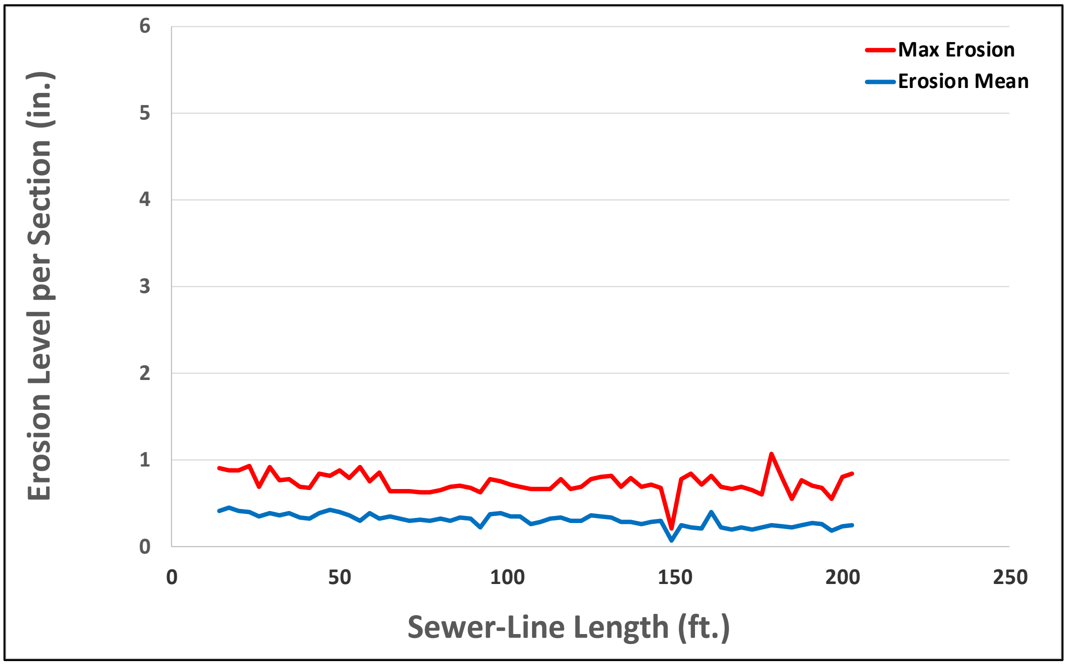


Figure 4-19 The erosion level per section area for line 13

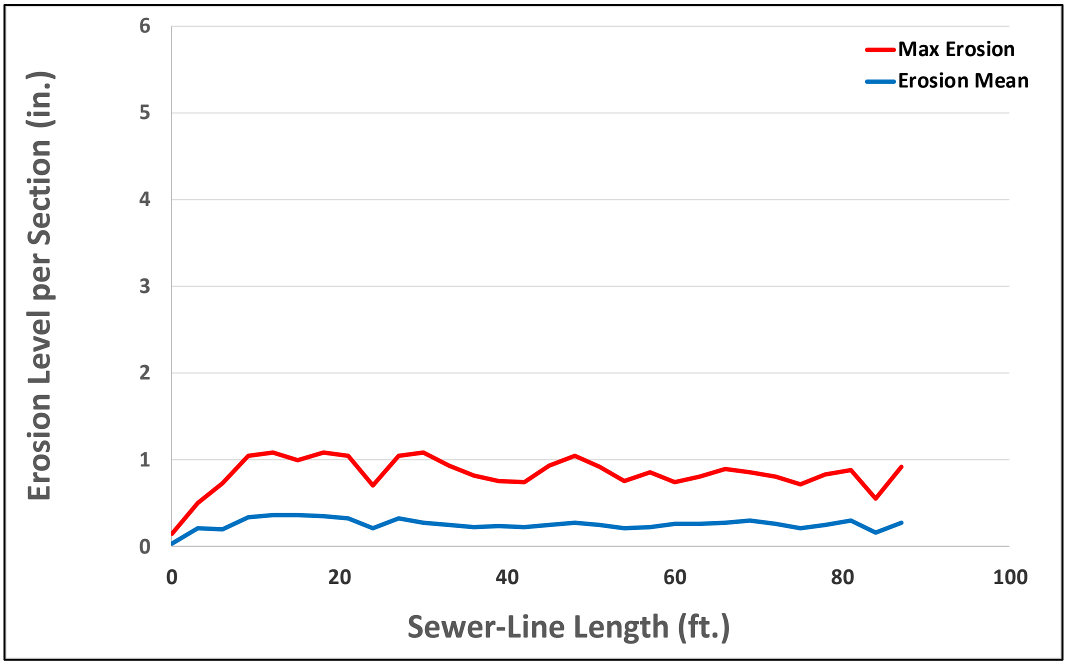


Figure 4-20 The erosion level per section area for line 14

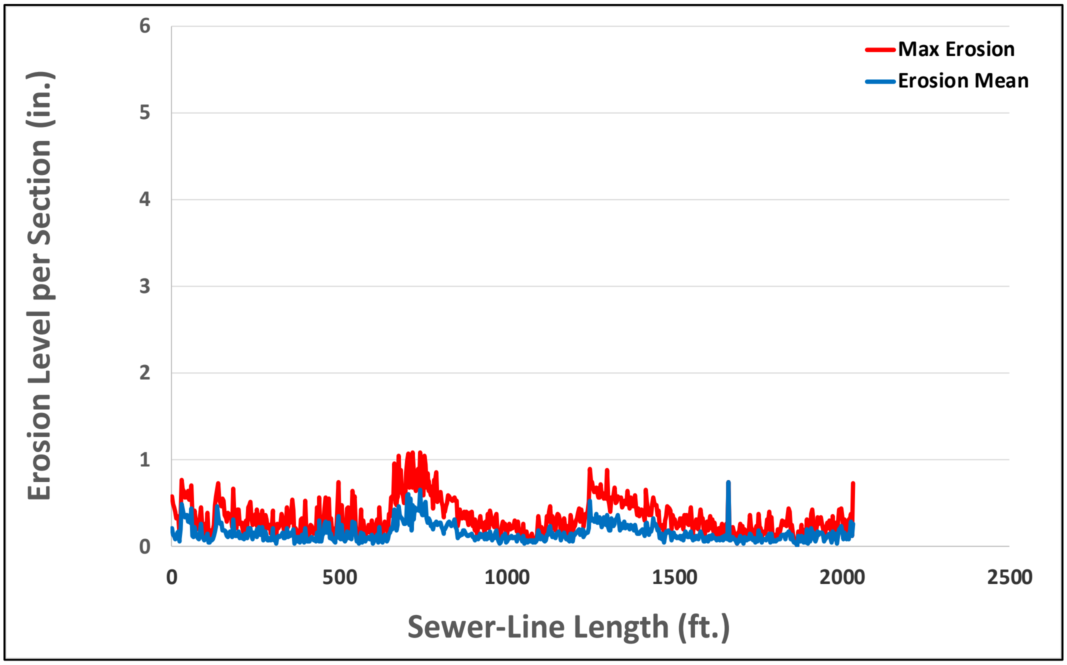


Figure 4-21 The erosion level per section area for line 18

Figure 4-21 shows a maximum erosion level of 1.1 inch and a maximum mean level of almost 0.74 inch. Moreover, the average value of the mean erosion level for the whole pipe is 0.15 inch.

The UTA team along with COA and Redzone has inspected one reinforced concrete sewer pipeline for the City of Rowlett. The result of the erosion level of the line is shown in Figure 4-22.

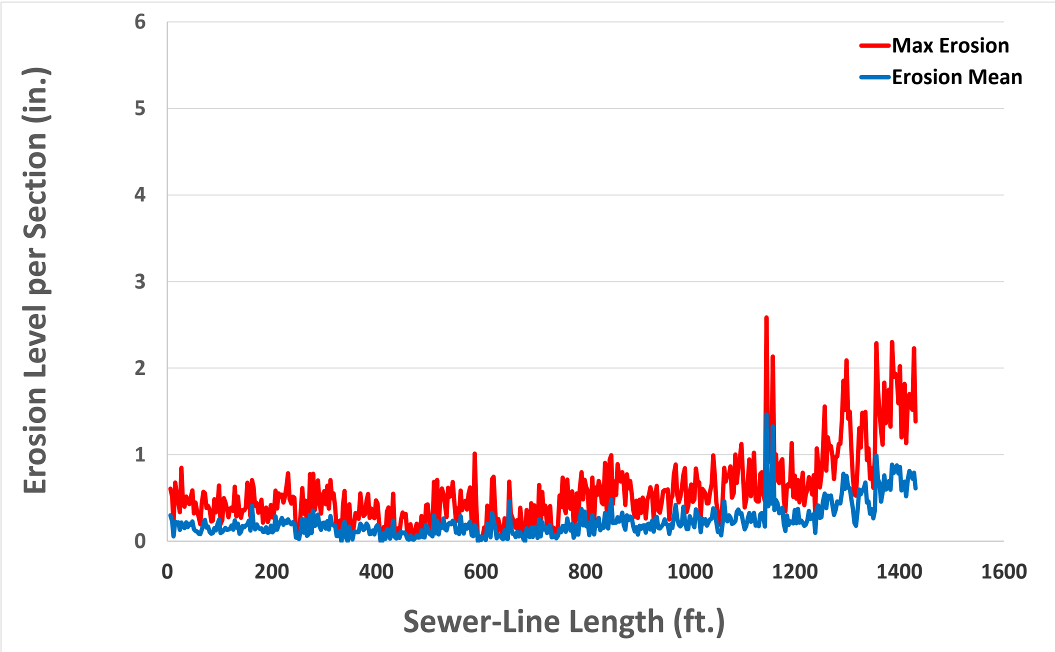


Figure 4-22 The erosion level per section area for City of Rowlett line

From Figure 4-22, it can be concluded that the City of Rowlett line has a maximum erosion level of almost 2.5 inches and maximum mean level of almost 0.36 inch. Also, the average value of the mean erosion level for the whole pipeline is 0.25 inch.

Visual Inspection Results

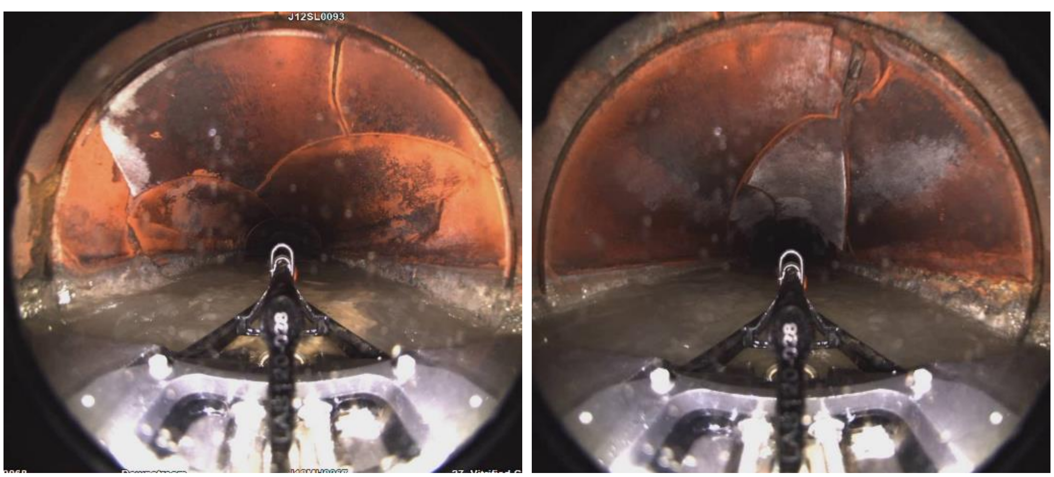
One of the COA requirements for this study is to code pipes according to PACP (Pipeline Assessment and Certification Program). The coding system is done for CCTV videos of the related typical line (manhole to manhole) as part of visual inspection method. UTA and COA teams has established a modified PACP scoring due to limitation of coding large diameter pipe. Each typical pipeline has a table, scoring, codes and pictures for all structural and O&M defects. Appendix C shows the defects type and codes. The visual inspection results are discussed in the following sections section.

Structural Defects

The structural defects include all kinds of fractures codes such as Fracture Longitudinal (FL), Fracture Multiple (FM) and Fracture Hinge (FH). Furthermore, the structural defects include Hole (H), Broken (B), Deformed (D) and collapse. Each typical sewer main is scored based on its structural defects. The mains' structural defect score denotes the amount and severity of issues found by analyzing the video collected during inspection. Defects are rated based on the modified PACP coding system illustrated in Chapter 2. This system is based solely on structural defect visible during review and rates issues from 1 to 5, with 5 being the most severe defect. The scores were added together to get a combined structural defect score, and this score is divided by the main length to come to an Average Structural Defect Score Per 100 Linear Feet of Main. This gives a quick summary of the overall visible structural condition of the pipe. The worst 5 mains below are listed in descending order from the mains with the highest combined score to the lowest (Table 4.4). Figures 4-23 to 4-27 show the worst structural defects for those 5 lines. Appendix A shows all other defects for all the inspected lines.

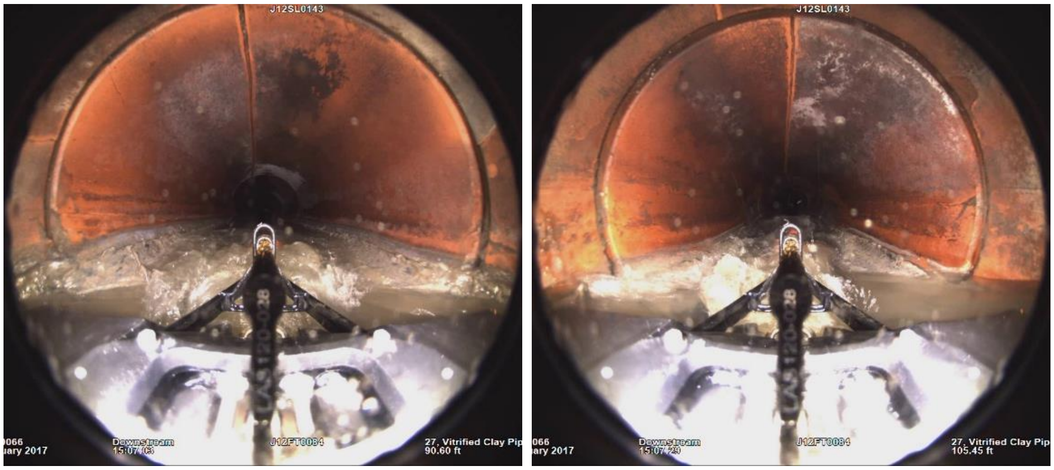
Table 4-4 Highest 5 structural pipe defective sewer mains

Rank	Line #	Observed Pipe Material	Observed Line Length (ft.)	Structural Defect Score	Average Defect Score Per 100 Linear Feet of Main	Worst Structural Defect Visible
1	26	VCP	490.6	186	37.9	Fracture Multiple, Deformed Rigid
2	28	VCP	162.3	42	25.8	Fracture Longitudinal
3	22	VCP	514.3	121	23.5	Fracture Multiple, Fracture Hinge3
4	25	VCP	497.8	108	21.6	Fracture Multiple, Broken
5	24	VCP	477	58	12.1	Fracture Multiple, Fracture Longitudinal



(a) (b)

Figure 4-23 Worst structural defects for line 26. It shows (a) Fracture Multiple (FM) and (b) Deformed Rigid (DR)

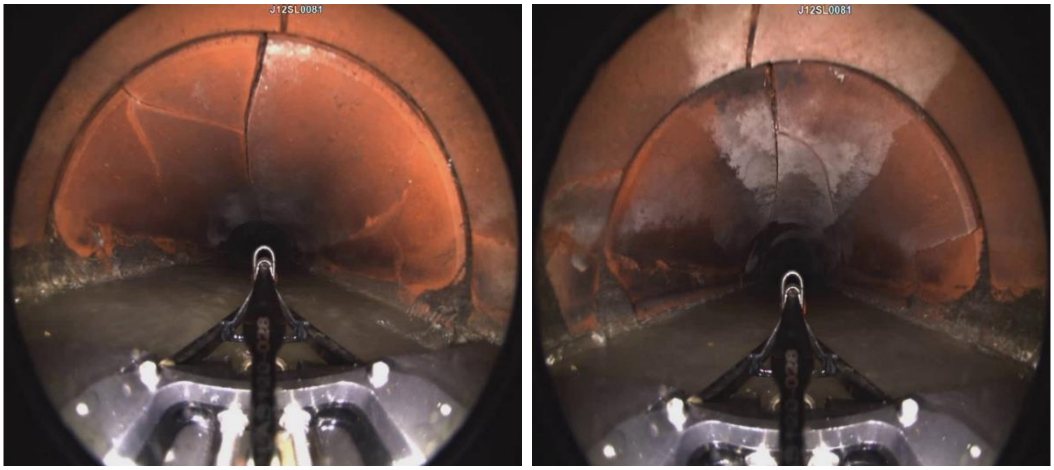


(a) (b)

Figure 4-24 Worst structural defects for line 28. It shows (a) Fracture Longitudinal (FL) and (b) Fracture Longitudinal (FL)

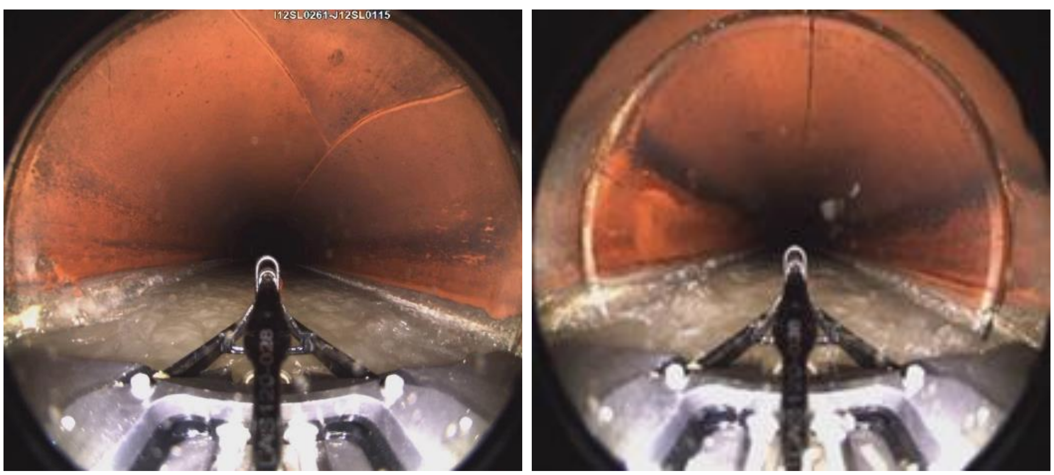
(a) (b)

Figure 4-25 Worst structural defects for line 22. It shows (a) Fracture Multiple (FM) and (b) Fracture Hinge (FH3)



(a) (b)

Figure 4-26 Worst structural defects for line 25. It shows (a) Fracture Multiple (FM) and (b) Broken (B)



(a) (b)

Figure 4-27 Worst structural defects for line 24. It shows (a) Fracture Multiple (FM) and (b) Fracture Longitudinal (FL)

Roots Intrusion

The visual inspection results of the roots intrusion are discussed in this section. The roots intrusion defects are rated based the modified PACP coding system illustrated in Chapter 2. The sewer pipelines' root intrusion score indicatess the amount and severity of issues found by analyzing the CCTV video collected during the inspection of each typical line. This system is based solely on defects visible during the video review and rates issues from 1 to 5, with 5 being the most severe defect. Furthermore, the scores were added together to obtain a Combined Root Defect Score, and this score was divided by the sewer main length to come to an Average Root Score Per 100 Linear Feet of Main. Moreover, the highest 5 combined root pipe scores below are listed in descending order from the sewer mains with the highest combined root intrusion score to the lowest, as it shown in Table 4.5. Figures 4-28 to 4-32 show the worst root intrusion defects for the worst 5 sewer lines. Appendix A shows all other defects for all the inspected lines.

Table 4-5 Pipe roots intrusion rank

Rank	Line #	Pipe Material	Line Length (ft.)	Combined Root Defect Score	Average Root Score Per 100 Linear Feet of Sewer Main	Worst Root Intrusion Defect
1	55	PVC	271.5	21	7.73	Roots Medium Joint
2	58	PVC	861.5	62	7.19	Roots Large Joint
3	25	VCP	497.8	30	6.02	Roots Medium Joint
4	37	PVC	264.7	12	4.53	Roots Large Joint
5	56	PVC	130.8	3	2.29	Roots Medium Joint

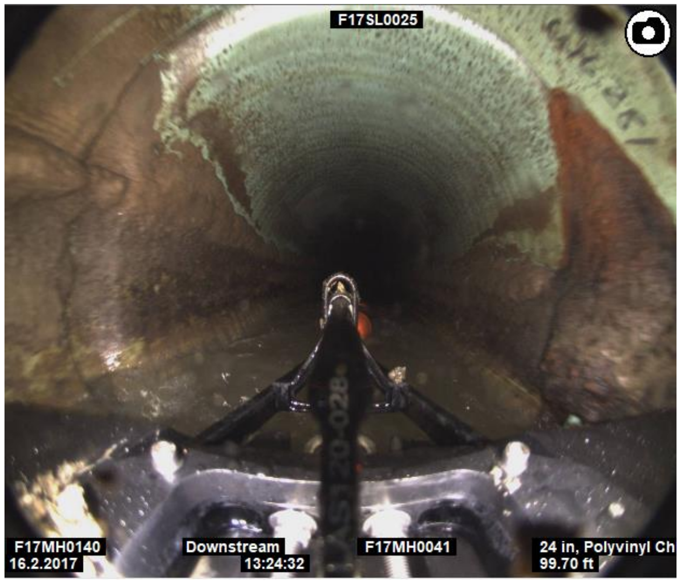


Figure 4-28 Roots intrusion for line 55

Figure 4-29 Roots intrusion for line 58

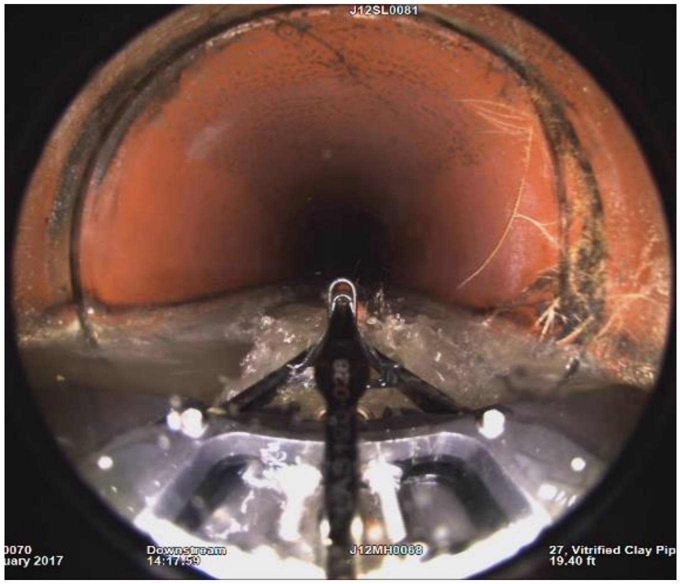


Figure 4-30 Roots intrusion for line 25

Figure 4-31 Roots intrusion for line 37

Figure 4-32 Roots intrusion for line 56

Other Significant Defects

Other significant defects are found through visual inspection using CCTV videos. These defects are useful for municipalities to have information about their sewer pipe system. Significant defects such as Deposit Attached Encrustation (DAE) for more than 20%, Deposit Attached Grease for more than 20%, (DAG) Joint Separation (JS), Infiltration Runner Joint (IRJ), Intruding Sealing Material Grout (ISGT), Miscellaneous General Observation (MGO), Tap Break-In/Hammer Active, Surface Damage Aggregate Visible (SAV) and Surface Damage Reinforcement Visible (SRV) are introduced in this section. MGO code is usually used for corrosion and change in the pipe direction.

Furthermore, the significant defects that are found through the visual inspection are introduced separately for each pipeline in this section (Figure 4-31 through Figure 4-58). Some pipelines in the system don't have any defects or minor defects. The latter defects are all shown in Appendix (A).

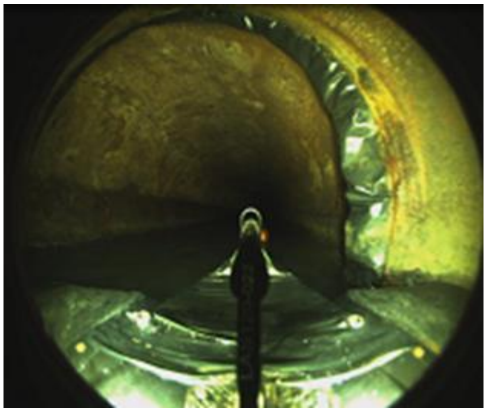


Figure 4-33 Significant defects in line 6 (ISGT and MGO)

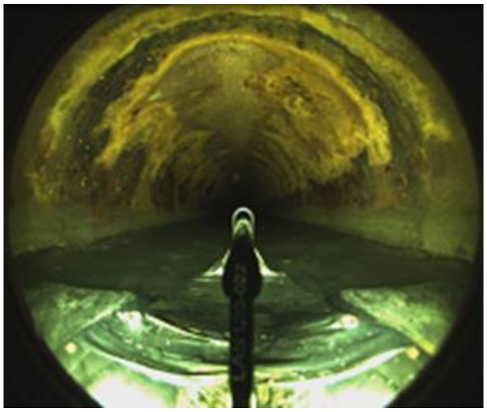


Figure 4-34 Significant defects in line 7 (MGO)

Figure 4-35 Significant defects in line 8 (MGO)

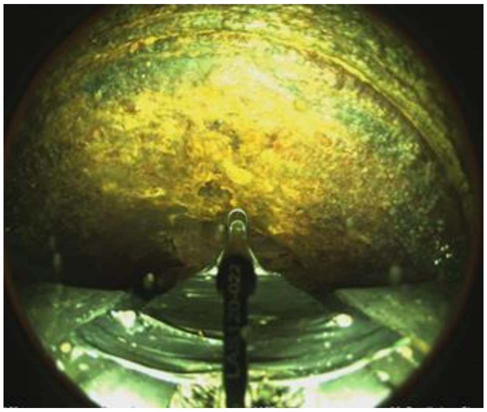


Figure 4-36 Significant defects in line 9 (MGO)

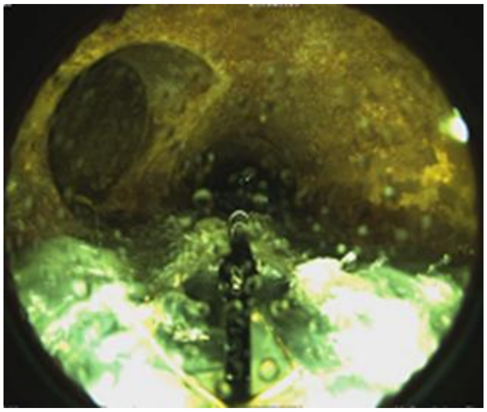


Figure 4-37 Significant defects in line 12 (TBA)

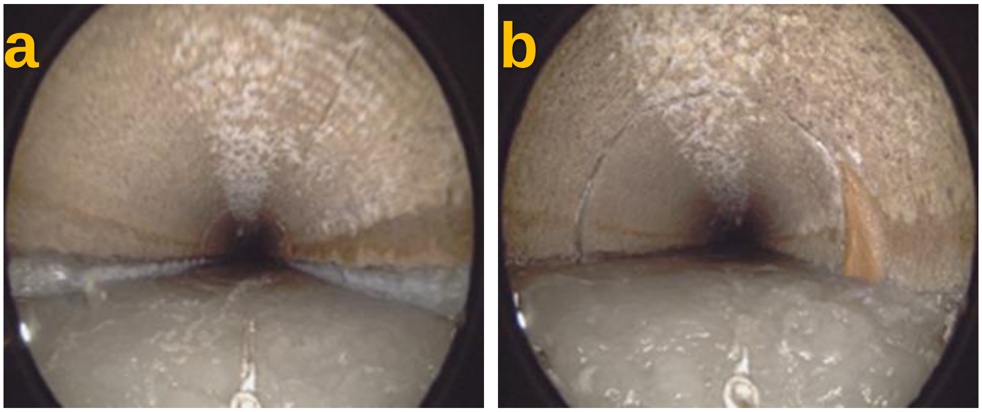


Figure 4-38 Significant defects in line 13. It shows (a) SRV and (b) SAV and JS

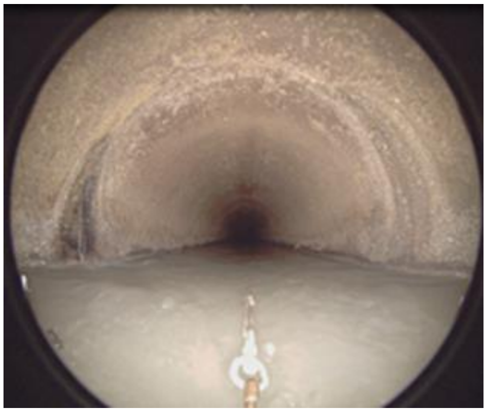


Figure 4-39 Significant defects in line 15 (IRJ)

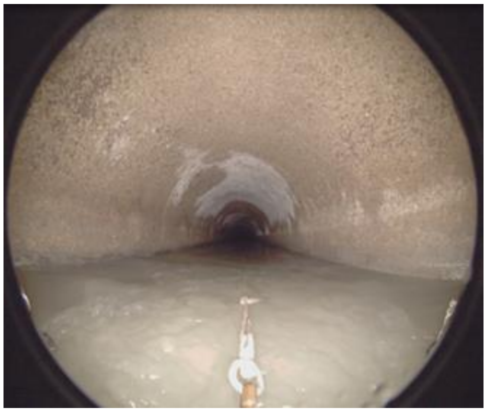


Figure 4-40 Significant defects in line 16 (SAV)

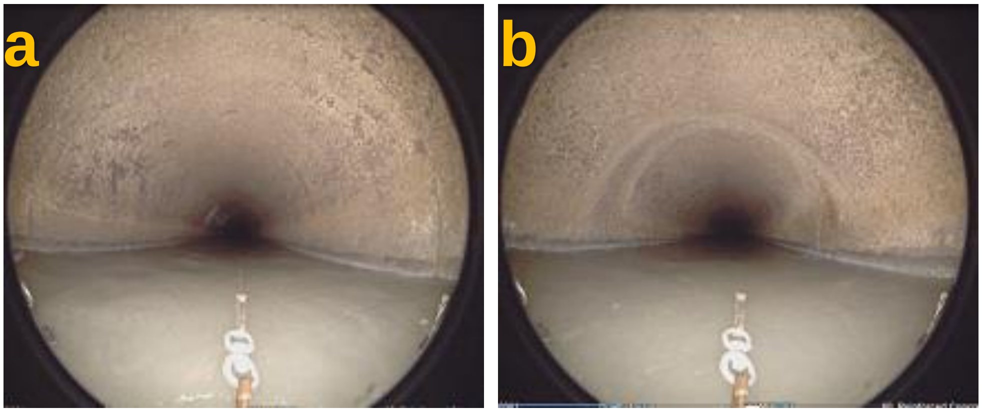


Figure 4-41 Significant defects in line 17. It shows (a) SAV and (b) IRJ

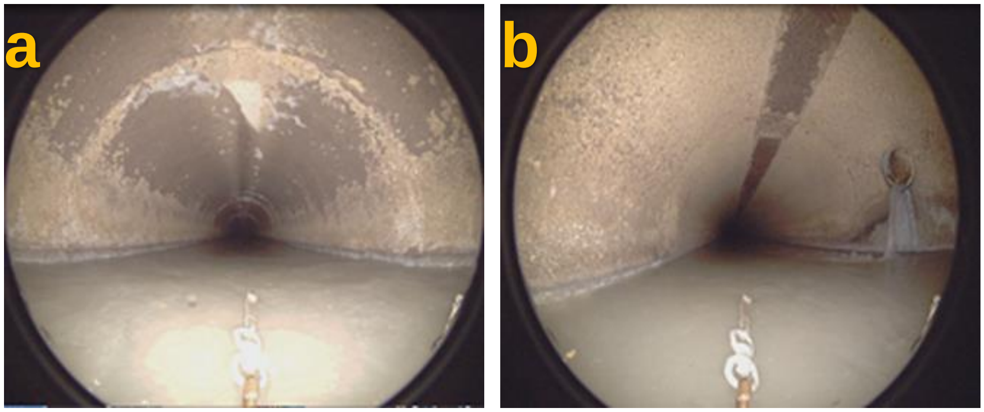


Figure 4-42 Significant defects in line 17. It shows (a) SAV and (b) TBA

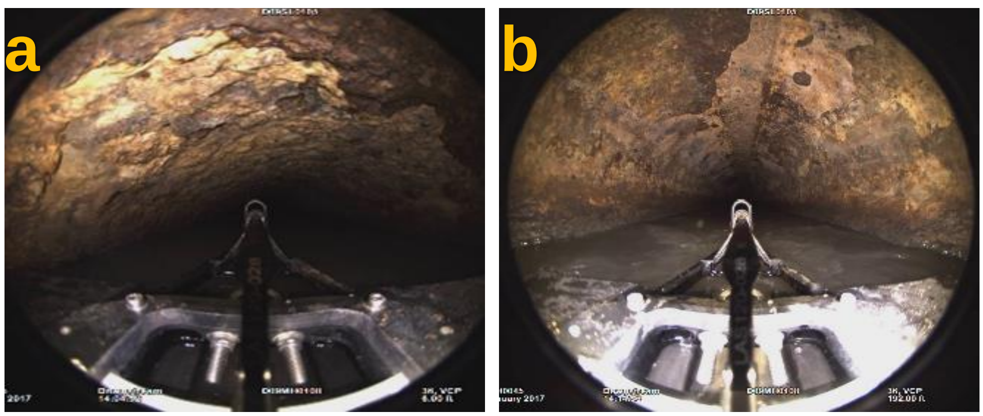


Figure 4-43 Significant defects in line 19. It shows (a) MGO and (b) DAG

Figure 4-44 Significant defects in line 21 (DAG)

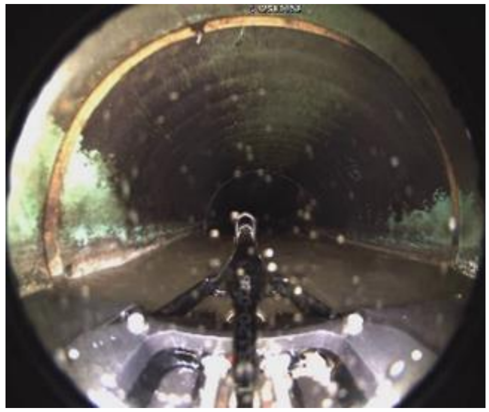


Figure 4-45 Significant defects in line 31 (JS)

Figure 4-46 Significant defects in line 39 (DAE)

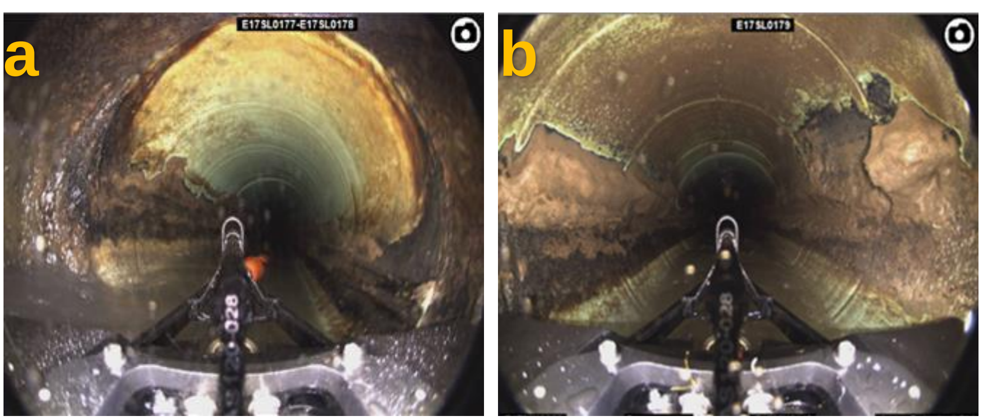


Figure 4-47 Significant defects in line 41. It shows (a) DAG and (b) DAE

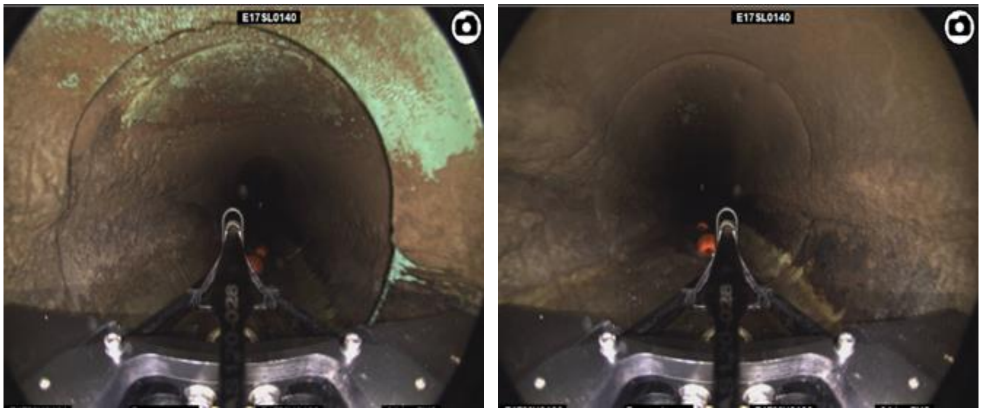


Figure 4-48 Significant defects in line 43 (DAE)

Figure 4-49 Significant defects in line 46 (DAE)

Figure 4-50 Significant defects in line 47 (DAG and DAE)

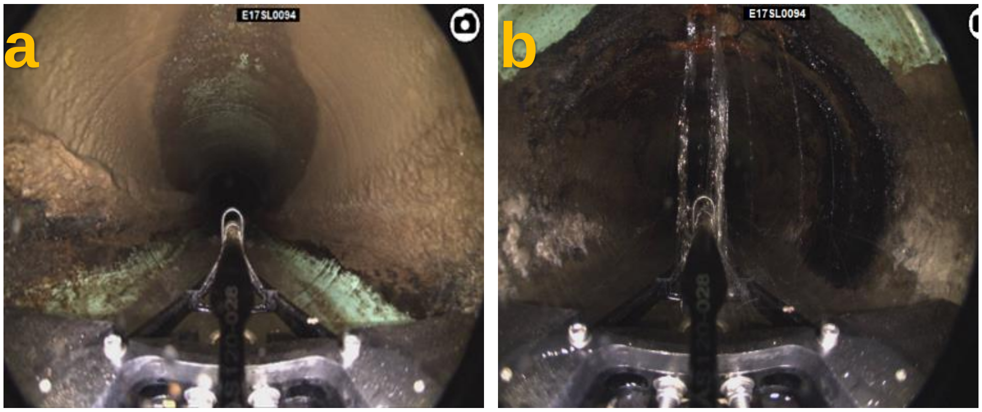


Figure 4-51 Significant defects in line 48. It shows (a) DAE and (b) IRJ

Figure 4-52 Significant defects in line 49 (DAE)

Figure 4-53 Significant defects in line 50 (DAG and DAE)

Figure 4-54 Significant defects in line 52 (JS)

Figure 4-55 Significant defects in line 53 (DAE)

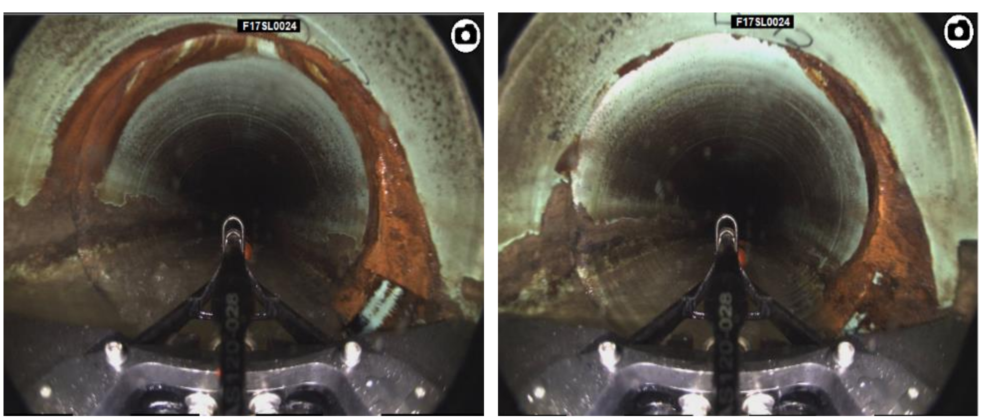


Figure 4-56 Significant defects in line 54 (JS)

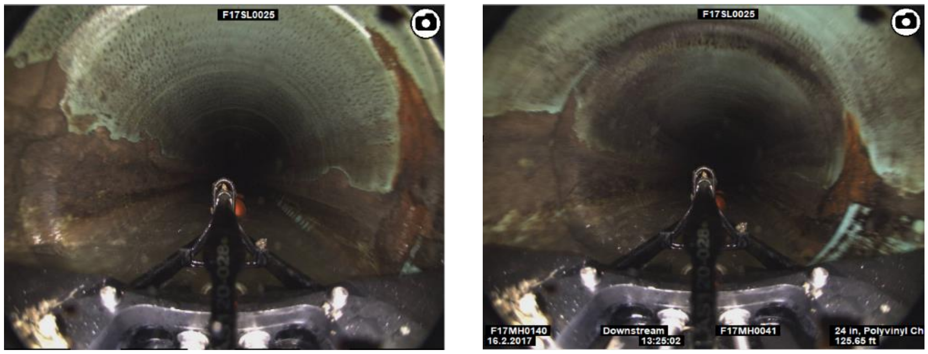


Figure 4-57 Significant defects in line 55 (JS)

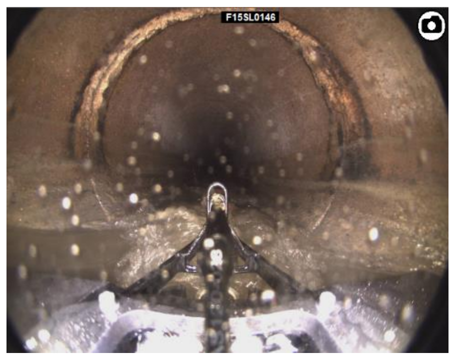


Figure 4-58 Significant defects in line 59 (JS)

Overall Inspection Summary

The summary of the inspection of six miles of the City of Arlington (COA) large diameter sewer pipeline system is presented in Table 4-6. The summary of the average debris volume per 100 feet of pipe for each pipe material inspected is shown in Figure 4-59. Also, the summary of the average deposit volume per 100 feet of pipe for each pipe material inspected is shown in Figure 4-60. Furthermore, maximum mean pipe blockage for each pipe material inspected is shown in Figure 4-61. Moreover, the percentage of corrosion classification in DI pipes, defect level percentage and percentage of the defect type are shown in Figures 4-62, 4-63 and 4-64, respectively. The later figures represent the summary of the inspected 6 miles and they are not based on a controlled study.

Table 4-6 Overall inspection summary

OVERALL INSPECTION SUMMARY		
1	Distance Planned (ft.)	36,002
2	Percentage of Non-Inspected Length	13%
3	Collapsed	0
4	Total Fractures Multiple	26
5	Total Fractures Hinge	3
6	Total Fractures Longitudinal	116
7	Total Fractures Circumferential	2
8	Broken	1
9	Deformed Rigid	2
10	Joint Offsets	12
11	Total Roots Occurrences	51
12	Level 5 Defects	0
13	Level 4 Defects	54
14	Total Defects	703
15	Total Debris Volume (ft^3)	4,524
16	Total Deposits Volume (ft^3)	1,675
17	Maximum Blockage (%)	28.3
18	Maximum Deposit Thickness (in)	4.4

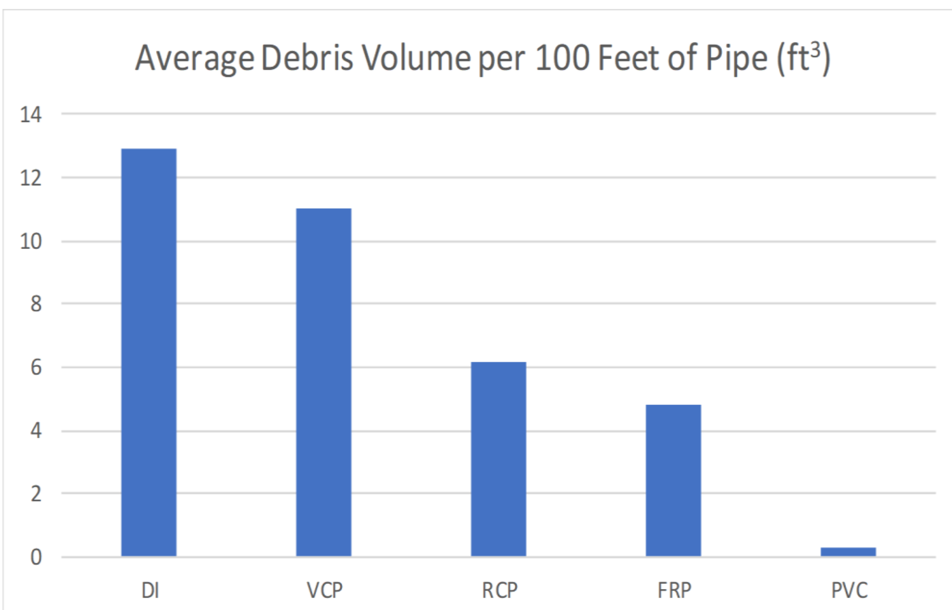


Figure 4-59 Average debris volume per 100 feet of pipe for each pipe material inspected

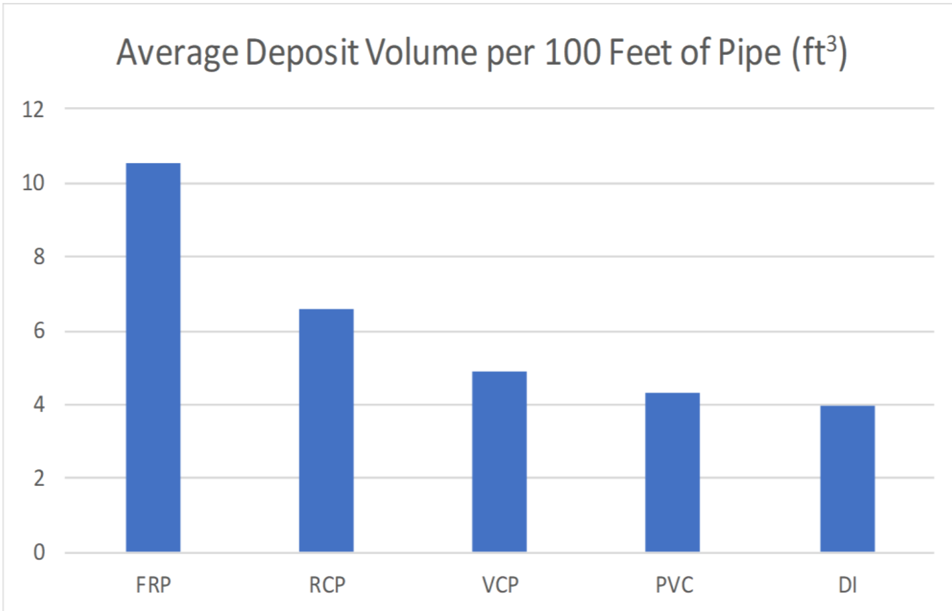


Figure 4-60 Average deposit volume per 100 feet of pipe for each pipe material inspected

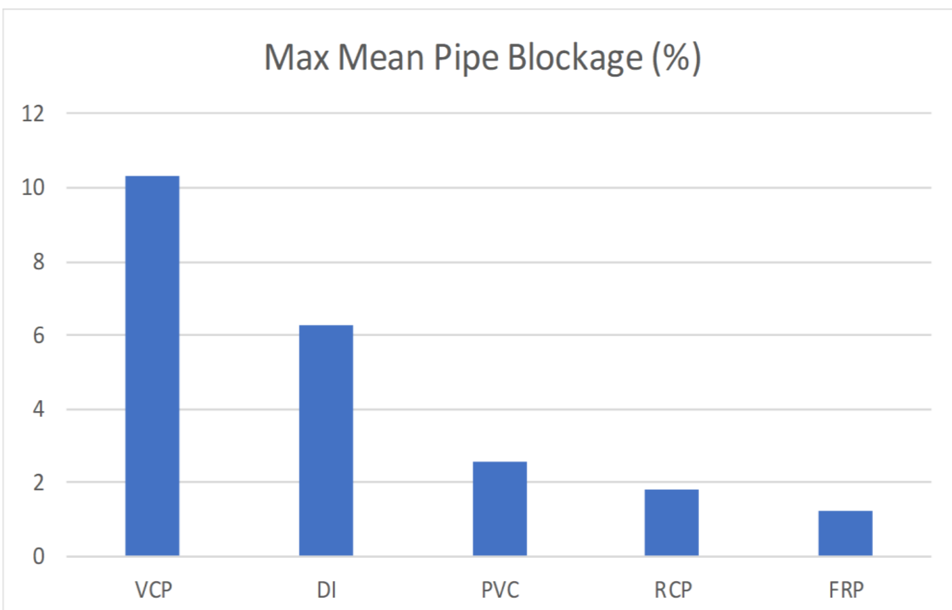


Figure 4-61 Maximum mean pipe blockage for each pipe material inspected

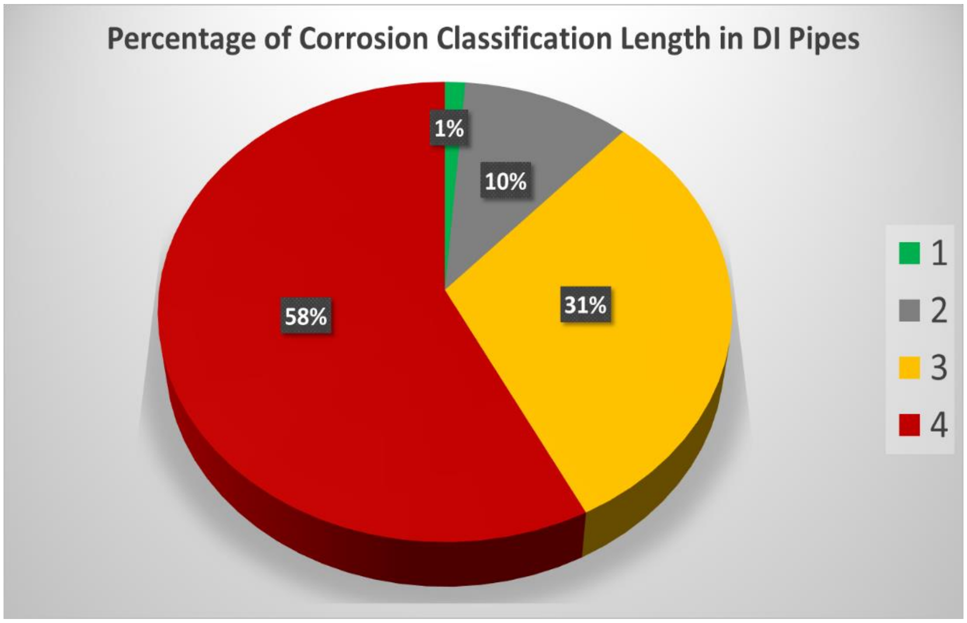


Figure 4-62 Percentage of corrosion classification in DI pipes

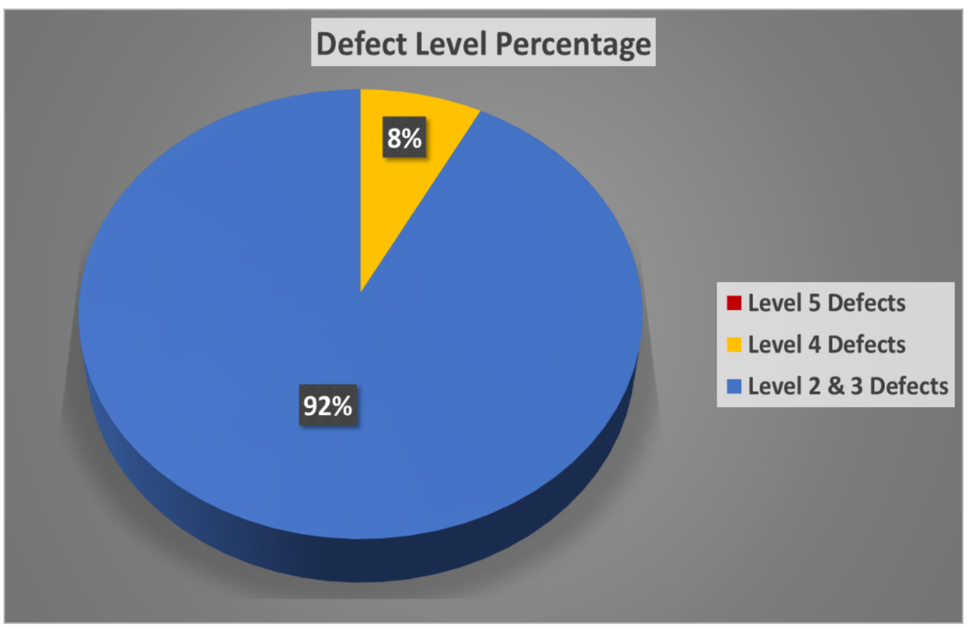


Figure 4-63 Defect level percentage

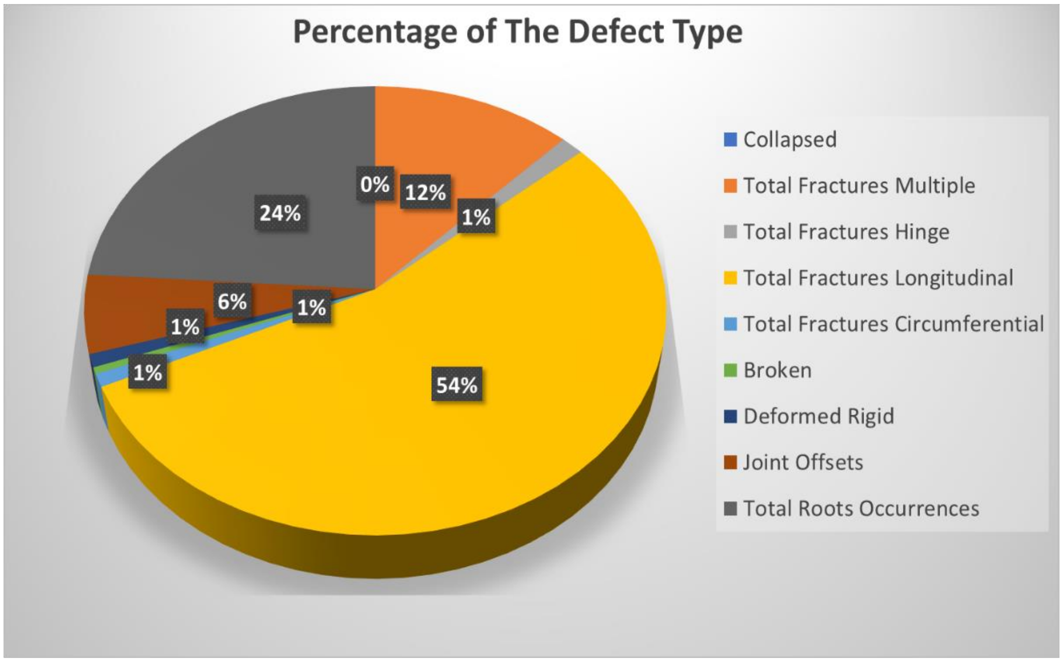


Figure 4-64 Percentage of the defect type

Chapter 5

Development of Pipe Damage Prediction Equations

Basis of Regression Analysis

Rregression analysis is a method to predict a dependent parameter from one or more independent parameters. The typical sample regression model for n observations (n=number of observations) with p independent parameters (p=number of independent parameters) is shown in Equation 5-1:

$$Y = XB + e \qquad \text{5-1}$$

Where Y is an n x 1 column vector containing data on the dependent variable (criterion);
X is an n x (p + 1) matrix containing data on the predictor (independent) variables;
B is a (p + 1) x 1 column vector containing estimated regression coefficients; and
e is an n x 1 column vector containing error terms (residuals).

The primary objective of multiple regression analysis is to create a regression equation that can be used in other samples to forecast an indefinite parameter with known data on the forecaster parameters. Multiple regression analysis uses Ordinary Least Squares (OLS) method to find the regression coefficients (B). These regression coefficients provide the best fit of the data to the model by minimizing residuals (prediction error) using Equation 5-2:

$$e = Y - XB = Y - \hat{Y} \qquad \text{5-2}$$

Where $\hat{Y}$ is an n x 1 column vector containing predicted Y values for the sample (Whittaker 2003).

To perform the regression analysis, it is common procedure to represent the response of dependent or response variable as a function of the independent variables.

In this study, the dependent variables of the pipe are measured as functions of the independent variables as it is shown in Equation 5-3:

$$Y = f(X_1, X_2, X_3, \dots \dots .. X_n) \quad \text{5-3}$$

In Equation 5-3, Y is a function of n independent or response variables intended to fit data collected from a study. A linear (or summation) regression model for the function is written as Equation 5-4:

$$Y = C_0 + C_1X_1 + C_2X_2 + C_3X_3 + \cdots + C_nX_n + C_{12}X_1X_2 + C_{12}X_1X_2 + \cdots + C_{n1}X_nX_1 + C_{123}X_1X_2X_3 + \cdots + C_{123\dots n}(X_1X_2X_3 \dots X_n) \quad \text{5-4}$$

This technique provides information on the relative significance of not only the main variables X_1, $X_2\dots$, X_n but also the relationship between the same variables X_1X_2, $X_1X_2X_3\dots$, $(X_1X_2\dots X_n)$. Yet, in most real problems, many of the higher-order relations could be removed based of physical and intuitive considerations. Possible relations must, however, be considered in the model. Nonlinear regression (Equation 5-5) is an alternative method that is used when a linear regression model is not presenting a good correlation.

$$Y = C_0 x_1^{c_1} x_2^{C_2} \dots X_n^{c_n} \quad \text{5-5}$$

This nonlinear regression method could be converted to a linear regression equation if the natural logarithms are taken off from both sides as shown in Equation 5-6:

$$lnY = lnC_0 + C_1 lnX_1 + C_2 lnX_2 + \cdots + C_n lnX_n \quad \text{5-6}$$

Equation 5-6 could be re-written as Equation 5-7 by denoting the natural logarithms of the numerous variables by prime superscripts.

$$Y' = c_0' + c_1X_1' + c_2X_2' + \cdots + c_nX_n' \quad \text{5-7}$$

Equation 5-7 is analogous to the linear terms in Equation 5-4. It is noted that in Equation 5-7, product terms of the form of X_1' , X_2' , X_3' etc., are not presented, so no relations between independent parameters are existing (Dezfooli 2013).

Estimating of Structural Damage in Vitrified Clay Pipes

The structural damage includes all kinds of fractures codes such as Fracture Longitudinal (FL), Fracture Multiple (FM) and Fracture Hinge (FH). Furthermore, the structural defects include Hole (H), Broken (B), Deformed (D) and collapse. Each typical sewer main is scored based on its structural defects. The mains' structural defect score denotes the amount and severity of issues found by analyzing the video collected during inspection. Defects are rated based on the modified PACP coding system illustrated in Chapter 2. This system is based solely on structural defect visible during review and rates issues from 1 to 5, with 5 being the most severe defect. The scores were added together to get a combined structural defect score, and this score is divided by the main length to come to an Average Structural Defect Score Per 100 Linear Feet of Main. This gives a quick summary of the overall visible structural condition of the pipe. The independent parameters that are considered in this study are shown in Table 5.1.

Moreover, some other parameters are neglected as they didn't show a significant correlation such as length and other parameters are neglected due to lack of information such as the applied load.

The input regression data is presented in Table 5.2 including all independent parameters as well as the dependent parameter SDS (Structural Defect Score) and the output excel program result table is shown in Figure 5-1 for linear multiple regression analysis.

Table 5-1 Independent parameters for the conducted regression analysis

Independent Parameters	Description
D	Pipe Diameter, in.
A	Pipe Age, years.
S	Pipe Slope
FD	Pipe Average Flow Depth, in.

Table 5-2 Regression data input for estimating the structural defect score

D	A	S	FD	SDS
27	48	0.0040	5.33	23.527
27	48	0.0040	7.78	2.586
27	48	0.0040	7.42	12.116
27	48	0.0040	6.43	21.669
27	48	0.0040	6.67	27.127
24	42	0.0054	5.08	17.867
24	42	0.0033	5.66	13.597
24	42	0.0033	5.75	16.833
24	42	0.0033	5.98	6.943
24	42	0.0033	7.06	6.681
24	42	0.0033	6.30	6.727
24	42	0.0030	6.54	6.500
27	48	0.0040	7.62	35.000
24	28	0.0016	8.83	2.603
24	28	0.0016	8.99	2.604

24	28	0.0020	9.06	1.000
24	42	0.0033	6.21	1.379
24	42	0.0033	6.56	0.782
27	48	0.0040	6.25	37.928

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.79
R Square	0.63
Adjusted R Square	0.52
Standard Error	8.06
Observations	19.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.00	1531.39	382.85	5.89	0.0054
Residual	14.00	909.58	64.97		
Total	18.00	2440.97			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-105.87	35.30	-3.00	0.0096	-181.59	-30.15
D	7.76	2.57	3.02	0.0092	2.25	13.28
A	-0.97	0.79	-1.23	0.2407	-2.67	0.73
S	1602.97	4459.11	0.36	0.7246	-7960.87	11166.82
FD	-6.00	3.24	-1.85	0.0854	-12.96	0.95

Figure 5-1 Linear regression summary output table for estimating SDS

As it is shown from Figure 5-1, the coefficient of determination (r^2) has a value of 0.63 and the coefficient of correlation (r) is equal to 0.79. The coefficients of the Y-intercept, pipe diameter, pipe age, pipe slope and the pipe average flow depth are -105.87, 7.76, -0.97, 1602.97, and -6.00, respectively. Therefore, the equation for estimating the dependent variable SDS for vitrified clay pipes is presented in Equation 5-8.

$$SDS = -105.87 + 7.76D - 0.79A + 1602.97S - 6FD \qquad 5\text{-}8$$

The observed versus predicted SDS are presented in Figure 5-2 with 18% upper and lower limits.

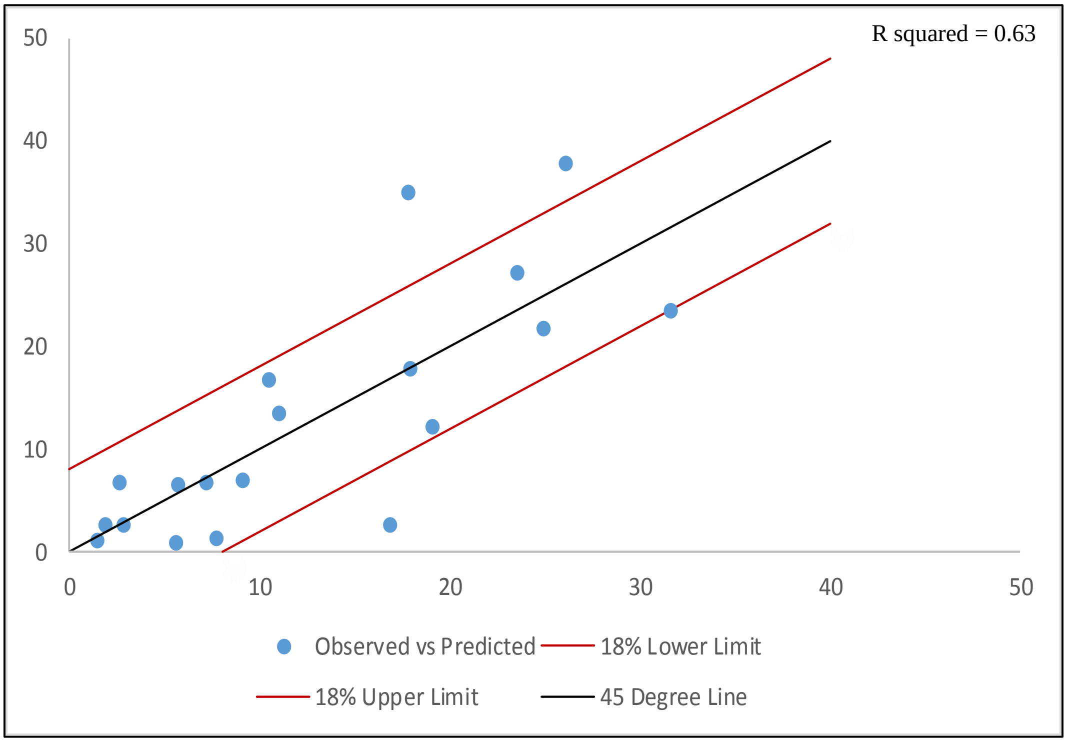


Figure 5-2 Observed vs predicted SDS for linear regression

The summary output table of the nonlinear multiple regression analysis is presented in Figure 5-3. As it is shown from Figure 5-3, the coefficient of determination (r^2) has a value of 0.58 and the coefficient of correlation (r) is equal to 0.76. The coefficients of the Y-intercept, pipe diameter, pipe age, pipe slope and the pipe average flow depth are -24.35, 15.08, -2.65, 0.74, and -4.26, respectively.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.76
R Square	0.58
Adjusted R Square	0.46
Standard Error	0.89
Observations	19.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4.00	15.48	3.87	4.90	0.0111
Residual	14.00	11.06	0.79		
Total	18.00	26.54			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-24.35	24.73	-0.98	0.3413	-77.39	28.68
D	15.08	6.09	2.48	0.0267	2.01	28.14
A	-2.65	3.97	-0.67	0.5159	-11.16	5.87
S	0.74	2.15	0.34	0.7358	-3.87	5.34
FD	-4.26	2.32	-1.84	0.0877	-9.24	0.72

Figure 5-3 Nonlinear regression summary output table for estimating SDS

Therefore, the equation for estimating the dependent variable SDS for vitrified clay pipes is presented in Equation 5-9.

$$SDS = e^{-24.35} D^{15.08} A^{-2.65} S^{0.74} FD^{-4.26} \tag{5-9}$$

The observed versus predicted SDS are presented in Figure 5-4 with 18% upper and lower limits.

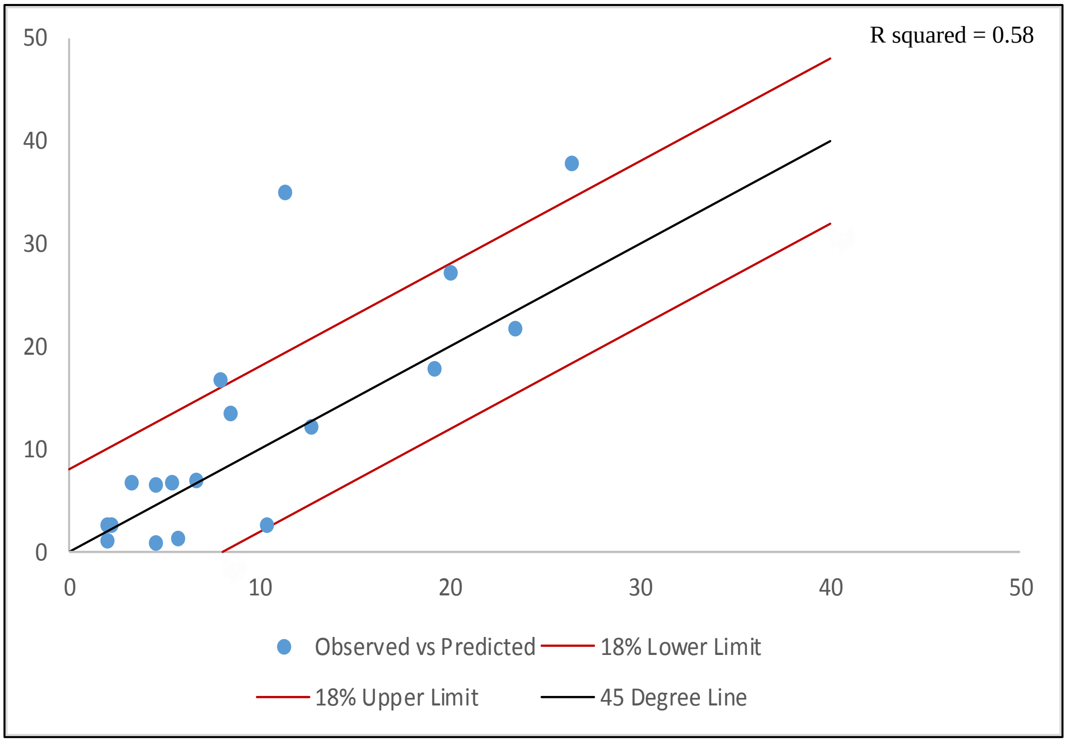


Figure 5-4 Observed vs predicted SDS for non-linear regression

Estimating of Corrosion Level in Ductile Iron Pipes

Estimating the level of the corrosion level is solely based on visual inspection of the corrosion visible during review of the CCTV videos. The rating of the corrosion level is established to be from 1 to 4, with 1 being good, 2 is moderate corrosion, 3 bad and 4 in very bad (need replacement). Therefore, the pipe classification would be from 1 to 4. The independent parameters that are considered in this study to estimate the corrosion level in ductile iron pipes are shown in Table 5.3.

Moreover, some other parameters are neglected as they didn't show a significant correlation such as length and other parameters are neglected due to lack of information such as the H_2S concentration.

Table 5-3 Independent parameters for the performed regression analysis

Independent Parameters	Description
D	Pipe Diameter, in.
A	Pipe Age, years.
S	Pipe Slope
FD	Pipe Average Flow Depth, %
V	Pipe Average Velocity, ft/s.

The input regression data for estimating the corrosion level is presented in Table 5.4 including all independent parameters as well as the dependent parameter CL (Corrosion Level) and the output excel program result table is shown in Figure 5-4 for linear multiple regression analysis.

Table 5-4 Regression data input for estimating the corrosion level

D	S	A	FD	V	CL
36	0.0009	34	21	2.57	4
36	0.0043	34	19	3.00	4
24	0.0034	42	33	3.41	4
24	0.0054	42	27	4.11	4
24	0.0034	42	31	3.45	4
24	0.0034	42	26	4.41	4
24	0.0034	42	30	3.58	4
24	0.0594	42	30	3.59	4
24	0.0594	42	30	3.49	4

30	0.0010	42	32	2.09	4
30	0.0010	42	22	3.43	4
30	0.0010	42	30	2.23	4
30	0.0010	42	30	2.23	4
36	0.0009	42	25	2.02	3
36	0.0009	42	21	2.69	2
36	0.0009	42	25	2.02	2
36	0.0009	42	32	1.45	1
36	0.0009	42	13	1.89	3
30	0.2000	42	28	1.98	3
30	0.2000	42	28	2.79	3
30	0.2000	42	29	2.63	4
30	0.2000	42	25	3.66	4
30	0.2000	42	26	3.51	4

As it is shown from Figure 5-5, the coefficient of determination (r^2) has a value of 0.63 and the coefficient of correlation (r) is equal to 0.79. The coefficients of the Y-intercept, pipe diameter, pipe slope, pipe age, the pipe average flow depth and the pipe average velocity are 18.57, -0.19, 1.36, -0.18, -0.05 and -0.16, respectively. Therefore, the equation for estimating the dependent variable CL for ductile iron pipes is presented in Equation 5-10.

$$CL = 18.57 - 0.19D + 1.36S - 0.18A - 0.05FD - 0.16V \qquad \text{5-10}$$

The observed versus predicted SDS are presented in Figure 5-6 with 18% upper and lower limits.

Regression Statistics	
Multiple R	0.79
R Square	0.63
Adjusted R Square	0.52
Standard Error	0.59
Observations	23.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5.00	9.88	1.98	5.74	0.0028
Residual	17.00	5.86	0.34		
Total	22.00	15.74			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	18.57	5.31	3.50	0.0028	7.36	29.78
D	-0.19	0.07	-2.79	0.0125	-0.34	-0.05
S	1.36	1.56	0.87	0.3965	-1.94	4.66
A	-0.18	0.07	-2.73	0.0143	-0.32	-0.04
FD	-0.05	0.04	-1.29	0.2145	-0.14	0.03
V	-0.16	0.33	-0.48	0.6352	-0.85	0.53

Figure 5-5 Linear regression summary output table for estimating CL

The summary output table of the nonlinear multiple regression analysis is presented in Figure 5-7. As it is shown from Figure 5-7, the coefficient of determination (r^2) has a value of 0.53 and the coefficient of correlation (r) is equal to 0.73. The coefficients of the Y-intercept, pipe diameter, pipe slope, pipe age, the pipe average flow depth and the pipe average velocity are 13.46, -1.32, 0.02, -1.8, -0.37 and 0.21, respectively. Therefore, the equation for estimating the dependent variable CL for ductile iron pipes is presented in Equation 5-11.

$$CL = e^{13.46} D^{-1.32} S^{0.02} A^{-1.8} FD^{-0.37} V^{0.21} \qquad 5\text{-}11$$

The observed versus predicted SDS are presented in Figure 5-8 with 18% upper and lower limits.

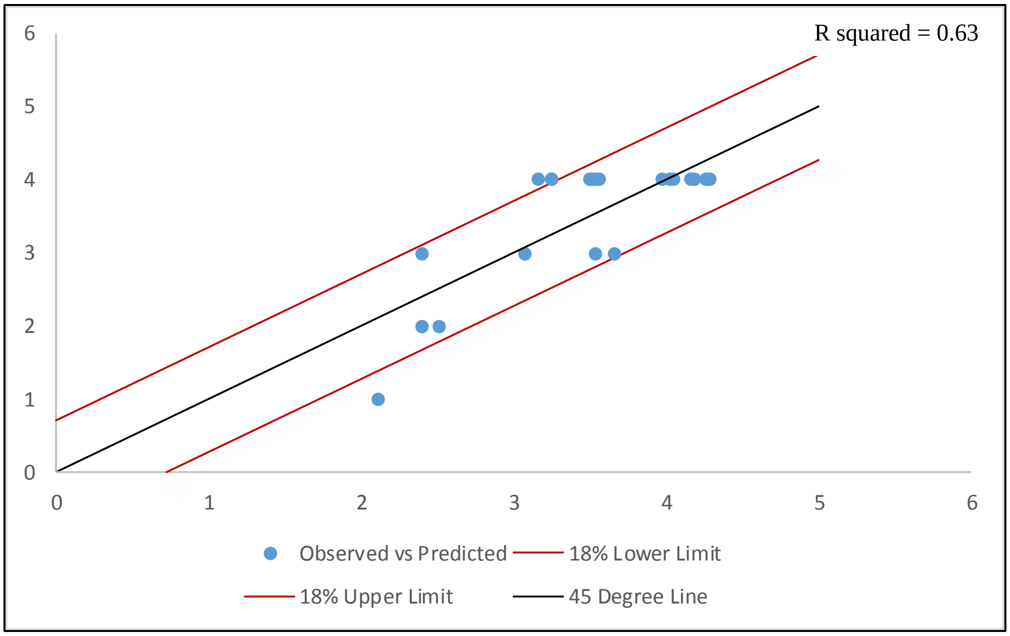


Figure 5-6 Observed vs predicted CL for linear regression

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.73
R Square	0.53
Adjusted R Square	0.39
Standard Error	0.27
Observations	23.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5.00	1.35	0.27	3.81	0.0168
Residual	17.00	1.20	0.07		
Total	22.00	2.54			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	13.46	6.70	2.01	0.0608	-0.68	27.60
D	-1.32	0.80	-1.65	0.1164	-3.01	0.36
S	0.02	0.03	0.57	0.5784	-0.04	0.08
A	-1.80	1.13	-1.59	0.1294	-4.19	0.58
FD	-0.37	0.39	-0.95	0.3556	-1.18	0.45
V	0.21	0.37	0.56	0.5805	-0.58	0.99

Figure 5-7 Nonlinear regression summary output table for estimating CL

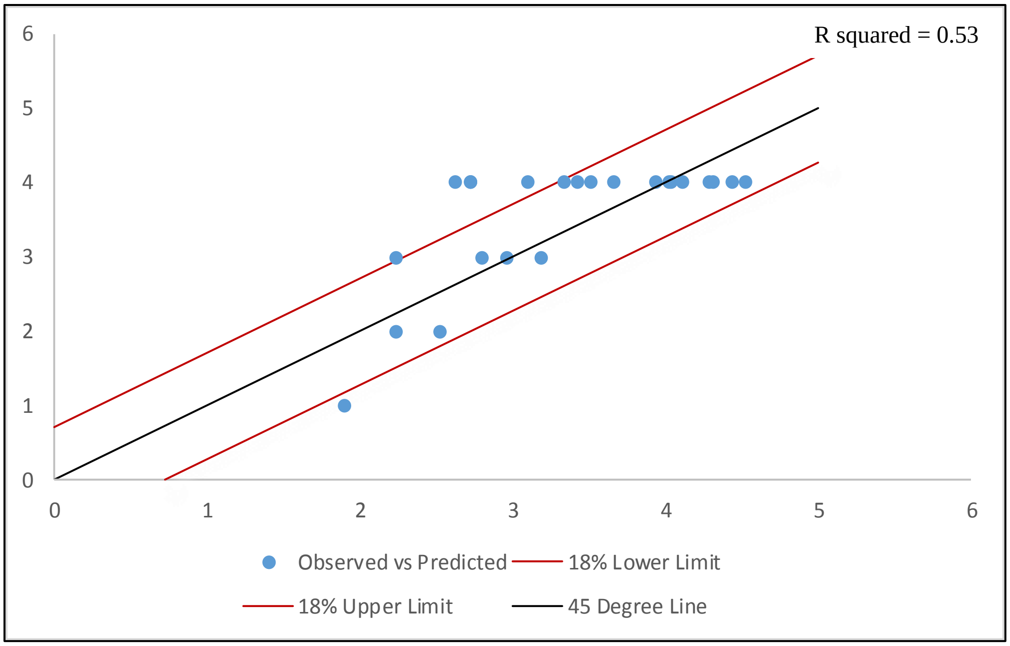


Figure 5-8 Observed vs predicted CL for non-linear regression

Chapter 6

Summary and Conclusions

Summary

Sewer systems account for approximately 50% of the underground infrastructure in the United States (Shook and Bell 1998). ASCE Assigns a Grade D to Nation's Infrastructure (limited information on condition of sewer pipelines). Without a condition assessment for the pipe, a collapse is imminent.

The sanitary sewer system might represent an investment of millions of dollars for a small municipality (NEIWPCC 2003). More than 19,000 sanitary sewer systems in the United States would have a replacement value of as much as two trillion dollars according to Environmental Protection Agency (EPA) (NEIWPCC 2003). The infrastructure need is estimated at $334.8 billion from Jan. 2007 through Dec. 2027 across the nation. The water and wastewater infrastructure represent the largest portion of $200.8 billion, according to a 2007 EPA survey. The system requires an efficient operation for 24 hours per day (Atchison 2012). One of the major rising problems in modern cities nowadays is the damage caused by the aging of sewage pipe systems (Vahidi et al., 2016).

The Urban drainage and water supply systems are intended to have a long service life. Because these underground infrastructures are capital-intensive and vital components of a sustainable urban system, it is essential to maintain a certain level of infrastructures serviceability. There is always a challenge to minimize the maintenance costs and maintain the risk of failures at a tolerable level. Information on the current status of the assets can enhance proper decision-making. There are several techniques available for the assessment of sewer conditions: visual inspection by closed circuit television (CCTV), radar, acoustic techniques, sonar, laser profiling or a combination of these technologies in order to benefit from the strengths of each technology (Stanić et al., 2017). The summary of this research work is:

- University of Texas at Arlington (UTA) and has established a program to perform a condition assessment on the current large-diameter pipeline system of The City of Arlington (COA) using advanced multi-sensor inspection (MSI) technology in cooperation with City of Arlington (COA) and RedZone Robotics under Technology Partnership Program (TPP).
- Field inspection is done for all the current large-diameter pipeline system of The City of Arlington (COA) sewer lines of 48 miles (24-inch inner diameter and above for rigid and flexible pipes).
- Six miles of the COA large diameter sewer pipes have been analyzed by UTA team.
- A pipe assessment software is developed for this study by UTA team to obtain information about the sewer pipes condition from laser and sonar profiles beyond conventional pipe visual inspection.
- A pipe visual inspection is performed using CCTV videos along with the laser and sonar inspection to identify all other defects in the sewer pipelines that couldn't be detected using MSI technology such as fractures and roots intrusion.
- Statistical models are developed for Identification of the probability of the pipe damage such as the corrosion level in ductile iron pipes and PACP structural defect score in vitrified clay pipes using few parameters such as pipe age, pipe diameter, pipe slope, pipe average flow depth and pipe average flow velocity.

Conclusions

- MSI Technology efficiently detects damages, deposit, erosion and debris in sewer pipelines.
- The developed sewer pipe assessment software is found to be capable of calculating the debris level, deposit level, blockage level, corrosion level, sewer water level, pipe sewer ovality as well as combining the laser and the sonar profiles.
- Pipe visual inspection is useful along with laser and sonar inspection to have a complete information about the sewer pipe condition.
- The defects found by visual inspection are Fracture Longitudinal (FL), Fracture Multiple (FM) and Fracture Hinge (FH), Hole (H), Broken (B), Deformed (D), Deposit Attached Encrustation (DAE), Deposit Attached Grease, (DAG) Joint Separation (JS), Infiltration Runner Joint (IRJ), Intruding Sealing Material Grout (ISGT), Miscellaneous General Observation (MGO), Tap Break-In/Hammer Active, Surface Damage Aggregate Visible (SAV) and Surface Damage Reinforcement Visible (SRV).
- The developed statistical models could help the municipalities to Identify the probability of the pipe damage such as the corrosion level in ductile iron pipes and PACP structural defect score in vitrified clay pipes using few parameters such as pipe age, pipe diameter, pipe slope, pipe average flow depth and pipe average flow velocity.
- Both of the developed sewer pipe assessment software and the statistical models for sewer pipelines could be very useful for to direct municipalities to take proactive actions for sewer pipe inspection, pipe rehabilitation and pipe replacement.

- The proactive measures taken as a result of proper inspection could be significantly better for tax payers in terms of cost than dealing with sewer pipe damage and collapsing problems when they happen.
- From the analysis of the investigation of the structural integrity of the 6 miles of the COA large diameter pipeline system, it can be concluded that (the pipe material results are not based on a controlled study):
  1. Total debris volume is 4,524 ft^3.
  2. Maximum percentage of the debris area per cross section area is 18%.
  3. Max debris volume per 100 feet of pipe is 63.7 ft^3.
  4. DI pipes have the largest amount of debris per 100 feet of pipe.
  5. Total deposit volume is 1,675 ft^3.
  6. Maximum percentage of the deposit area per cross section area is 4%.
  7. Max deposit volume per 100 feet of pipe is 6 ft^3.
  8. FRP pipes have the largest amount of deposit per 100 feet of pipe.
  9. Maximum percentage of the blockage area (debris and deposits) per cross section area is 28%.
  10. VCP pipes have the max mean pipe blockage.
  11. The highest five lines of Structural Defect Score (SDS) found are VCP pipes among all inspected pipes.
  12. Four PVC lines out of five have the highest Root Intrusion Score (RIS) among all inspected pipes.
  13. The percentage of the non-inspected length is 13%.
  14. Total number of level 4 defects is 54.
  15. Total number of level 5 defects is 0.
  16. Total defects 703.

17. The percentage of the corrosion classification length in DI pipes is shown in Figure 6-1. Where, 1 is good, 2 has a moderate corrosion, 3 is bad, and 4 is very bad (the classification is made by engineering judgement using visual inspection.
18. The percentage of the level 2, 3, 4 and 5 defects from the total number of the detected defects is shown in Figure 6-2.
19. The percentage of the defect type (the number of the one defect occurrences with respect to the total number of the defect occurrences is shown in Figure 6-3.

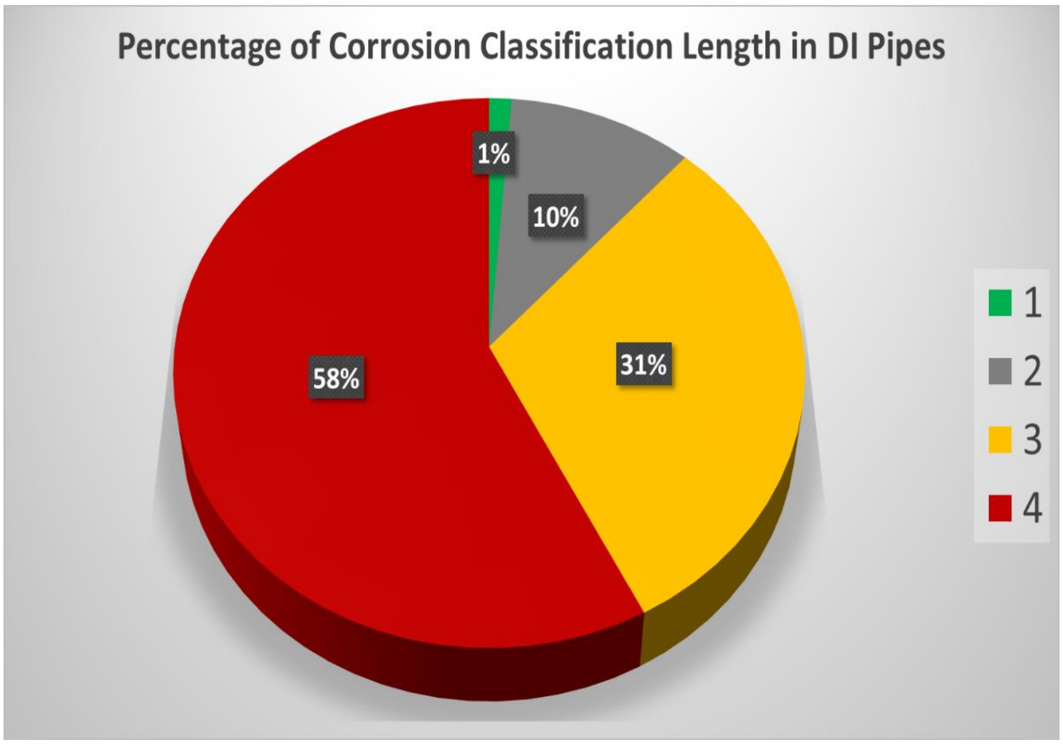


Figure 6-1 Percentage of corrosion classification in DI pipes

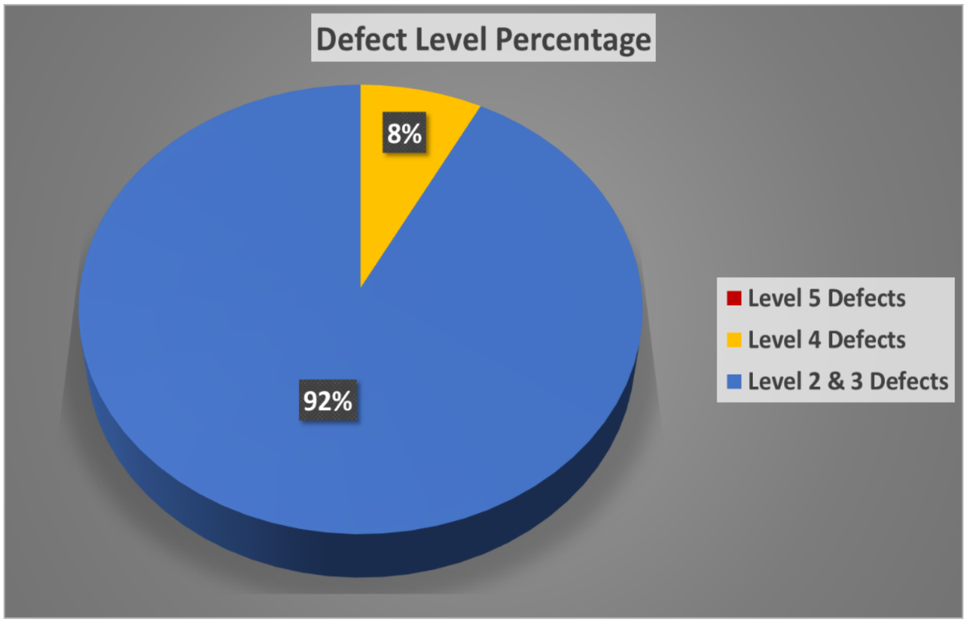


Figure 6-2 Defect level percentage

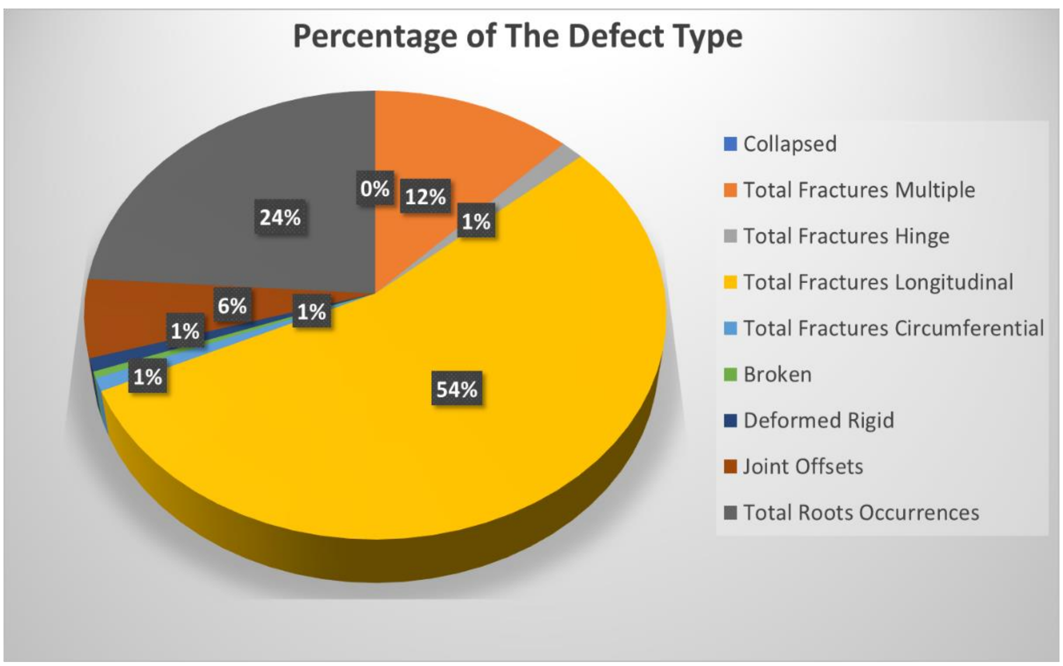


Figure 6-3 Percentage of the defect type

Appendix A

All Results

Line 1 Summary

TableA1-1: Results Summary of Sewer Line 1

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	351
Percentage of The Line Not Inspected	3.6%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	0
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	21738.01
Maximum Blockage (%)	0.90
Maximum Deposit Height (in)	0..49

Deposit Data

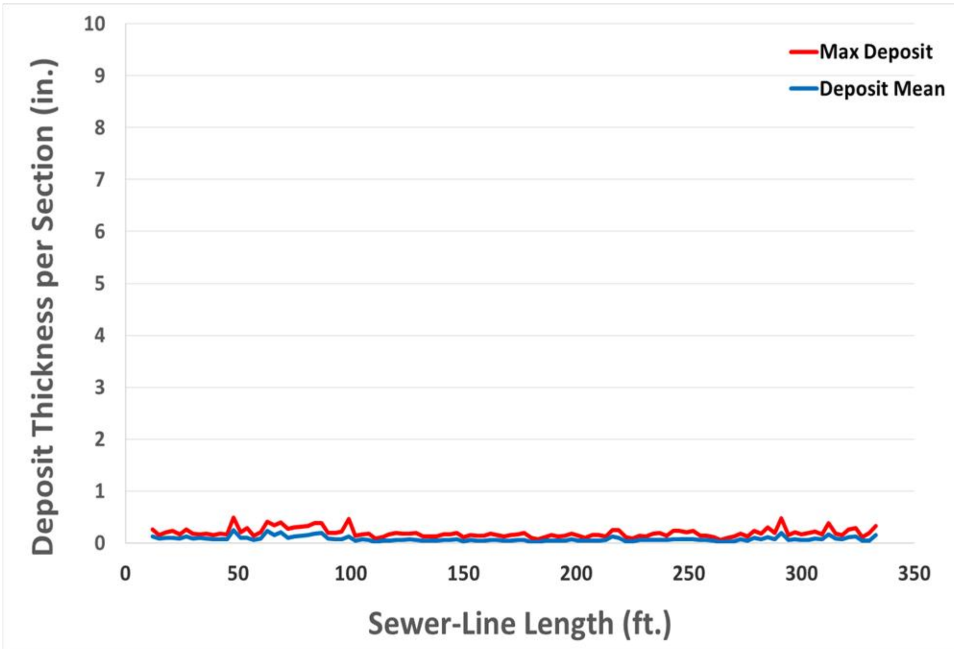


Figure A1-1 Deposit thickness per cross-section

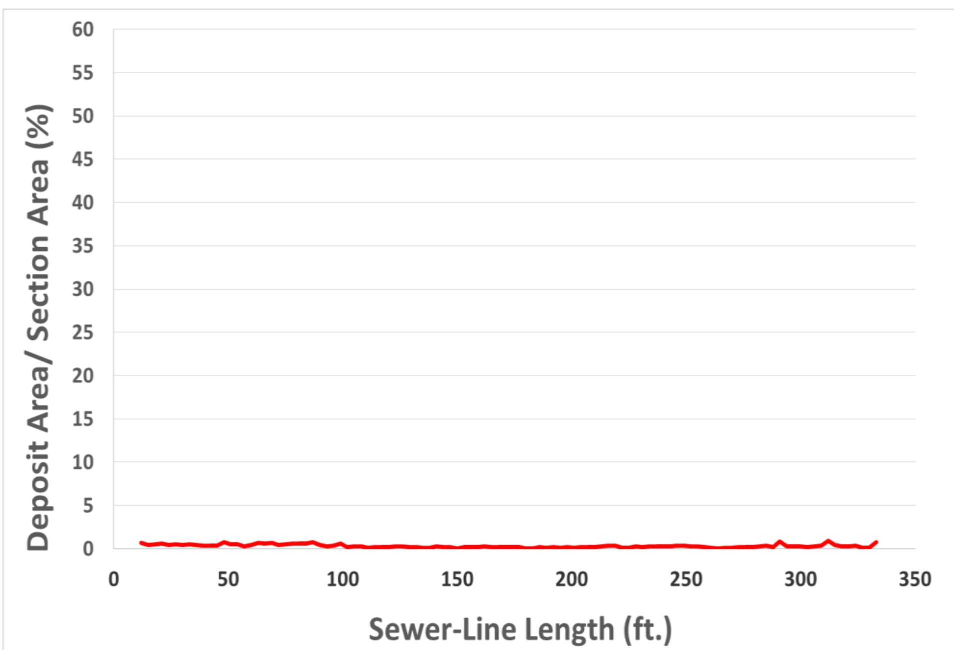


Figure A1-2 Deposit area percentage of the pipe cross section area

Blockage Data

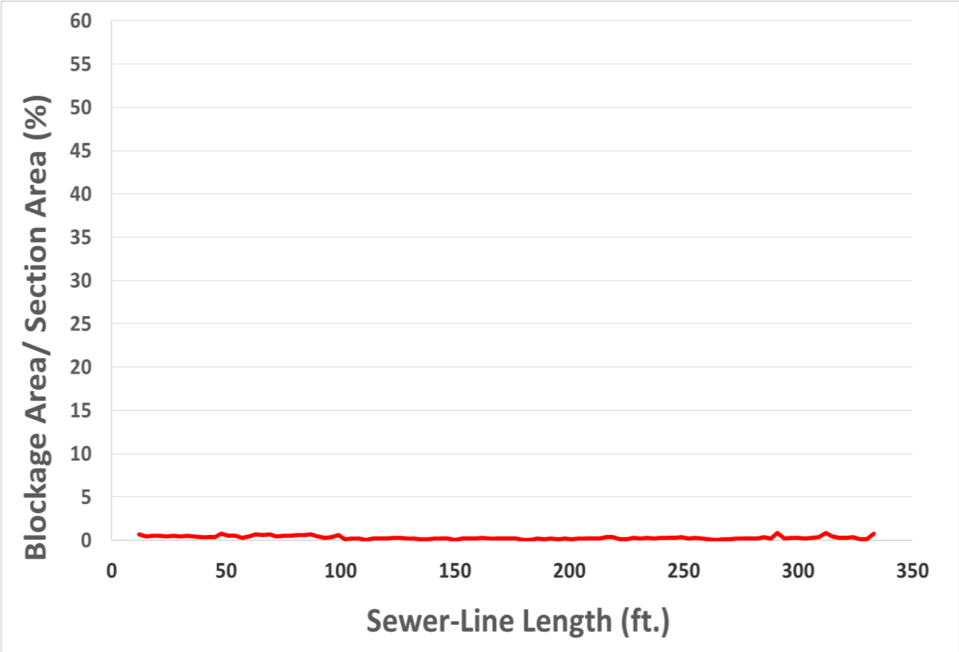


Figure A1-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A1-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				15%					
3	333		MSA									

Line 2 Summary

Table A2-1 Results Summary of Sewer Line 2

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	534.3
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	0
Total Debris Volume (ft3)	27.4
Total Deposits Volume (in3)	103502.15
Maximum Blockage (%)	2.07
Maximum Deposit Height (in)	0.59

Deposit Data

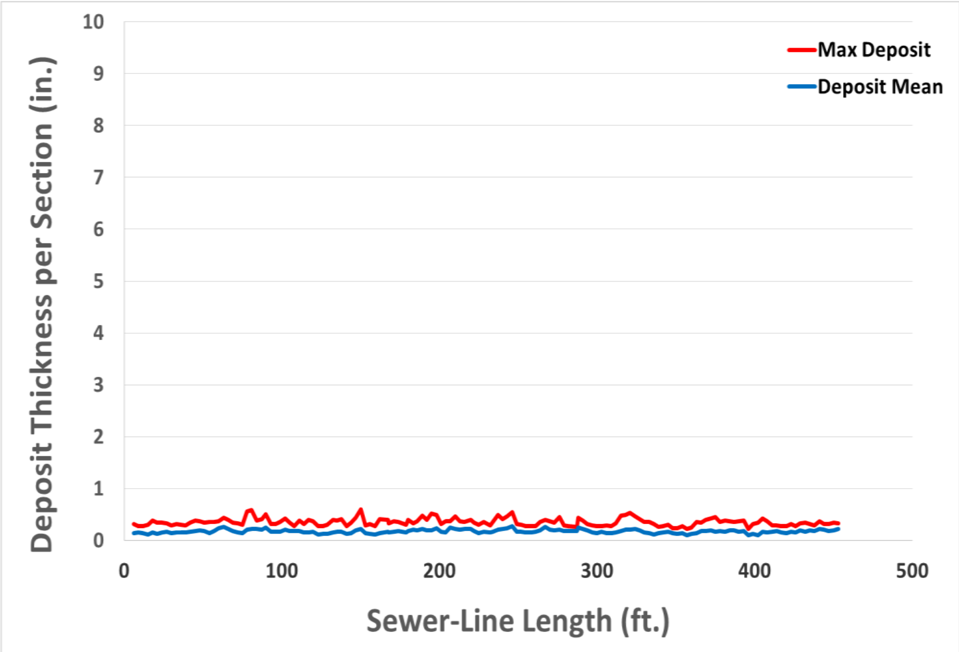


Figure A2-1 Deposit thickness per cross-section

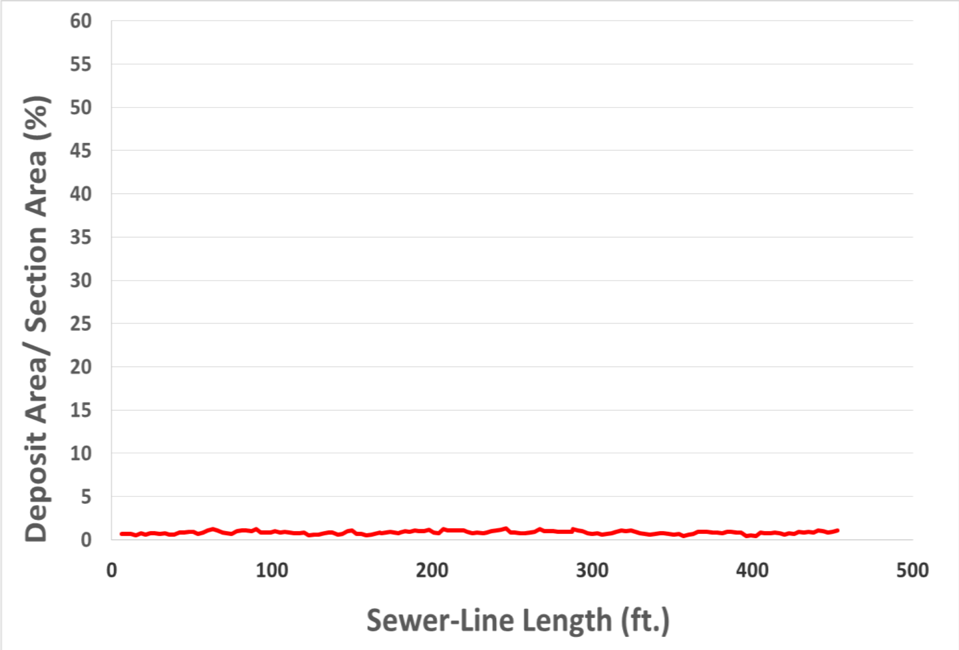


Figure A2-2 Deposit area percentage of the pipe cross section area

Debris Data

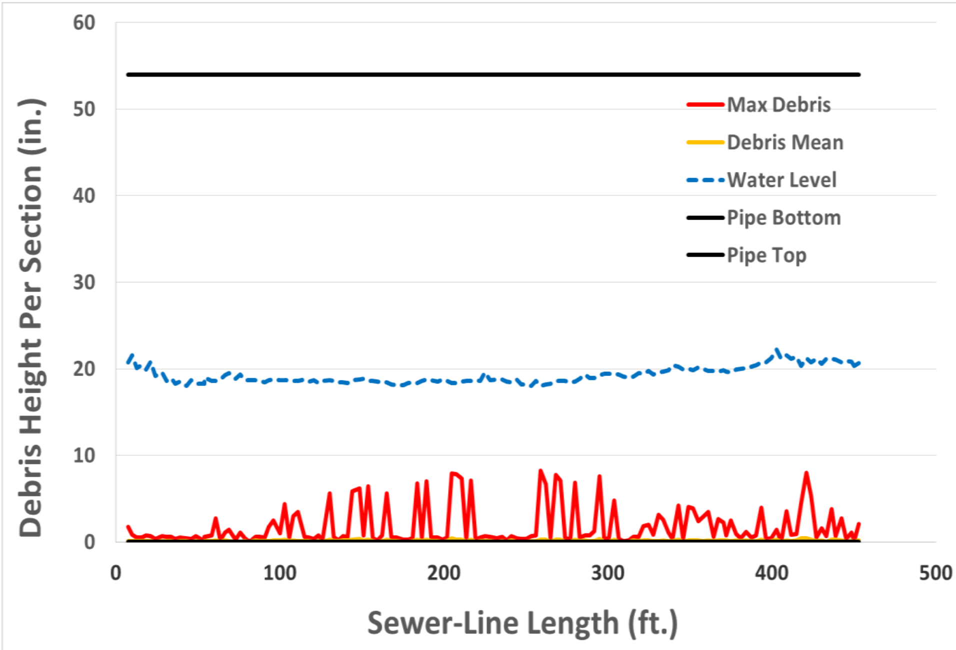


Figure A2-3 Debris height per cross-section

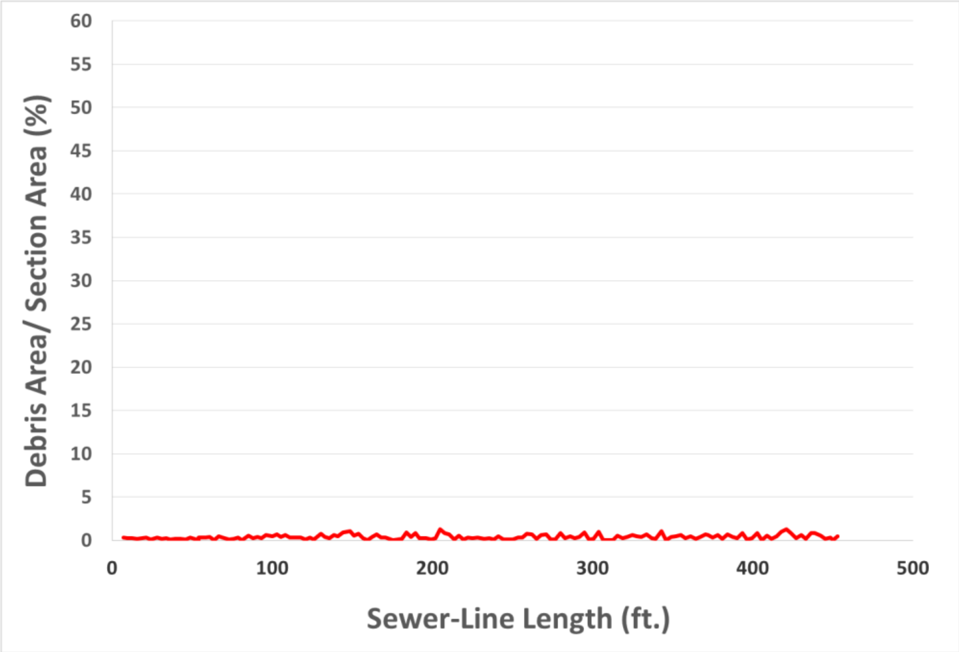


Figure A2-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

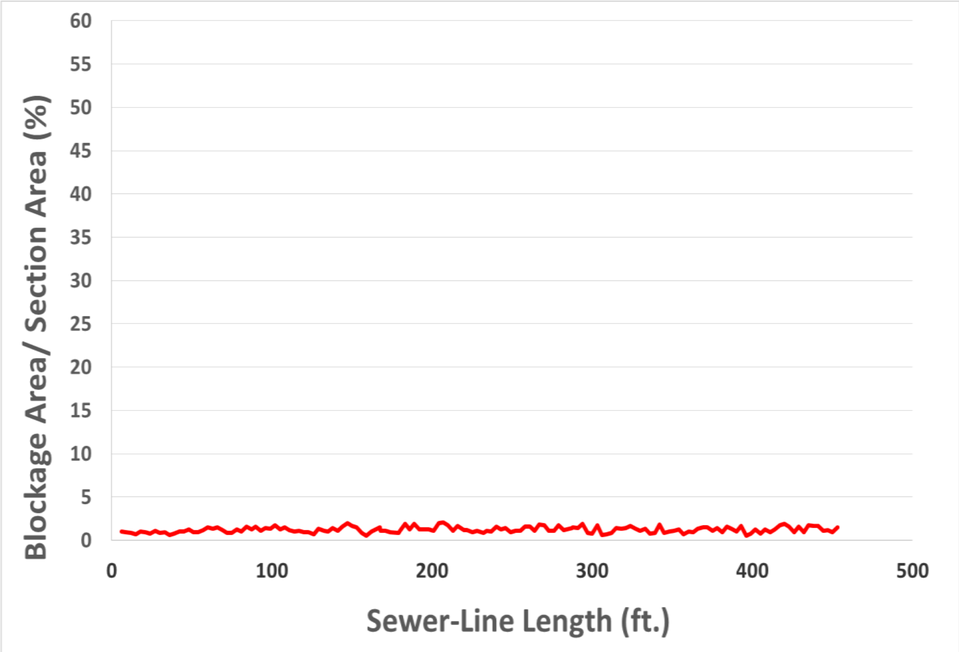


Figure A2-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A2-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code: Group/ Descriptor/ Modifier	Continuous Defect	Value: Dimension 1st	Value: Dimension 2nd	Value: %	Joint	Circumferential Location: At/From	Circumferential Location: To	Img Reference	Remarks
1	0		AMH									
2	6		MWL				15%					
3	456.1		MSA									

Line 3 Summary

Table A3-1 Results Summary of Sewer Line 3

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	855
Percentage of The Line Not Inspected	3.04%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	0
Total Debris Volume (ft3)	39.16
Total Deposits Volume (in3)	117077.93
Maximum Blockage (%)	2.30
Maximum Deposit Height (in)	0.88

Deposit Data

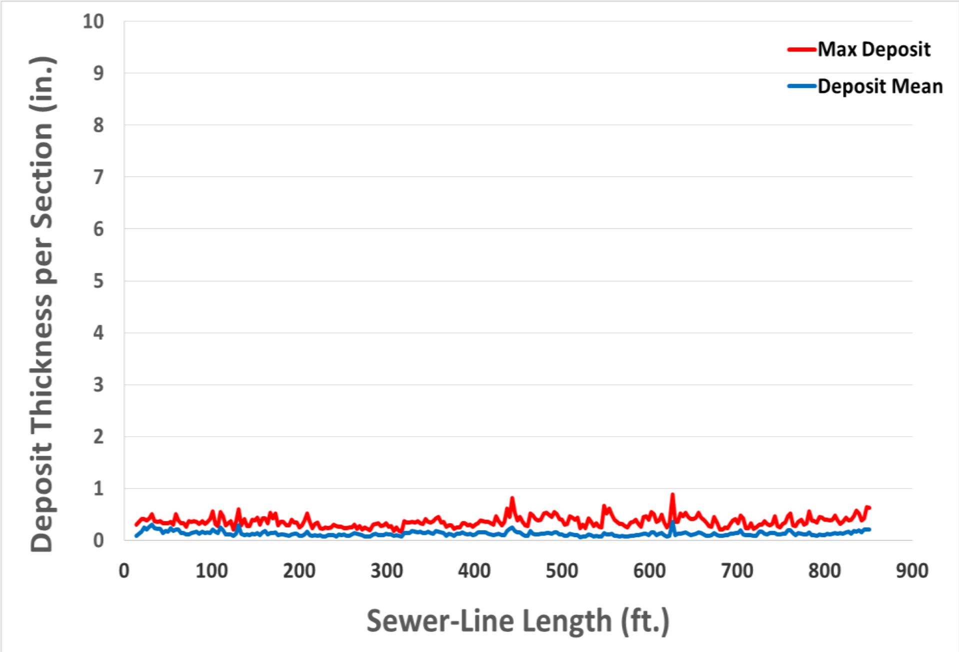


Figure A3-1 Deposit thickness per cross-section

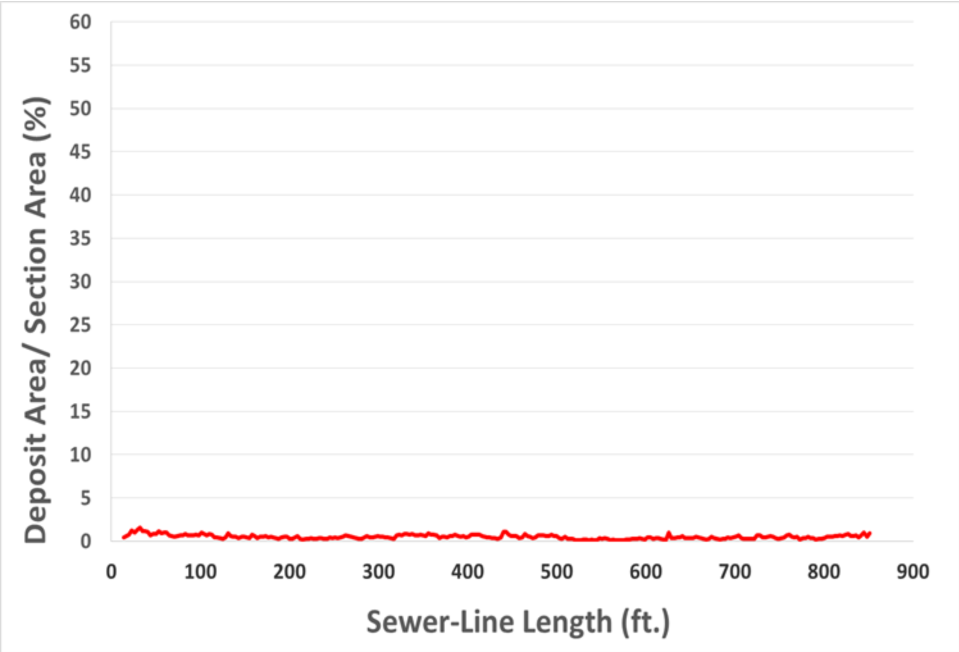


Figure A3-2 Deposit area percentage of the pipe cross section area

Debris Data

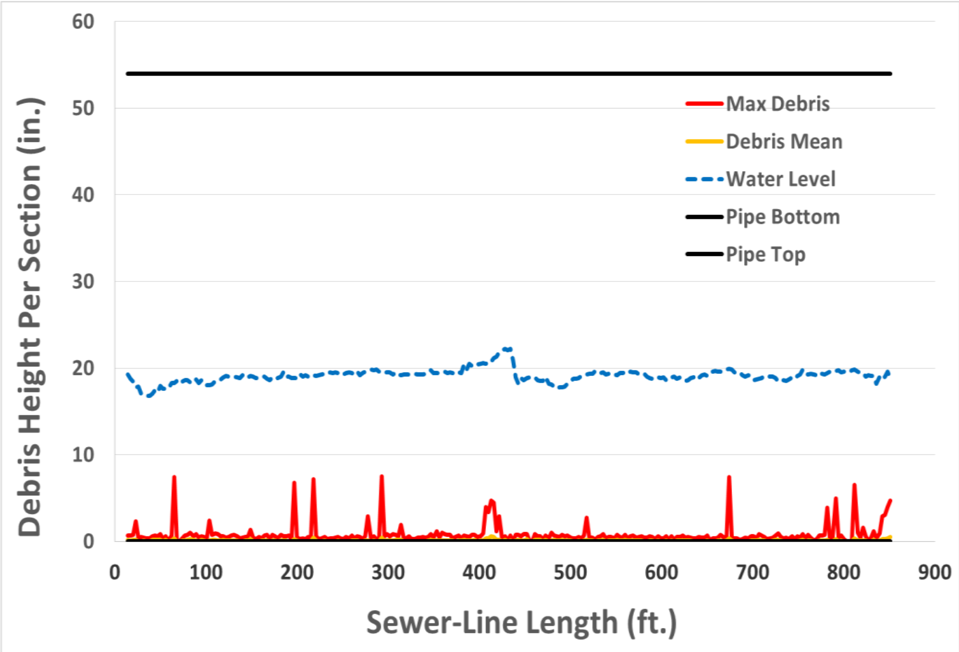


Figure A3-4 Debris height per cross-section

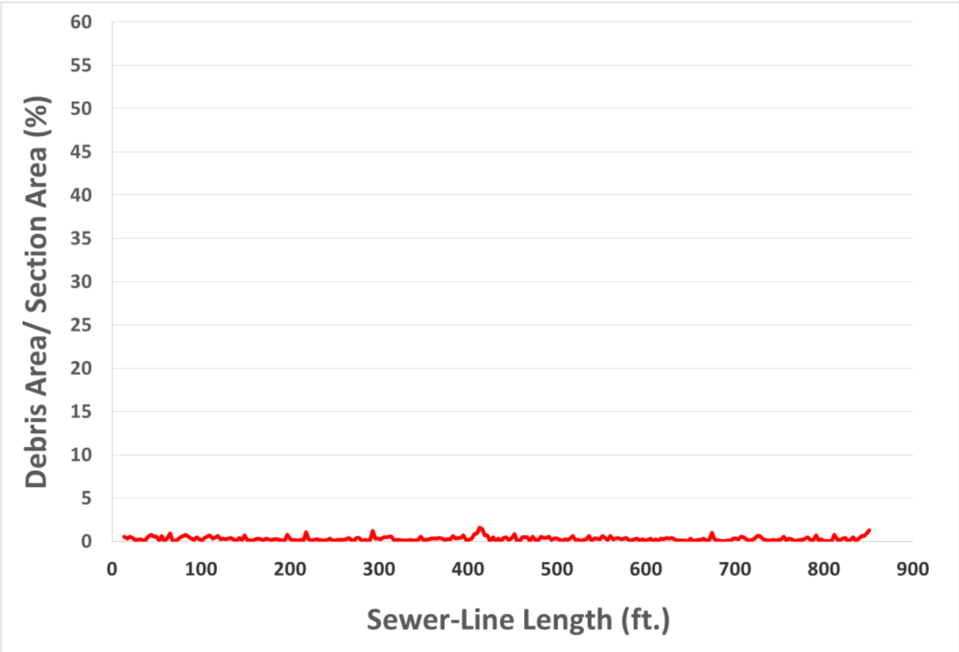


Figure A3-5 Debris area percentage of the pipe cross-sectional area

Blockage Data

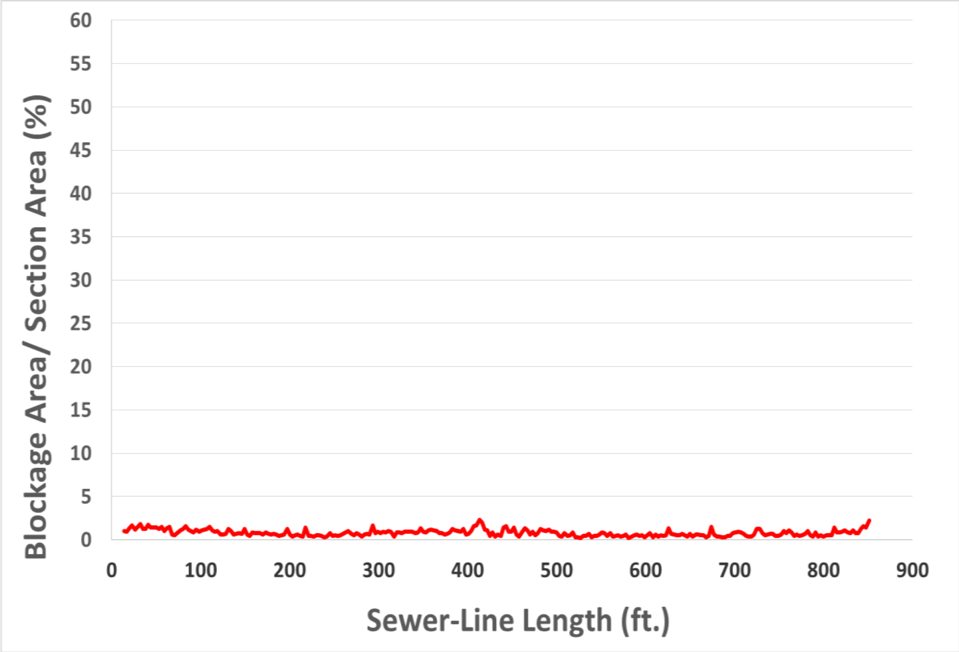


Figure A3-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A3-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				15%					
5	460		MSA									

Line 4 Summary

Table A4-1 Results Summary of Sewer Line 4

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	174.1
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	0
Total Debris Volume (ft3)	19.16
Total Deposits Volume (in3)	9311.60
Maximum Blockage (%)	10.77
Maximum Deposit Height (in)	1.03

Deposit Data

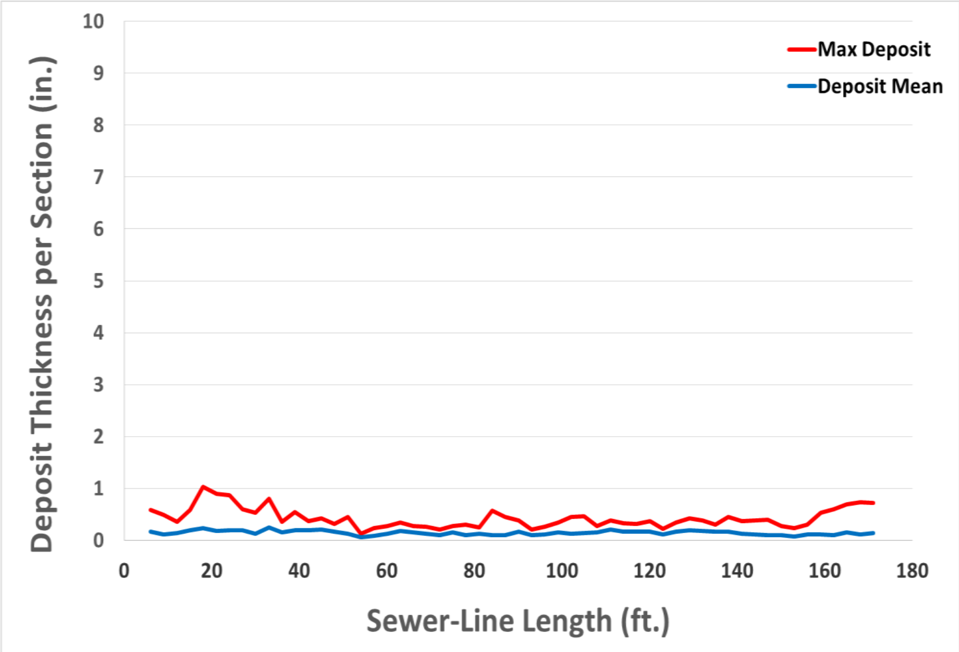


Figure A4-1 Deposit thickness per cross-section

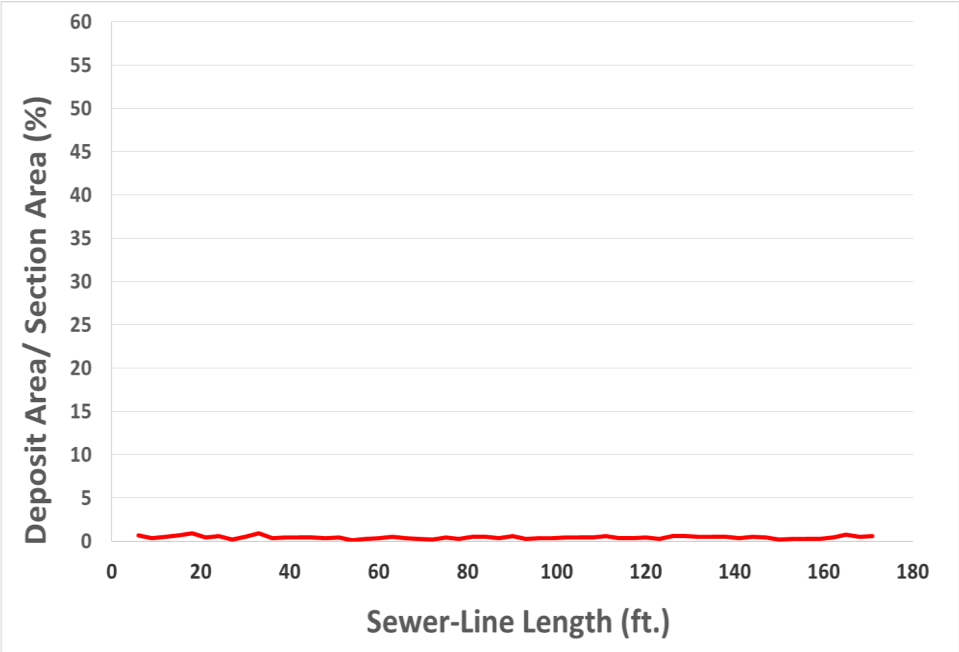


Figure A4-2 Deposit area percentage of the pipe cross section area

Debris Data

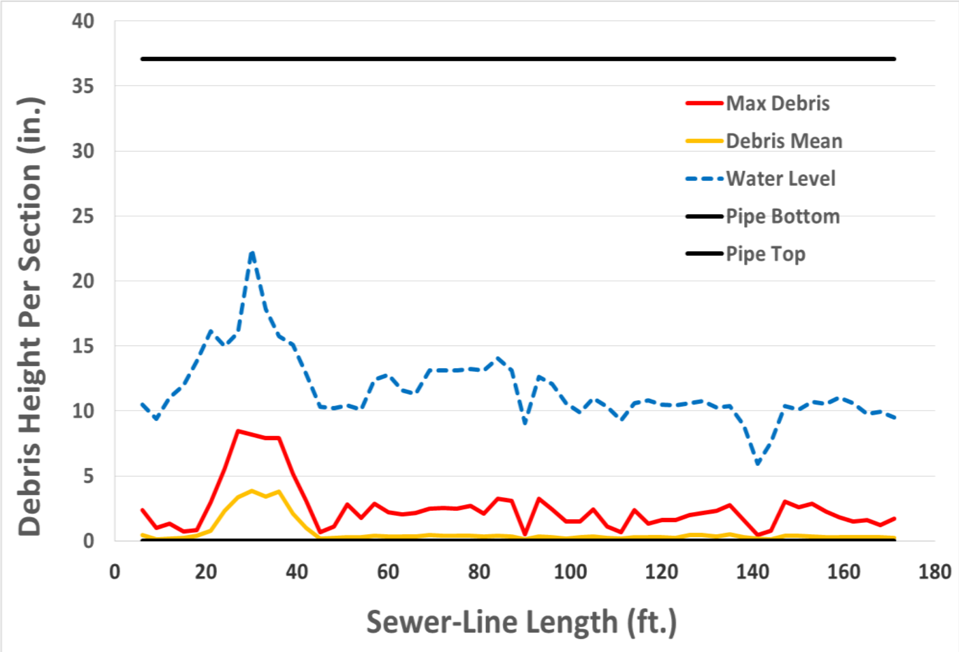


Figure A4-3 Debris height per cross-section

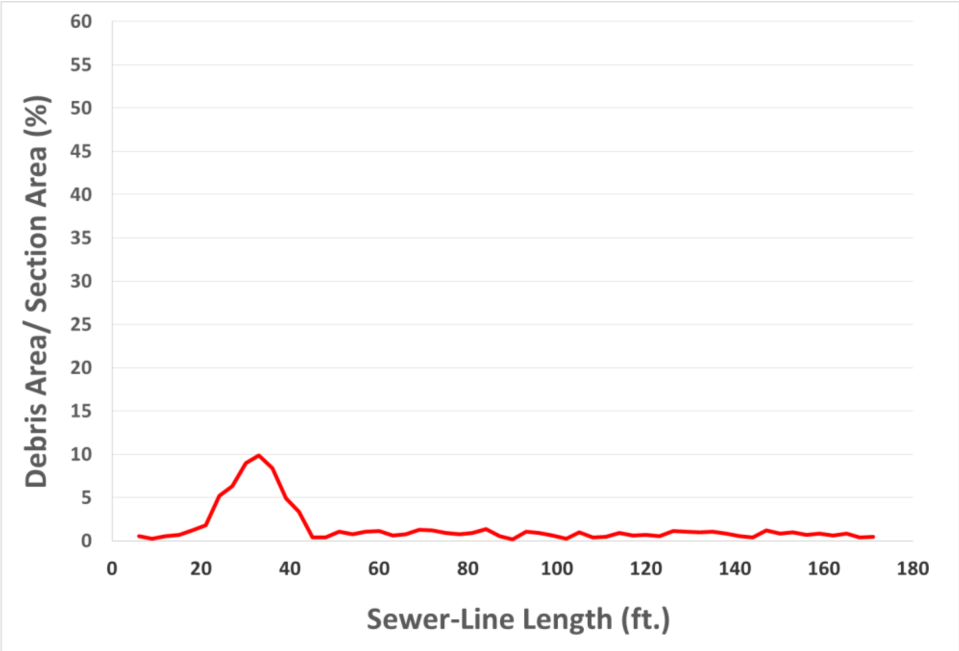


Figure A4-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

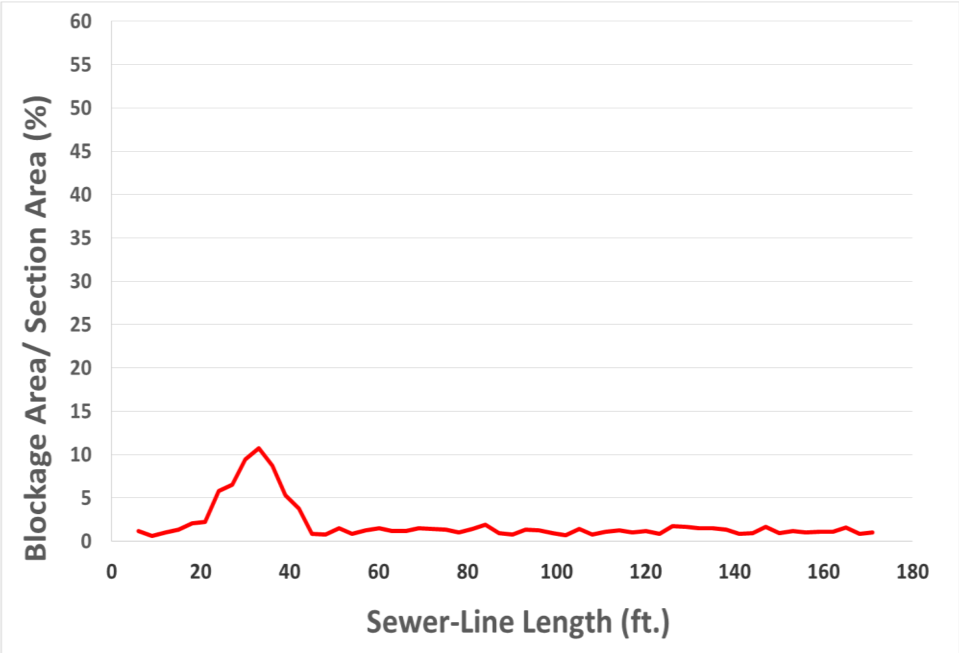


Figure A4-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A4-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	6		MWL				15%					
3	7.05			S01							1 TO 3	CORROSION
4	182.55			F01								CORROSION
5	182.55		MSA									

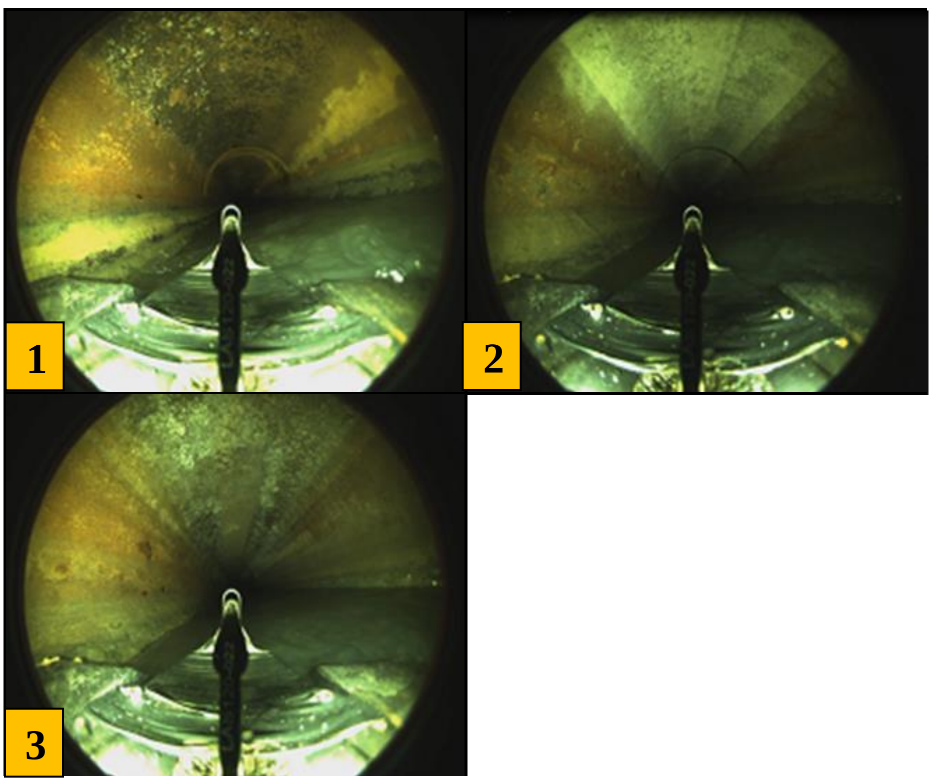


Figure A4-6 images from 1 through 3

Line 5 Summary

Table A5-1 Results Summary of Sewer Line 5

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	350.3
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	1
Total Debris Volume (ft3)	12.60
Total Deposits Volume (in3)	33521.68
Maximum Blockage (%)	2.29
Maximum Deposit Height (in)	2.26

Deposit Data

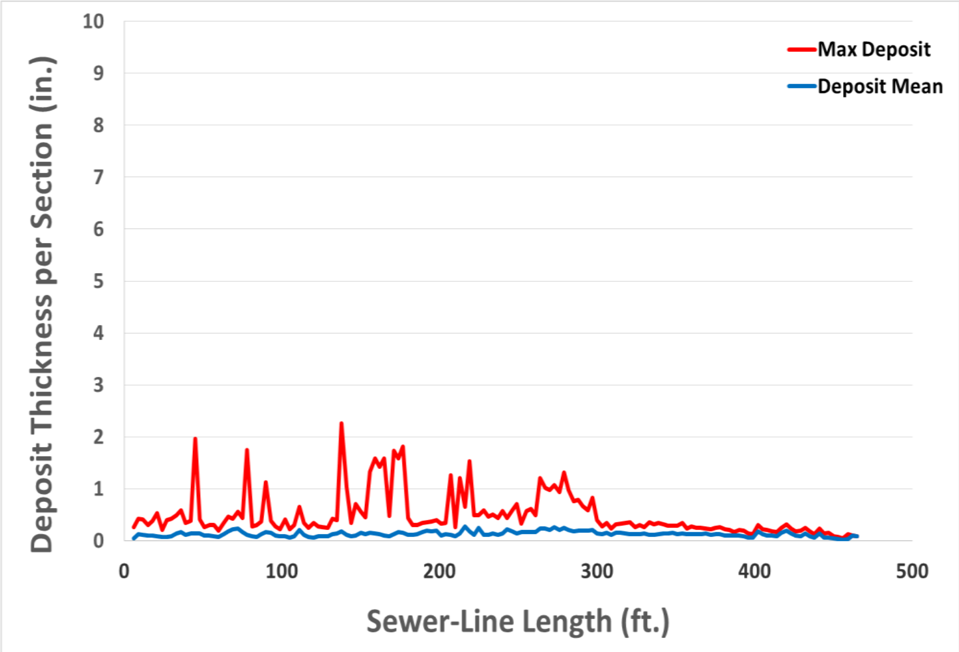


Figure A5-1 Deposit thickness per cross-section

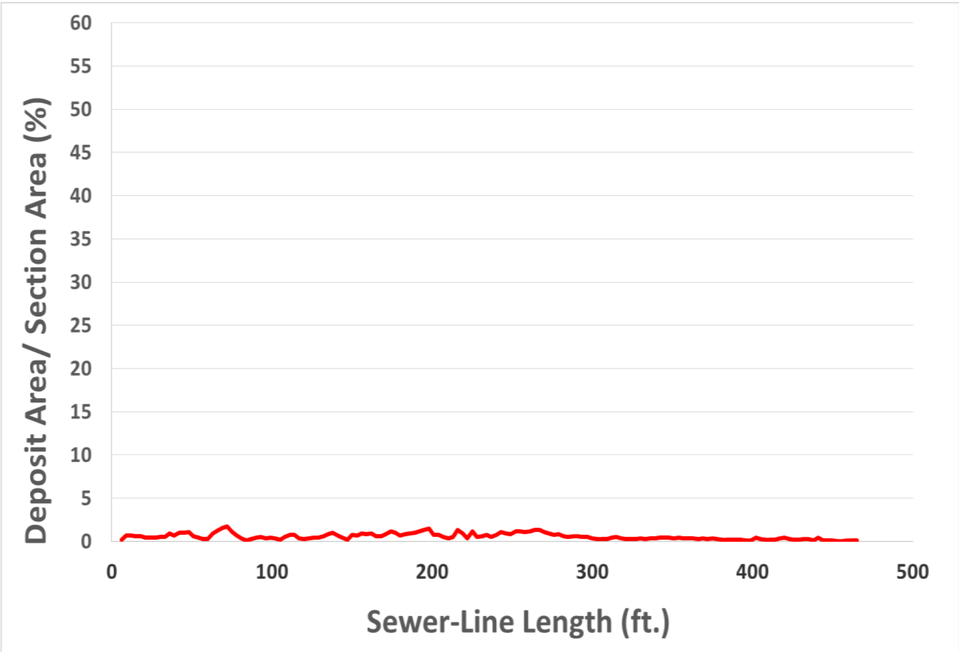


Figure A5-2 Deposit area percentage of the pipe cross section area

Debris Data

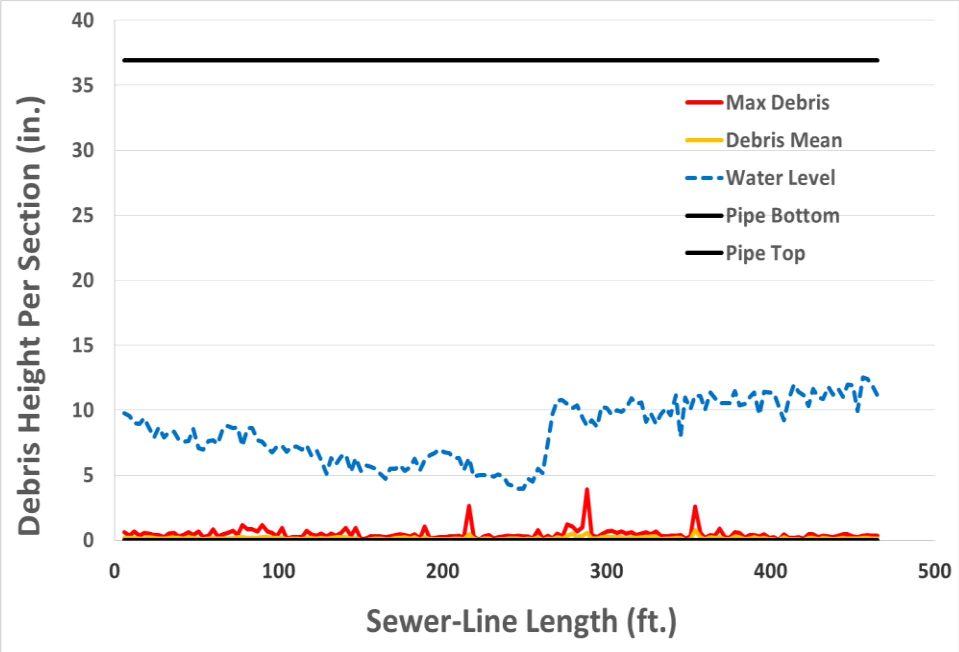


Figure A5-3 Debris height per cross-section

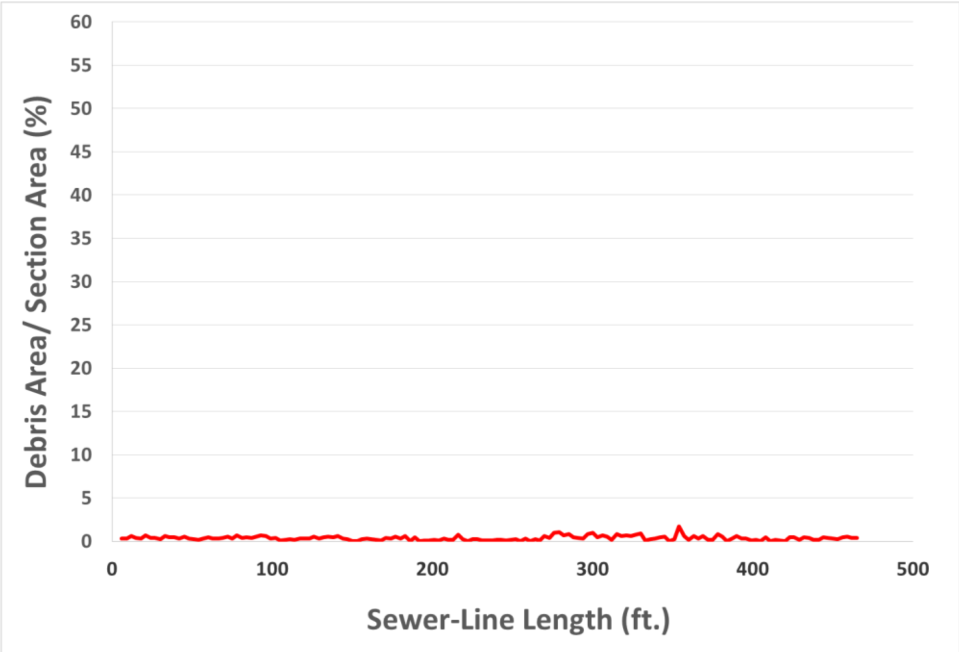


Figure A5-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

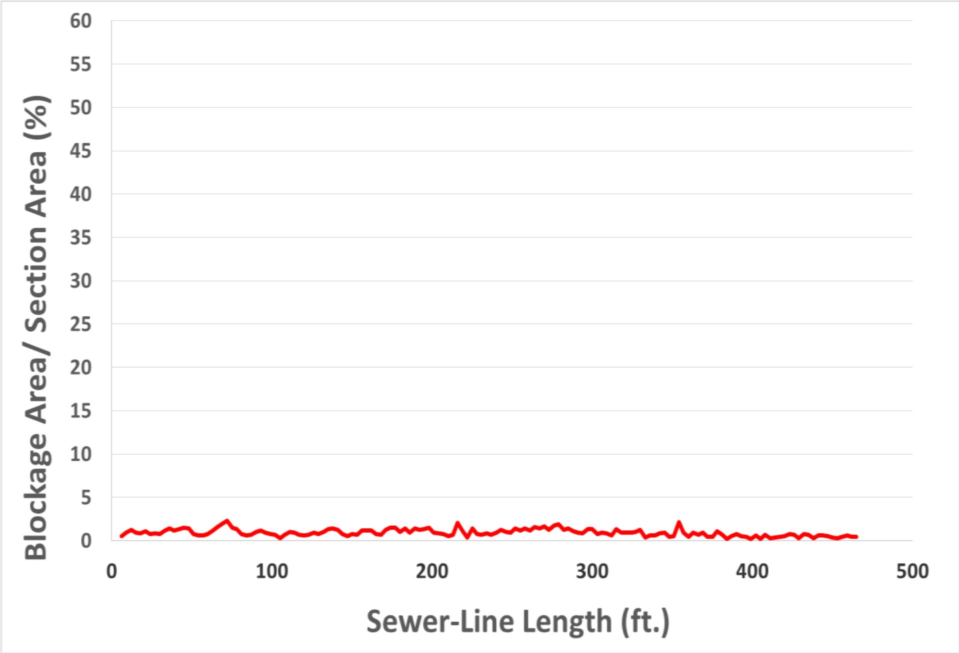


Figure A5-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A5-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code: Group/ Descriptor/ Modifier	Continuous Defect	Value: Dimension 1st	Value: Dimension 2nd	Value: %	Joint	Circumferential Location: At/From	Circumferential Location: To	Img Reference	Remarks
1	0		AMH									
2	6.1		MWL				5%					
3	32.5			S01							1	CORROSION
4	42.5			F01								CORROSION
5	51.25			S02							2	CORROSION
6	60.1			F02								CORROSION
7	66.5							J			3	CORROSION
8	86.6							J			4	CORROSION
9	279.5		DAE	S03			5%				5	
10	313.45			F03								
11	373.8							J			6	CORROSION
12	375.6			S04							7	CORROSION
13	470.3			F04								CORROSION
14	470.3		MSA									

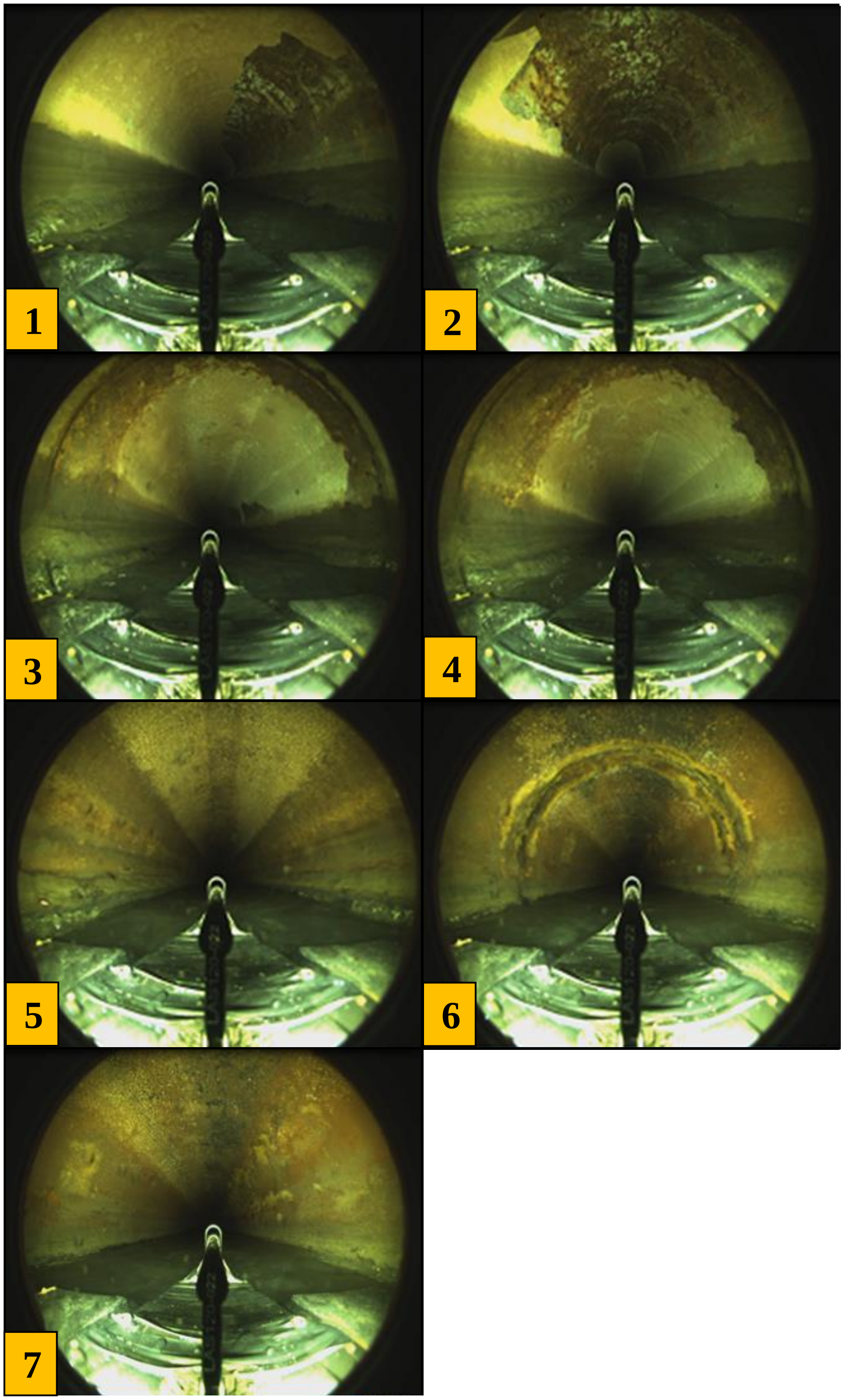


Figure A5-6 images from 1 through 7

Line 6 Summary

Table A6-1 Results Summary of Sewer Line 6

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	173.4
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	2
Total Debris Volume (ft3)	10.76
Total Deposits Volume (in3)	7703.60
Maximum Blockage (%)	5.14
Maximum Deposit Height (in)	0.49

Deposit Data

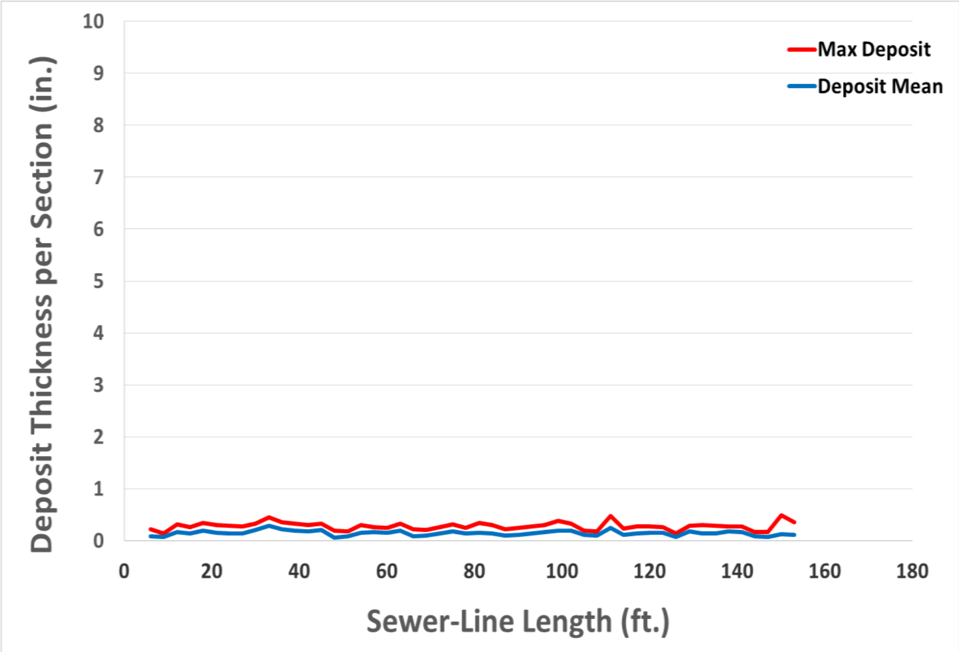


Figure A6-1 Deposit thickness per cross-section

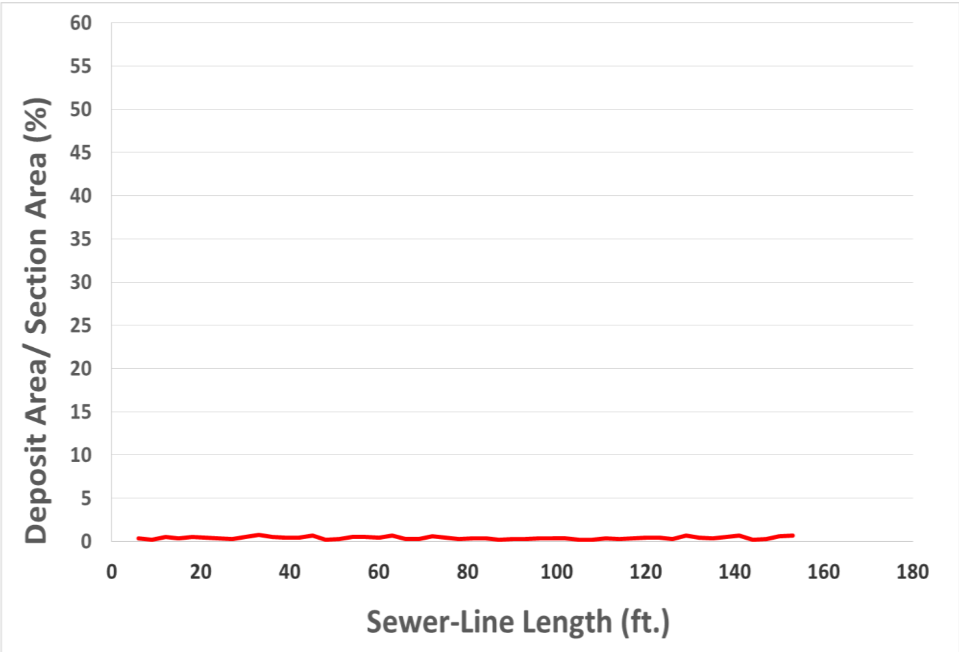


Figure A6-2 Deposit area percentage of the pipe cross section area

Debris Data

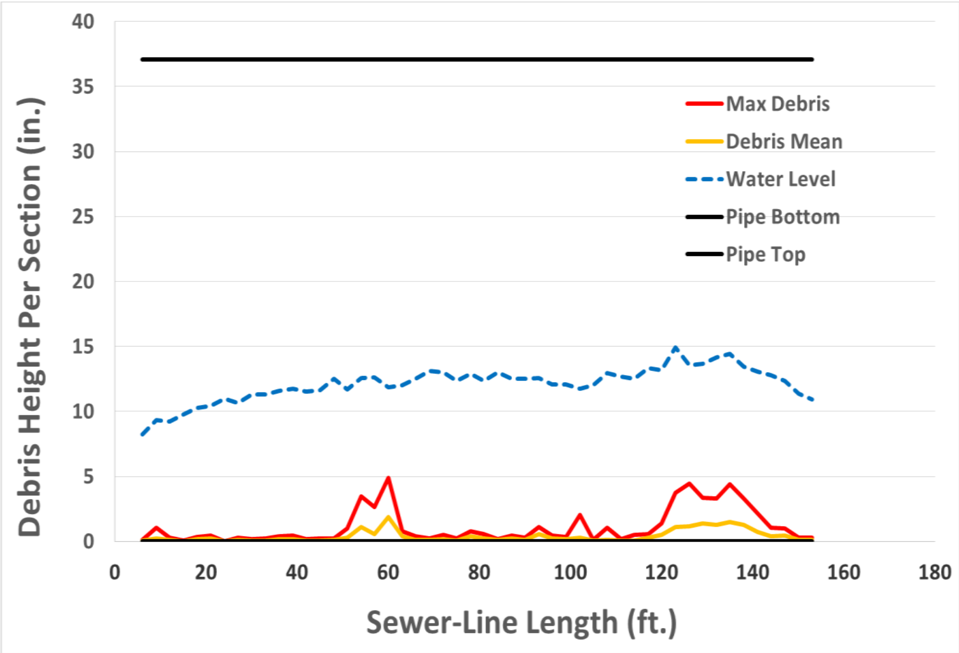


Figure A6-3 Debris height per cross-section

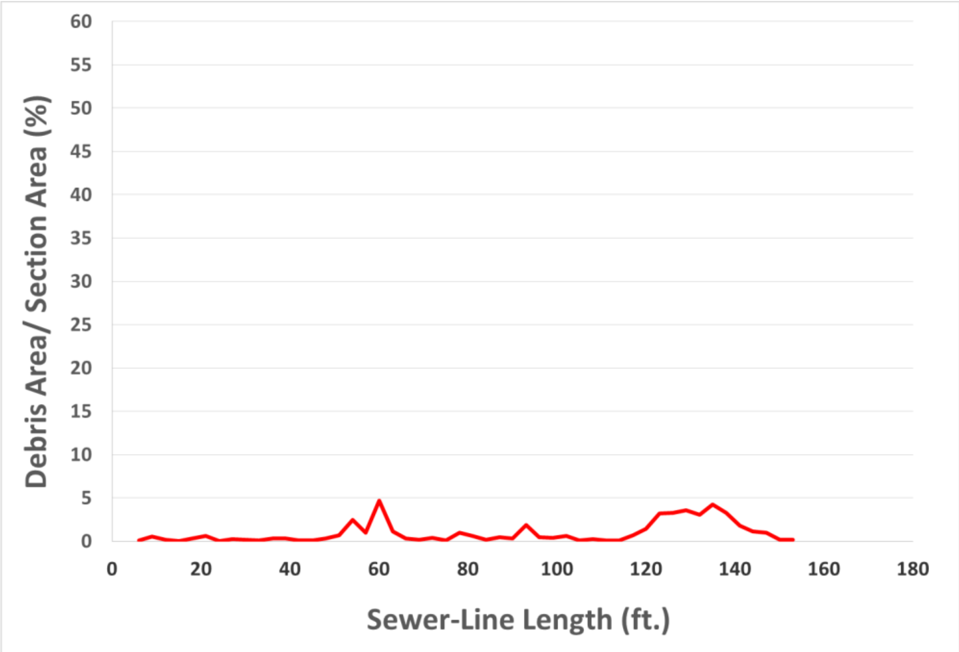


Figure A6-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

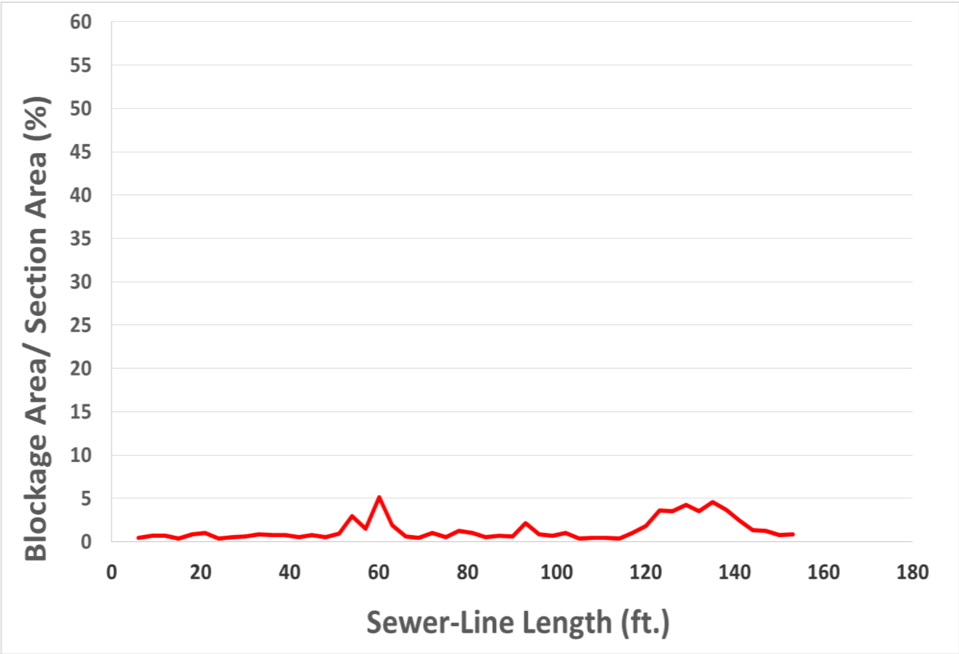


Figure A6-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A6-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code Group/ Descriptor/ Modifier	Continuous Defect	Value Dimension 1st	Value Dimension 2nd	Value %	Joint	Circumferential Location At/From	Circumferential Location To	Img Reference	Remarks
1	0		AMH									
2	4.45		MWL				5%					
3	104.45							J			1	CORROSION
4	146.5		MGO								2	THE PIPE DIRECTION HAS CHANGED
5	146.5		ISGT				5%	J			2	
6	147.3			S01							3	CORROSION
7	155.3			F01								CORROSION
8	155.3		MSA									

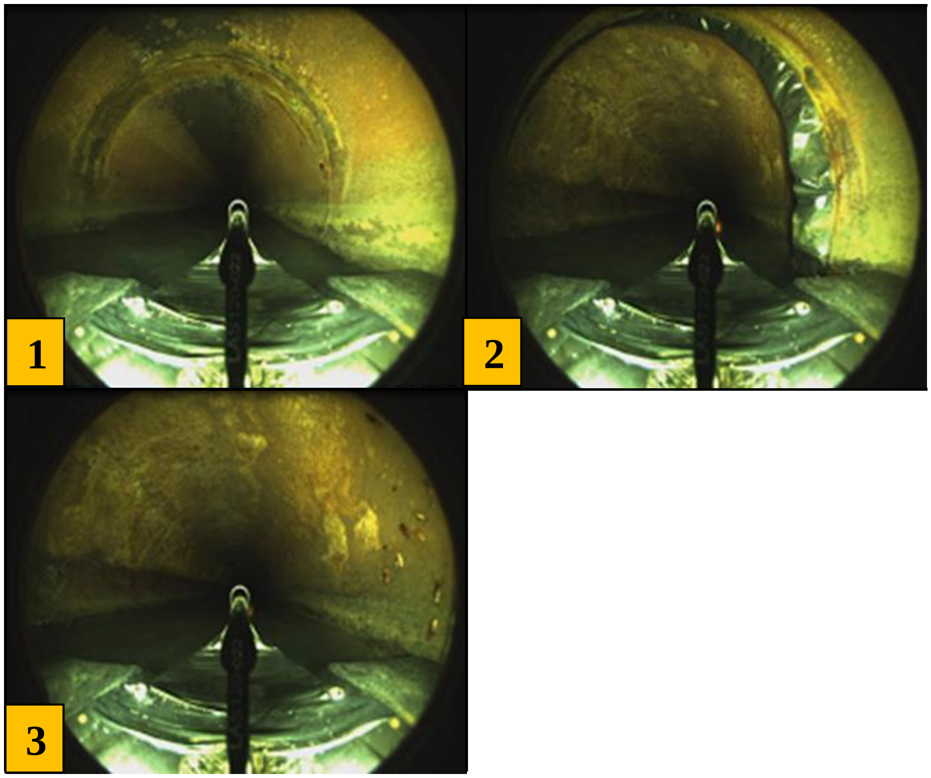


Figure A6-6 images from 1 through 3

Line 7 Summary

Table A7-1 Results Summary of Sewer Line 7

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	577.7
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	0
Total Debris Volume (ft3)	0
Total Deposits Volume (in3)	32897.02
Maximum Blockage (%)	1.96
Maximum Deposit Height (in)	0.87

Deposit Data

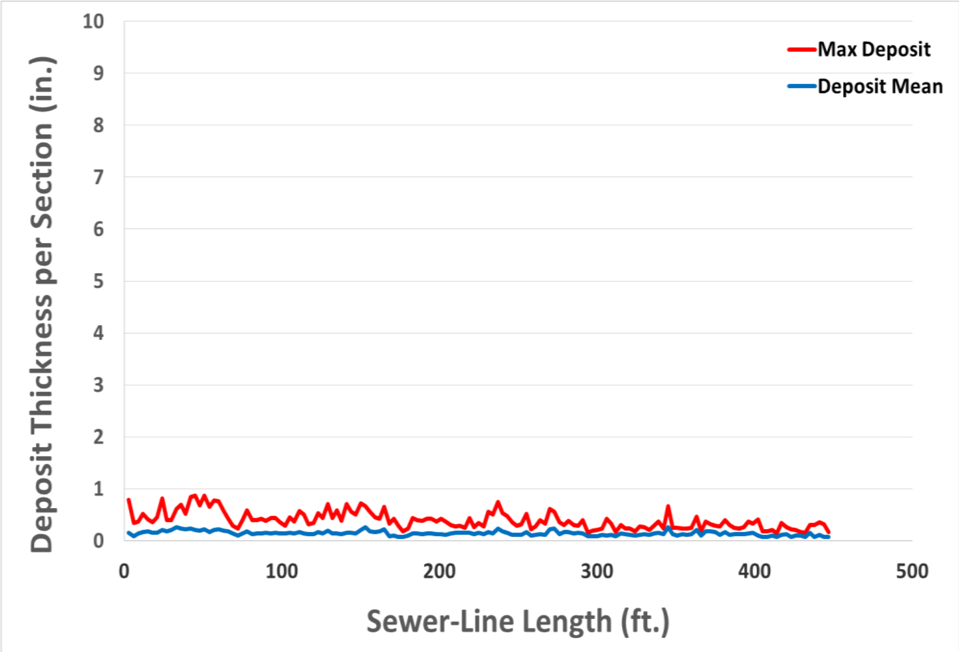


Figure A7-1 Deposit thickness per cross-section

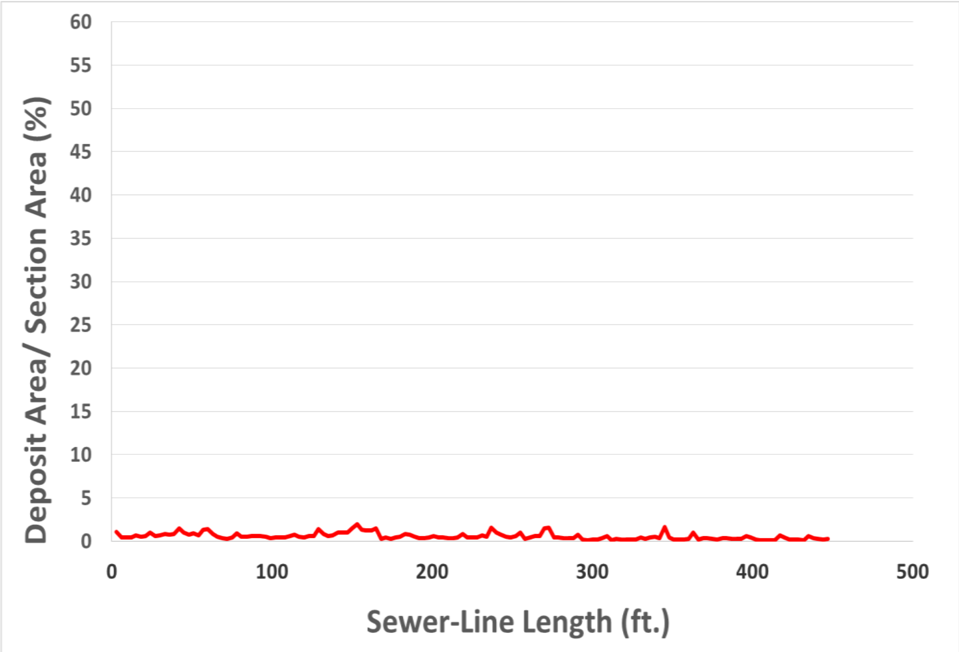


Figure A7-2 Deposit area percentage of the pipe cross section area

Blockage Data

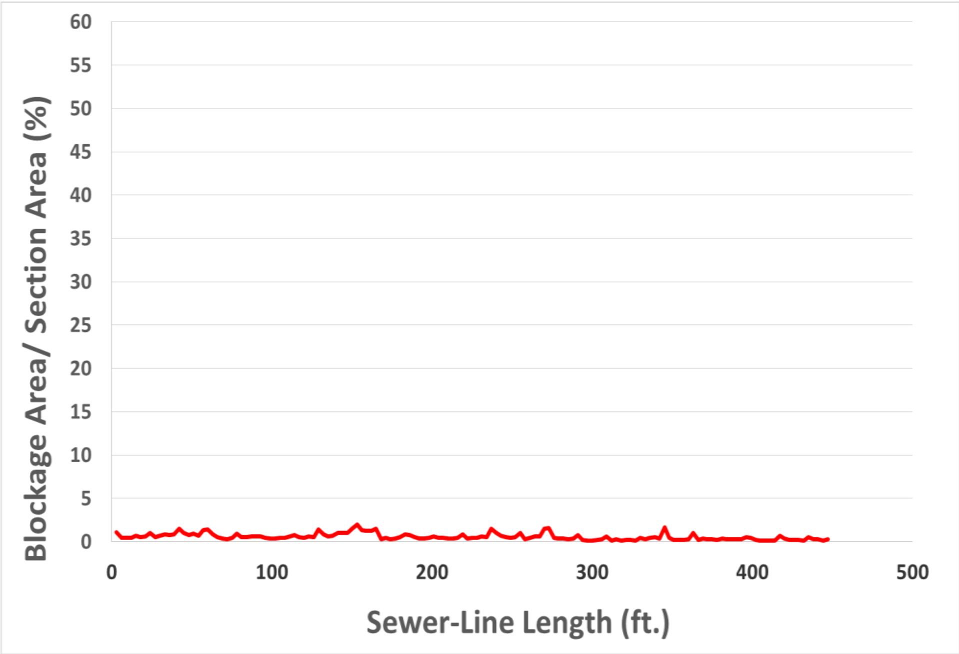


Figure A7-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A7-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0.4		MWL				10%					
5	97.35			S01							1	CORROSION
6	105.7			F01								CORROSION
7	220.85							J			2	CORROSION
8	310.6			S02							3	CORROSION
9	320.2			F03								CORROSION
10	320.2		MSA									

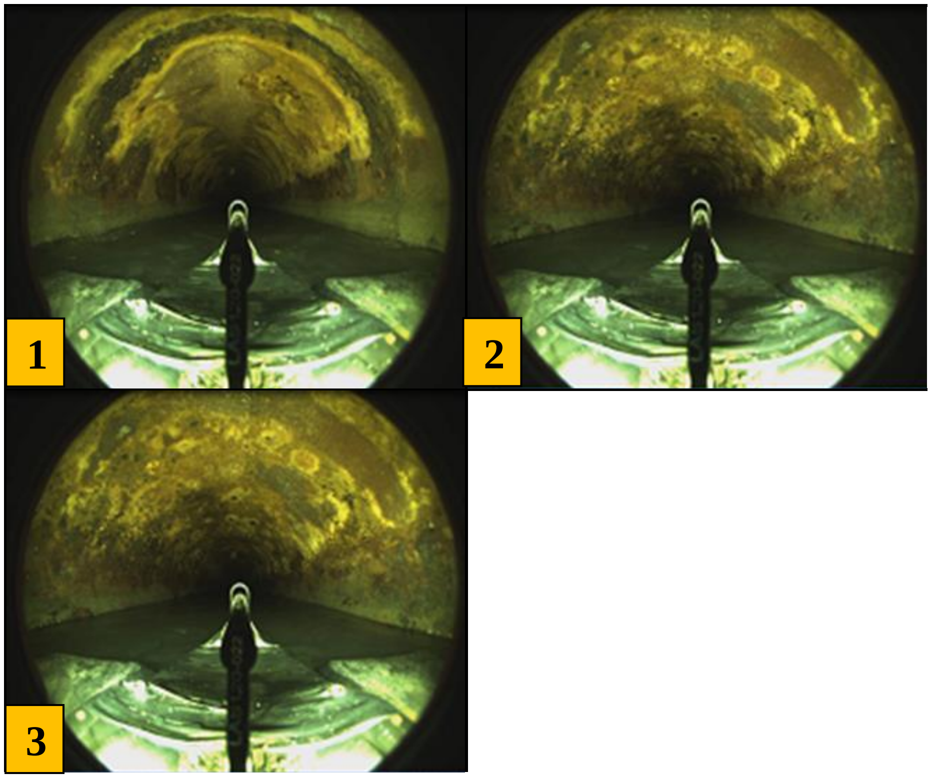


Figure A7-4 images from 1 through 3

Line 8 Summary

Table A8-1 Results Summary of Sewer Line 8

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	58.1
Percentage of The Line Not Inspected	21.77%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	1
Total Debris Volume (ft3)	3.53
Total Deposits Volume (in3)	5809.96
Maximum Blockage (%)	6.73
Maximum Deposit Height (in)	0.93

Deposit Data

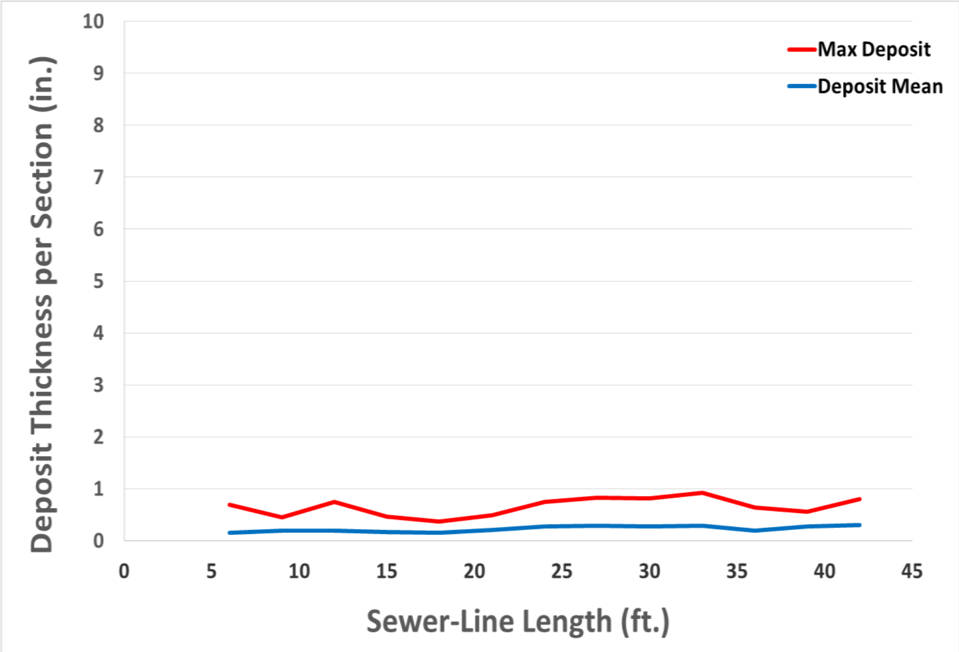


Figure A8-1 Deposit thickness per cross-section

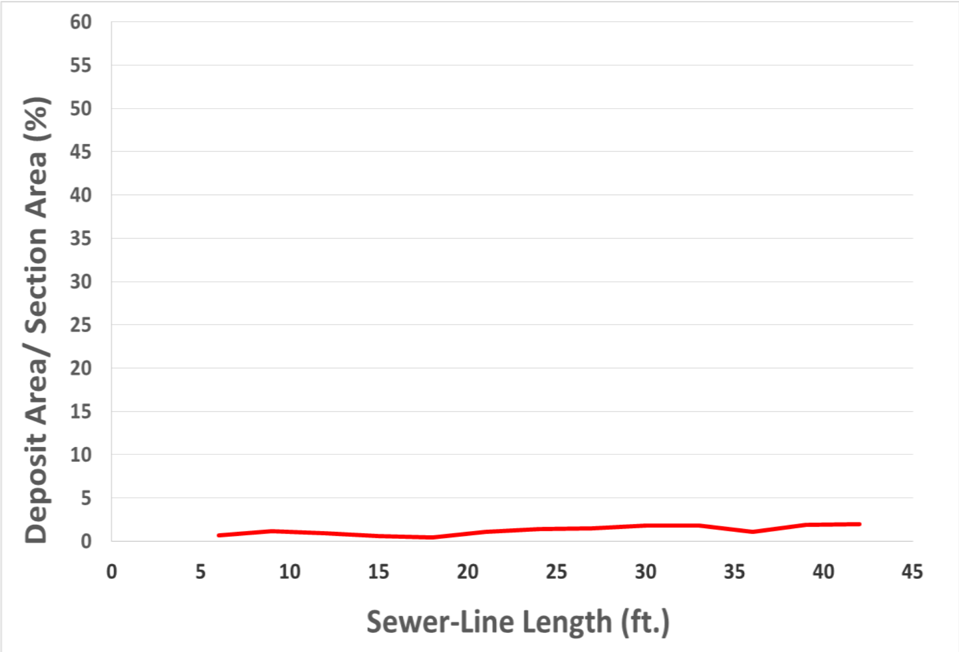


Figure A8-2 Deposit area percentage of the pipe cross section area

Debris Data

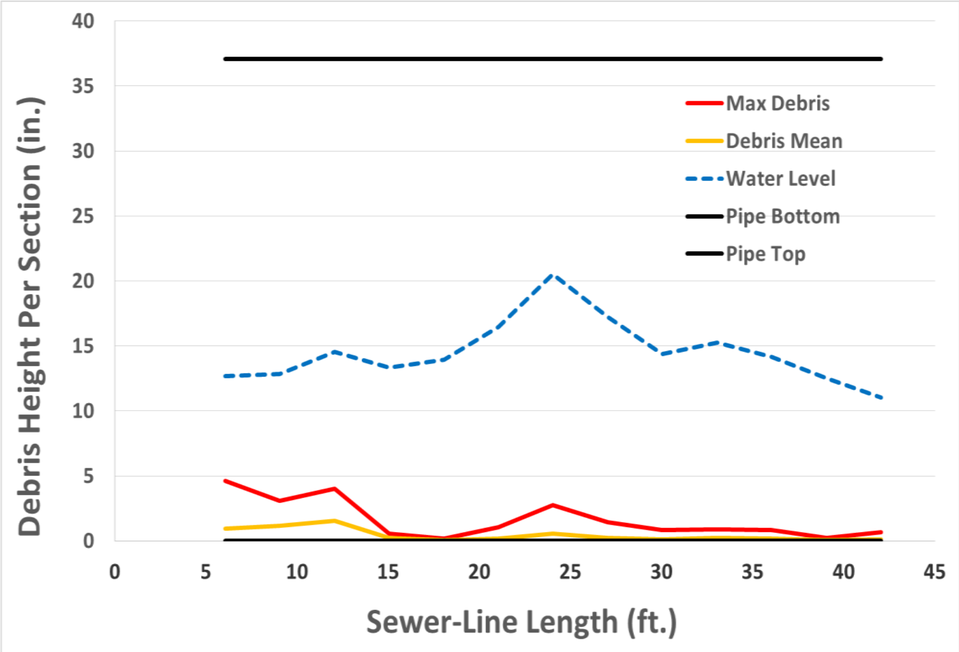


Figure A8-3 Debris height per cross-section

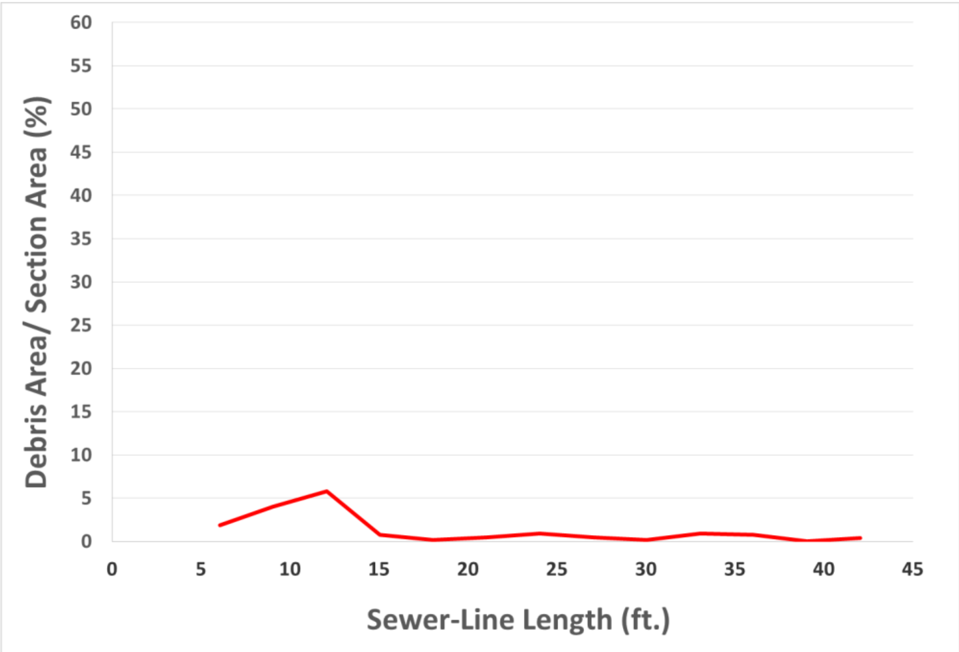


Figure A8-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

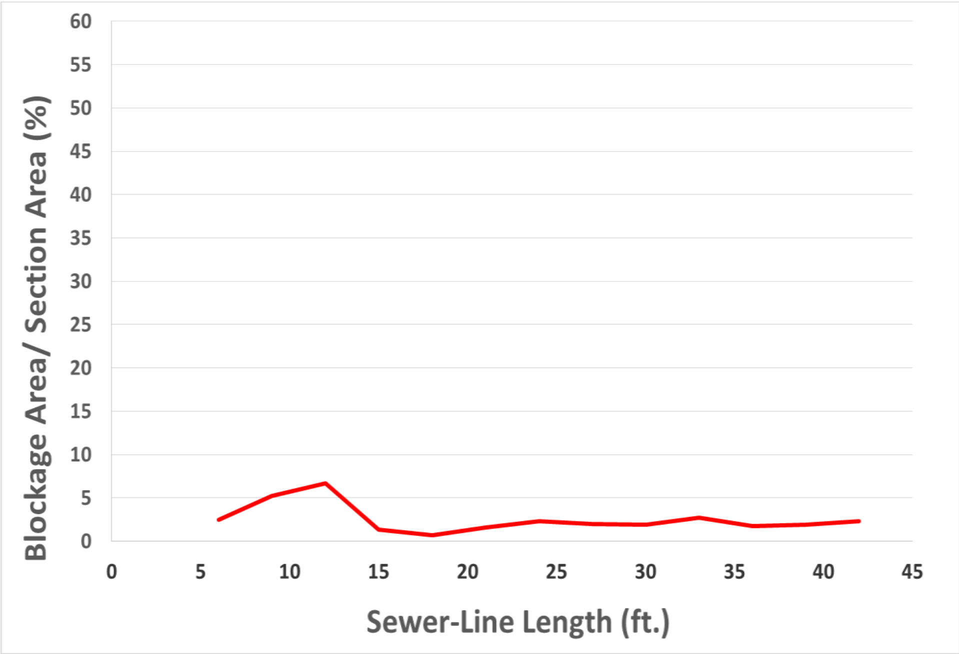


Figure A8-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A8-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				20%					
3	5.1			S01							1 TO 3	CORROSION
4	44.4			F01								CORROSION
5	45		MMC								4	MATERIAL HAS CHANGED TILL THE END
6	56.25		MSA									

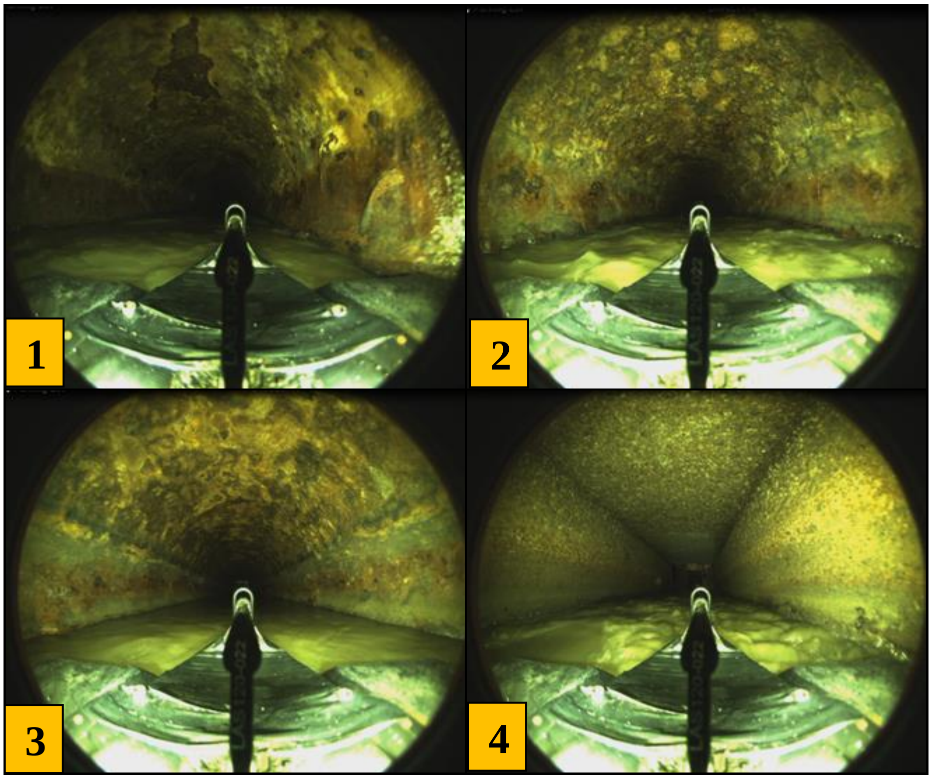


Figure A8-6 images from 1 through 4

Line 9 Summary

Table A9-1 Results Summary of Sewer Line 9

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	12.7
Percentage of The Line Not Inspected	100%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	0
Total Debris Volume (ft3)	N/A
Total Deposits Volume (in3)	N/A
Maximum Blockage (%)	N/A
Maximum Deposit Height (in)	N/A

Visual Observations

Table A9-1 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code Group/ Descriptor/ Modifier	Continuous Defect	Value Dimension 1st	Value Dimension 2nd	Value %	Joint	Circumferential Location At/From	Circumferential Location To	Img Reference	Remarks
1	0		AMH									
2	0.6		MWL				10%					
3	14.4										1	CORROSION
4	18.6										2	CORROSION
5	19.35		MSA									

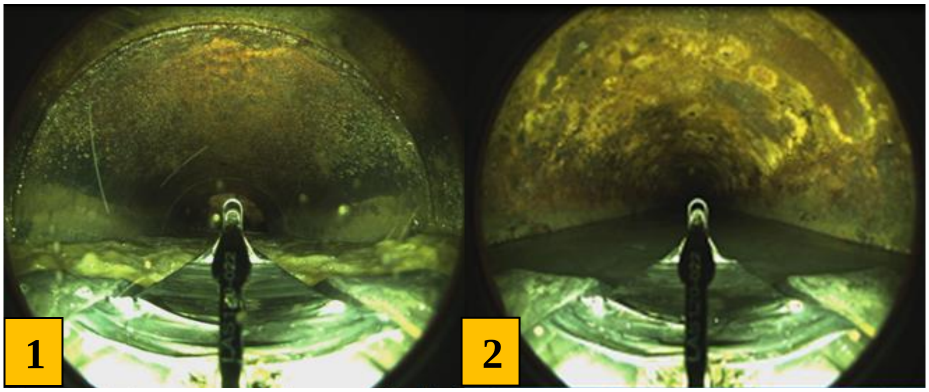


Figure A9-1 images from 1 through 2

Line 10 Summary

Table A10-1 Results Summary of Sewer Line 10

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	722.4
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	0
Total Debris Volume (ft3)	0
Total Deposits Volume (in3)	16372.48
Maximum Blockage (%)	1.06
Maximum Deposit Height (in)	1.36

Deposit Data

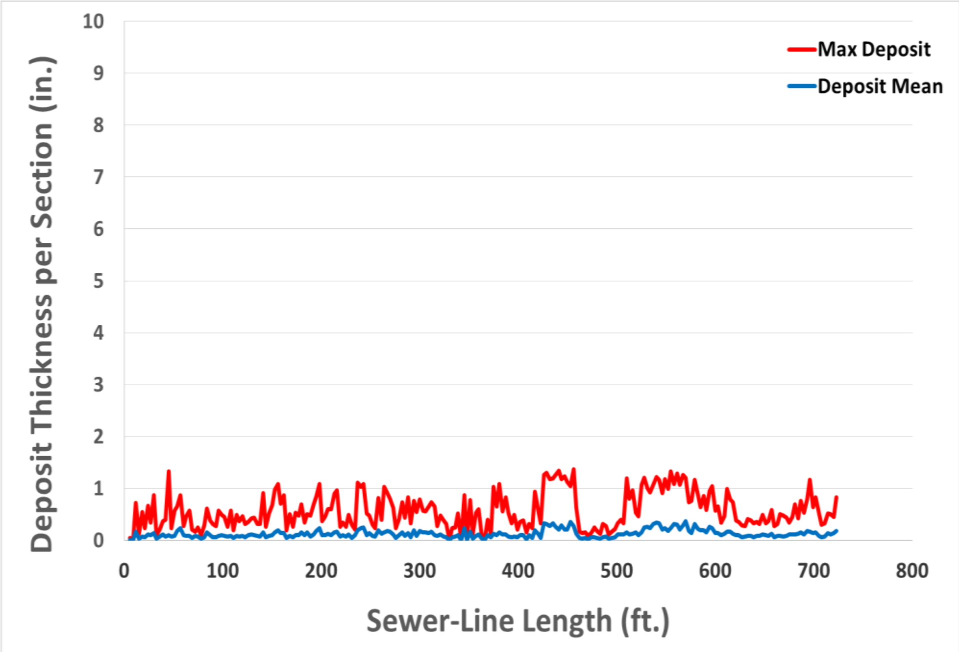


Figure A10-1 Deposit thickness per cross-section

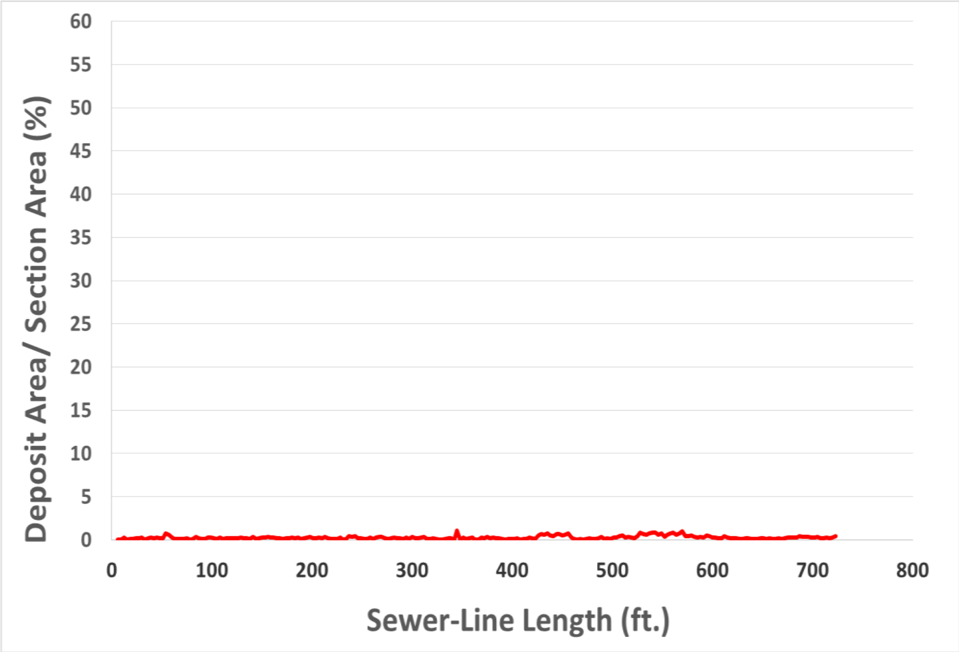


Figure A10-2 Deposit area percentage of the pipe cross section area

Blockage Data

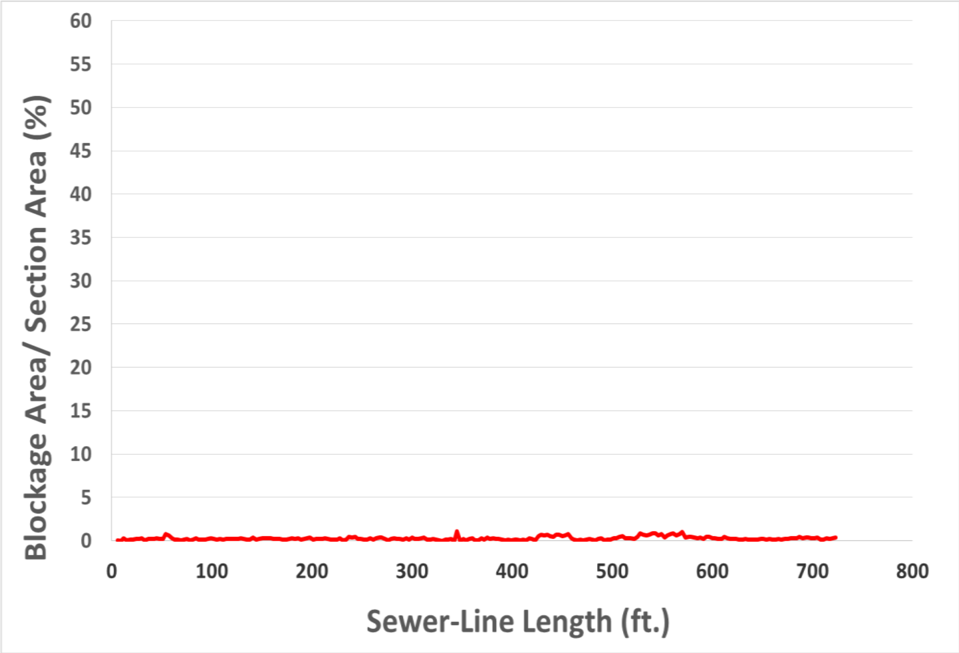


Figure A10-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A10-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	6.3		MWL				10%					
3	6.6			S01							1 TO 5	CORROSION
4	729.75			F01								CORROSION
5	729.75		MSA									

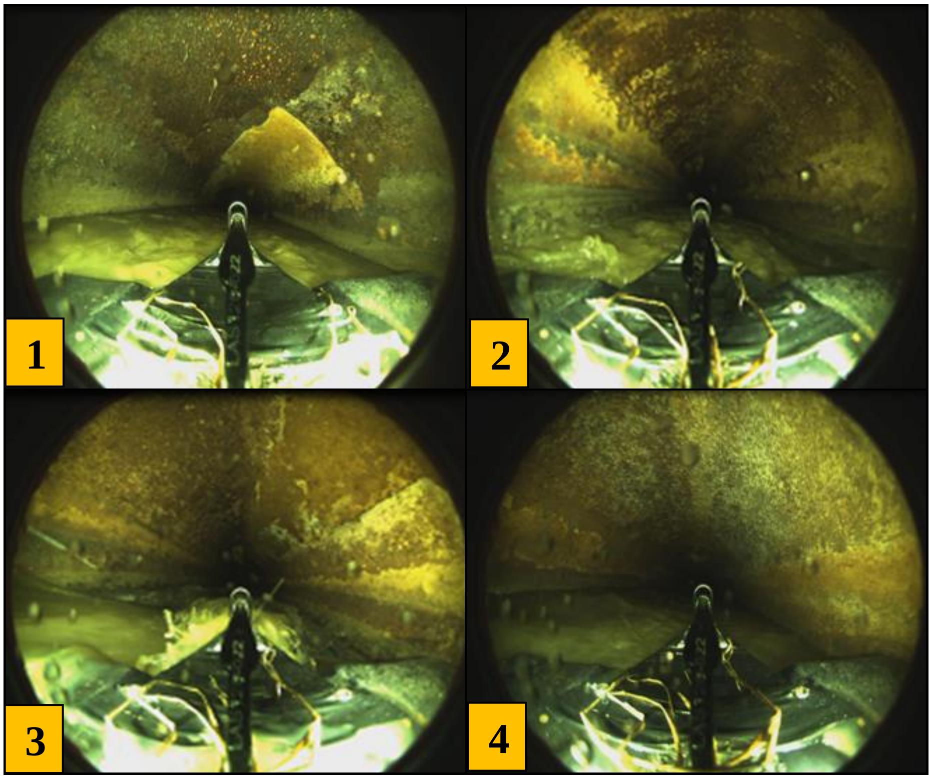


Figure A10-4 images from 1 through 4

Line 11 Summary

Table A11-1 Results Summary of Sewer Line 11

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	1151.3
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	0
Total Debris Volume (ft3)	0
Total Deposits Volume (in3)	50746.92
Maximum Blockage (%)	1.72
Maximum Deposit Height (in)	1.79

Deposit Data

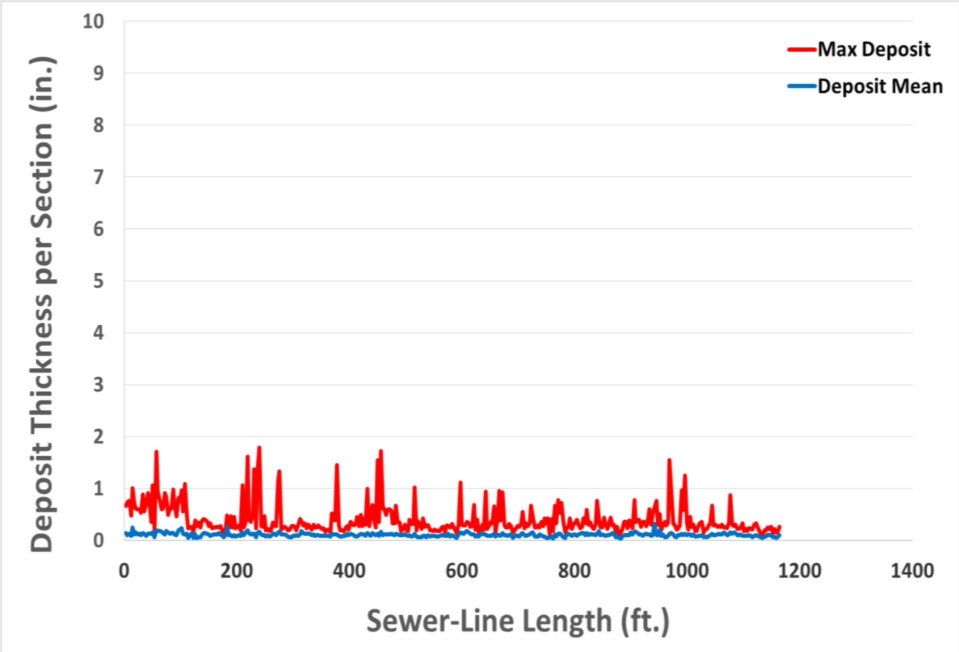


Figure A11-1 Deposit thickness per cross-section

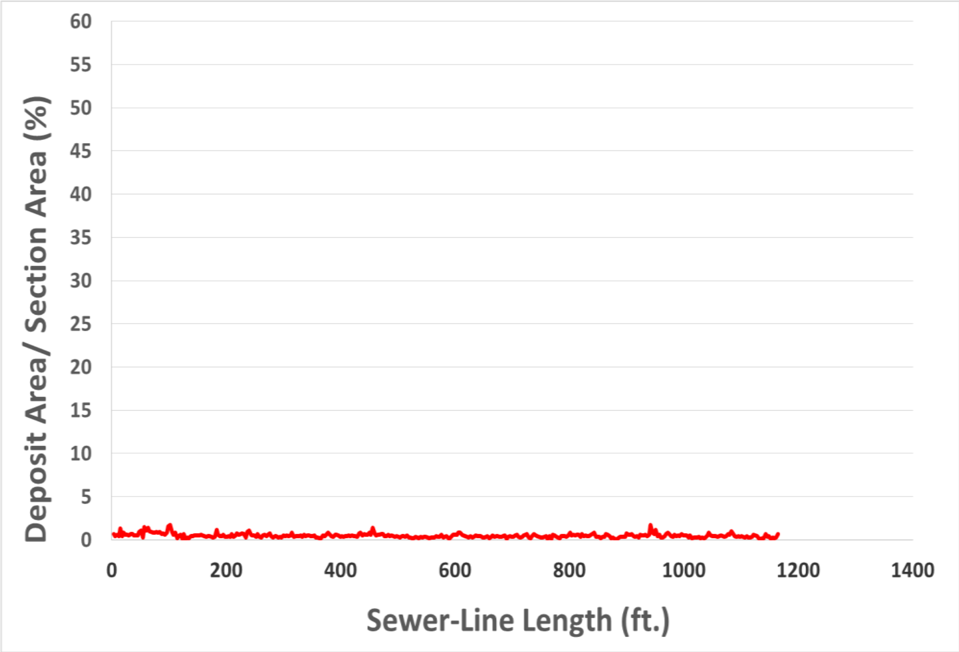


Figure A11-2 Deposit area percentage of the pipe cross section area

Blockage Data

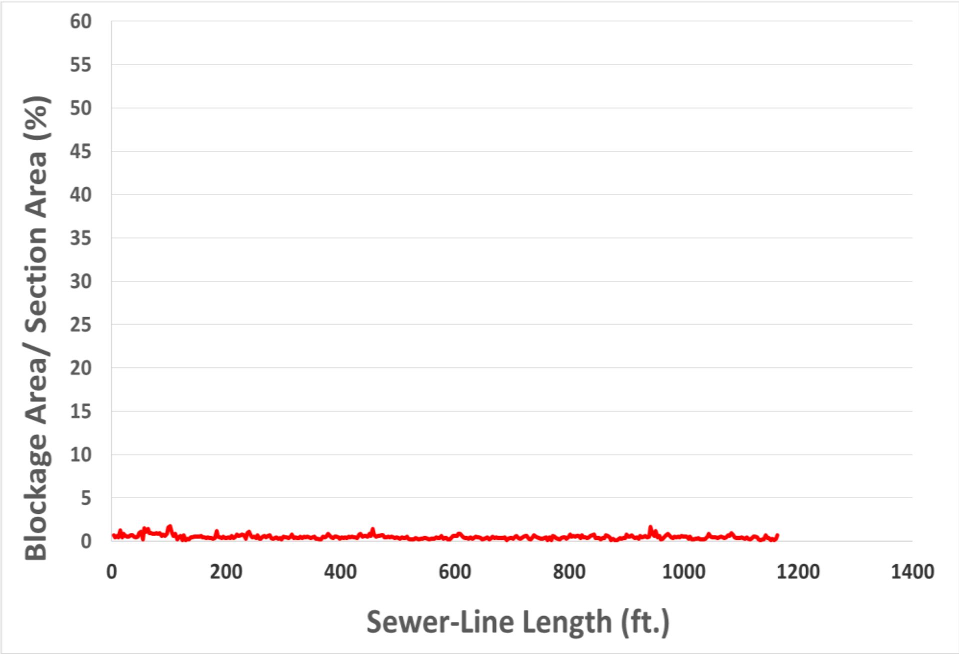


Figure A11-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A11-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	2.65		MWL				10%					
3	52.5			S01							1	CORROSION
4	60.25			F01								CORROSION
5	85.05			S02							2	CORROSION
6	96.1			F02								CORROSION
9	1167.55		MSA									

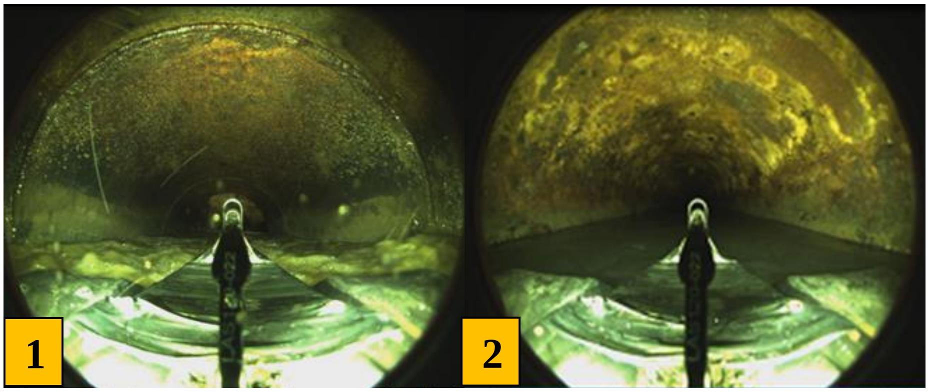


Figure A11-1 images from 1 through 2

Line 12 Summary

Table A12-1 Results Summary of Sewer Line 12

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	1019.1
Percentage of The Line Not Inspected	100%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	1
Total Debris Volume (ft3)	N/A
Total Deposits Volume (in3)	N/A
Maximum Blockage (%)	N/A
Maximum Deposit Height (in)	N/A

Visual Observations

Table A12-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0.9		MWL				10%					
3	733.8			S01							1	CORROSION
4	746.6			F01								CORROSION
5	796.95										2	CORROSION
6	983.7		TBA						9	12	3	
7	993.6		MSA									

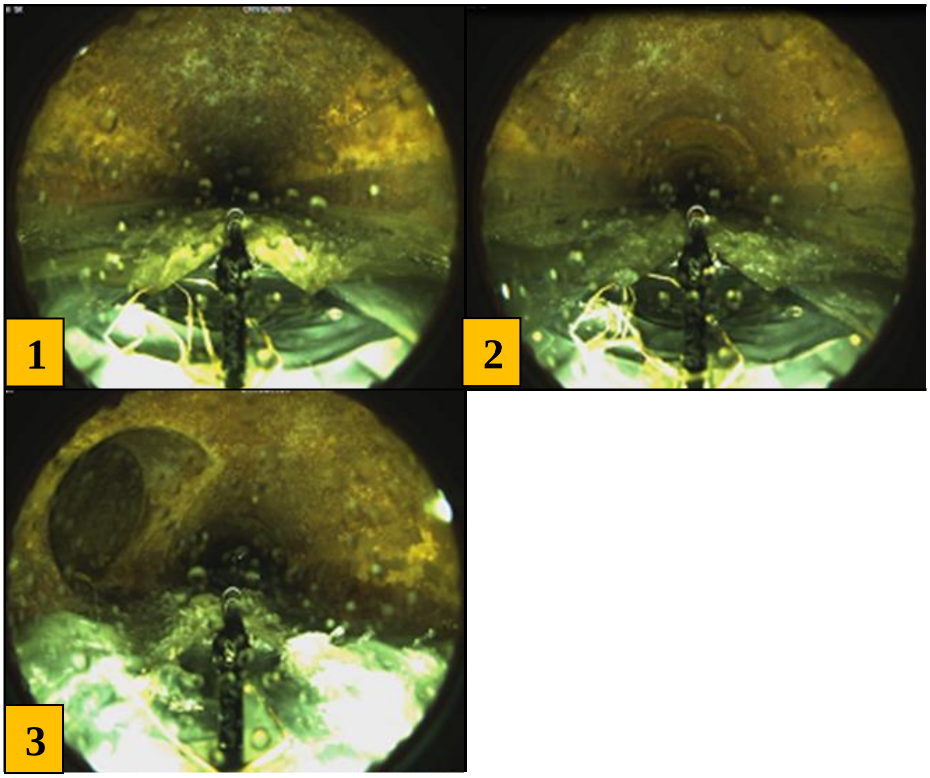


Figure A12-1 images from 1 through 3

Line 13 Summary

Table A13-1 Results Summary of Sewer Line 13

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	202
Percentage of The Line Not Inspected	6.18%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	3
Level 4 Structural Defects	0
Total Defects	4
Total Debris Volume (ft3)	19.88
Total Deposits Volume (in3)	2183.89
Maximum Blockage (%)	2.58
Maximum Deposit Height (in)	0.48

Deposit Data

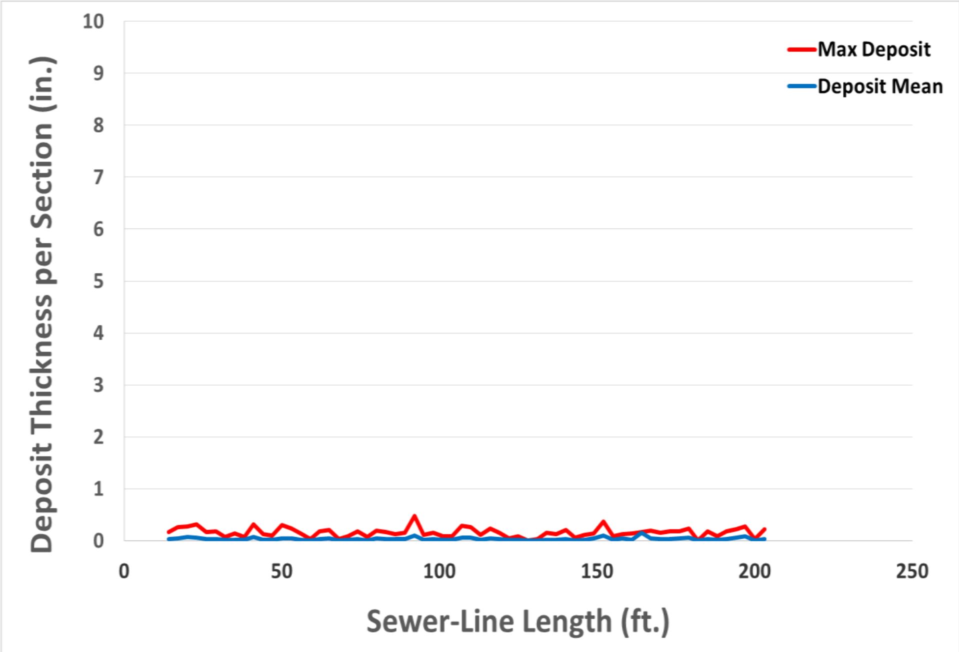


Figure A13-1 Deposit thickness per cross-section

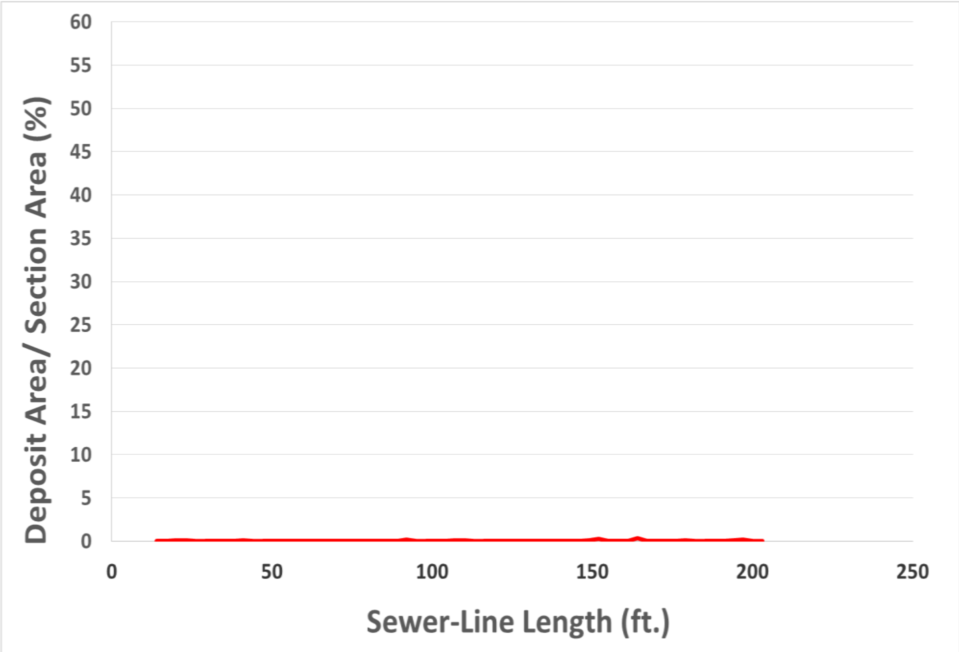


Figure A13-2 Deposit area percentage of the pipe cross section area

Debris Data

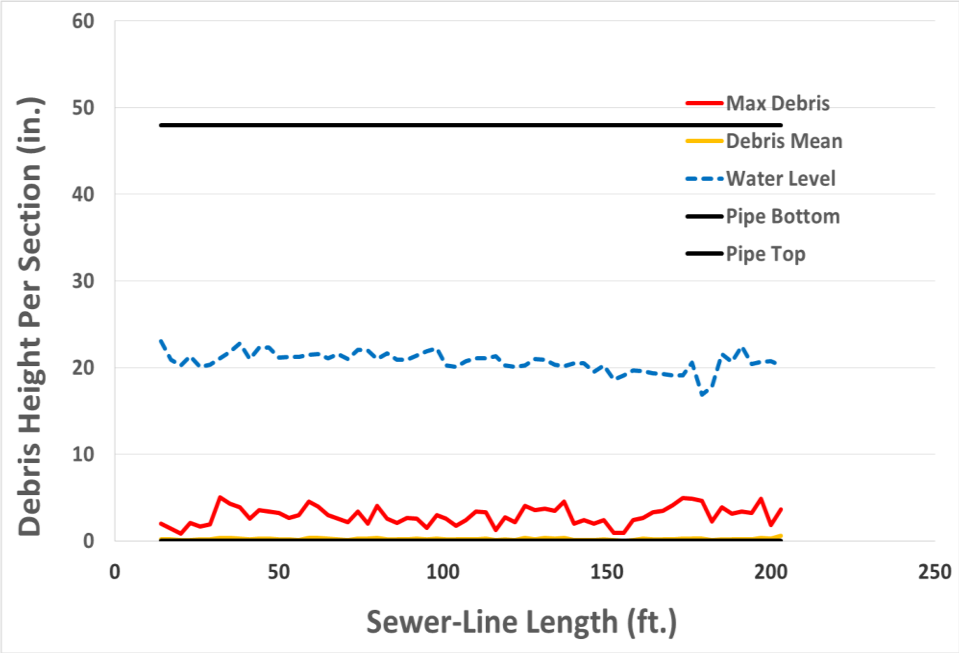


Figure A13-3 Debris height per cross-section

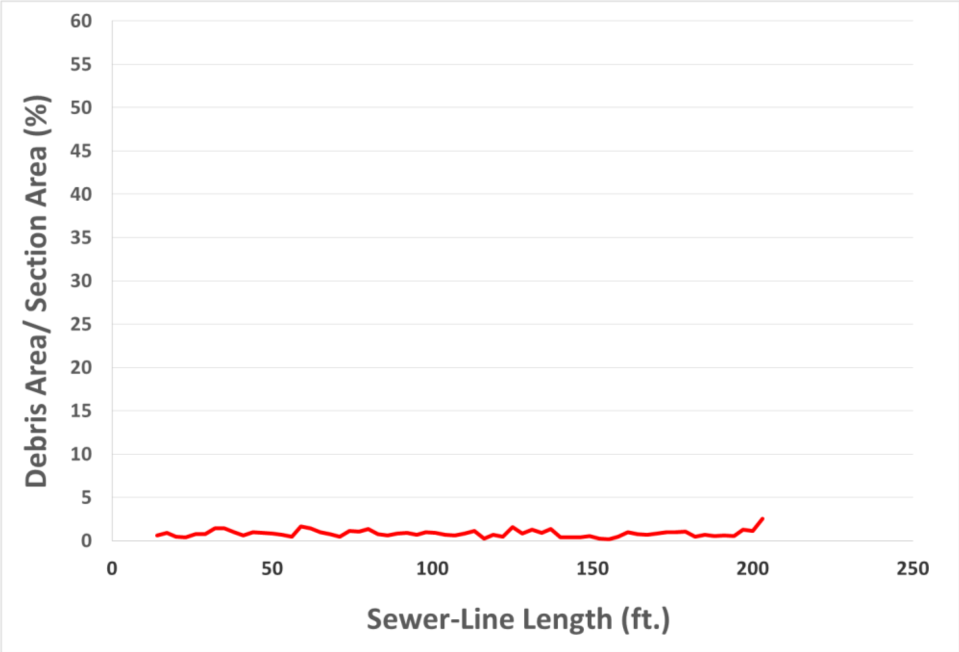


Figure A13-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

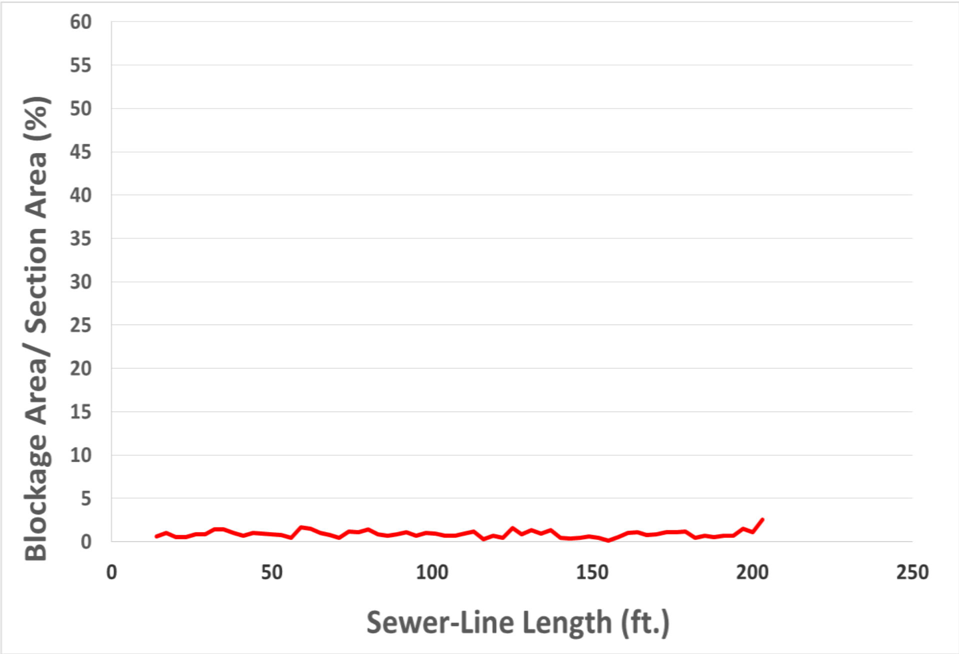


Figure A13-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion Data

Table A13-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	D09SL0032-33-3	RCP	48	48	1.07	0.3

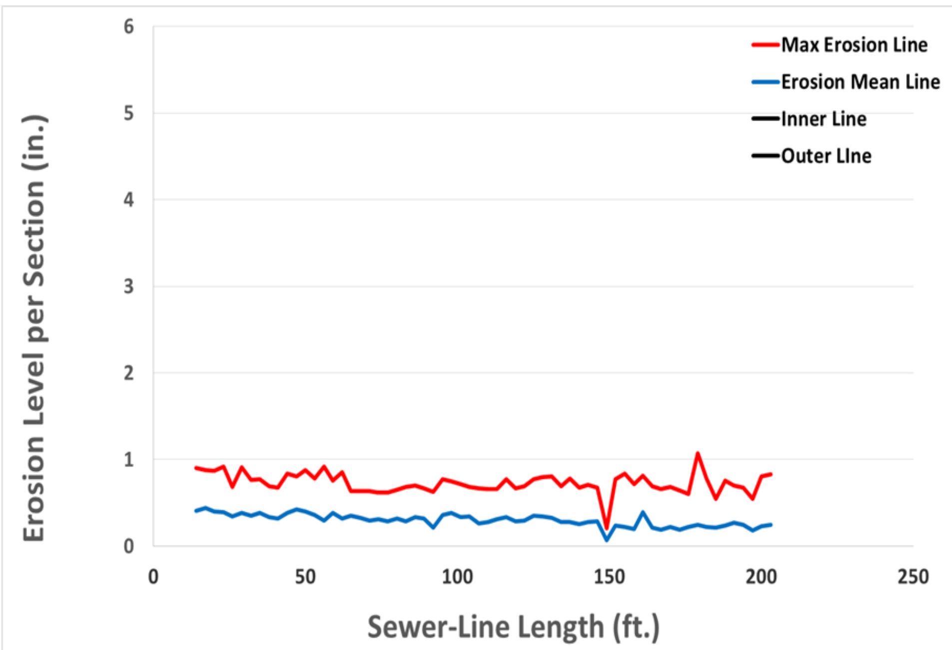


Figure A13-6 Erosion level per-section

Visual Observations

Table A13-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension 1st	Dimension 2nd	%		At/From	To		
1	0		AMH									
2	6.1		MWL				10%					
3	6.1		SRV								1	
4	7.75		SAV	S01							2,4,5	
5	9.8							J			3	MUD INTRUDING
6	160.45							J			6	MUD INTRUDING
7	161.9		SRV								7	
8	186.7		SRV	S02							8	
9	193.8		SRV	F02								
9	202.65		SAV	F01							9	
10	205.3		MSA									

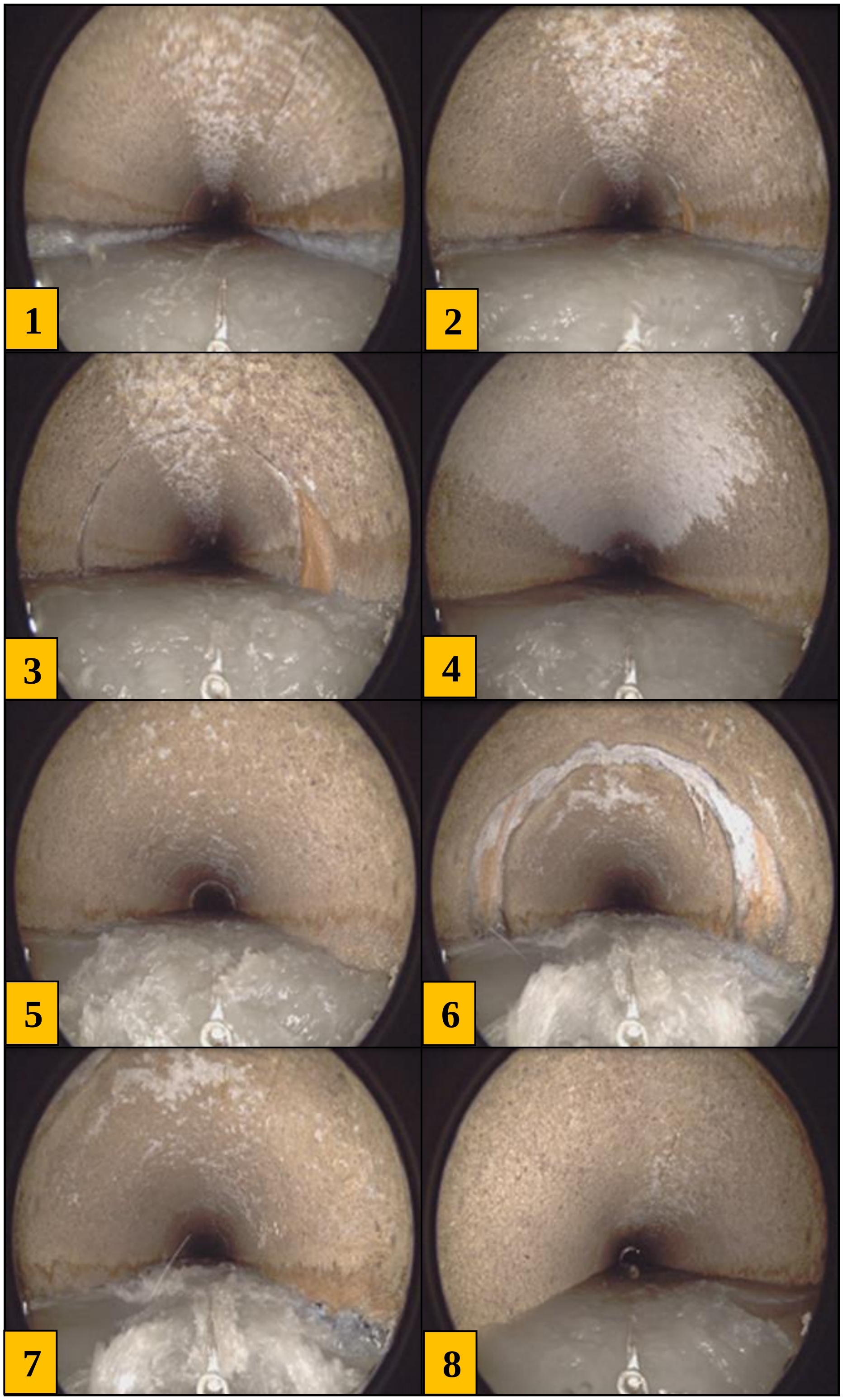


Figure A12-7 images from 1 through 9

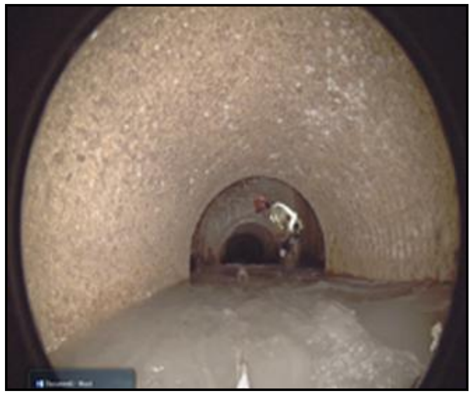


Figure A12-7 image 9

Line 14 Summary

Table A14-1 Results Summary of Sewer Line 14

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	138
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	2
Level 4 Structural Defects	0
Total Defects	3
Total Debris Volume (ft3)	0
Total Deposits Volume (in3)	24237.65
Maximum Blockage (%)	1.33
Maximum Deposit Height (in)	1.03

Deposit Data

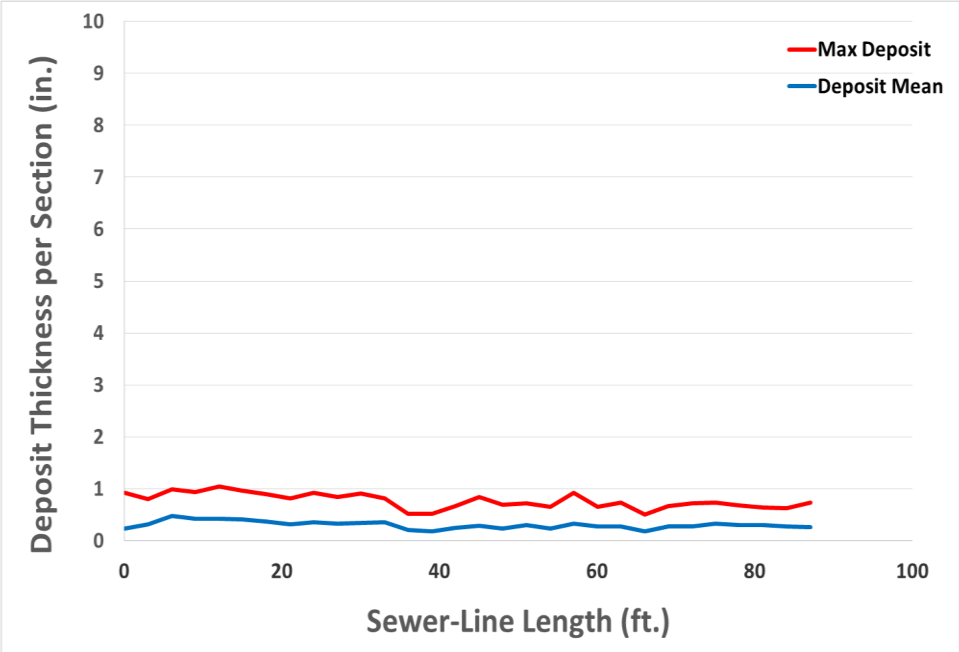


Figure A14-1 Deposit thickness per cross-section

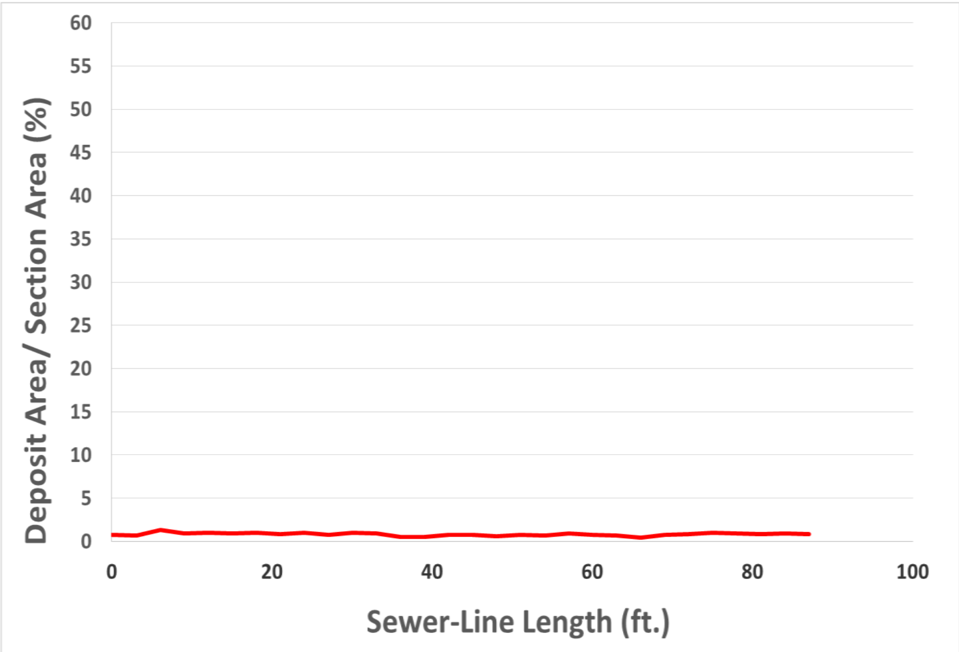


Figure A14-2 Deposit area percentage of the pipe cross section area

Blockage Data

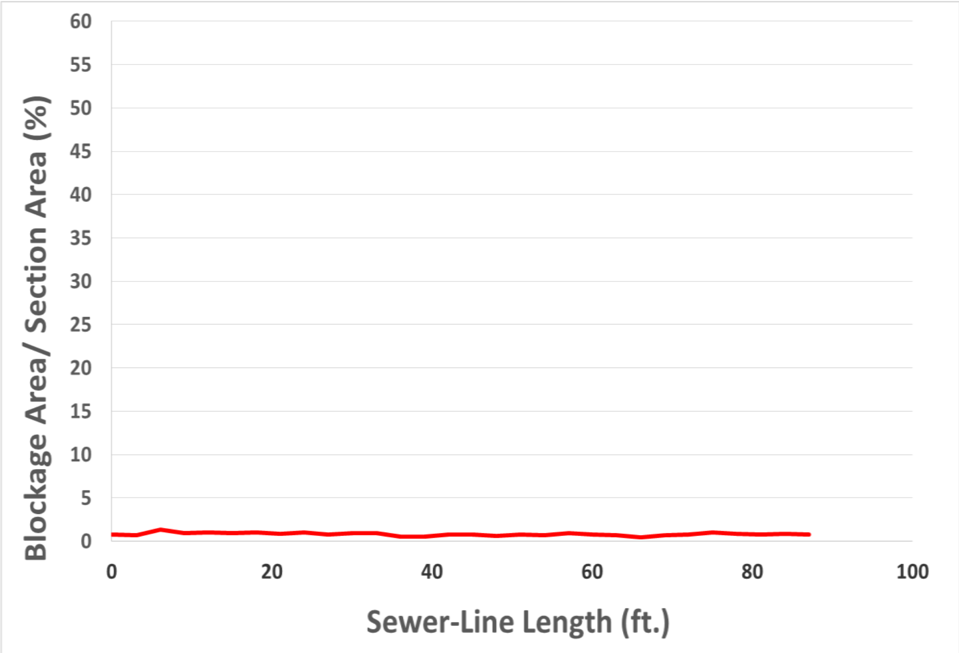


Figure A14-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion Data

Table A14-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	D09SL0189	RCP	60	60	1.08	0.25

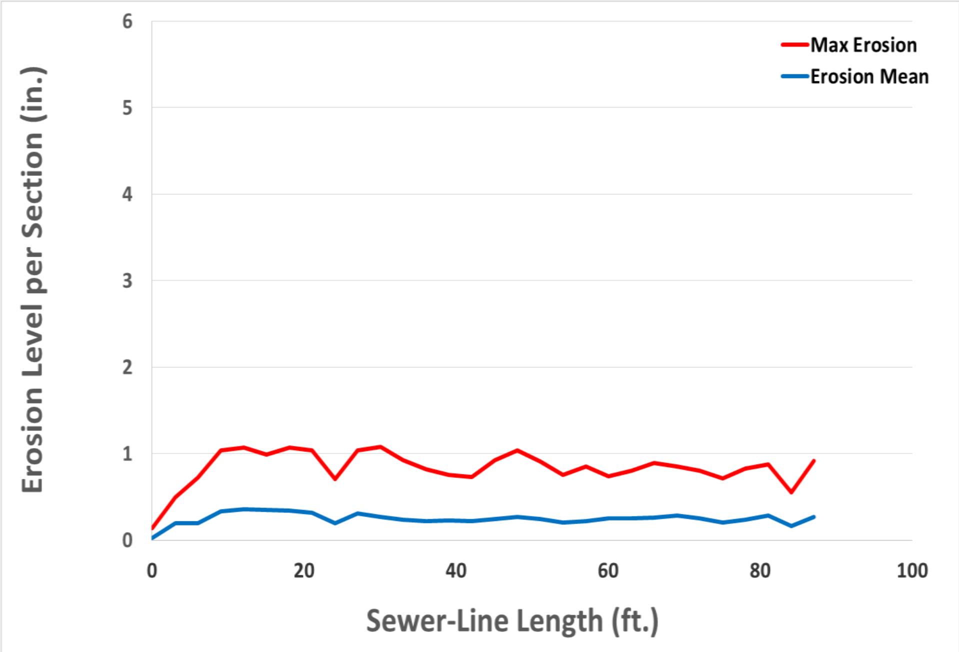


Figure A14-4 Erosion level per section.

Visual Observations

Table A14-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code Group/ Descriptor/ Modifier	Continuous Defect	Value Dimension 1st	Value Dimension 2nd	Value %	Joint	Circumferential Location At/From	Circumferential Location To	Img Reference	Remarks
1	0		AMH									
2	1.45		MWH				10%					
3	1.45		SAV	S01								
3	36.5		SRV	S02							1 TO 3	
4	55.1		SRV	F02								
4	83.05		SRV								2	
5	102.6		SAV	F01								
6	102.6		MSA									

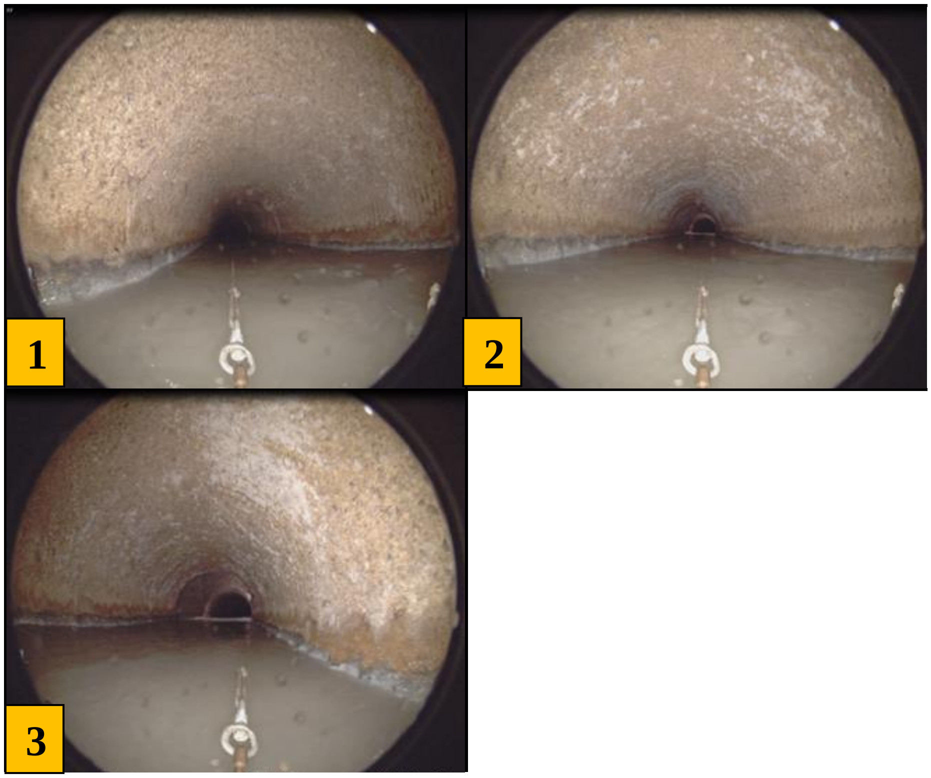


Figure A14-5 images from 1 through 3

Line 15 Summary

Table A15-1 Results Summary of Sewer Line 15

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	2847.9
Percentage of The Line Not Inspected	0.44%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	2
Total Debris Volume (ft3)	0
Total Deposits Volume (in3)	415189.47
Maximum Blockage (%)	1.40
Maximum Deposit Height (in)	1.00

Deposit Data

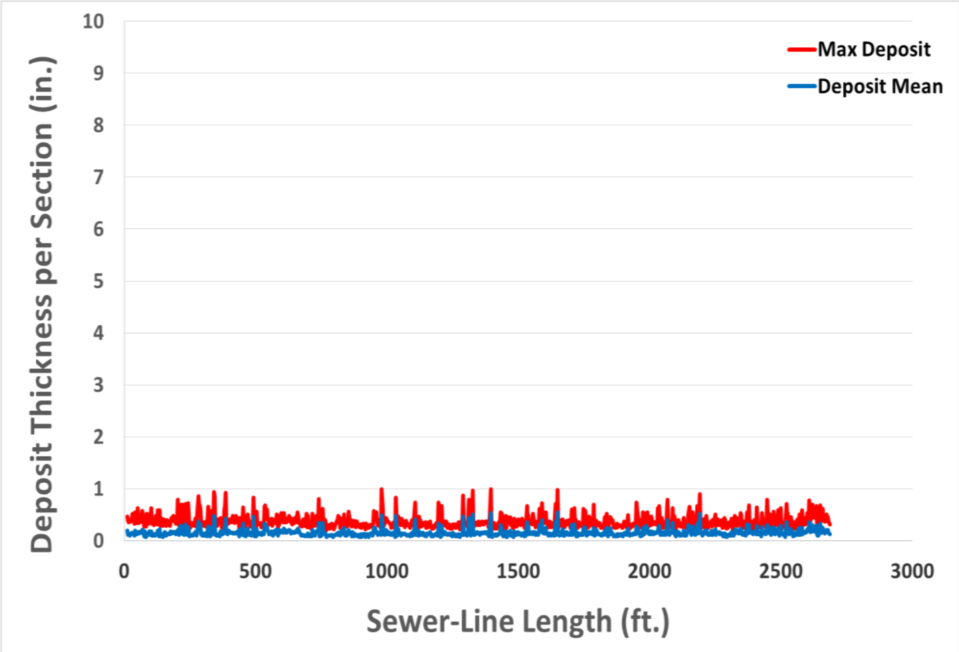


Figure A15-1 Deposit thickness per cross-section

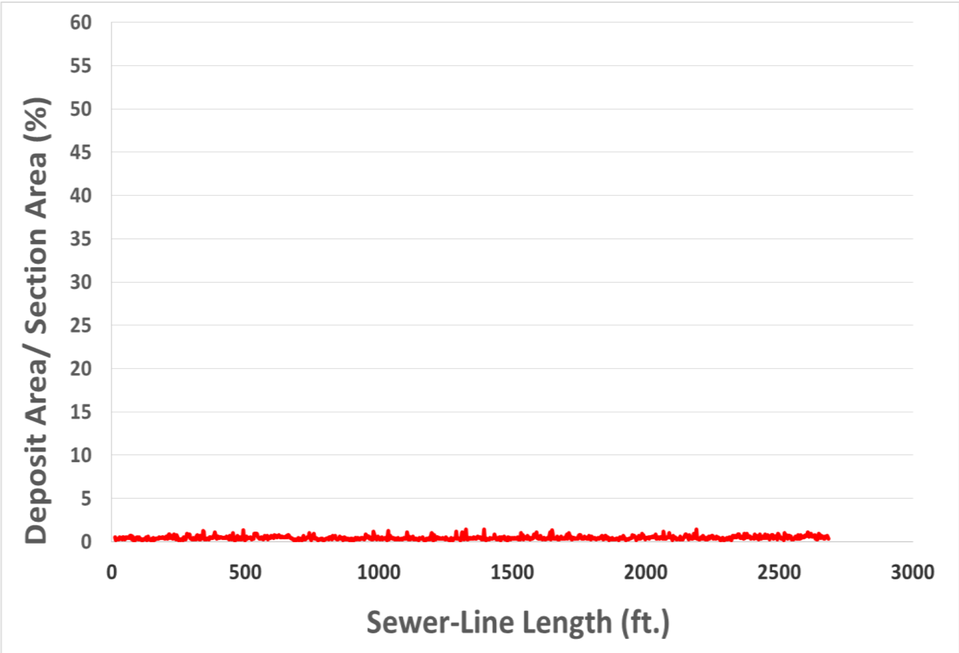


Figure A15-2 Deposit area percentage of the pipe cross section area

Blockage Data

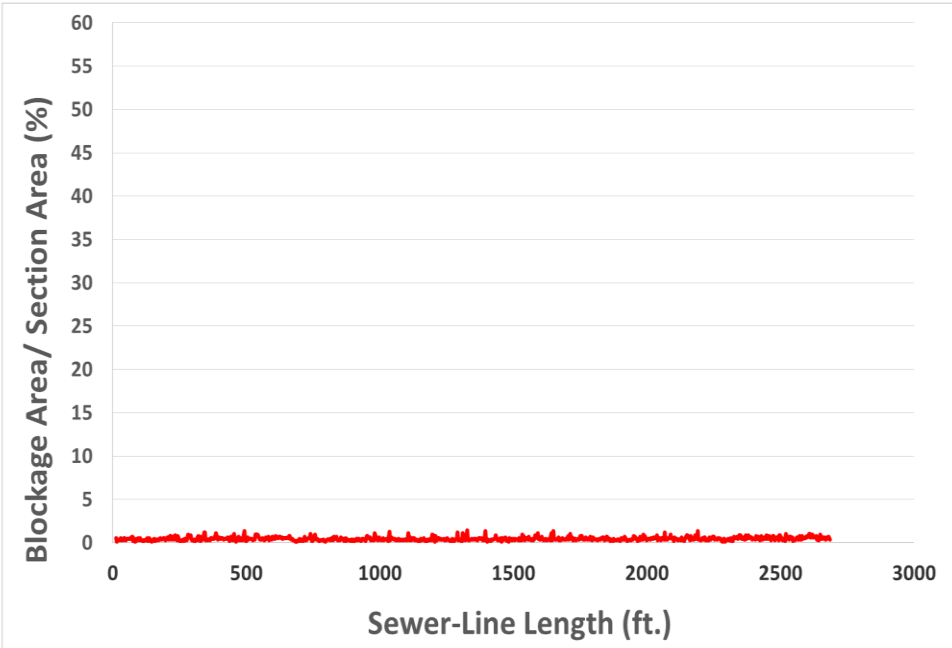


Figure A15-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion Data

Table A15-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	D08SL0002	RCP	60	60	1.96	0.12

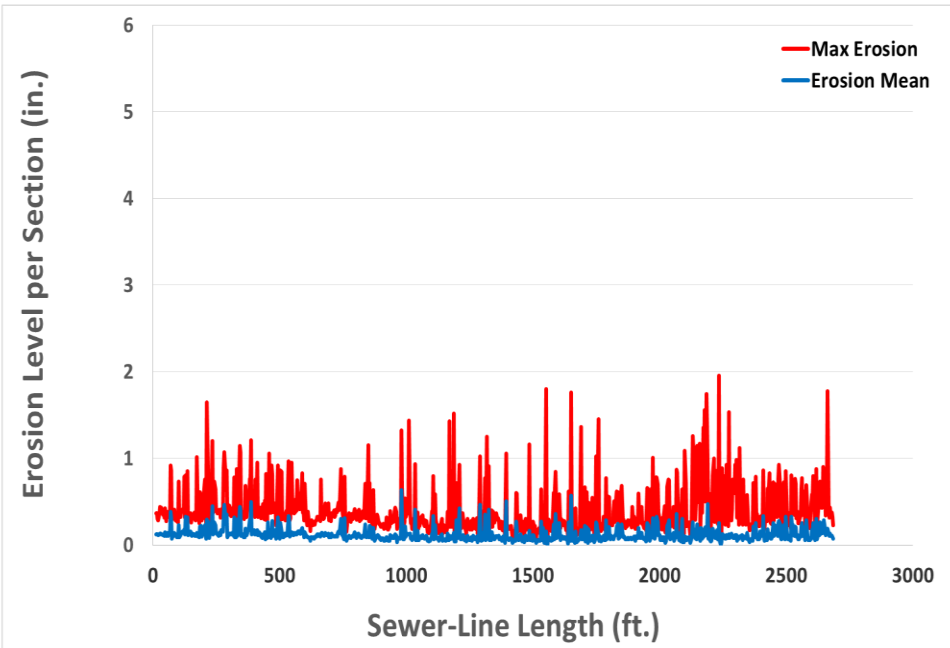


Figure A15-4 Erosion level per section

Visual Observations

Table A15-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0.05		MWL				15%					
3	5.35		SAV	S01							1 TO 6	
4	1237		IDJ								2	
5	2688.7		SAV	F01								
6	2688.7		MSA									

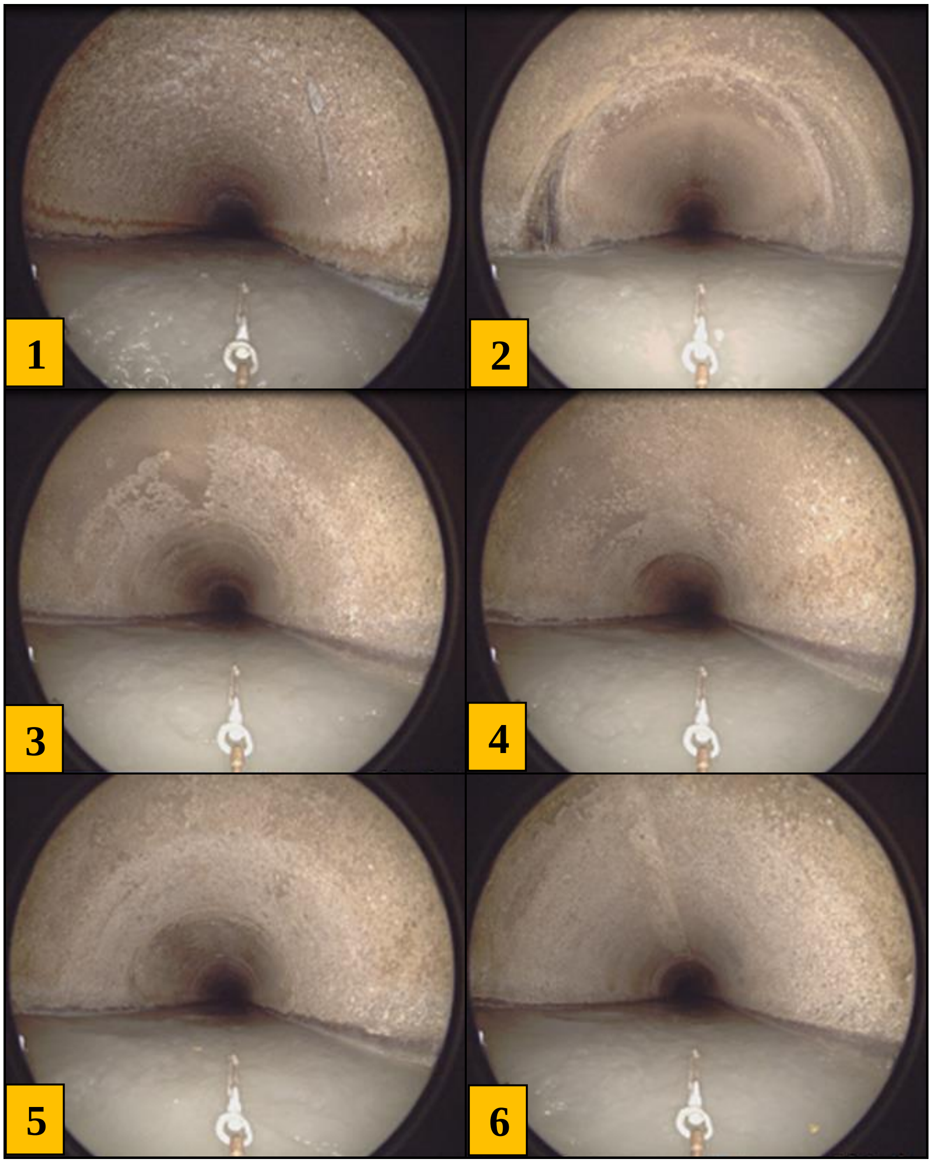


Figure A15-5 images from 1 through 6

Line 16 Summary

Table A16-1 Results Summary of Sewer Line 16

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	596.7
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	1
Total Debris Volume (ft3)	0
Total Deposits Volume (in3)	40198.25
Maximum Blockage (%)	0.61
Maximum Deposit Height (in)	0.48

Deposit Data

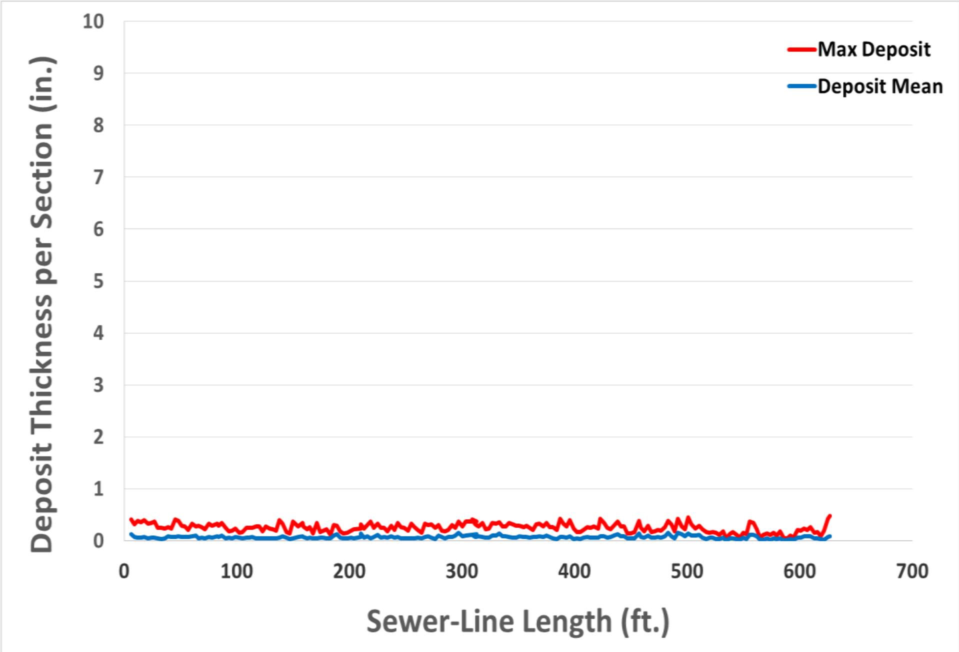


Figure A16-1 Deposit thickness per cross-section

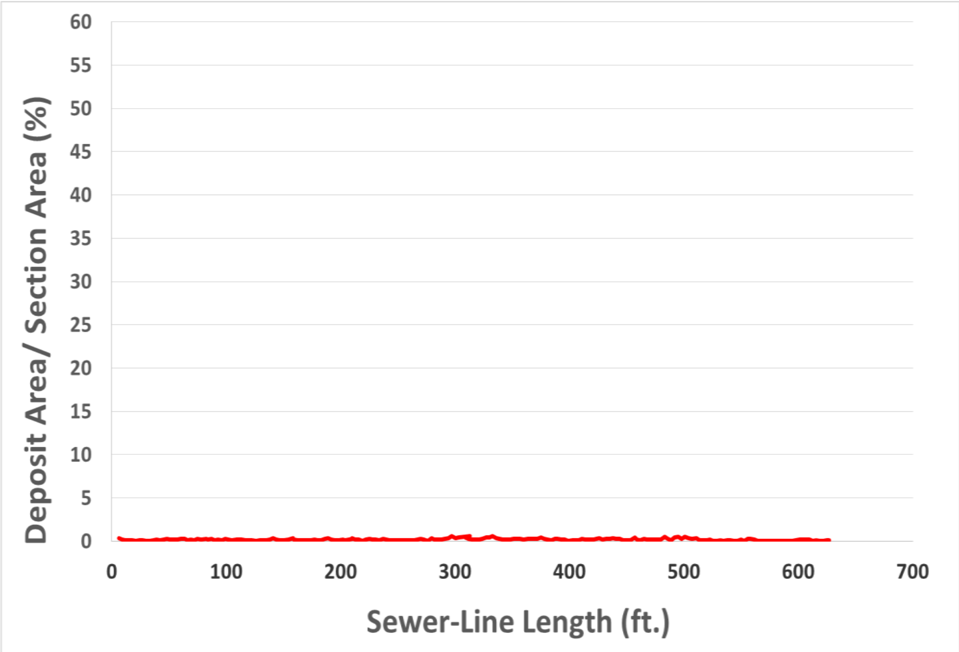


Figure A16-2 Deposit area percentage of the pipe cross section area

Blockage Data

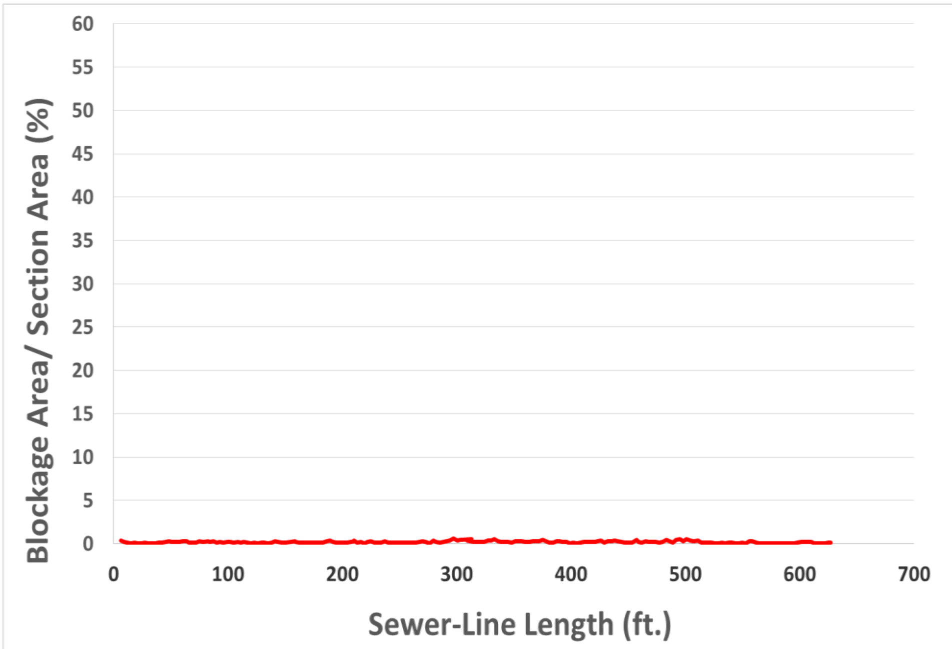


Figure A16-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion Data

Table A16-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	D08SL0002	RCP	60	60	0.6	0.07

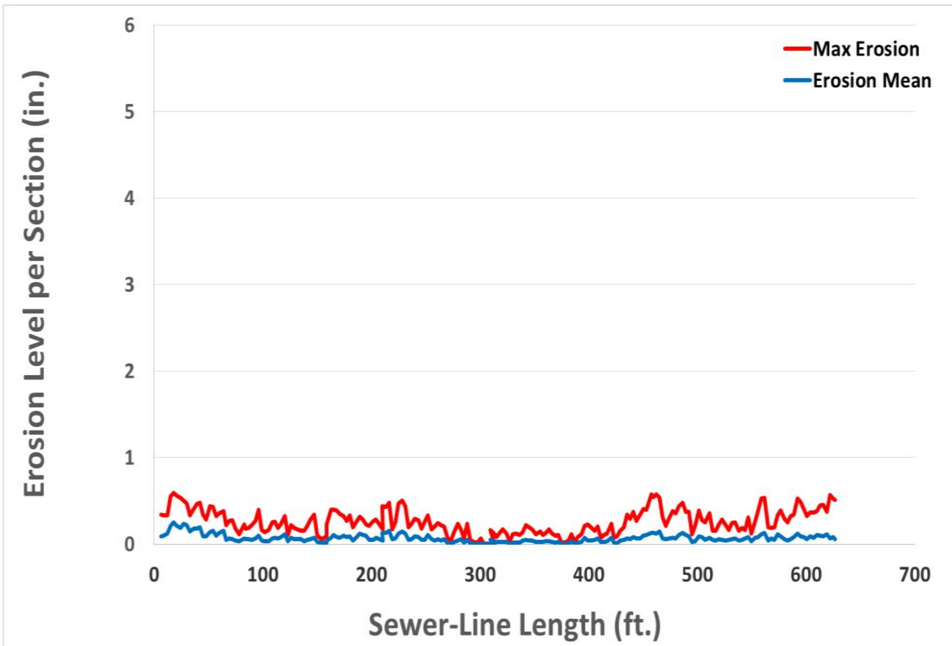


Figure A16-4 Erosion level per section

Visual Observations

Table A16-4Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	7.5		MWL				15%					
3	7.5		SAV	S01							1 TO 5	
4	626		SAV	F01								
5	626		MSA									

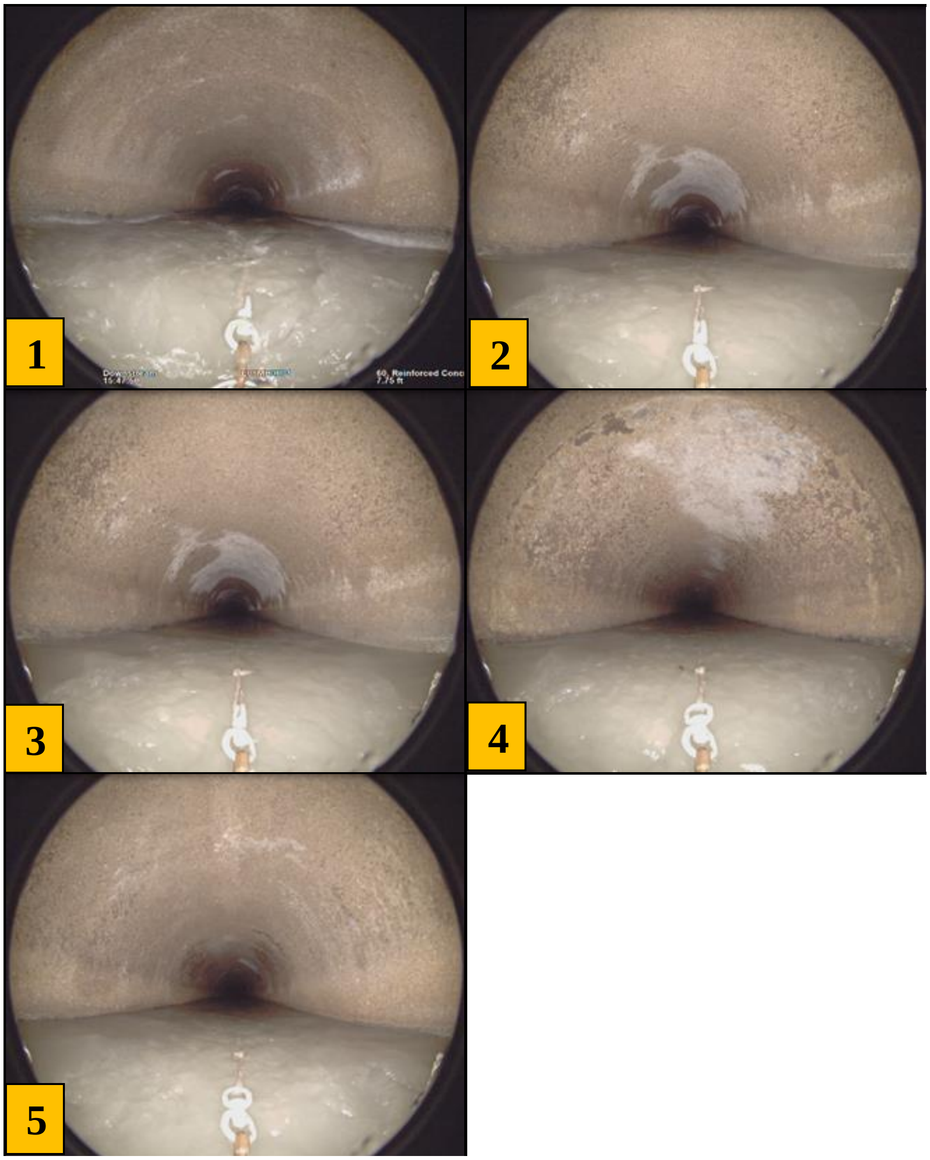


Figure A16-5 images from 1 through 5

Line 17 Summary

Table A17-1 Results Summary of Sewer Line 17

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	1391.8
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	2
Total Debris Volume (ft3)	3261.21
Total Deposits Volume (in3)	220563.27
Maximum Blockage (%)	4.27
Maximum Deposit Height (in)	0.8

Deposit Data

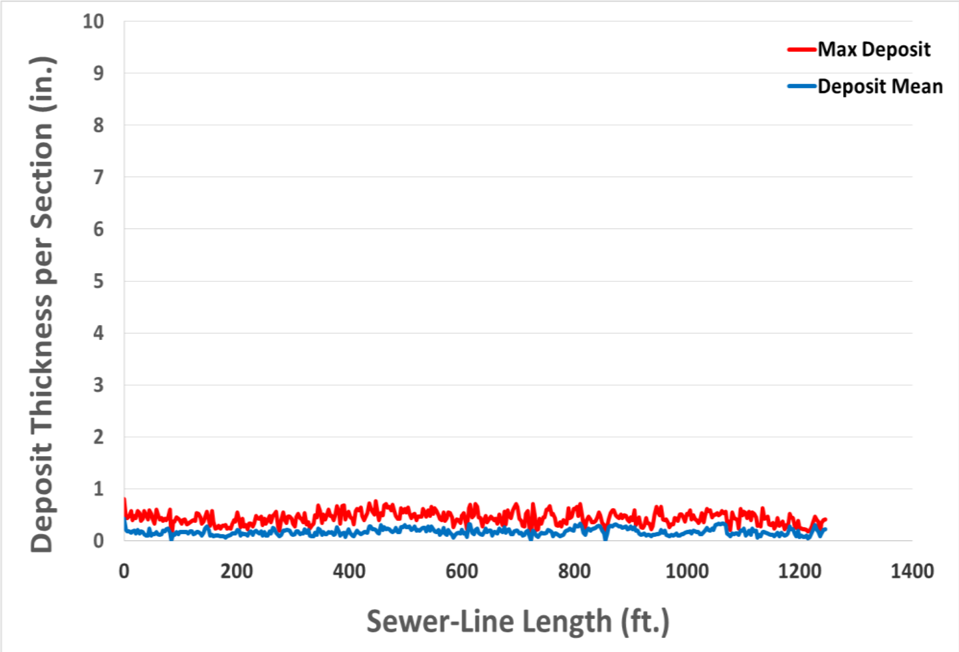


Figure A17-1 Deposit thickness per cross-section

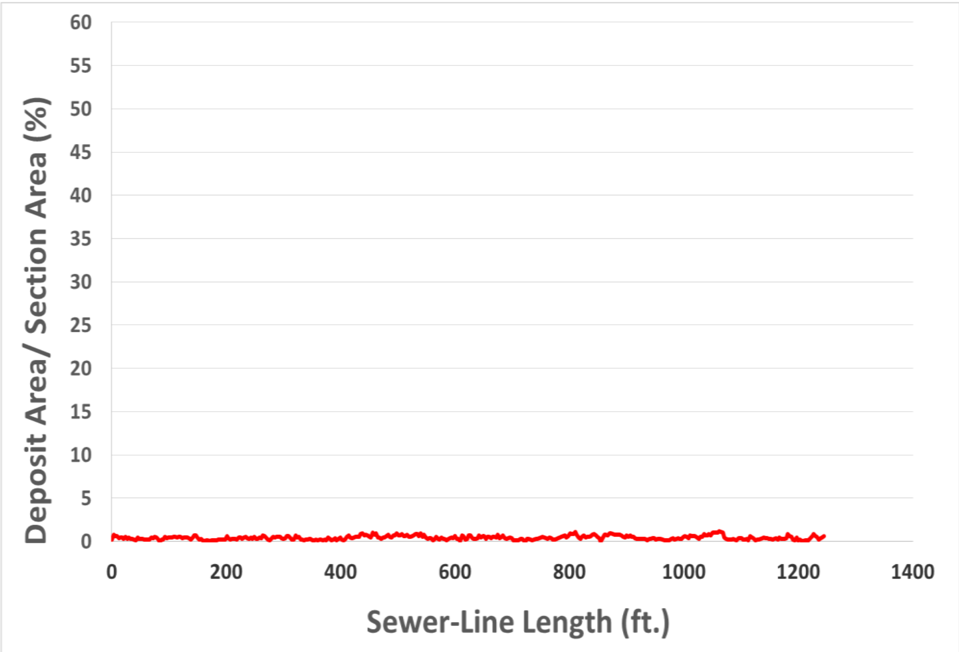


Figure A17-2 Deposit area percentage of the pipe cross section area

Debris Data

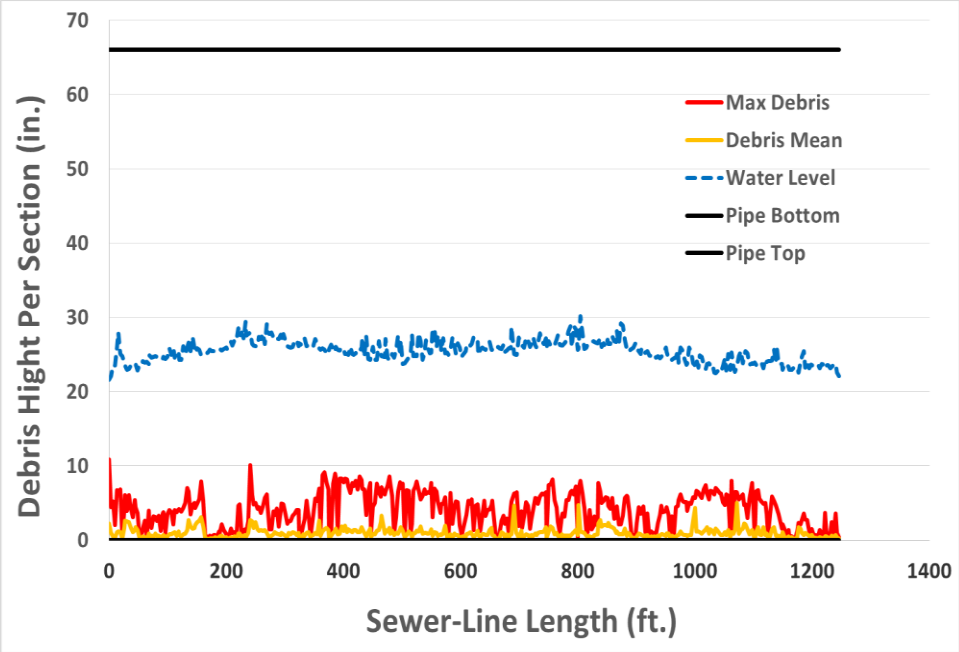


Figure A17-3 Debris height per cross-section

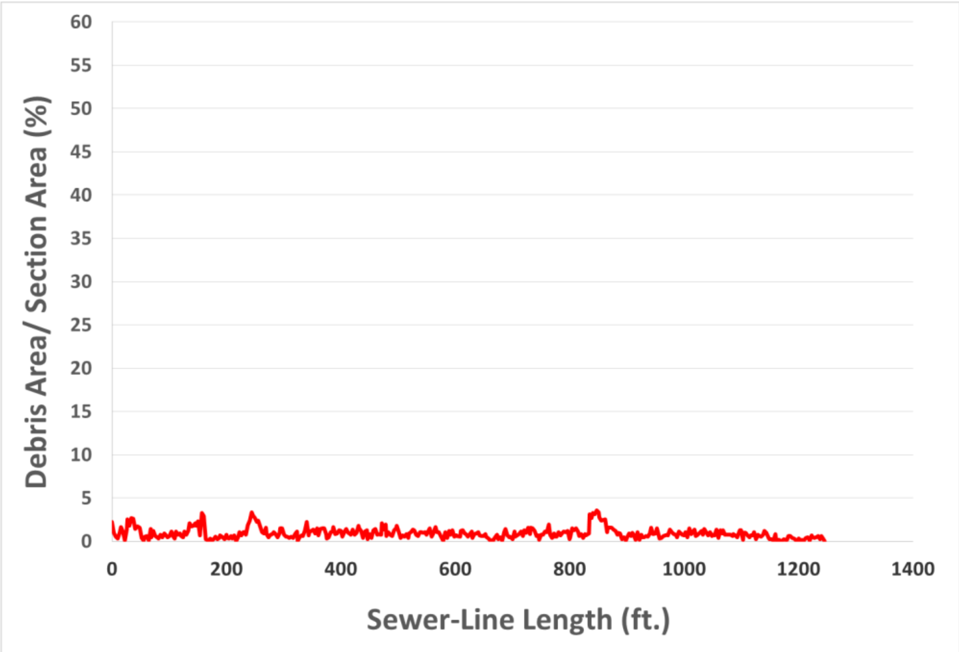


Figure A17-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

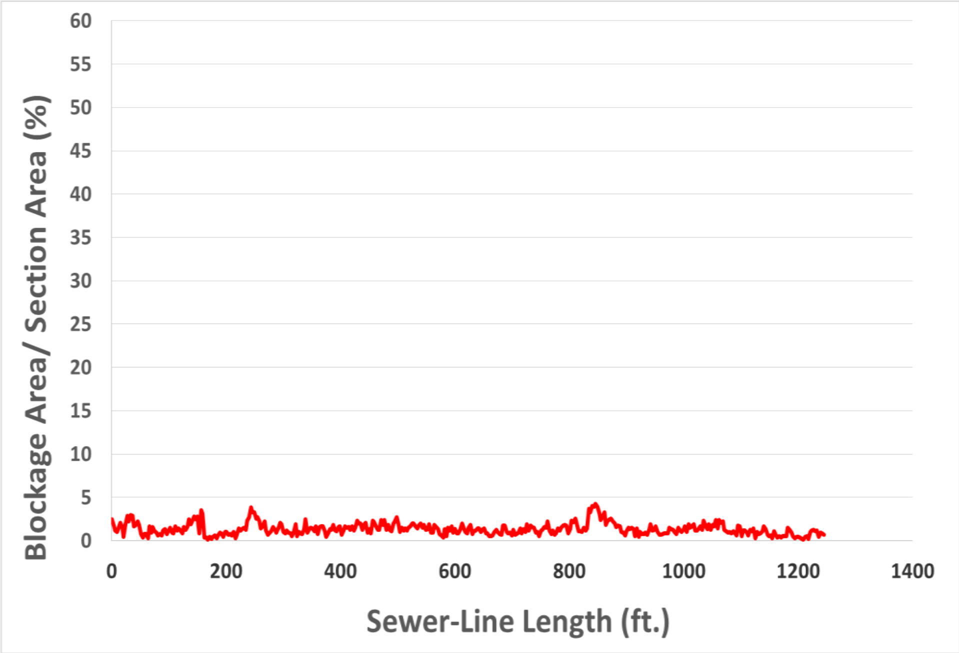


Figure A17-5 Blockage area (deposits and debris areas) percentage of pipe cross section area.

Erosion Data

Table A17-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	E08SL0001	RCP	66	66	0.65	0.65

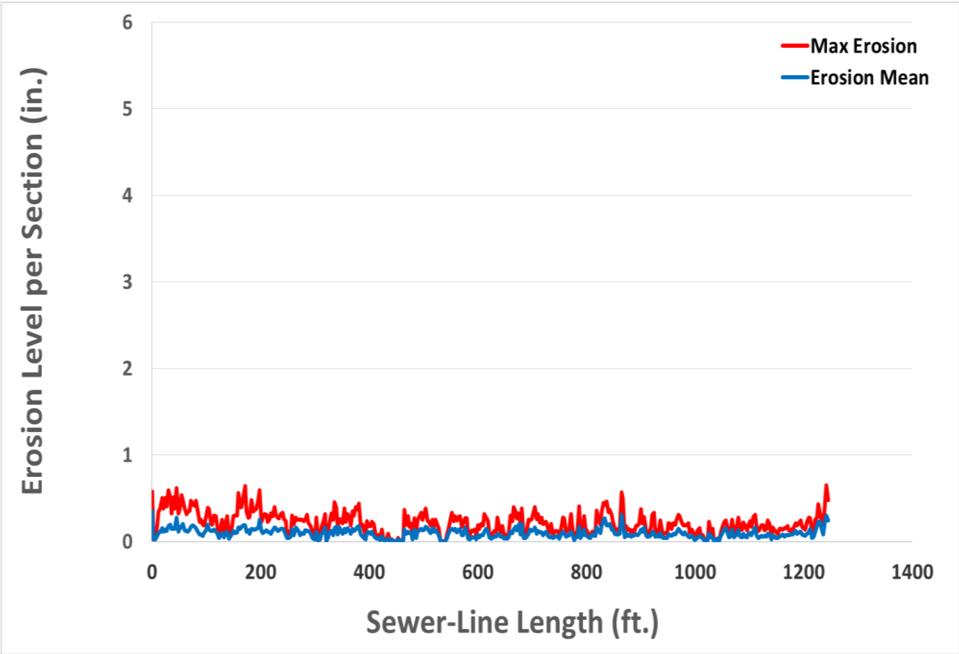


Figure A17-6 Erosion level per section

Visual Observation

Table A17-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	6		MWL				15%					
3	6		SAV	S01							1,3	
4	277.6		IDJ								2	
5	1220.45		SAV	F01								
6	1220.45		MSA									

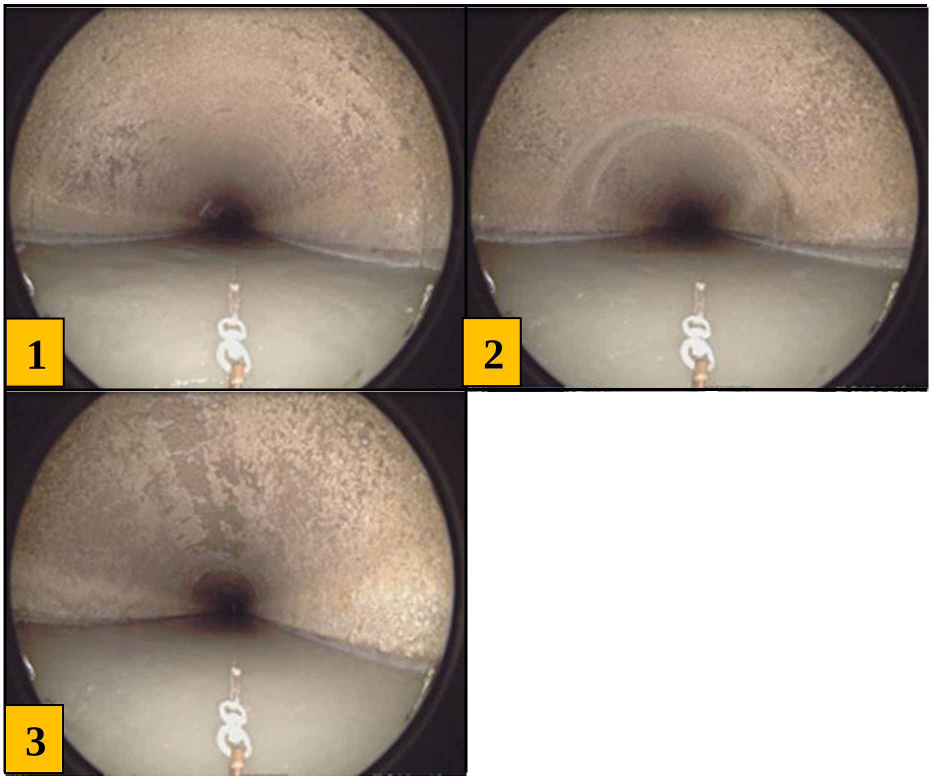


Figure A17-7 images from 1 through 3

Line 18 Summary

Table A18-1 Results Summary of Sewer Line 18

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	2090.5
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 O&M Defects	0
Level 5 Structural Defects	0
Level 4 O&M Defects	0
Level 4 Structural Defects	0
Total Defects	2
Total Debris Volume (ft3)	486.98
Total Deposits Volume (in3)	239652.49
Maximum Blockage (%)	6.99
Maximum Deposit Height (in)	1.00

Deposit Data

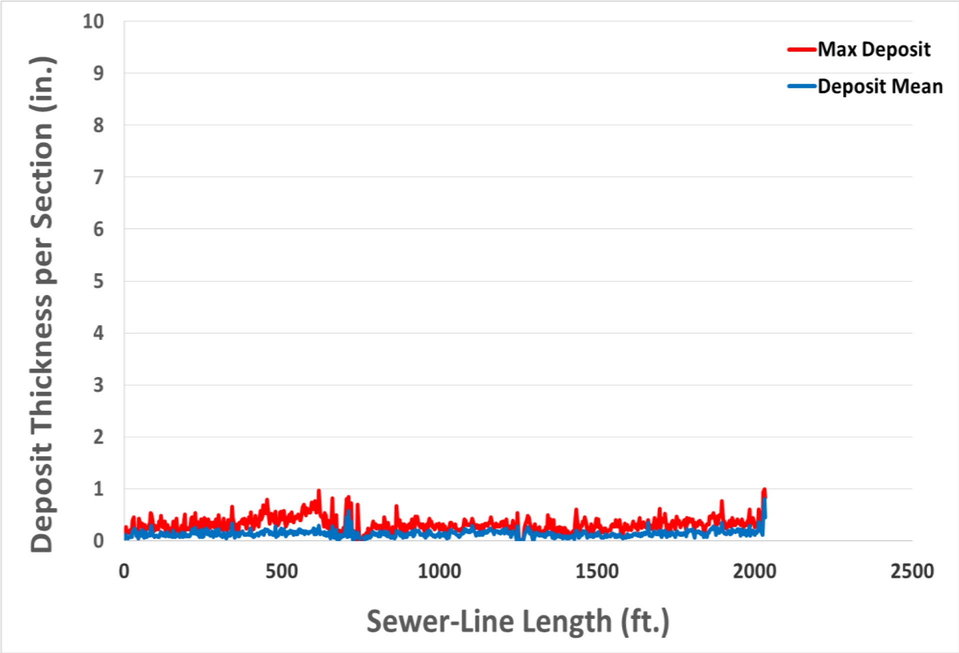


Figure A18-1 Deposit thickness per cross-section

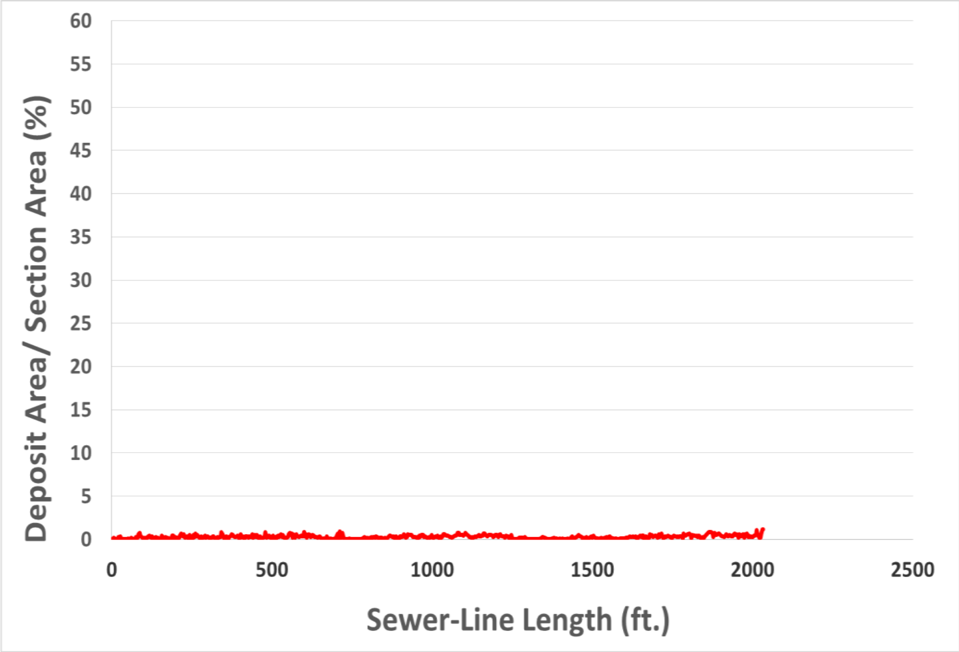


Figure A18-2 Deposit area percentage of the pipe cross section area

Debris Data

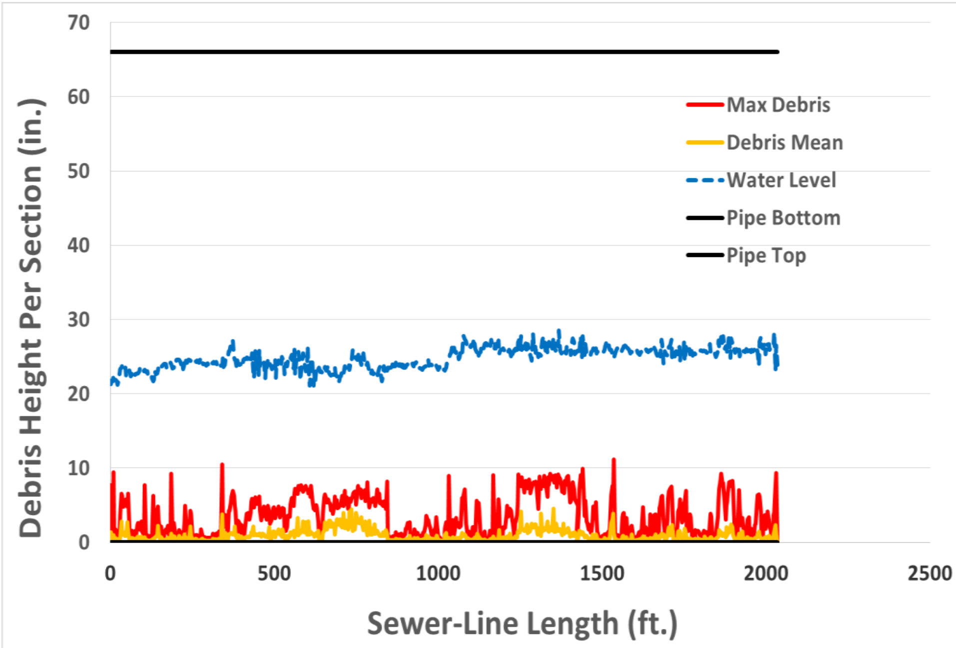


Figure A18-3 Debris height per cross-section

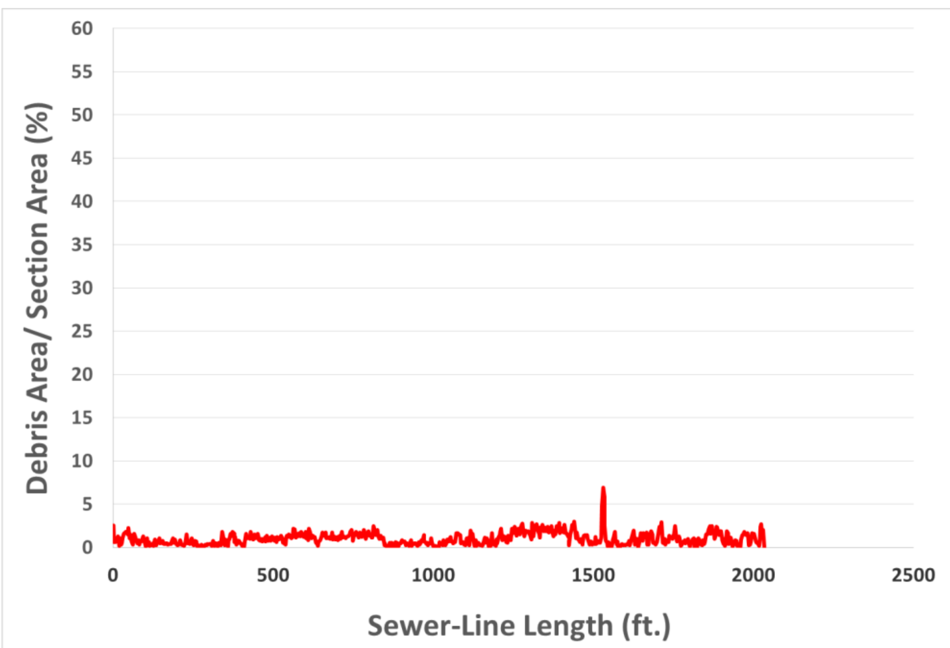


Figure A18-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

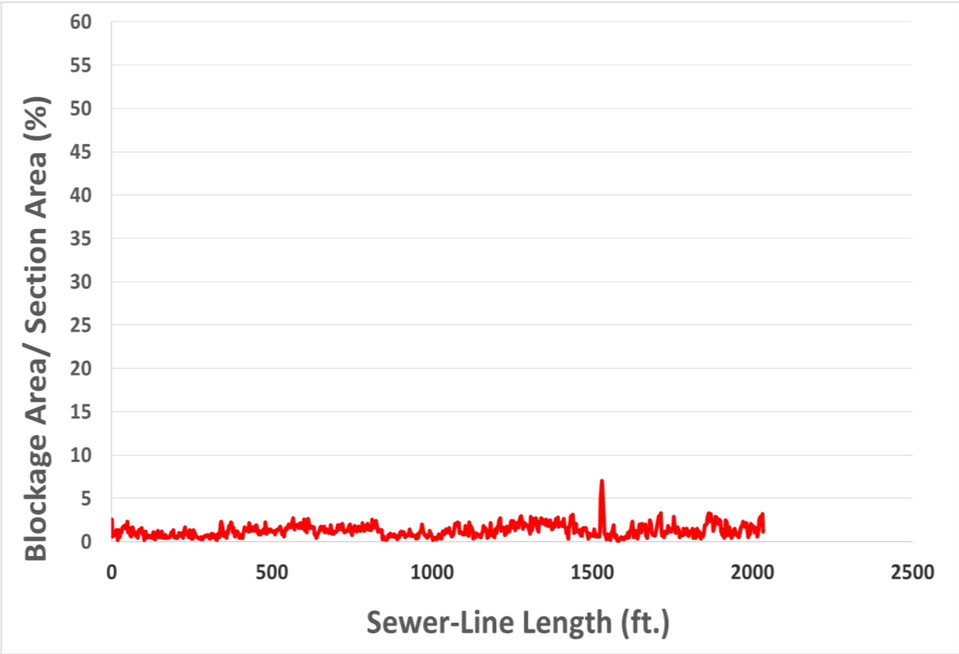


Figure A18-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion Data

Table A18-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	E08SL0209-243	RCP	66	66	1.08	0.15

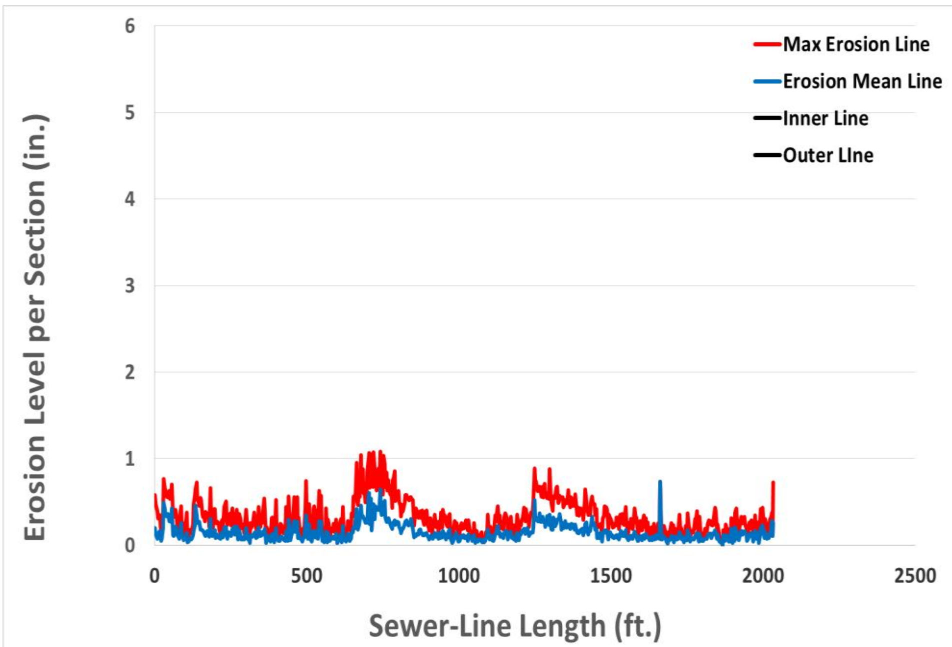


Figure A18-6 Erosion level per section

Visual Observations

Table A18-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0.85		MWL				10%					
3	0.85		SAV	S01							1 TO 4	
4	1306.35		TBA						12	3	3	
5	2035.55		SAV	F01								
6	2035.55		MSA									

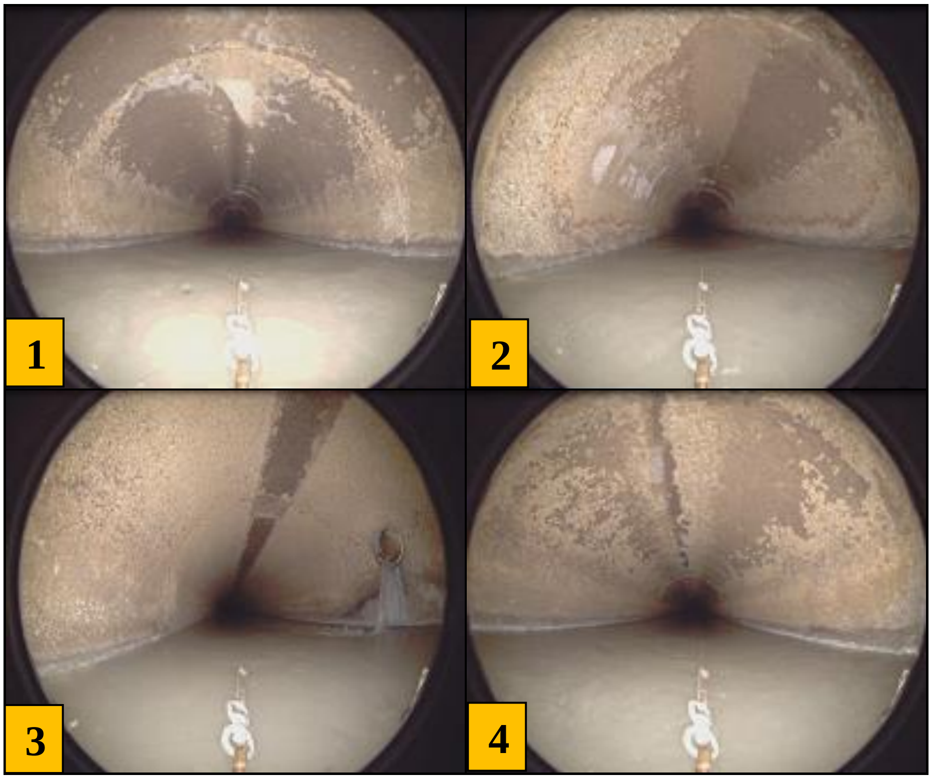


Figure A18-7 images from 1 through 4

Line 19 Summary

Table A19-1 Results Summary of Sewer Line 19

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	592
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	2
Total Defects	18
Total Debris Volume (ft^3)	20.9
Total Deposits Volume (in^3)	49983.5
Maximum Blockage (%)	18
Maximum Deposit Height (in)	1.6

Deposit Data

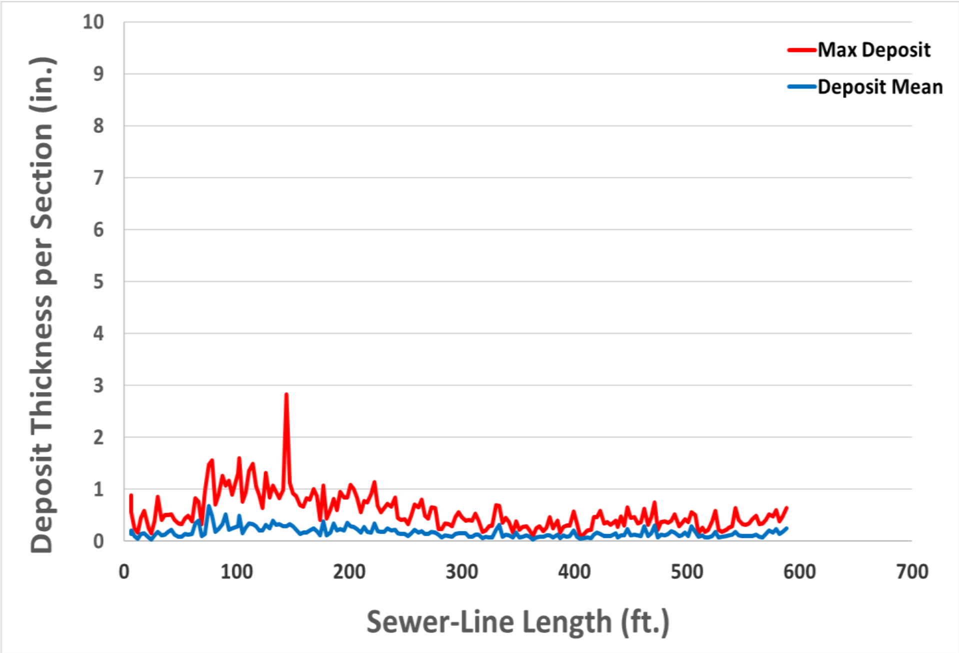


Figure A19-1: Deposit thickness per cross-section

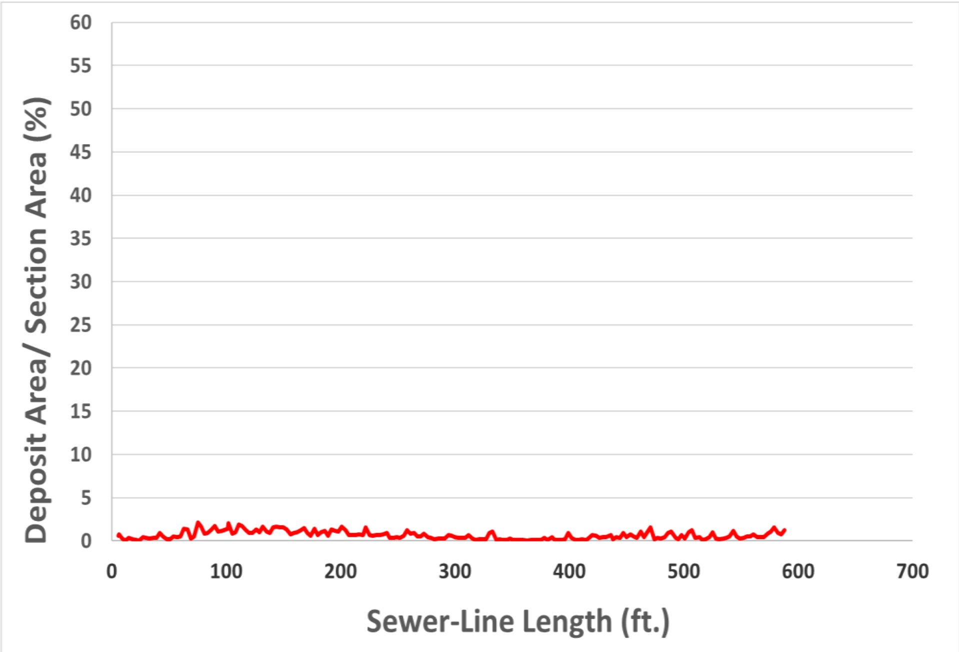


Figure A19-2: Deposit area percentage of the pipe cross section area

Debris Data

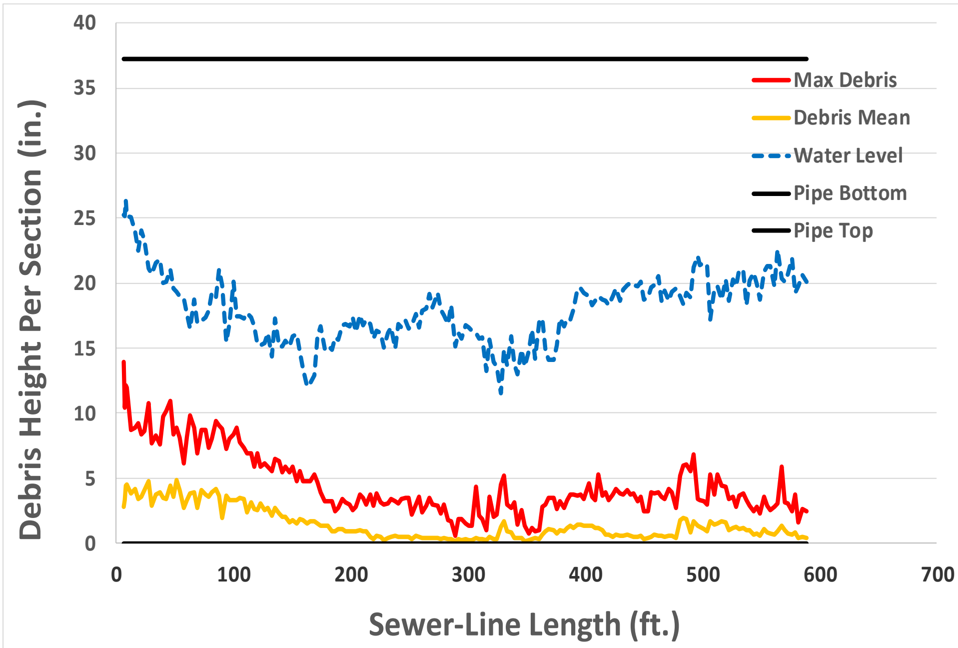


Figure A19-3: Debris height per cross-section

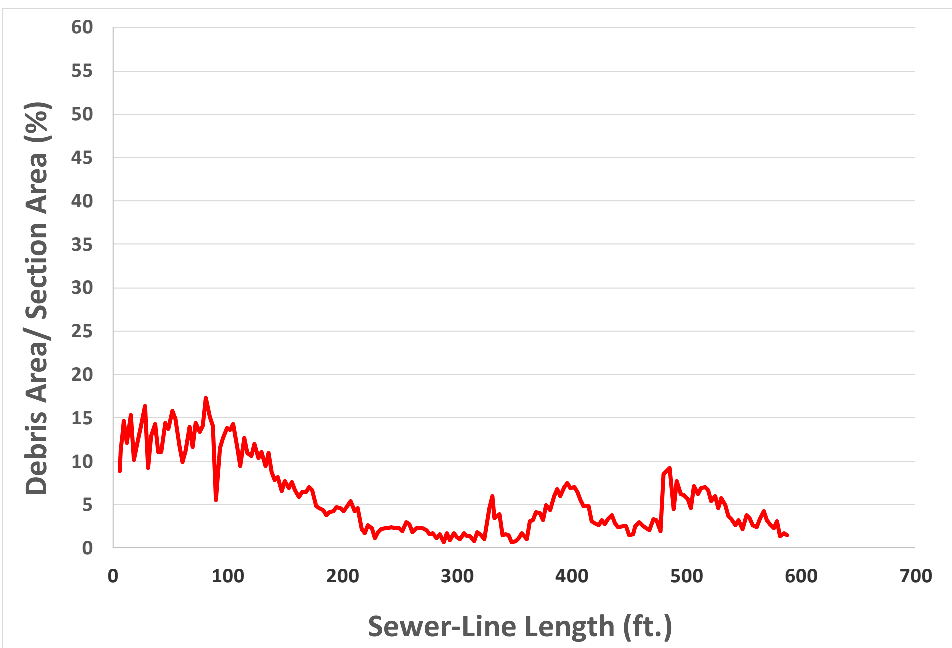


Figure A19-4: Debris area percentage of the pipe cross-sectional area

Blockage Data

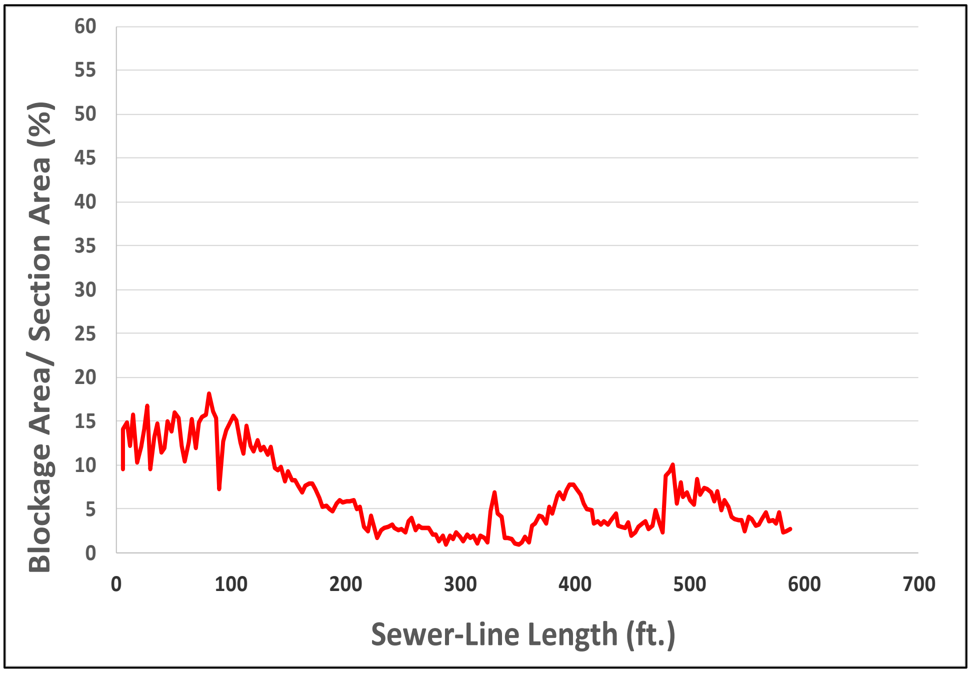


Figure A19-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A19-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code Group/ Descriptor/ Modifier	Continuous Defect	Value Dimension 1st	Value Dimension 2nd	Value %	Joint	Circumferential Location At/From	Circumferential Location To	Img Reference	Remarks
1	0		AMH									
2	0		MWL				40%					
3	6		DAE	S01			30%				1	COVERED AS A LAYER
4	6		DAG	S02			30%				1	
5	10.45		DAE	F01							2	
6	10.45		DAG	F02							2	
7	10.45		DAE	S03			20%				2 TO 7	COVERED AS A LAYER
8	10.45		DAG	S04			20%				2 TO 7	
9	278.5		DAG	F04							17	
10	278.5		DAE	F03							17	
11	295.05		DAE				5%	J			8	
12	295.05		DAG				5%				8	
13	312.75		DAG	S05			5%				9	
14	312.75		DAE	S06			5%				9	
15	367.5		DAE	F06							18	
16	367.5		DAG	F05							18	
17	383.85		DAE	S07			10%				10	
18	383.85		DAG	S08			10%				10	
19	457.1		DAE	F07							19	
20	457.1		DAG	F08							19	
21	472.35		DAG				5%	J			11	
22	489.9		DAG				5%	J			12	
23	505.05		DAG				5%				13	
24	507.9		DAG				5%				14	
25	524.3		DAG	S09			5%				15	
26	524.3		DAE	S10			5%				15	
27	545.4		DAE	F10							20	
28	545.4		DAG	F09							20	
29	562.6		DAE	S11			10%				16	
30	562.6		DAG	S12			10%				16	
31	581.05		DAE	F11							21	
32	581.05		DAG	F12							21	
33	590.85		MSA									

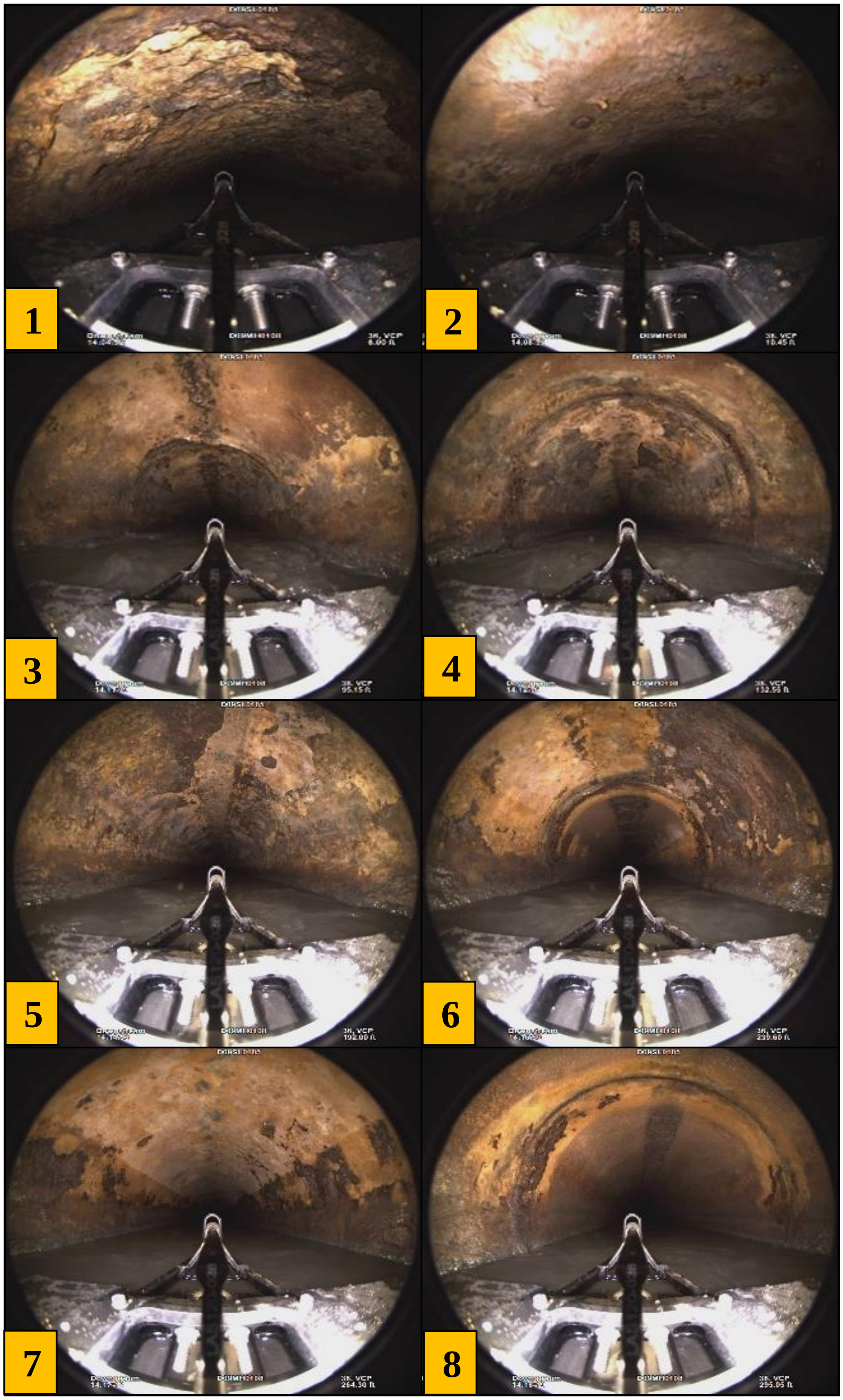


Figure A19-6 images from 1 through 8

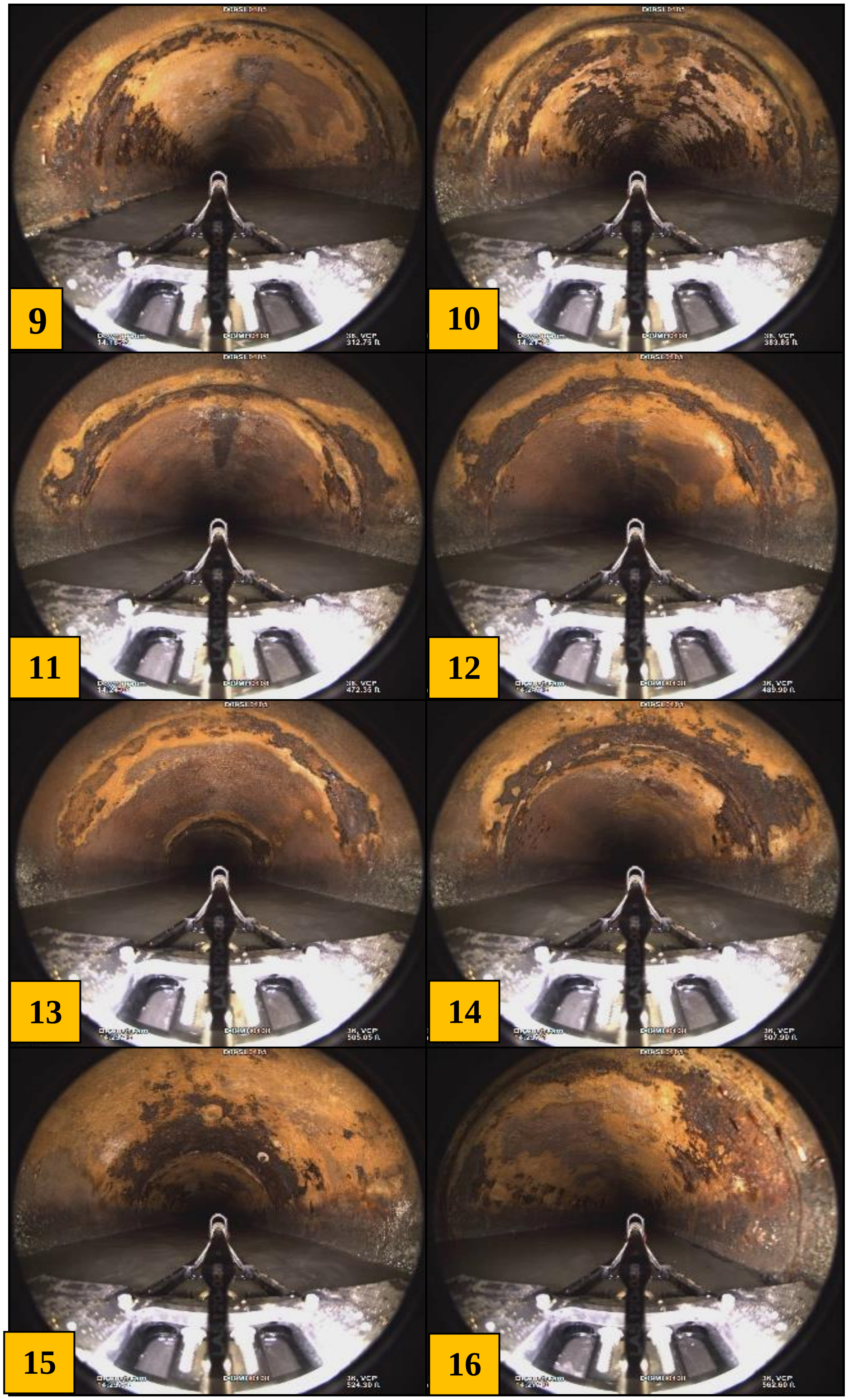


Figure A19-7 images from 9 through 16

Line 20 Summary

Table A20-1 Results Summary of Sewer Line D09SL0222

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	750
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	16
Total Debris Volume (ft^3)	138.6
Total Deposits Volume (in^3)	63827.4
Maximum Blockage (%)	10.2
Maximum Deposit Height (in)	1.6

Deposit Data

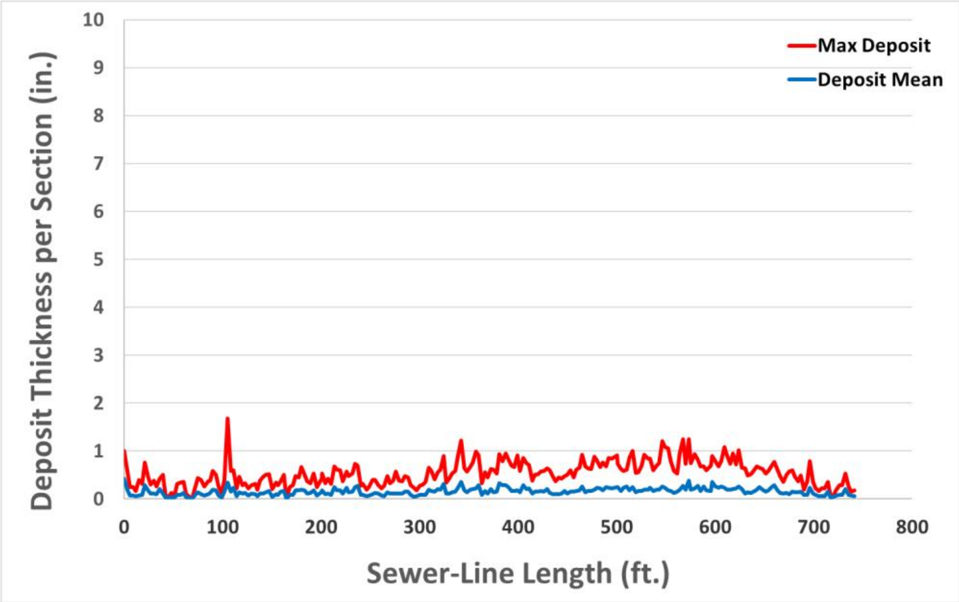


Figure A20-1 Deposit thickness per cross-section

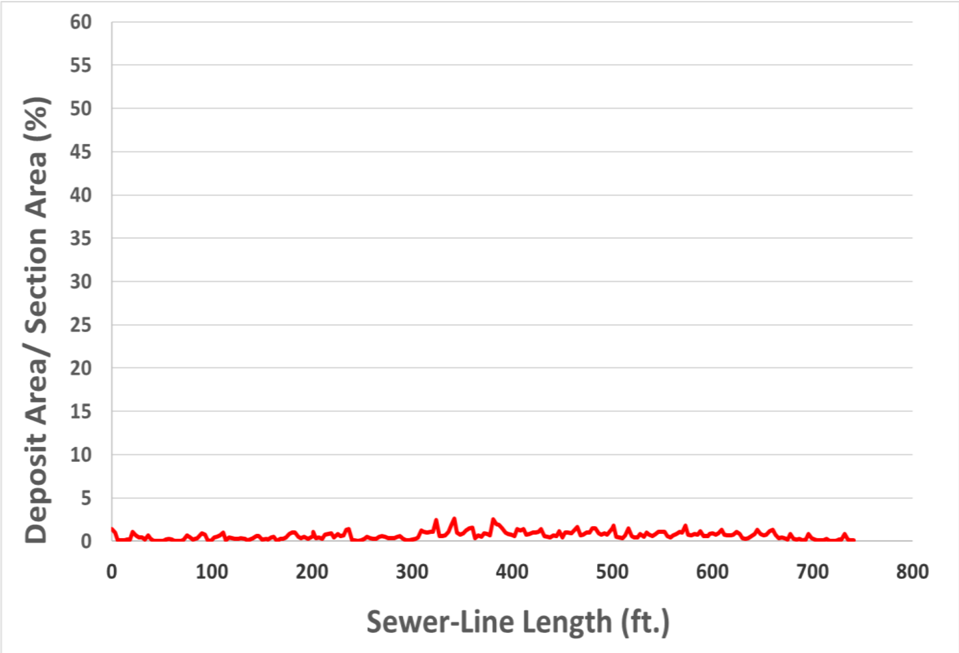


Figure A20-2 Deposit area percentage of the pipe cross section area

Debris Data

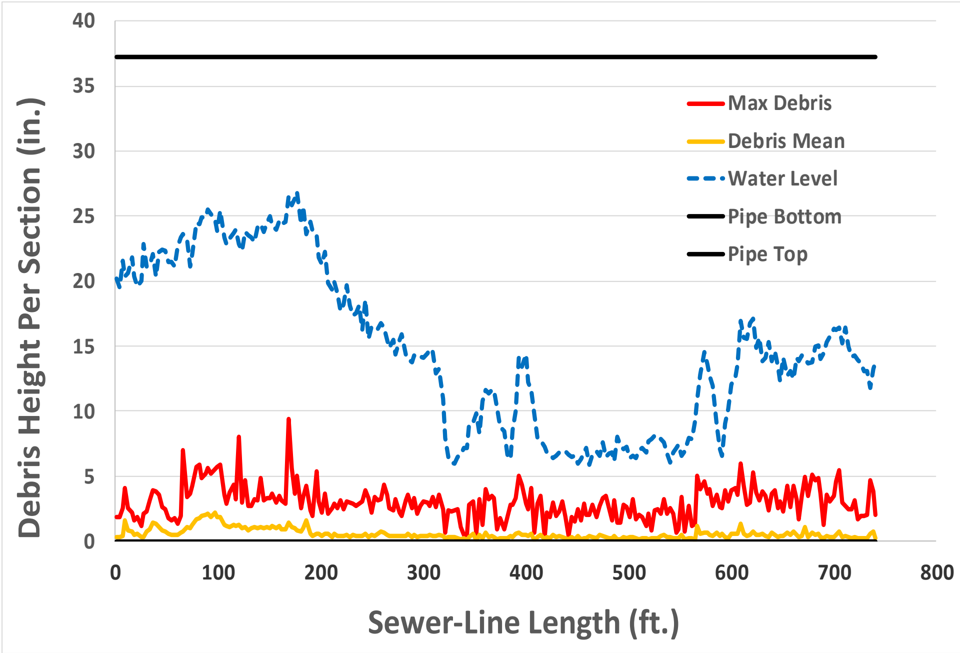


Figure A20-3 Debris height per cross-section

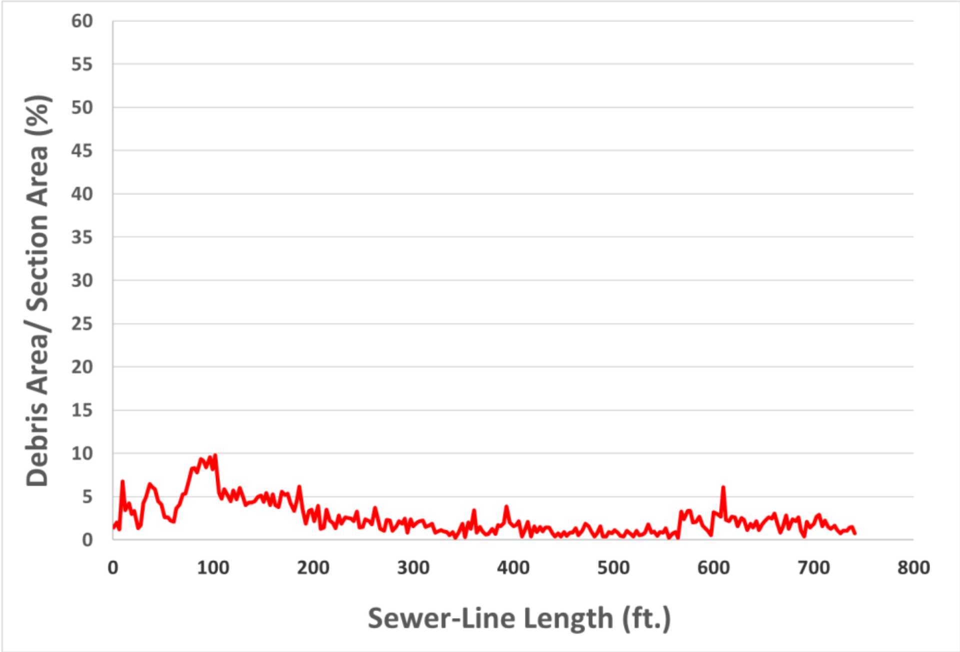


Figure A20-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

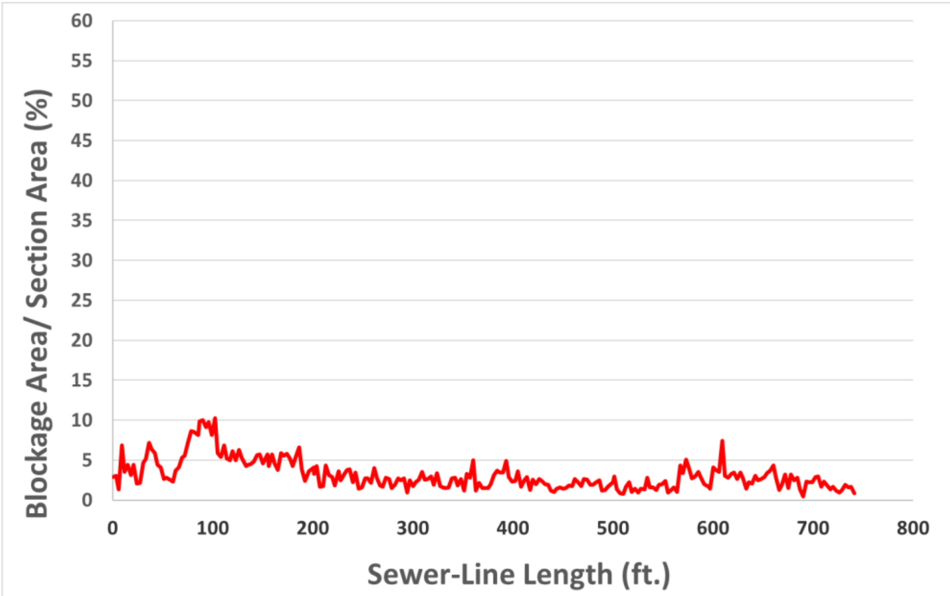


Figure A20-5: Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A20-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				30%					
3	5.35		DAG	S01			10%				1	
4	43		DAG	F01							17	
5	76.9		DAG	S02			10%				2	
6	95.2		DAG	F02							18	
7	112.5		DAG	S03			10%				3	
8	127.8		DAE	S04			15%				4	
9	132		DAG	F03							19	
10	166.2		DAG				10%				5	
11	220.8		DAG				10%				6	
12	239.75		DAE	F04							20	
13	256.65		DAG				5%				7	
14	274.2		DAG	S05			10%				8	
15	292.95		DAG	F05							21	
16	309.6		DAG				5%	J			9	
17	379.9		DAG				5%	J			10	
18	412.45		DAG	S06			5%				11	
19	415.1		DAG	F06							22	
20	450.65		DAG	S07			10%				12,13	
21	642.05		DAG	F07							23	
22	663.7		DAG				5%				14	
23	681.85		DAG	S09			10%				15,24	
24	700		DAG	F09							25	
25	721.3		DAG	S10			5%				16	
26	735.4		DAG	F10							26	
27	747.2		MSA									

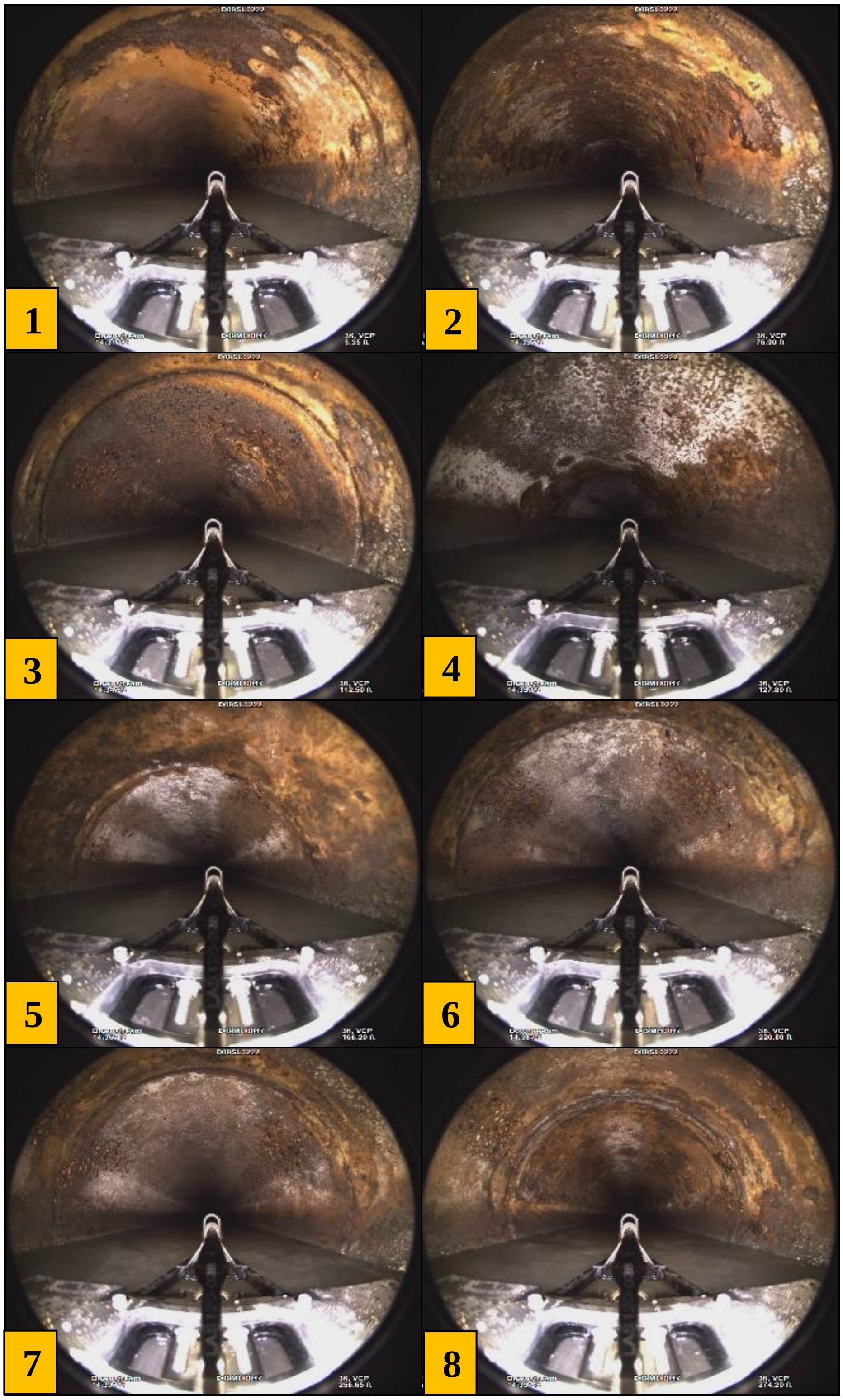


Figure A20-6 images from 1 through 8

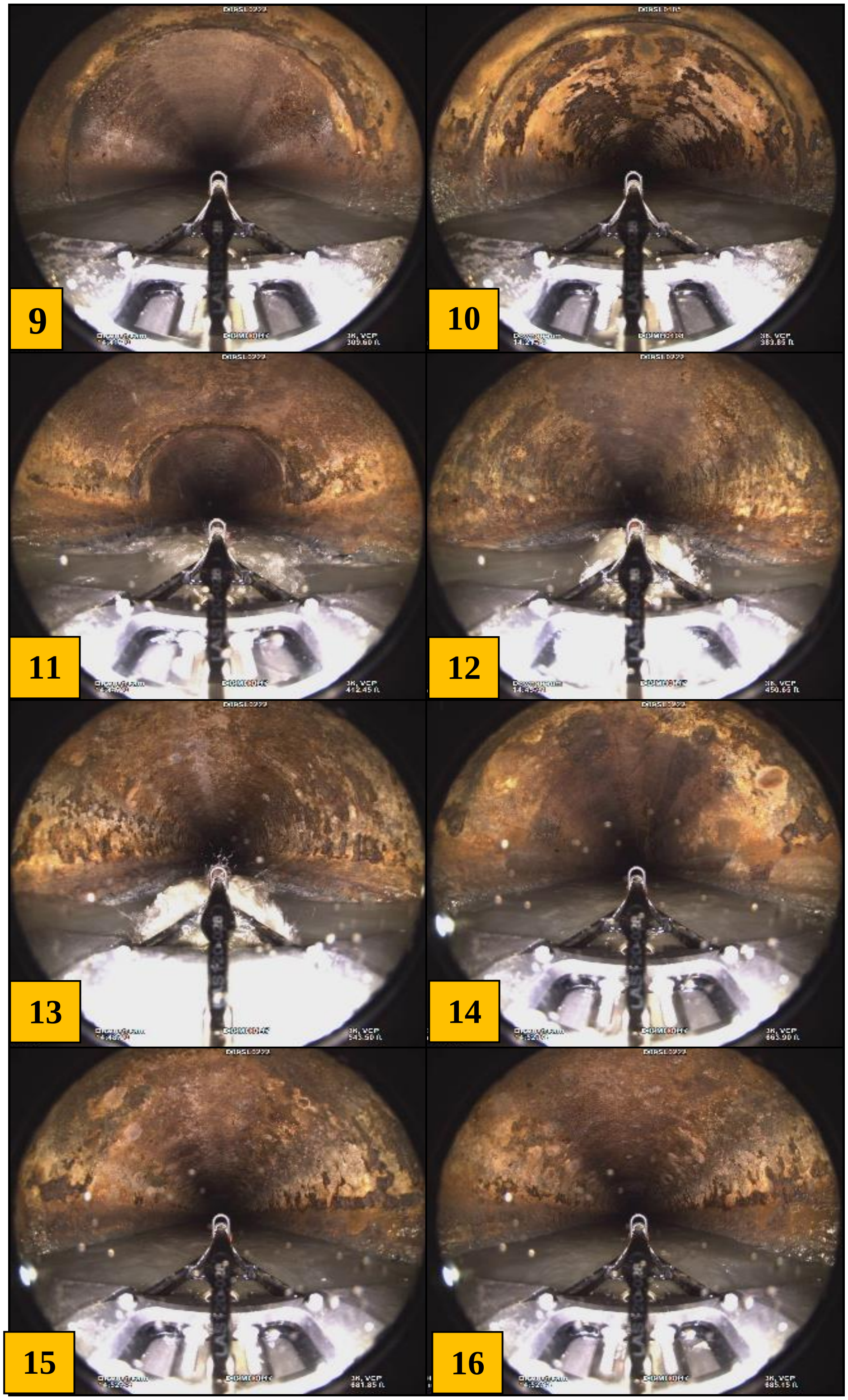


Figure A20-7 images from 9 through 16

Figure A20-8 image 17

Line 21 Summary

Table A21-1 Results Summary of Sewer Line 21

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	376
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	7
Total Debris Volume (ft^3)	73.3
Total Deposits Volume (in^3)	24206.1
Maximum Blockage (%)	7.6
Maximum Deposit Height (in)	1.2

Deposit Data

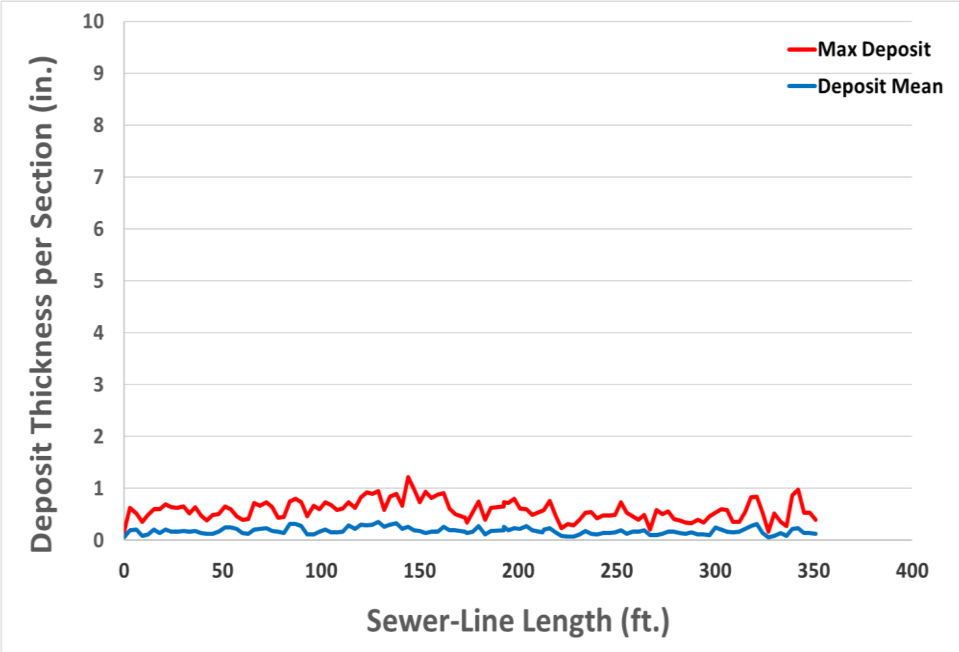


Figure A21-1 Deposit thickness per cross-section

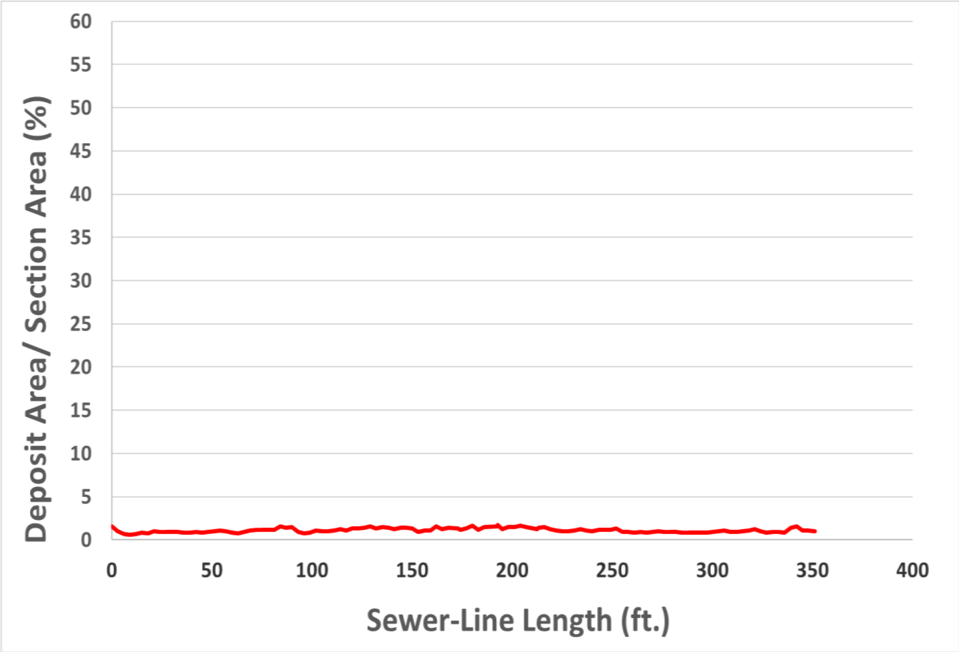


Figure A21-2 Deposit area percentage of the pipe cross section area

Debris Data

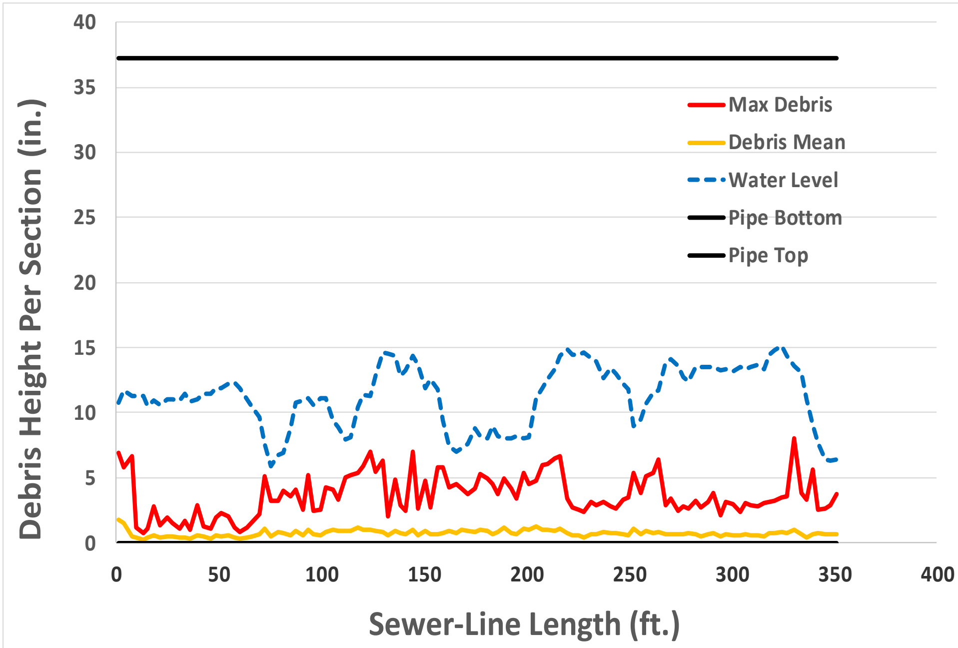


Figure A21-3 Debris height per cross-section

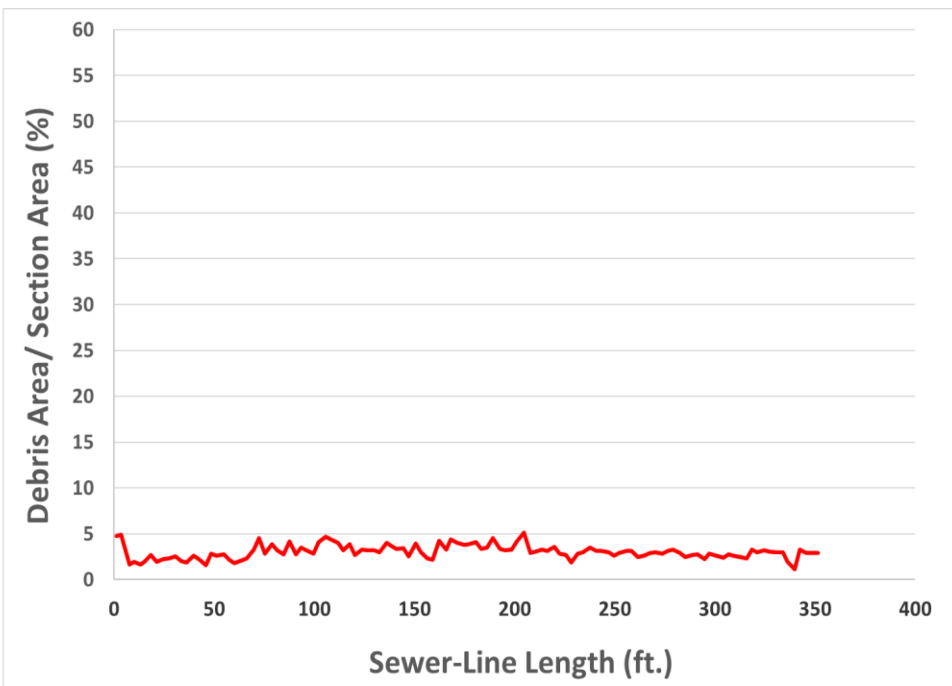


Figure A21-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

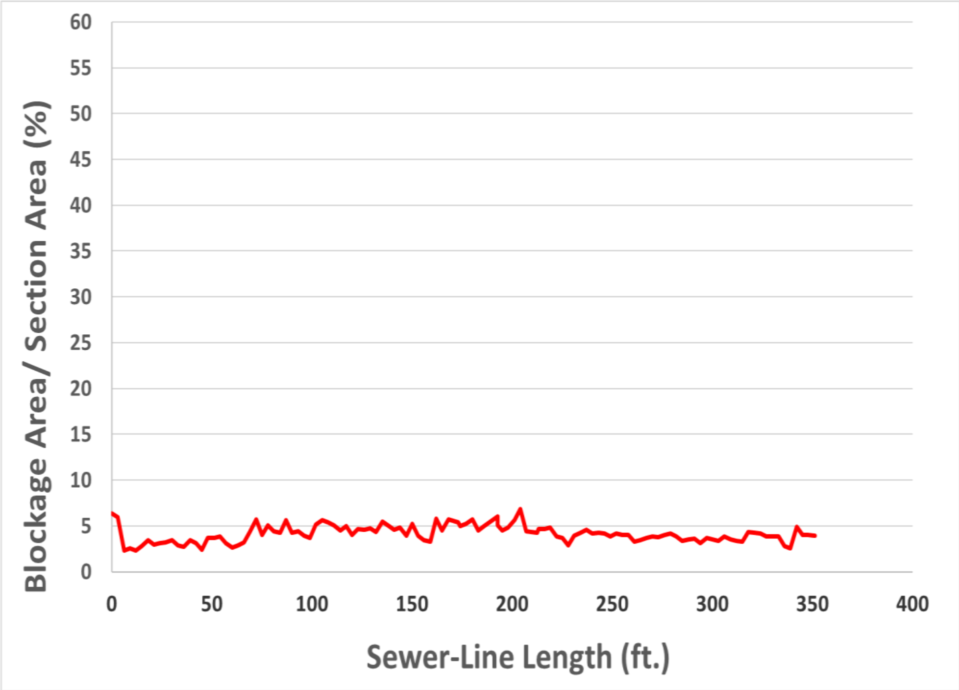


Figure A21-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A21-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				20%					
3	5.05		DAG	S01			10%				1	
4	22.05		DAG	F01							9	
5	39.5		DAG, DAE	S02			5 TO 20%				2,3	
6	93.15		DAG, DAE	F02							10	
7	110.2		DAG	S03			5%				4	
8	183.9		DAG	F03							11	
9	200.1		DAG	S04			10%				5,6	
10	219.7		DAG	F04							12	
11	237		DAG	S05			10%				7	
12	273.25		DAG	F05							13	
13	307.7		DAG	S06			20%				8	
14	326.1		DAG	F06							14	
15	353.45		MSA									

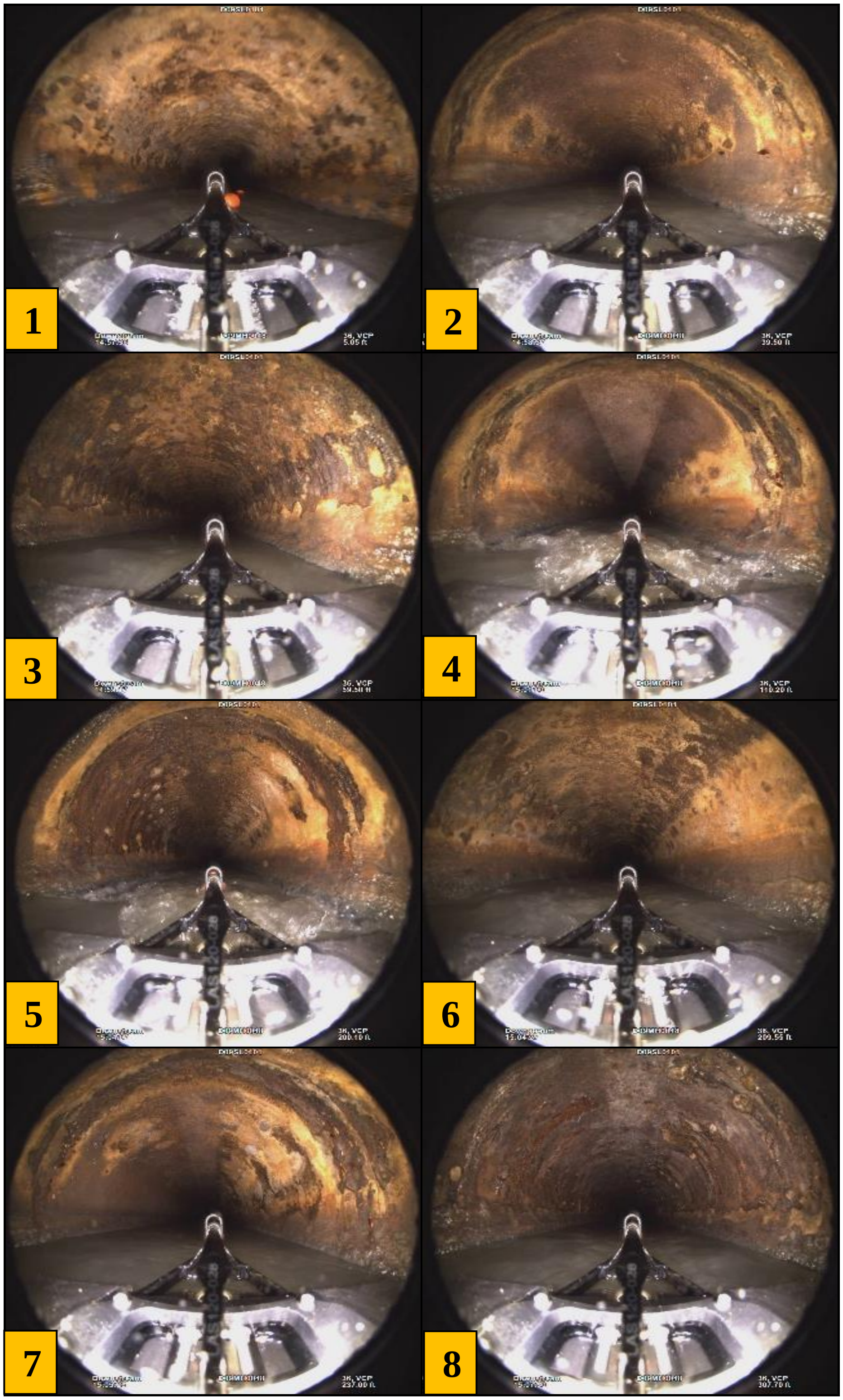


Figure A21-6 images from 1 through 8

Line 22 Summary

Table A22-1: Results Summary of Sewer Line 22

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	519
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	6
Total Fractures Hinge	3
Total Fractures Longitudinal	24
Total Fractures Circumferential	2
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	9
Total Defects	39
Total Debris Volume (ft^3)	24.3
Total Deposits Volume (in^3)	27338.7
Maximum Blockage (%)	11.6
Maximum Deposit Height (in)	0.9

Deposit Data

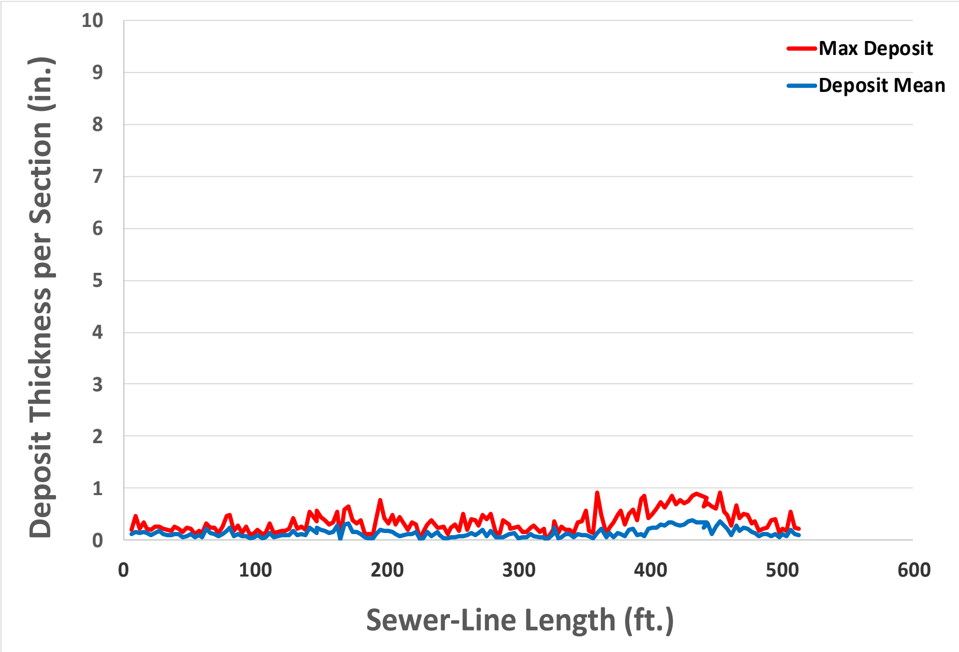


Figure A22-1 Deposit thickness per cross-section

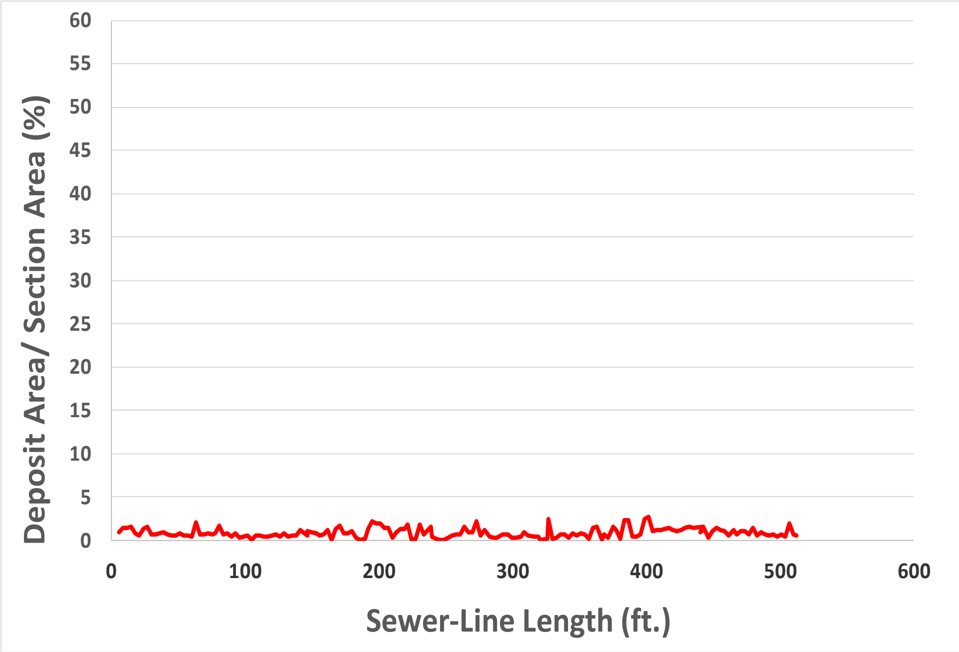


Figure A22-2 Deposit area percentage of the pipe cross section area

Debris Data

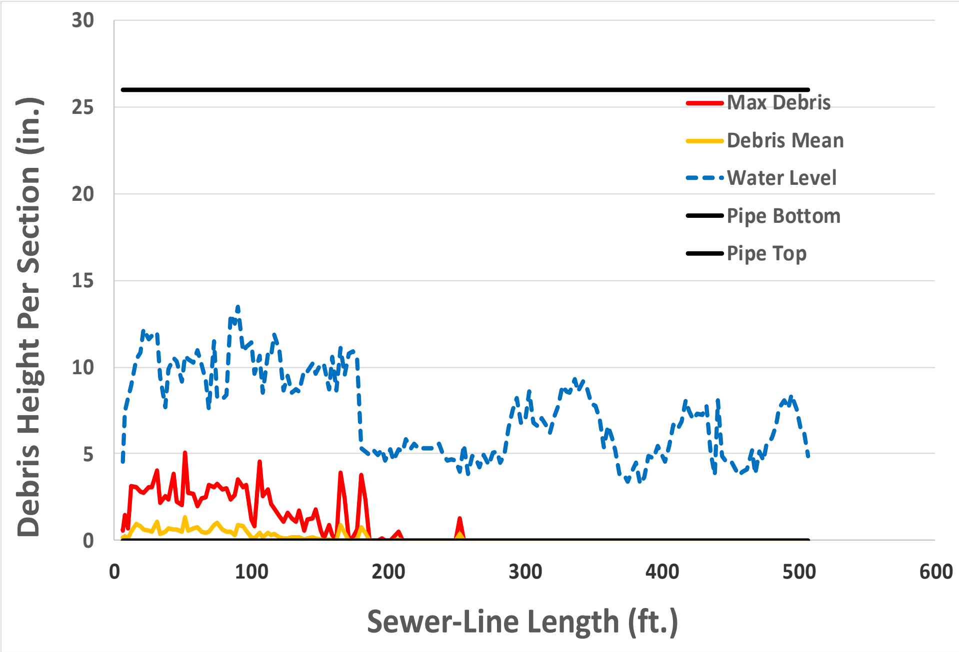


Figure A22-3 Debris height per cross-section

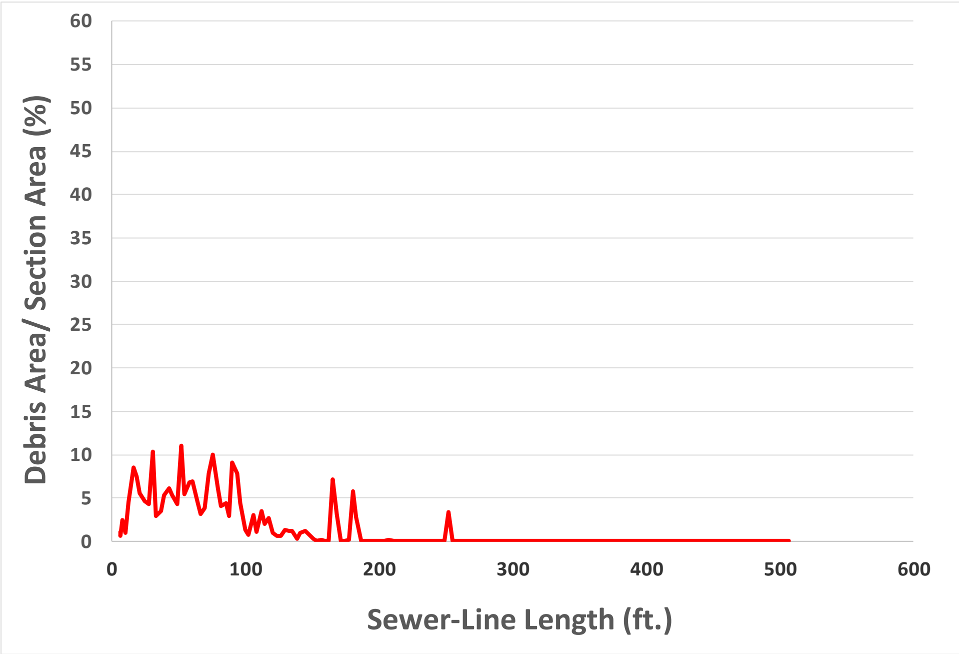


Figure A22-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

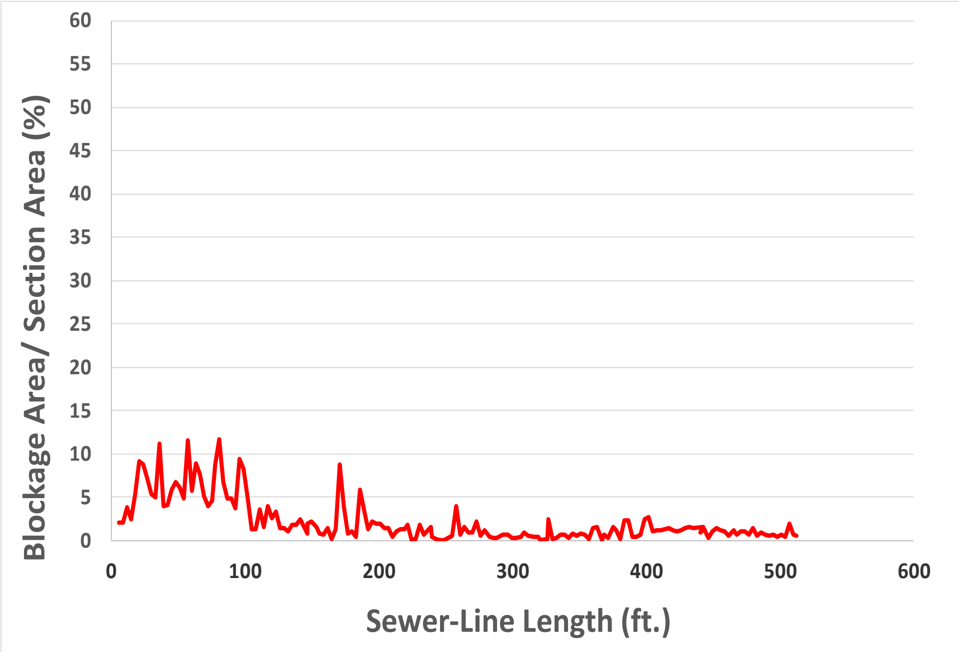


Figure A22-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A22-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value				Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%			At/From	To		
					1st	2nd							
1	0		AMH										
2	6		MWL				10%						
3	60.5		DAE	S01			10%					1,2	
4	65.05		DAE	F01								70	
5	125.6		FL	S02					J			3,38	LASER SHOWS VERY LITTLE VERTICAL FRACTURE MOVEMENT
6	139.55		FL	F02								4	
7	139.55		FM						J			4,39	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT
8	144.85		FL	S03					J			5,40	LASER SHOWS VERY LITTLE FRACTURE HORIZONTAL AND VERTICAL MOVEMENT
9	148.2		FL	F03					J			6	LASER SHOWS VERY LITTLE VERTICAL FRACTURE MOVEMENT
10	148.2		FM									6,41	LASER SHOWS VERY LITTLE VERTICAL FRACTURE MOVEMENT
11	149.7		FL	S04					J			7,42	LASER SHOWS VERY LITTLE FRACTURE OPENING
12	150.25		FC									8,43	LASER DOESN'T SHOW FRACTURE MOVEMENT
13	154.7		FL	F04					J			9	
14	154.7		FL	S05					J			9,44	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT
15	159.65		FL	F05					J			10	
16	159.65		FL	S06					J			10,45	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT
17	164.6		FL	F06					J			11	

18	164.6		FL	S07				J			11,46	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT
19	169.65		FL	F07				J			12	
20	169.65		FL	S08				J			12,47	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT
21	172.45		FL	F08				J			13	
22	172.45		FL	S09				J			13,48	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT
23	172.55		FL	F09							14	
24	172.55		FM	S10							14,49	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT
25	174.6		FM	F10				J			15	
26	174.6		FL								15,50	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT
27	176.94		FM	S11							16,51	LASER DOESN'T SHOW FRACTURE OPENING
28	179.65		FM	F11							71	
29	188.8		DAE	S12			10%	J			17	
30	198.85		DAE	F12							72	
31	236.6		FL	S13							18,19	
32	243.85		FL	F13							20	
33	256.7		FL								21	JUST 1 FOOT
34	323.35		DAE	S14			15%				52	
35	328.15		DAE	F14							75	
36	358.1		DAE	S15			15%				73	
37	362.95		DAE	F15							74	
38	402.15		FL	S16				J			22,53	LASER DOESN'T SHOW FRACTURE OPENING
39	412.35		FL	F16				J			23	
40	412.35		FL	S17				J			23,54	LASER SHOWS BOTH HORIZONTAL AND VERTICAL FRACTURE MOVEMENT
41	417.9		FL	F17				J			24	
42	417.9		FL	S18				J			24,55	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT
43	423.2		FL	F18				J			25	
44	423.2		FH3	S19				J			25,56	LASER SHOWS LITTLE HORIZONTAL MOVEMENT AND LASER RING DEFORMED
45	428		FH3	F19				J			26	
46	428		FL	S20				J			26,57	LASER SHOWS LITTLE HORIZONTAL MOVEMENT AND LASER RING DEFORMED

47	432.85		FL	F20				J			27	
48	432.85		FL	S21				J			27,58	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
49	432.85		FL	S22				J			27,58	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
50	438.25		FL	F21				J			28	
51	438.25		FL	F22				J			28	
52	438.25		FH3	S23				J			28,59	LASER SHOWS BOTH HORIZONTAL AND VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
53	439.8		FC								64	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
54	443.3		FH3	F23				J			29	
55	443.3		FH3	S24				J			29,60	LASER SHOWS BOTH HORIZONTAL AND VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
56	447.3		FH3	F24				J			30	
57	447.3		FL	S25				J			30,61	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
58	452.8		FL	F25				J			31	
59	452.8		FL	S26				J			31,62	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
60	452.8		FL	S27				J			31,62	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
61	455.65		FL	F26							32	
62	455.65		FL	F27							32	
63	455.65		FM								32,63,	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
64	457.8		FL	S28				J			33,65	LASER SHOWS BOTH VERTICAL AND HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
65	462.65		FL	F28				J			34	
66	462.65		FL	S29				J			34,66	LASER SHOWS VERTICAL FRACTURE MOVEMENT
67	465.9		FL	F29							35	

68	465.9		FM	S30							35,67	LASER SHOWS VERTICAL FRACTURE MOVEMENT
69	467.8		FM	F30				J			36	
70	467.8		FL	S31				J			36,68	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
71	472.45		FL	F31				J			37	
72	472.45		FL	S32				J			37,69	LASER SHOWS VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
73	477.45		FL	F32							76	
74	514.3		MSA									

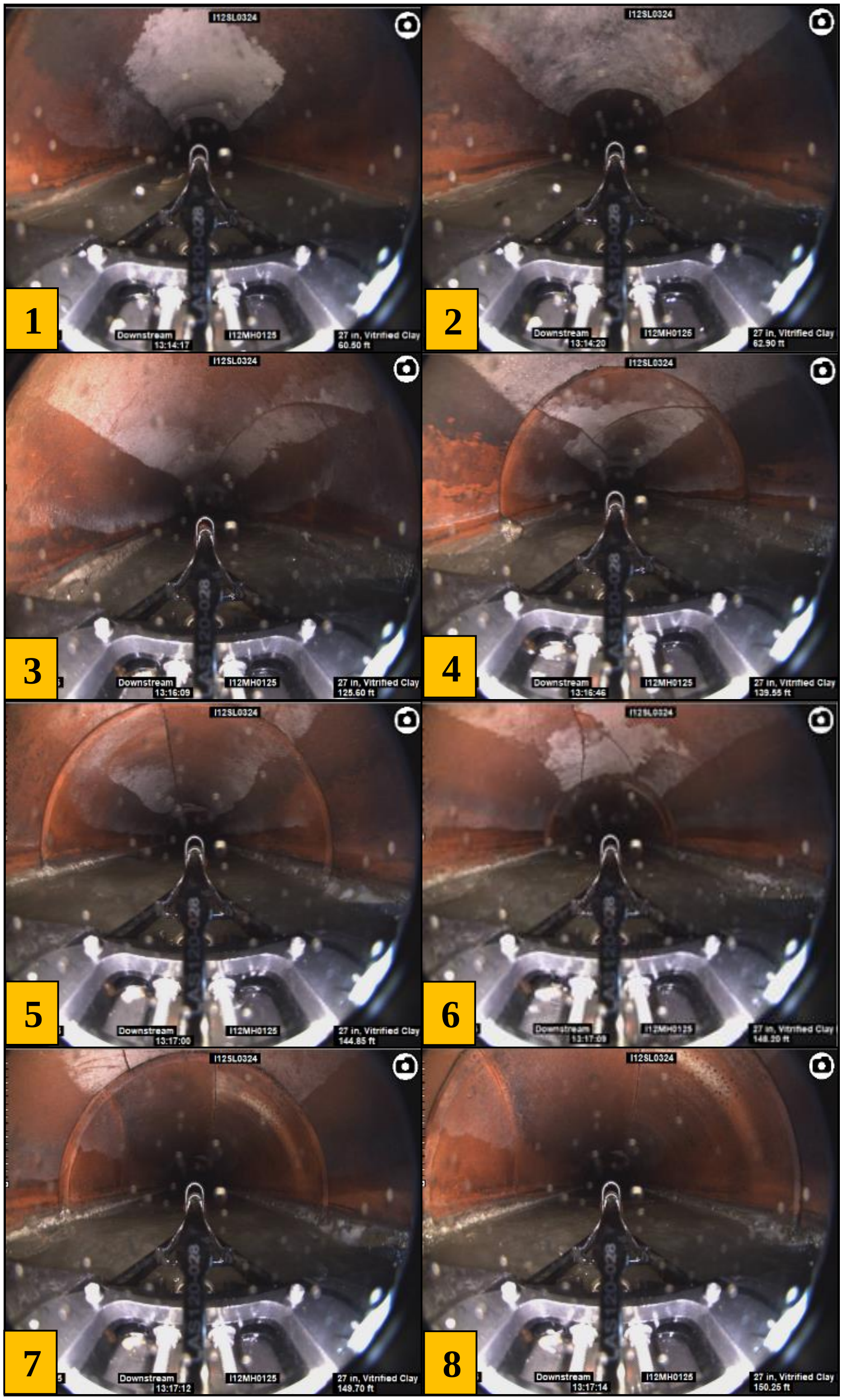


Figure A22-6 images from 1 through 8

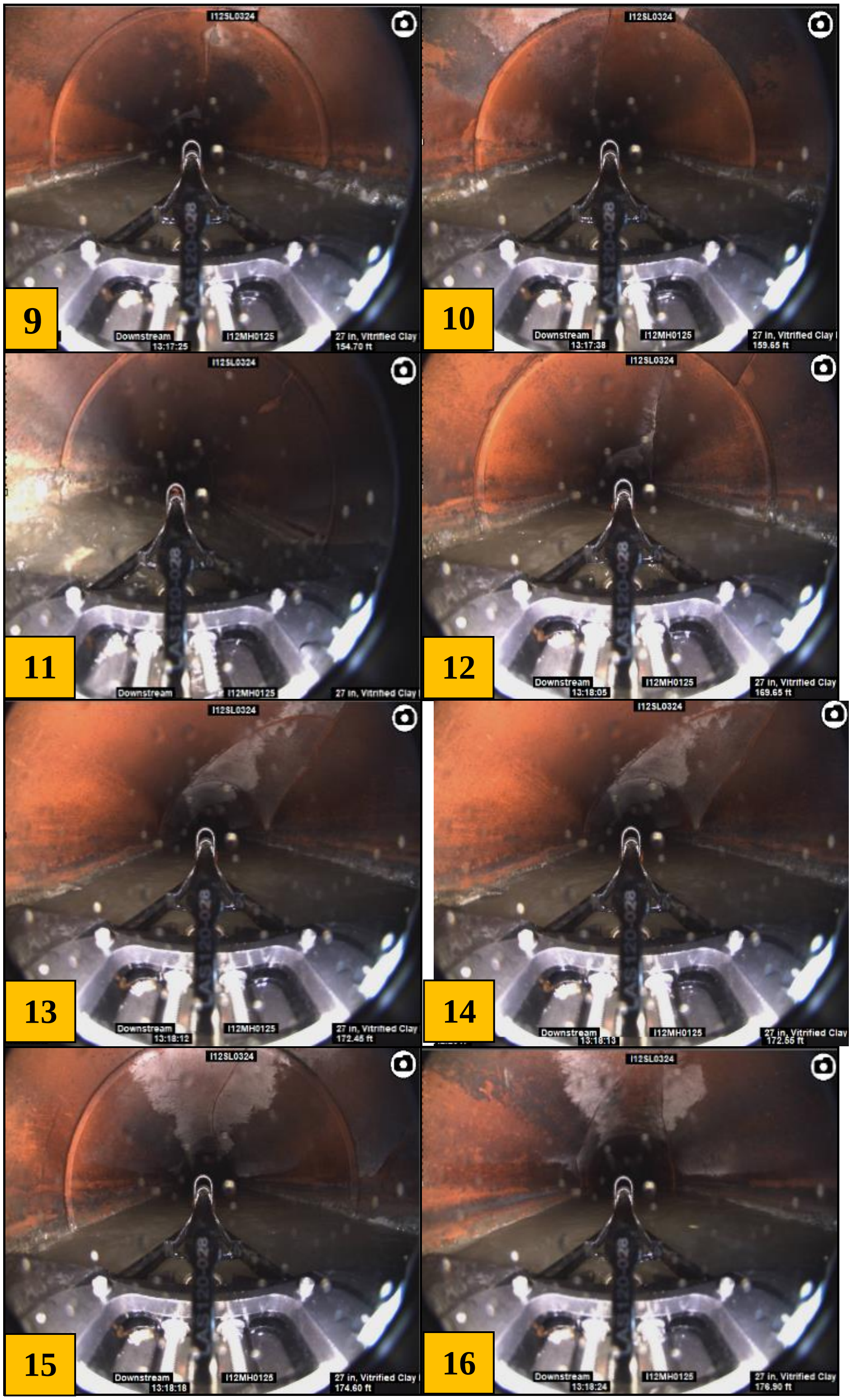


Figure A22-7 images from 9 through 16

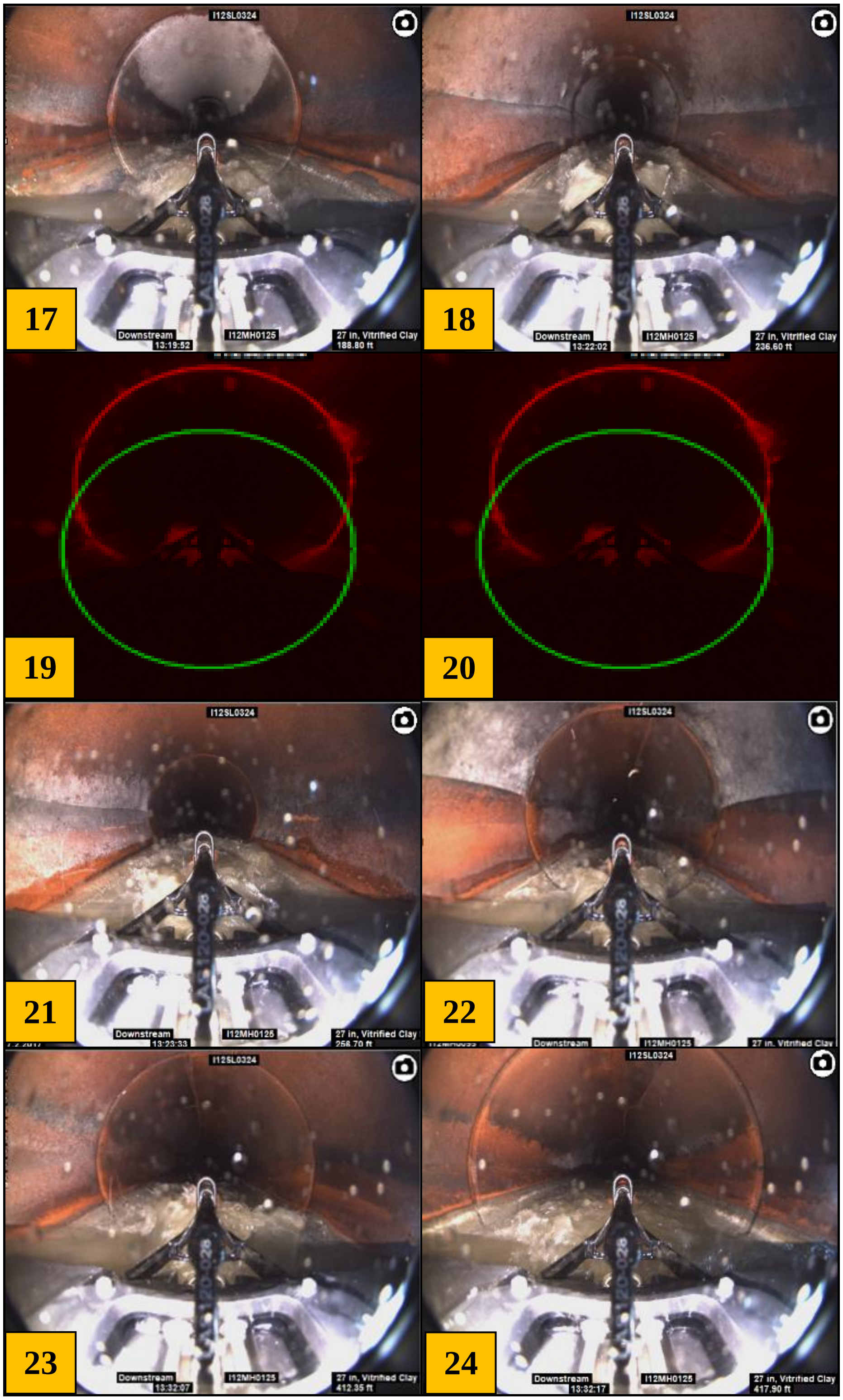


Figure A22-8 images from 17 through 24

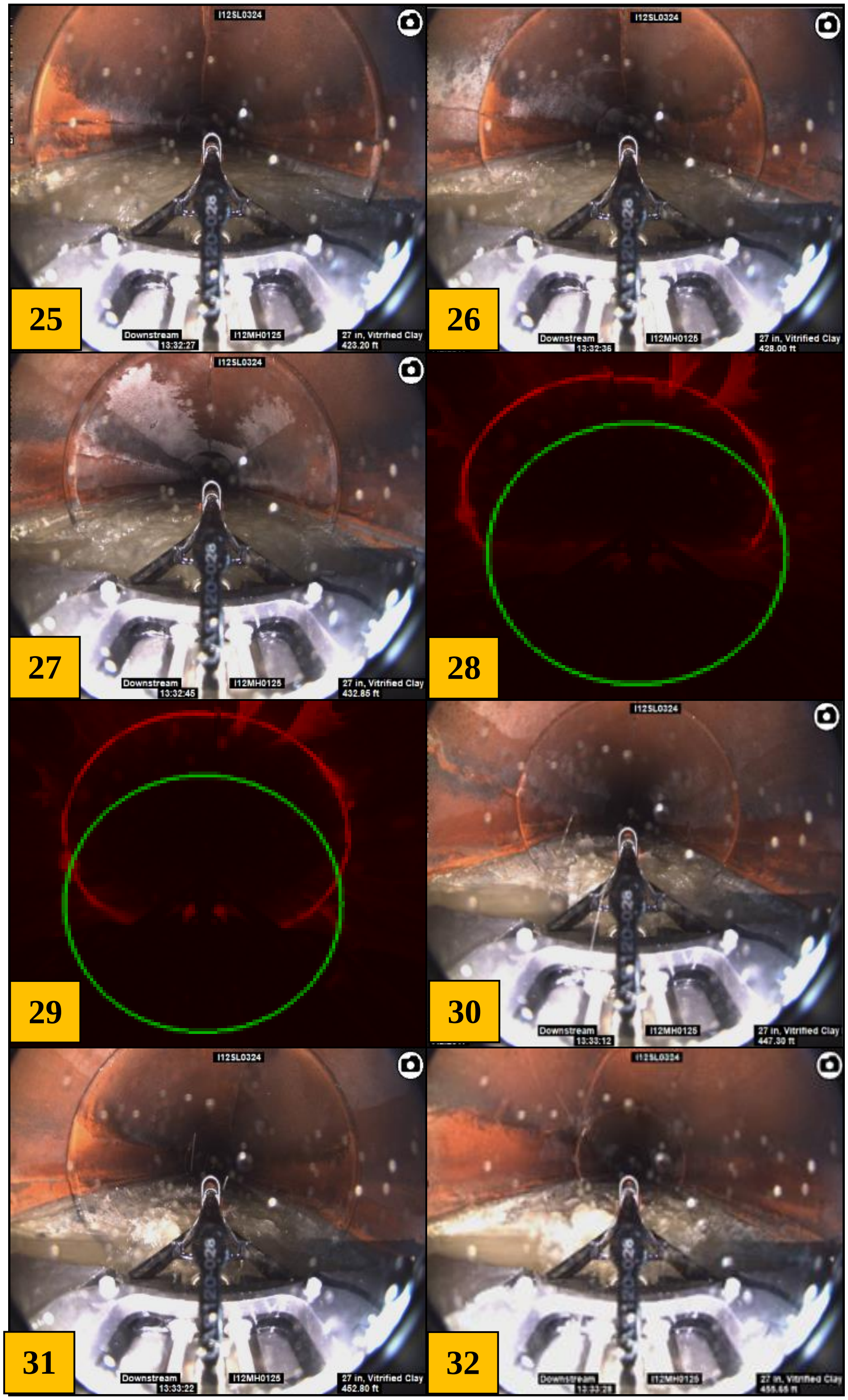


Figure A22-8 images from 25 through 32

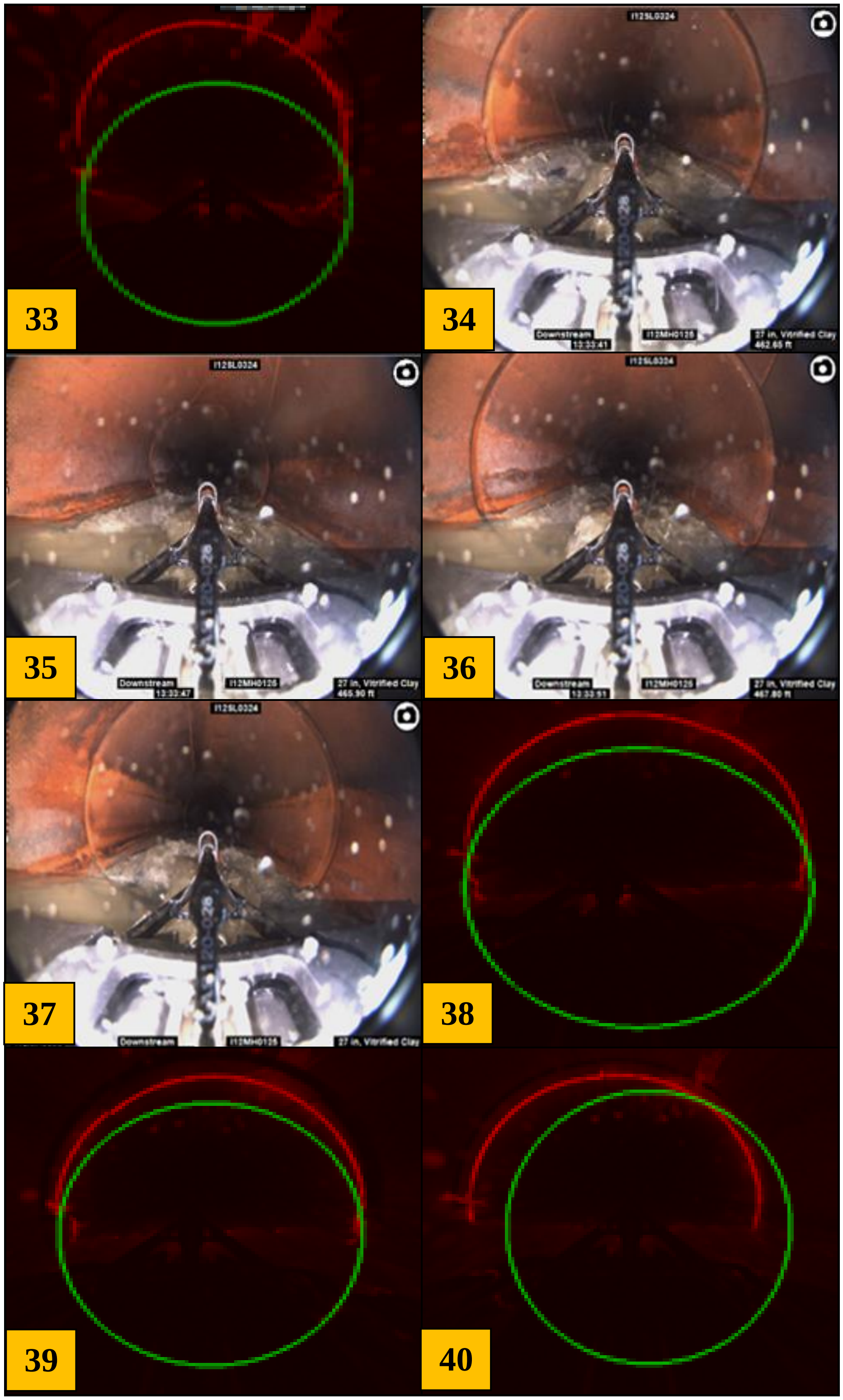


Figure A22-9 images from 33 through40

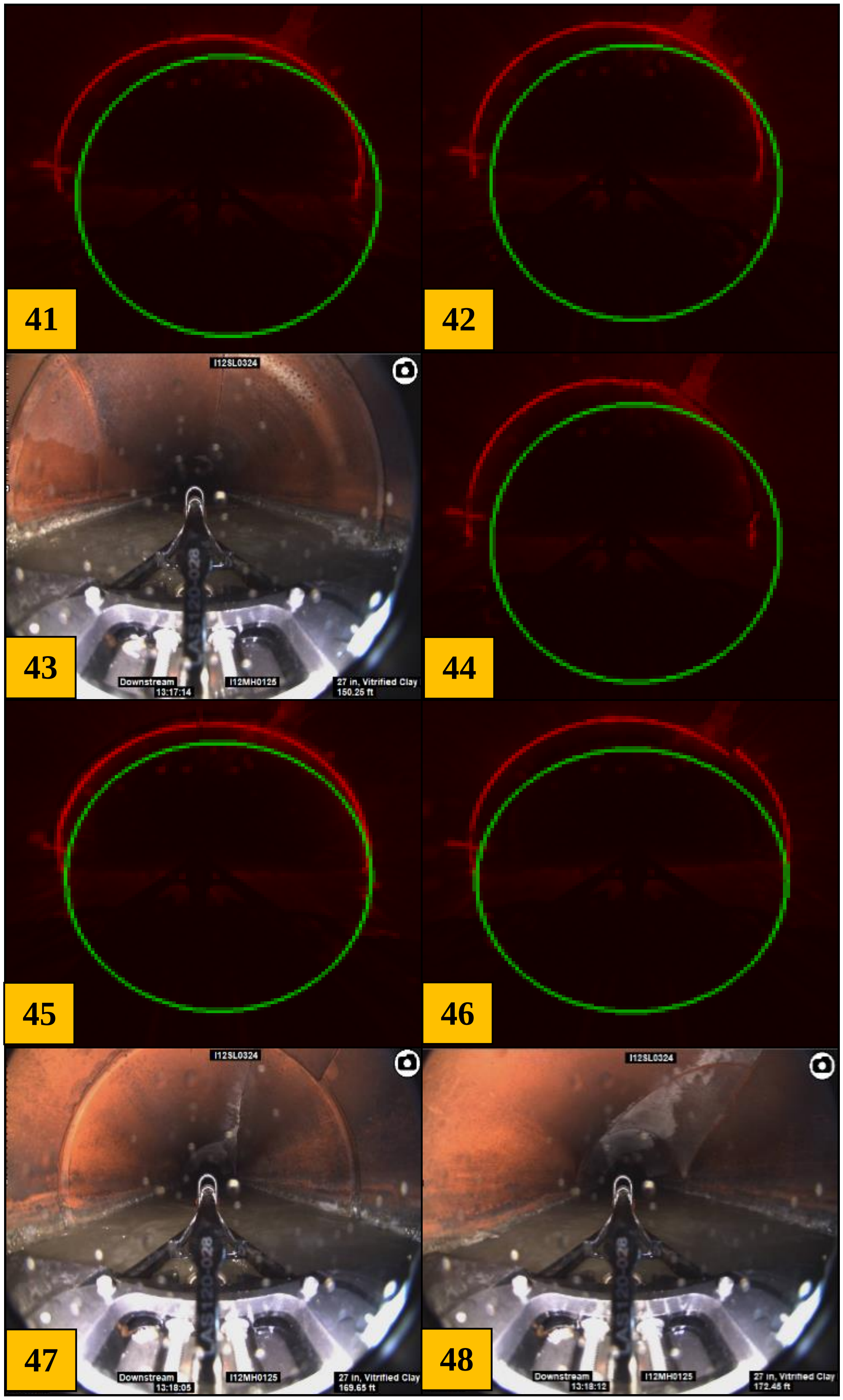


Figure A22-10 images from 40 through 48

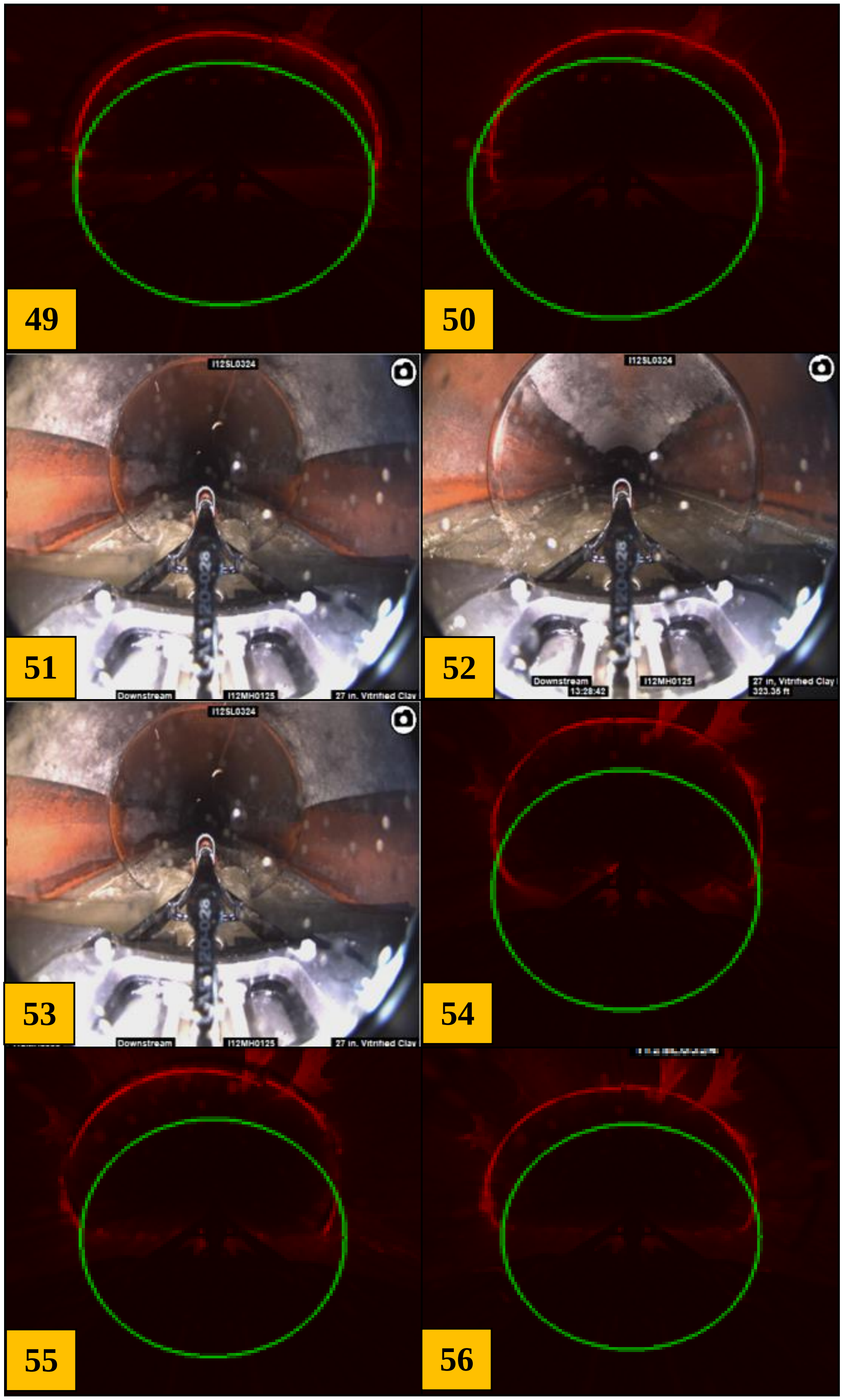


Figure A22-11 images from 49 through 56

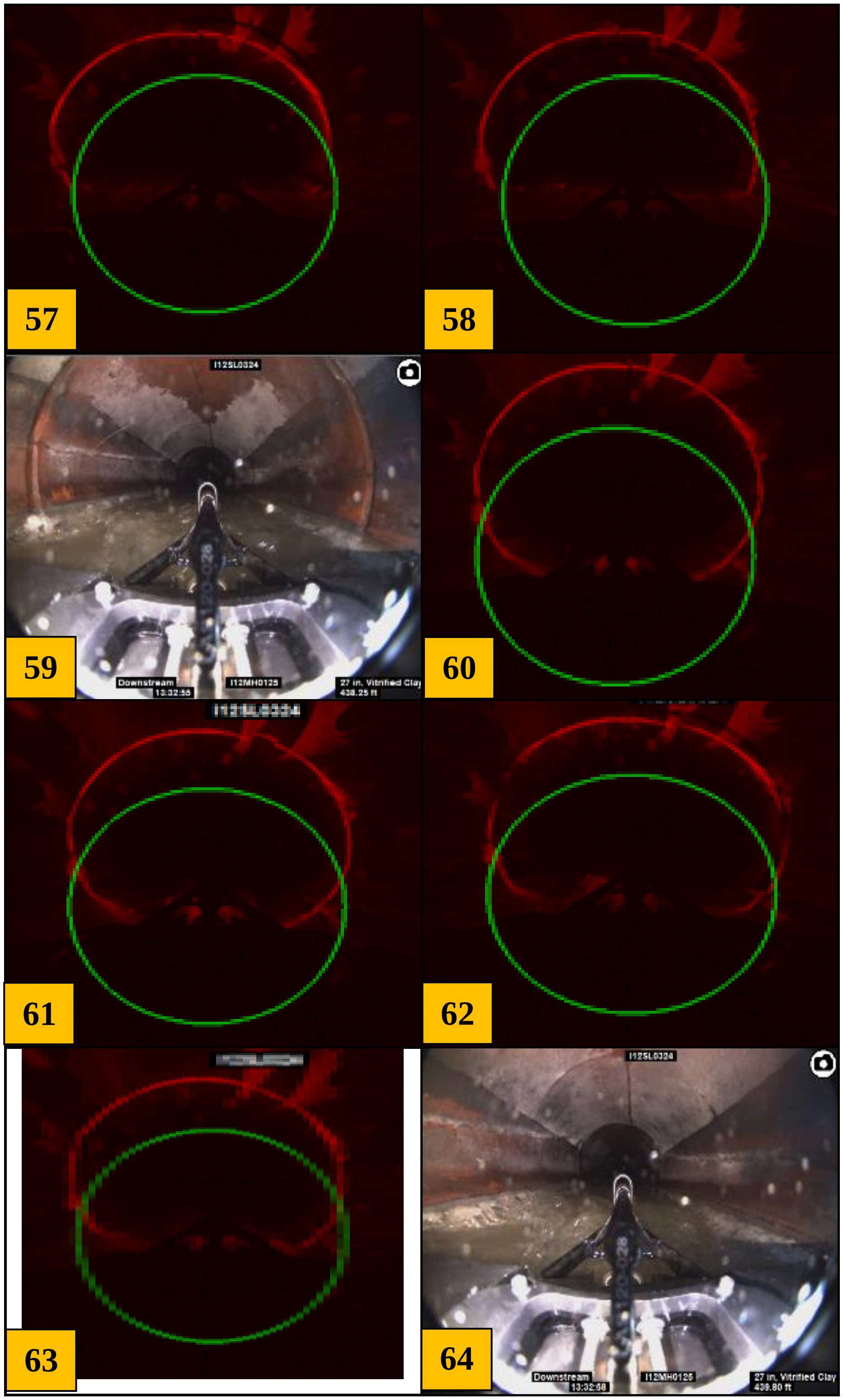


Figure A22-12 images from 57 through 64

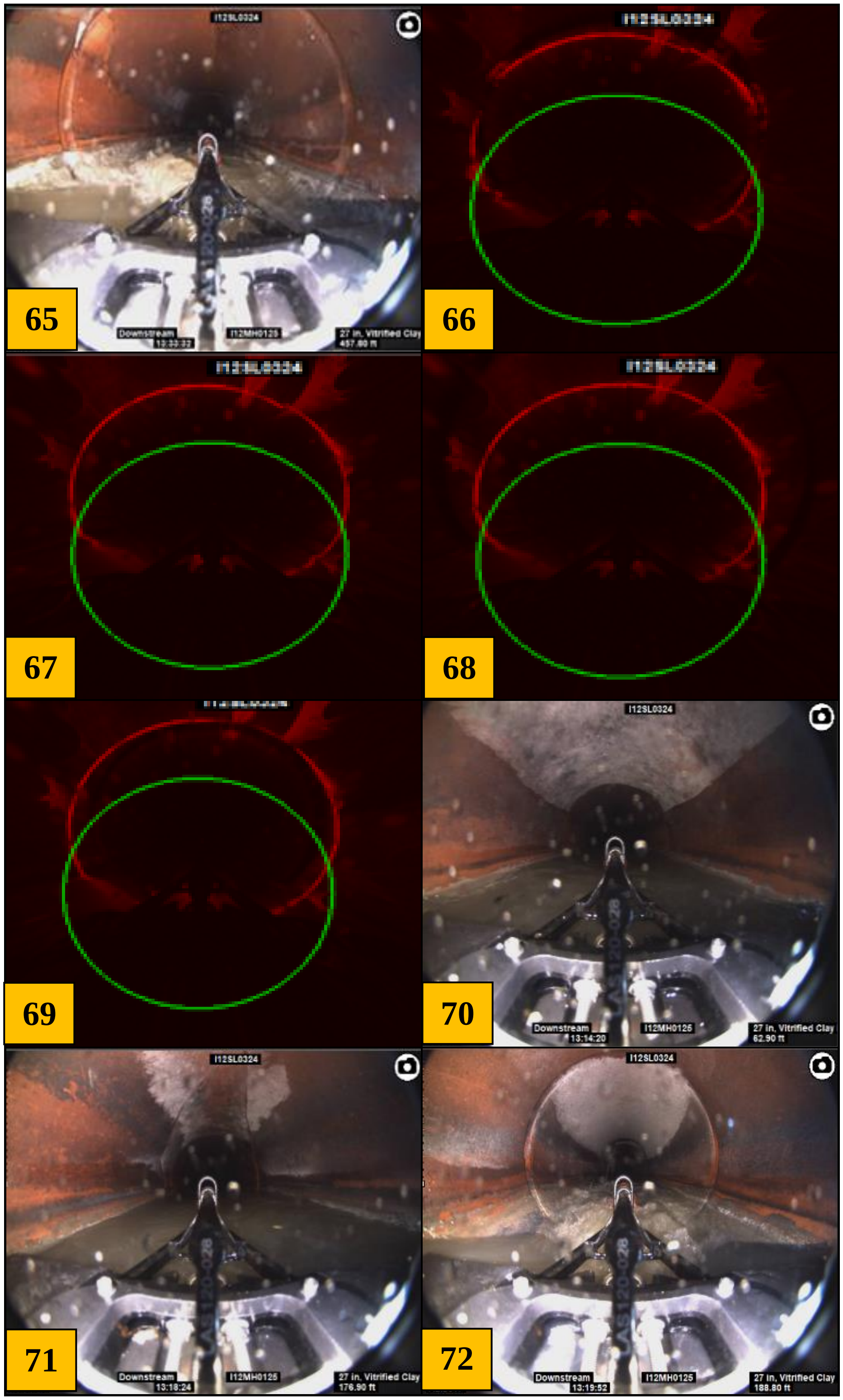


Figure A22-13 images from 57 through 72

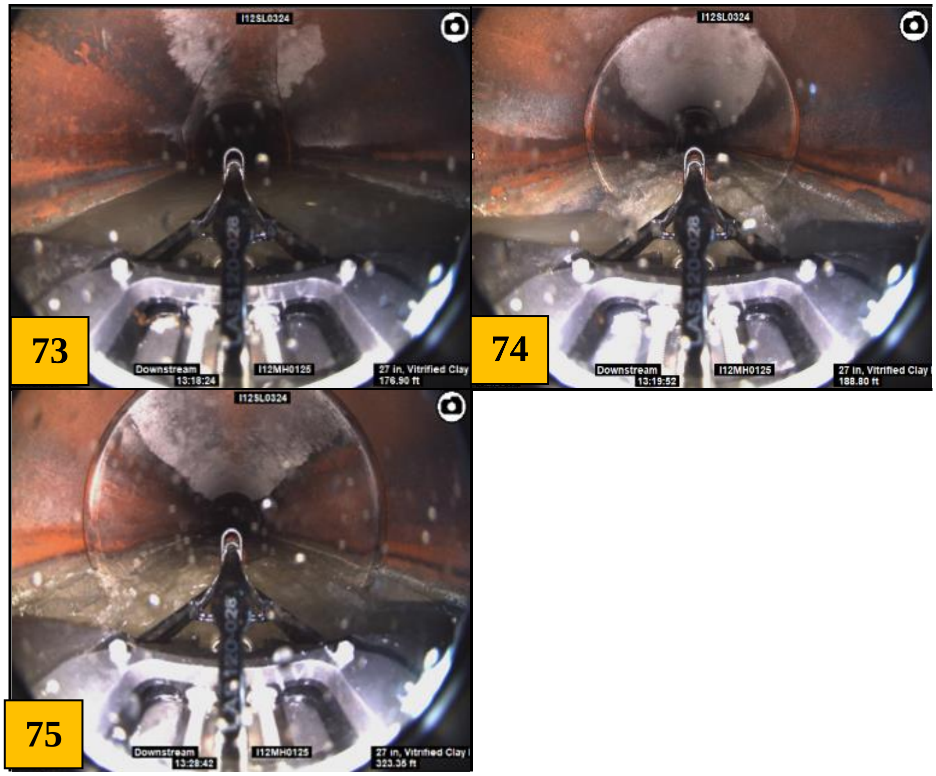


Figure A22-14 images from 73 through 75

Line 23 Summary

Table A23-1 Results Summary of Sewer Line 23

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	495
Percentage of The Line Not Inspected	2.3%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	4
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	4
Total Debris Volume (ft^3)	168.6
Total Deposits Volume (in^3)	25492.6
Maximum Blockage (%)	28.3
Maximum Deposit Height (in)	1.4

Deposit Data

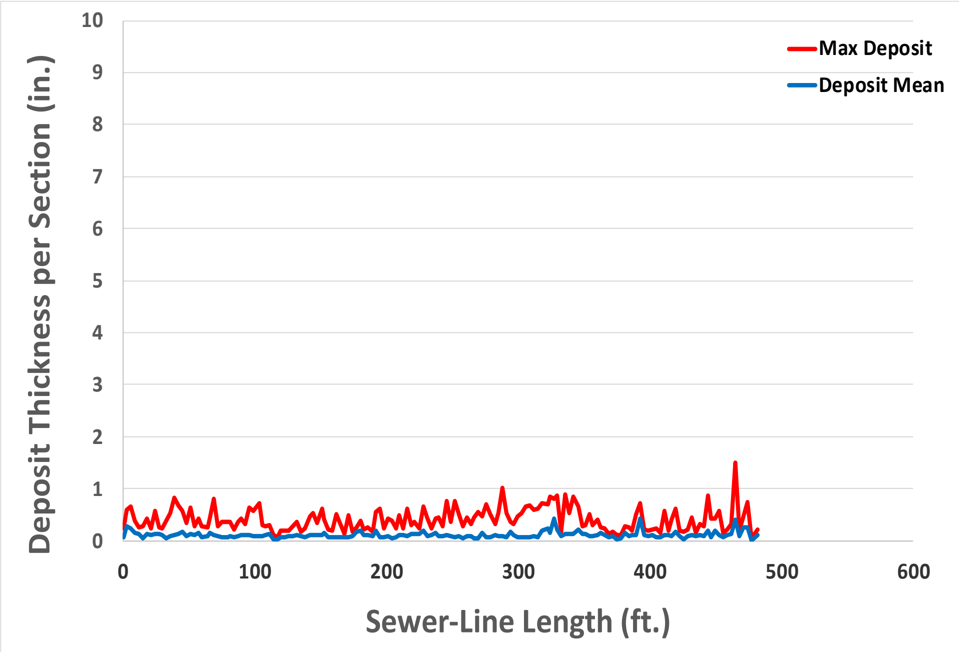


Figure A23-1 Deposit thickness per cross-section

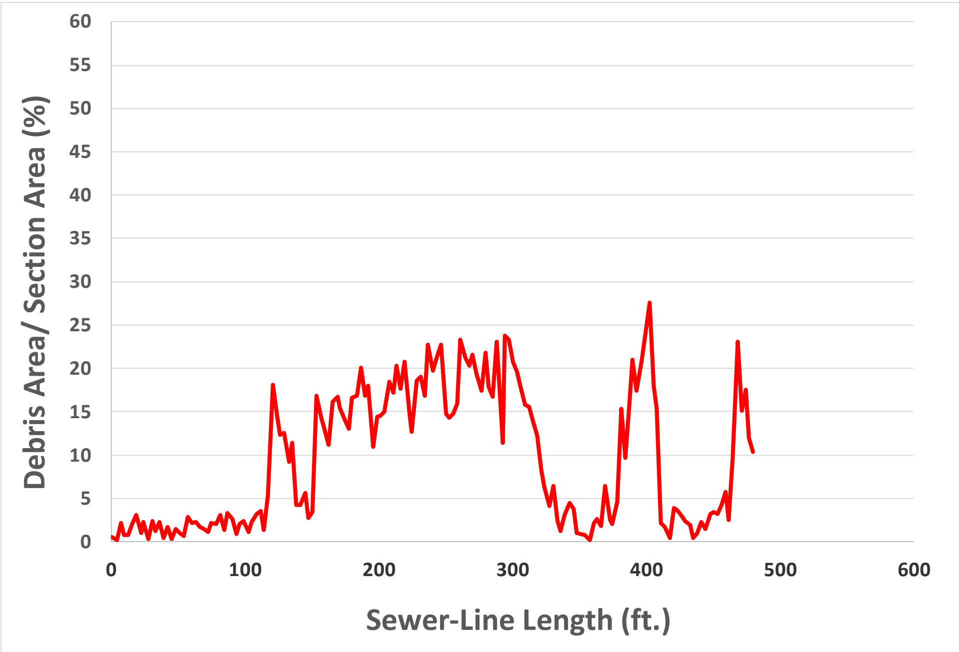


Figure A23-2 Deposit area percentage of the pipe cross section area

Debris Data

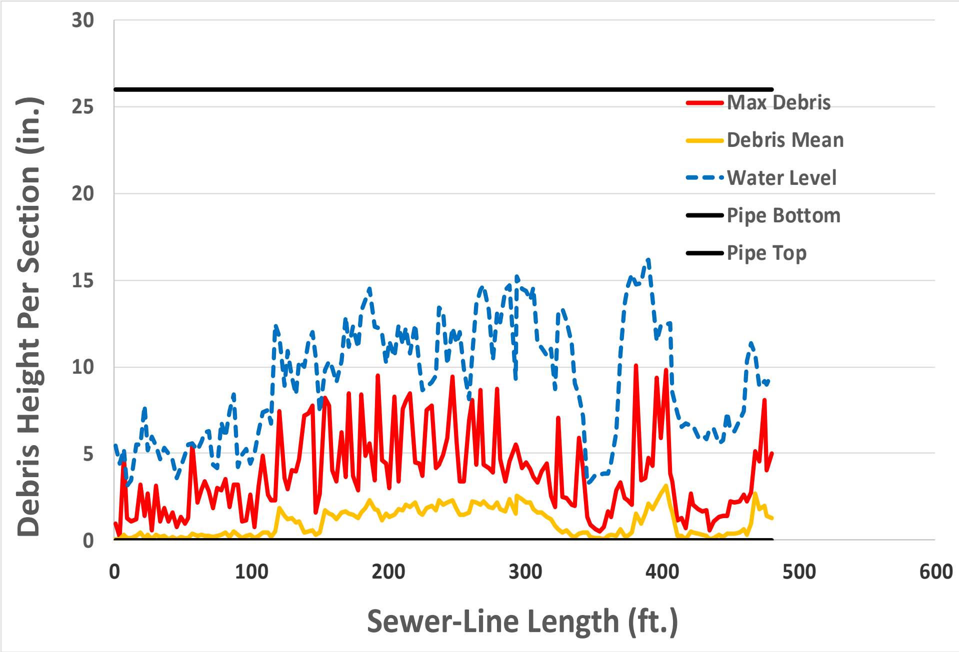


Figure A23-3 Debris height per cross-section

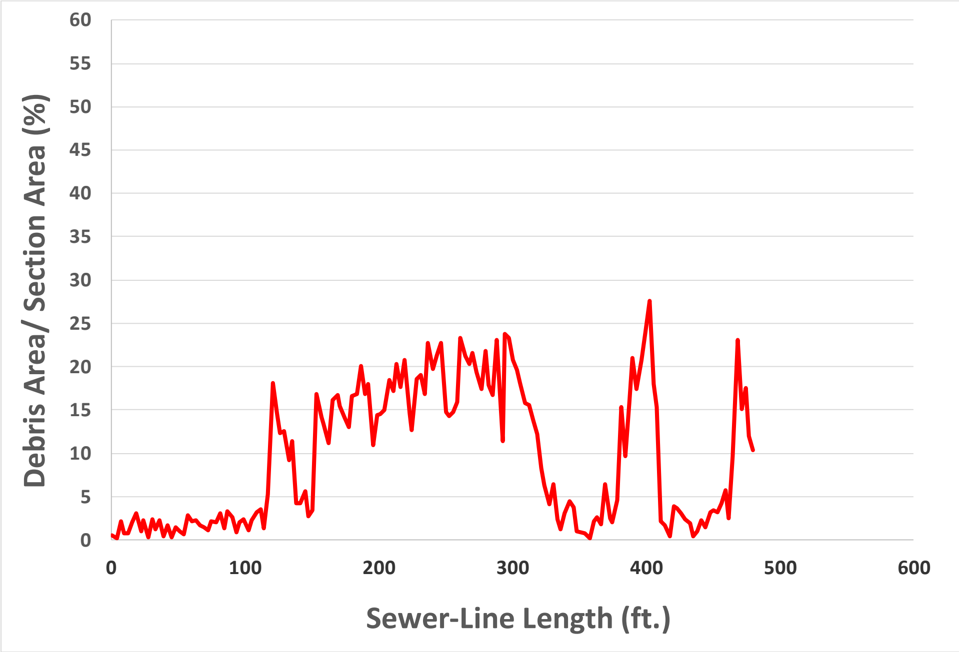


Figure A23-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

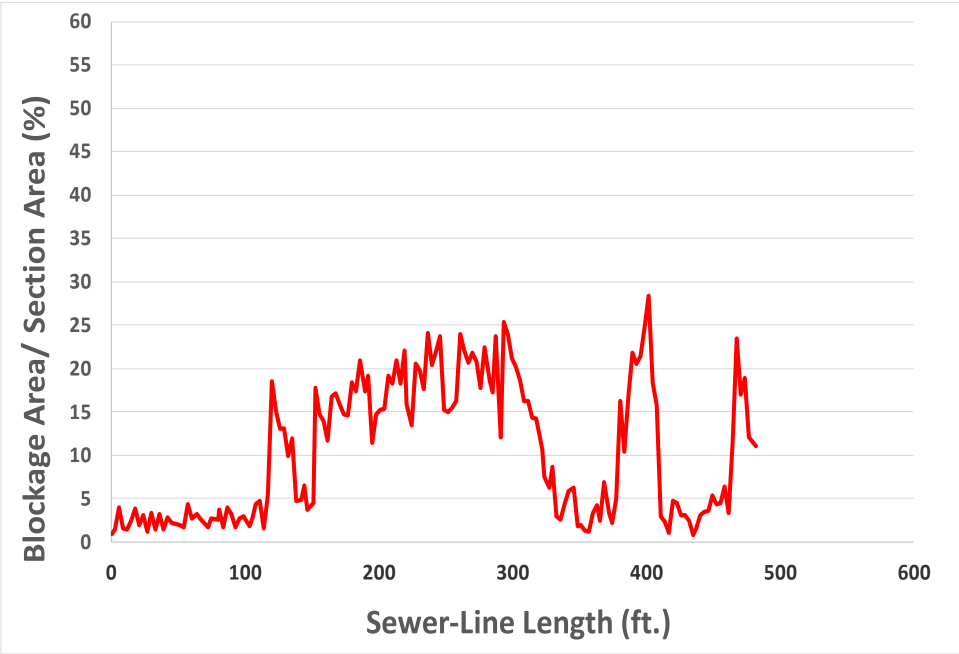


Figure A23-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A23-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				5%					
3	112.95		FL	S01				J			1,8	LASER DOESN'T SHOW FRACTURE MOVEMENT
4	118		FL	F01							2	
5	128.1		FL	S02							3	
6	133.05		FL	F02							4	
7	187.75		FL	S03				J			5,9	LASER DOESN'T SHOW FRACTURE MOVEMENT
8	192.6		FL	F03							6	
9	371.15		FL					J			7,10	LASER DOESN'T SHOW FRACTURE MOVEMENT
10	464.05		MSA									

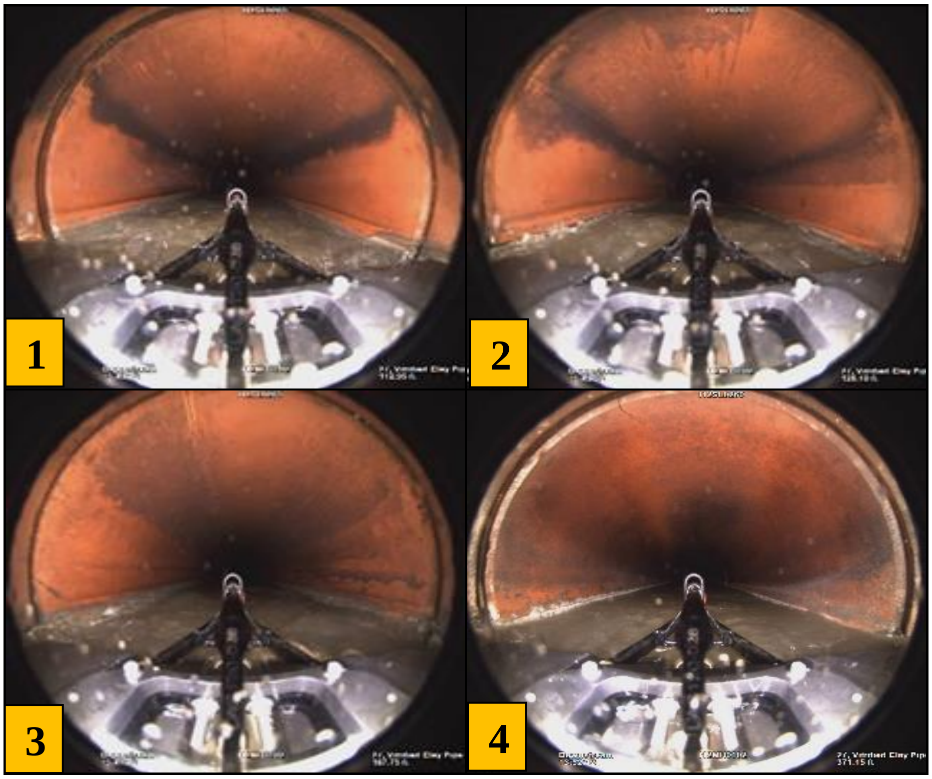


Figure A20-6 images from 1 through 4

Line 24 Summary

Table A24-1 Results Summary of Sewer Line 24

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	483
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	1
Total Fractures Hinge	0
Total Fractures Longitudinal	16
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	1
Total Defects	18
Total Debris Volume (ft^3)	93.9
Total Deposits Volume (in^3)	40538.9
Maximum Blockage (%)	25.2
Maximum Deposit Height (in)	1.9

Deposit Data

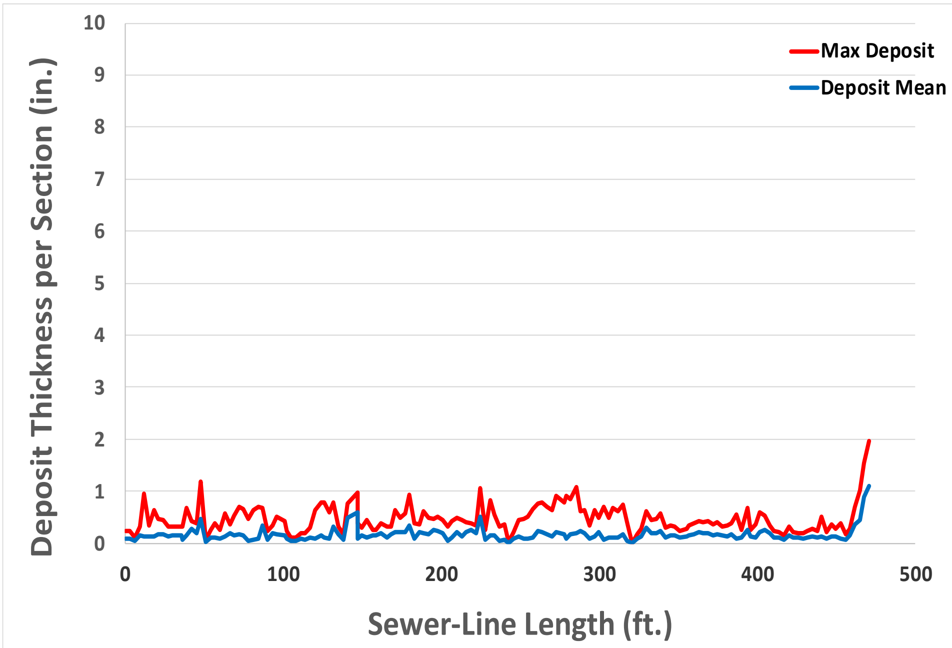


Figure A24-1 Deposit thickness per cross-section

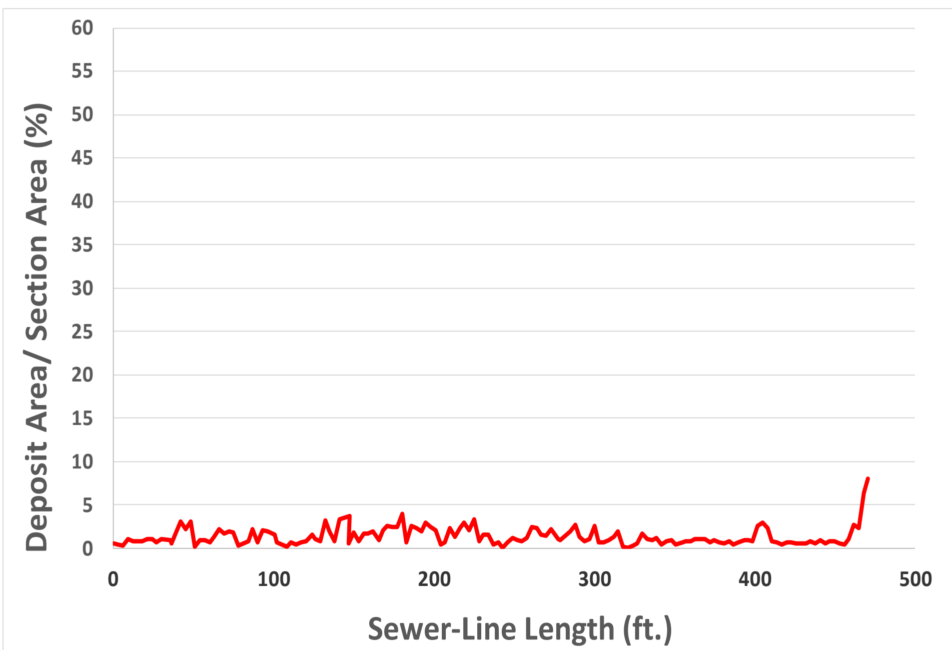


Figure A24-2 Deposit area percentage of the pipe cross section area

Debris Data

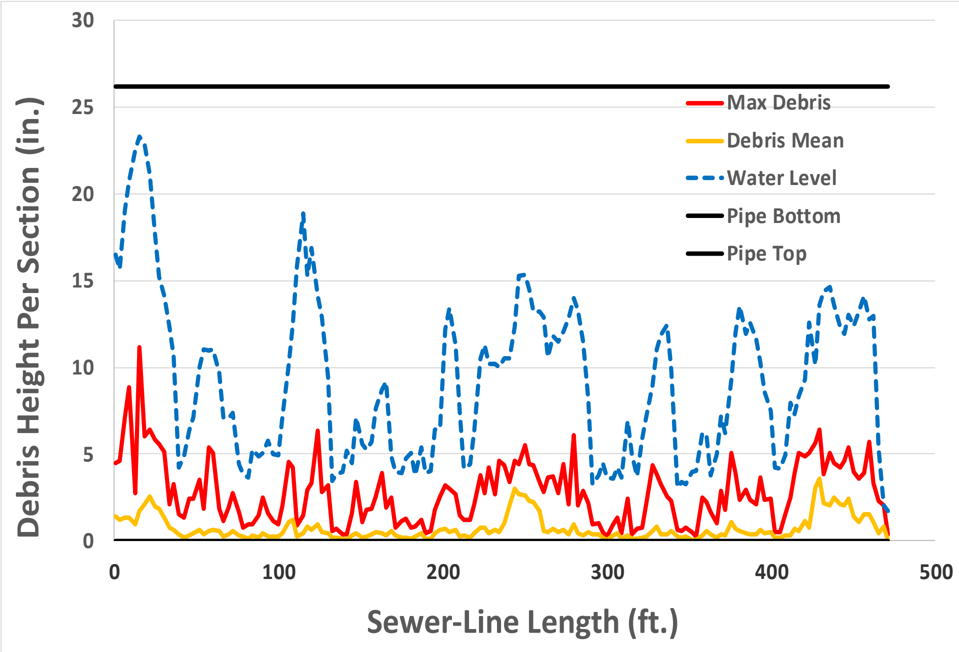


Figure A24-3 Debris height per cross-section

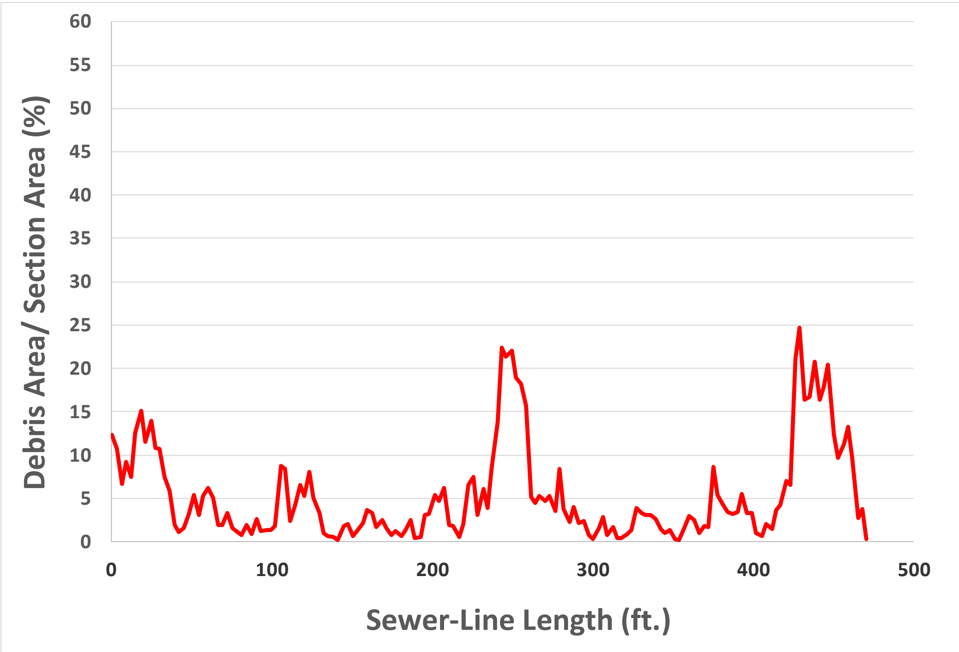


Figure A24-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

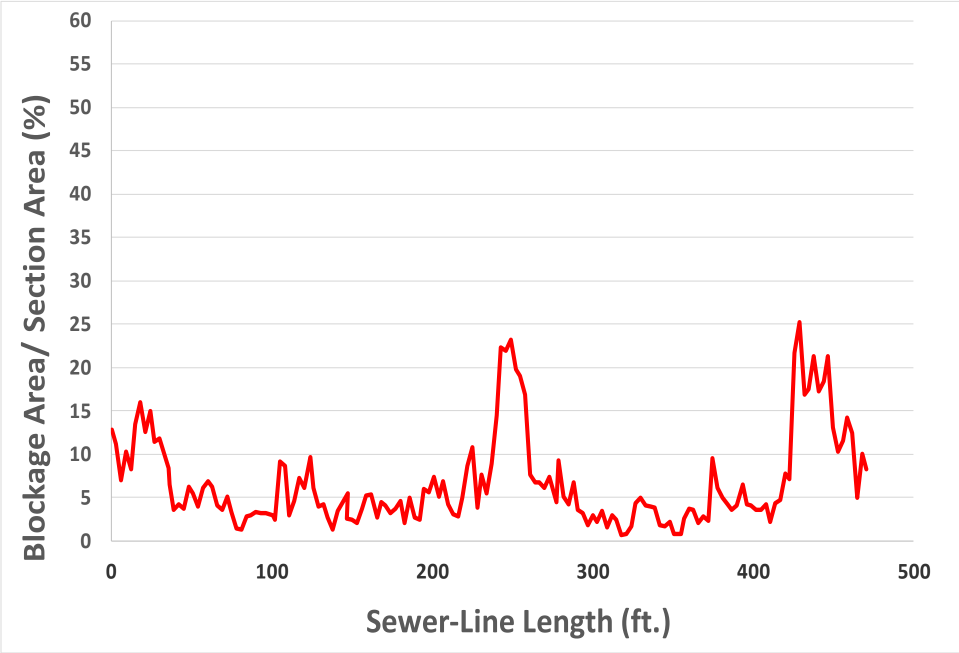


Figure A24-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A24-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				20%					
3	24.2		FL	S01				J			1,18	LASER DOESN'T SHOW FRACTURE MOVEMENT
4	29.05		FL	F01				J			2	
5	29.05		FL	S02				J			2,19	LASER DOESN'T SHOW FRACTURE MOVEMENT
6	33.8		FL	F02				J			3	
7	33.8		FL	S03				J			3	
8	33.8		FL	S04				J			3	
9	38.8		FL	F03							33	
10	38.8		FL	F04							33	
11	321.7		FL	S05				J			4,20	LASER DOESN'T SHOW FRACTURE MOVEMENT
12	326.55		FL	F05				J			5	
13	326.55		FL	S06				J			5,21	LASER SHOWS HORIZONTAL FRACTURE MOVEMENT AND LASER RING SLIGHTLY DEFORMED
14	331.8		FM					J			6,22	LASER DOESN'T SHOW FRACTURE MOVEMENT
15	332		FL	F06				J			6	

16	332		FL	S07				J			6,23	LASER DOESN'T SHOW FRACTURE MOVEMENT
17	336.65		FL	F07				J			7	
18	336.65		FL	S08				J			7,24	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
19	341.5		FL	F08				J			8	
20	341.5		FL	S09				J			8,25	LASER DOESN'T SHOW FRACTURE OPENING AND LASER RING DEFORMED
21	346.75		FL	F09				J			9	
22	346.75		FL	S10				J			9,26	LASER DOESN'T SHOW FRACTURE OPENING
23	356.3		FL	F10				J			10	
24	356.3		FL	S11				J			10,27	LASER DOESN'T SHOW FRACTURE OPENING
25	366.3		FL	F11				J			11	
26	366.3		FL	S12				J			11,28	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
27	371.3		FL	F12				J			12	
28	371.3		FL	S13				J			12,29	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
29	376.45		FL	F13				J			13	
30	376.45		FL	S14				J			13,30	LASER DOESN'T SHOW FRACTURE OPENING AND LASER RING DEFORMED
31	381.7		FL	F14				J			14	
32	381.7		FL	S15				J			14,31	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
33	386.55		FL	F15				J			15	
34	386.55		FL	S16				J			15,32	LASER DOESN'T SHOW FRACTURE MOVEMENT
35	391.45		FL	F16							16	
36	475.5		DAE				5%	J			17	
37	478.7		MSA									

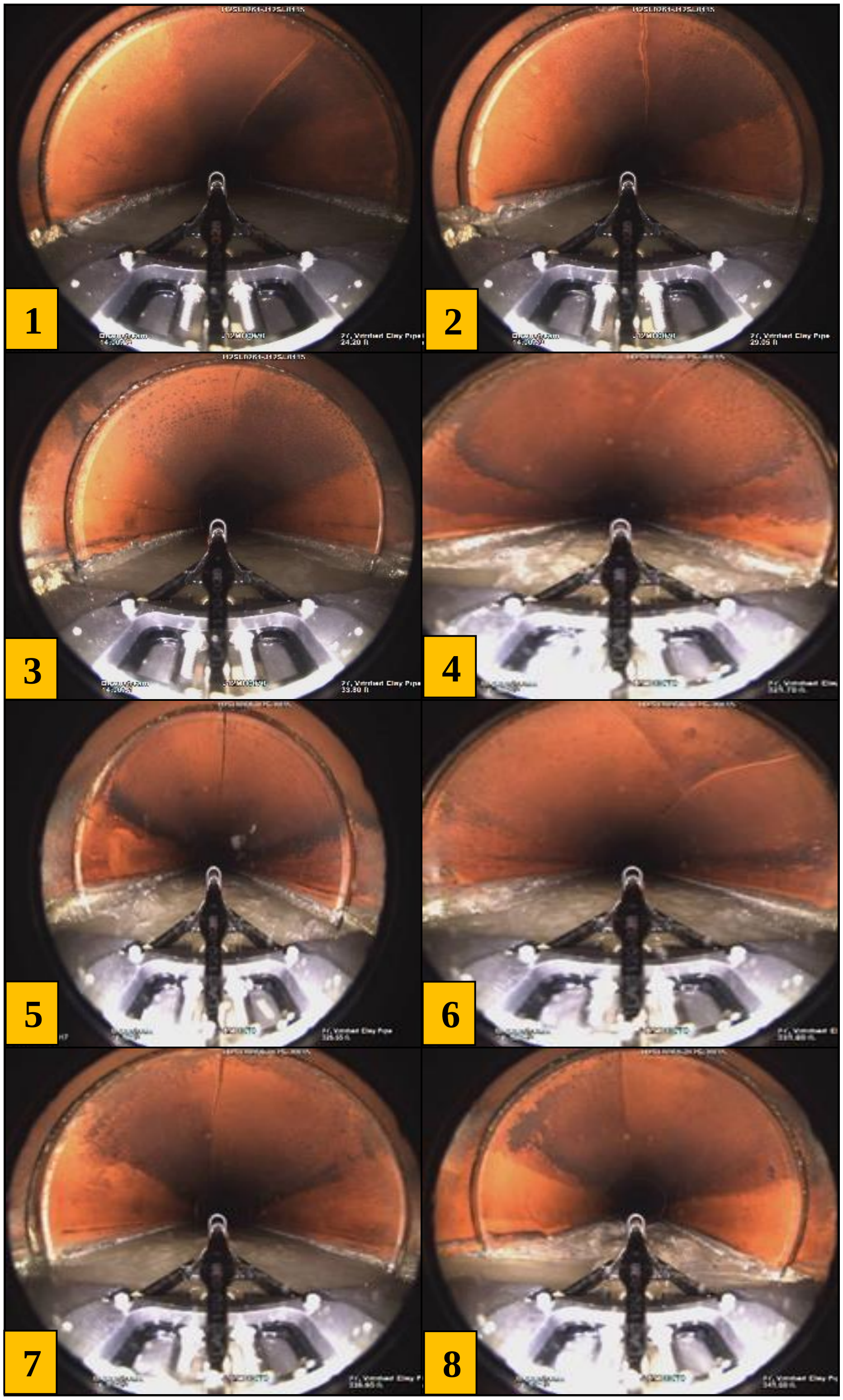


Figure A24-6 images from 1 through 8

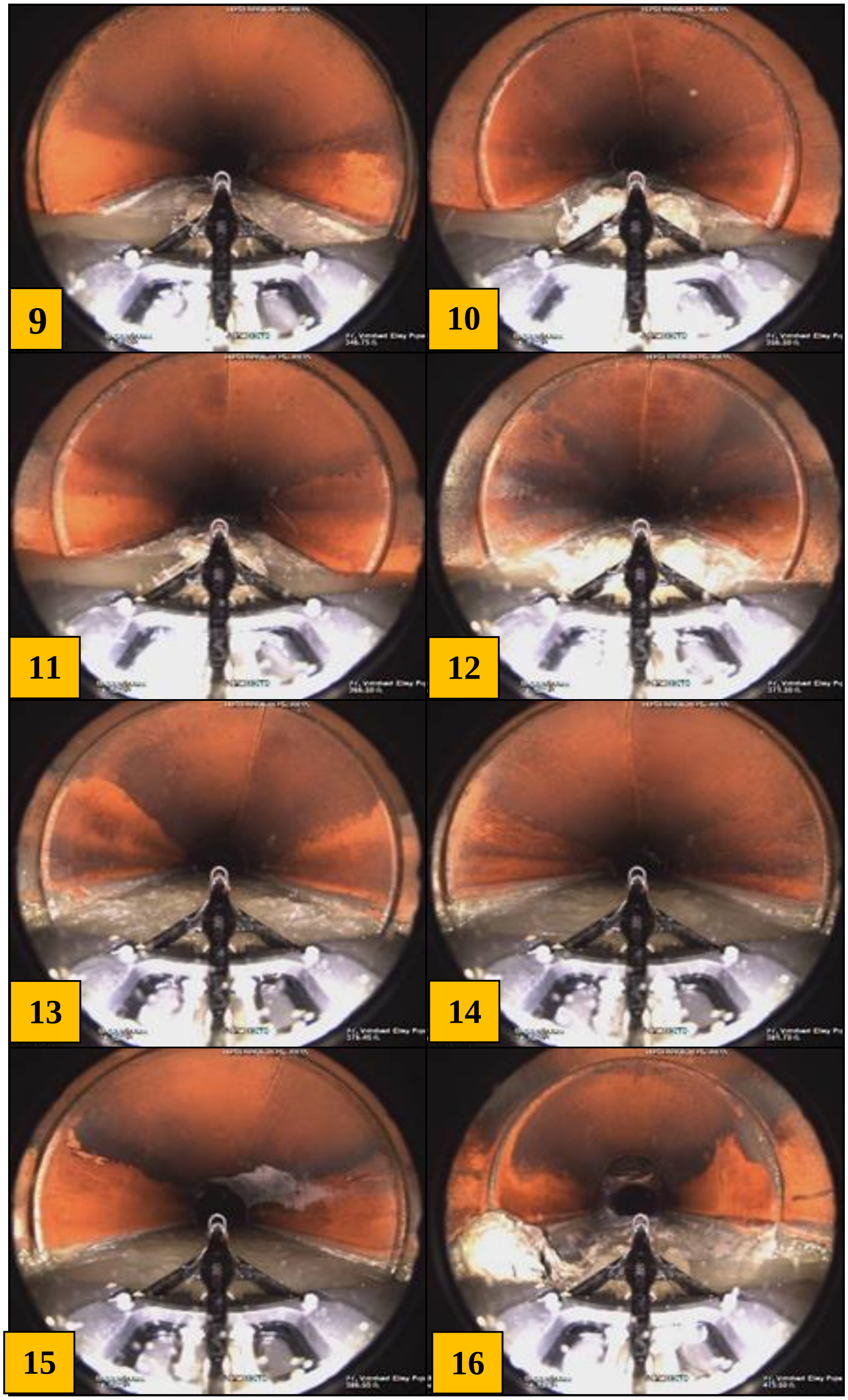


Figure A24-7 images from 9 through 16

17

Figure A24-8 image17

Line 25 Summary

Table A25-1 Results Summary of Sewer Line 25

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	501
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	11
Total Fractures Hinge	0
Total Fractures Longitudinal	20
Total Fractures Circumferential	0
Broken	1
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	10
Level 5 Defects	0
Level 4 Defects	12
Total Defects	41
Total Debris Volume (ft^3)	9.8
Total Deposits Volume (in^3)	50329.6
Maximum Blockage (%)	8.2
Maximum Deposit Height (in)	1.7

Deposit Data

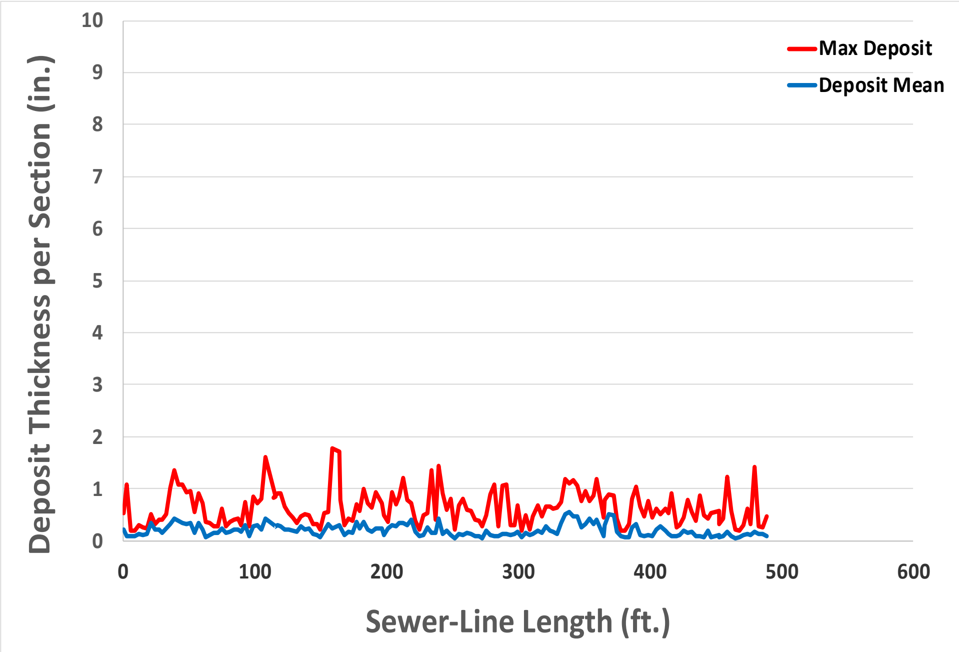


Figure A25-1 Deposit thickness per cross-section

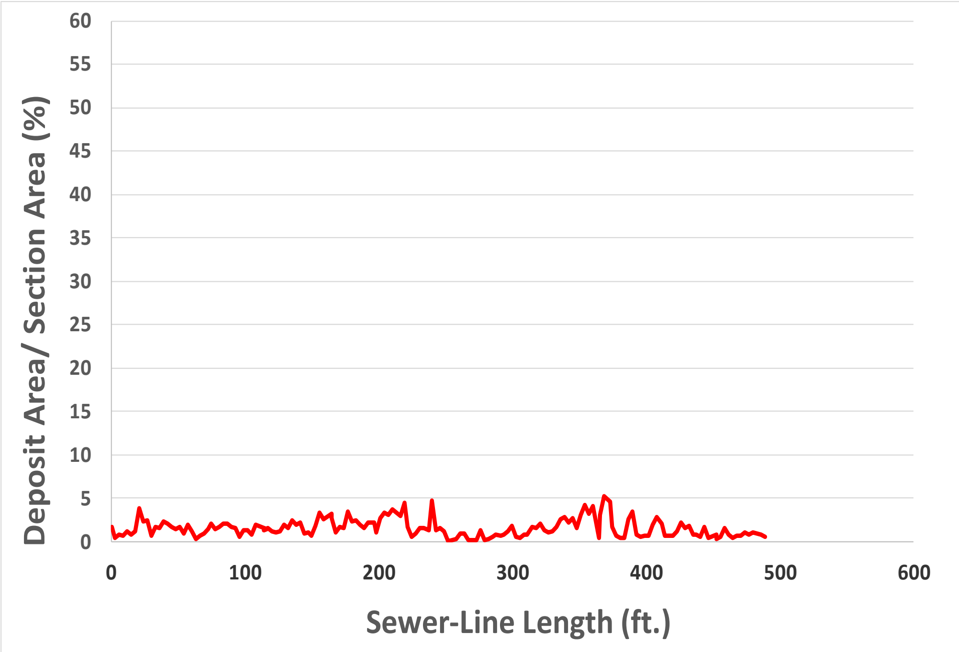


Figure A25-2 Deposit area percentage of the pipe cross section area

Debris Data

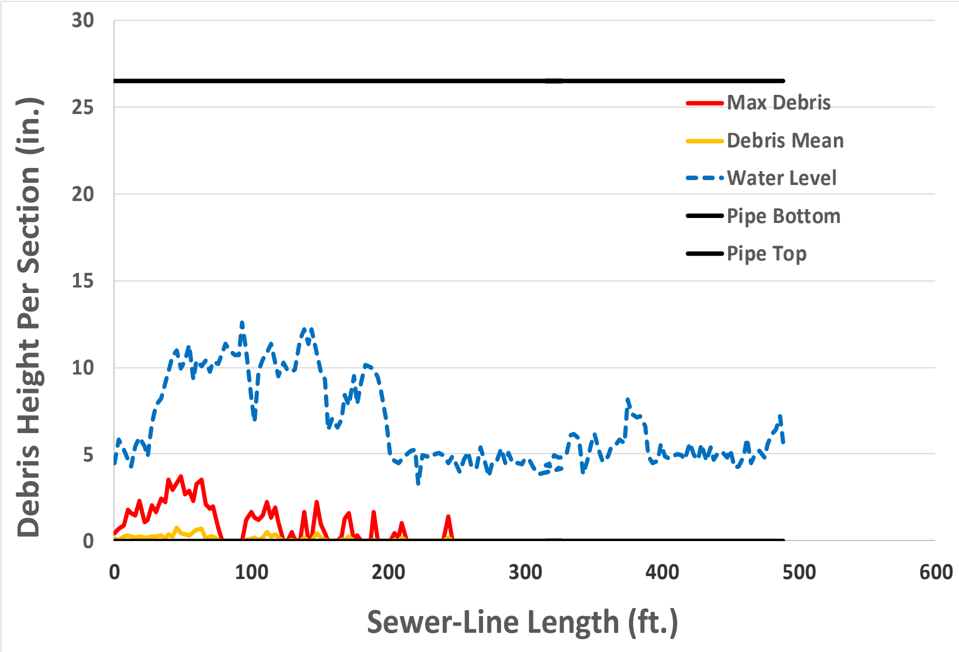


Figure A25-3 Debris height per cross-section.

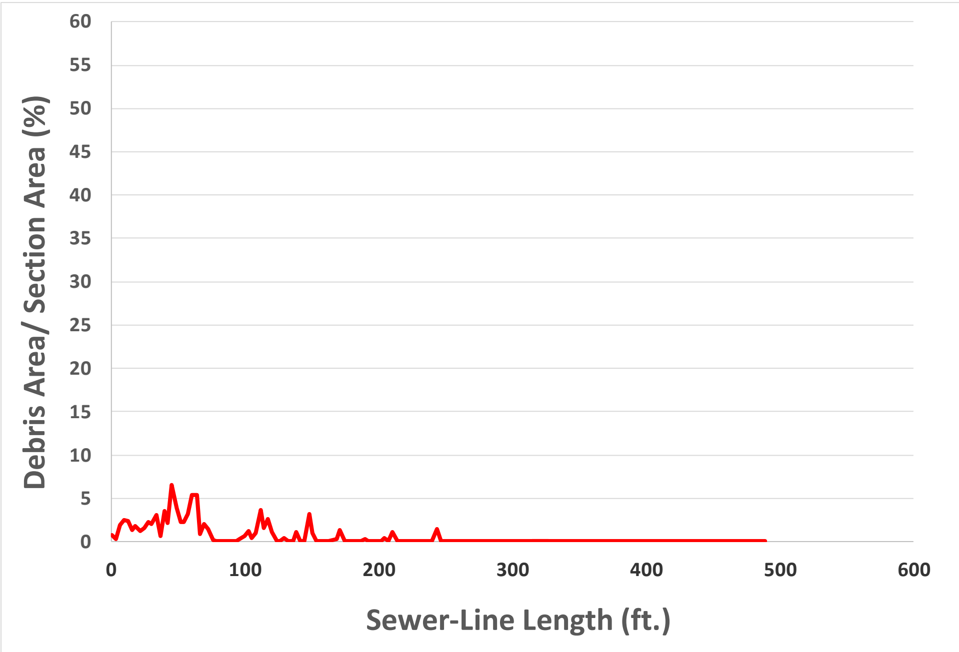


Figure A25-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

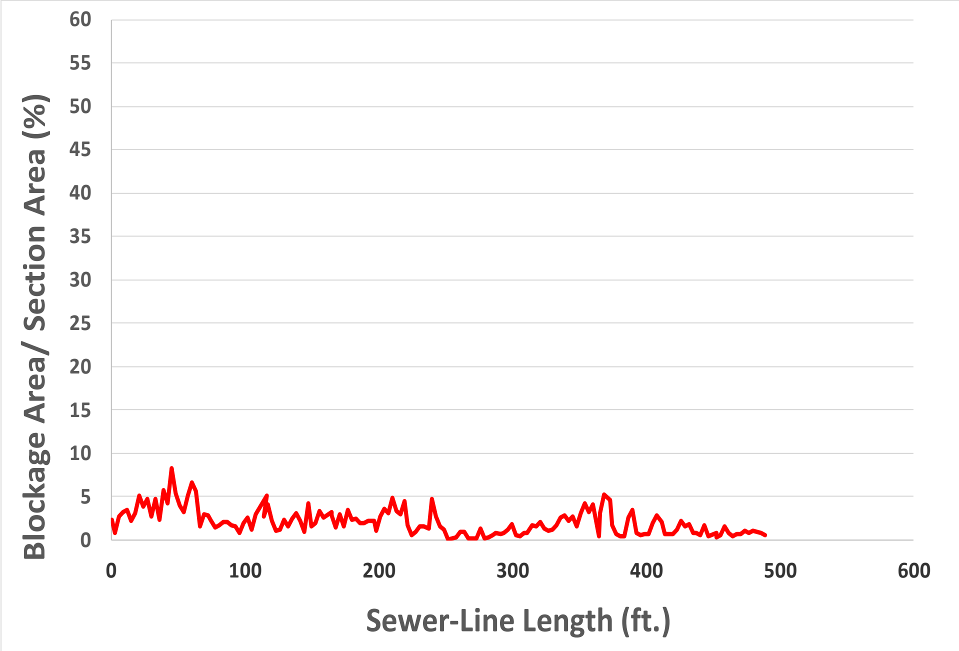


Figure A25-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A25-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				5%					
3	4.45		RMJ					J			1	
4	19.4		RMJ					J			2	
5	29.4		FM					J			3,34	
6	29.4		RMJ					J			3,34	LASER DOESN'T SHOW FRACTURE MOVEMENT
7	31.35		FL	S01				J			4,35	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT
8	34.45		FM					J			5,36	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT
9	34.45		FL	F01							5	
10	34.45		RMJ					J			5	
11	35.6		FL	S02							6,37	LASER SHOWS VERY LITTLE VERTICAL FRACTURE MOVEMENT
12	39.45		FL	F02				J			7	
	39.45		FL	S03				J			7,38	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT
13	40.05		FM					J			8,39	LASER SHOW VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
14	44.55		FL	F03				J			9	
	44.55		FL	S04				J			9,40	LASER SHOWS VERTICAL FRACTURE MOVEMENT
15	44.55		RMJ								9	
16	49.55		RMJ					J			10	
17	49.55		FL	F04				J			10	
	49.55		FL	S05				J			10,41	LASER SHOWS HORIZONATL FRACTURE MOVEMENT AND LASER RING DEFORMED
18	52.35		FM								11,42	LASER DOESN'T SHOW FRACTURE MOVEMENT
19	54.35		RMJ					J			12	
20	54.35		FL	F05				J			12	

21	52.35		FM								11,42	LASER DOESN'T SHOW FRACTURE MOVEMENT
22	54.35		RMJ					J			12	
23	54.35		FL	F05				J			12	
24	54.35		FL	S06				J			12,43	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT
25	59.35		RMJ					J			13	
26	59.35		FL	F06				J			13	
27	59.35		FL	S07				J			13,44	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT
28	64.1		FL	F07				J			14	
29	64.1		FL	S08				J			14,45	LASER SHOWS VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
30	69.15		FL	F08				J			15	
31	69.15		FL	S09				J			15,46	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
32	74		FL	F09							16	
33	93.65		RMJ					J			17	
34	93.65		FM					J			17,63	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
35	95.4		FL	S10				J			17,47	LASER DOESN'T SHOW FRACTURE OPENING
36	98.5		FM					J			18,48	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
37	98.5		RMJ					J			18	
38	98.5		FL	F10				J			18	
39	98.5		FL	S11				J			18,48	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
40	103.5		FL	F11							19	
41	103.5		FM					J			19,49	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
42	104.95		FL	S12				J			19,64	LASER SHOWS VERTICAL MOMENT AND LASER RING DEFORMED
43	108.4		FL	F12							20	
44	108.4		FM					J			20,50	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
45	109.4		FL	S13				J			20,51	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
46	113.35		FL	F13				J			21	

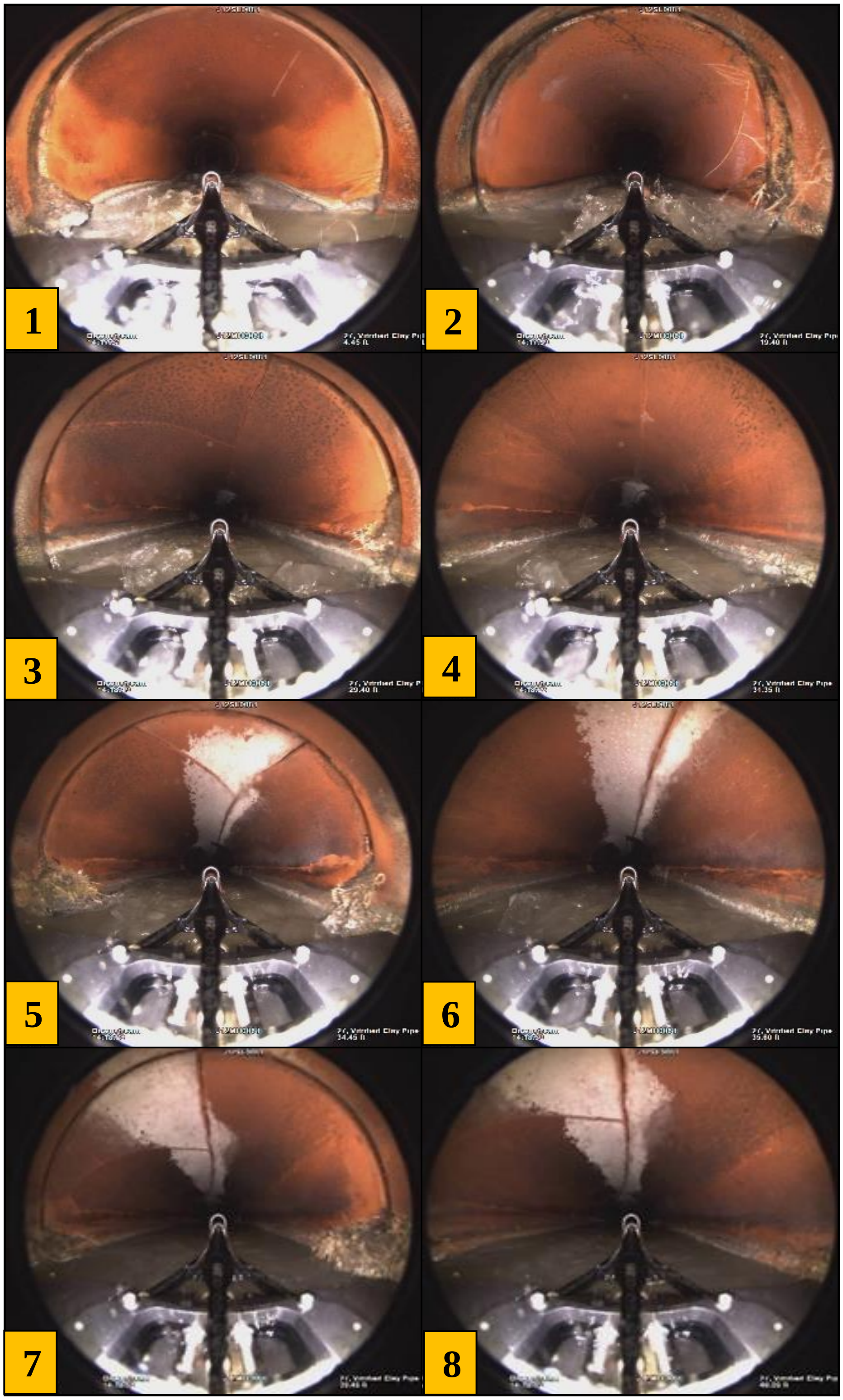


Figure A25-6 images from 1 through 8

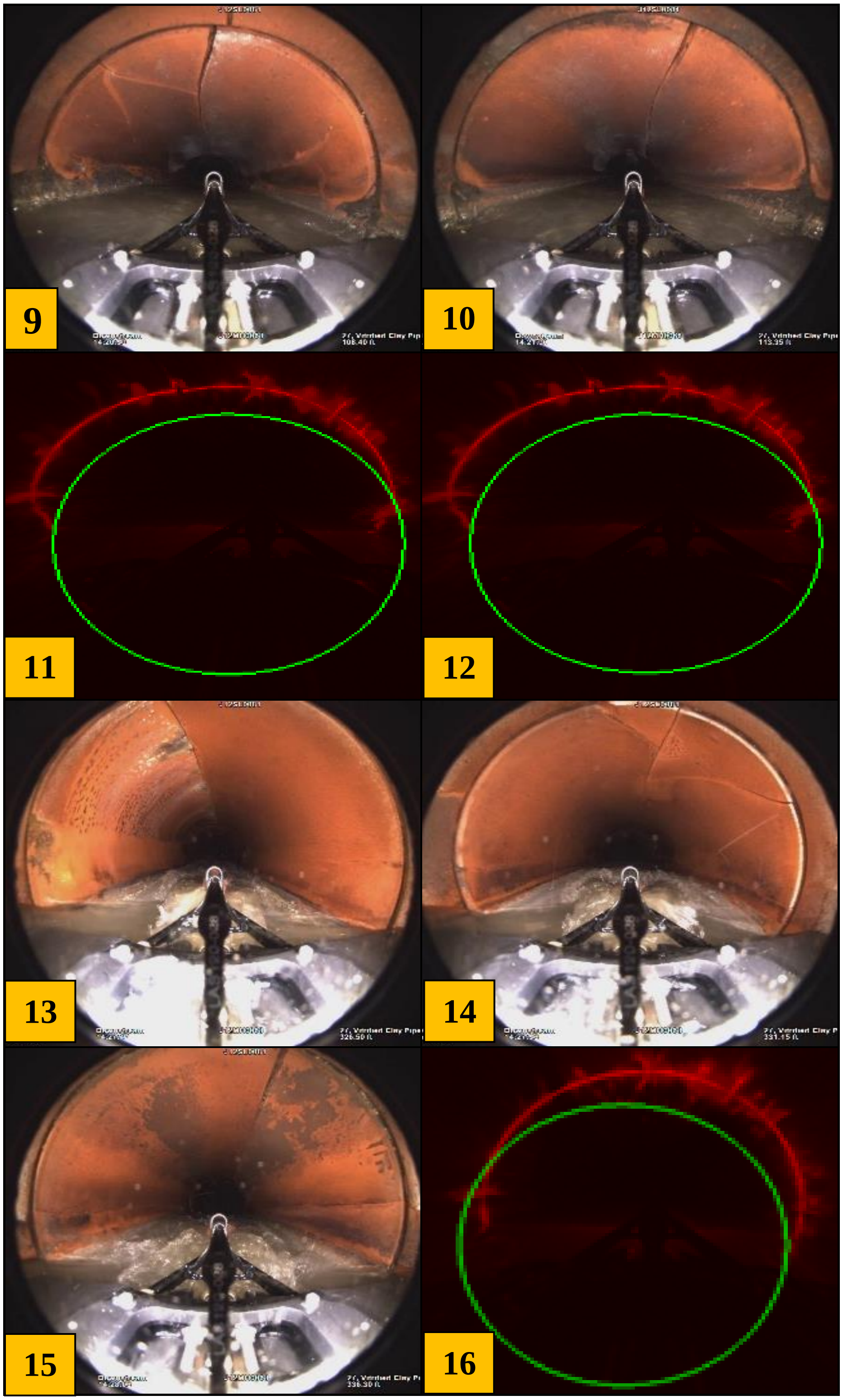


Figure A25-7 images from 9 through 16

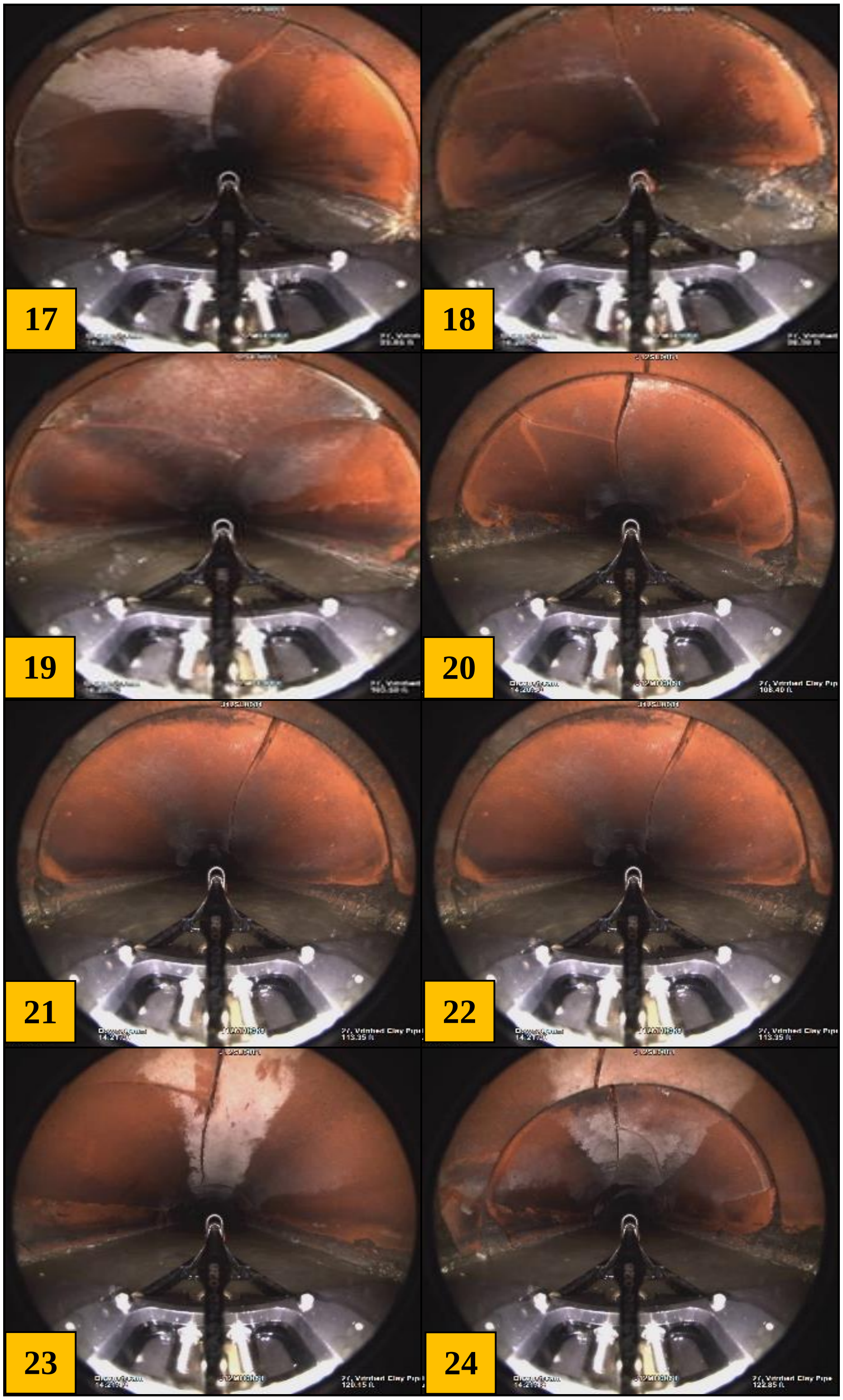


Figure A25-8 images from 17 through 24

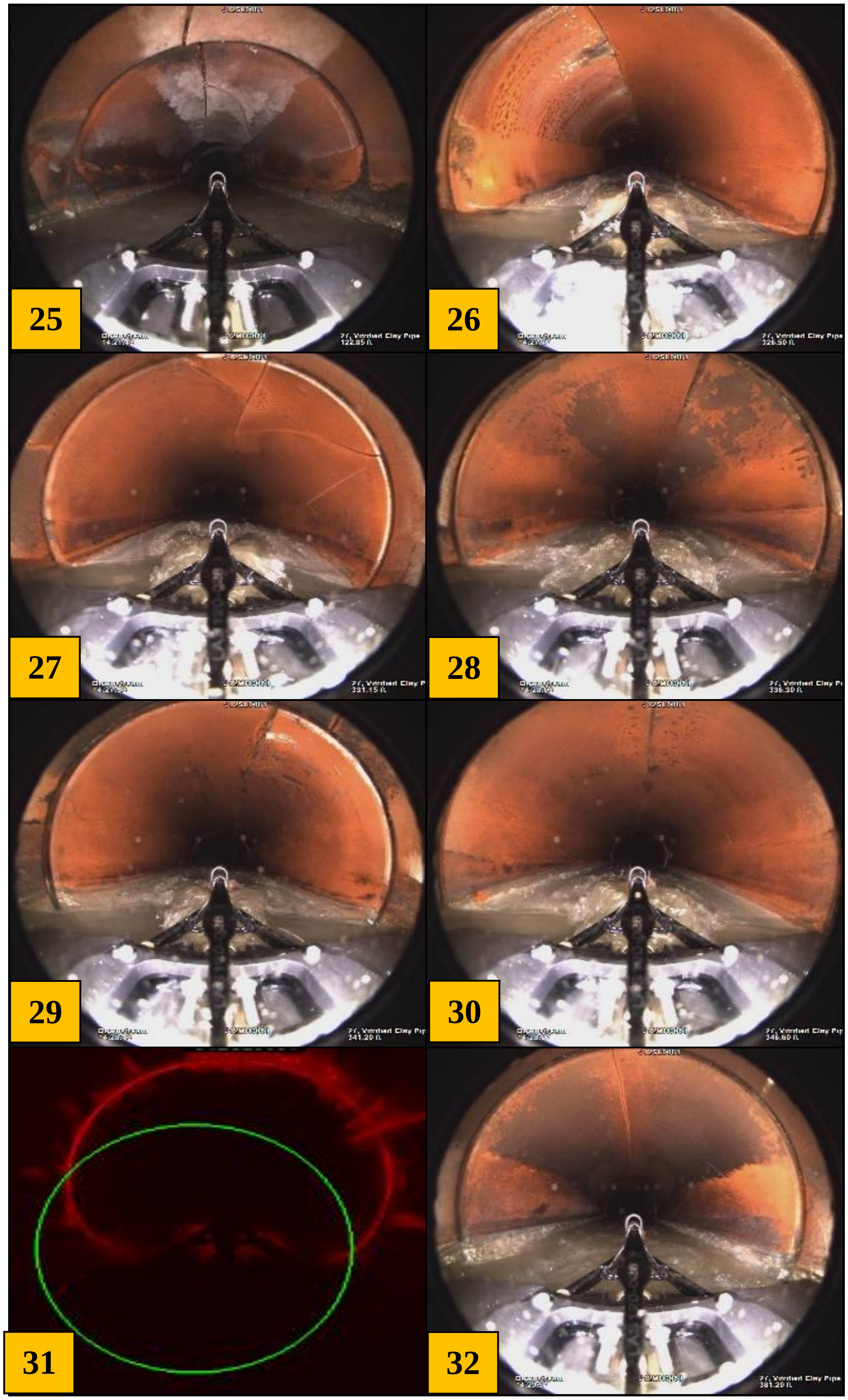


Figure A25-9 images from 25 through 32

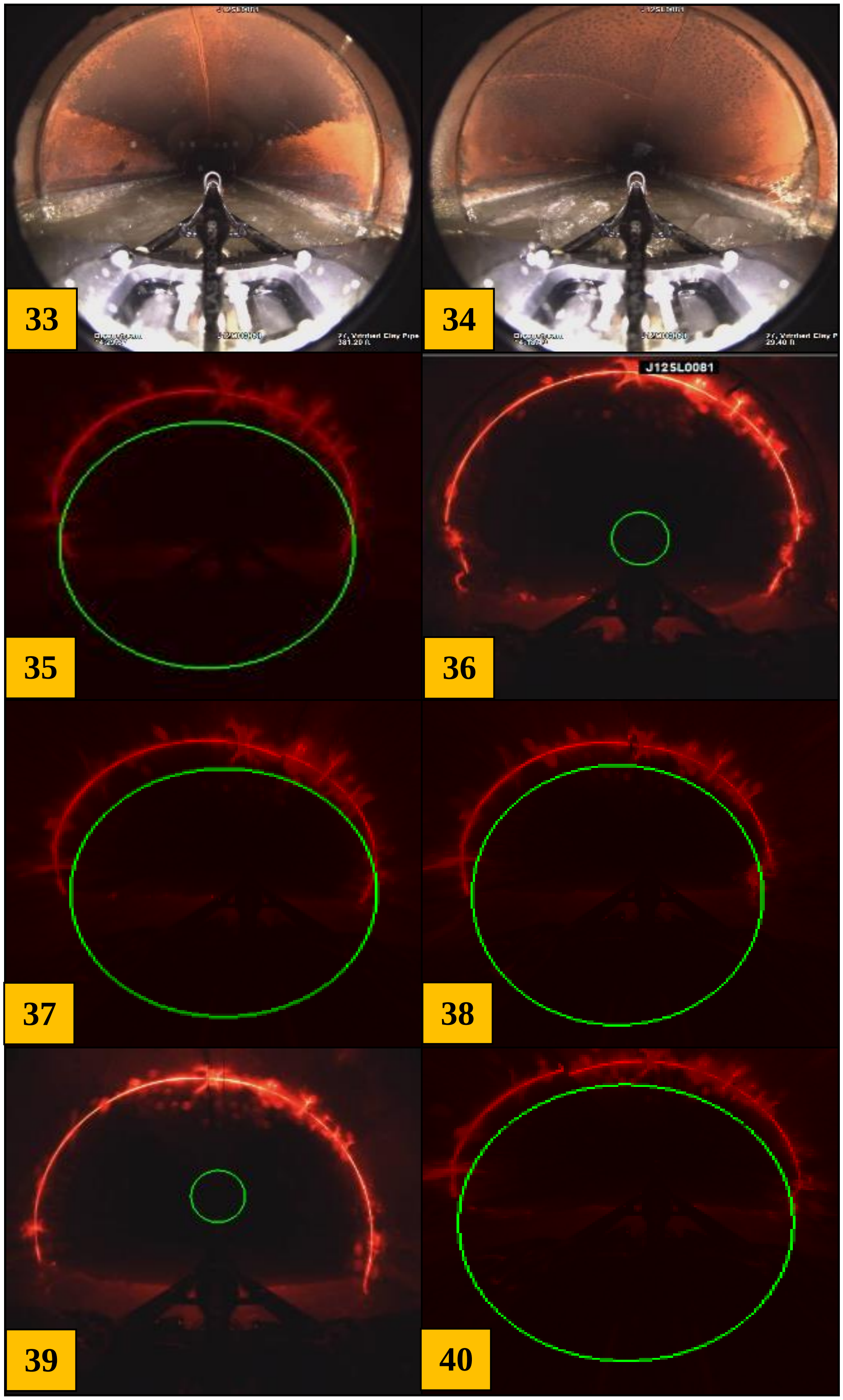


Figure A25-10 images from 33 through40

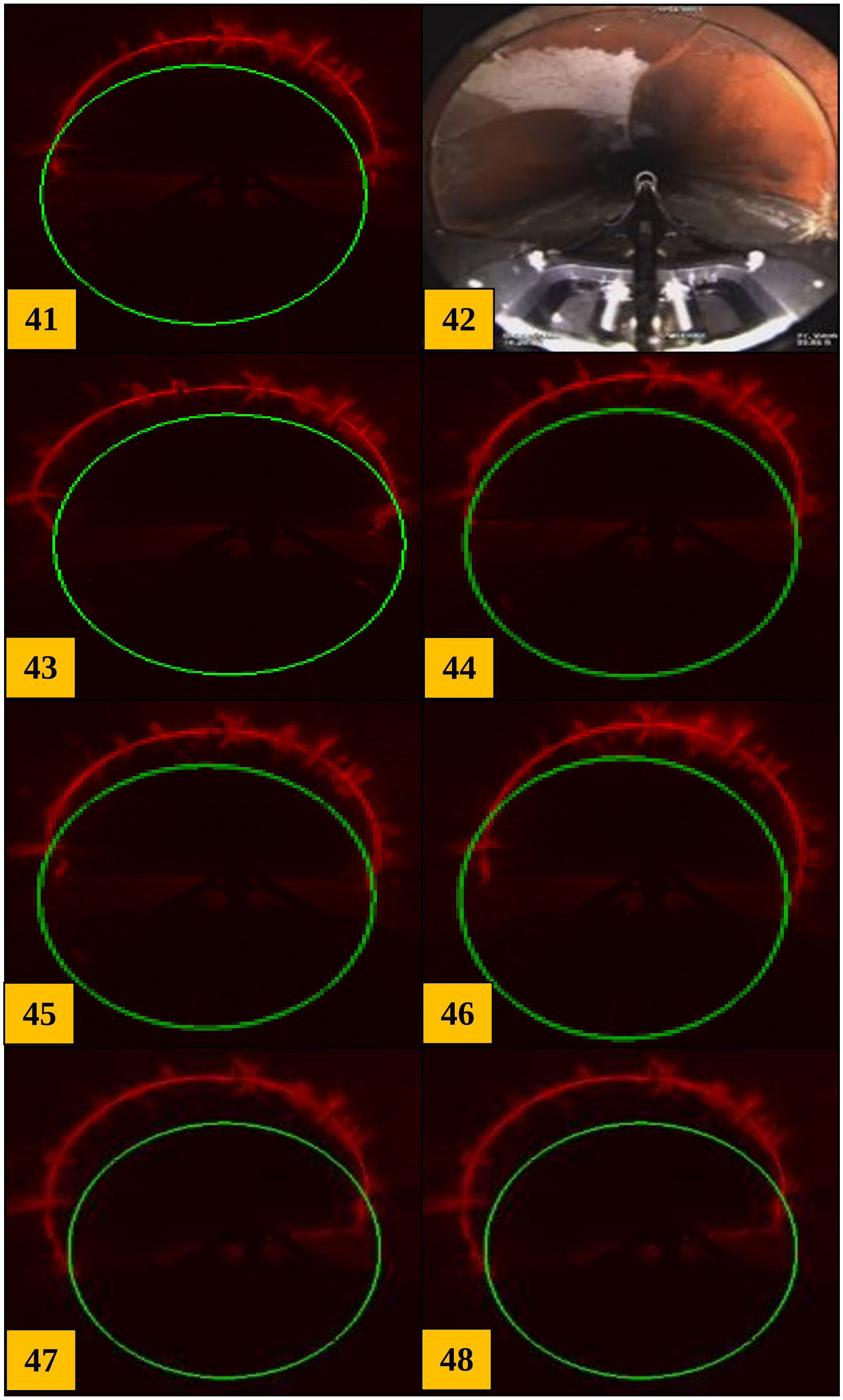


Figure A25-11 images from 40 through 48

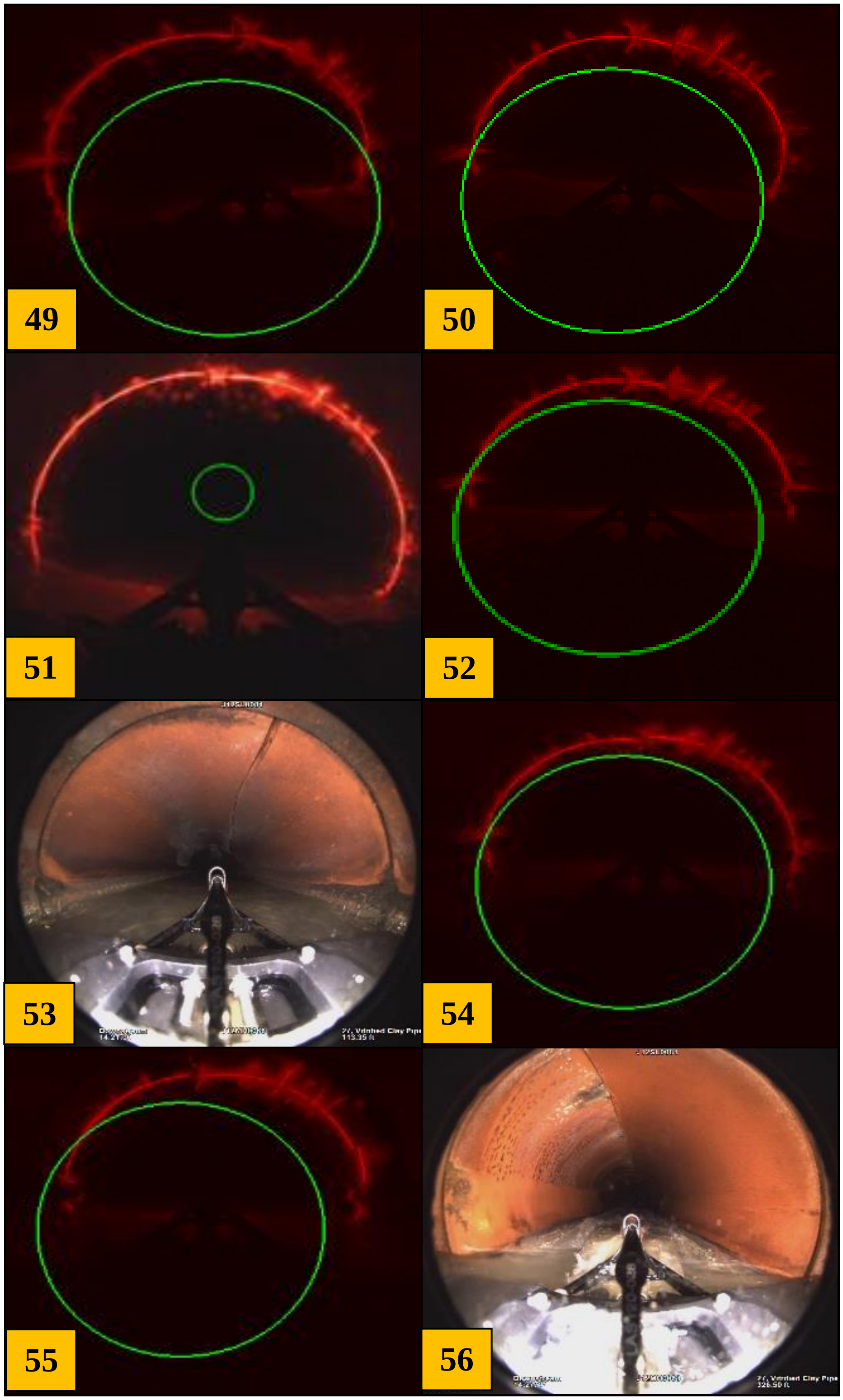


Figure A25-12 images from 49 through 56

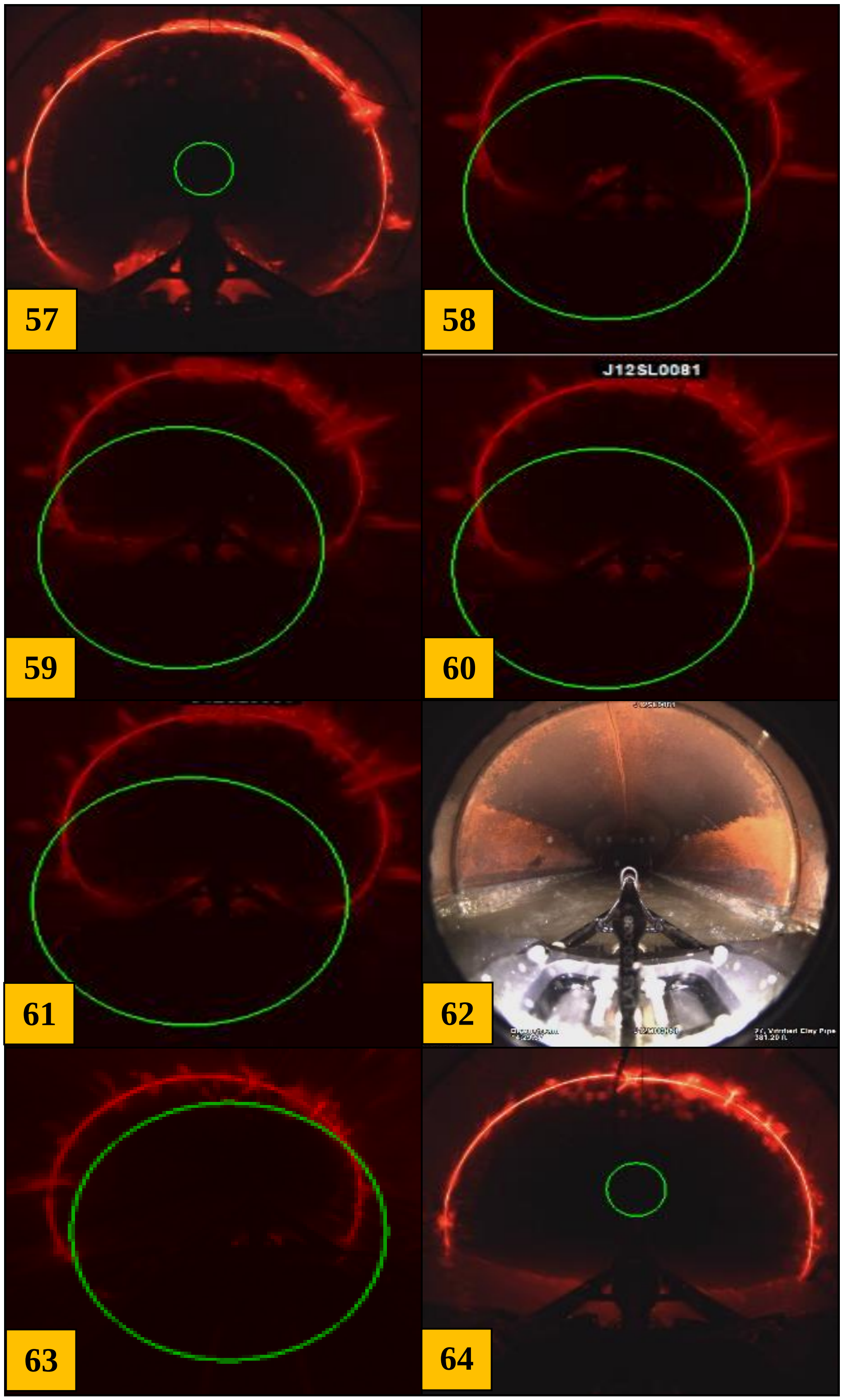


Figure A25-13 images from 57 through 64

Line 26 Summary

Table A26-1 Results Summary of Sewer Line 26

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	418.8
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	8
Total Fractures Hinge	0
Total Fractures Longitudinal	39
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	2
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	10
Total Defects	53
Total Debris Volume (ft^3)	81
Total Deposits Volume (in^3)	38161.8
Maximum Blockage (%)	24.4
Maximum Deposit Height (in)	1.6

Deposit Data

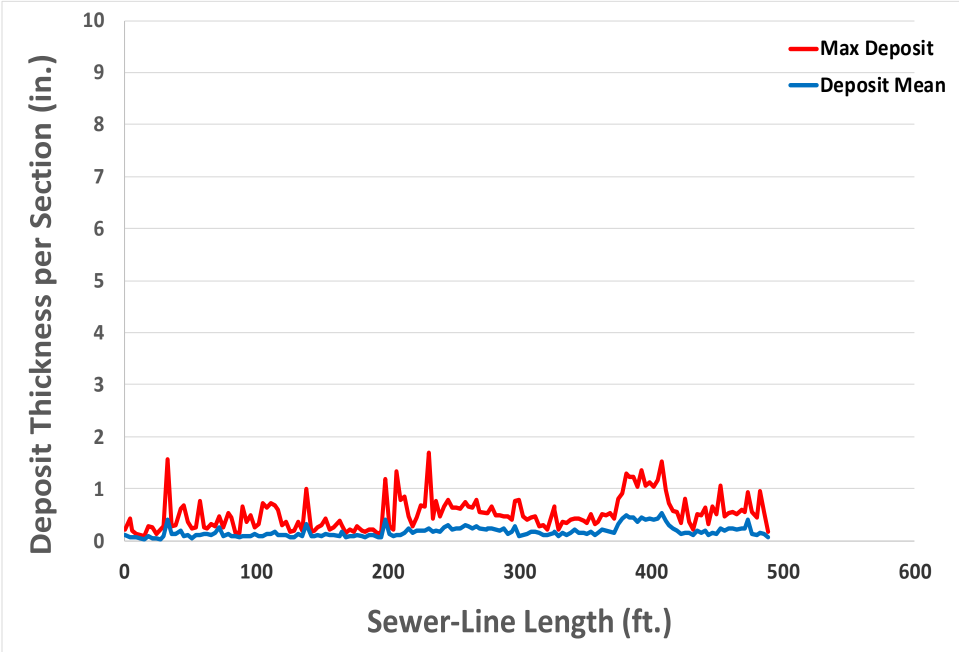


Figure A26-1 Deposit thickness per cross-section

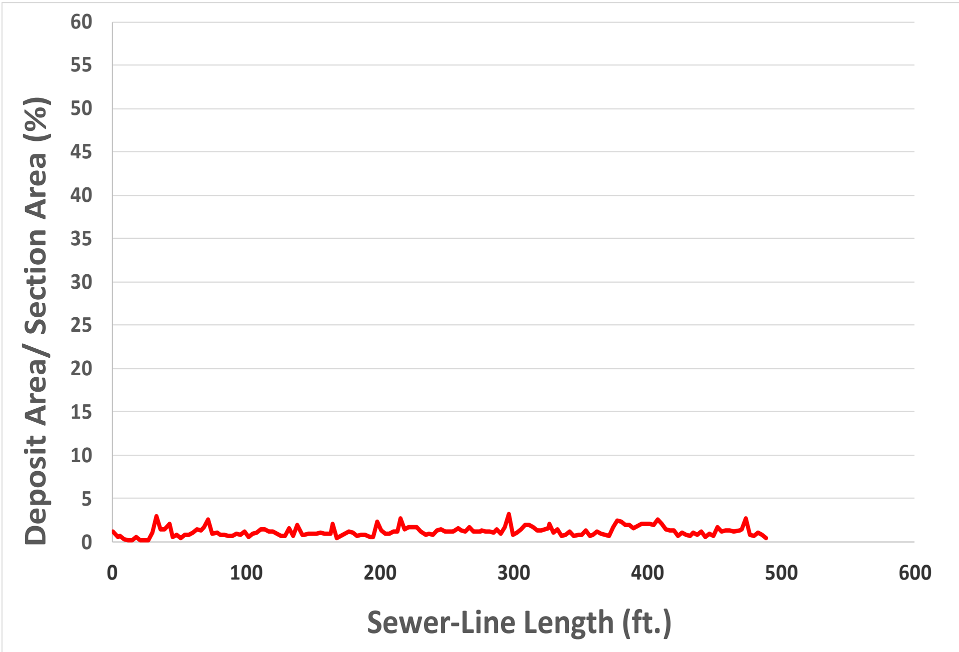


Figure A26-2 Deposit area percentage of the pipe cross section area

Debris Data

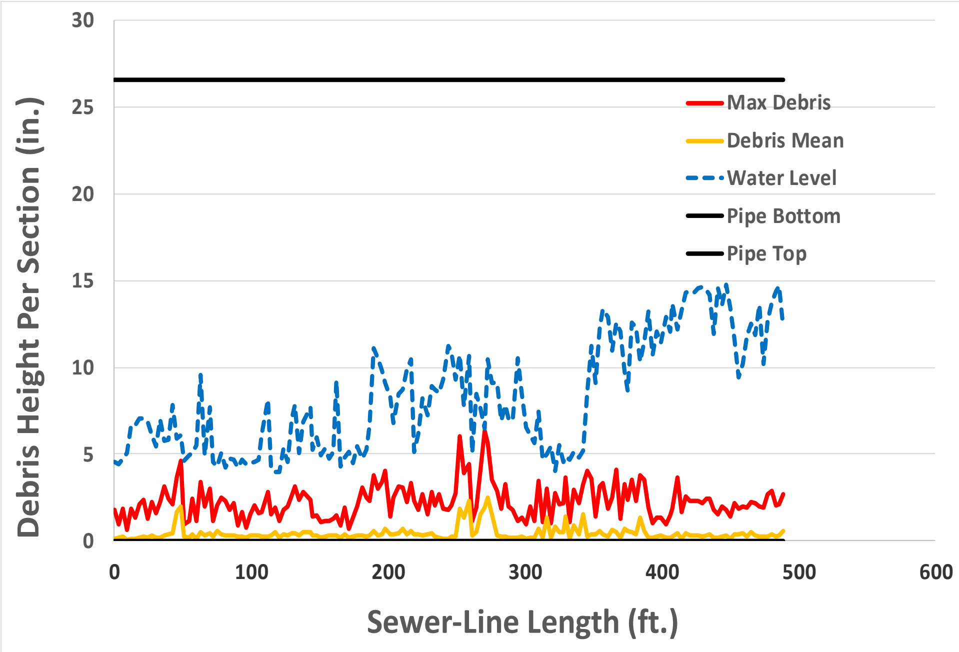


Figure A26-3 Debris height per cross-section

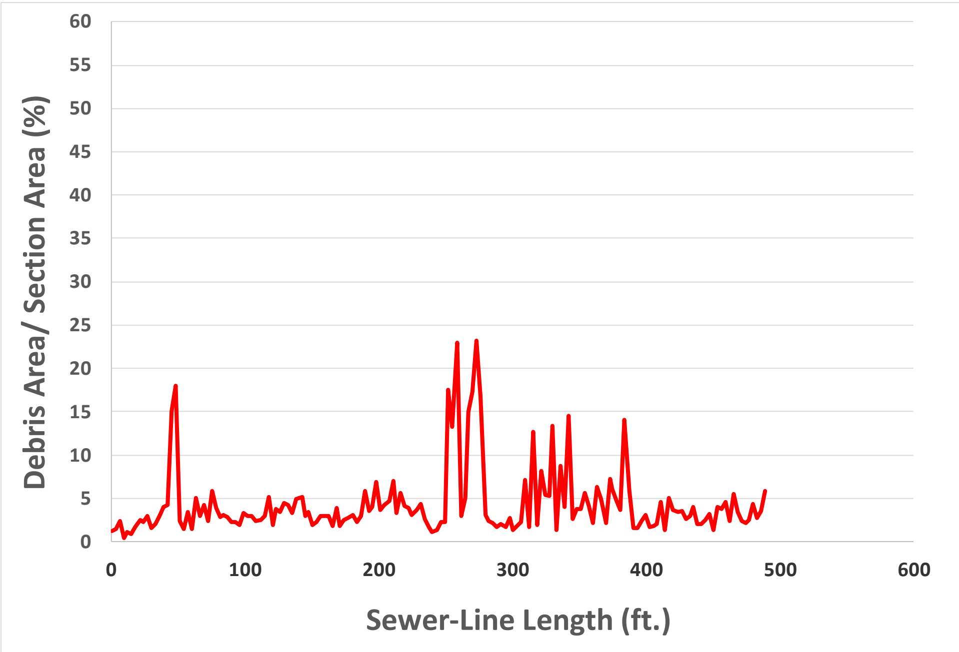


Figure A26-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

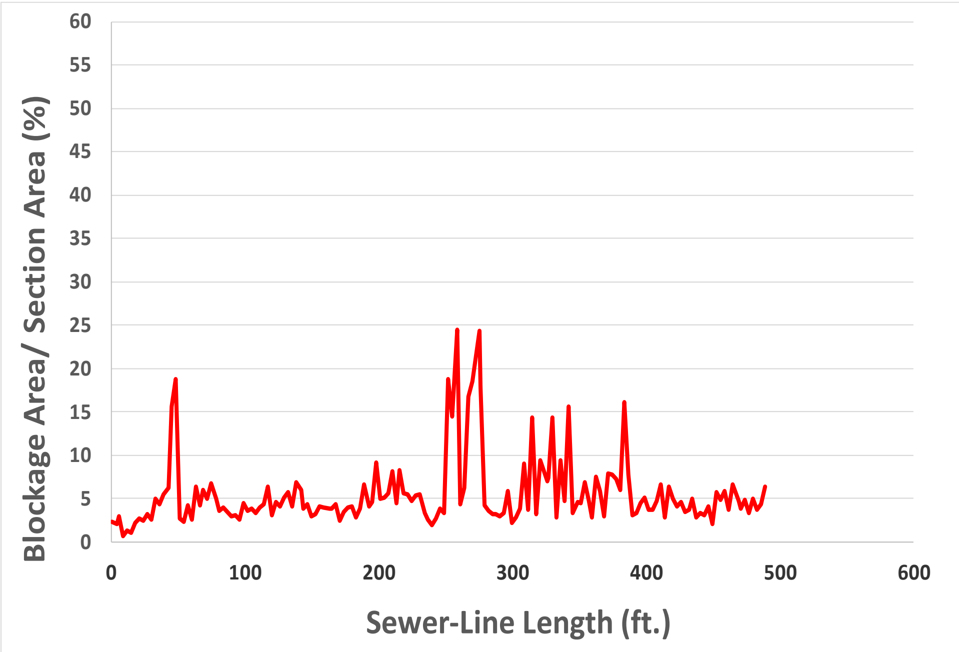


Figure A26-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A26-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				10%					
3	228.4		FM					J			1,45	LASER DOESN'T SHOW FRACTURE MOVEMENT
4	229.4		FL	S01				J			1,46	LASER SHOWS VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
5	233.6		FL	F01				J			2	
6	233.6		FL	S02				J			2,47	LASER DOESN'T SHOW FRACTURE OPENING
7	238.4		FL	F02				J			3	
8	238.4		FL	S03				J			3,48	LASER SHOWS HORIZONTAL FRACTURE MOVEMENT
9	243.65		FL	F03				J			4	
10	243.65		FL	S04				J			4,49	LASER SHOWS HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
11	243.65		DAE	S05			10%				4	
12	248.8		FL	F04				J			5	
13	248.8		FL	S06				J			5,50	LASER SHOWS HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED

14	248.8		DAE	F05			10%				5	
15	253.2		FL	F06							6	
16	253.2		FL	S07							6,51	LASER SHOWS HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
17	258.35		DAE	S08			10%				7	
18	258.35		FL	F07				J			7	
19	258.35		FL	S09				J			7,52	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
20	263.4		DAE	F08			10%				8	
21	263.4		FL	F09				J			8	
22	263.4		FL	S10				J			8,53	LASER SHOWS HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
23	268.25		FL	F10				J			9	
24	268.25		FL	S11				J			9,54	LASER SHOWS BOTH HORIZONTAL AND VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
25	273.25		FL	F11				J			10	
26	273.25		FL	S12				J			10,55	LASER SHOWS HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
27	278.25		FL	F12				J			11	
28	278.25		FL	S13				J			11,56	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
29	280.85		FM					J			12,57	LASER DOESN'T SHOW FRACTURE OPENING
30	283.25		FL	F13				J			13	
31	283.25		FL	S14				J			13,58	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
32	288.05		FL	F14				J			14	
33	288.05		FL	S15				J			14,59	LASER DOESN'T SHOW FRACTURE OPENING
34	318.1		DAG				10%	J			15	
35	333.3		FL	F15							16	
36	333.3		FL	S16							16,60	LASER DOESN'T SHOW FRACTURE OPENING

37	337.85		FL	F16				J			17	
38	337.85		FL	S17				J			17,61	LASER SHOWS HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
39	342.9		FL	F17				J			18	
40	342.9		FL	S18				J			18,62	LASER DOESN'T SHOW FRACTURE MOVEMENT
41	344.85		MWL				15%				19	
42	348.25		FL	F18				J			20	
43	348.25		FL	S19				J			20,63	LASER SHOWS VERY VERY LITTLE VERTICAL FRACTURE MOVEMENT
44	353.35		FL	F19				J			21	
45	353.35		FL	S20				J			21,64	LASER DOESN'T SHOW FRACTURE MOVEMENT
46	358.5		FL	F20				J			22	
47	358.5		FL	S21				J			22,65	LASER SHOWS VERTICAL FRACTURE MOVEMENT
48	363.4		FM					J			23,66	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
49	364.3		FL	F21				J			23	
50	364.3		FL	S22				J			23,67	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
51	368.3		FL	F22				J			24	
52	368.3		FL	S23				J			24,68	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
53	373.25		FL	F23				J			25	
54	373.25		FL	S24				J			25,69	LASER SHOWS LITTLE VERTICAL FRACTURE MOVEMENT
55	378.15		FL	F24							26	
56	378.15		FM					J			26,70	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
57	380.85		FL	S25				J			26,71	LASER SHOWS VERTICAL FRACTURE MOVEMENT AND LASER RING DEFORMED
58	383.25		FM					J			27,72	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
59	383.25		FL	F25				J			27	

82	438.6		FL	S35				J			36,84	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
83	443.65		FL	F35				J			37	
84	443.65		FL	S36				J			37,85	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
85	448.65		FL	F36				J			38	
86	448.65		FL	S37				J			38,86	LASER DOESN'T SHOW FRACTURE OPENING
87	453.4		FL	F37				J			39	
88	453.4		FL	S38				J			39,87	LASER DOESN'T SHOW FRACTURE OPENING
89	458.65		FL	F38				J			40	
90	458.65		FL	S39				J			40,88	LASER DOESN'T SHOW FRACTURE OPENING
91	463.5		FL	F39				J			41	
92	463.5		FL	S40				J			41,89	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
93	468.5		FL	F40				J			42	
94	468.5		FL	S41				J			42,90	LASER DOESN'T SHOW FRACTURE OPENING
99	473.6		FL	F41				J			43	
96	473.6		FL	S42				J			43,91	LASER DOESN'T SHOW FRACTURE OPENING
97	478.75		FL	F42							44	
98	490.45		MSA									

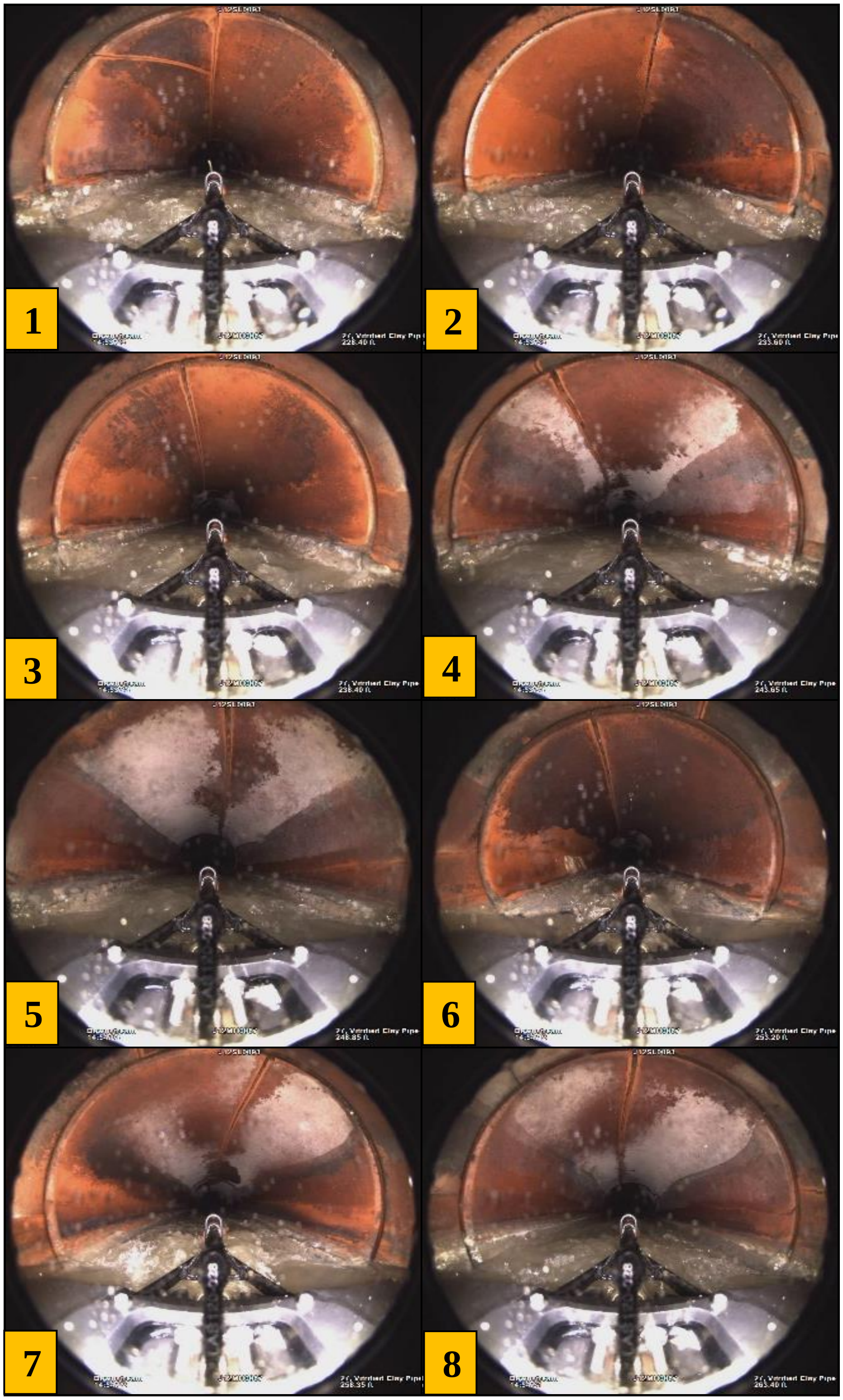


Figure A26-6 images from 1 through 8

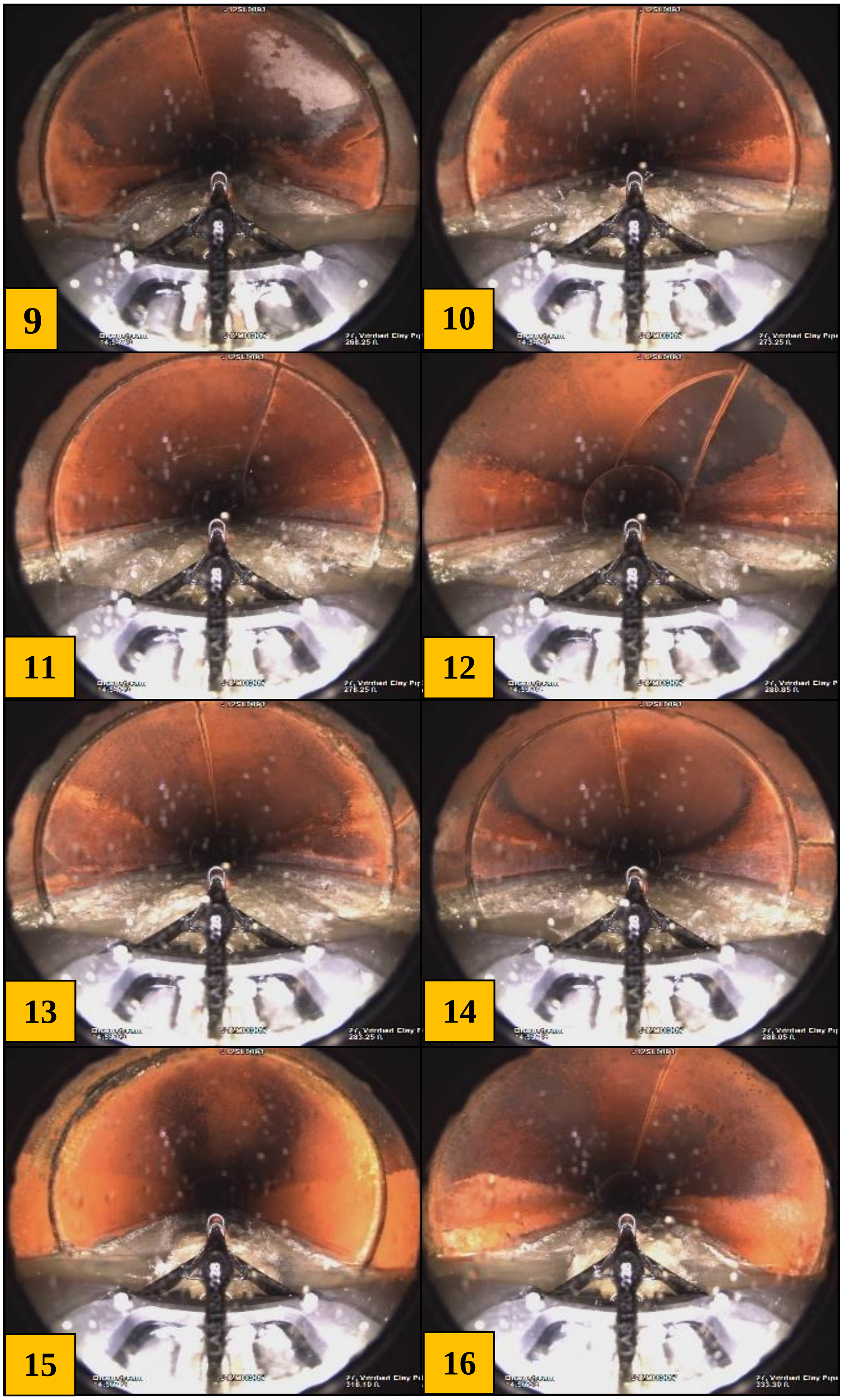


Figure A26-7 images from 9 through 16

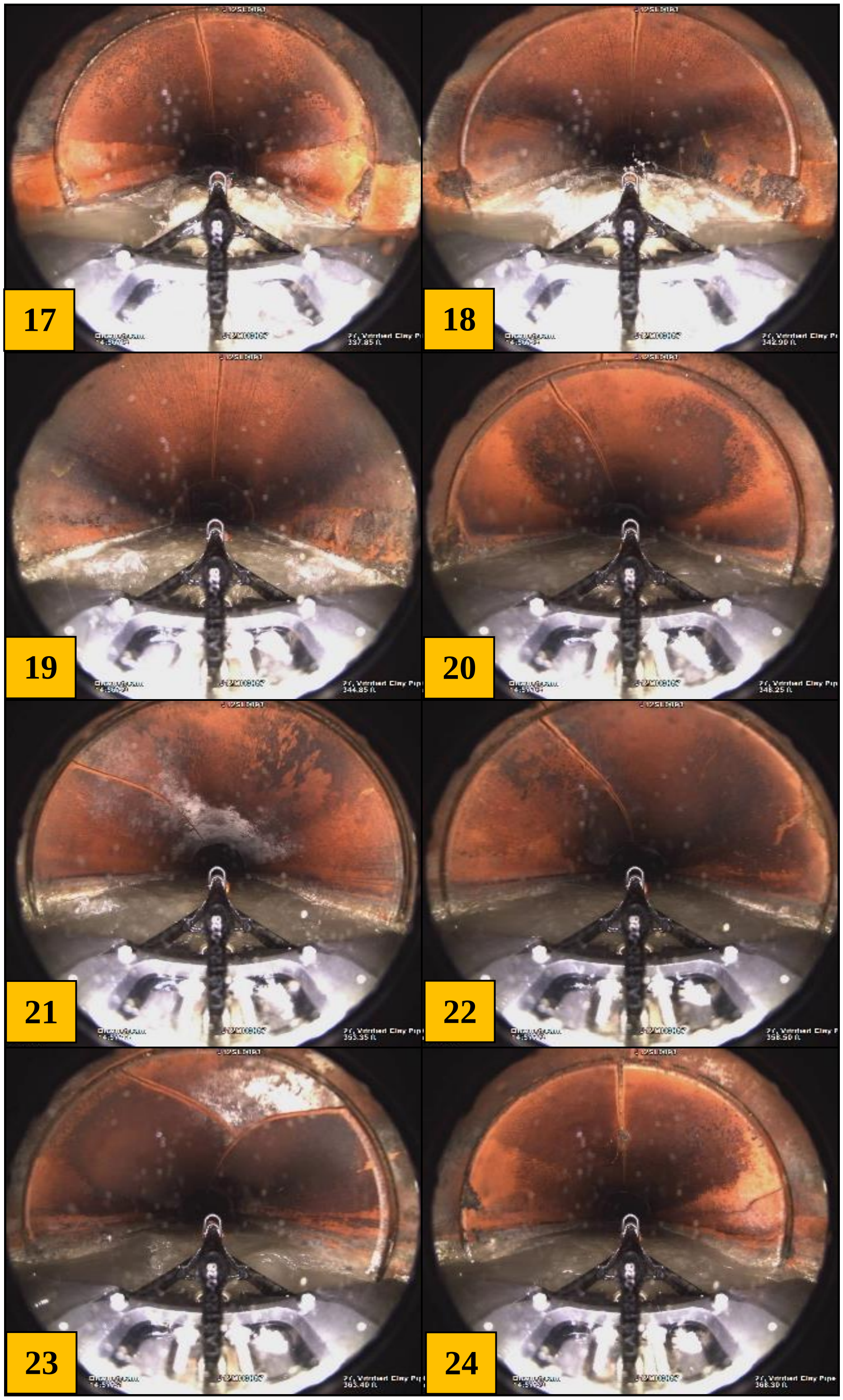


Figure A26-8 images from 17 through 24

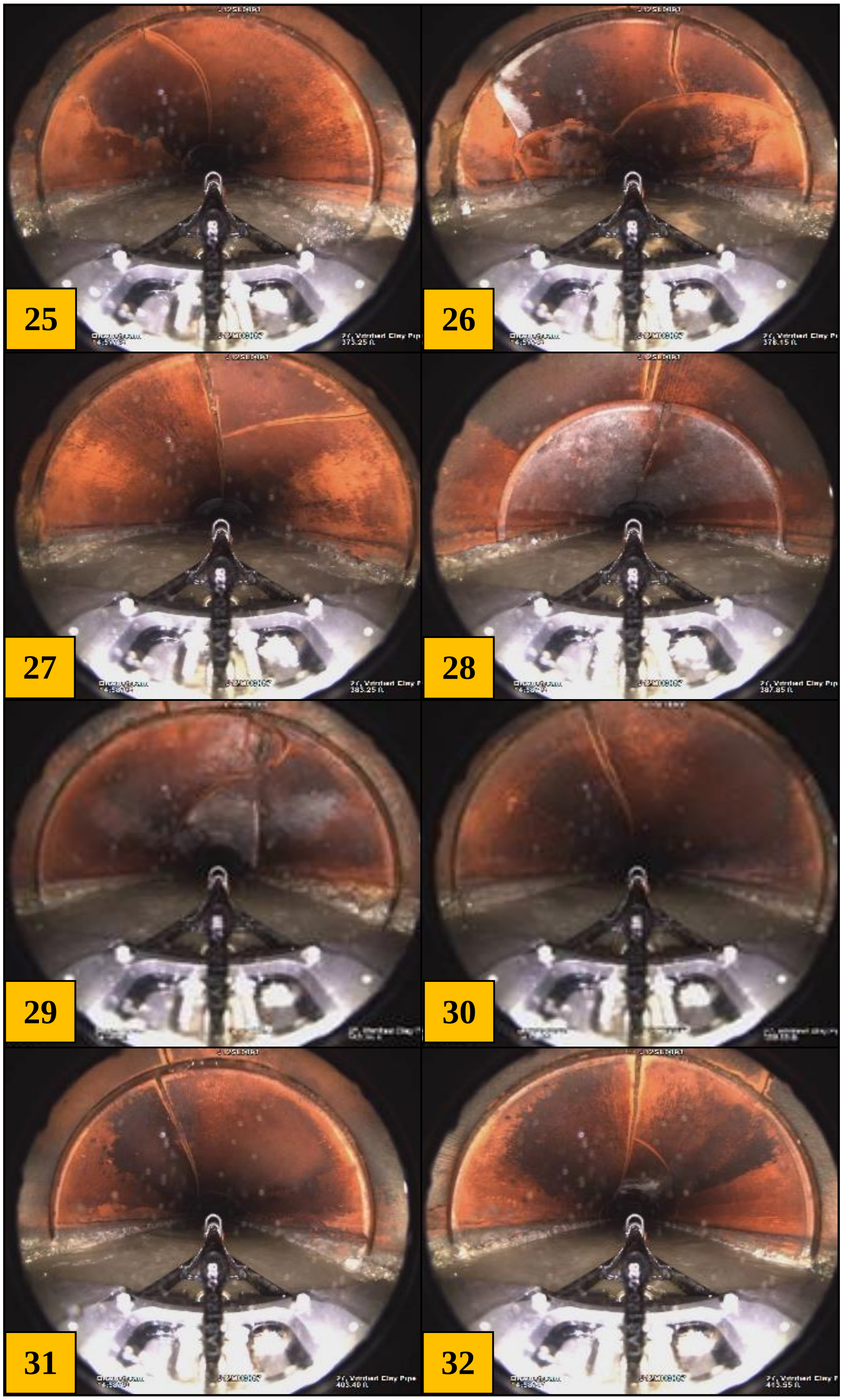


Figure A26-9 images from 25 through 32

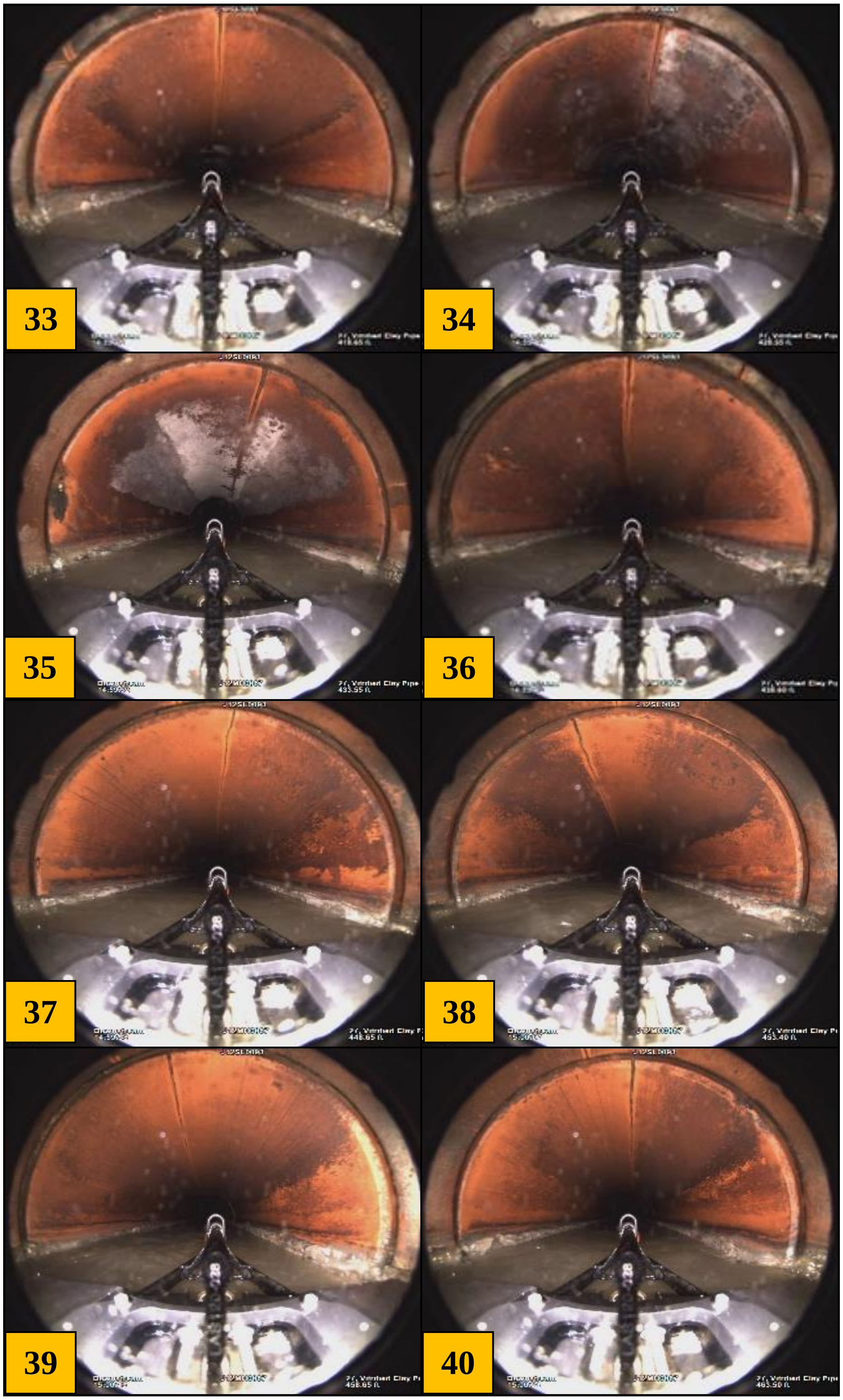


Figure A26-10 images from 33 through 40

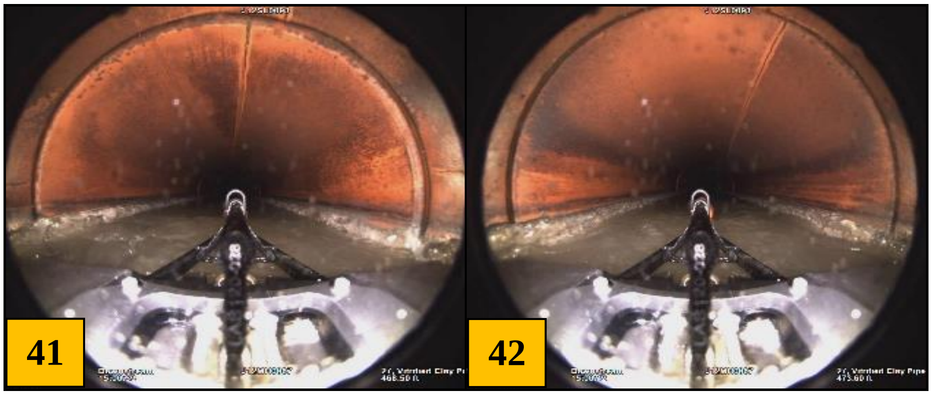


Figure A25-10 images from 41 through 42

Line 27 Summary

Table A 27-2 Results Summary of Sewer Line J12SL0057

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	82.1
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	0
Total Debris Volume (ft^3)	0.1
Total Deposits Volume (in^3)	5940.0
Maximum Blockage (%)	3.3
Maximum Deposit Height (in)	1.1

Deposit Data

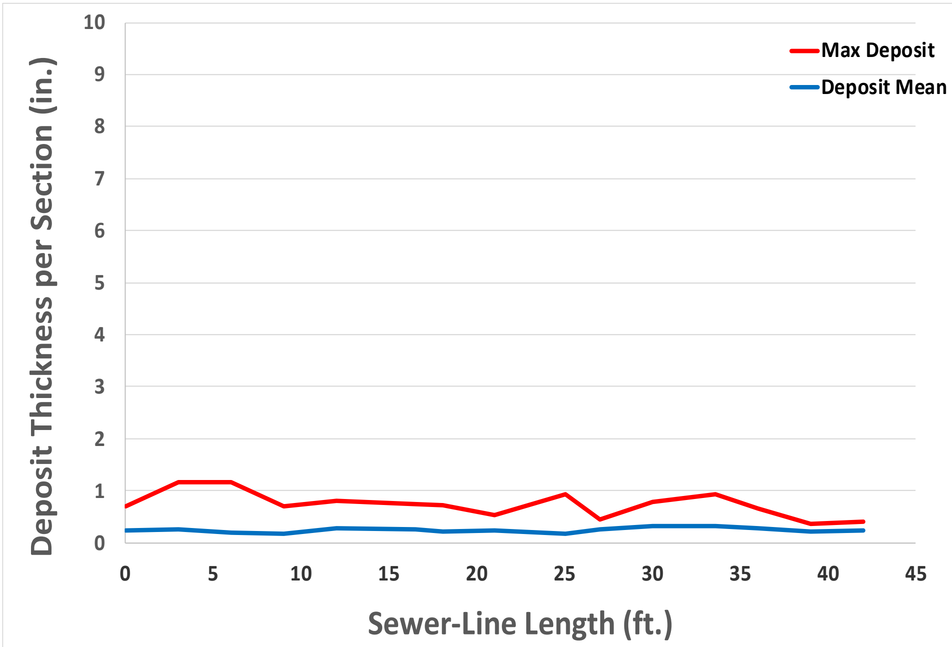


Figure A27-1 Deposit thickness per cross-section

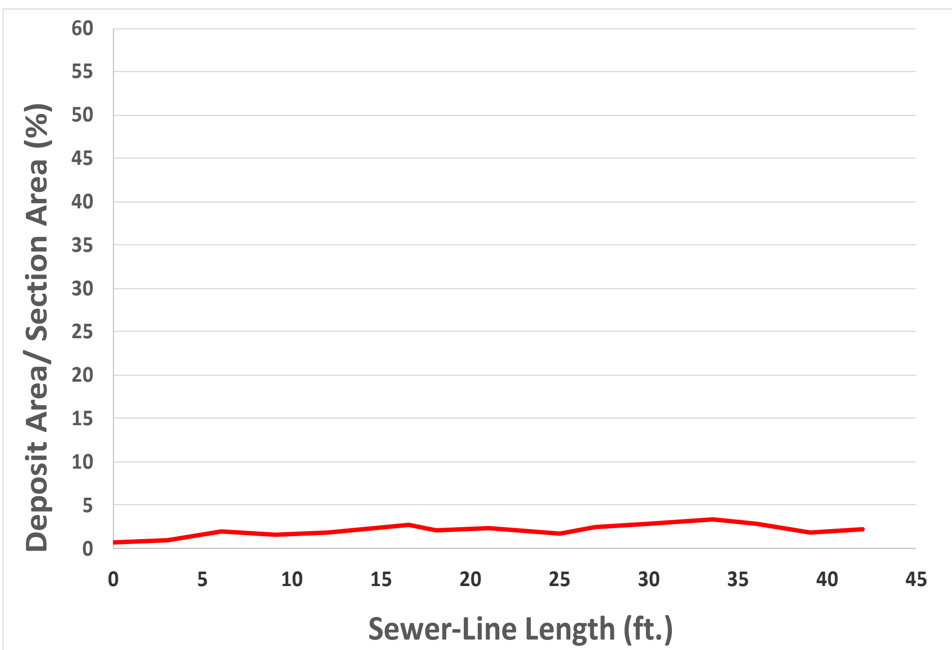


Figure A27-2 Deposit area percentage of the pipe cross section area

Debris Data

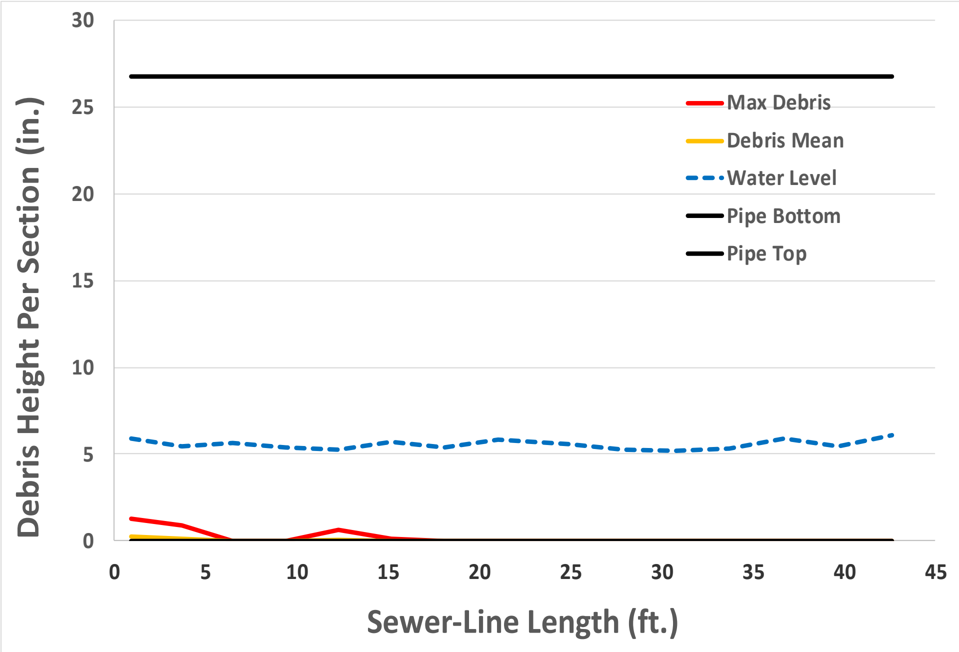


Figure A27-3 Debris height per cross-section

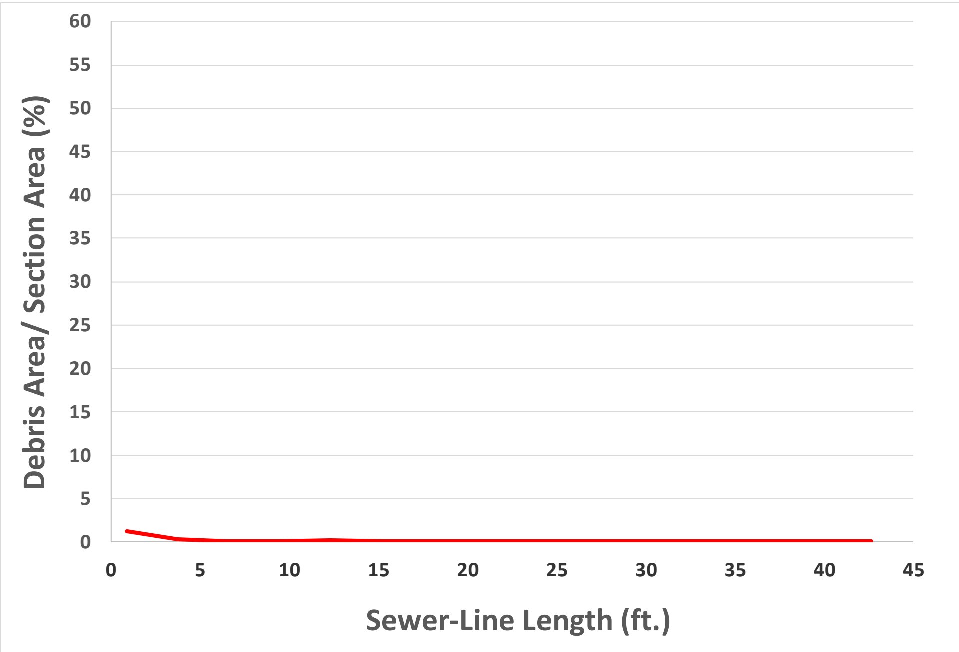


Figure A27-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

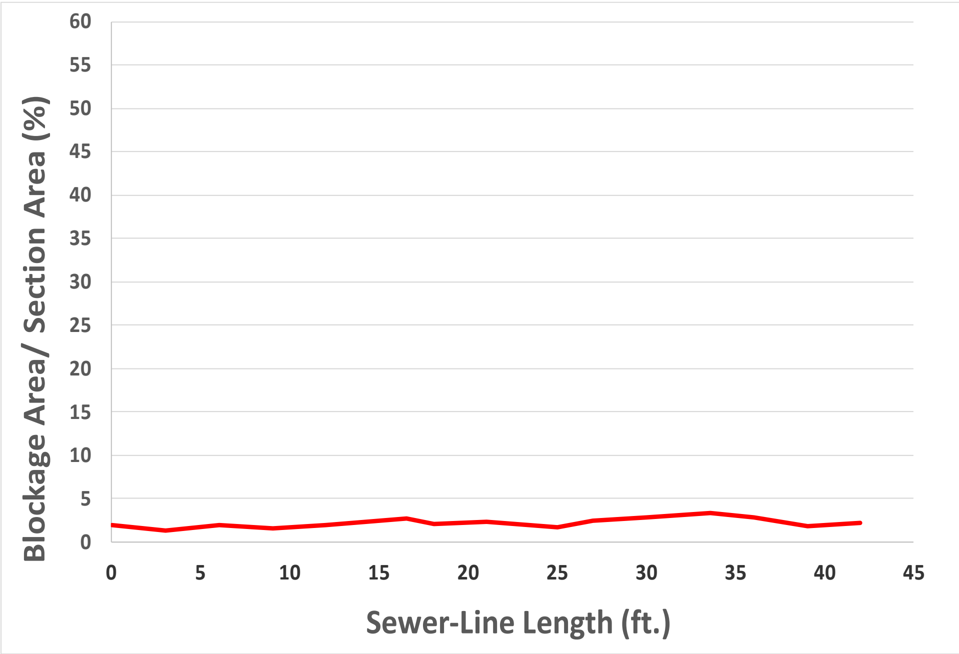


Figure A27-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A27-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code: Group/ Descriptor/ Modifier	Continuous Defect	Value: Dimension 1st	Value: Dimension 2nd	Value: %	Joint	Circumferential Location: At/From	Circumferential Location: To	Img Reference	Remarks
1	0		AMH									NO DEFECTS
2	0		MWL				5%					
3	44.2		MSA									

Line 28 Summary

Table A28-1 Results Summary of Sewer Line 28

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	183.5
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	13
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	13
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	13844.7
Maximum Blockage (%)	4.5
Maximum Deposit Height (in)	2.7

Deposit Data

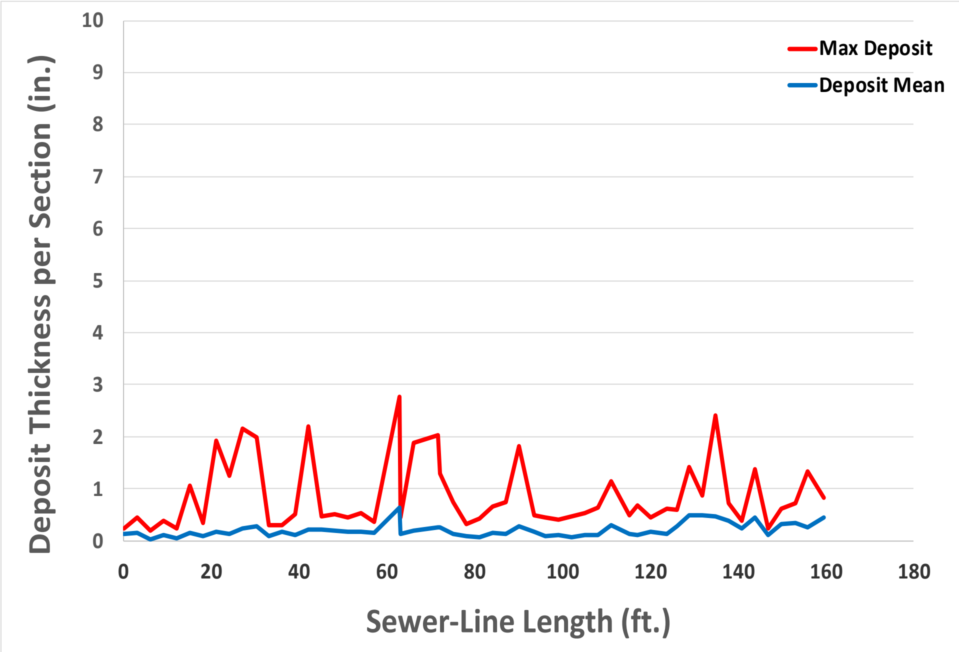


Figure A28-1 Deposit thickness per cross-section

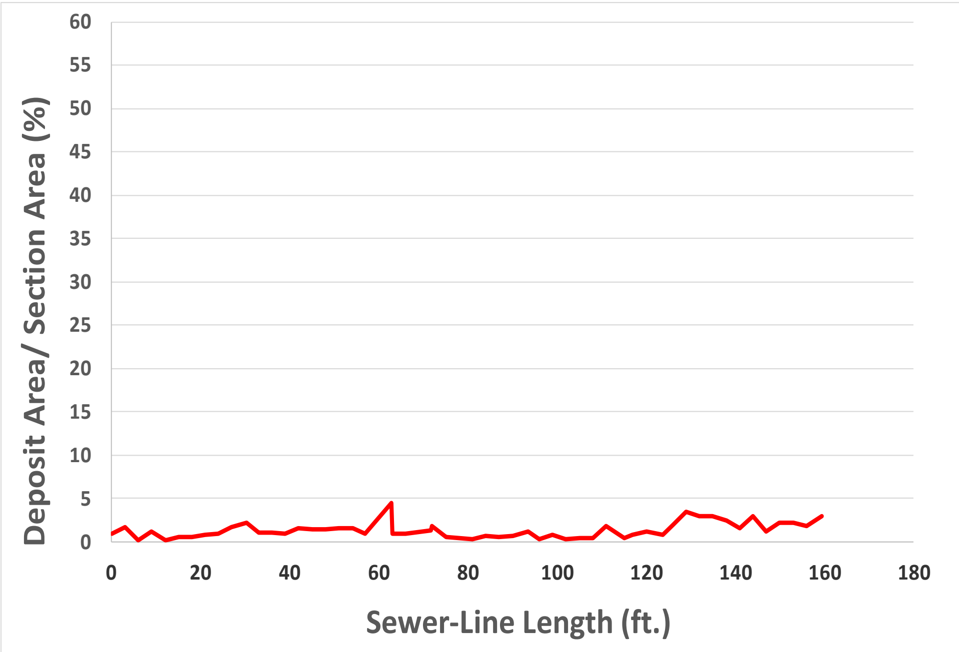


Figure A28-2 Deposit area percentage of the pipe cross section area

Blockage Data

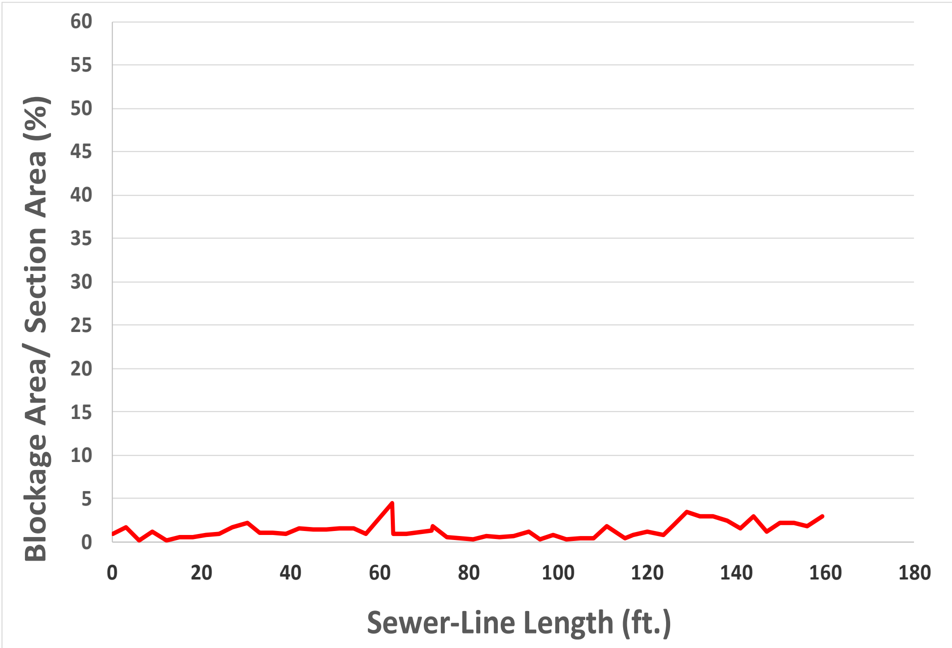


Figure A28-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A28-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code Group/ Descriptor/ Modifier	Continuous Defect	Value Dimension 1st	Value Dimension 2nd	Value %	Joint	Circumferential Location At/From	Circumferential Location To	Img Reference	Remarks
1	0		AMH									
2	0		MWL				5%					
3	10.75		FL	S01				J			1,14	LASER DOESN'T SHOW FRACTURE MOVEMENT
4	15.45		FL	F01							27	
5	16.2		FL	S02				J			2,15	LASER DOESN'T SHOW FRACTURE MOVEMENT
6	20		FL	F02							28	
7	66.15		FL	S03				J			3,16	LASER DOESN'T SHOW FRACTURE MOVEMENT
8	70.7		FL	F03				J			4	
9	70.7		FL	S04				J			4,17	LASER DOESN'T SHOW FRACTURE MOVEMENT
10	75.55		FL	F04				J			5	
11	75.55		FL	S05				J			5,18	LASER DOESN'T SHOW FRACTURE MOVEMENT
12	80.45		FL	F05				J			6	
13	80.45		FL	S06				J			6,19	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT
14	85.85		FL	F06				J			7	
15	85.85		FL	S07				J			7,20	LASER DOESN'T SHOW FRACTURE MOVEMENT
16	90.6		FL	F07				J			8	
17	90.6		FL	S08				J			8,21	LASER SHOWS LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED

18	95.5		FL	F08				J			9	
19	95.5		FL	S09				J			9,22	LASER SHOWS VERY VERY LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
20	100.5		FL	F09				J			10	
21	100.5		FL	S10				J			10,23	LASER DOESN'T SHOW FRACTURE MOVEMENT
22	105.45		FL	F10				J			11	
23	105.45		FL	S11				J			11,24	LASER SHOWS VERY LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
24	110.5		FL	F11				J			12	
25	110.5		FL	S12				J			12,25	LASER SHOWS VERY LITTLE HORIZONTAL FRACTURE MOVEMENT AND LASER RING DEFORMED
26	120.35		FL	F12				J			13	
27	120.35		FL	S13				J			13,26	LASER DOESN'T SHOW FRACTURE MOVEMENT
28	125.45		FL	F13							29	
29	162.25		MSA									

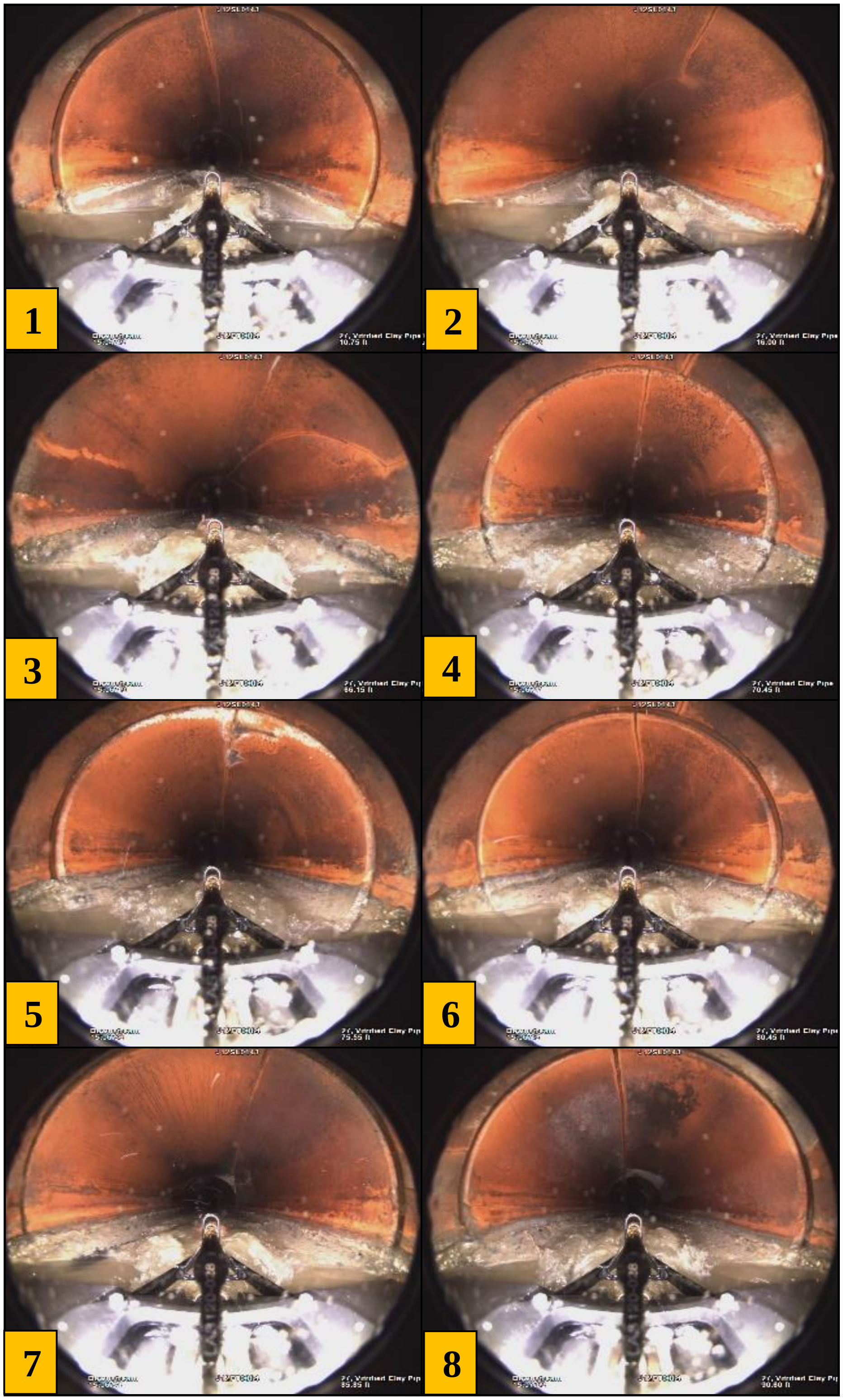


Figure A28-4 images from 1 through 8

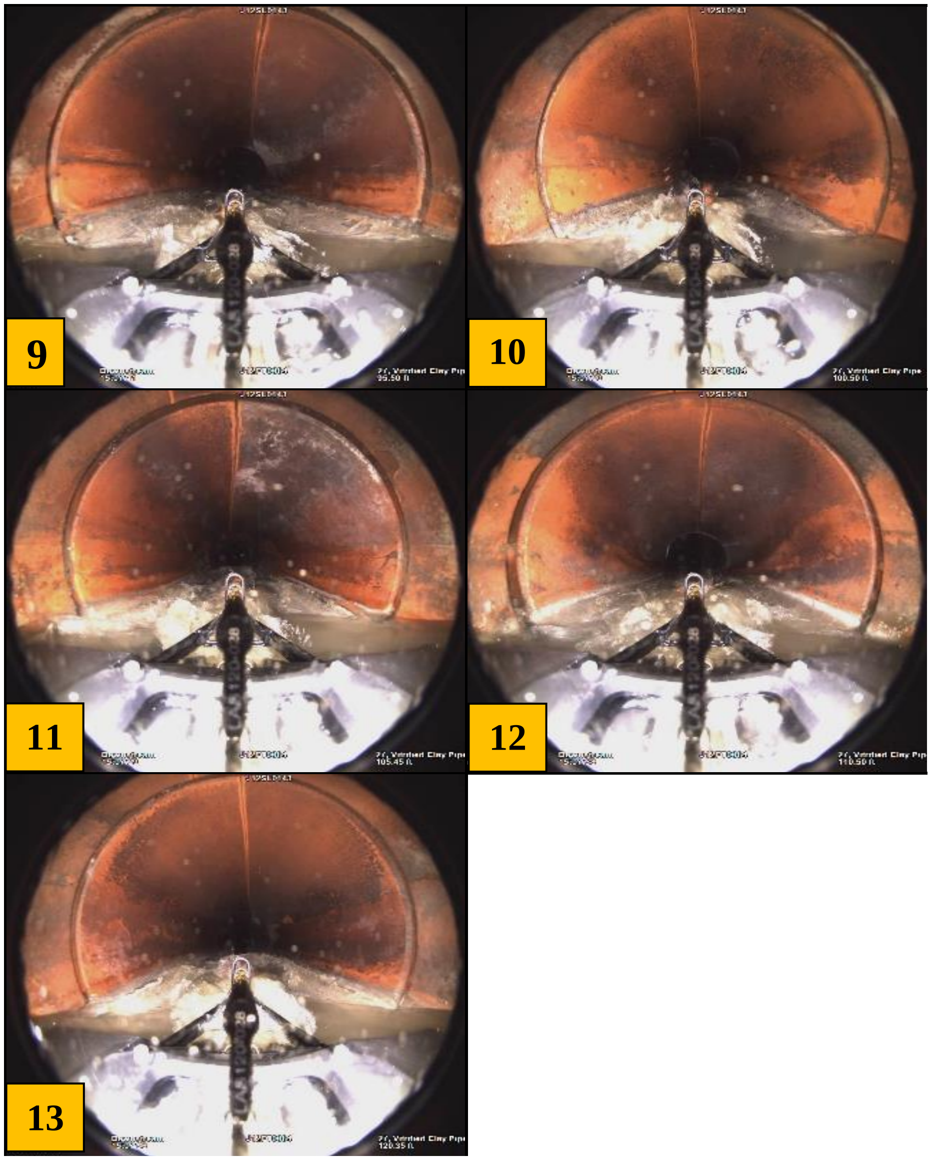


Figure A28-5 images from 9 through 13

Line 29 Summary

Table A29-1 Results Summary of Sewer Line 29

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	N/A
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	1
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	421.2
Maximum Blockage (%)	1.0
Maximum Deposit Height (in)	0.3

Deposit Data

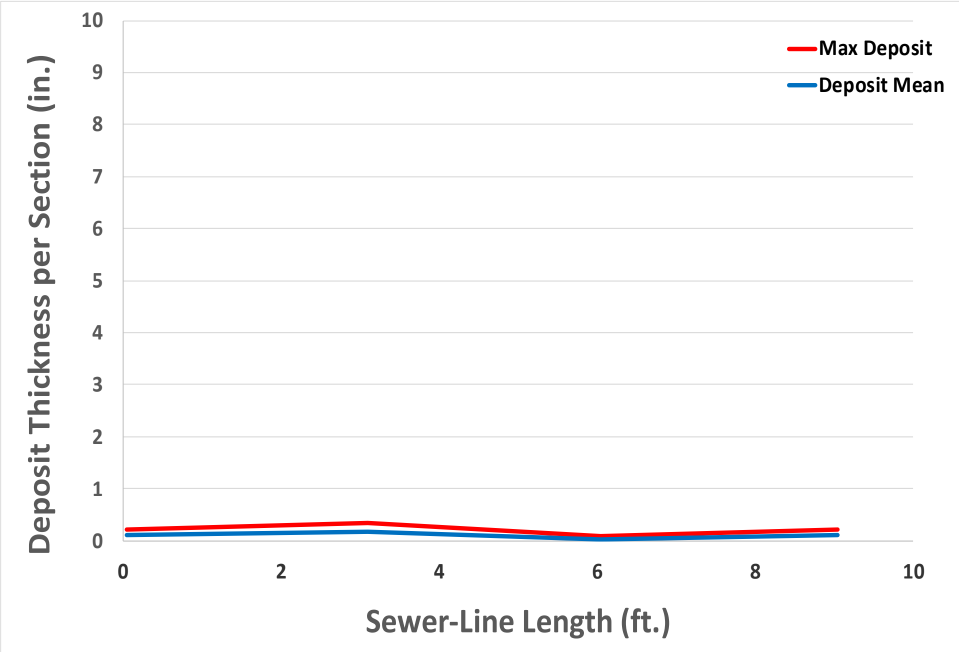


Figure A29-1 Deposit thickness per cross-section

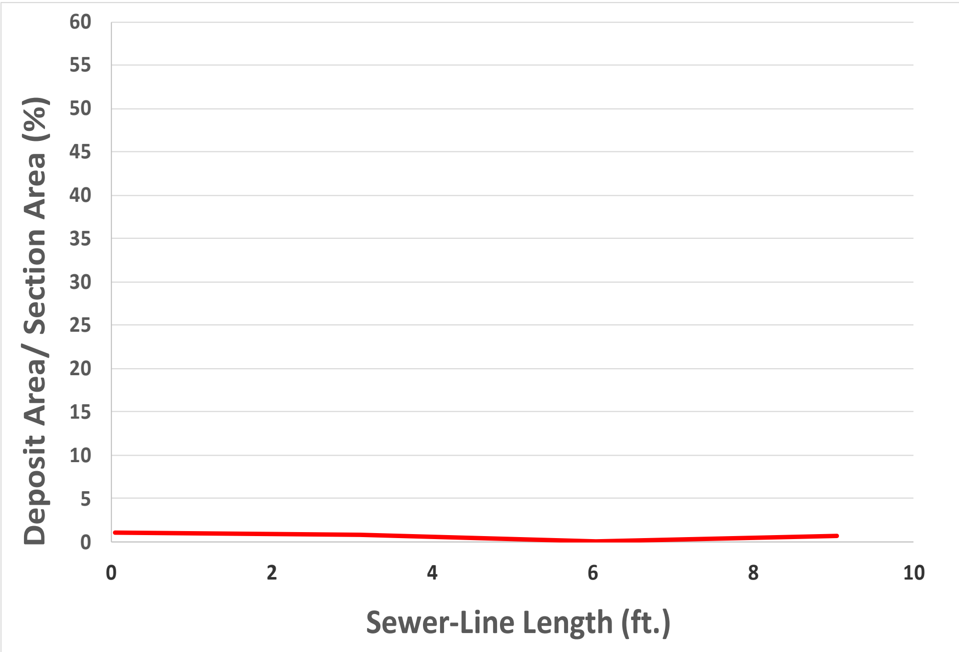


Figure A29-2 Deposit area percentage of the pipe cross section area

Blockage Data

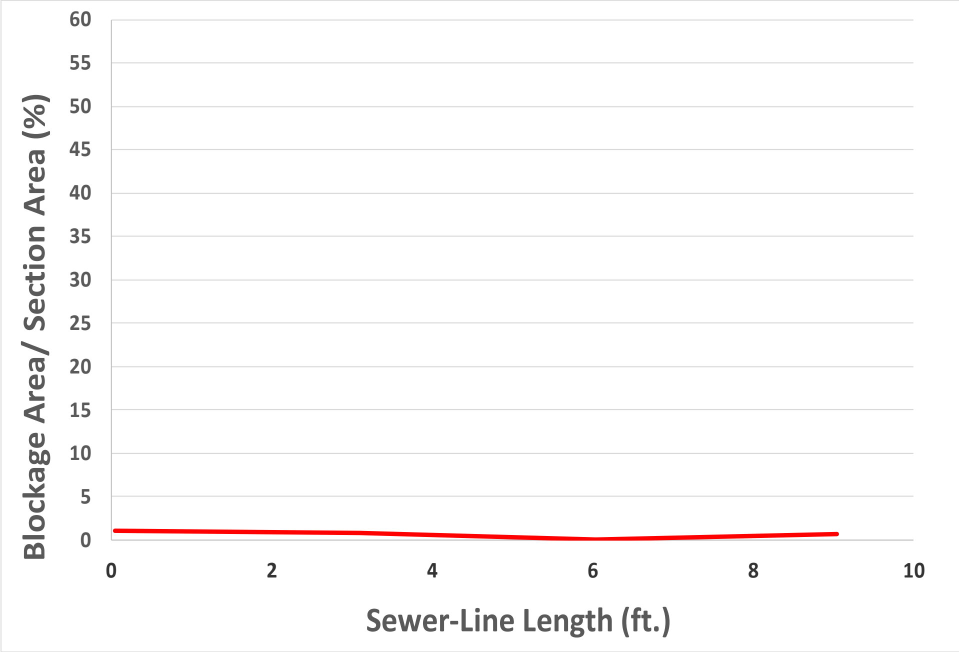


Figure A29-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observation

Table A29-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									NO DEFECTS
2	0		MWL				15%					
3	11.8		MSA									

Line 30 Summary

Table A30-1 Results Summary of Sewer Line 30

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	125
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	2
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	12184.9
Maximum Blockage (%)	2
Maximum Deposit Height (in)	1.4

Deposit Data

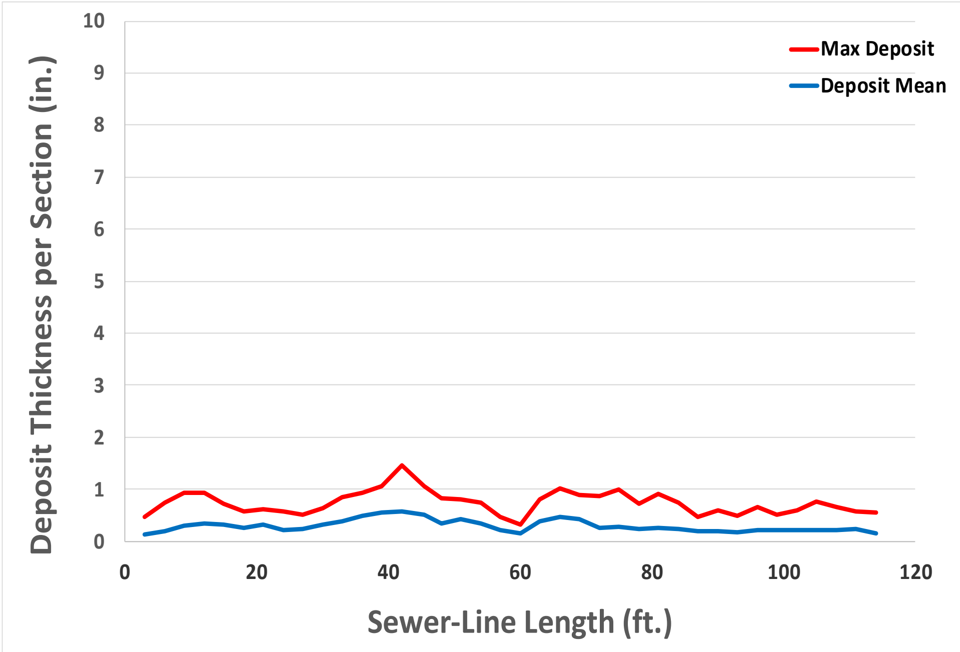


Figure A30-1 Deposit thickness per cross-section

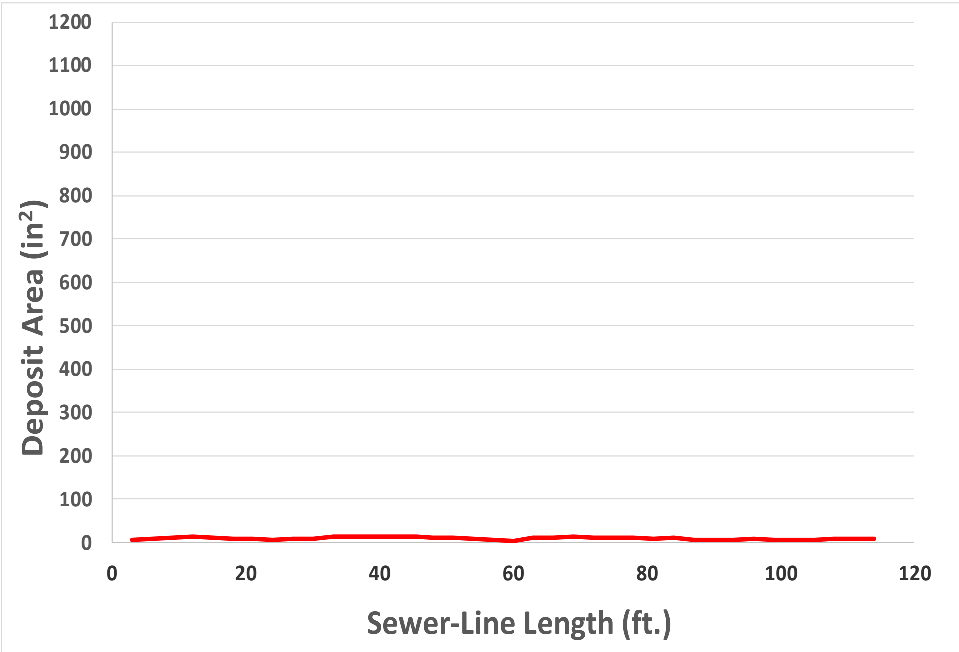


Figure A30-2 Deposit area percentage of the pipe cross section area

Blockage Data

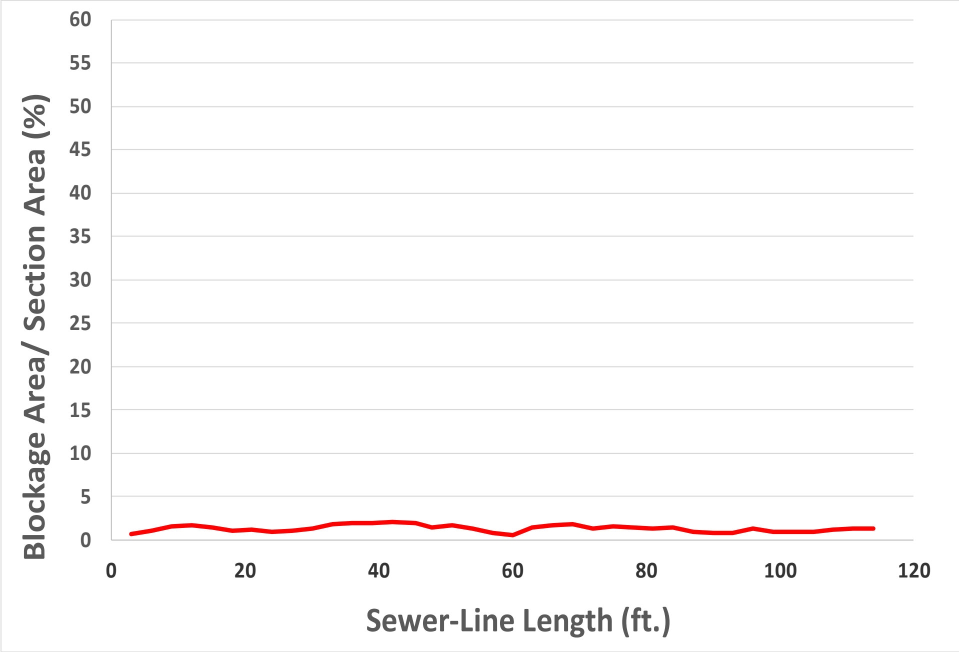


Figure A30-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A30-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code: Group/ Descriptor/ Modifier	Continuous Defect	Value: Dimension 1st	Value: Dimension 2nd	Value: %	Joint	Circumferential Location: At/From	Circumferential Location: To	Img Reference	Remarks
1	0		AMH									
2	6		MWL				5%					
3	25.75		MWL				15%			1,2		
4	63.25		MWL				5%			3		
5	106.55		MSA									

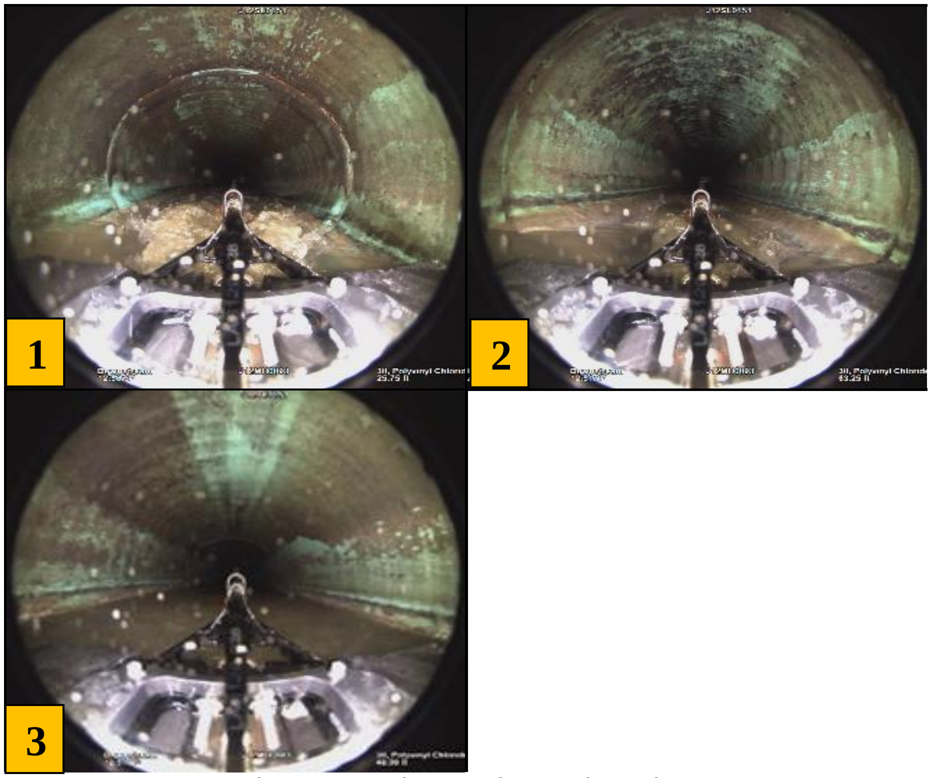


Figure A30-4 images from 1 through 3

Line 31 Summary

Table A31-1 Results Summary of Sewer Line 31

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	738
Percentage of The Line Not Inspected	2.2%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	2
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	3
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	72819.4
Maximum Blockage (%)	3.5
Maximum Deposit Height (in)	1.8

Due to software issues, distance from 482 ft. to 493.15 ft. could not be processed.

Deposit Data

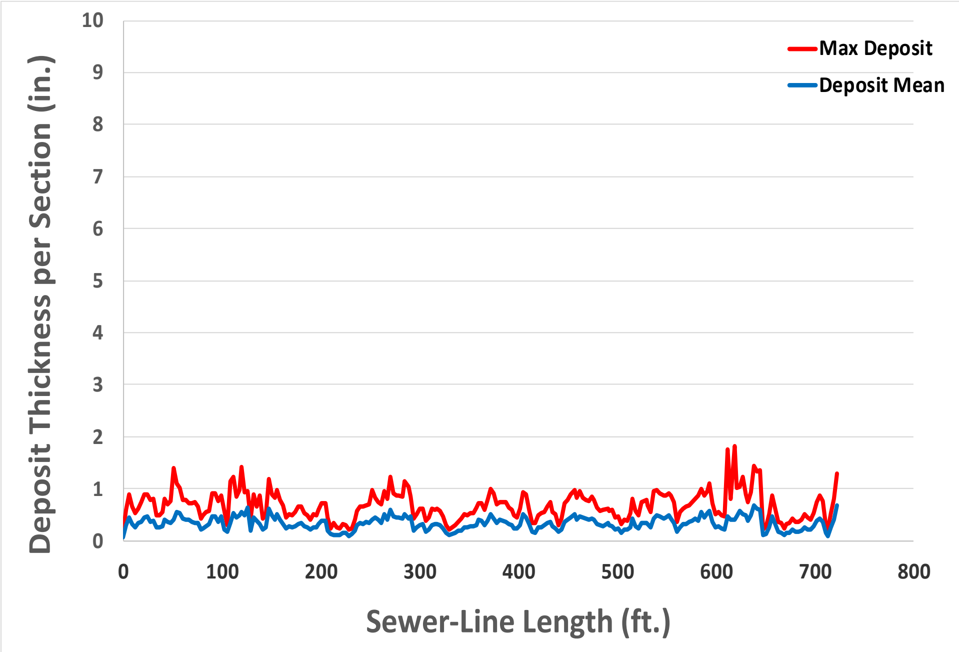


Figure A31-1 Deposit thickness per cross-section

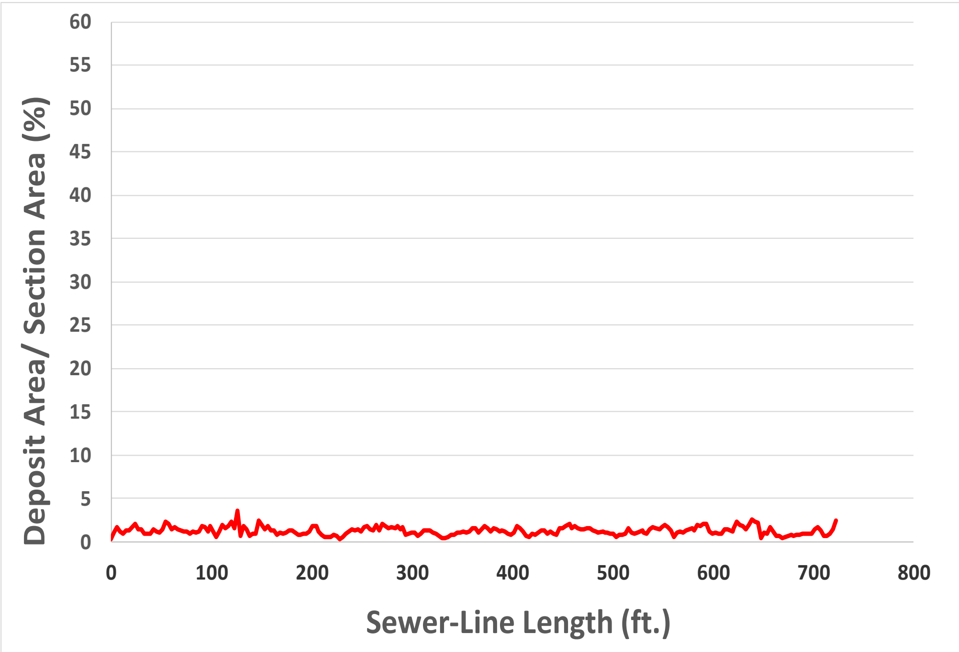


Figure A31-2 Deposit area percentage of the pipe cross section area

Blockage Data

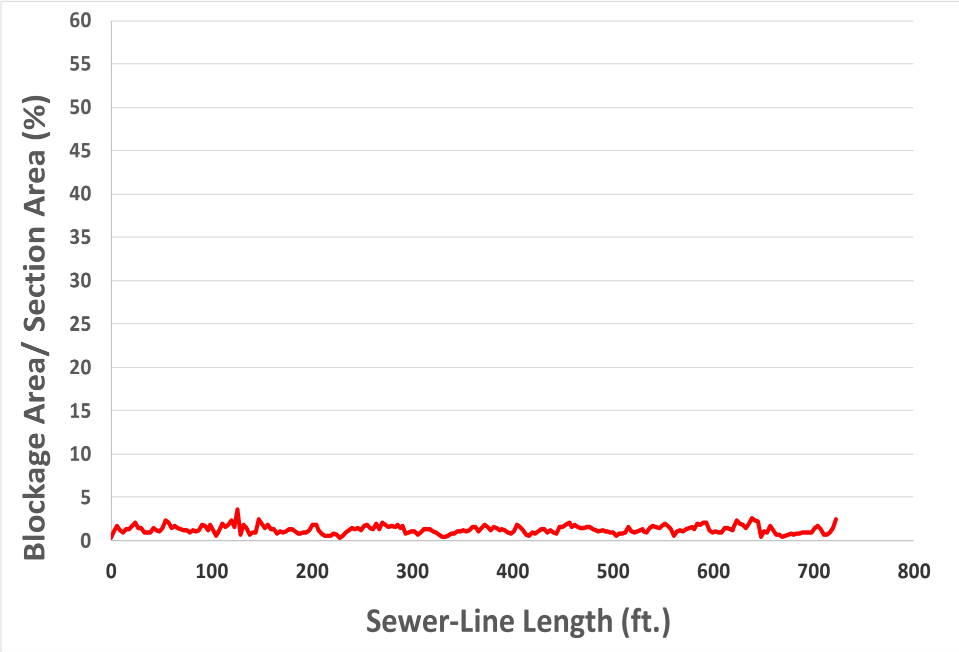


Figure A31-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A31-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				10%					
3	285.2		MWL				15%				3	VIDEO JUMPED
4	608.8		JO								1	
5	612.2		JO								2	
6	737.8		MSA									

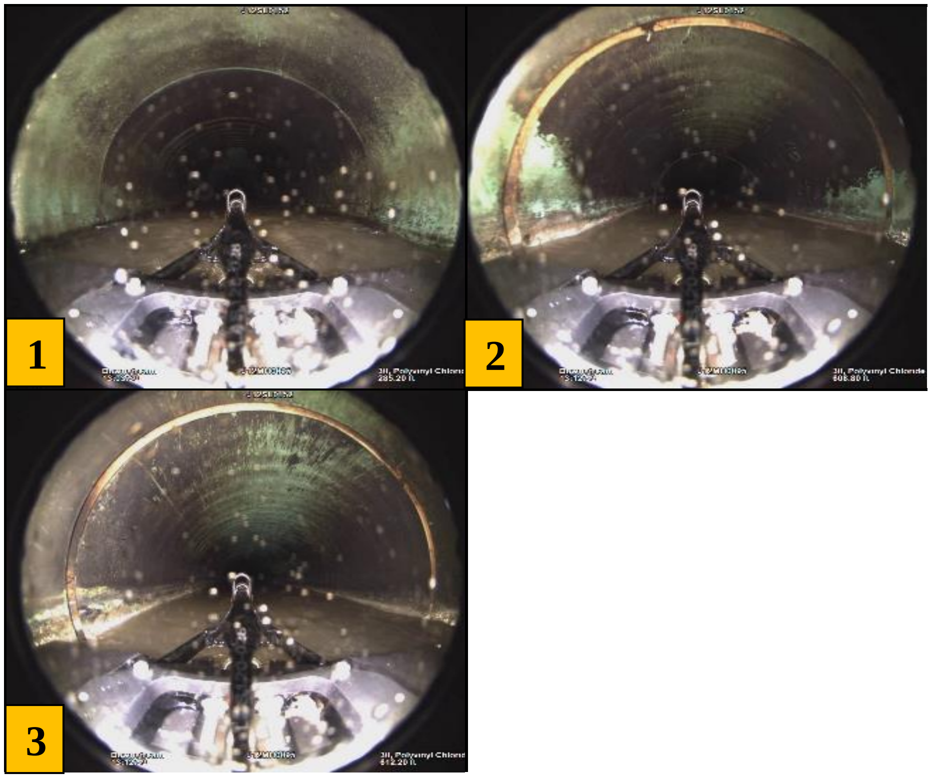


Figure A31-4 images from 1 through 3

Line 32 Summary

Table A32-1 Results Summary of Sewer Line 32

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	66
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	2
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	2
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	4783.9
Maximum Blockage (%)	1.4
Maximum Deposit Height (in)	0.8

Deposit Data

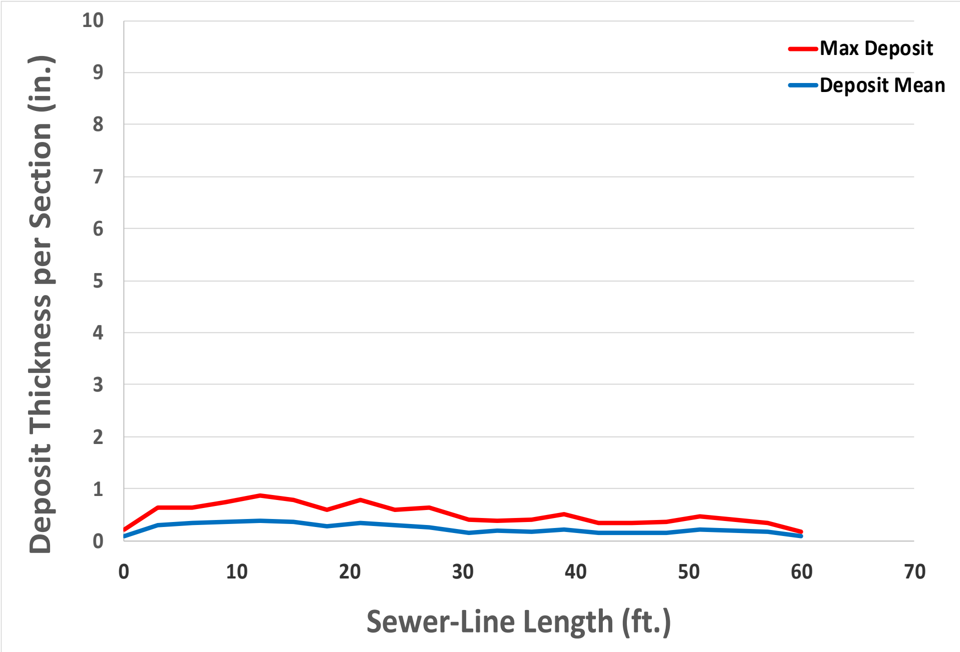


Figure A32-1 Deposit thickness per cross-section

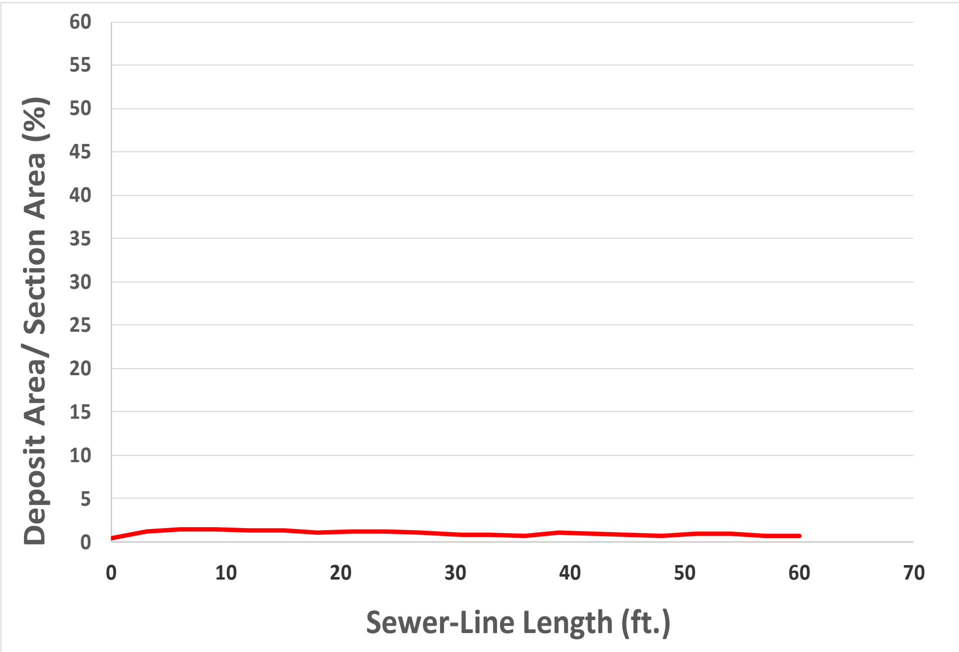


Figure A32-2 Deposit area percentage of the pipe cross section area

Blockage Data

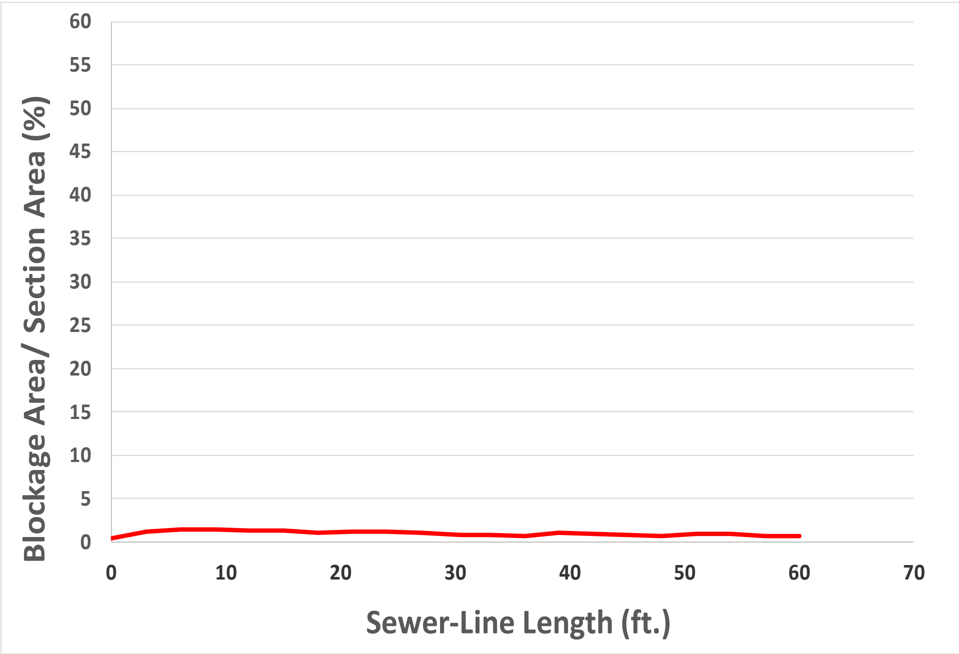


Figure A32-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A32-2Visual inspection observations

SN	Distance (feet)	Video Ref.	Code Group/ Descriptor/ Modifier	Continuous Defect	Value Dimension 1st	Value Dimension 2nd	Value %	Joint	Circumferential Location At/From	Circumferential Location To	Img Reference	Remarks
1	0		AMH									
2	0		MWL				5%					
3	9.05		MWL				10%				1,2	
4	21.95		MWL				5%				3	
5	60.75		MSA									

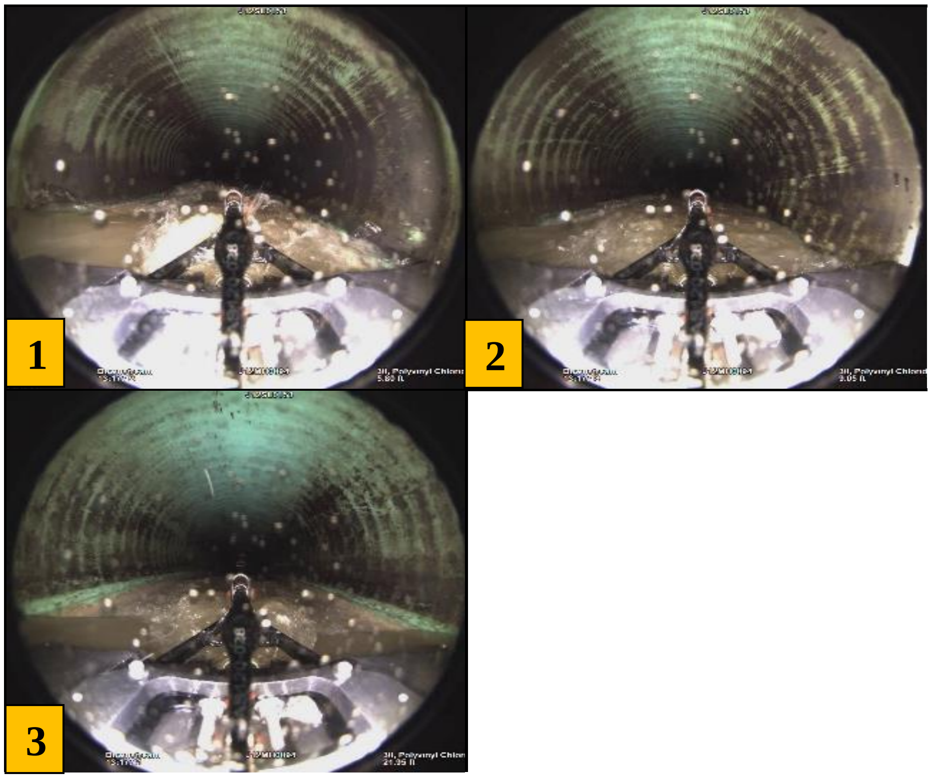


Figure A32-4 images from 1 through 3

Line 33 Summary

Table A33-1 Results Summary of Sewer Line 33

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	1273.3
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	4
Level 5 Defects	0
Level 4 Defects	3
Total Defects	6
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	121362.6
Maximum Blockage (%)	8.7
Maximum Deposit Height (in)	2.2

Deposit Data

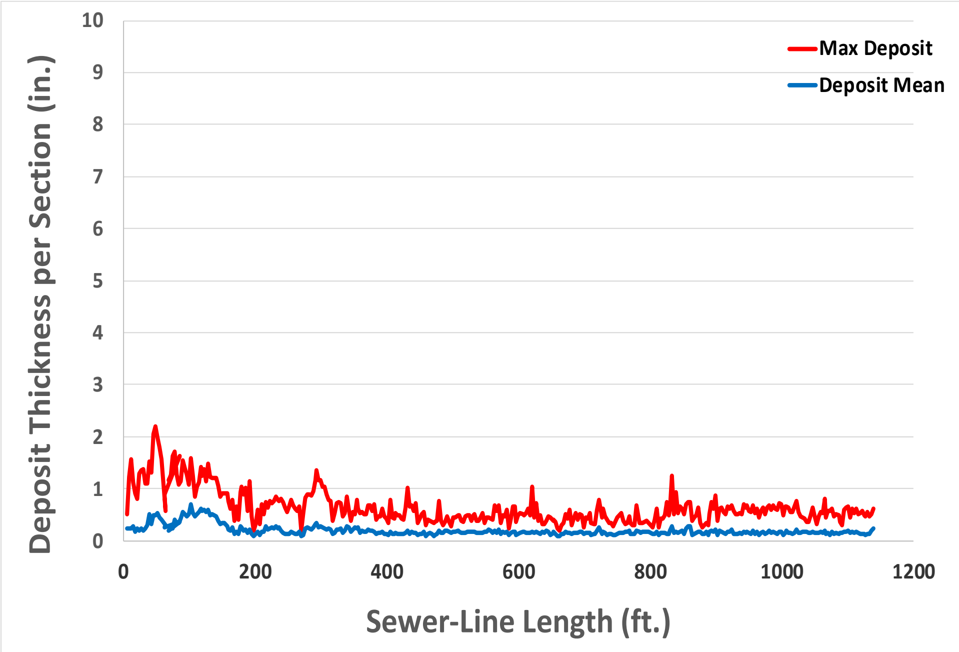


Figure A33-1 Deposit thickness per cross-section

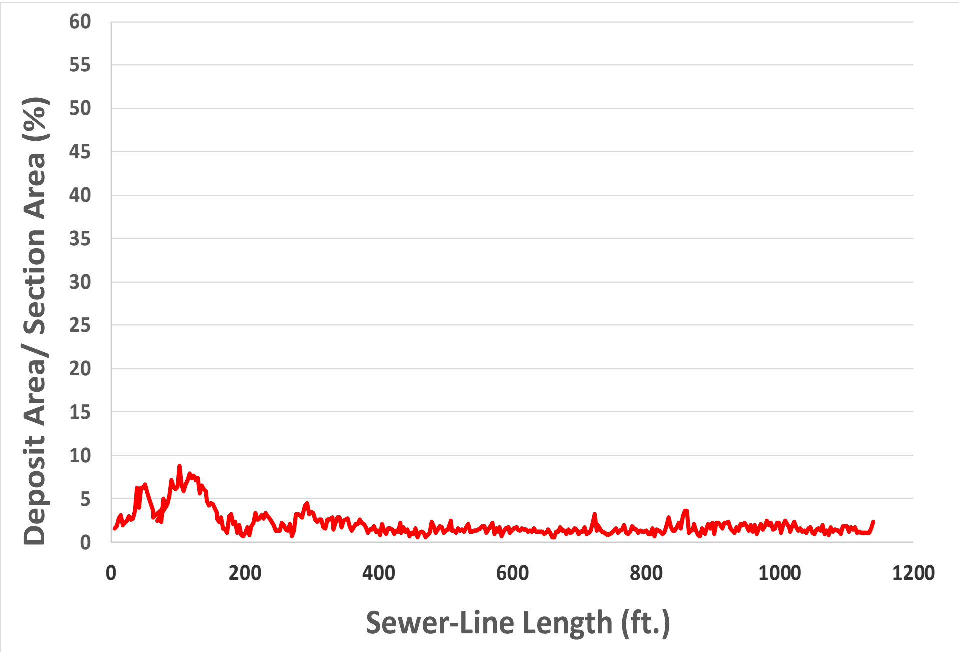


Figure A33-2 Deposit area percentage of the pipe cross section area

Blockage Data

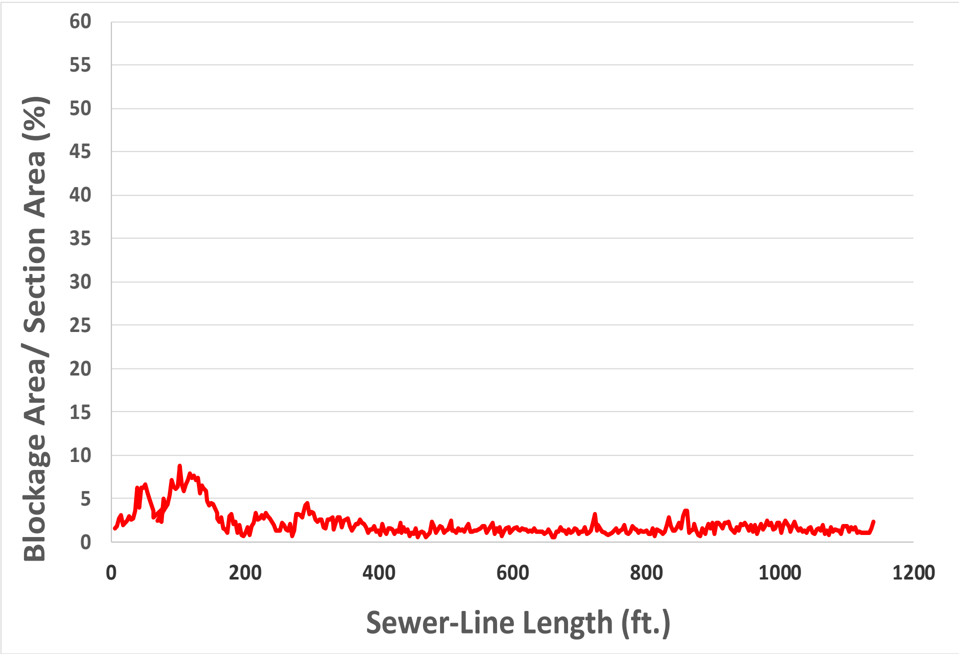


Figure A33-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A33-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				5%					
3	6		DAE	S01			5%				1	
4	355.55		RLJ					J			2	
5	645.65		RLJ					J			3	
6	830.9		RMB	S02							5	
7	836.5		RLJ								4	
8	836.5		DAG				10%	J			4	
9	845.25		RMB	F02								
10	1141.45		DAE	F01								
11	1141.45		MSA									

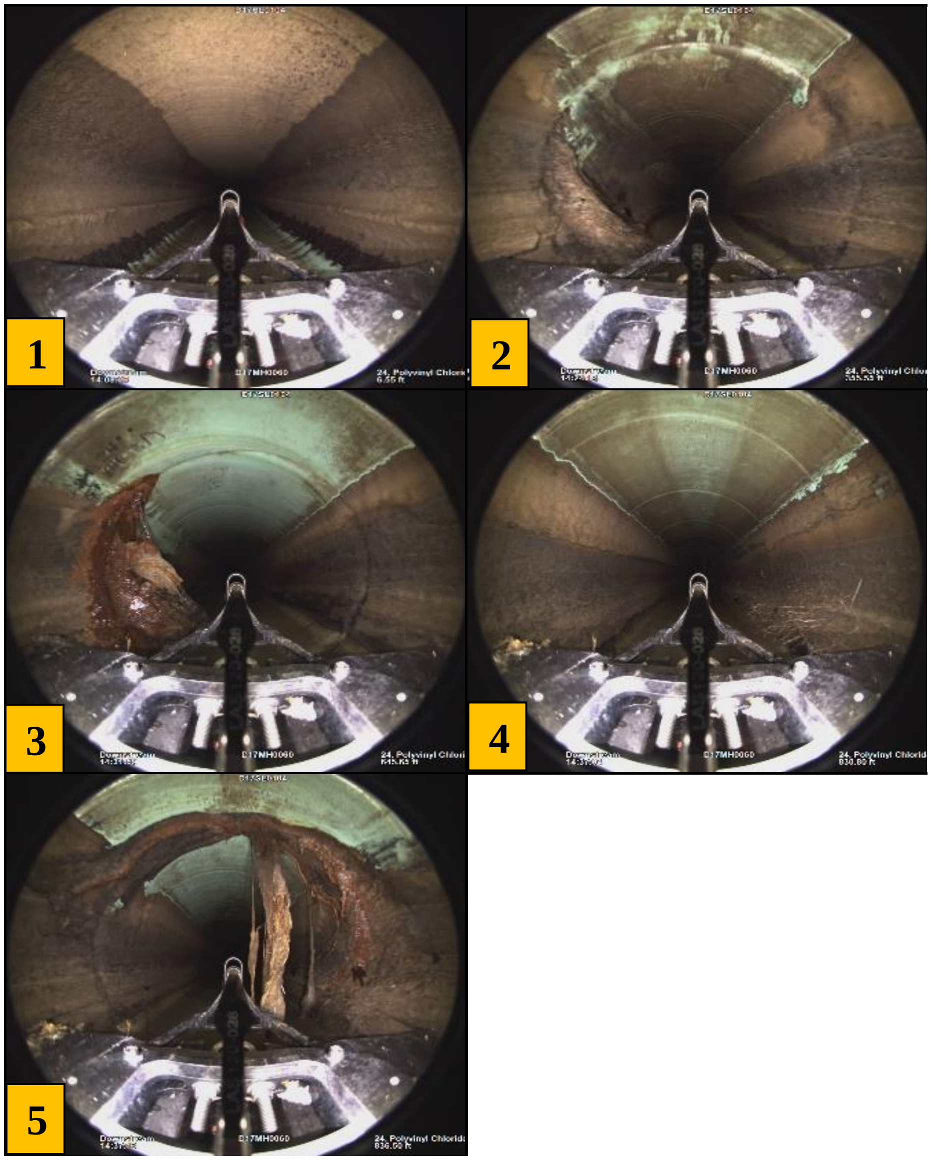


Figure A33-4 images from 1 through 5

Line 34 Summary

Table A34-1 Results Summary of Sewer Line 34

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	762.9
Percentage of The Line Not Inspected	0.7%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	1
Level 5 Defects	0
Level 4 Defects	0
Total Defects	3
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	60082.67
Maximum Blockage (%)	5.1
Maximum Deposit Height (in)	1

Due to software issues, distance from 837.05 ft. to 843.3 ft. could not be processed.

Deposit Data

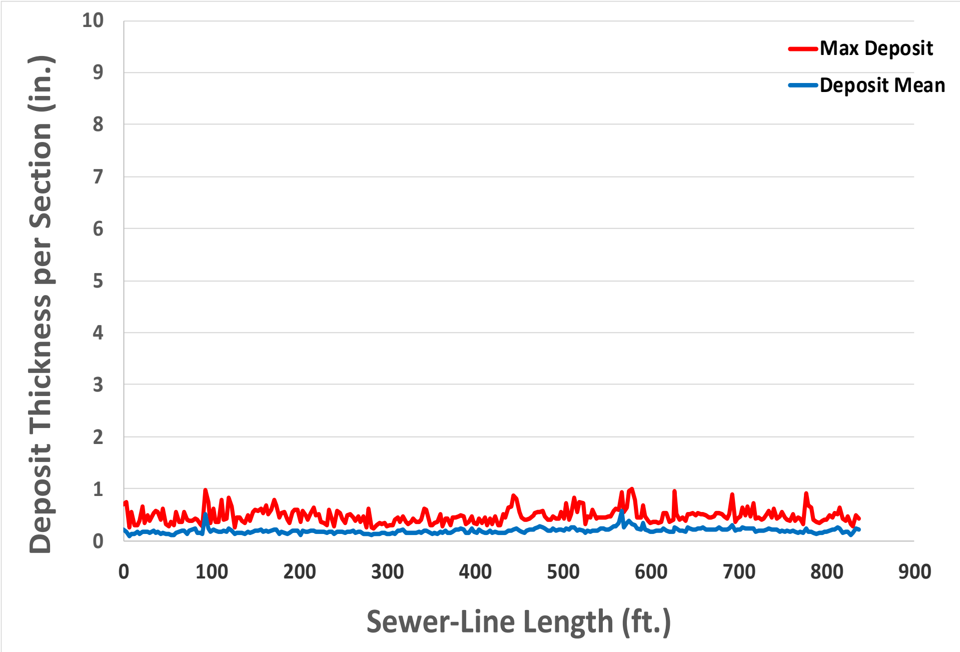


Figure A34-1Deposit thickness per cross-section

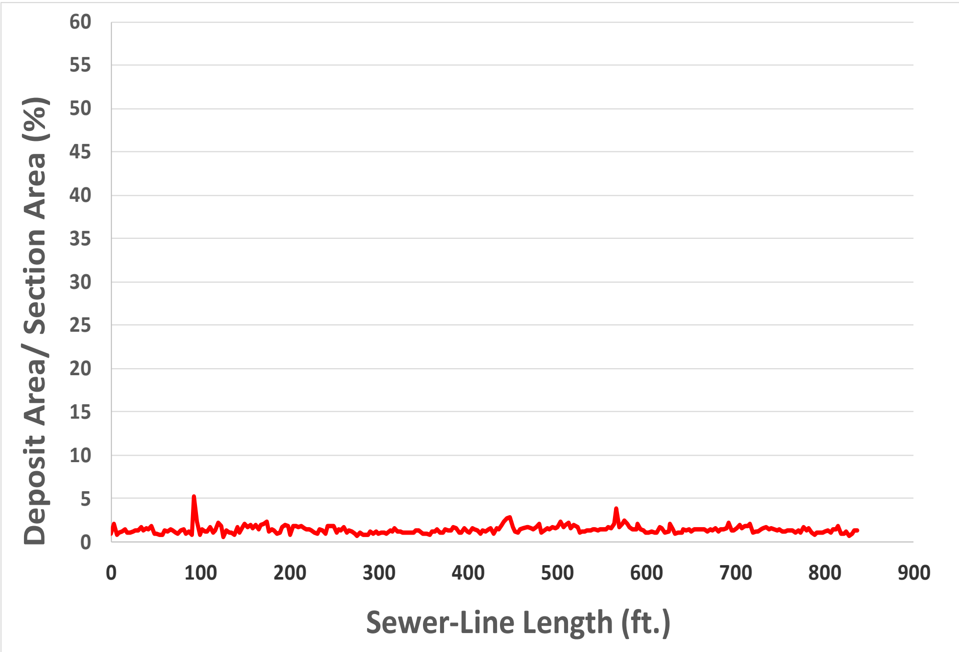


Figure A34-2 Deposit area percentage of the pipe cross section area

Blockage Data

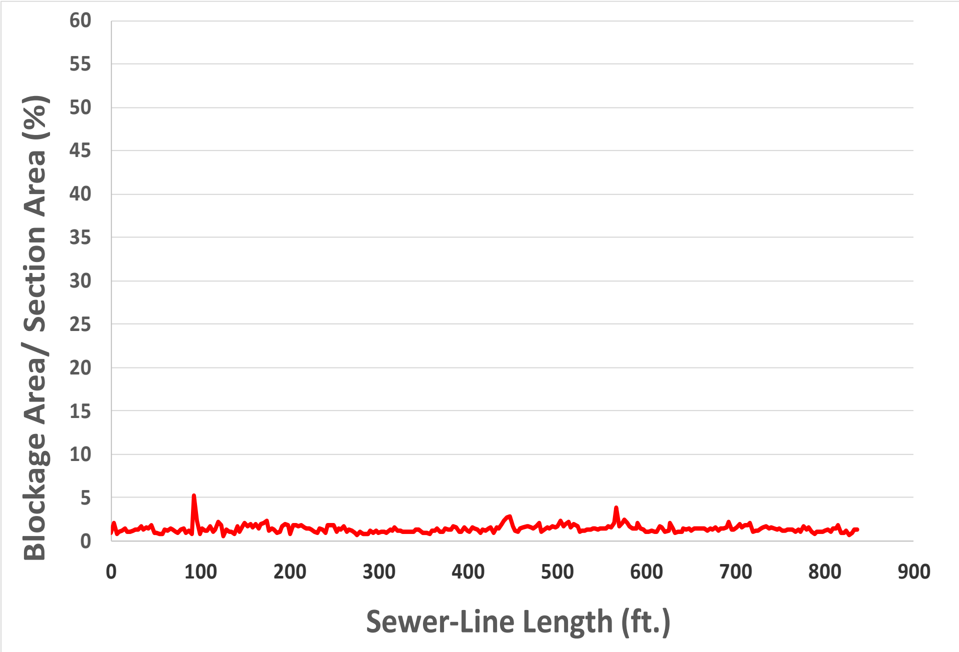


Figure A34-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A34-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				0%					
3	6		DAE	S01			5%				3 TO 8	
4	590.2		RMJ				5%	J			1	MIGHT BE MUD ENTERING IN TO THE PIPE THROUGH A FRACTURE.
5	647.3		DAG				5%				2	
6	851		DAE	F01								
7	851		MSA									

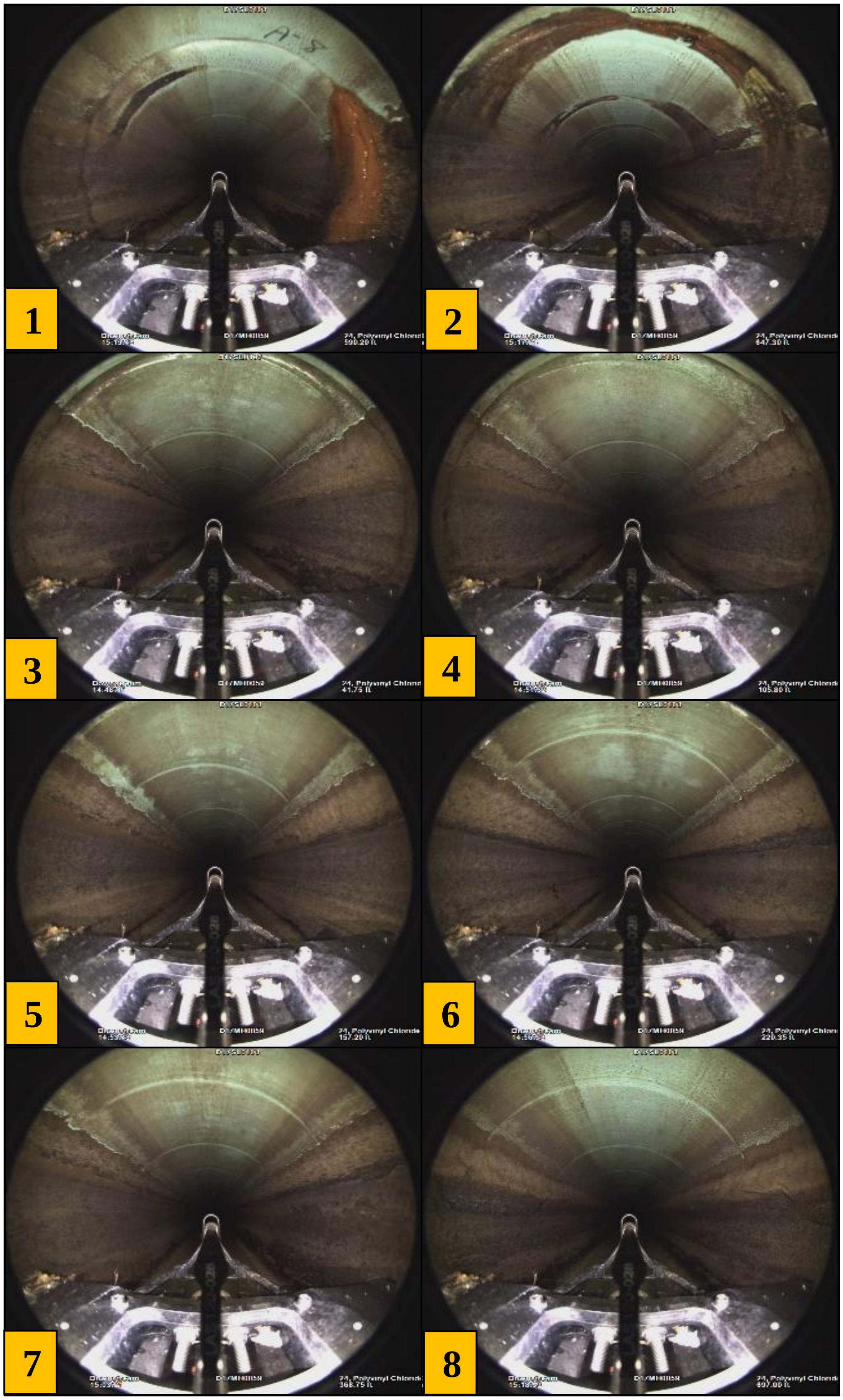


Figure A34-4 images from 1 through 8

Line 35 Summary

Table A35-1 Results Summary of Sewer Line 35

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	549
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	3
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	30563.05
Maximum Blockage (%)	2.5
Maximum Deposit Height (in)	1.3

Deposit Data

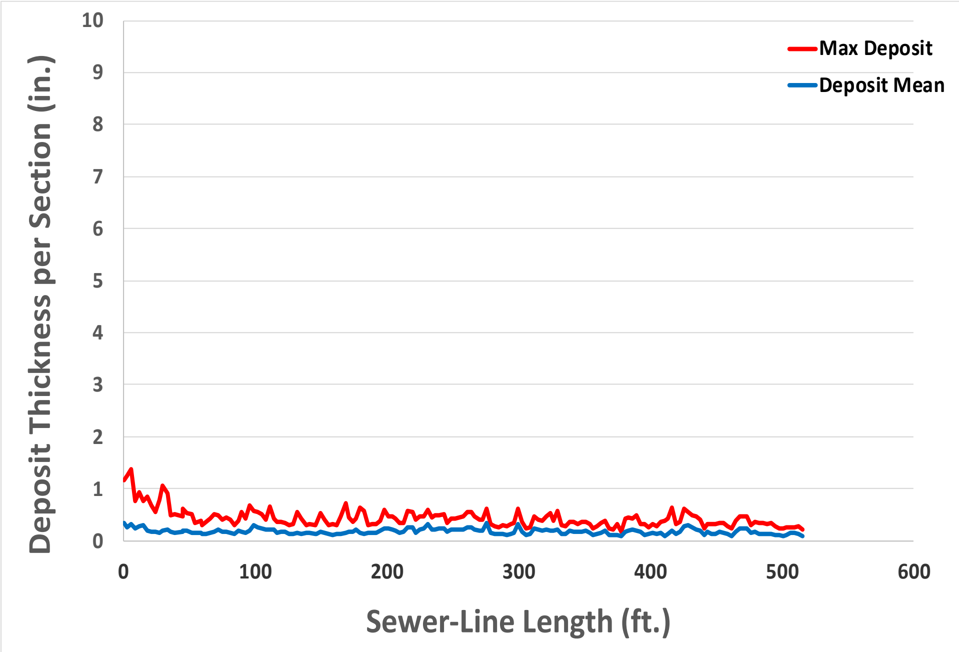


Figure A35-1 Deposit thickness per cross-section

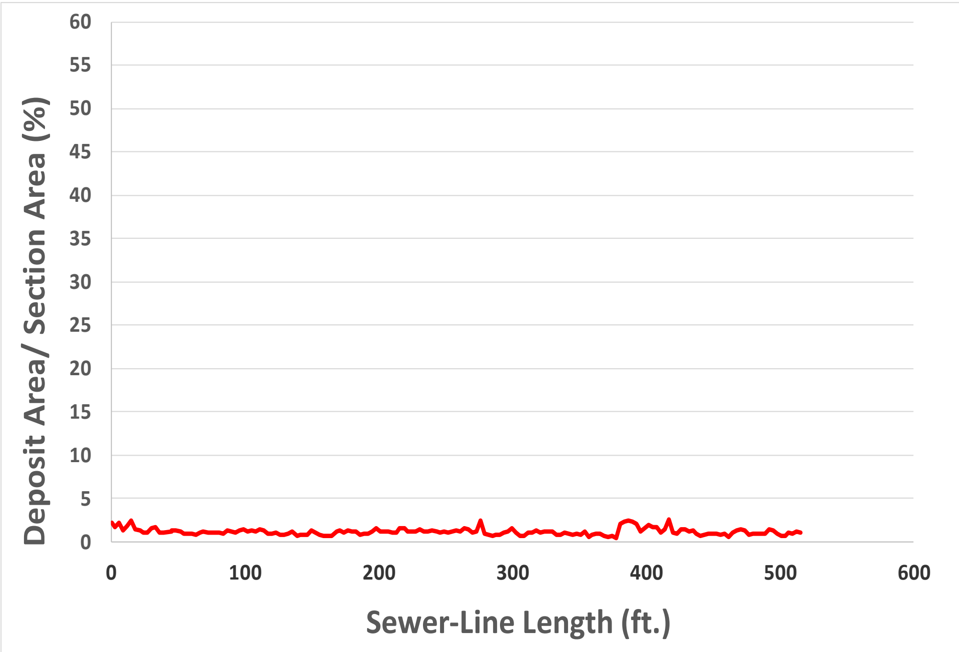


Figure A35-2 Deposit area percentage of the pipe cross section area

Blockage Data

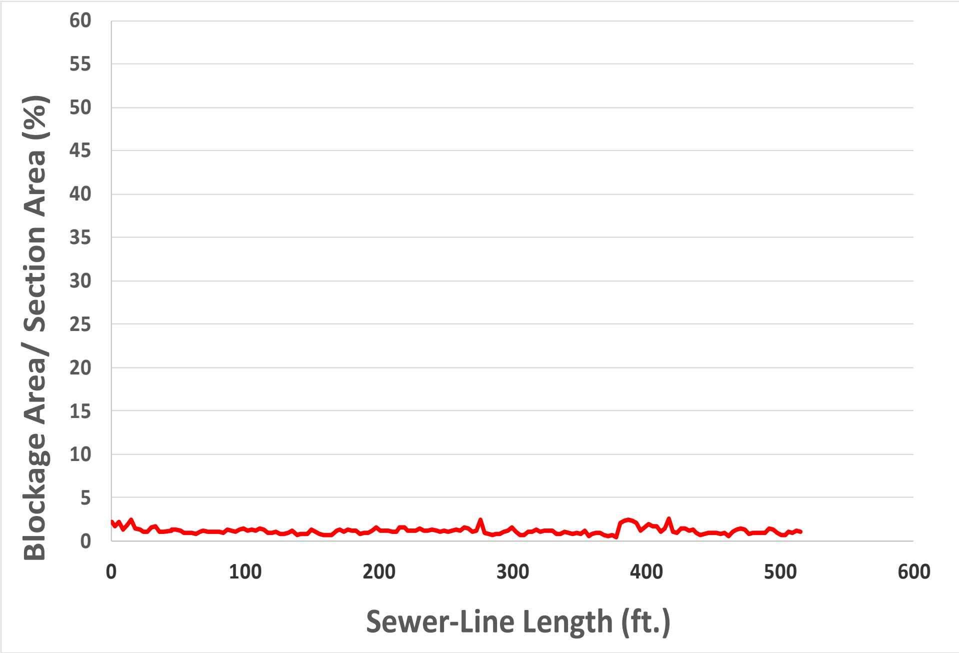


Figure A35-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A35-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				5%					
3	6		DAE	S01			5%				1,2,5,6	
4	312.7		DAG				10%	J			3	
5	375.65		DAG				5%	J			4	
6	525.85		DAE	F01								
7	525.85		MSA									

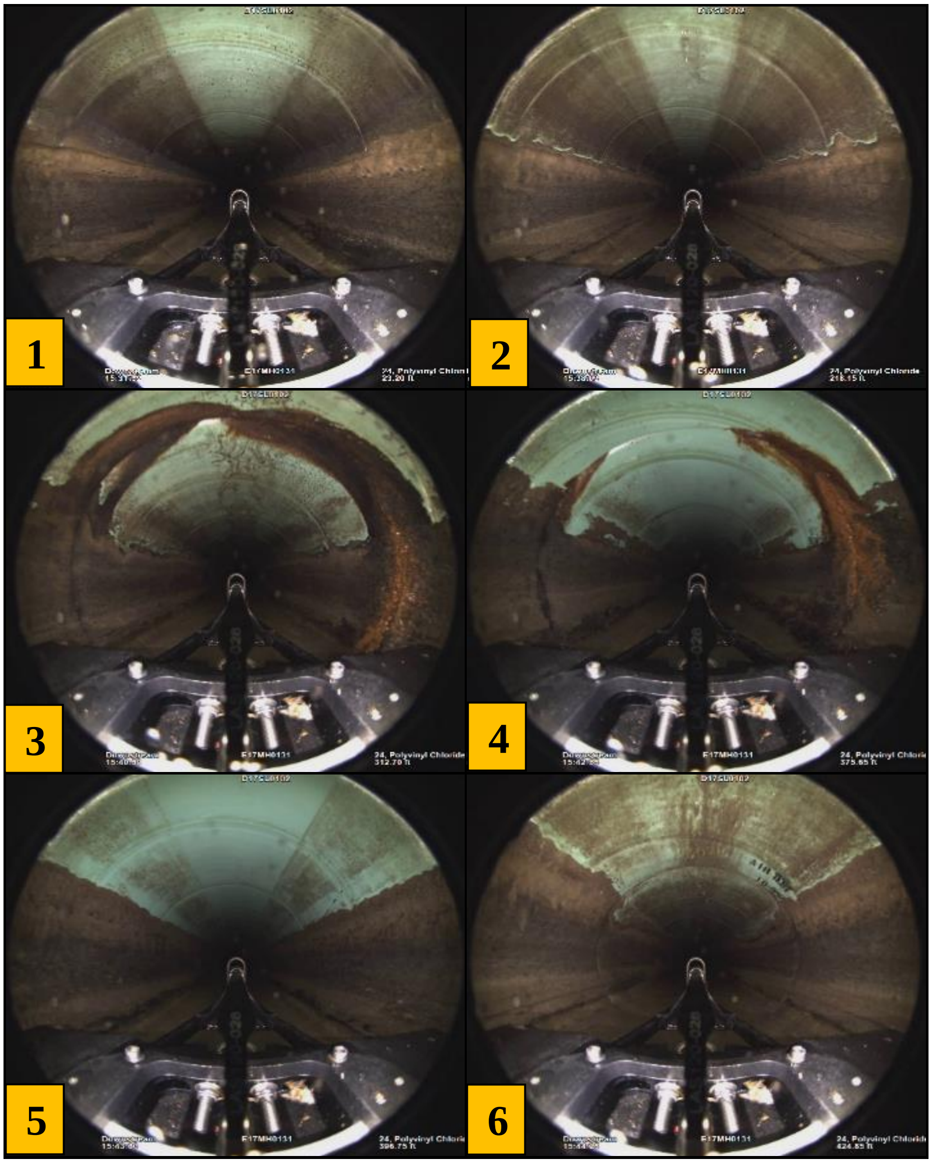


Figure A35-4 images from 1 through 6

Line 36 Summary

Table A36-1 Results Summary of Sewer Line 36

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	485
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	1
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	29120.66
Maximum Blockage (%)	3
Maximum Deposit Height (in)	1.9

Deposit Data

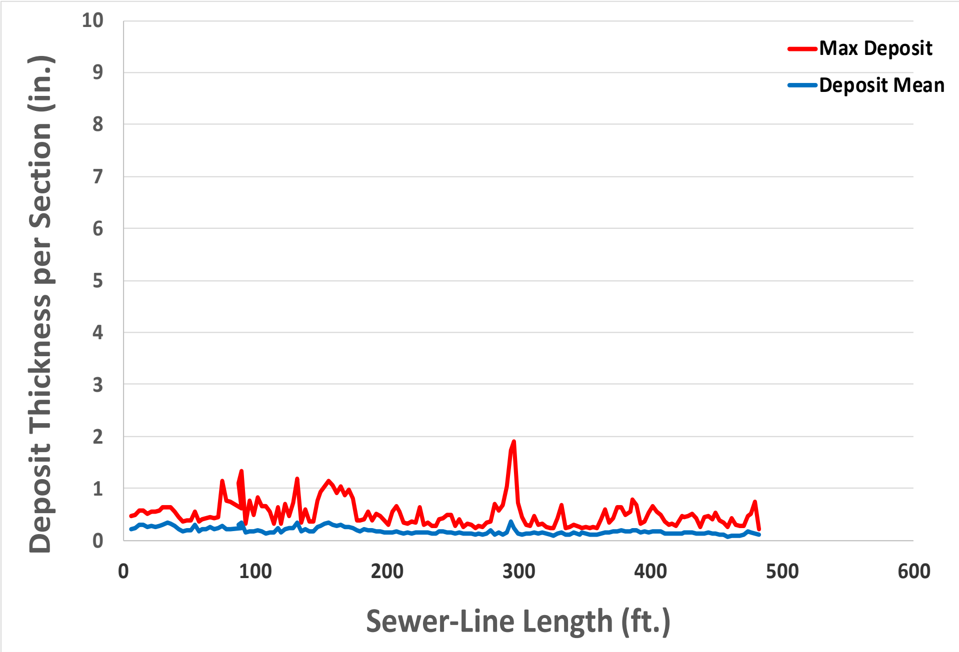


Figure A36-1 Deposit thickness per cross-section

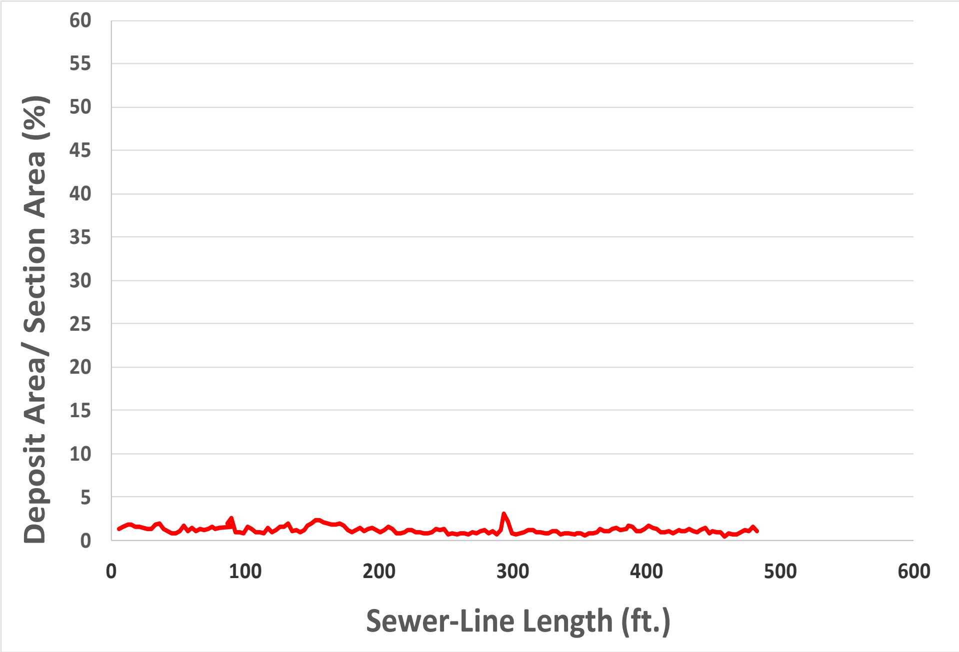


Figure A36-2 Deposit area percentage of the pipe cross section area

Blockage Data

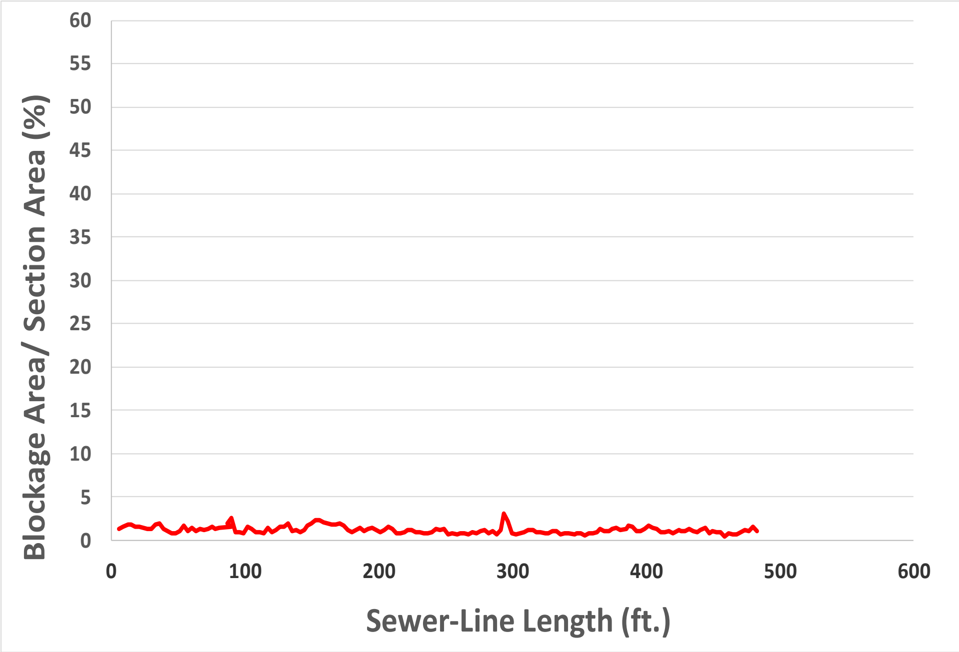


Figure A36-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A36-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value				Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%			At/From	To		
					1st	2nd							
1	0		AMH										
2	0		MWL				3%						
3	6		DAE	S01			5%					1 TO 4	
4	472.05		DAE	F01									
5	472.05		MSA										

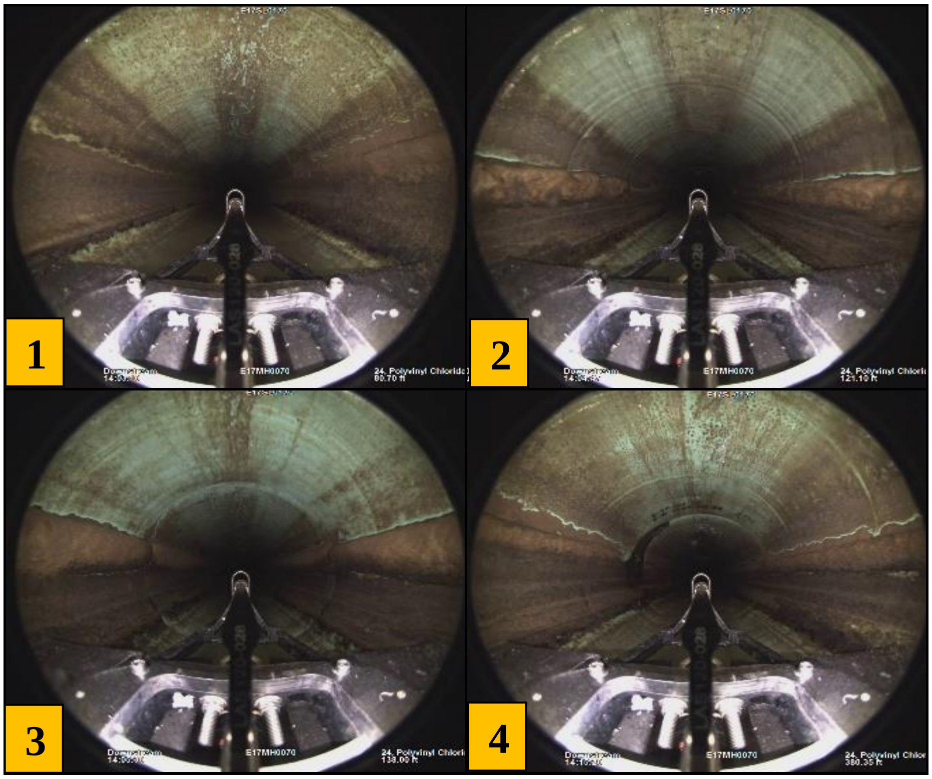


Figure A36-4 images from 1 through 4

Line 37 Summary

Table A37-1 Results Summary of Sewer Line 37

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	264
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	3
Level 5 Defects	0
Level 4 Defects	3
Total Defects	4
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	19406.22
Maximum Blockage (%)	2.4
Maximum Deposit Height (in)	1.1

Deposit Data

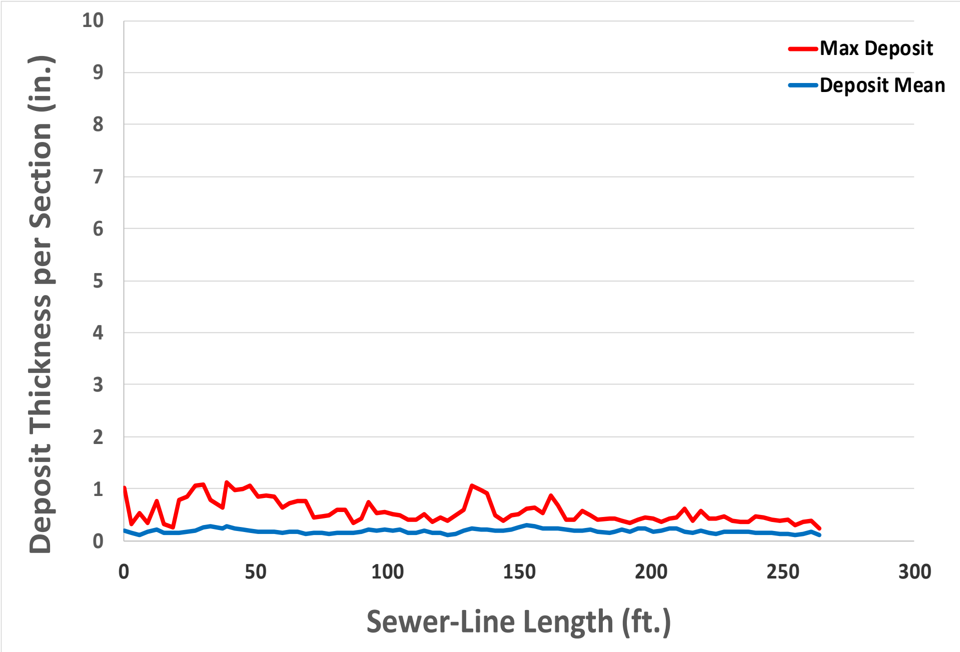


Figure A37-1 Deposit thickness per cross-section

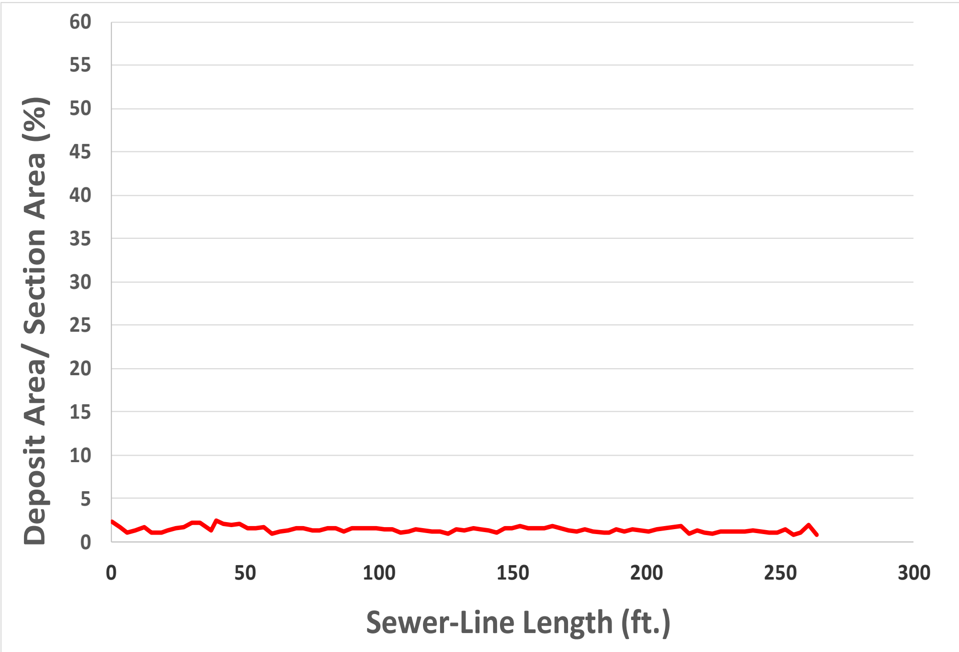


Figure A37-2 Deposit area percentage of the pipe cross section area

Blockage Data

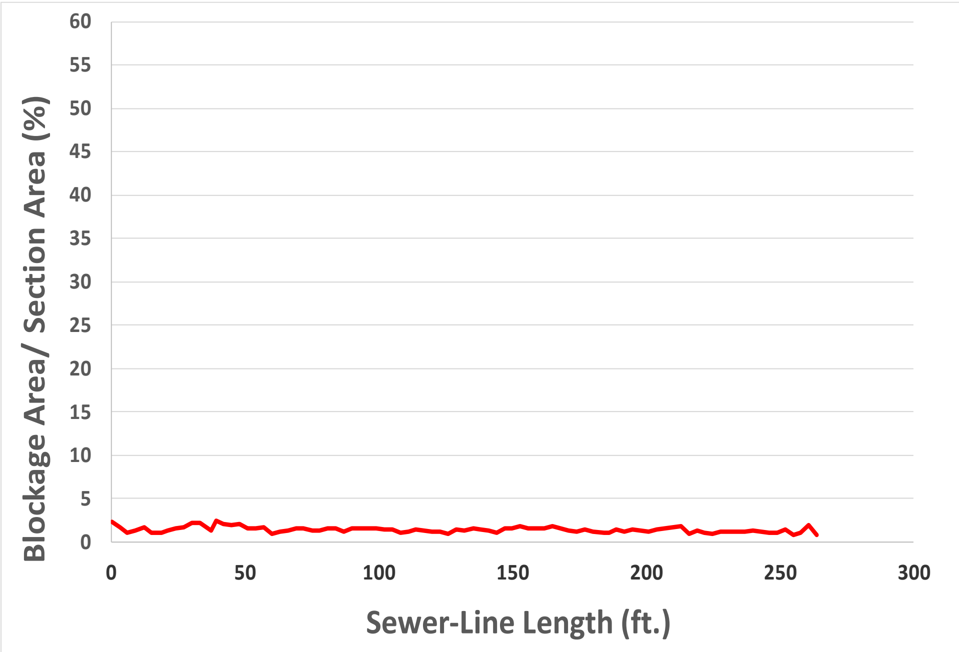


Figure A37-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A37-2Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				3%					
3	0		DAE	S01			5%				4	
4	32.95		RLJ					J			1	
5	122.85		RLJ					J			2	
6	148.1		RLJ					J			3	
7	263.1		DAE	F01								
8	263.1		MSA									

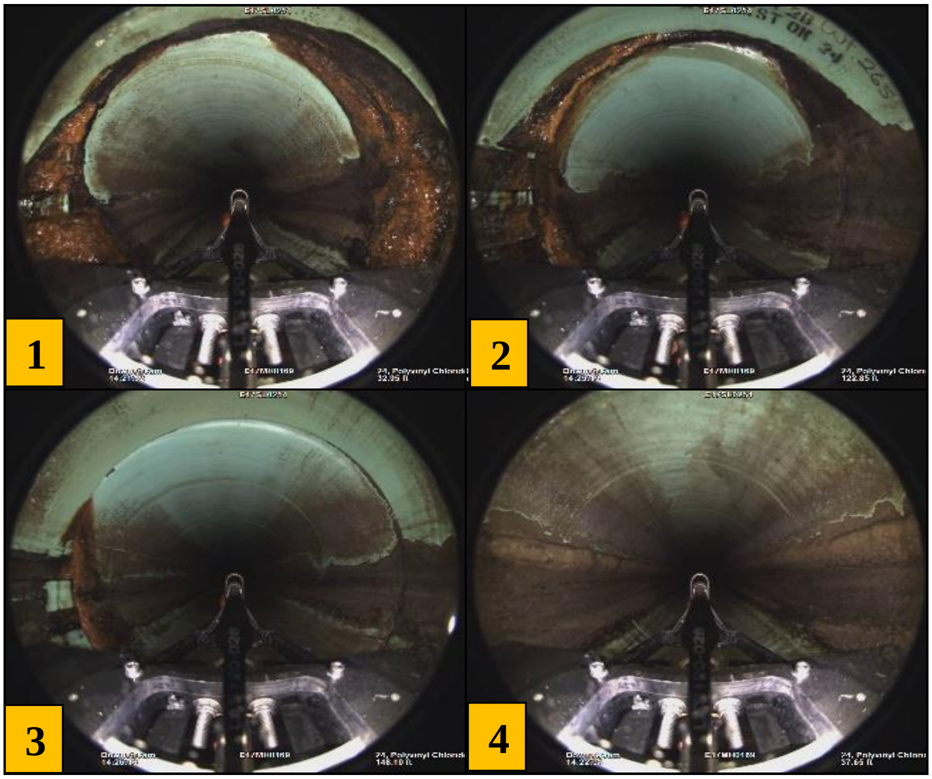


Figure A37-4 images from 1 through 4

Line 38 Summary

Table A38-1 Results Summary of Sewer Line 38

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	551
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	17
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	77245.6
Maximum Blockage (%)	4.5
Maximum Deposit Height (in)	2.2

Deposit Data

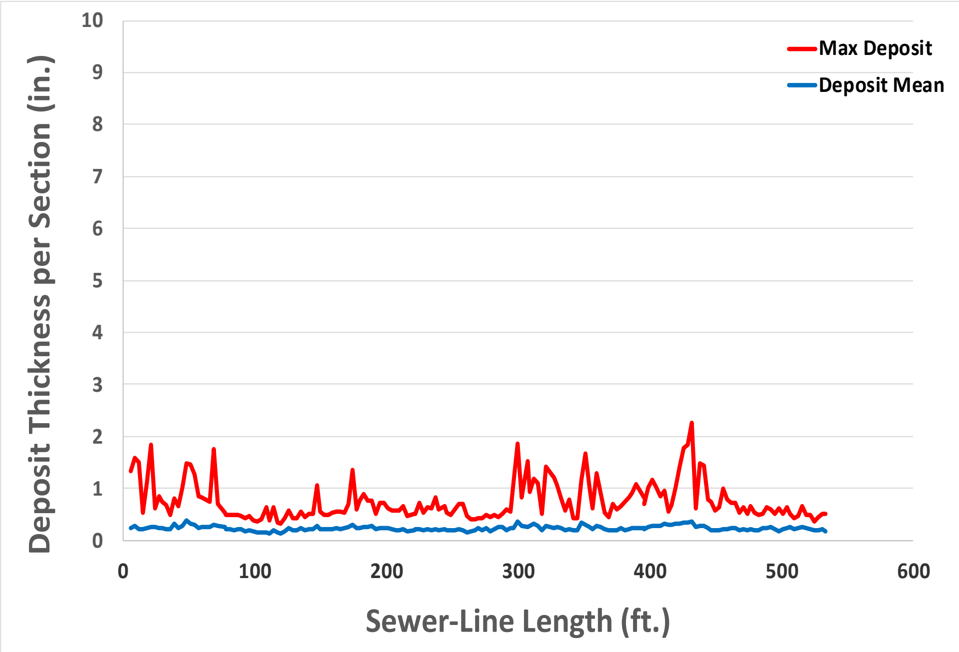


Figure A38-1 Deposit thickness per cross-section

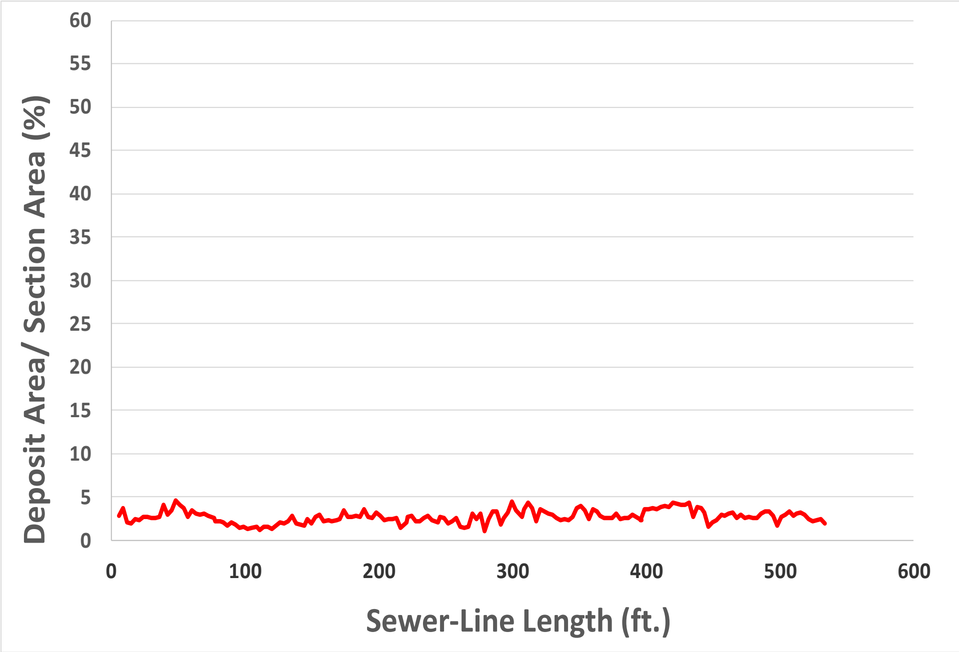


Figure A38-2 Deposit area percentage of the pipe cross section area

Blockage Data

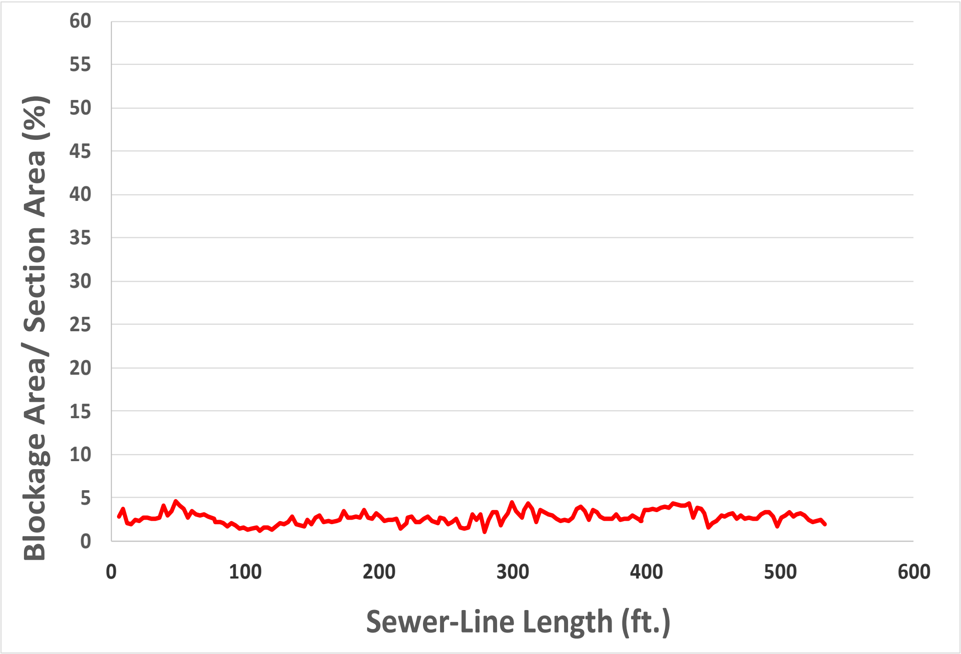


Figure A38-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A38-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				5%					
3	0		DAE	S01			10%				1	
4	8.35		DAE	F01								
5	9.25		DAG				5%				2	
6	10.65		DAE	S02			10%				3	
7	59.5		DAE	F02								
8	59.5		DAE	S03			5 TO 10%				4 TO 8	
9	62.85		MWL				10%				9	
10	125.35		MWL				5%				10	
11	248.65		MWL				10%				11	
13	276.9		MWL				5%				12	
14	294.65		DAE	F03								
15	294.65		DAE	S04			10%				13,14	
16	303.65		DAE	F04								
17	303.65		DAE	S05			10%				15	
18	321.85		MWL				10%				16	
19	331.3		DAE	F05								
20	331.3		DAE	S06			5%				17	
21	341.75		MWL				5%				18	
22	346.4		DAE	F06								
23	346.4		DAE	S07			10%				19	
24	369.1		DAE	F07								
25	369.1		DAE	S08			10%				20 TO 25	
26	459		DAE	F08								
24	459		DAE	S09			5%				26	
25	491.75		MWL				10%				27	
26	534.35		DAE	F09								
27	534.35		MSA									

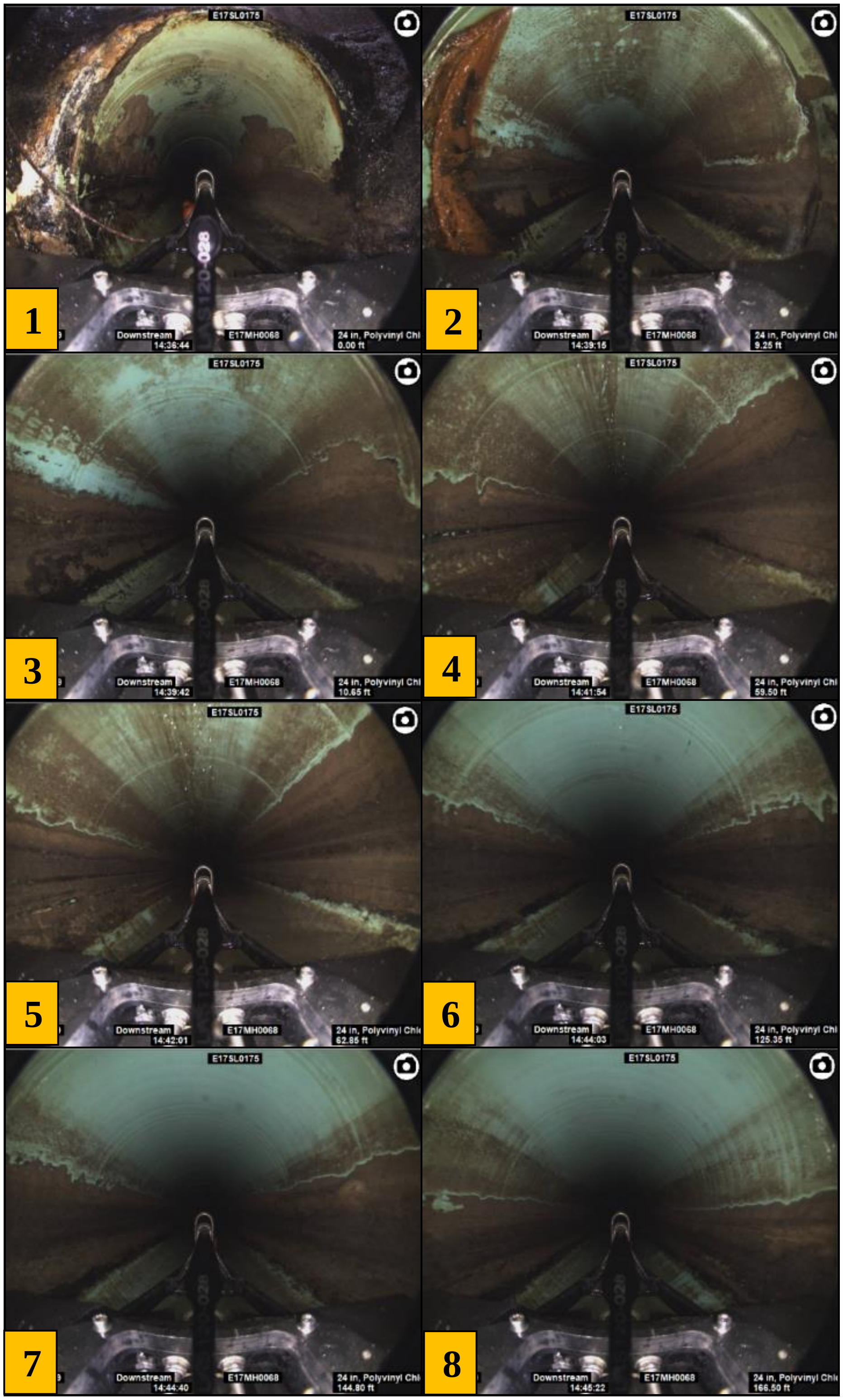


Figure A38-4 images from 1 through 8

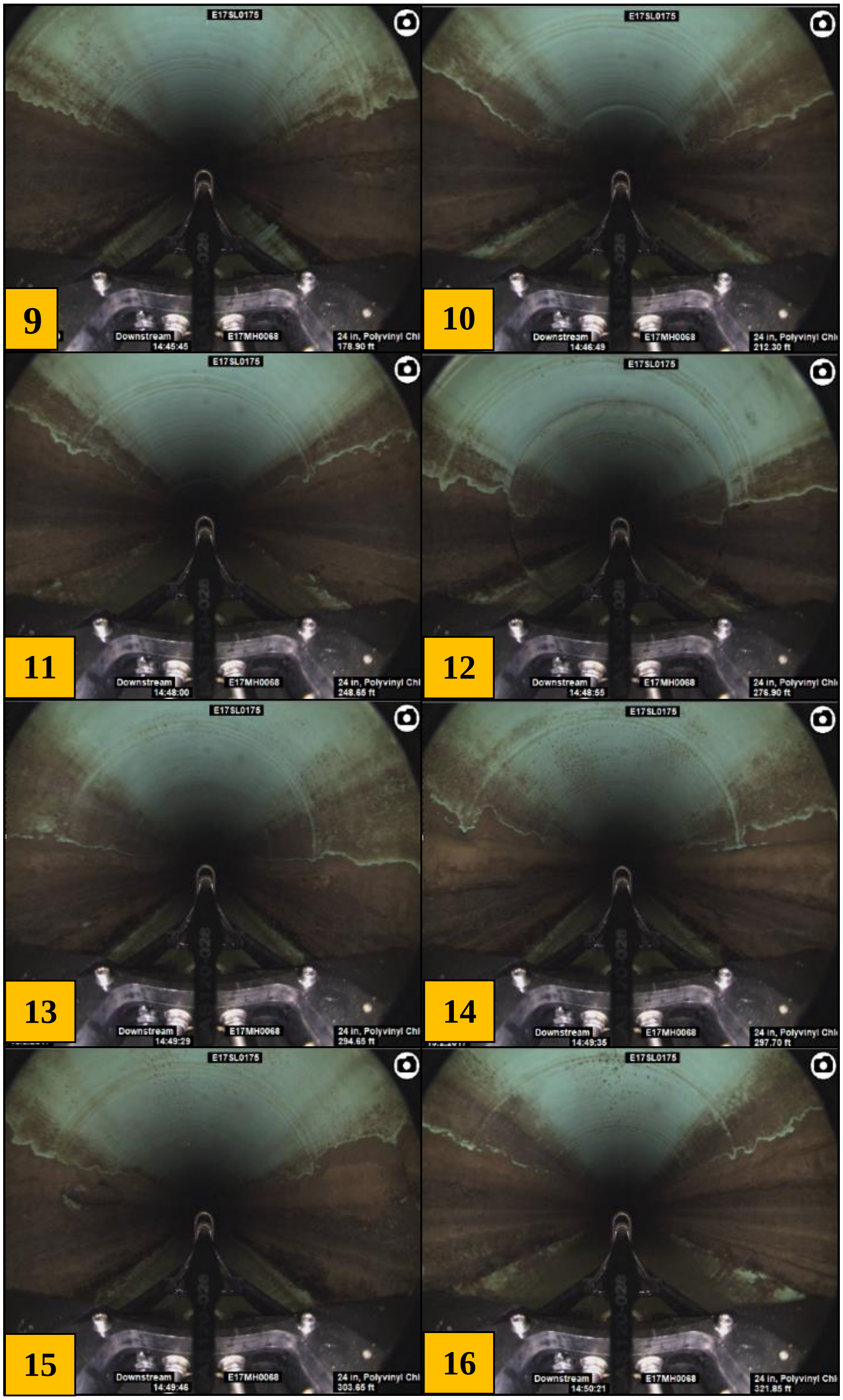


Figure A38-5 images from 9 through 16

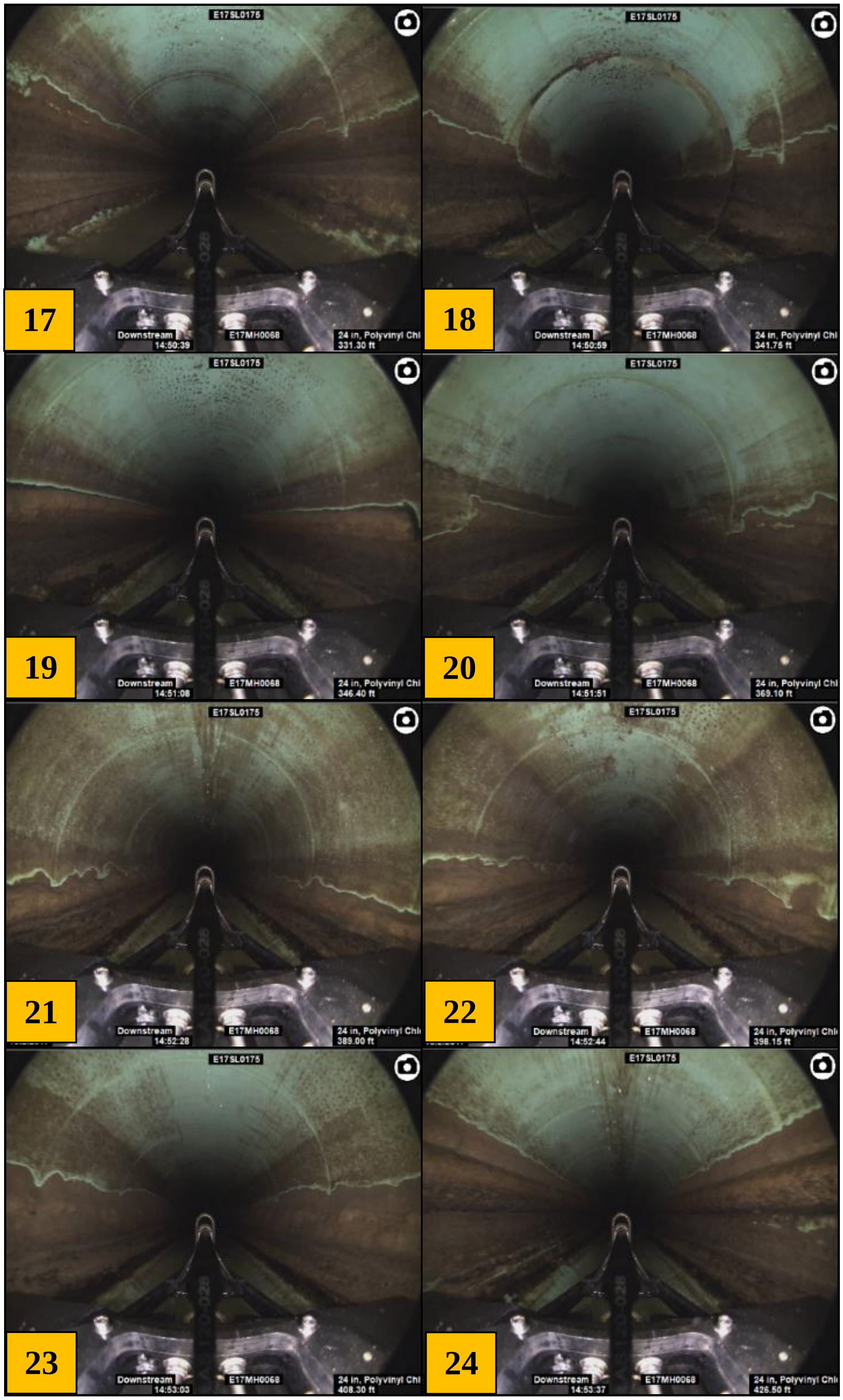


Figure A38-6 images from 17 through 24

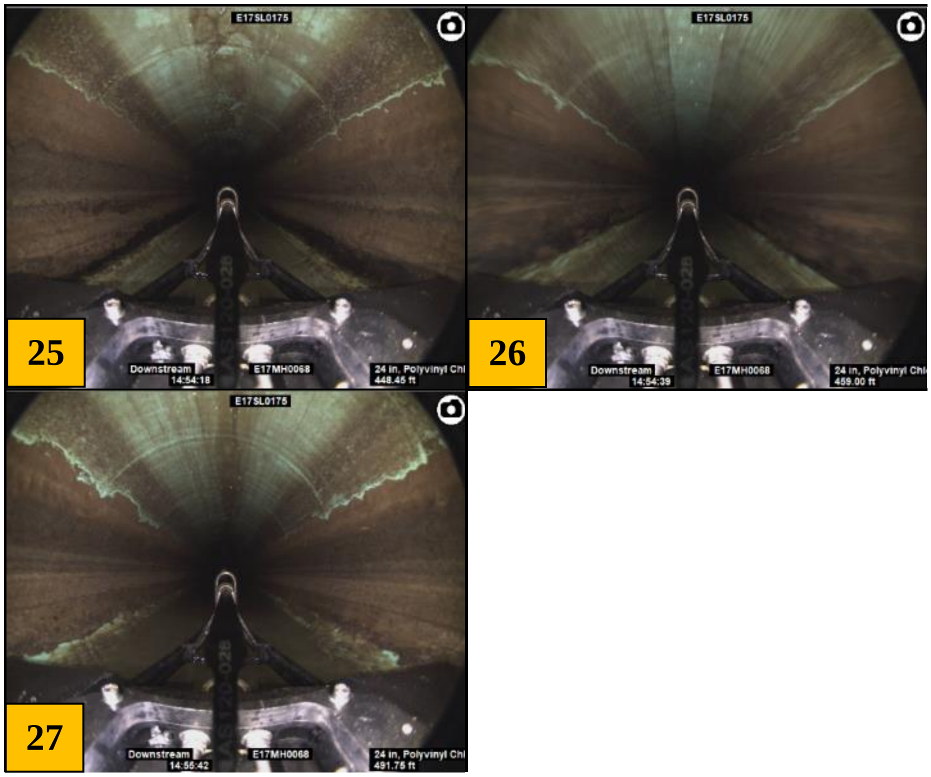


Figure A38-7 images from 25 through 27

Line 39 Summary

Table A39-1 Results Summary of Sewer Line 39

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	545
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	1
Level 5 Defects	0
Level 4 Defects	1
Total Defects	12
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	77804.0
Maximum Blockage (%)	4.3
Maximum Deposit Height (in)	1.8

Deposit Data

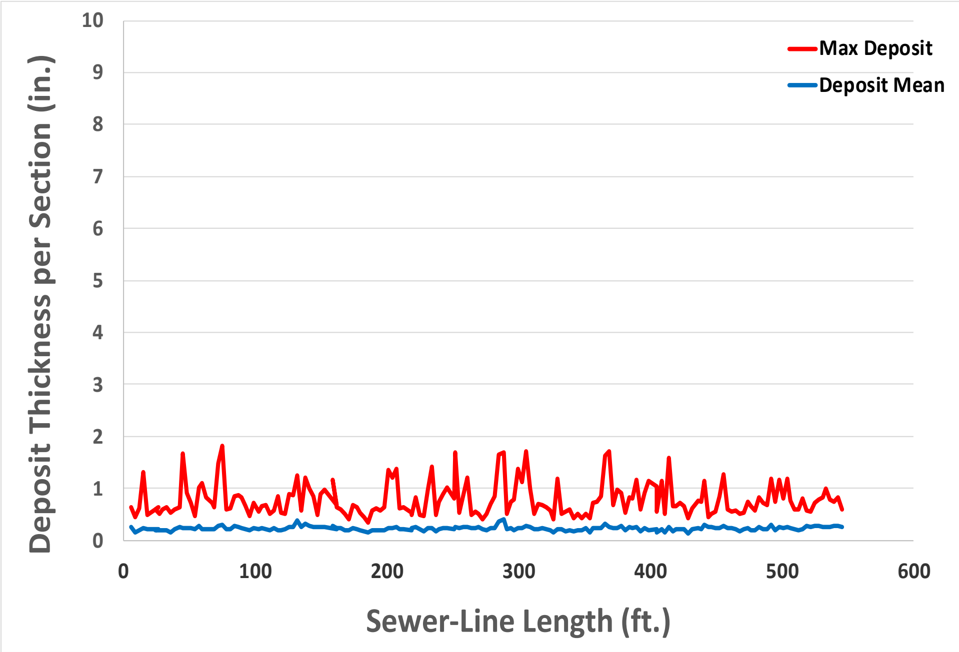


Figure A39-1 Deposit thickness per cross-section

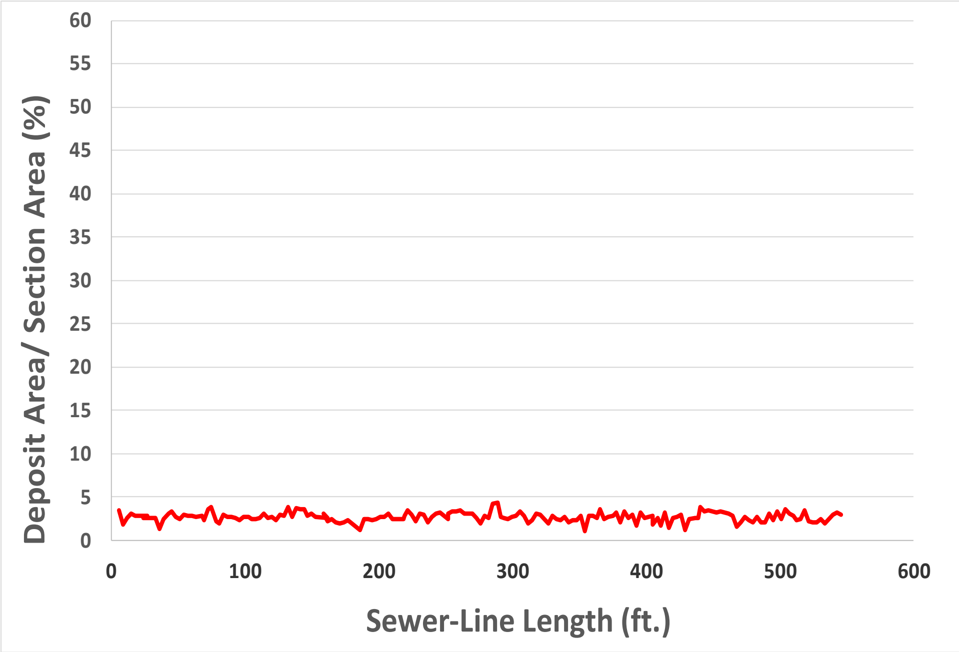


Figure A39-2 Deposit area percentage of the pipe cross section area

Blockage Data

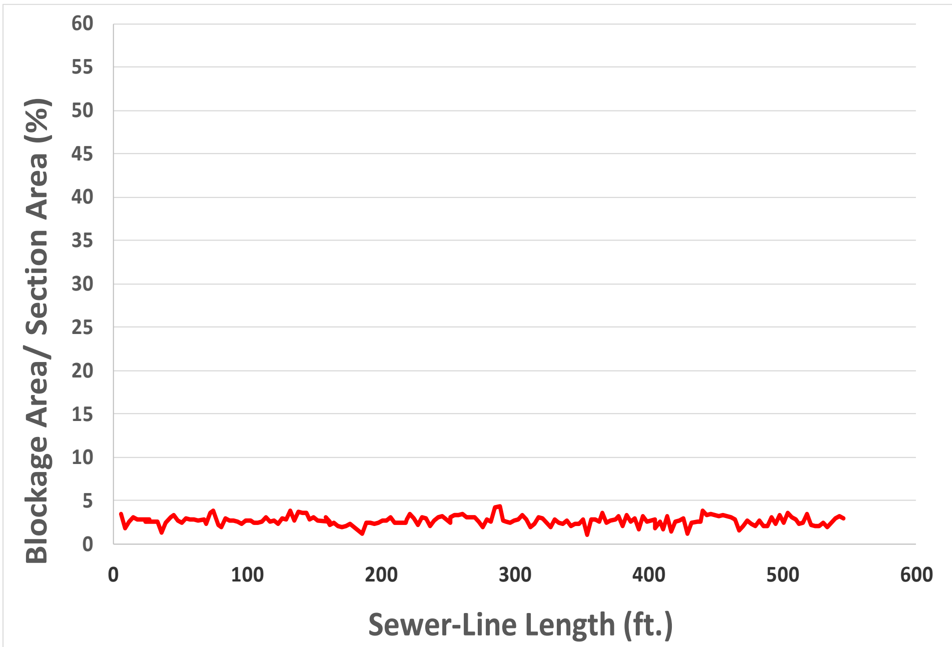


Figure A39-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A39-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				5%					
3	0		DAE				5%				1	
4	0.2		DAE	S01			5 TO 10%				2 TO 15	
5	142		MWL				10%				16	
6	155.55		MWL				5%				17	
7	255.6		MWL				10%				18	
8	271.6		MWL				5%				19	
9	391.8		MWL				10%				20	
10	412		MWL				5%				21	
11	422.7		MWL				10%				22	
12	438.3		MWL				5%				23	
13	506		MWL				10%				24	
14	541.4		DAE	F01								
15	541.4		RLJ								25	
16	541.4		MSA									

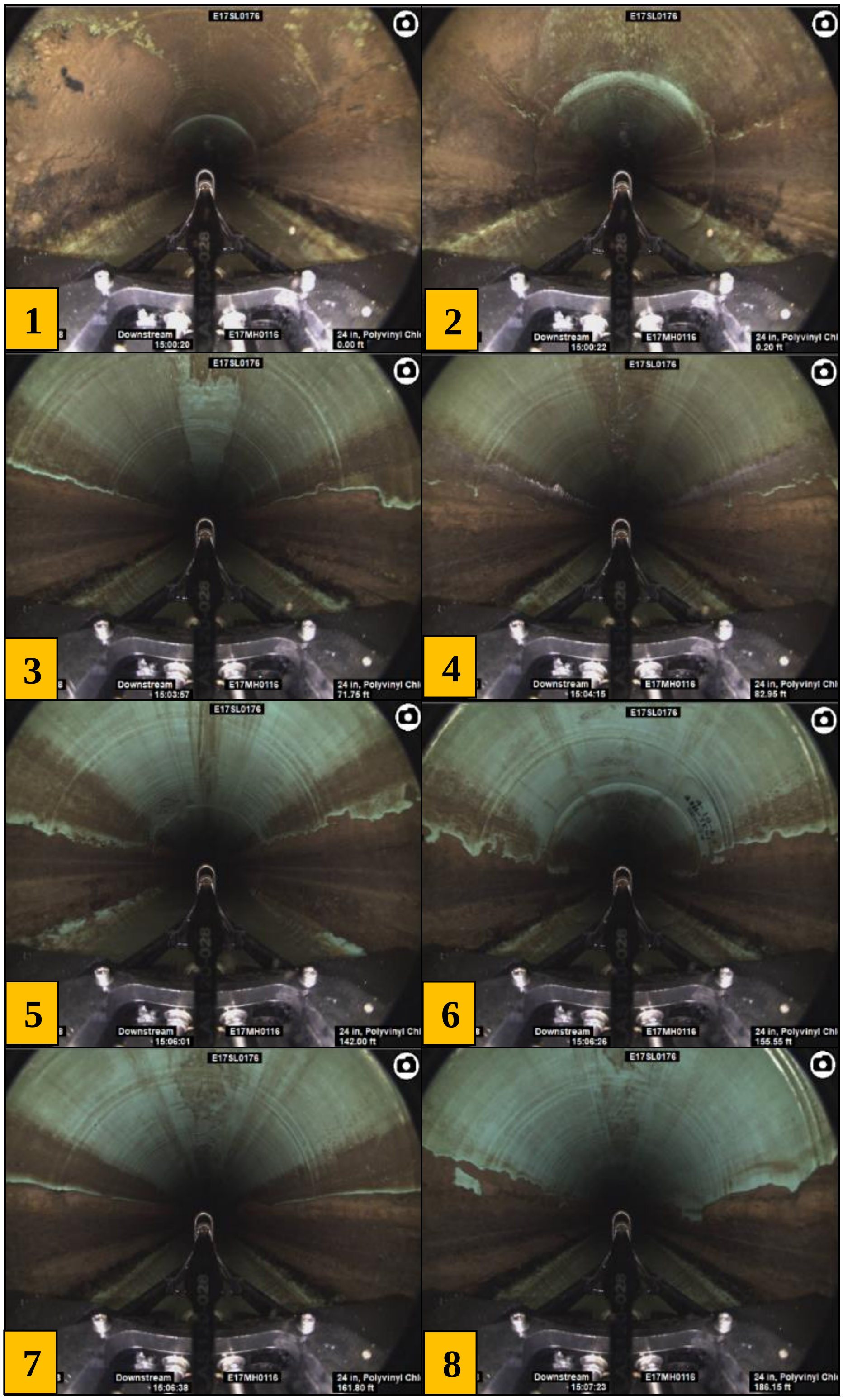


Figure A39-4 images from 1 through 8

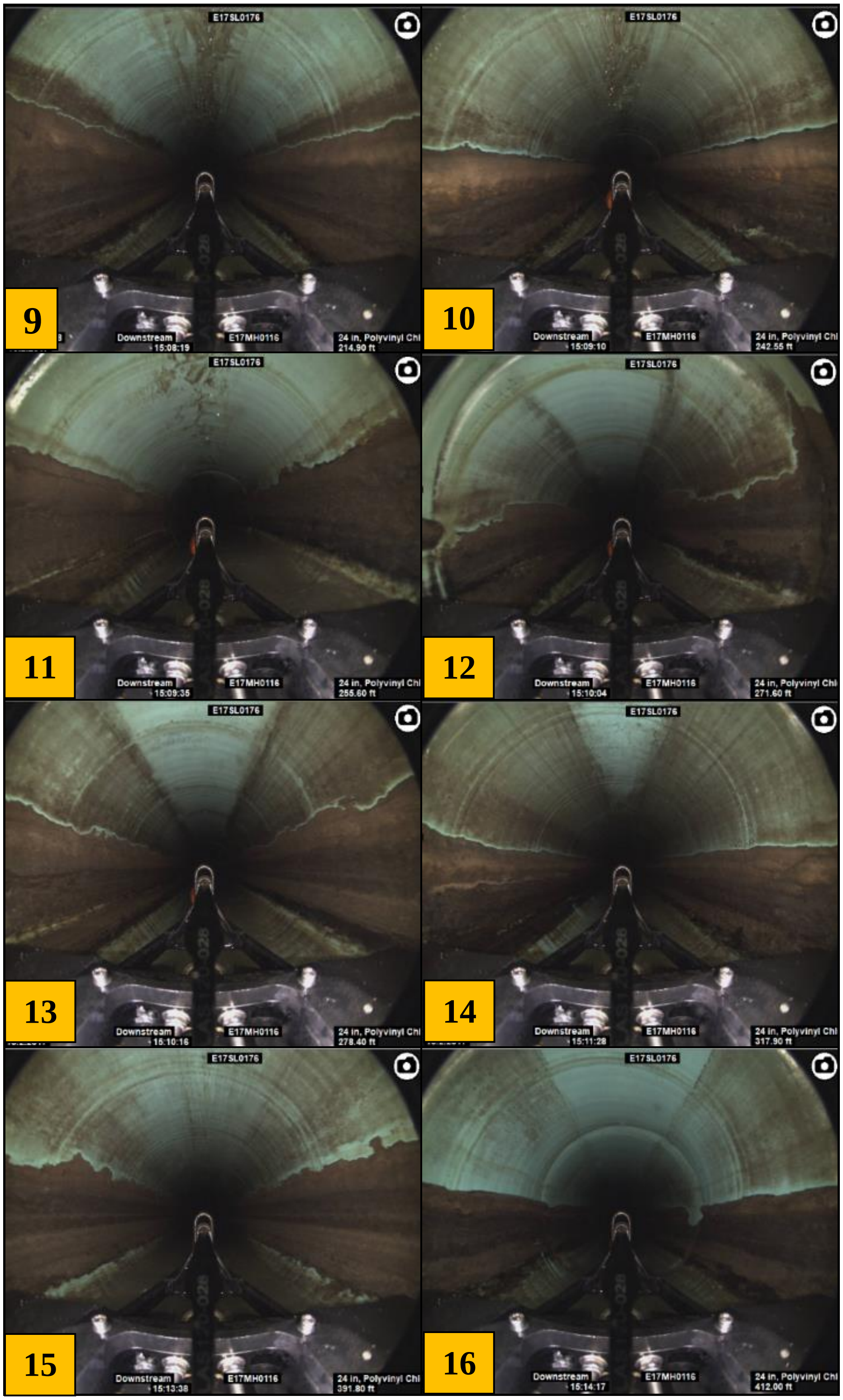


Figure A39-5 images from 9 through 16

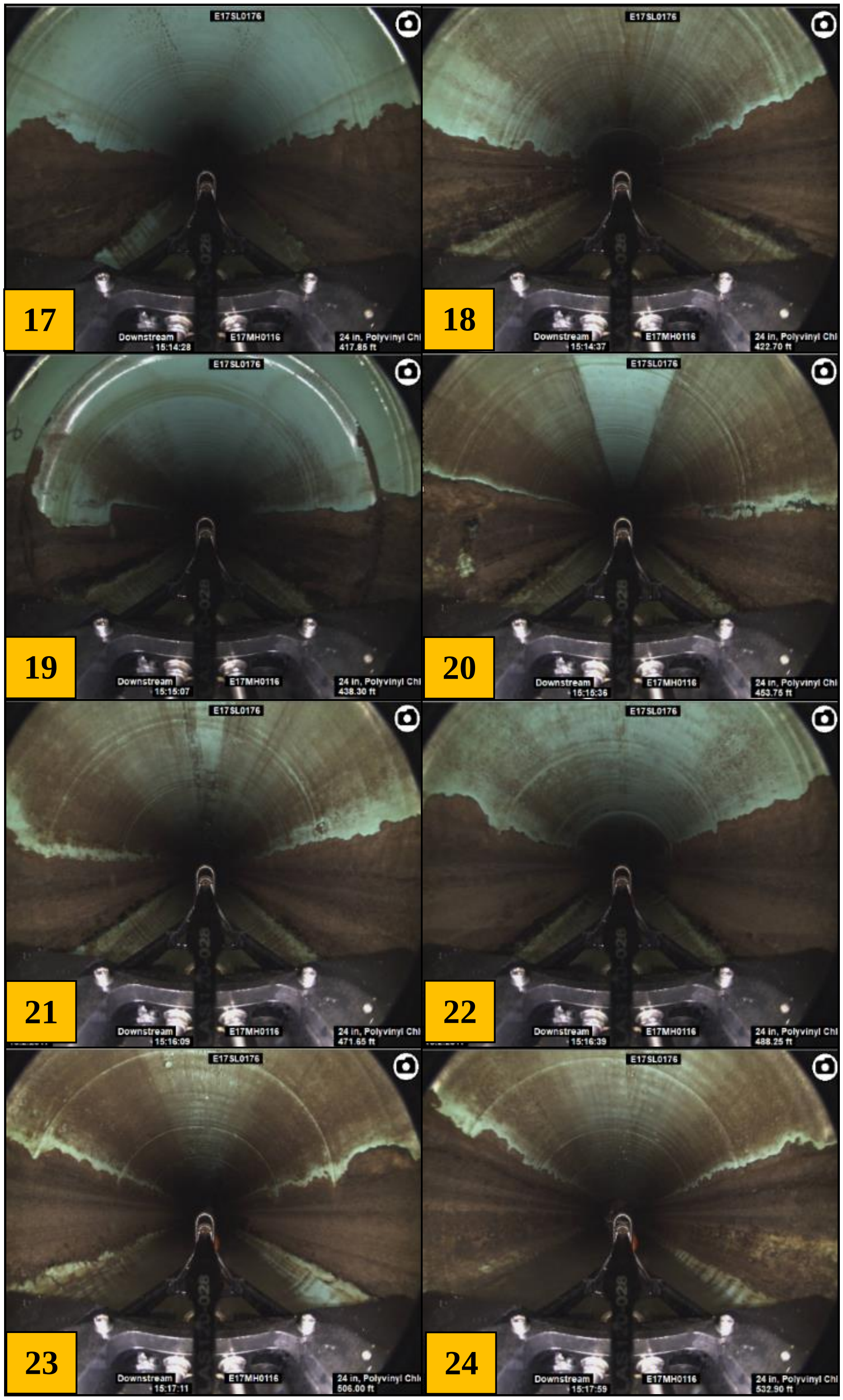


Figure A39-6 images from 17 through 24

Figure A39-7 images from 25

Line 40 Summary

Table A40-1 Results Summary of Sewer Line 40

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	625
Percentage of The Line Not Inspected	2.3%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	1
Level 5 Defects	0
Level 4 Defects	0
Total Defects	13
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	80264.0
Maximum Blockage (%)	4
Maximum Deposit Height (in)	2.3

Due to software issues, distance from 606.05 ft.-620.4 ft. could not be processed.

Deposit Data

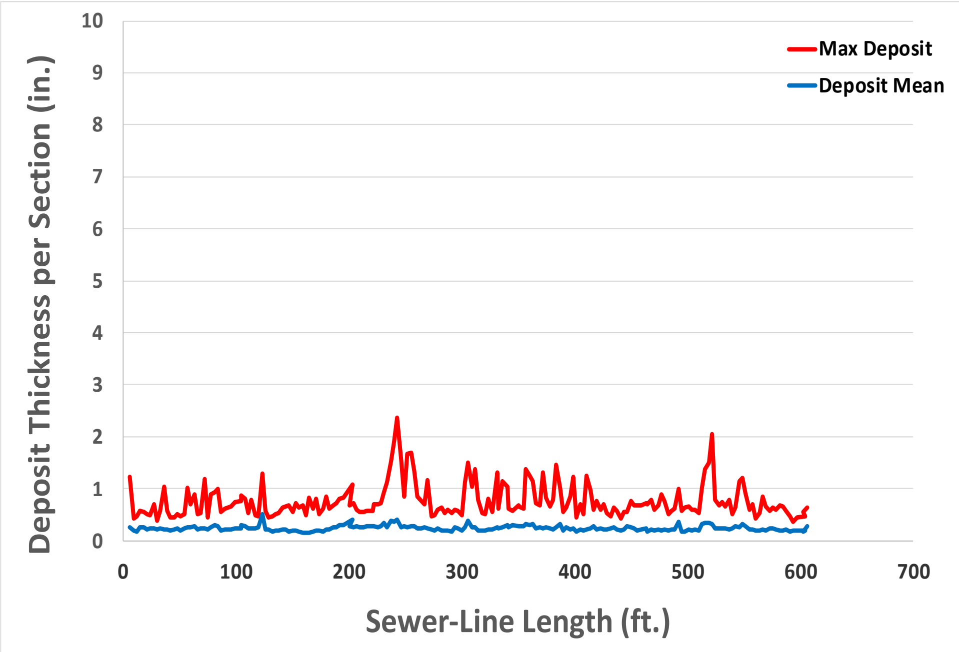


Figure A40-1 Deposit thickness per cross-section

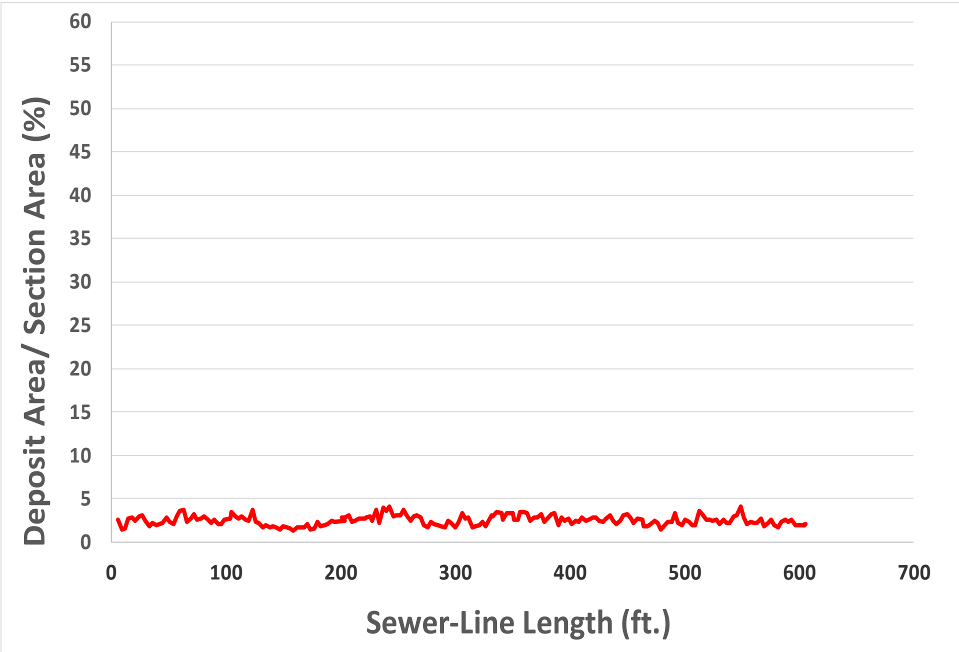


Figure A40-2 Deposit area percentage of the pipe cross section area

Blockage Data

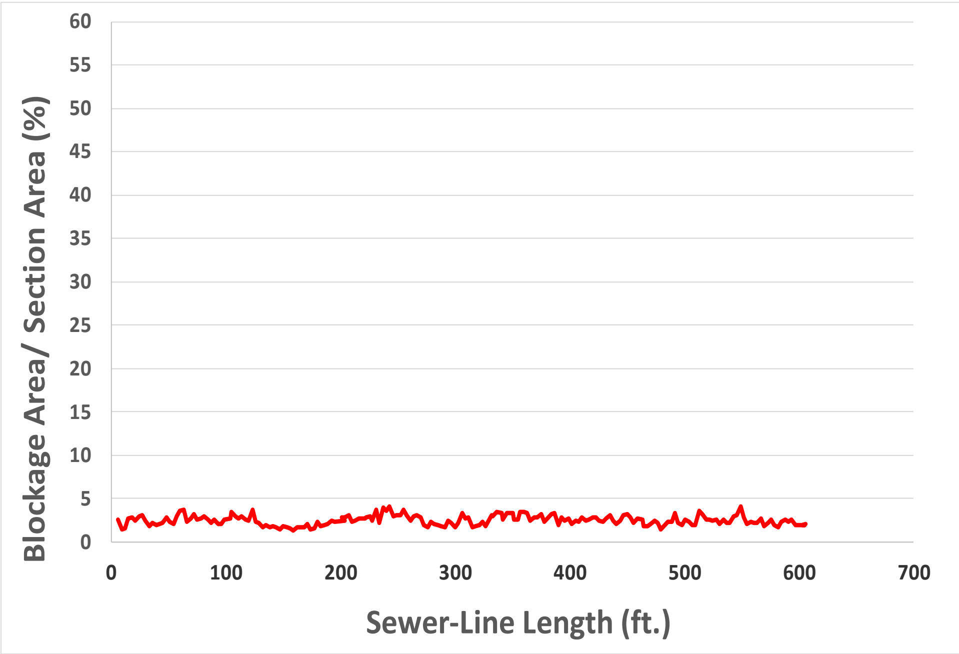


Figure A40-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A40-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL					10%				
3	0		DAE	S01				5 TO 10%			1 , 3 TO 15	
4	29.8		MWL					5%			2	
5	137.6		MWL					10%			16	
6	185.15		MWL					5%			17	
7	195.65		MWL					10%			18	
8	233.8		MWL					5%			19	
9	263.25		MWL					10%			20	
10	274.25		MWL					5%			21	
11	312.9		MWL					10%			22	
12	327.2		MWL					5%			23	
13	428.3		RMJ								24	
14	454.85		MWL					10%			25	
15	478.25		MWL					5%			26	
16	621.3		DAE	F01								
17	621.3		MSA									

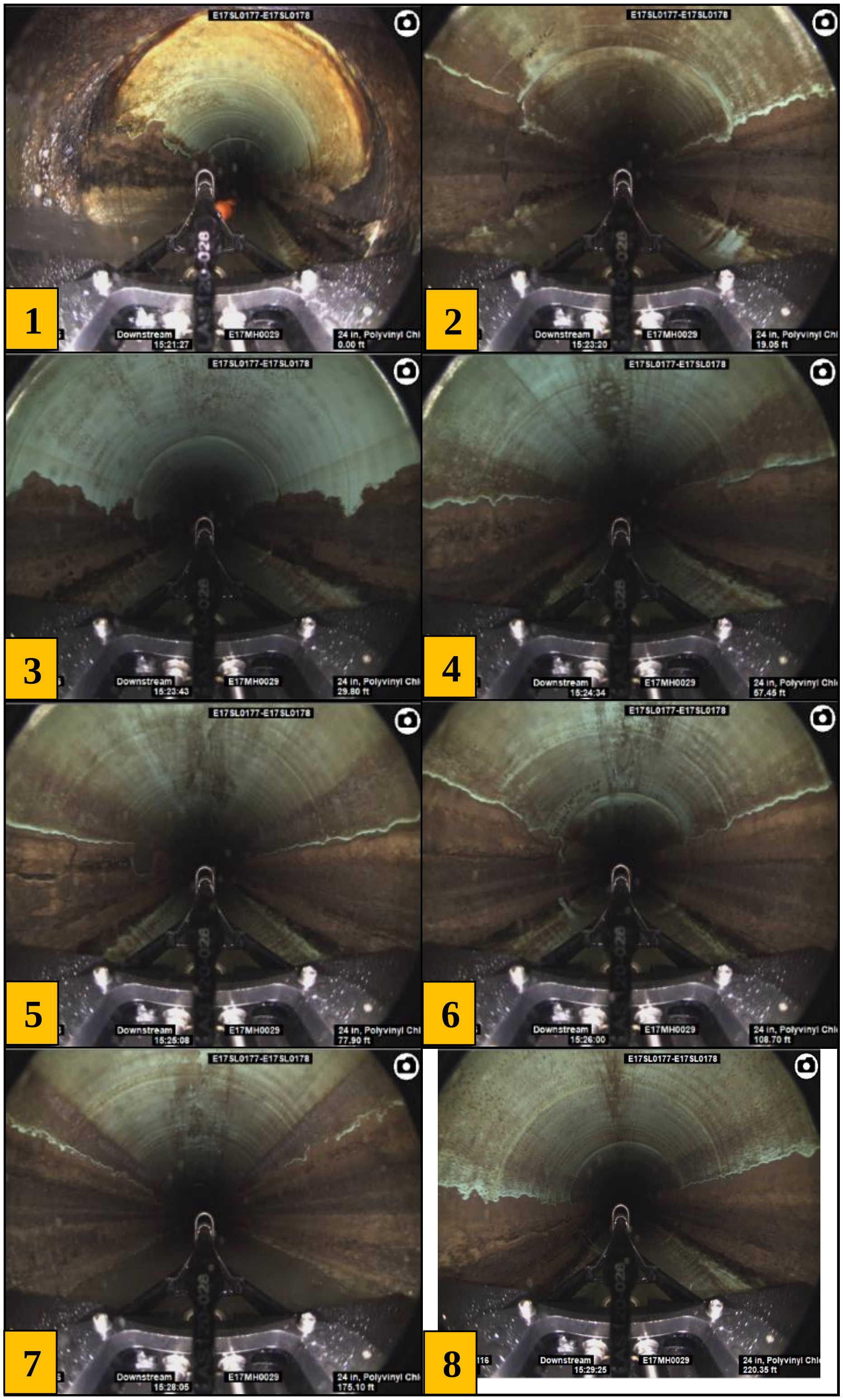


Figure A40-4 images from 1 through 8

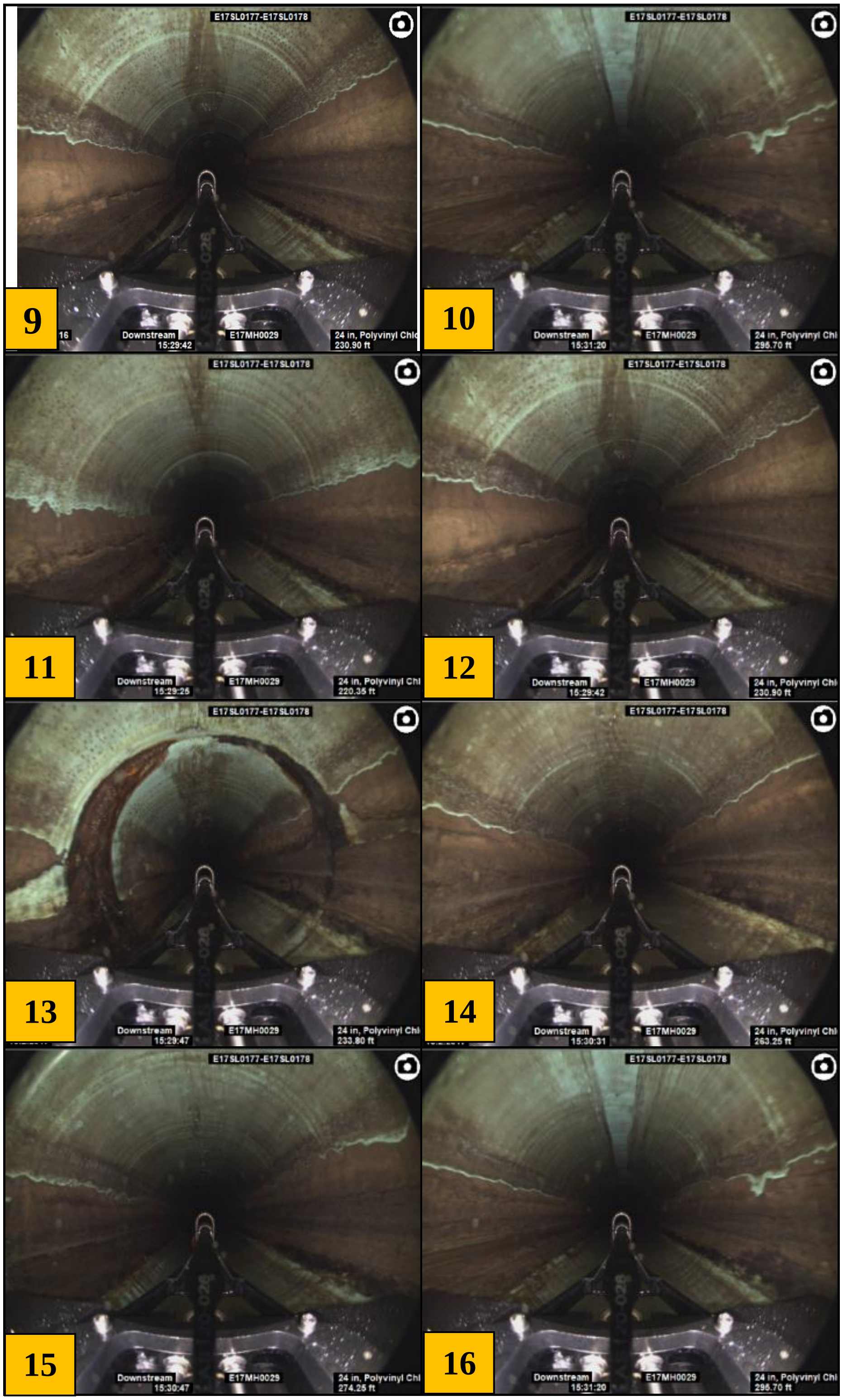


Figure A40-5 images from 9 through 16

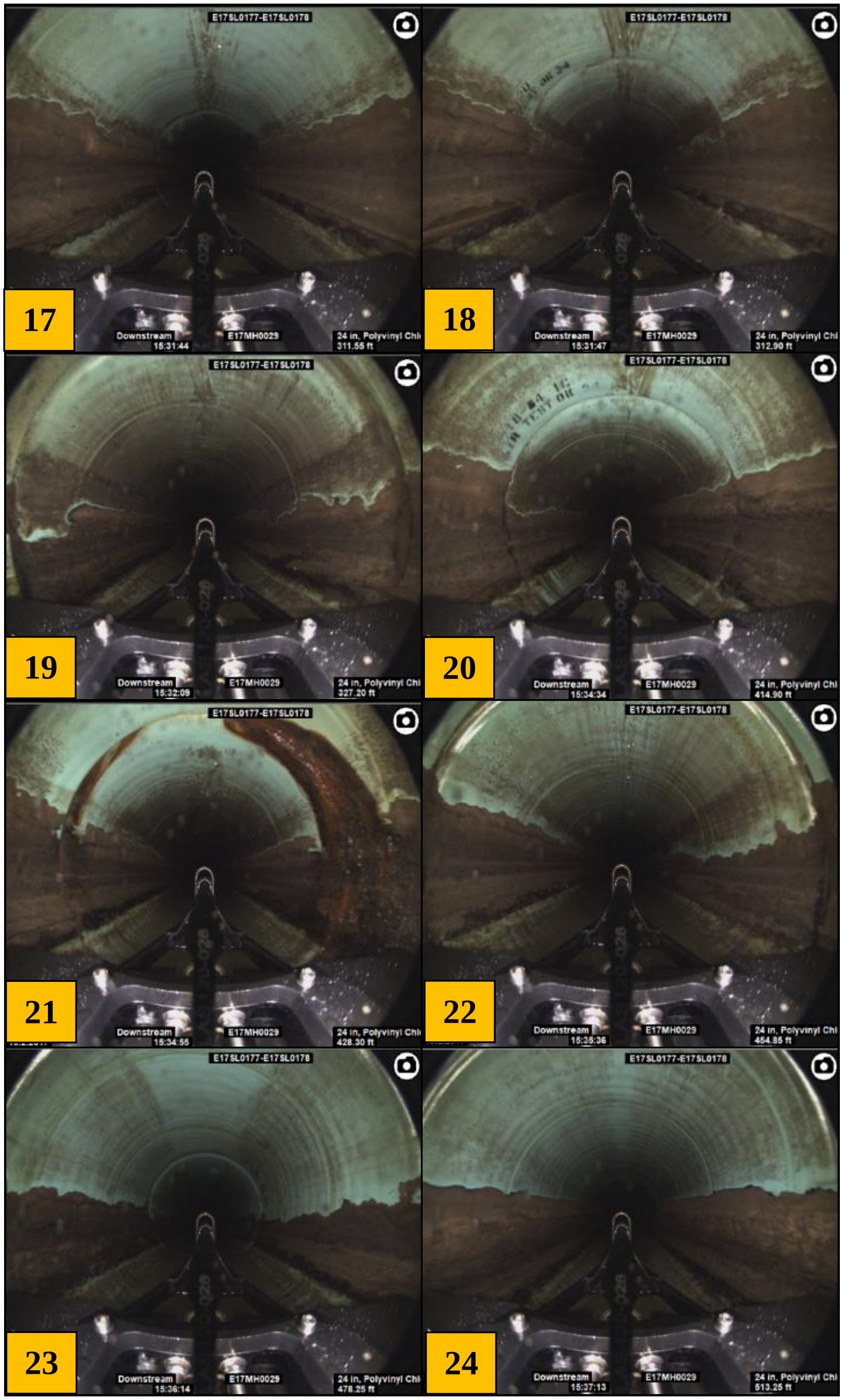


Figure A40-6 images from 17 through 24

Figure A40-6 images from 25 through 26

Line 41 Summary

Table A41-1 Results Summary of Sewer Line 41

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	490
Percentage of The Line Not Inspected	45.6%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	1
Level 5 Defects	0
Level 4 Defects	1
Total Defects	23
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	37065.6
Maximum Blockage (%)	4.6
Maximum Deposit Height (in)	2.3

The device hit roots at 265 ft. Mud covered part of the laser ring. Video recording is obtained, and the laser profile is partially obtained.

Deposit Data

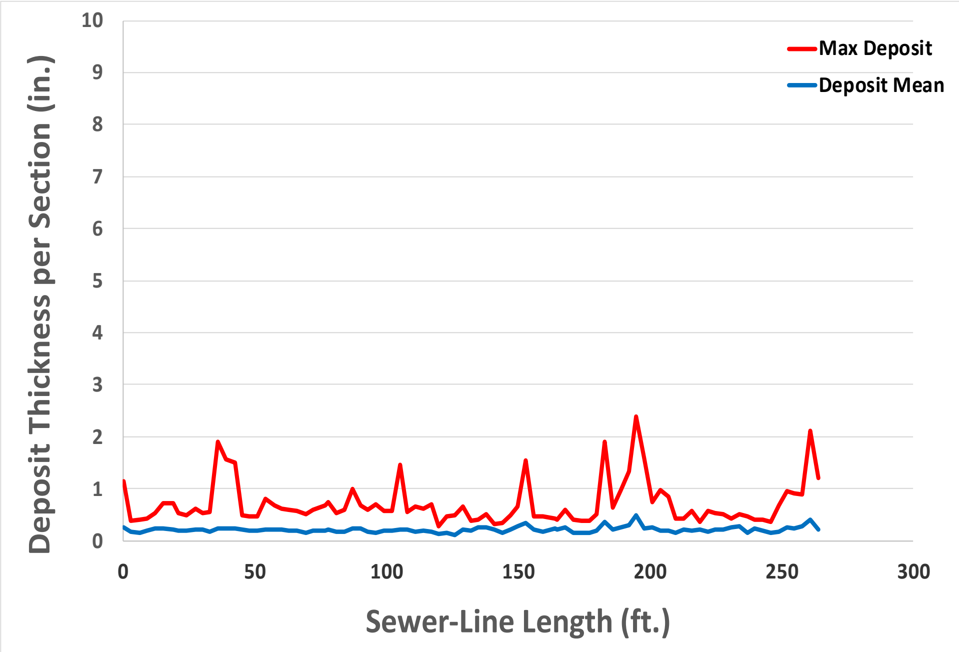


Figure A41-1 Deposit thickness per cross-section

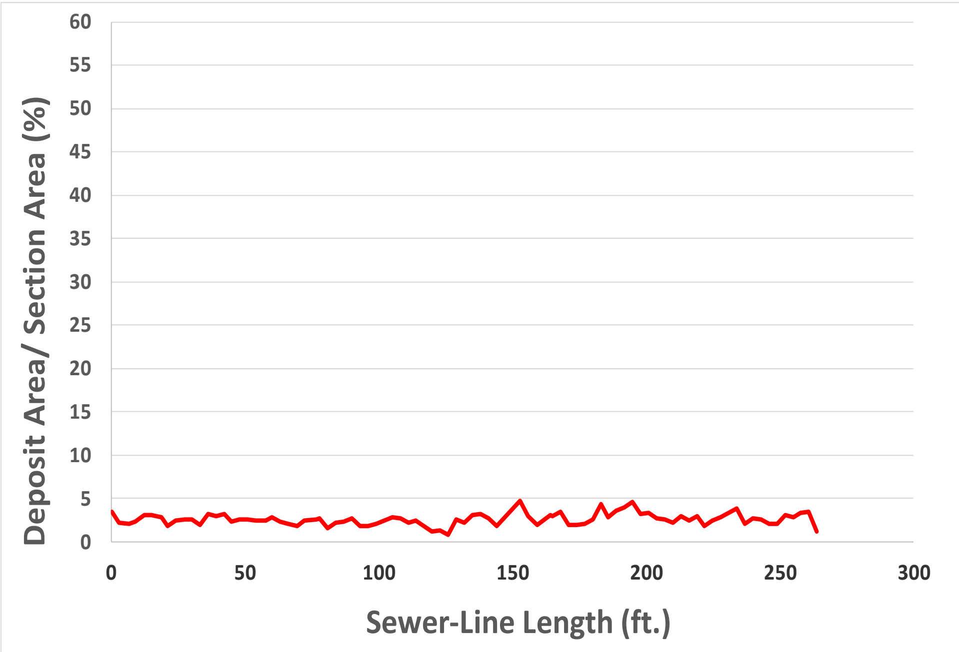


Figure A41-2 Deposit area percentage of the pipe cross section area

Blockage Data

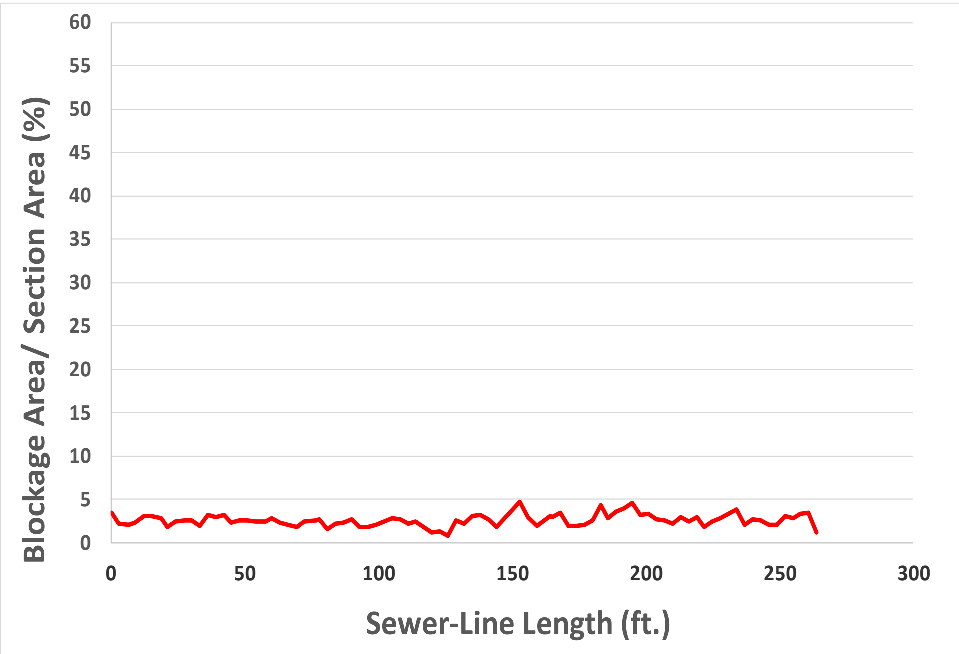


Figure A41-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A41-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				10%					
3	0		DAG				10%				1	
4	0.7		DAE				5%				2	
5	3.1		DAE	S01			5 TO 10%				3 TO 12	
6	7.95		MWL				5%				13	
7	17.75		MWL				10%				14	
8	32.8		MWL				5%				15	
9	58.3		MWL				10%				16	
10	68.6		MWL				5%				17	
11	79.15		MWL				10%				18	
12	144.35		MWL				5%				19	
13	192.1		MWL				10%				20	
14	208.65		MWL				5%				21	
15	210.3		DAE	F01								
16	242.4		MWL				10%				22	
17	261.4		RLJ								23	
18	264.55		DAE	S02			5%				24,25	
19	295		MWL				5%				26	
20	302.6		MWL				10%				27	
21	323.6		MWL				5%				28	
22	344.15		MWL				10%				29	
23	360.45		MWL				5%				30	
24	391.15		MWL				10%				31	
25	406.65		MWL				5%				32	
26	482.45		MWL				10%				33	
27	485.65		DAE	F02								
28	485.65		MSA									

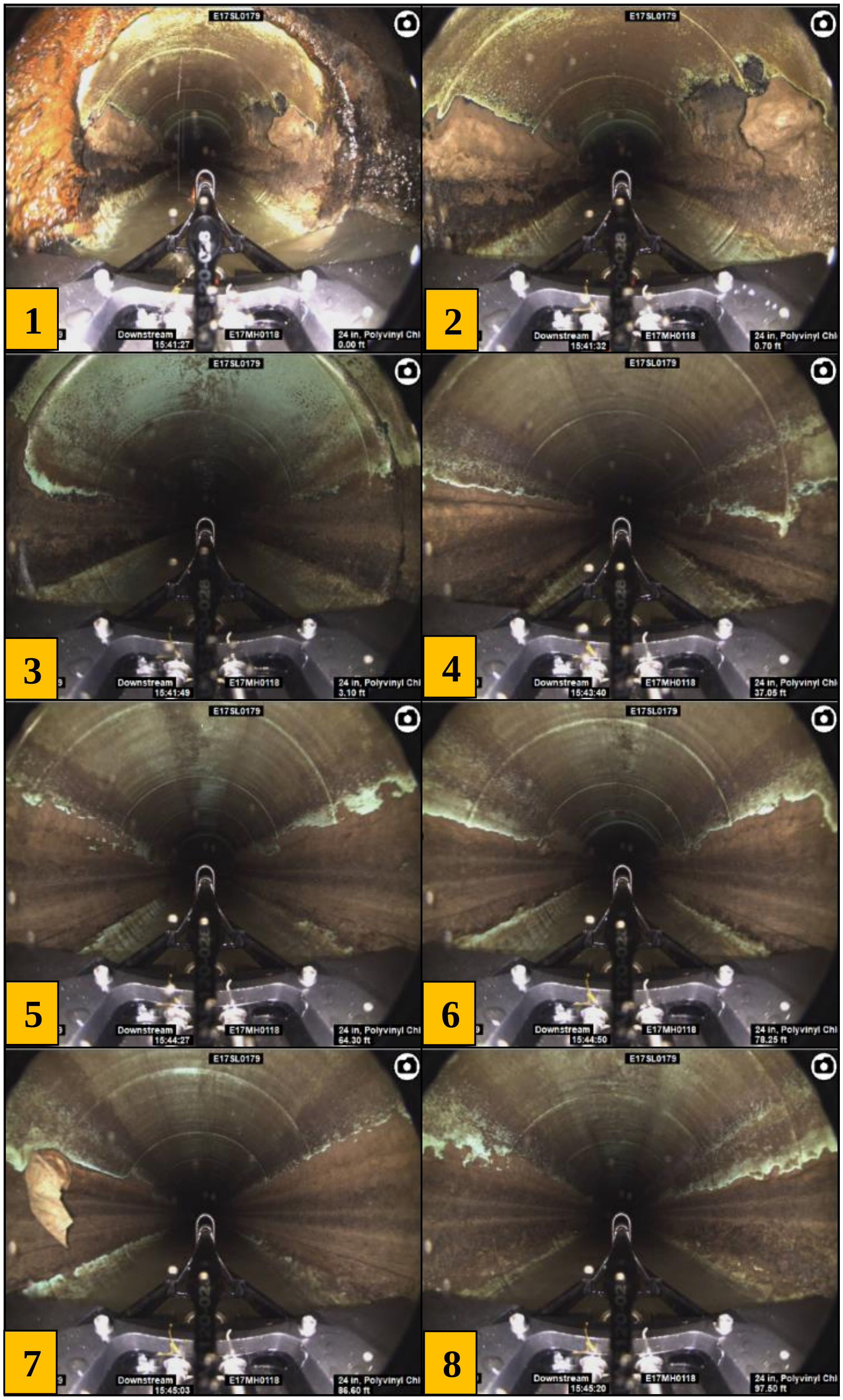


Figure A41-4 images from 1 through 8

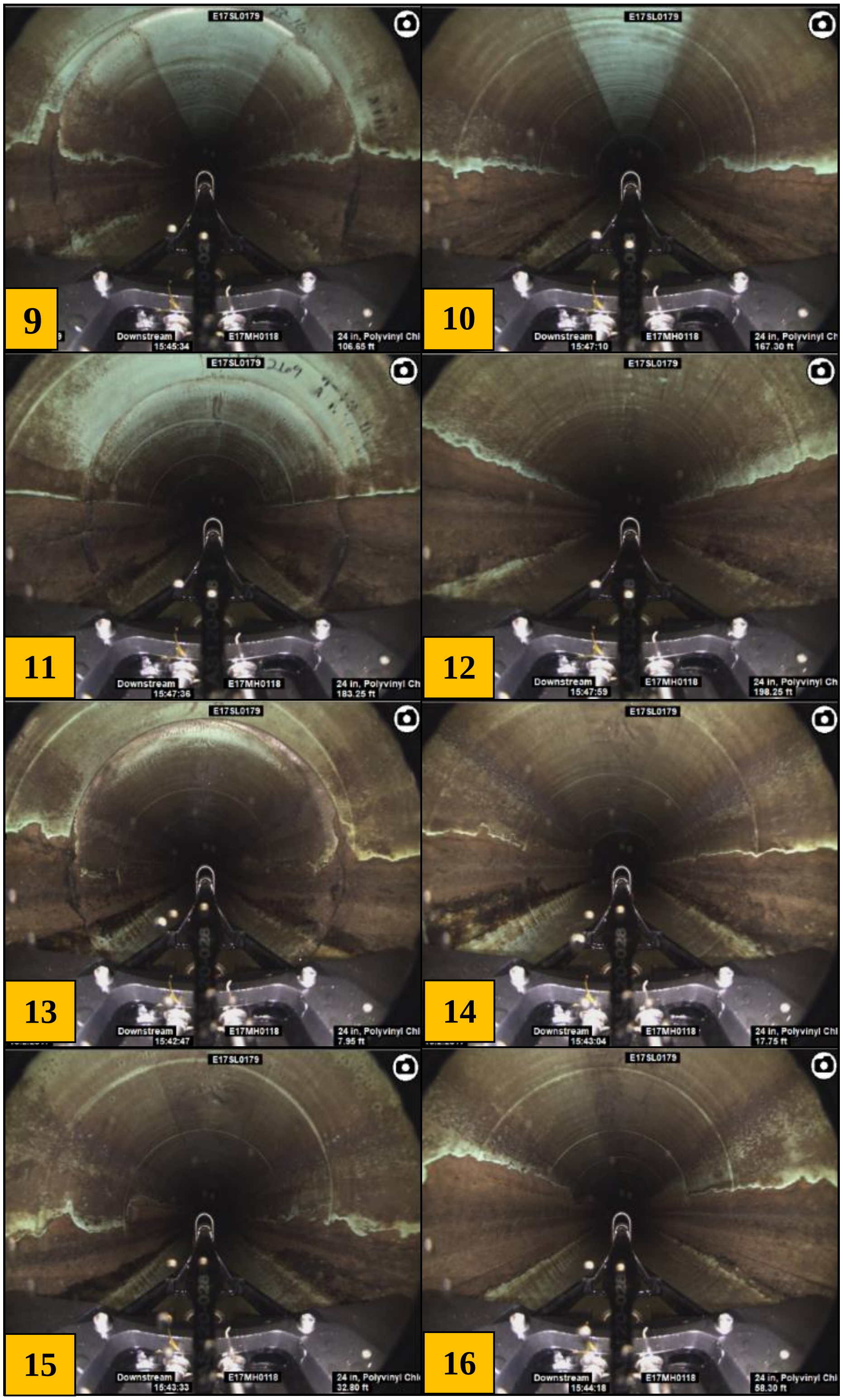


Figure A41-5 images from 9 through 16

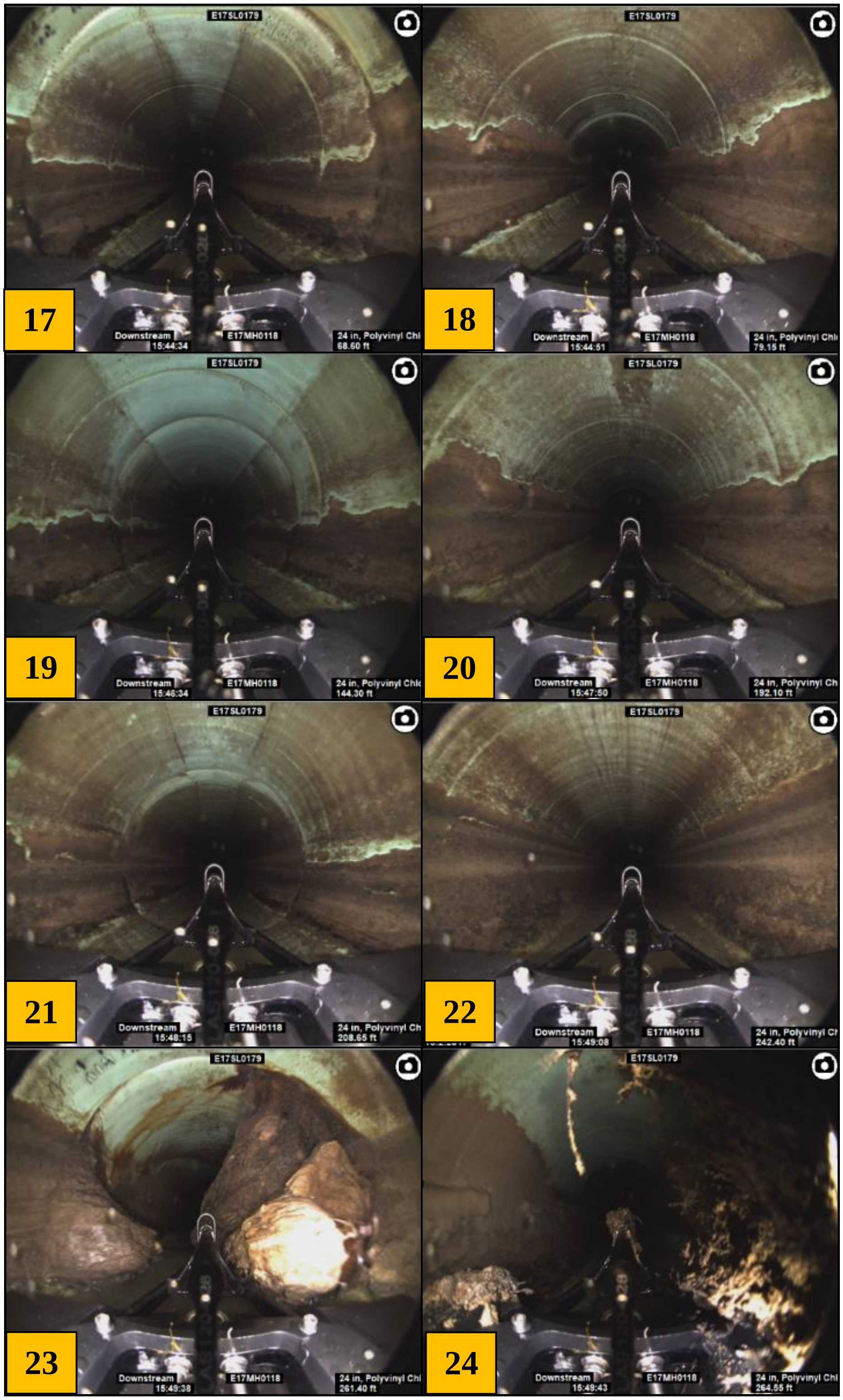


Figure A41-6 images from 17 through 24

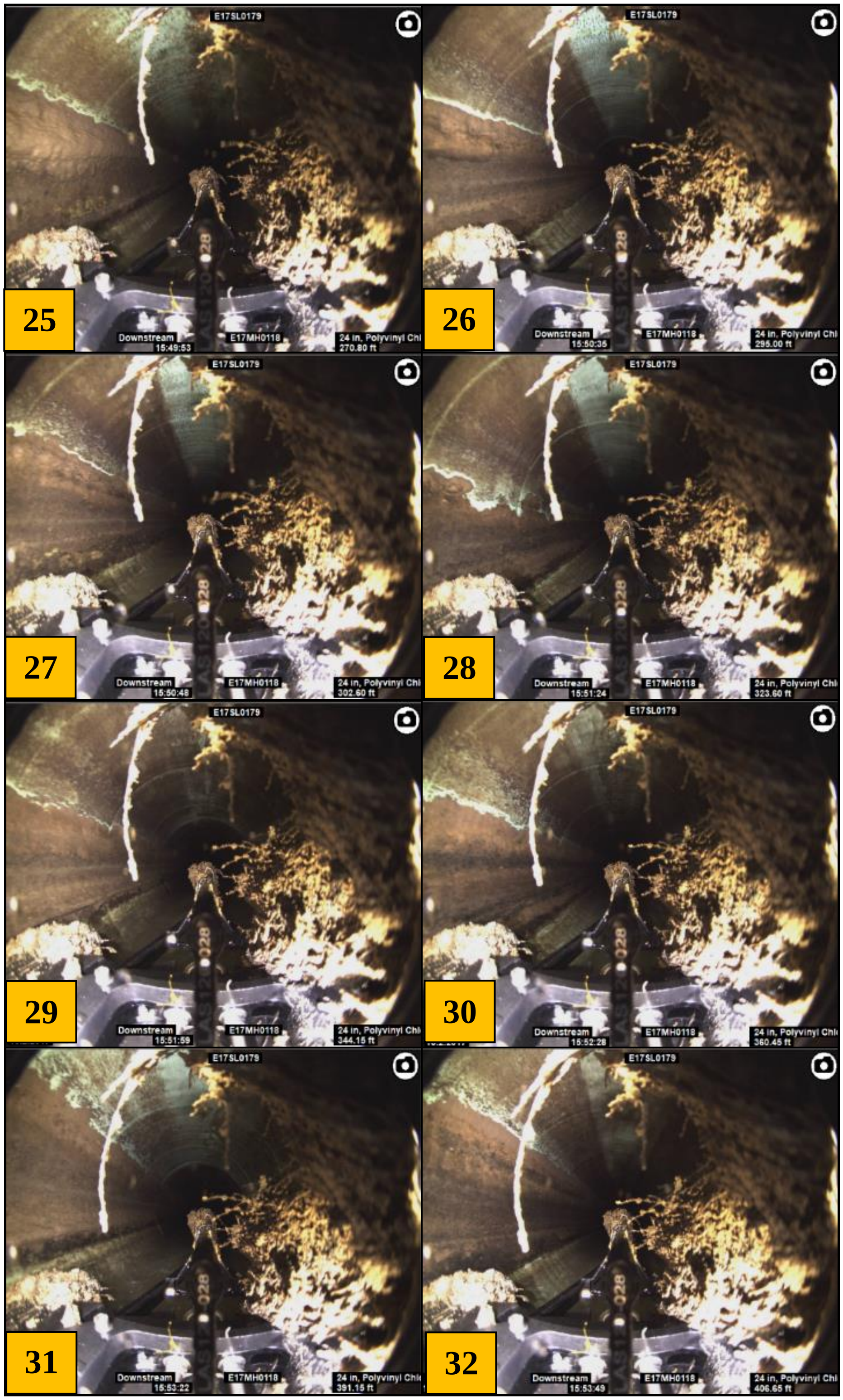


Figure A41-7 images from 25 through 32

Figure A41-8 image 33

Line 42 Summary

Table A42-1 Results Summary of Sewer Line 42

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	453.6
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	19
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	77892.8
Maximum Blockage (%)	4.7
Maximum Deposit Height (in)	1.9

Deposit Data

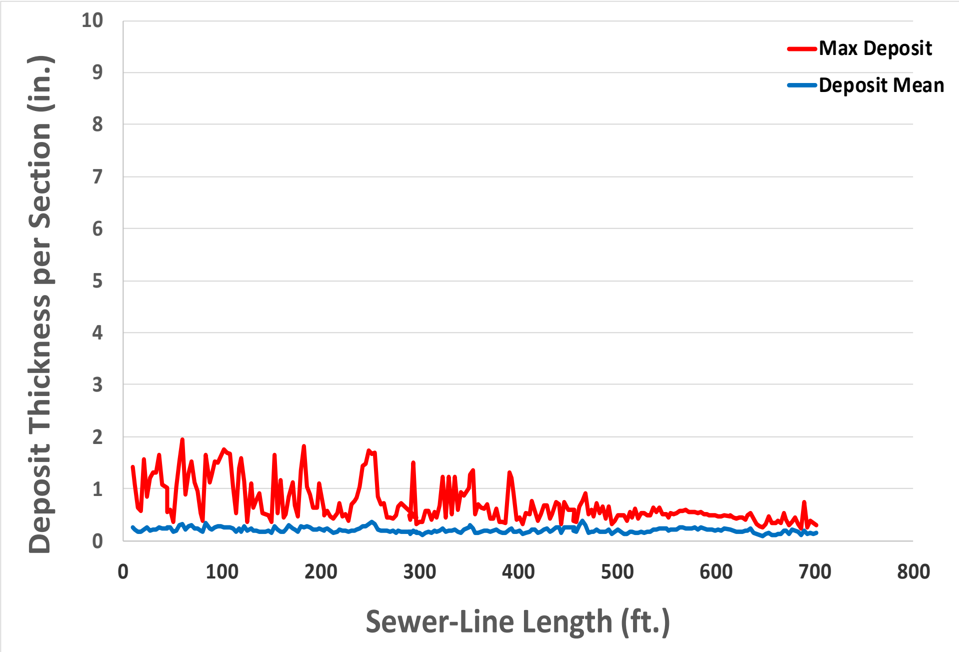


Figure A42-1 Deposit thickness per cross-section

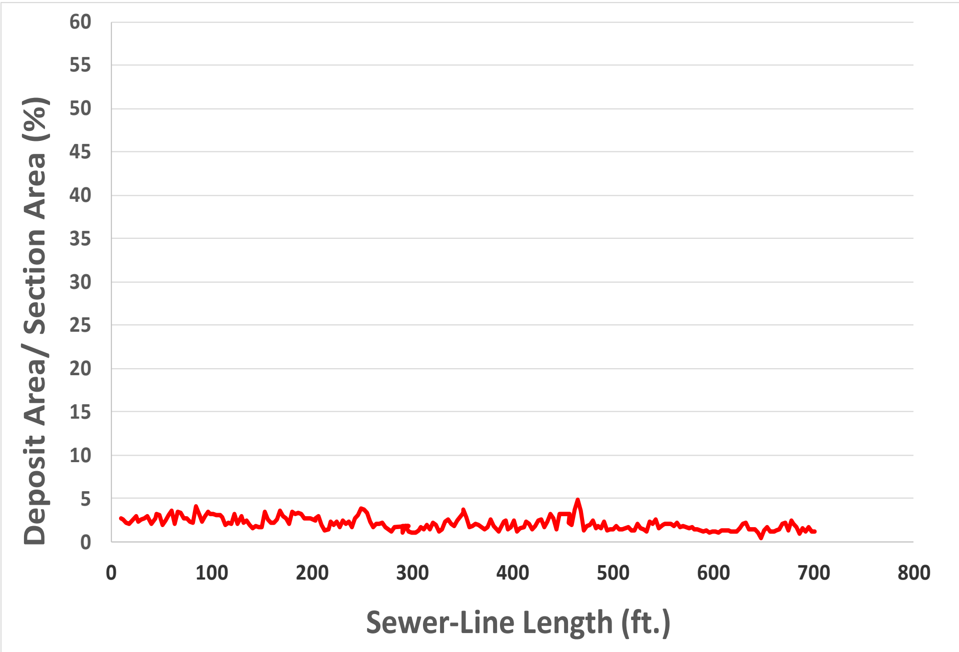


Figure A42-2 Deposit area percentage of the pipe cross section area

Blockage Data

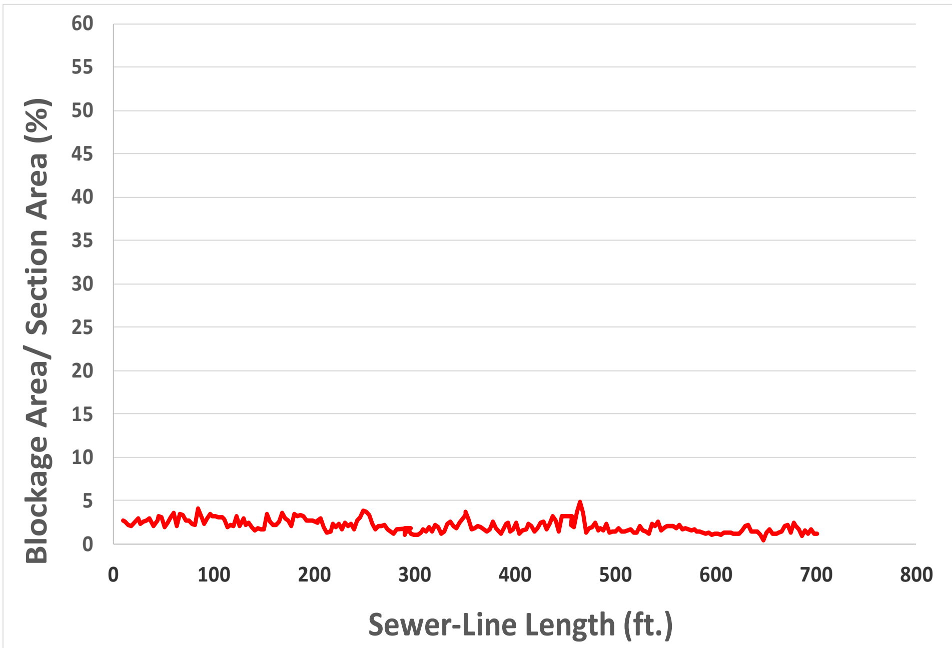


Figure A42-3Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A42-2Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	10		MWL				10%					
3	10		DAE	S01			5 TO 10%				1	
4	29.05		MWL				5%				2	
5	44.2		MWL				10%				3	
6	53.25		MWL				5%				4	
7	64.75		MWL				10%				5	
8	80.2		MWL				5%				6	
9	133		MWL				10%				7	
10	161		MWL				5%				8	
11	191.65		MWL				10%				9	
12	230.7		MWL				5%				10	
13	255.55		MWL				10%				11	
14	322.5		MWL				5%				12	
15	368.4		MWL				10%				13	
16	387.4		MWL				5%				14	
17	396.6		MWL				10%				15	
18	471.5		MWL				5%				16	
19	493.5		MWL				10%				17	
20	536.5		MWL				5%				18	
21	549.6		MWL				10%				19	
22	704.05		DAE	F01								
23	704.05		MSA									

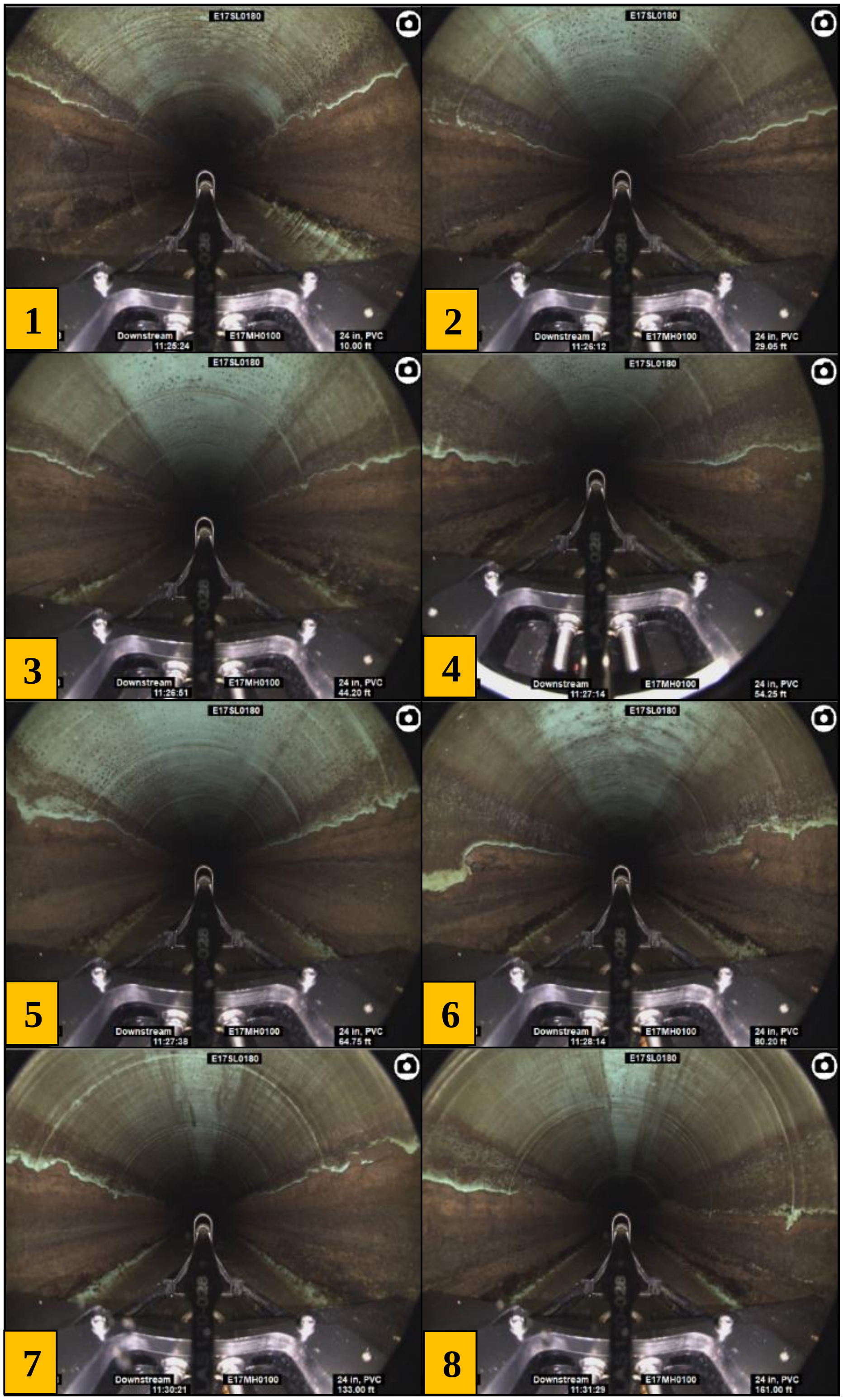


Figure A42-4 images from 1 through 8

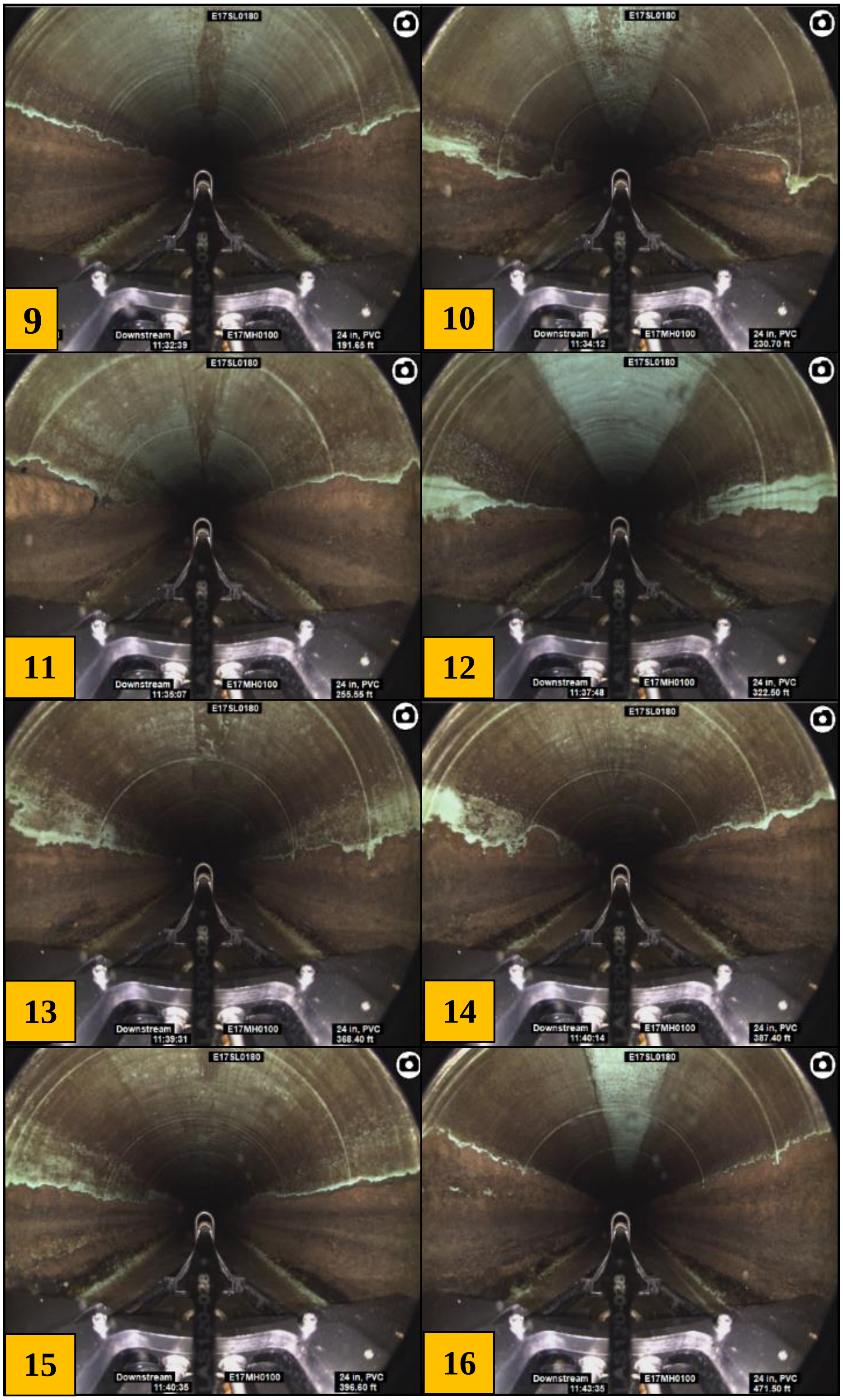


Figure A42-5 images from 9 through 16

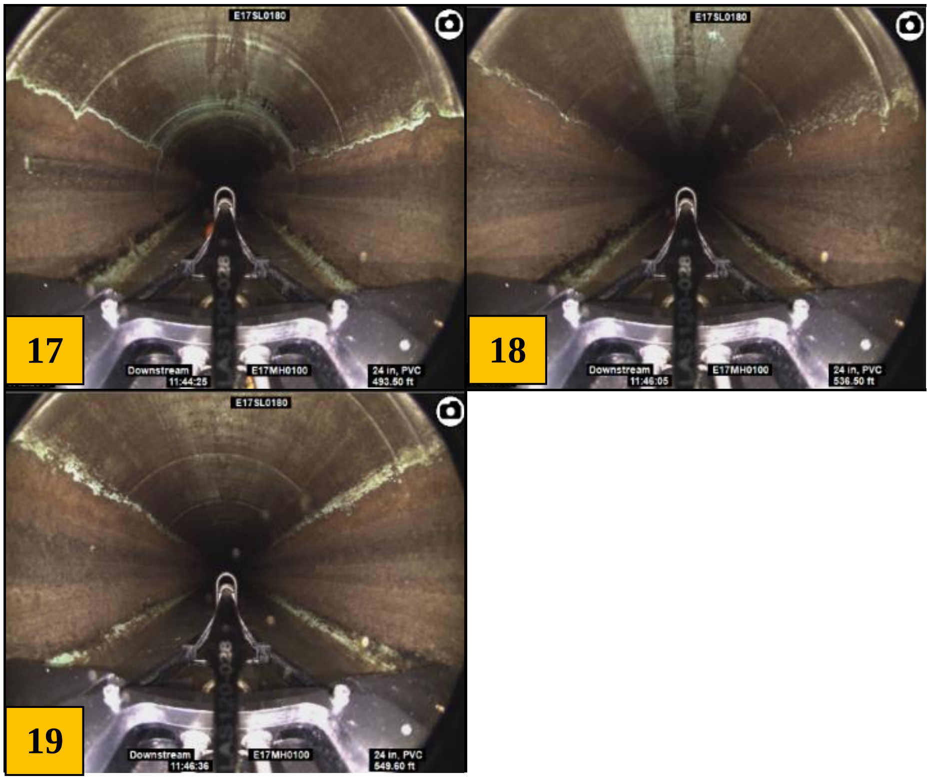


Figure A42-6 images from 17 through 19

Line 43 Summary

Table A43-1 Results Summary of Sewer Line 43

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	188.3
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	1
Total Defects	3
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	10052.2
Maximum Blockage (%)	4.3
Maximum Deposit Height (in)	1.6

Deposit Data

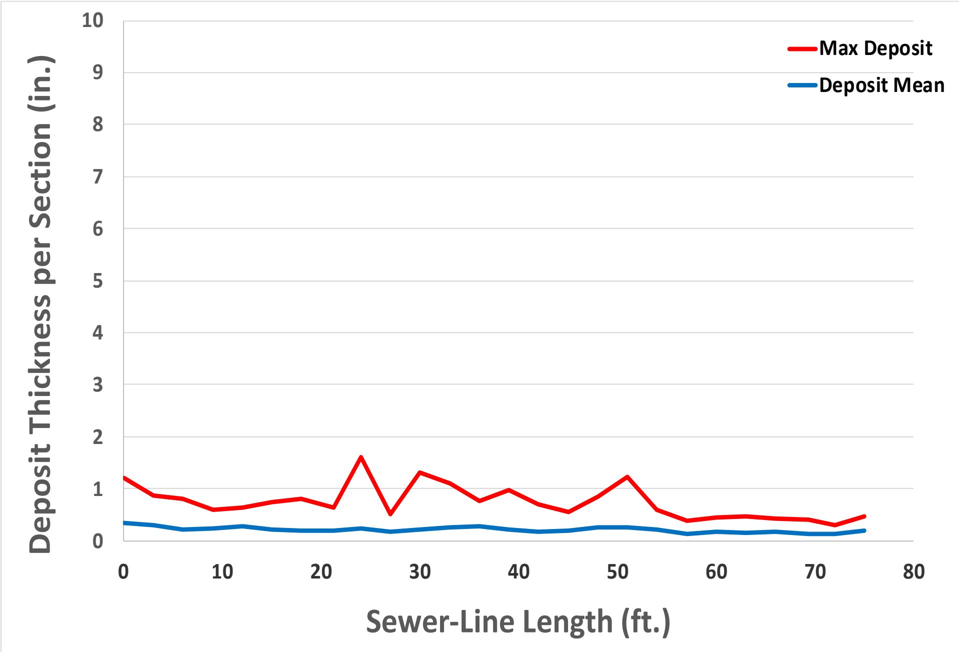


Figure A43-1 Deposit thickness per cross-section

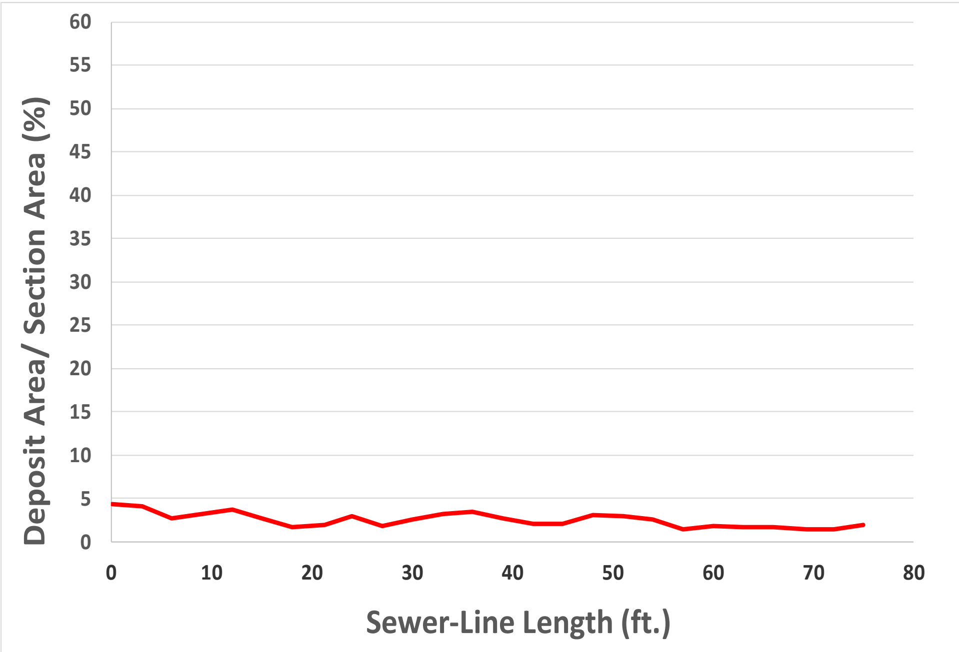


Figure A34-2 Deposit area percentage of the pipe cross section area

Blockage Data

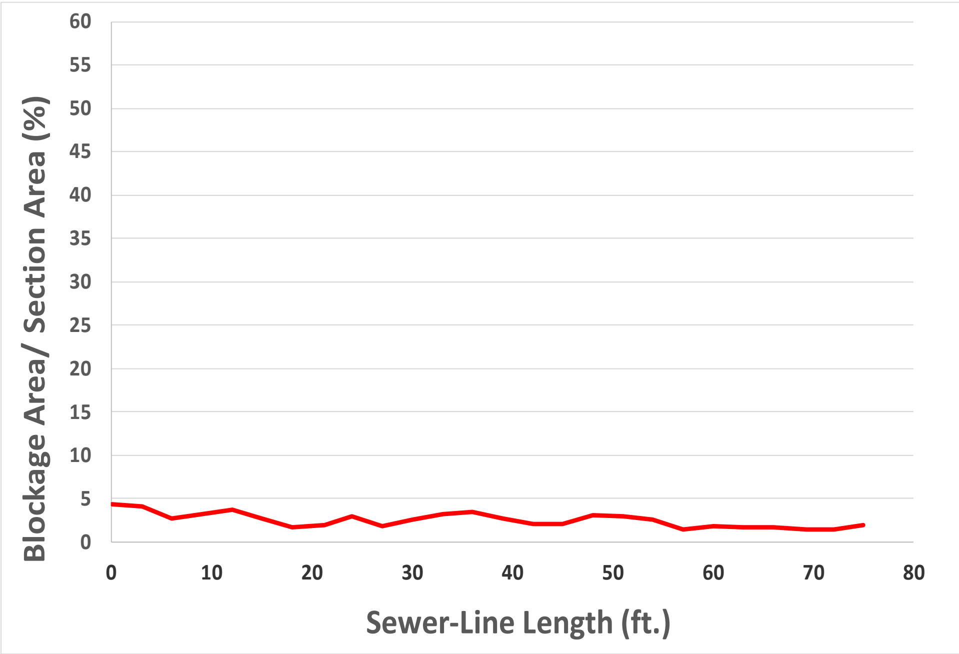


Figure A43.3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A43-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				5%					
3	0.1		DAE	S01			50%				1,2	
4	8.15		DAE	F01								
5	8.15		DAE	S02			20%				3	
6	14.1		MWL				10%				4	
7	78.4		DAE	F02								
8	79.75		MSA									

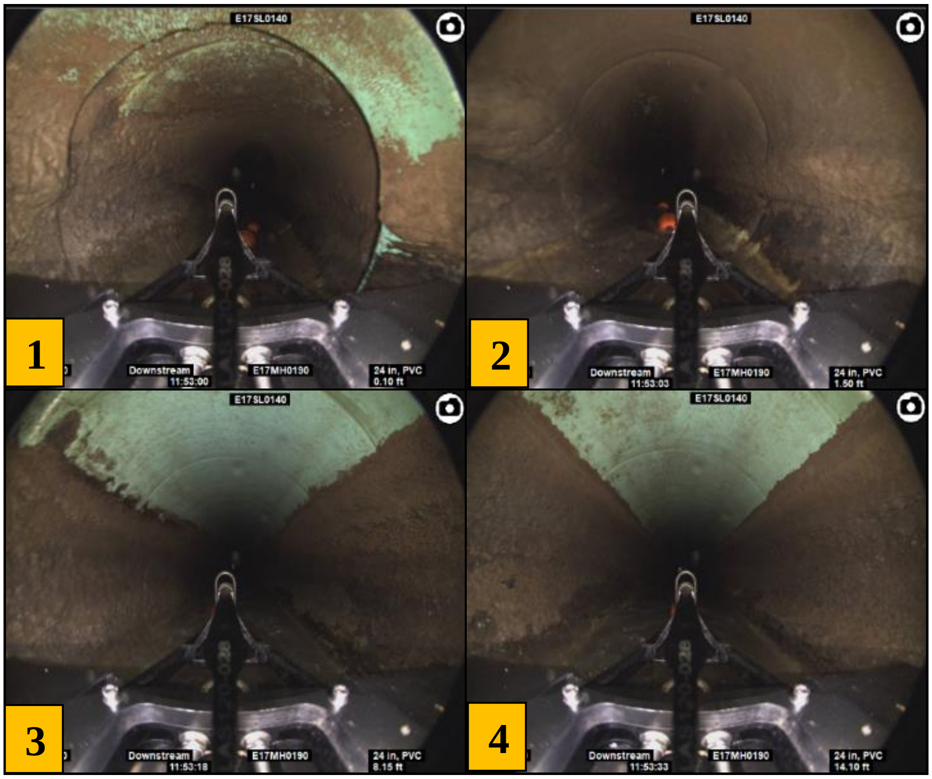


Figure A43-4 images from 1 through 4

Line 44 Summary

Table A44-1 Results Summary of Sewer Line 44

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	24
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	2
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	1881.3
Maximum Blockage (%)	3.2
Maximum Deposit Height (in)	0.7

Deposit Data

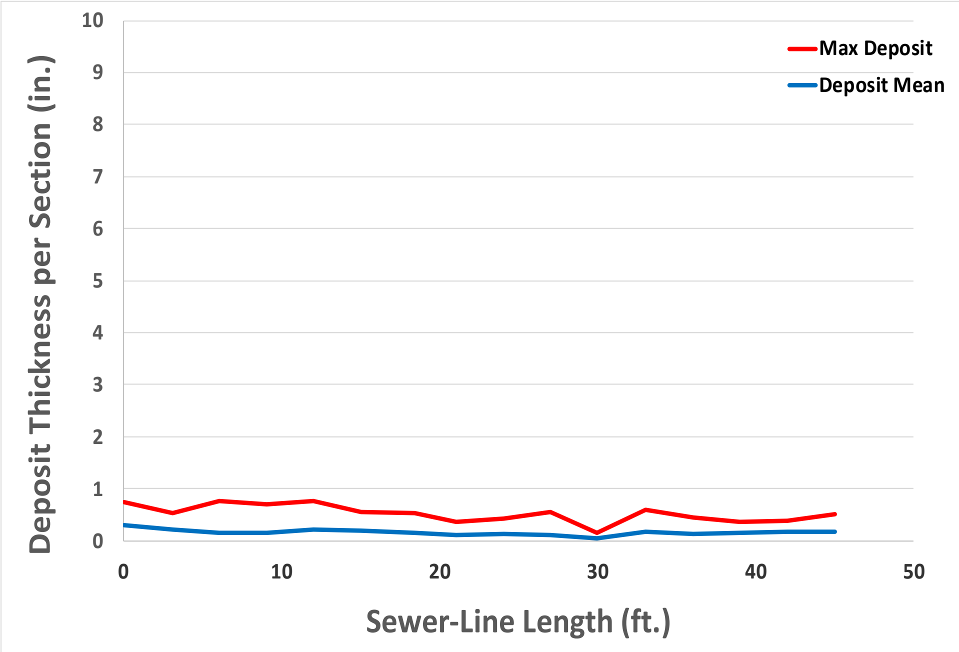


Figure A44-1 Deposit thickness per cross-section

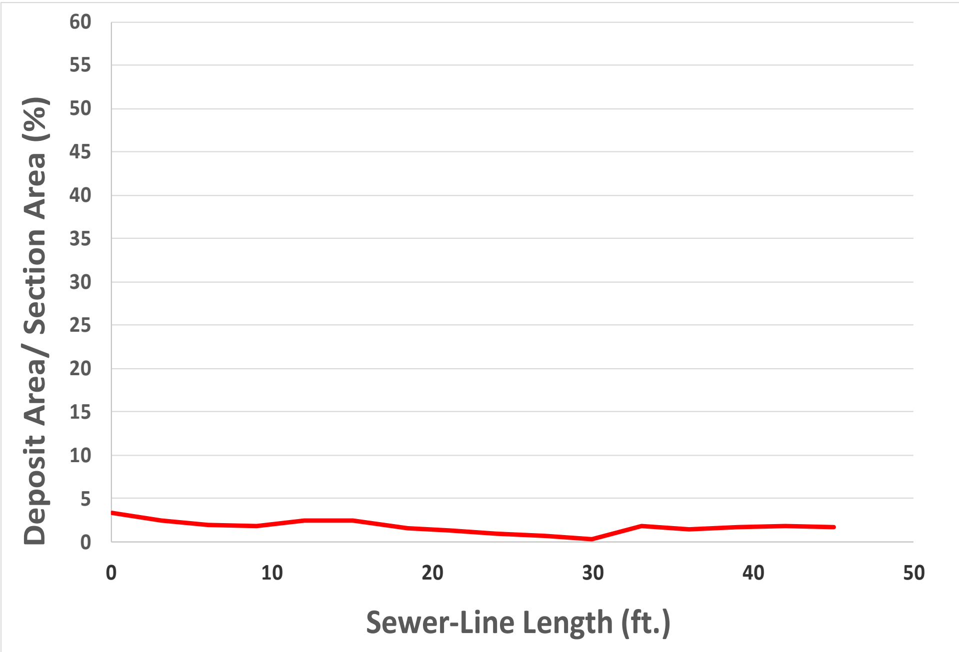


Figure A44-2 Deposit area percentage of the pipe cross section area

Blockage Data

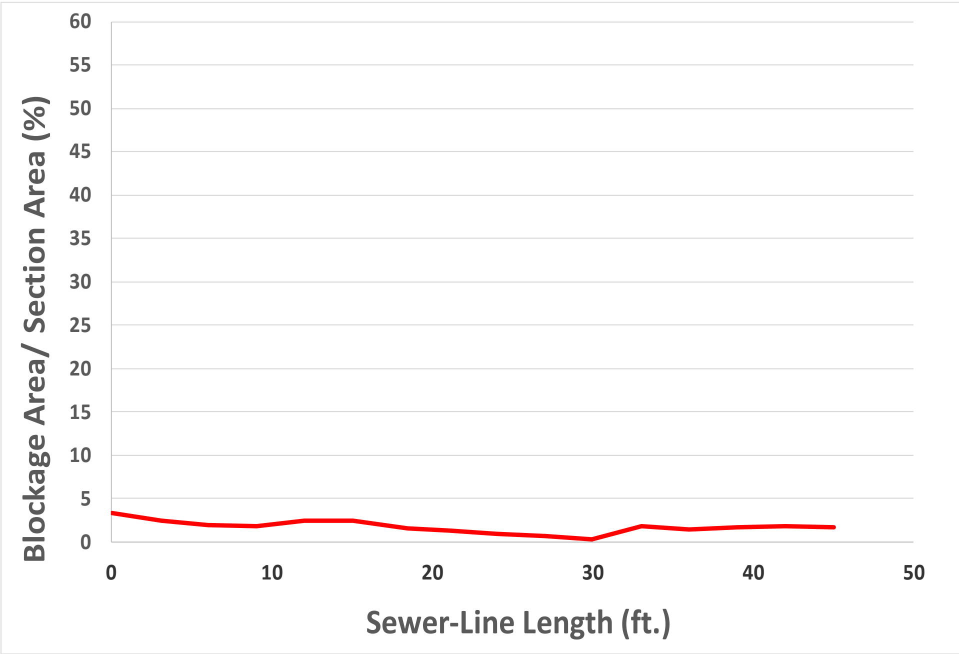


Figure A44-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A44-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				10%					
3	0		DAE				15%				1	COVERED AS A LAYER
4	3.75		DAE	S01			<5%				2	
5	18.65		DAE	F01								
6	18.65		MSA									

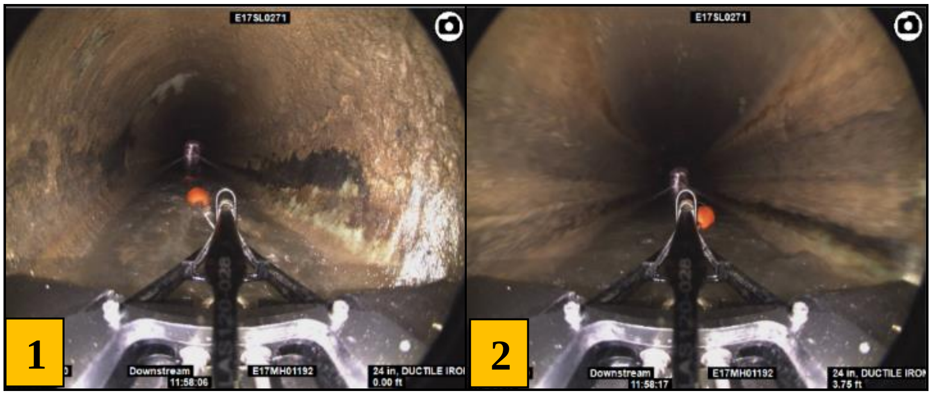


Figure A44-4 images from 1 through 2

Line 45 Summary

Table A45-1 Results Summary of Sewer Line 45

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	70
Percentage of The Line Not Inspected	3.2 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	0
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	3573.7
Maximum Blockage (%)	2.8
Maximum Deposit Height (in)	0.5

Due to software issues, distance from 45.05 ft. to 65.15 ft. could not be processed.

Deposit Data

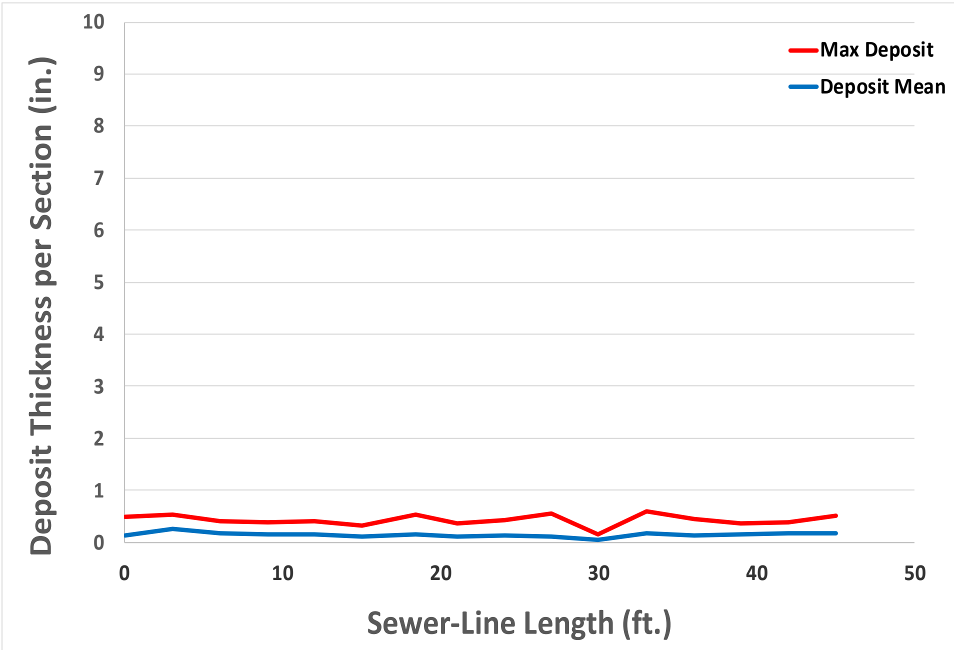


Figure A45-1 Deposit thickness per cross-section

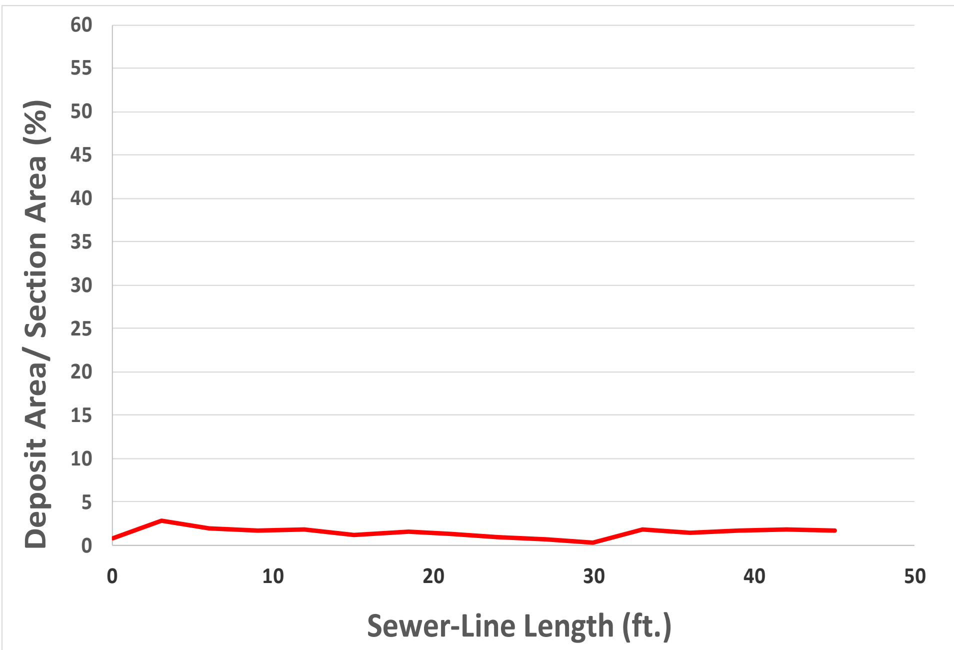


Figure A45-2 Deposit area percentage of the pipe cross section area

Blockage Data

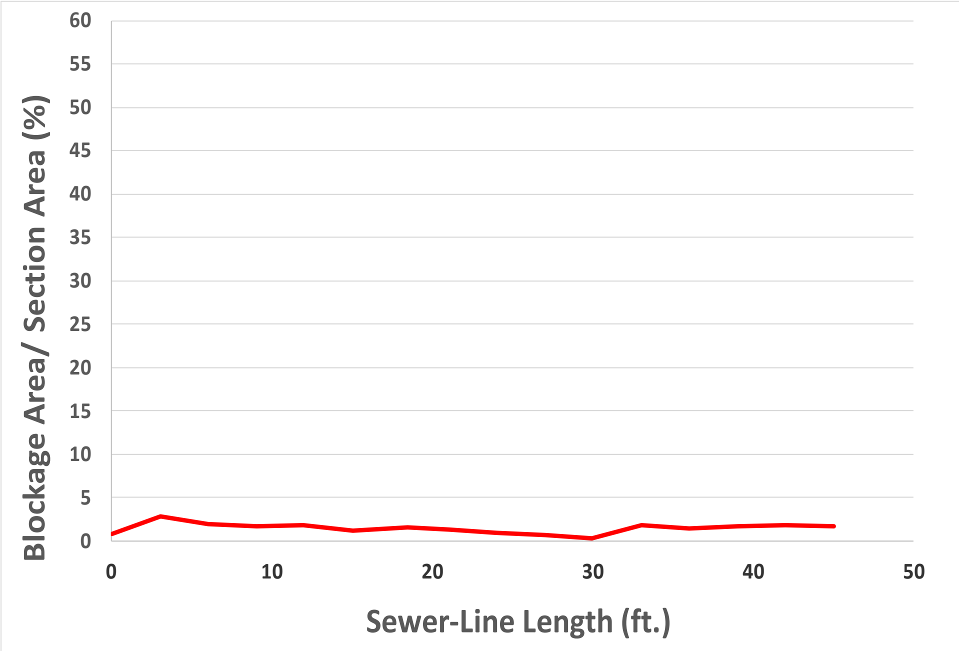


Figure A45-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A45-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code Group/ Descriptor/ Modifier	Continuous Defect	Value Dimension 1st	Value Dimension 2nd	Value %	Joint	Circumferential Location At/ From	Circumferential Location To	Img Reference	Remarks
1	0		AMH									NO MUCH DEFECTS. VERY VERY LITTLE DEPOSITS THROUGHOUT THE LENGTH OF PIPE (<5%) IMAGES 1 TO 4
2	0		MWL				10%					
3	65.15		MSA									

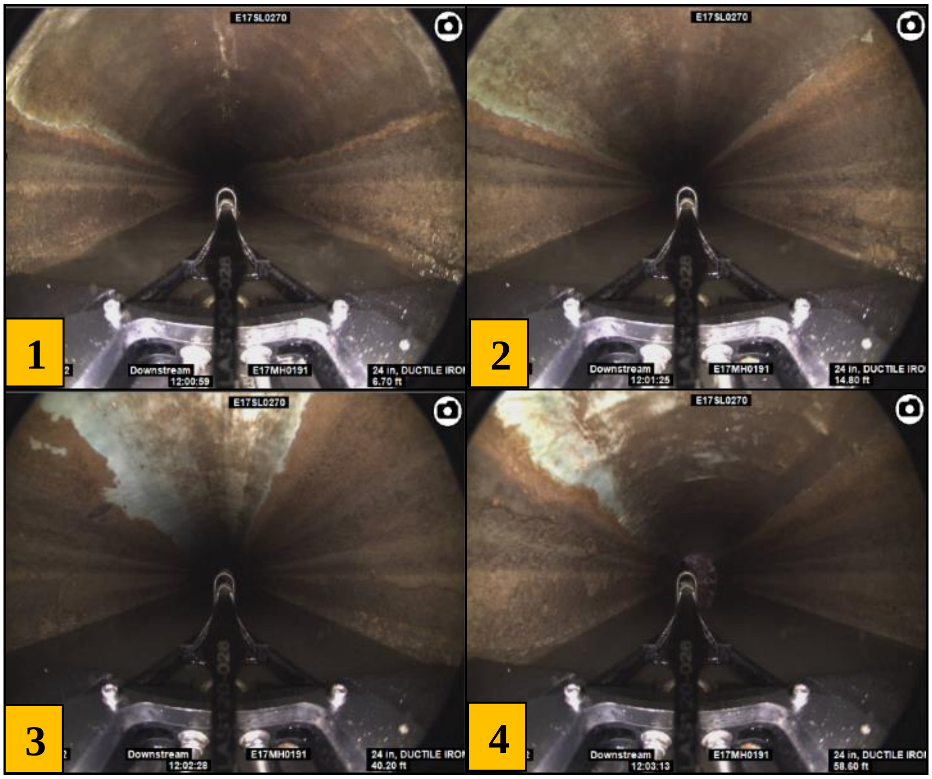


Figure A45-4 images from 1 through 4

Line 46 Summary

Table A46-1 Results Summary of Sewer Line 46

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	411
Percentage of The Line Not Inspected	0 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	24
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	54545.6
Maximum Blockage (%)	4
Maximum Deposit Height (in)	2.2

Deposit Data

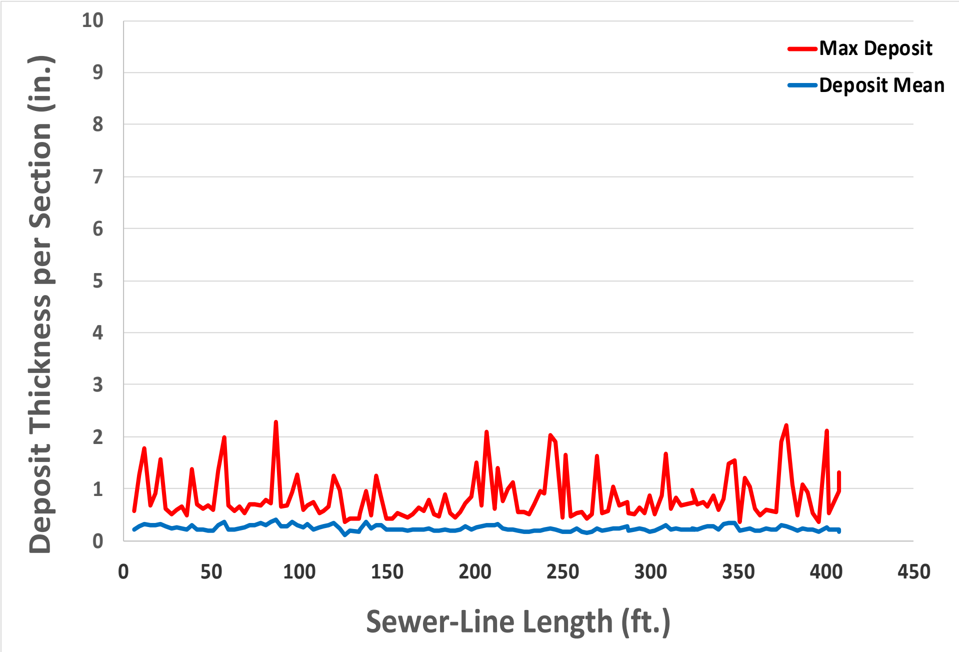


Figure A46-1 Deposit thickness per cross-section

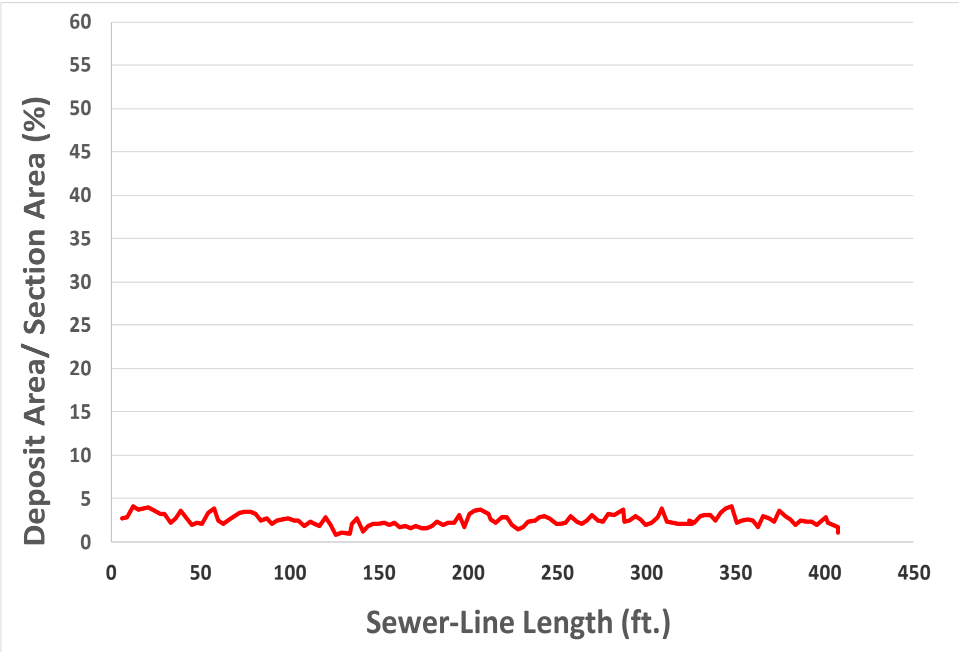


Figure A46-2 Deposit area percentage of the pipe cross section area

Blockage Data

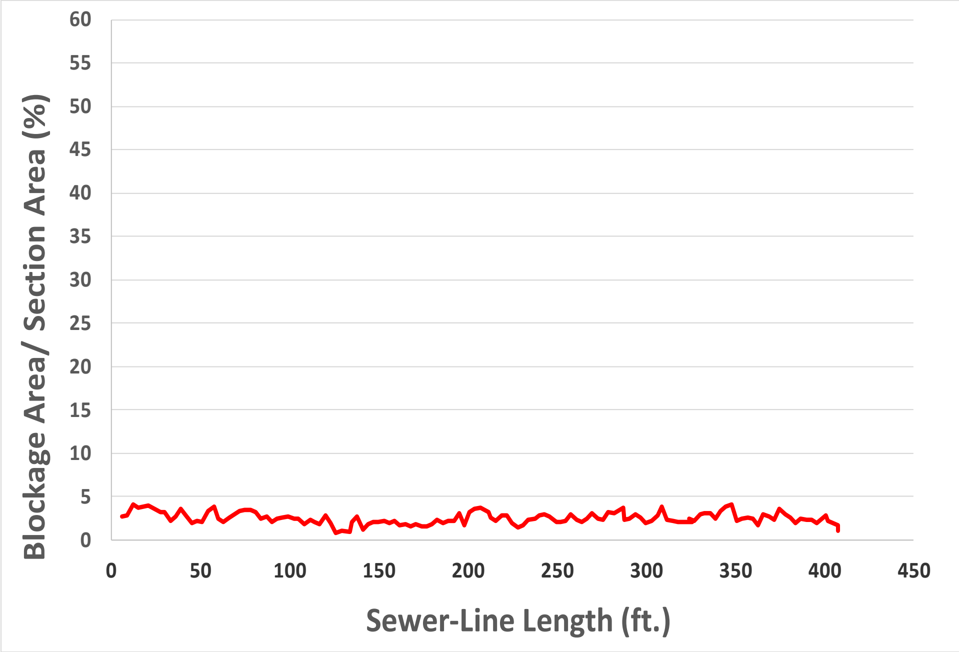


Figure A46-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A46-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	6		MWL				5%					
3	6		DAE	S01			10%				1,2,3	
4	13.35		MWL				10%				4	
5	34.55		MWL				5%				5	
6	75.25		MWL				10%				6	
7	82.85		DAE	F01								
8	82.85		DAE	S02			5%				7,8	
9	107.35		MWL				5%				9	
10	116.35		DAE	F02								
11	116.35		DAE	S03			10 TO 15%				10,11,12	
12	119.2		MWL				15%				13	
13	143.95		MWL				5%				14	
14	147.45		DAE	F03								
15	147.45		DAE	S04			5%				15,16,17,18	
16	151.35		MWL				10%				19	
17	177.25		MWL				5%				20	
18	195.05		MWL				10%				21	
19	221.95		MWL				5%				22	
20	233.1		MWL				10%				23	
21	261.7		MWL				5%				24	
22	271.15		MWL				10%				25	
23	300.45		DAE	F04			5%					
24	300.45		DAE	S05			10%				26,27	
25	301.45		MWL				5%				28	
26	313.65		MWL				10%				29	
27	320		DAE	F05								
28	320		DAE	S06			10%				30,31	
29	325.4		MWL				5%				32	
30	351.35		DAE	F06								
31	352.45		DAE	S07			5%				33,34,35,36	
32	364.7		MWL				10%				37	
33	410.55		DAE	F07								
34	410.55		MSA									

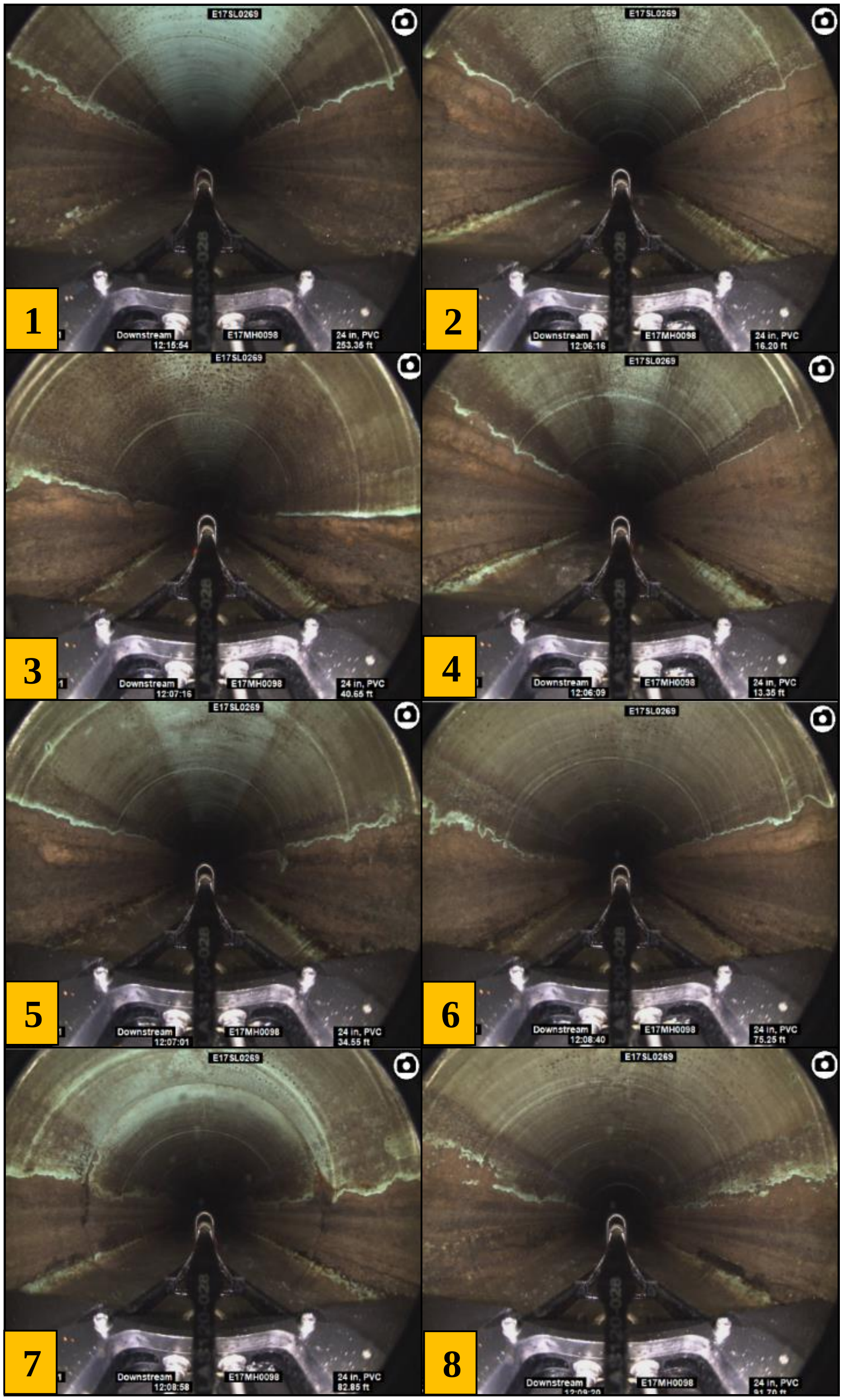


Figure A46-4 images from 1 through 8

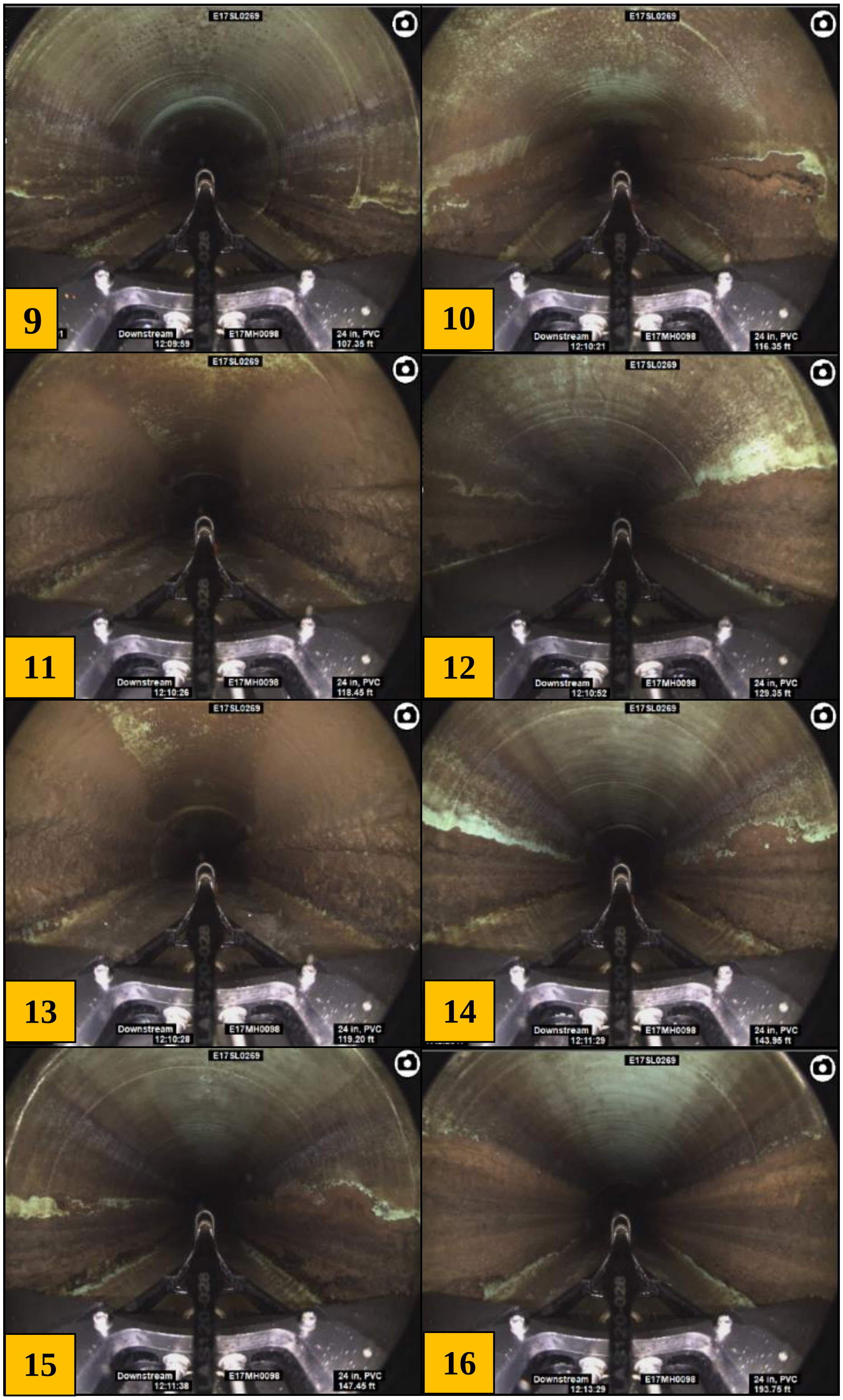


Figure A46-5 images from 9 through 16

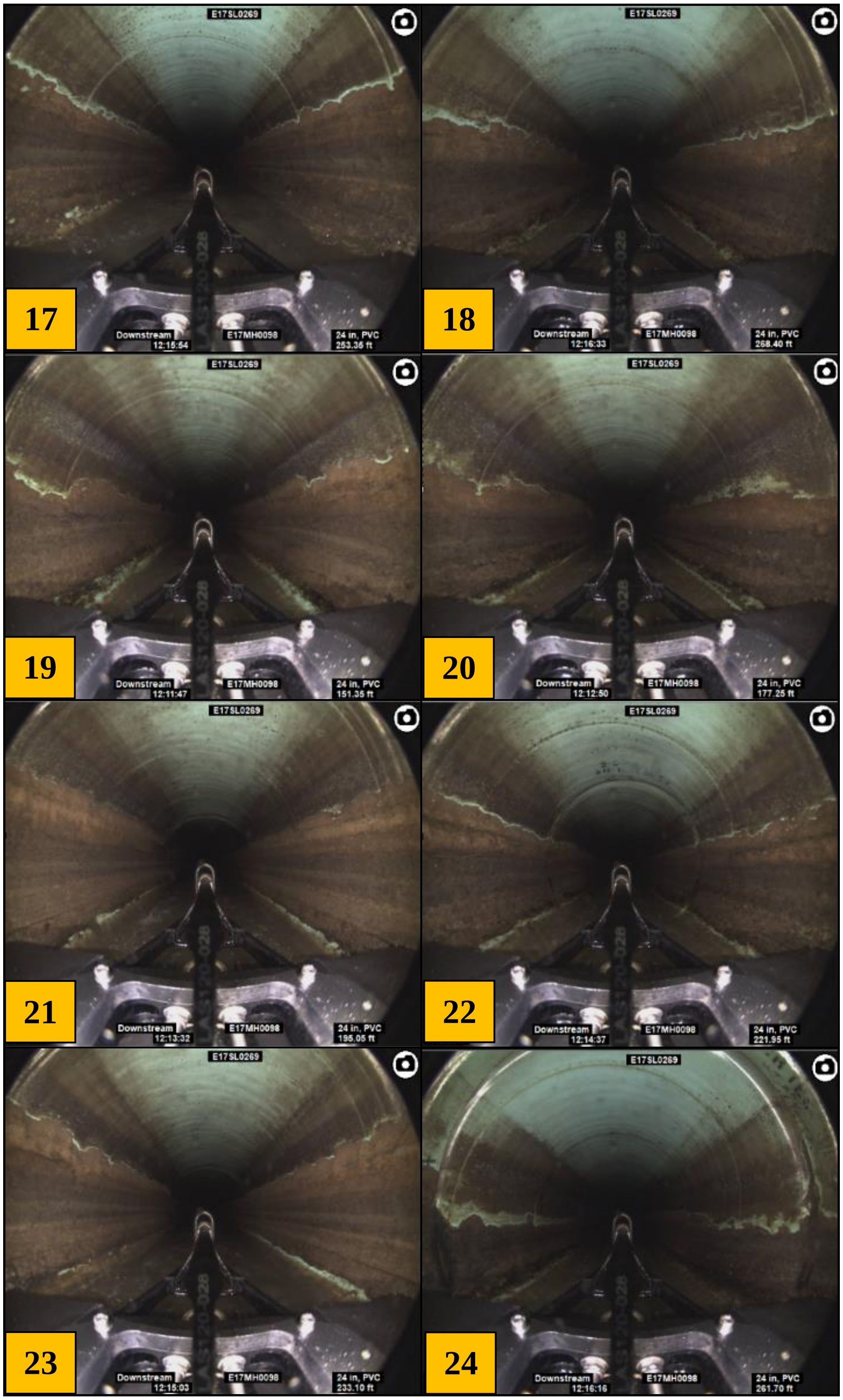


Figure A46-6 images from 17 through 24

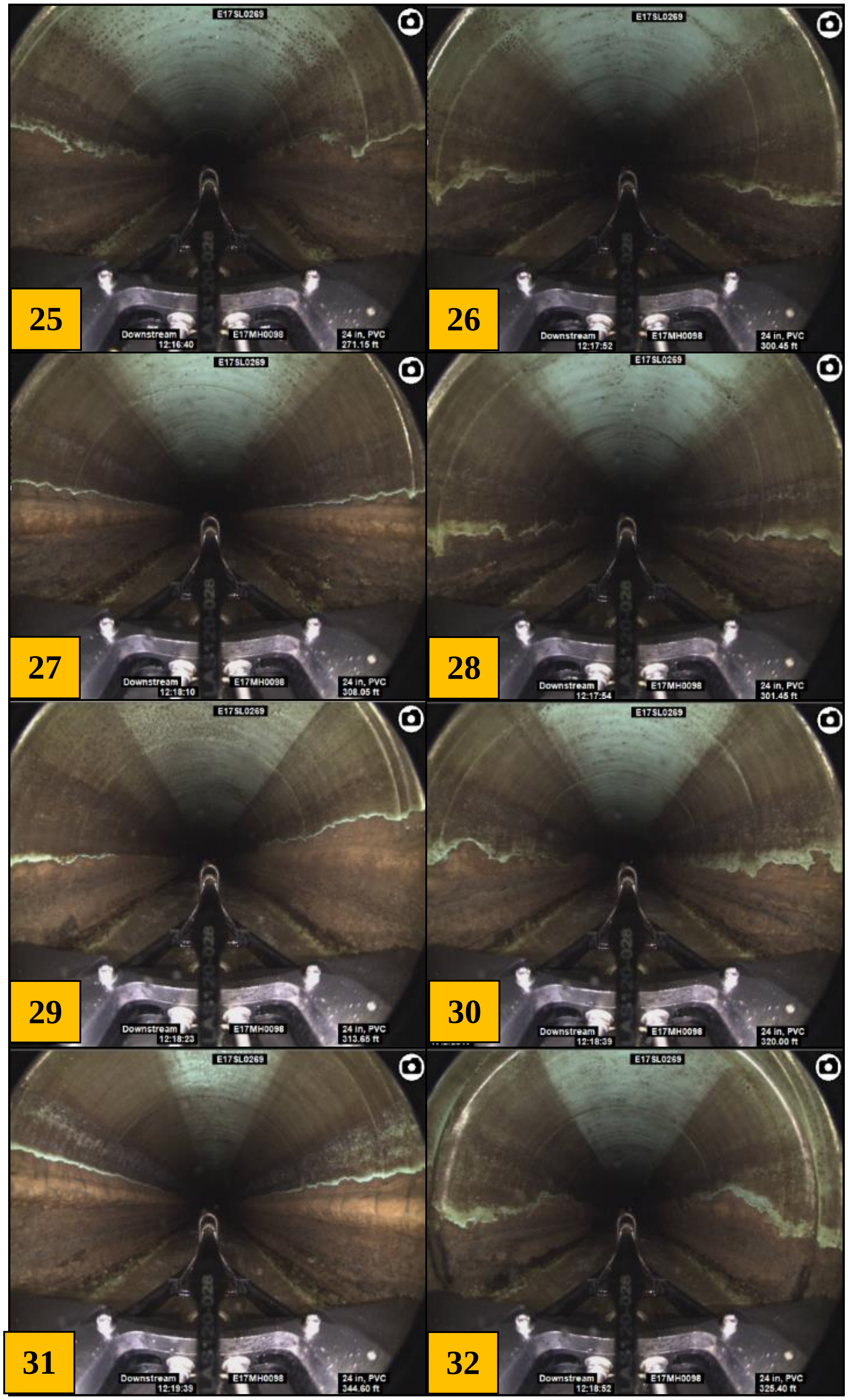


Figure A46-7 images from 25 through 32

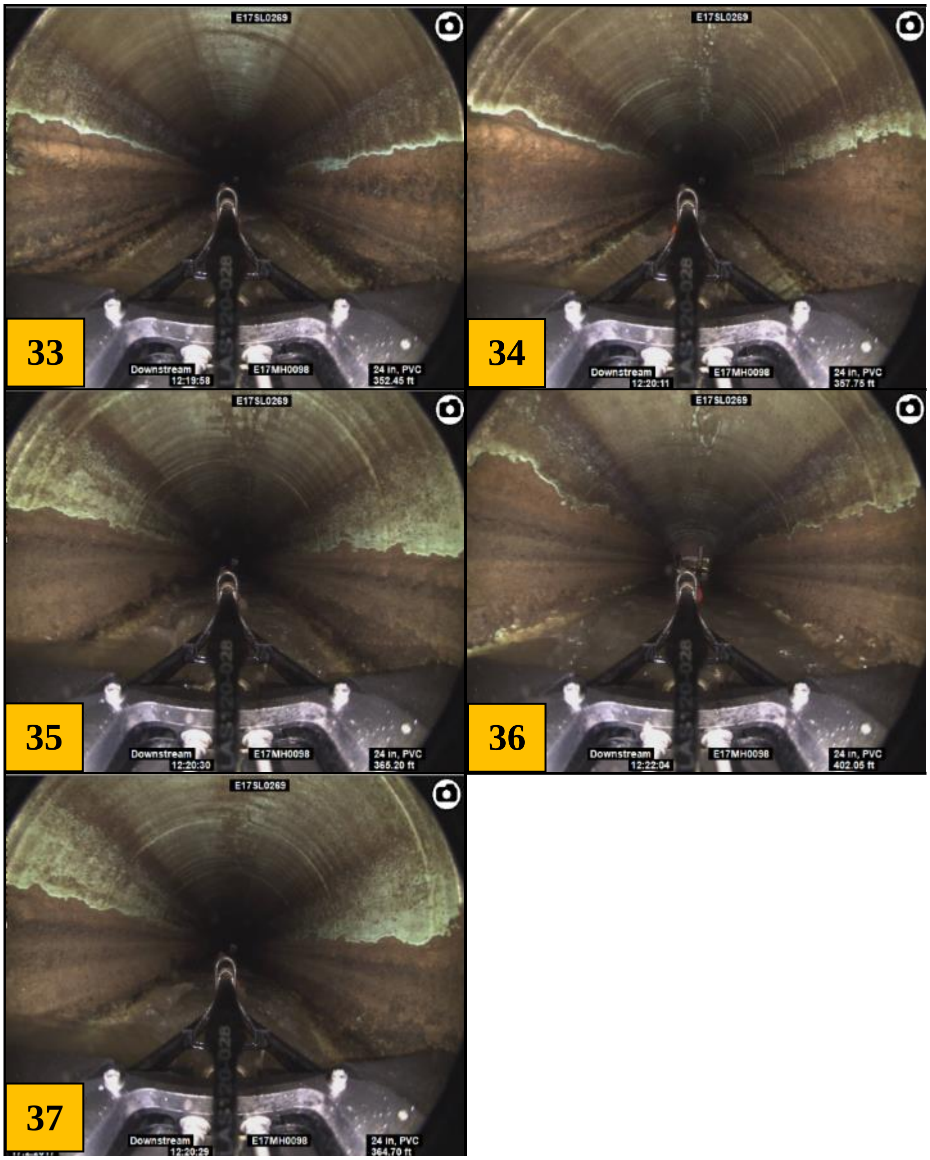


Figure A46-8 images from 33 through 37

Line 47 Summary

Table A47-1 Results Summary of Sewer Line 47

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	500
Percentage of The Line Not Inspected	0 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	21
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	69274.5
Maximum Blockage (%)	5.7
Maximum Deposit Height (in)	4.4

Deposit Data

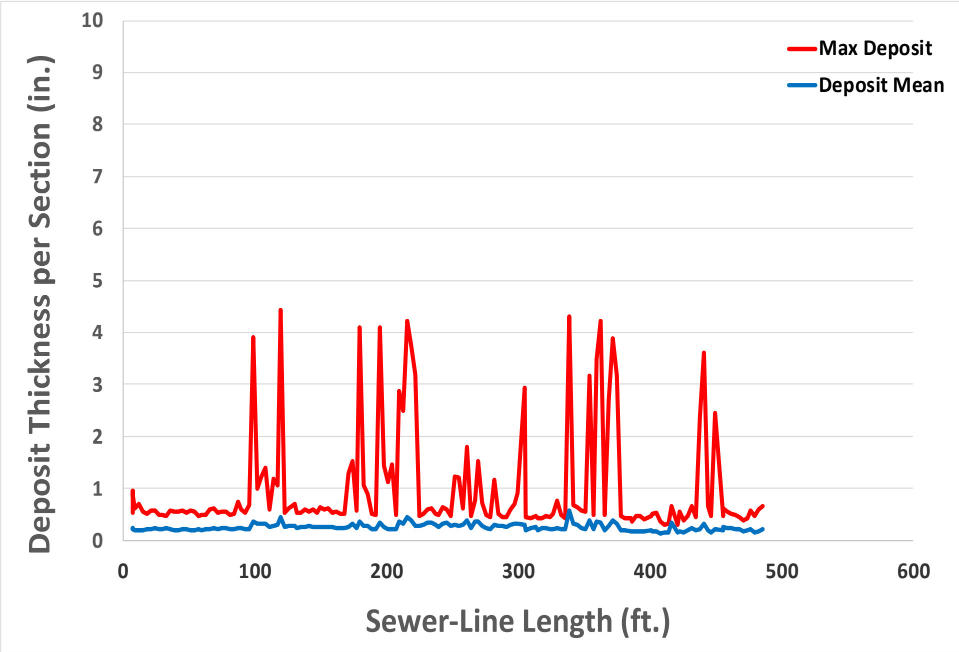


Figure A47-1 Deposit thickness per cross-section

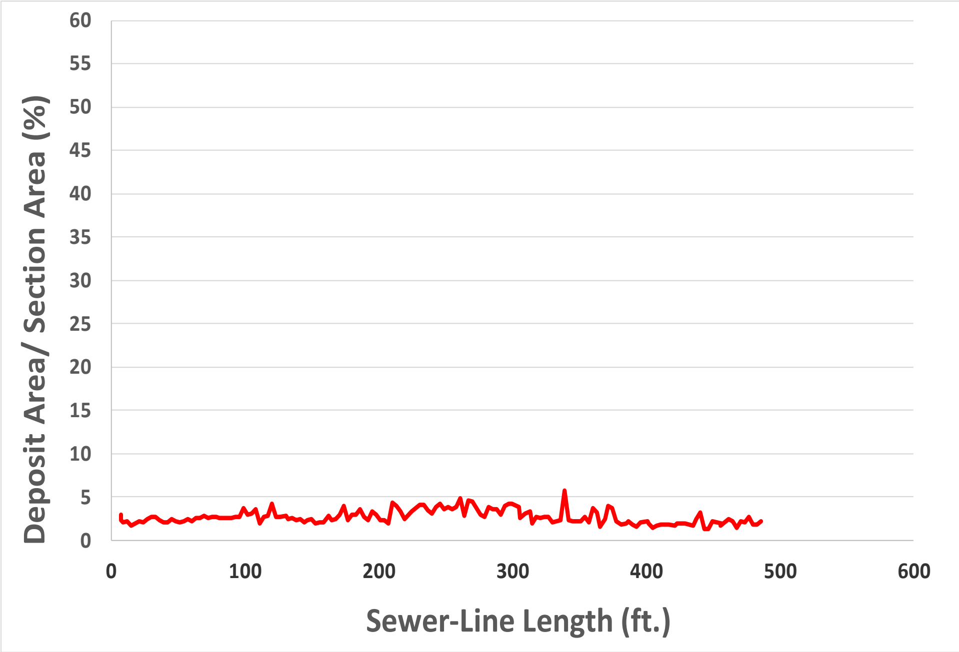


Figure A47-2 Deposit area percentage of the pipe cross section area

Blockage Data

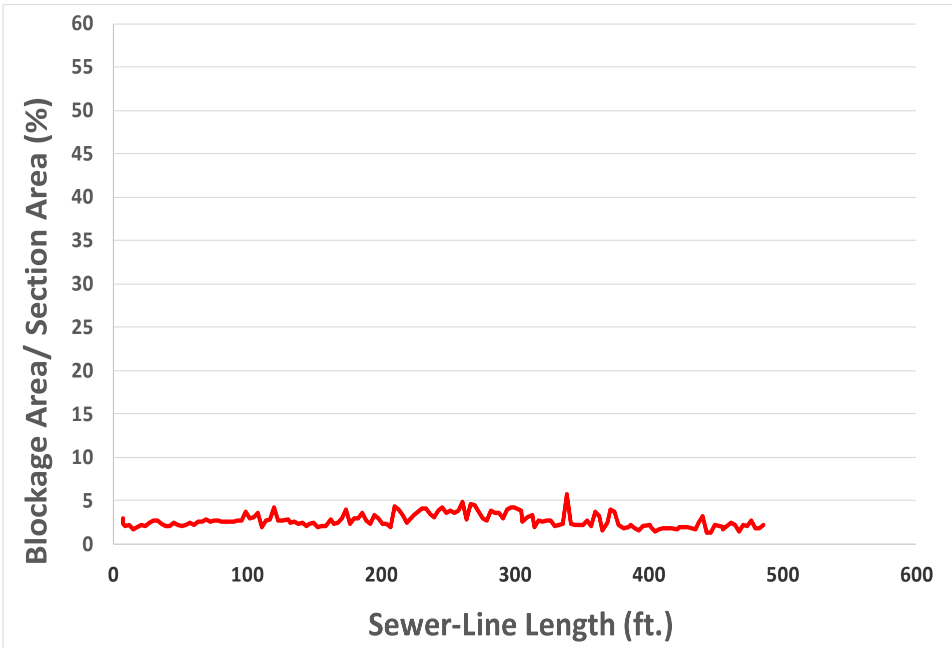


Figure A34-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A47-1Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	7		MWL				5%					
3	9.55		DAG				10%	J			1	
4	10.1		DAE				5%				2	
5	48.15		DAE	S01			5%				3,4,5,6	
6	86.55		DAE	F01								
7	97.1		DAE	S02			5%				7,8	
8	124.45		DAE	F02								
9	146		DAE	S03			5%				9	
10	162.75		DAE	F03								
11	168.85		DAE	S04			5%				10	
12	175.05		DAE	F04								
13	182.6		DAE	S05			5%				11	
14	187.5		DAE	F05								
15	193.45		DAE				5%				12	
16	196.15		MWL				10%				13	
17	242.25		DAE				5%				14	
18	250.7		DAE	S06			5%				15	
19	253.2		MWL				5%				16	
20	264.8		DAE	F06								
21	269.3		DAE	S07			5%				17	
22	276.35		DAE	F07								
23	282.1		DAE				5%				18	
24	287.05		DAE				5%				19	
25	294		DAE	S08			10%				20	
26	321.95		DAE				5%				21	
27	355.35		MWL				10%				22	
28	381.2		MWL				5%				23	
29	439.5		MWL				10%				24	
30	468.45		MWL				5%				25	
31	489.4		DAE	F08								
32	489.4		MSA									

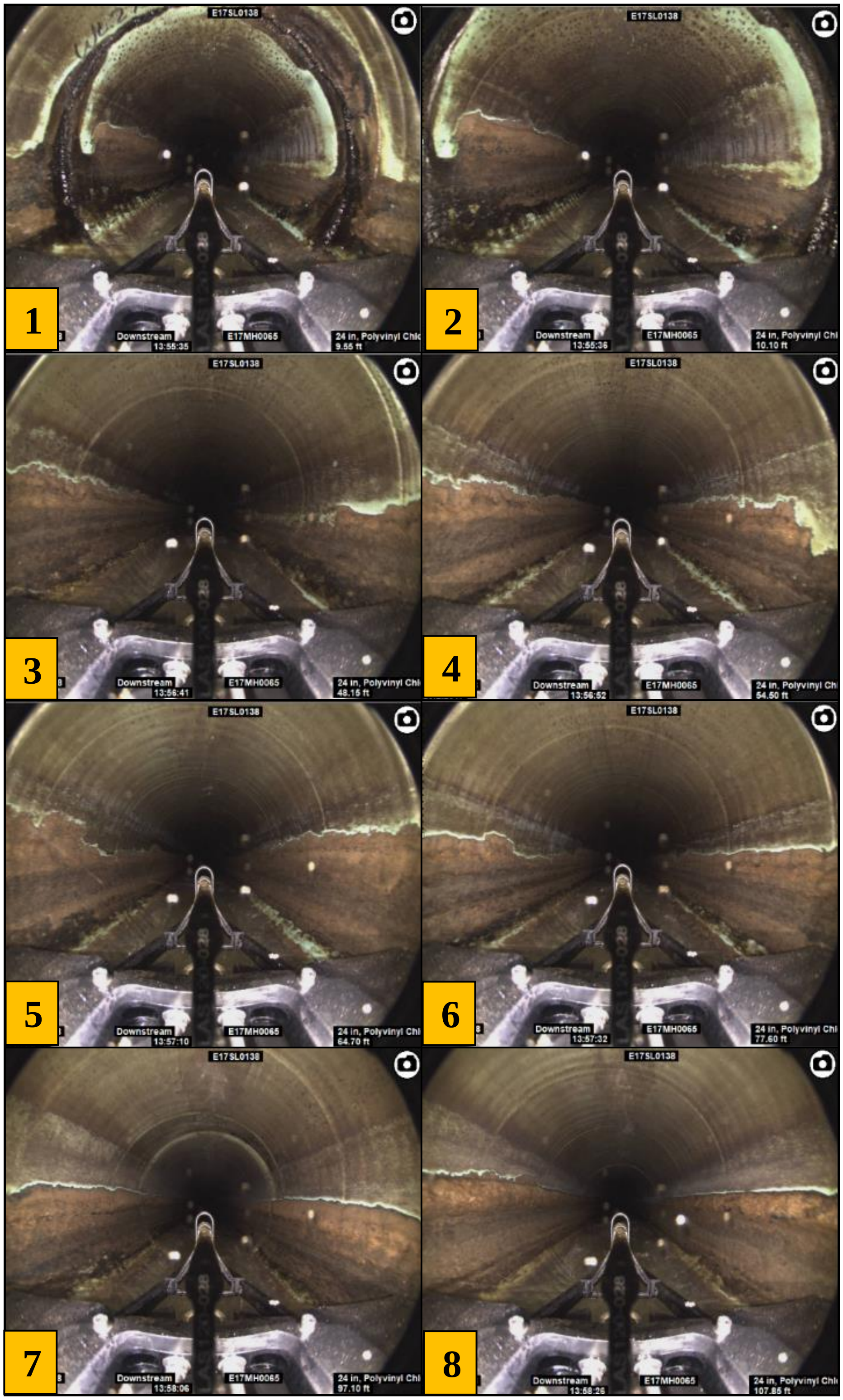


Figure A47-4 images from 1 through 8

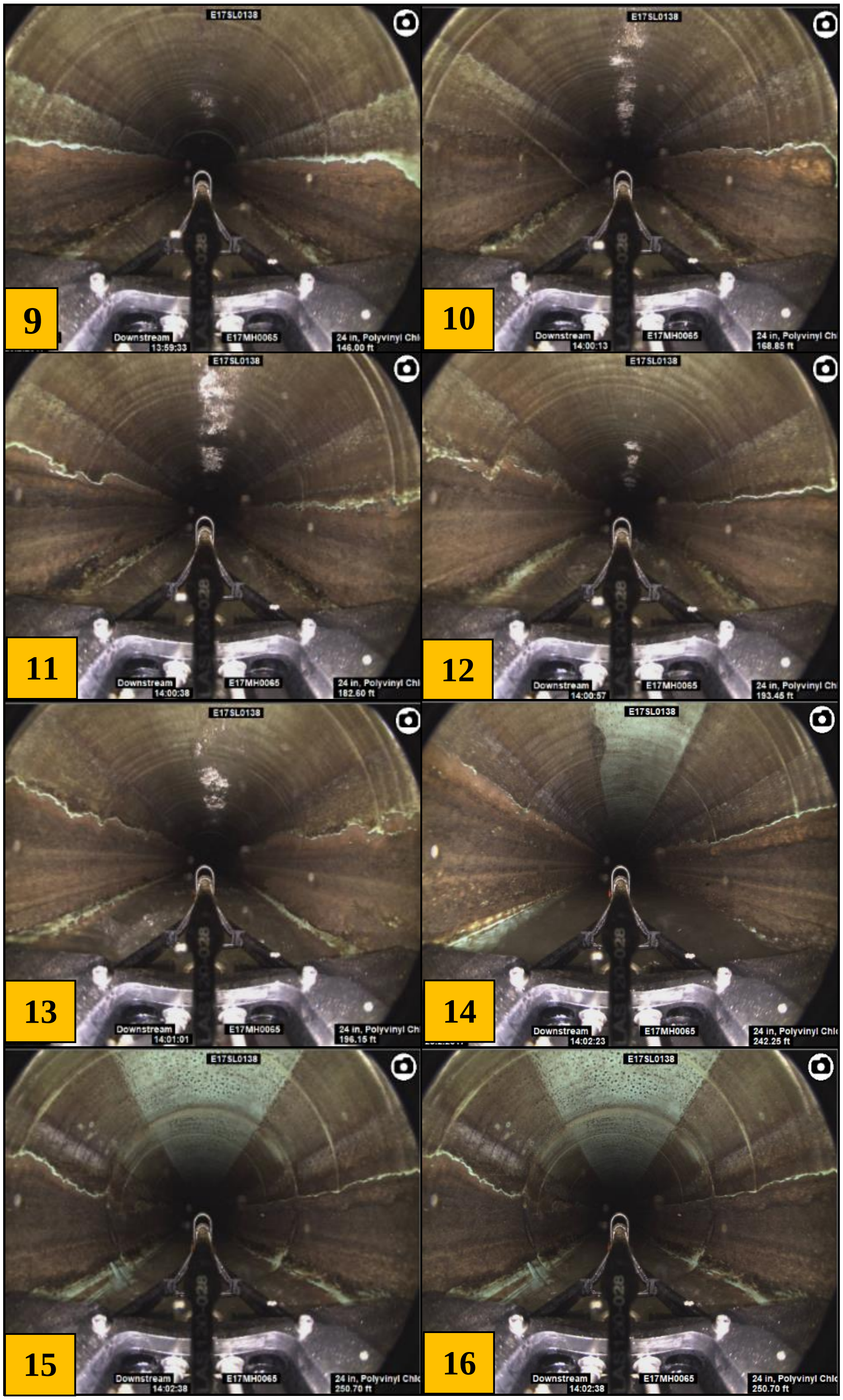


Figure A47-5 images from 9 through 16

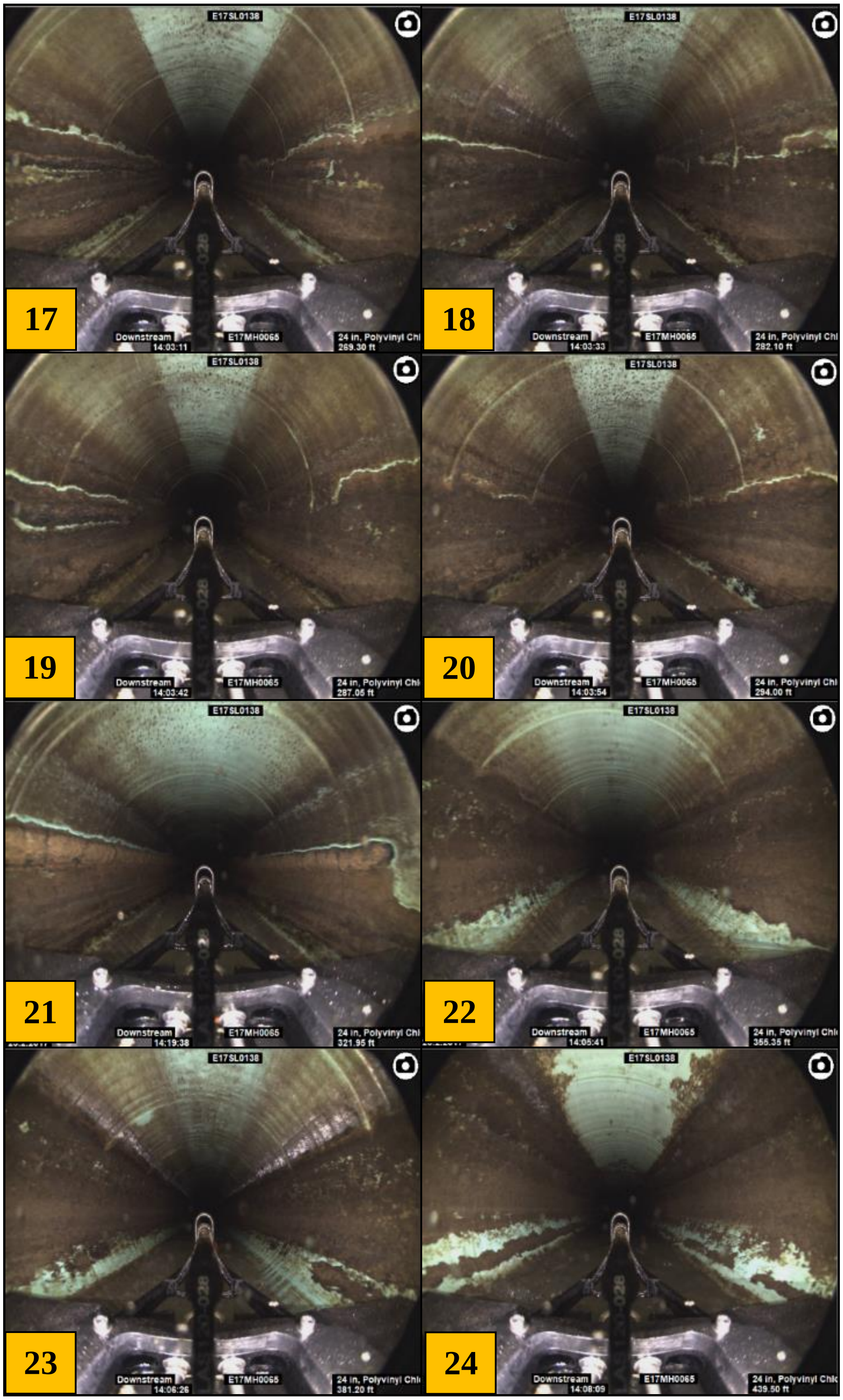


Figure A47-6 images from 17 through 24

Figure A47-7 images from 25

Line 48 Summary

Table A48-1 Results Summary of Sewer Line 48

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	600
Percentage of The Line Not Inspected	0 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	29
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	82772.1
Maximum Blockage (%)	4.6
Maximum Deposit Height (in)	3.2

Deposit Data

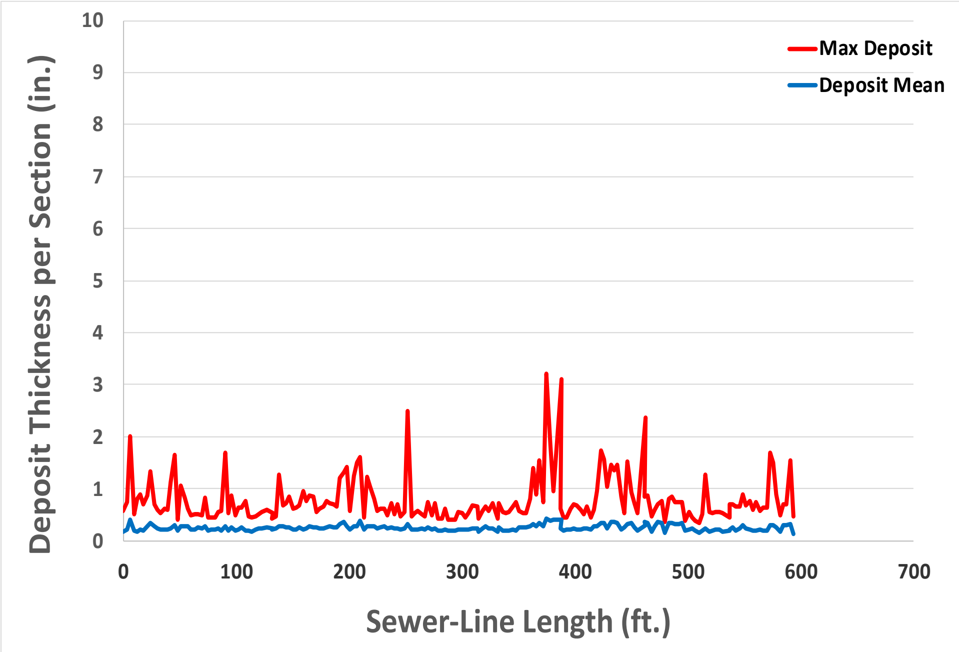


Figure A48-1 Deposit thickness per cross-section

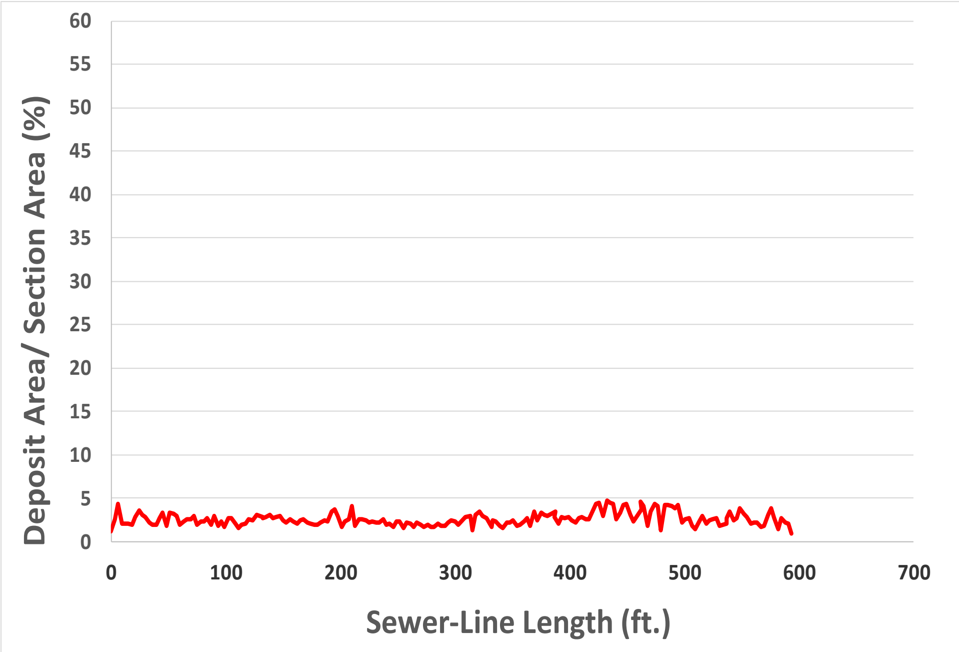


Figure A48-2 Deposit area percentage of the pipe cross section area

Blockage Data

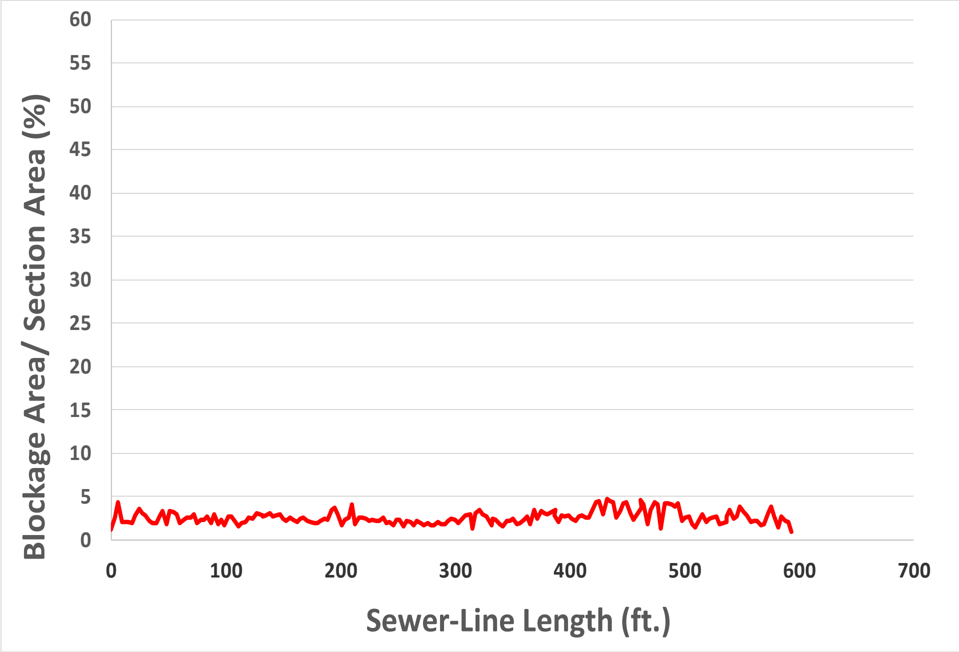


Figure A48-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A48-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				<5%					
3	1		DAE	S01			20%				1,2	
4	2.75		DAG				15%	J			3	
5	9		DAE	F01								
6	11.95		DAE	S02			10%				4,6	
7	18.55		MWL				10%				5	
8	33.55		DAE	F02								
9	35.05		MWL				5%				7	
10	35.05		DAE	S03			15%				7,8,9,10	
11	53.95		MWL				10%				10	
12	66.8		MWL				5%				11	
13	91.2		DAE	F03								
14	93.4		DAE	S04			5%				12	
15	98.6		MWL				10%				13	
16	112.4		MWL				5%				14	
17	159.7		DAE	F04								
18	183.95		DAE	S05			15%				15,16	
19	199.35		DAE	F05								
20	202.85		DAE	S06			5%				17	

21	212.9		DAE	F06								
22	214.15		DAE	S07			5%				18	
23	225.85		DAE	F07								
24	225.85		DAE	S08			10%				19	
25	248.75		MWL				10%				20	
26	268		IDJ								21	
27	270.85		DAE	F08								
28	272.95		DAE	S09			10%				22,23,25,26	
29	302.75		MWL				5%				24	
30	354		DAE	F09								
31	355.95		DAE	S10			10%				27,28,	
32	372.2		MWL				10%				29	
33	416.95		DAE	F10								
34	418.65		MWL				5%				30	
35	420.75		DAE	S11			10%				31,32	
36	436.15		MWL				10%				33	
37	442.6		DAE	F11			10%					
38	443.25		DAE	S12			5%				34,35	
39	529.4		DAE	F12								
40	532		MWL				5%				36	
41	548.6		DAE	S13			5 TO 10%				37	
42	565.25		DAE	F13								
43	568.45		DAE	S14			5%				38,40	
44	587.75		MWL				10%				39	
45	596.15		DAE	F14								
46	596.15		MSA									

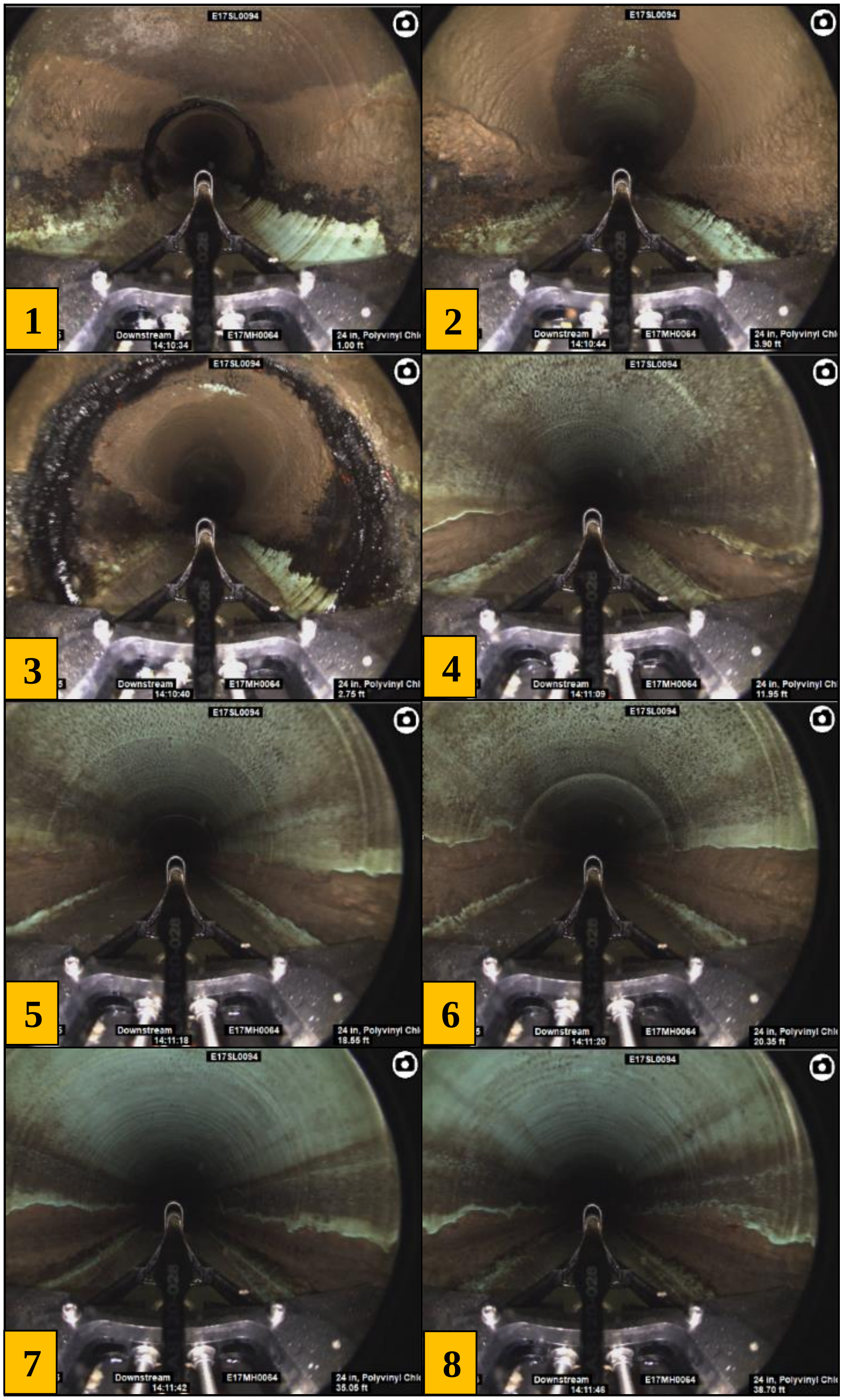


Figure A48-4 images from 1 through 8

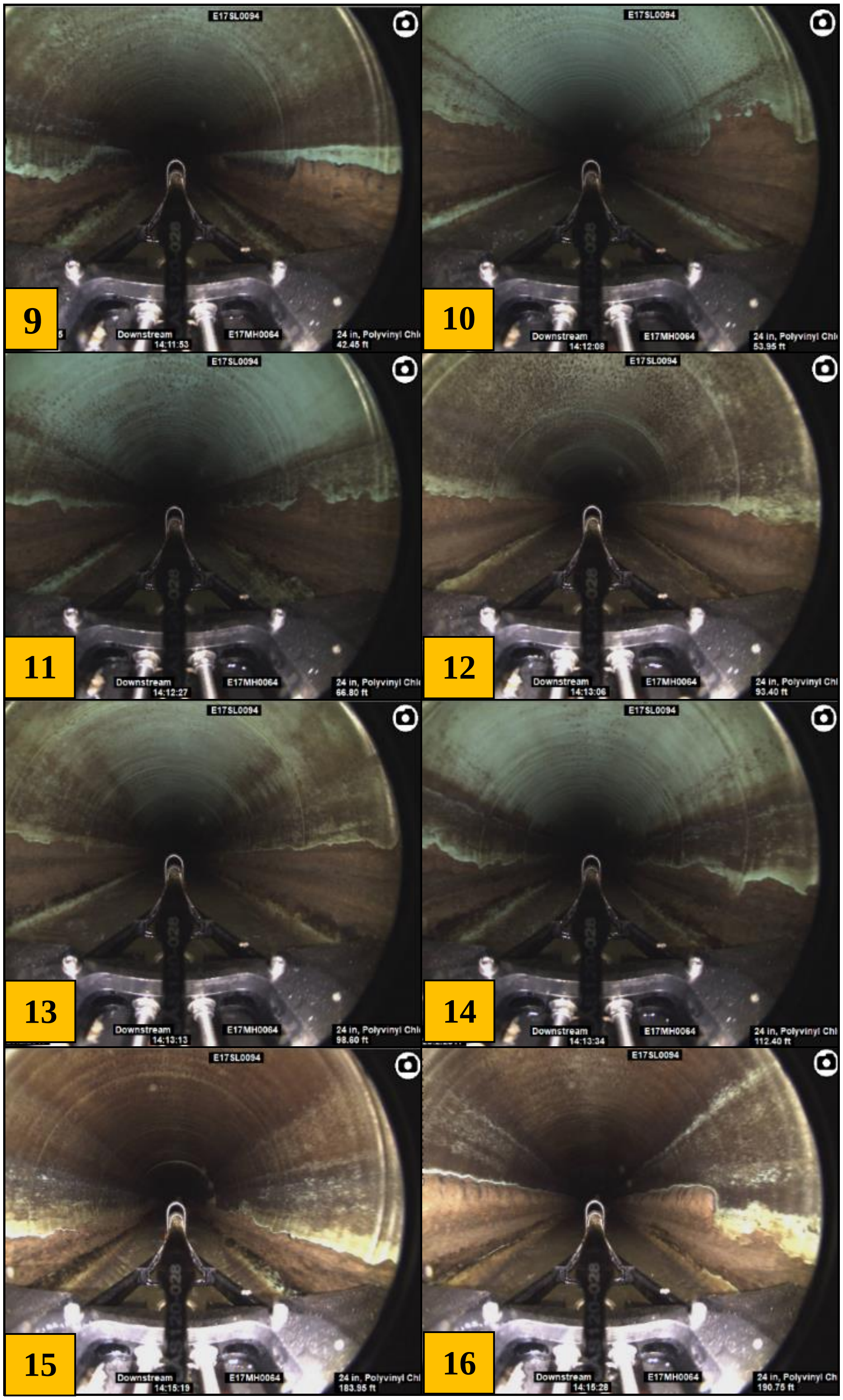


Figure A48-5 images from 9 through 16

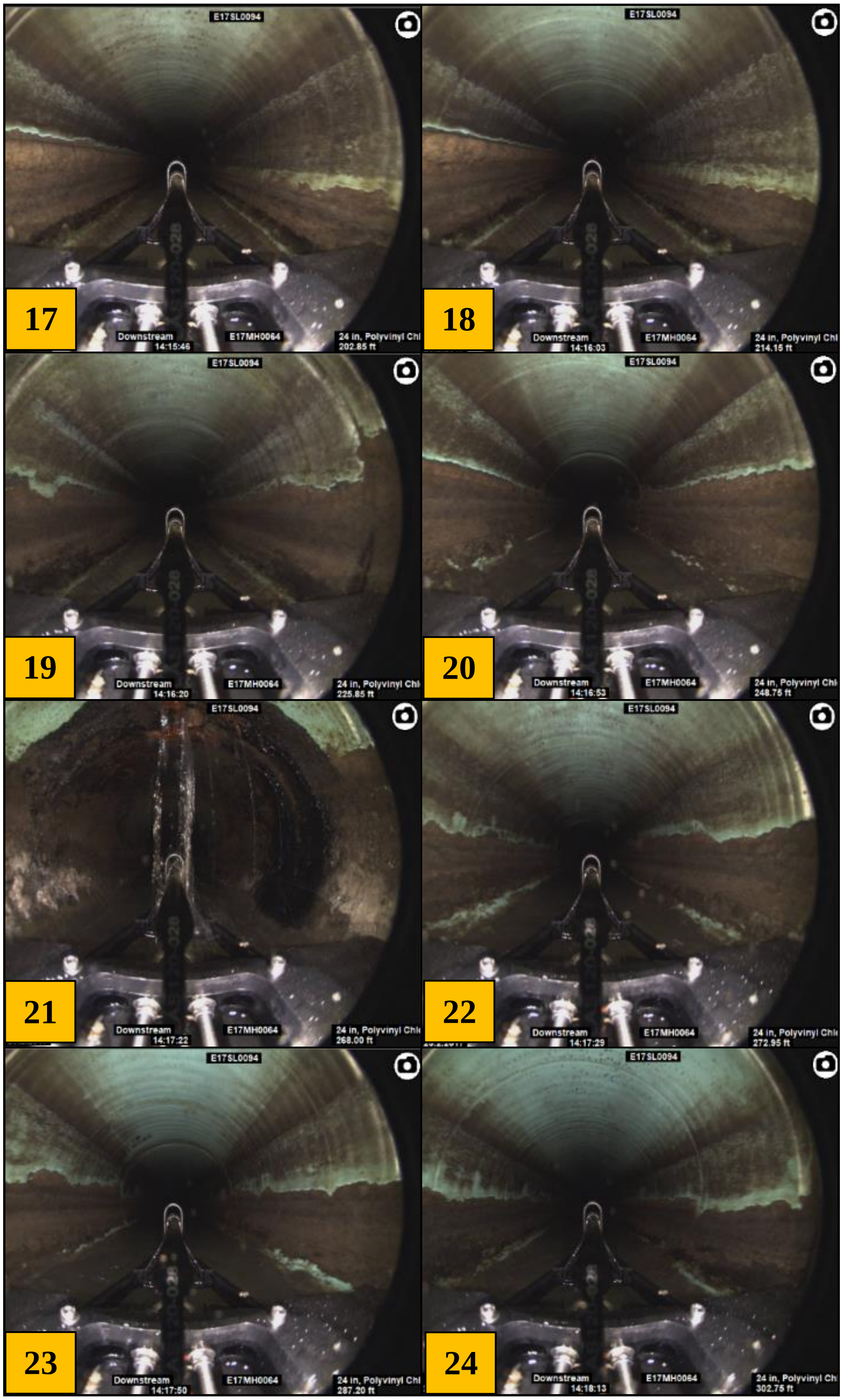


Figure A48-6 images from 17 through 24

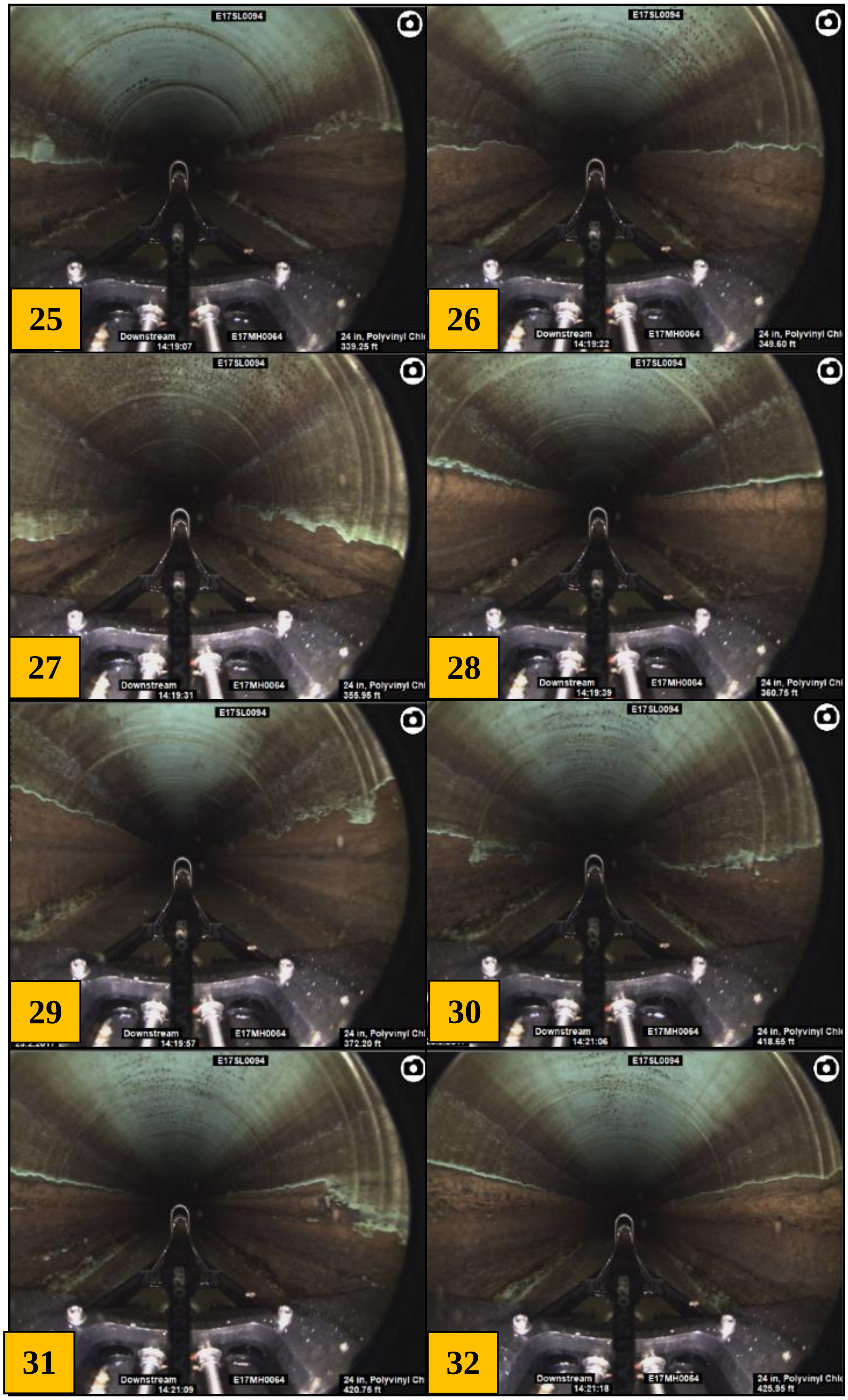


Figure A48-7 images from 25 through 32

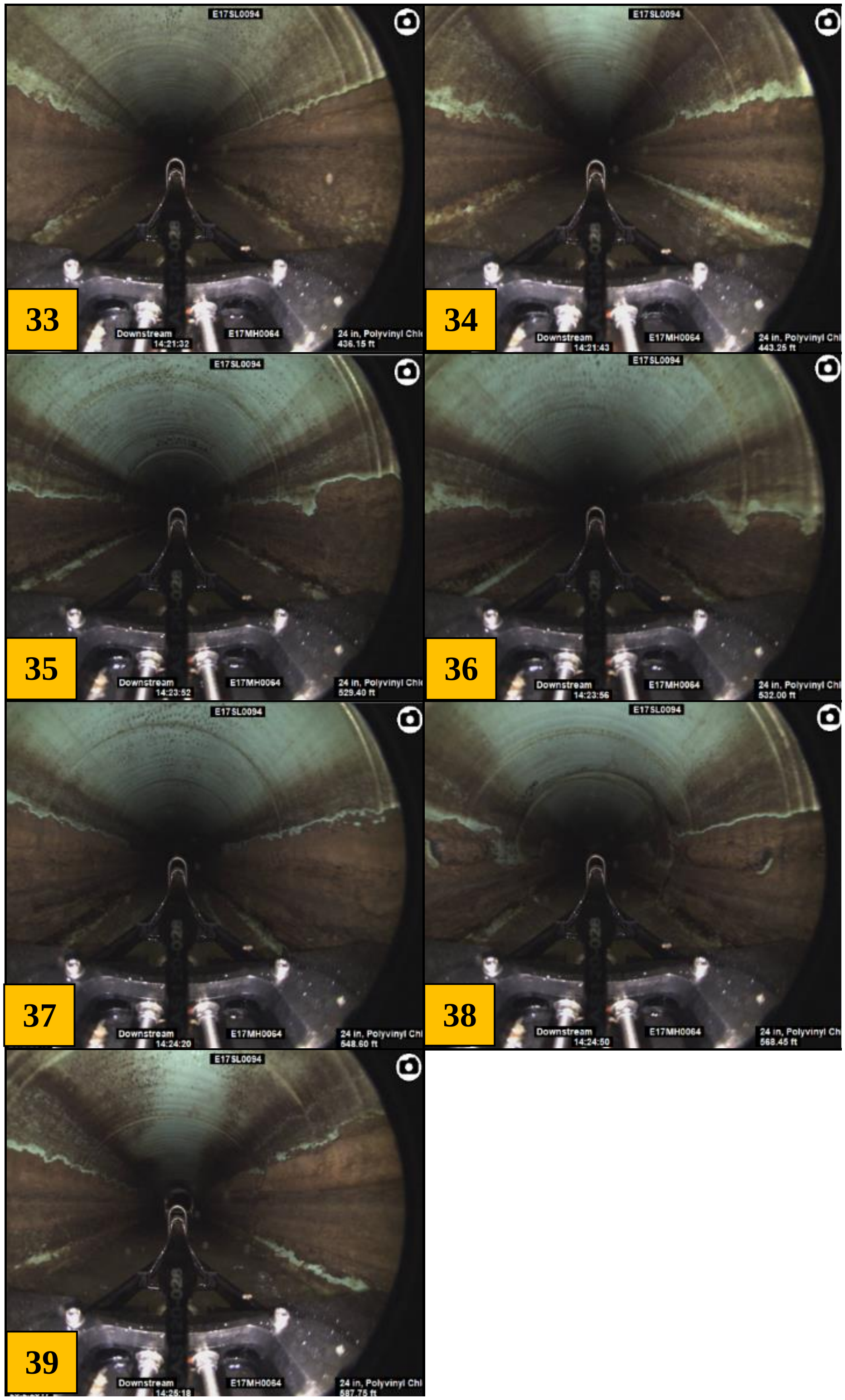


Figure A48-8 images from 33 through 39

Line 49 Summary

Table A49-1 Results Summary of Sewer Line 49

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	88
Percentage of The Line Not Inspected	100 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	6
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	0
Maximum Blockage (%)	0
Maximum Deposit Height (in)	0

Video recording is obtained, but the laser and sonar are not clear to be analyzed due to the splashed water.

Visual Observations

Table A49-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension 1st	Dimension 2nd	%		At/ From	To		
1	0		AMH									
2	0		MWL				10%					
3	9.1		MWL				5%				1	
4	15.05		DAE	S01			5 TO 10%				2	
5	29.7		MWL				10%				3	
6	46.65		DAE	F01								
7	49.05		MWL				5%				4	
8	55.25		DAE				5%				5	
9	79.1		DAE	S02			15%				6,7	
10	84		DAE	F02								
11	84		MSA									

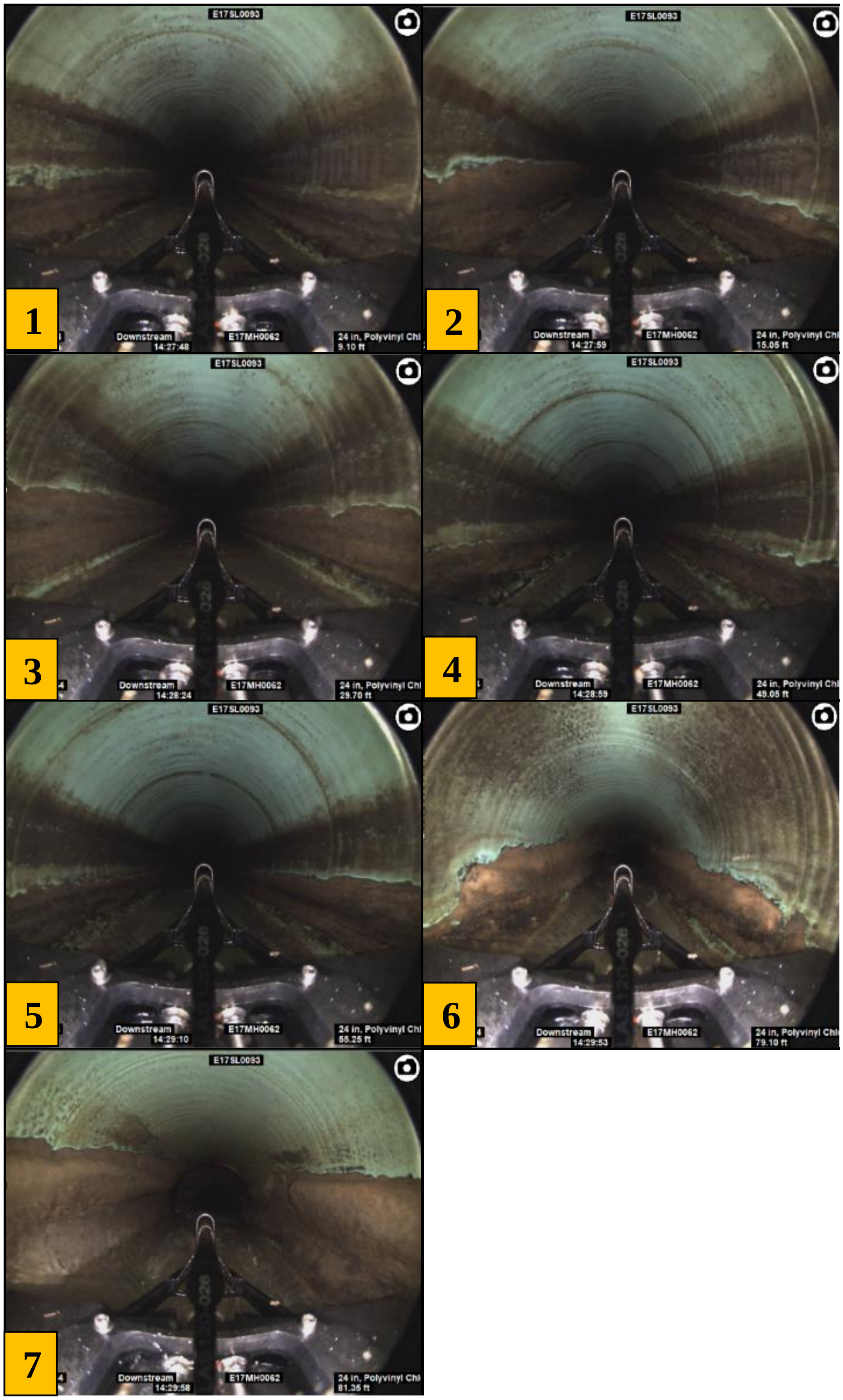


Figure A49-1 images from 1 through 7

Line 50 Summary

Table A50-1 Results Summary of Sewer Line E17SL0088

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	390
Percentage of The Line Not Inspected	100 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	14
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	0
Maximum Blockage (%)	0
Maximum Deposit Height (in)	0

Video recording is obtained, but the laser and sonar are not clear to be analyzed due to the splashed water.

Visual Observations

Table A50-2Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				10%					
3	0.3		DAG				10%				1	
4	0.95		DAE	S01			5%				2,3	
5	20.05		MWL				5%				4	
6	62.9		DAE	F01								
7	87.3		DAE				5%				5	
8	92.3		DAE				5%				6	
9	104.4		DAE	S02			5%				7	
10	109		DAE	F02								
11	121.4		DAE	S03			5%				8	
12	137.5		DAE	F03								
13	139.6		DAE				5%				10	
14	153.95		DAE	S04			10%				11,12	
15	161.95		DAE	F04								
												FOUND UNNAMED MANHOLE
16	30.8		DAE	S05			5%				13,14	
17	120.2		DAE	F05								
18	128.85		DAE	S06			5 TO 10%				15,16,17	
19	168.45		DAE	F06								
20	173		DAE				5%				18	
21	176.15		DAE	S07			5%					
22	200.6		DAE	F07								
23	202.65		DAE	S08			5 TO 10%				19,20	
24	221.3		DAE	F08								
25	383.25		MSA									

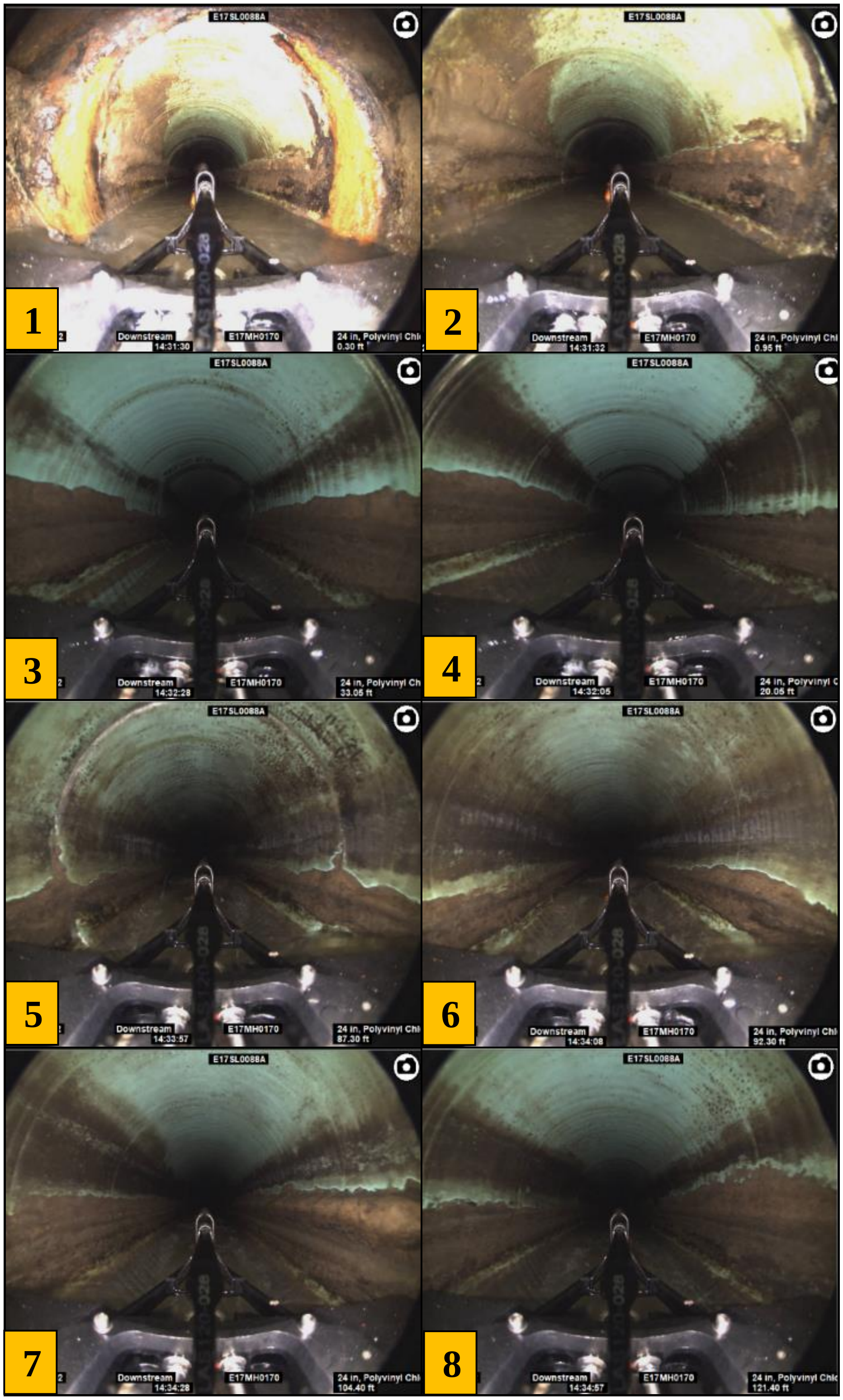


Figure A50-1 images from 1 through 8

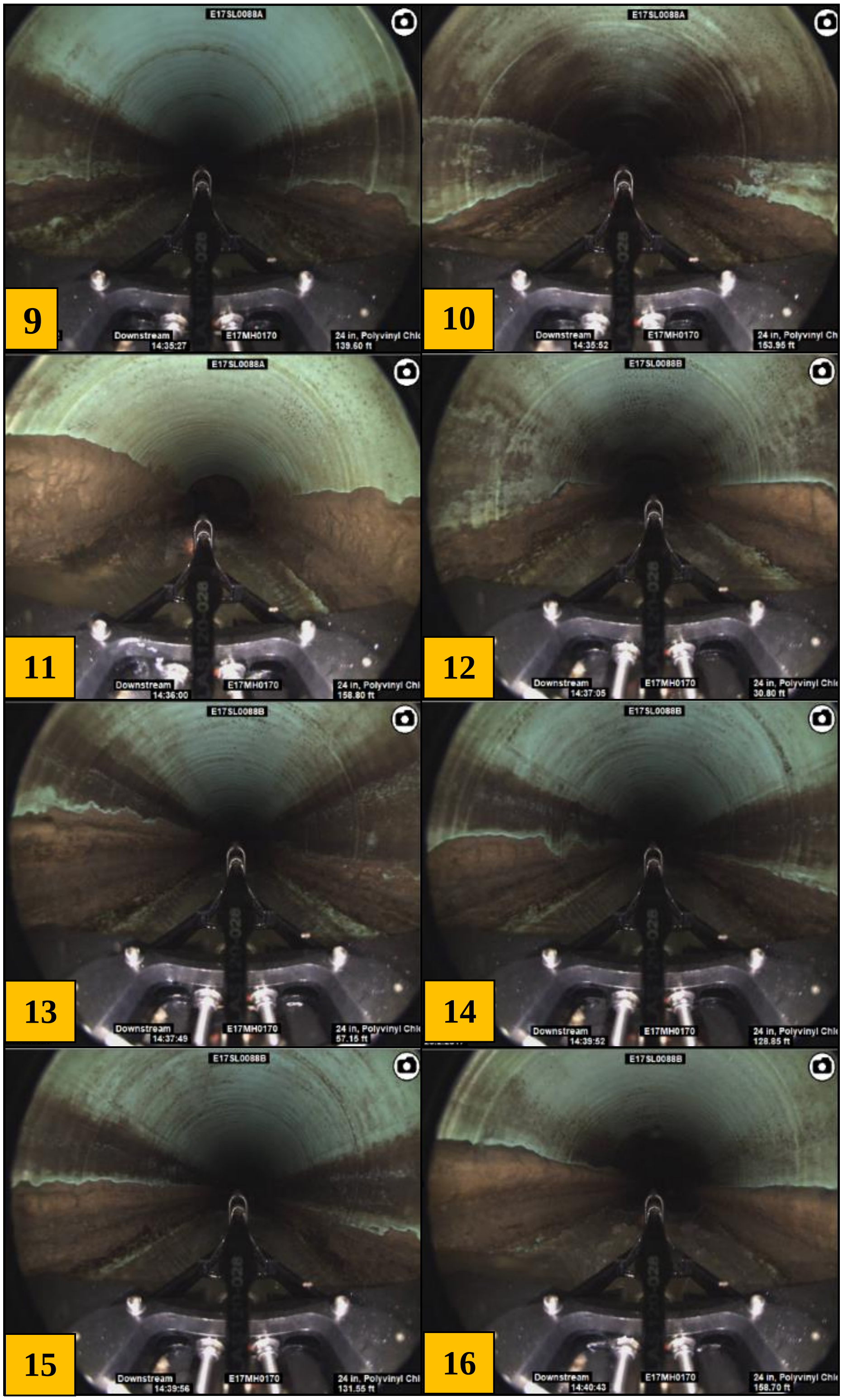


Figure A50-2 images from 9 through 16

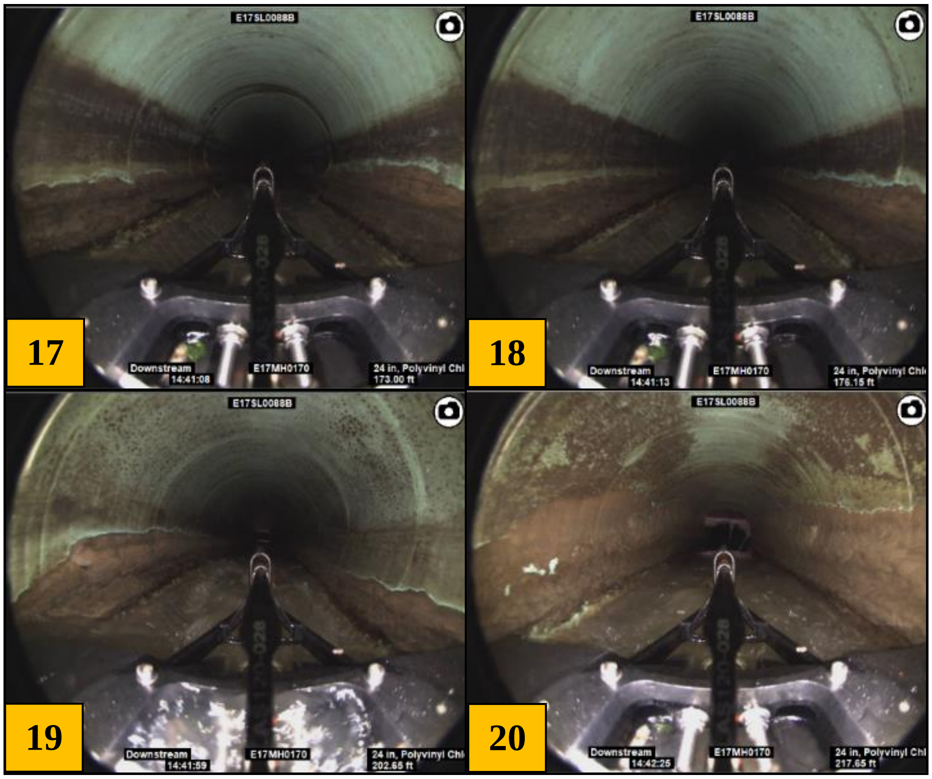


Figure A50-3 images from 17 through 20

Line 51 Summary

Table A51-1 Results Summary of Sewer Line 51

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	127
Percentage of The Line Not Inspected	0 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	9
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	0
Maximum Blockage (%)	0
Maximum Deposit Height (in)	0

Video recording is obtained, but the laser and sonar are not clear to be analyzed due to the splashed water.

Visual Observations

Table A51-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				10%					
3	0.7		DAG				5%	J			1	
4	1.85		DAE	S01			5TO 10%				2	
5	77.75		DAE	F01								
6	18.5		MWL				5%				3	
7	78.95		DAE	S02			5%				4	
8	90.45		DAE	F02								
9	79.4		MWL				10%				5	
10	91.1		MWL				5%				6	
11	91.25		DAE	S03			5 TO 10%				7	
12	121.7		DAE	F03								
13	110.55		MWL				10%				8	
14	115.45		DAG				5%	J			9	
15	121.7		MSA									

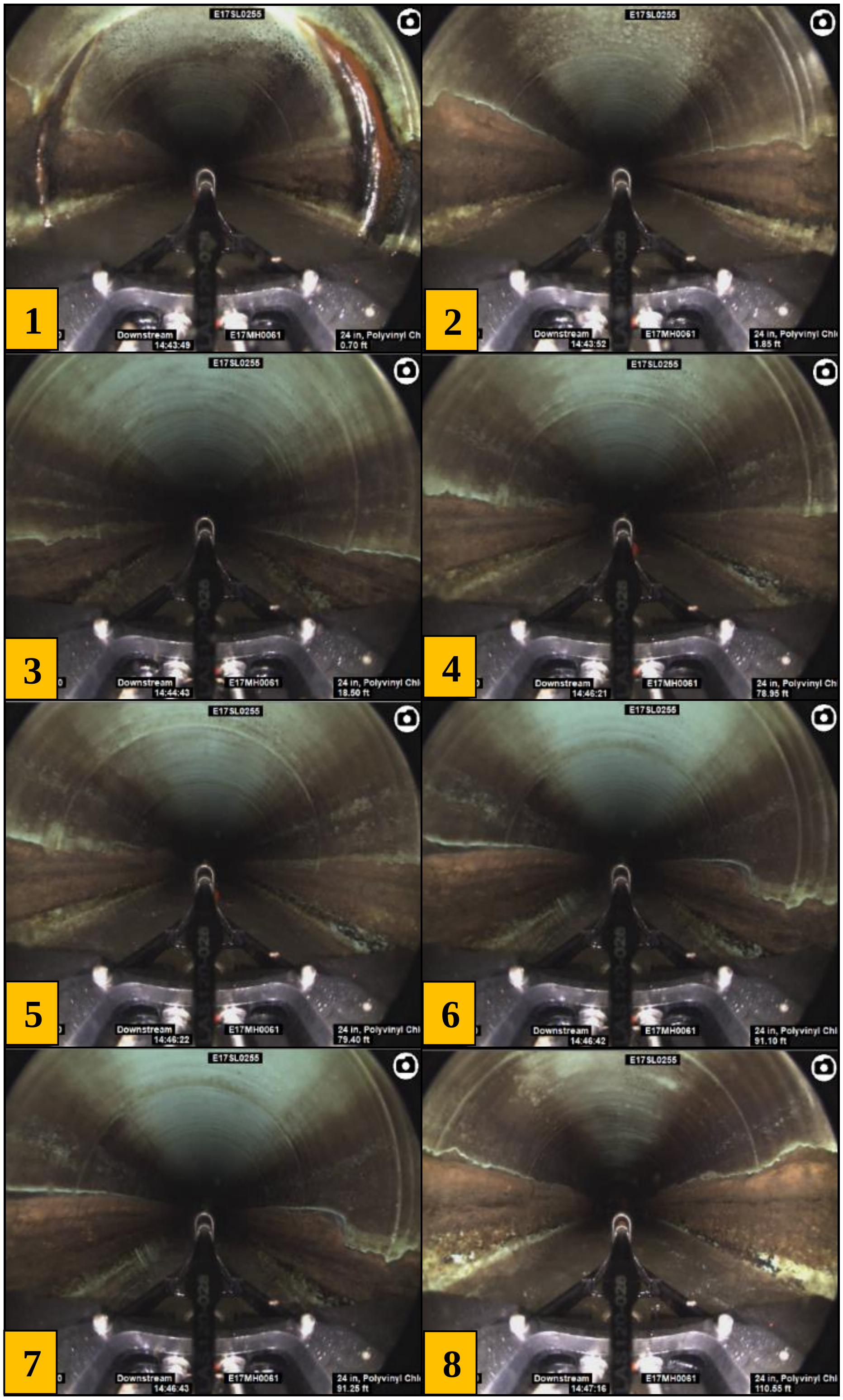


Figure A51-1 images from 1 through 8

Figure A51-2 images from 9

Line 52 Summary

Table A52-1 Results Summary of Sewer Line 52

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	860
Percentage of The Line Not Inspected	0 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	41
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	84393.2
Maximum Blockage (%)	7.5
Maximum Deposit Height (in)	2.3

Deposit Data

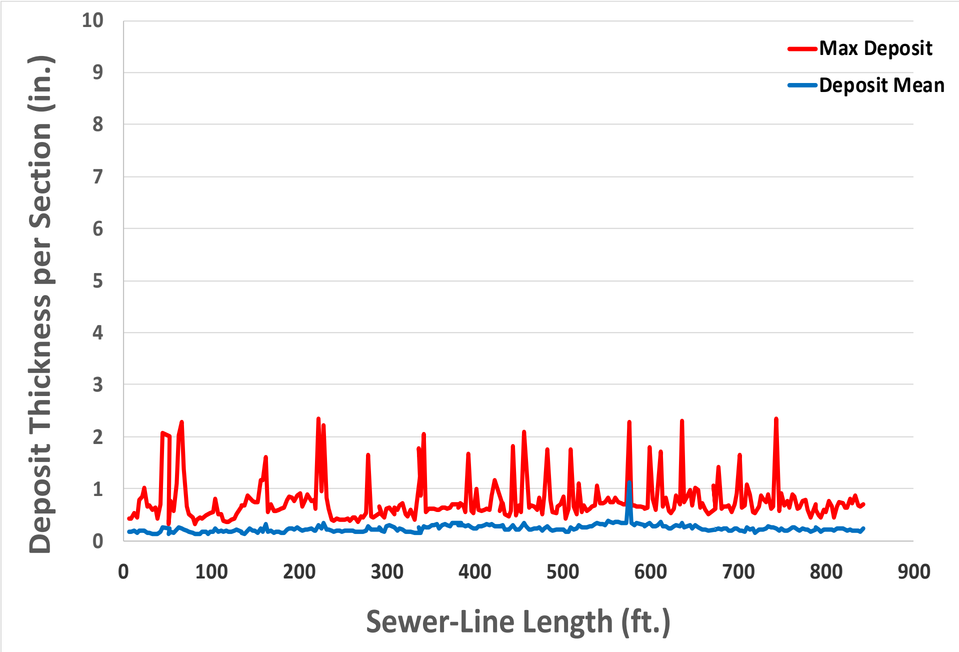


Figure A52-1 Deposit thickness per cross-section

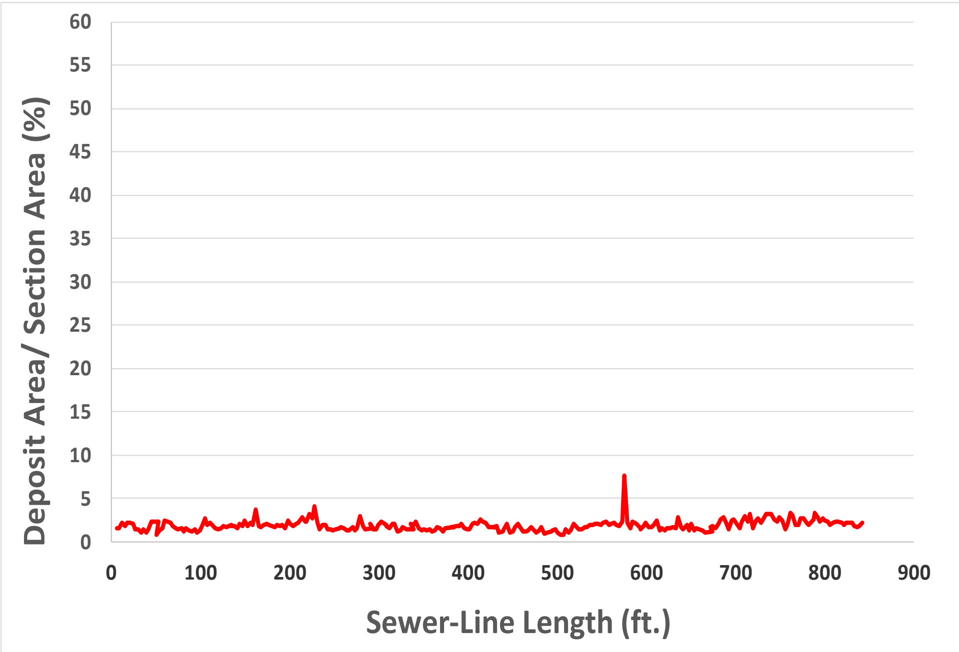


Figure A52-2 Deposit area percentage of the pipe cross section area

Blockage Data

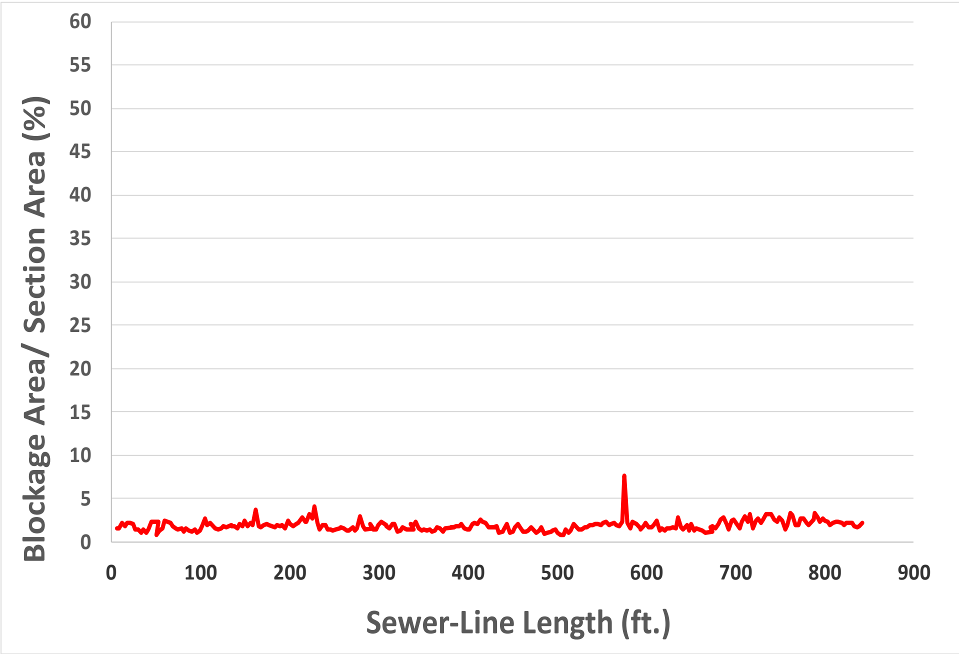


Figure A52-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A52-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	6		MWL					5%				
3	6		DAE	S01				10%			1 TO 31	PIPE IS COVERED WITH DEPOSISTS ON BOTH SIDES THROUGH OUT THE LENGTH OF THE PIPE. (<5%)
4	13.05		DAG					10%	J		2	
5	499.1		DAG					5%	J		19	
6	47.6		MWL					10%			32	
7	53.8		MWL					5%			33	
8	62.95		MWL					10%			34	
9	78		MWL					5%			35	
10	105.85		MWL					10%			36	
11	115.9		MWL					5%			37	
12	163.45		MWL					10%			38	
13	181.15		MWL					5%			39	
14	224.9		MWL					10%			40	
15	234.4		MWL					5%			41	
16	279.25		MWL					10%			42	
17	296.05		MWL					5%			43	
18	330.25		MWL					10%			44	
19	339.35		MWL					5%			45	
20	444.85		MWL					10%			46	
21	449.6		MWL					5%			47	
22	457.15		MWL					10%			48	
23	465.45		MWL					5%			49	
24	472.5		MWL					10%			50	
25	487.8		MWL					5%			51	
26	505.25		MWL					10%			52	
27	514.3		MWL					5%			53	
28	520.45		MWL					10%			54	
29	526.4		MWL					5%			55	
30	593.2		MWL					10%			56	

31	**603.45**		**MWL**					**5%**			**57**	
32	**609**		**MWL**					**10%**			**58**	
33	**628.8**		**MWL**					**5%**			**59**	
34	**633.8**		**MWL**					**10%**			**60**	
35	**642.55**		**MWL**					**5%**			**61**	
36	**658.9**		**MWL**					**10%**			**62**	
37	**681**		**MWL**					**5%**			**63**	
38	**744.3**		**MWL**					**10%**			**64**	
39	**756.9**		**MWL**					**5%**			**65**	
40	**774.45**		**MWL**					**10%**			**66**	
41	**782.85**		**MWL**					**5%**			**67**	
42	**787.9**		**MWL**					**10%**			**68**	
43	**795.9**		**MWL**					**5%**			**69**	
44	**844.3**		**DAE**	**F01**								
45	**844.3**		**MSA**									

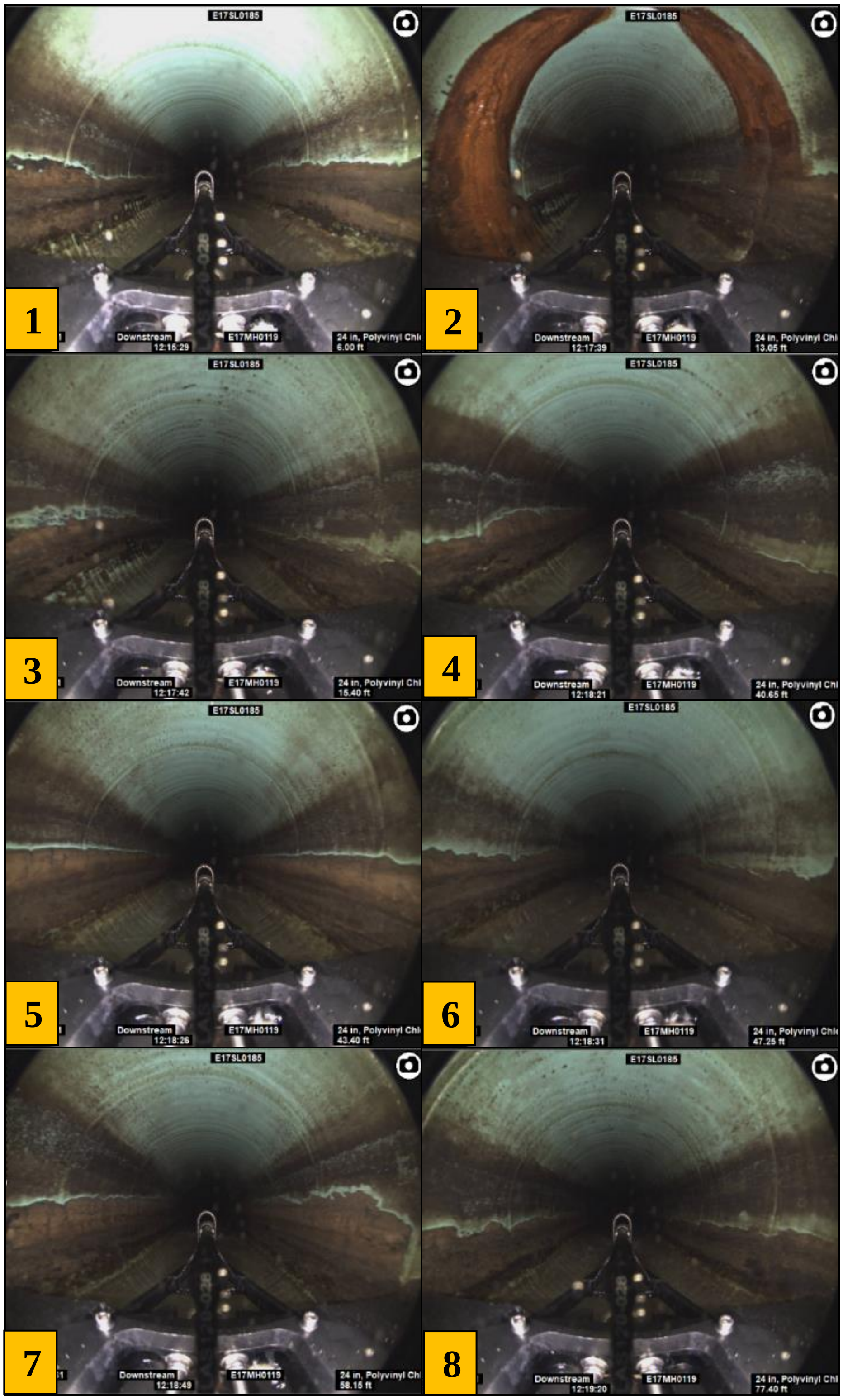


Figure A52-4 images from 1 through 8

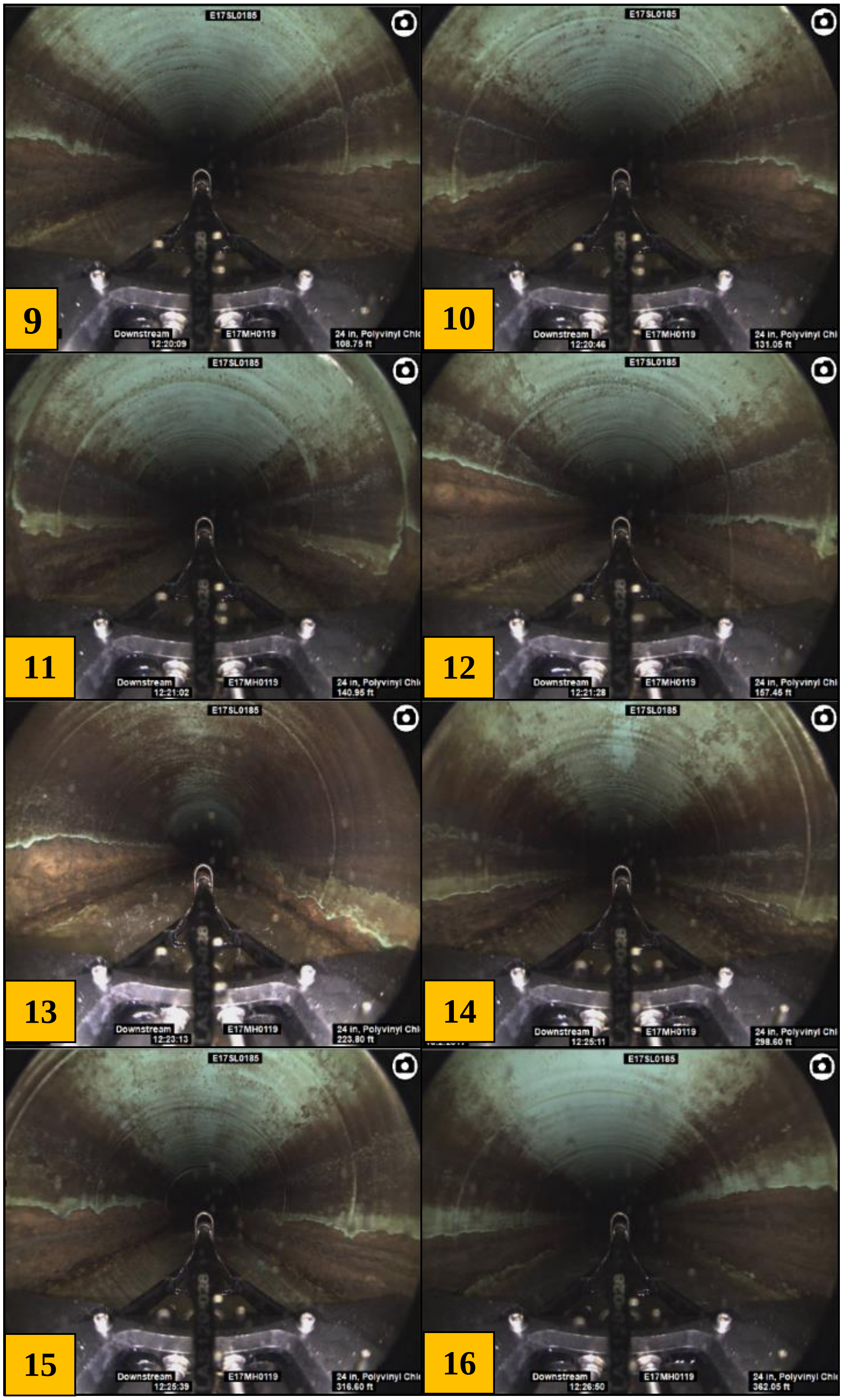


Figure A52-5 images from 9 through 16

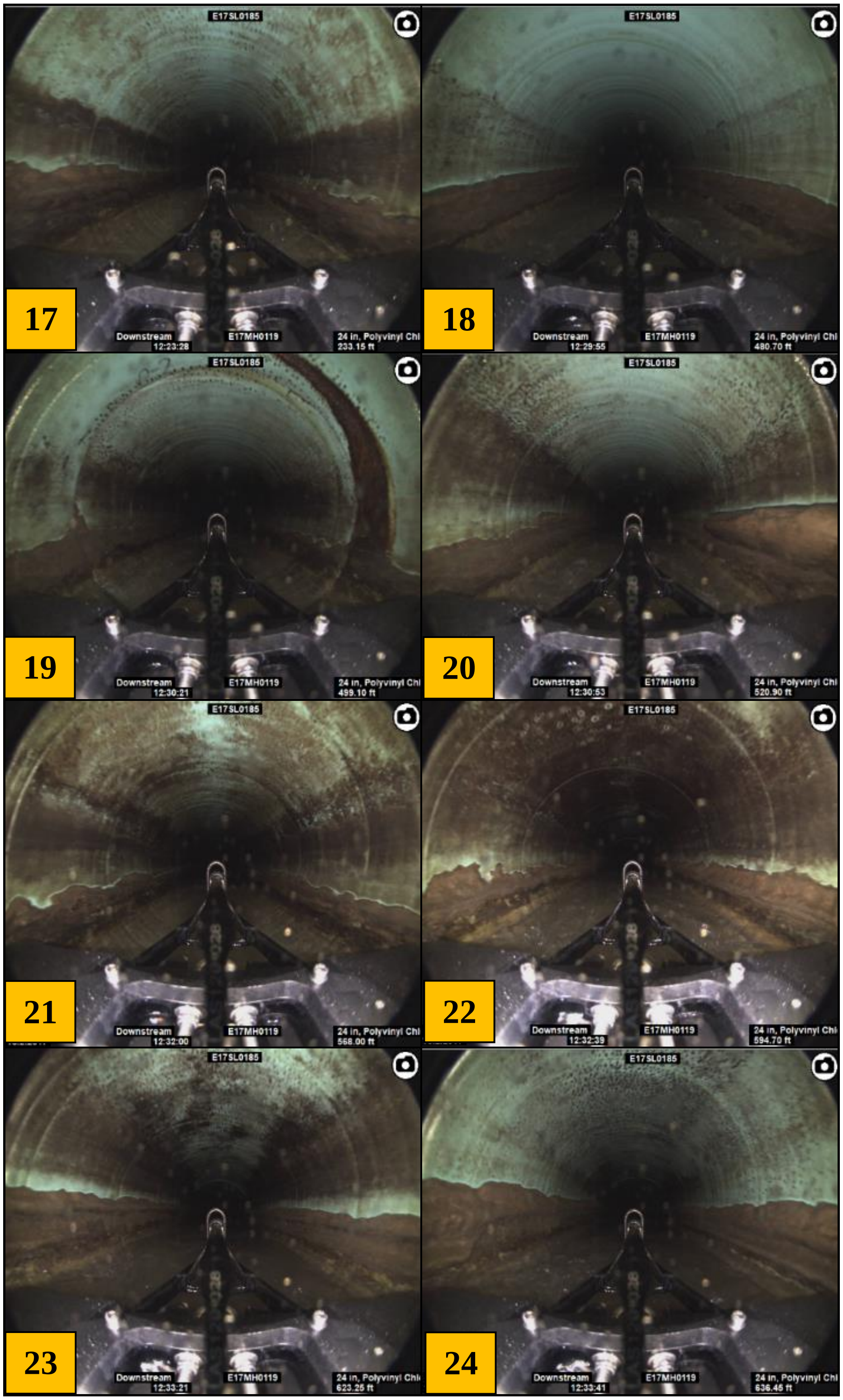


Figure A52-6 images from 17 through 24

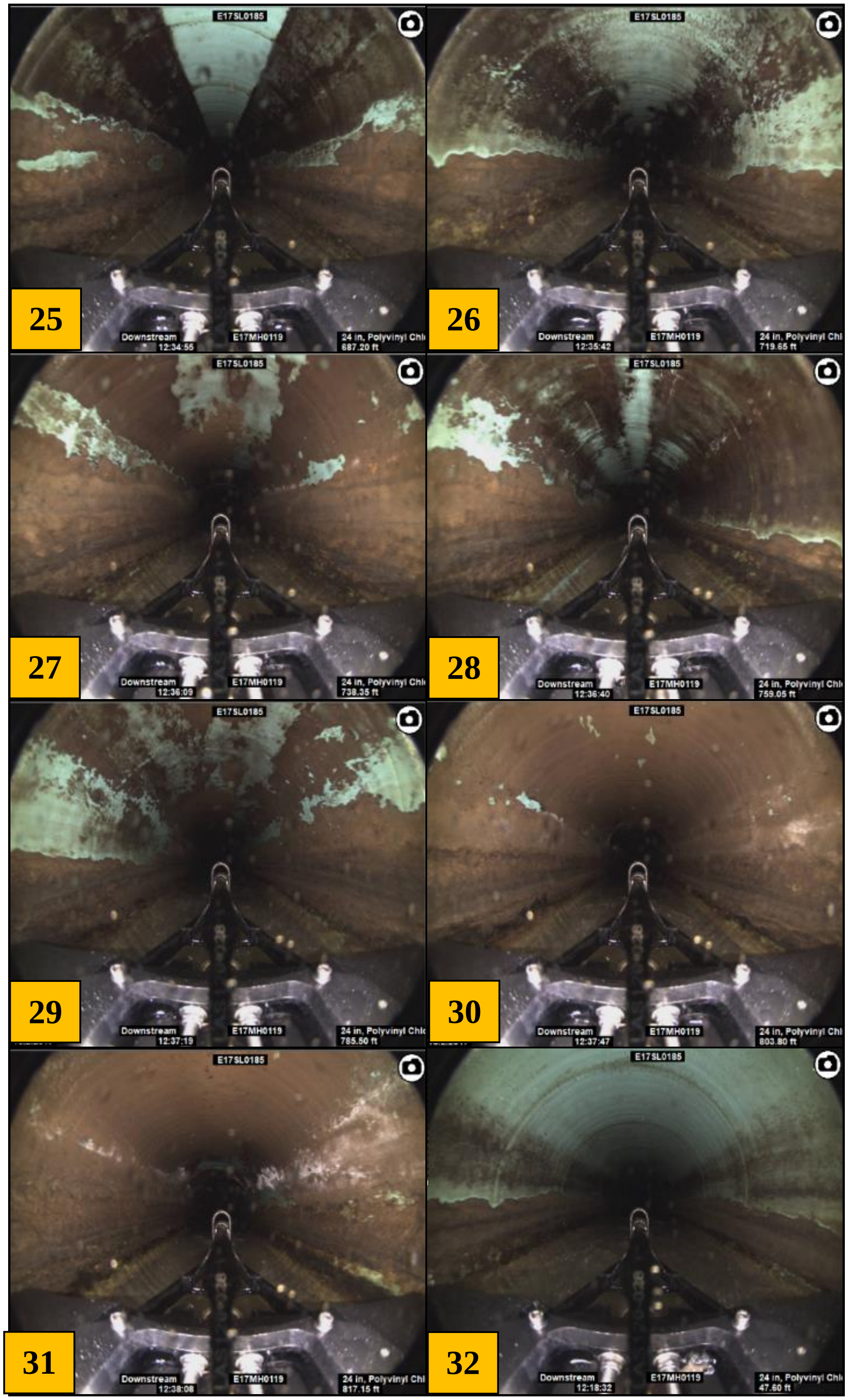


Figure A52-7 images from 25 through 32

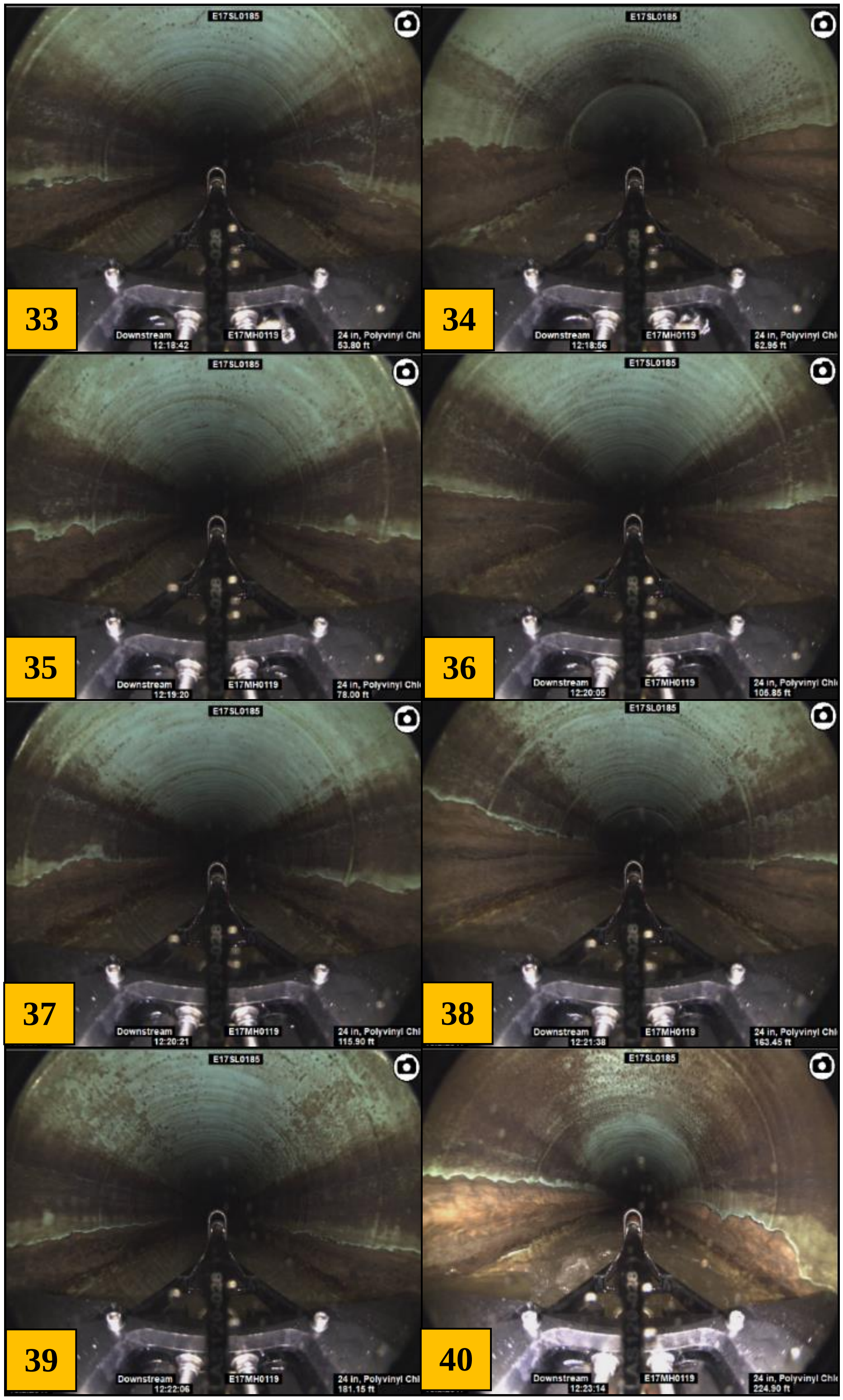


Figure A52-8 images from 33 through40

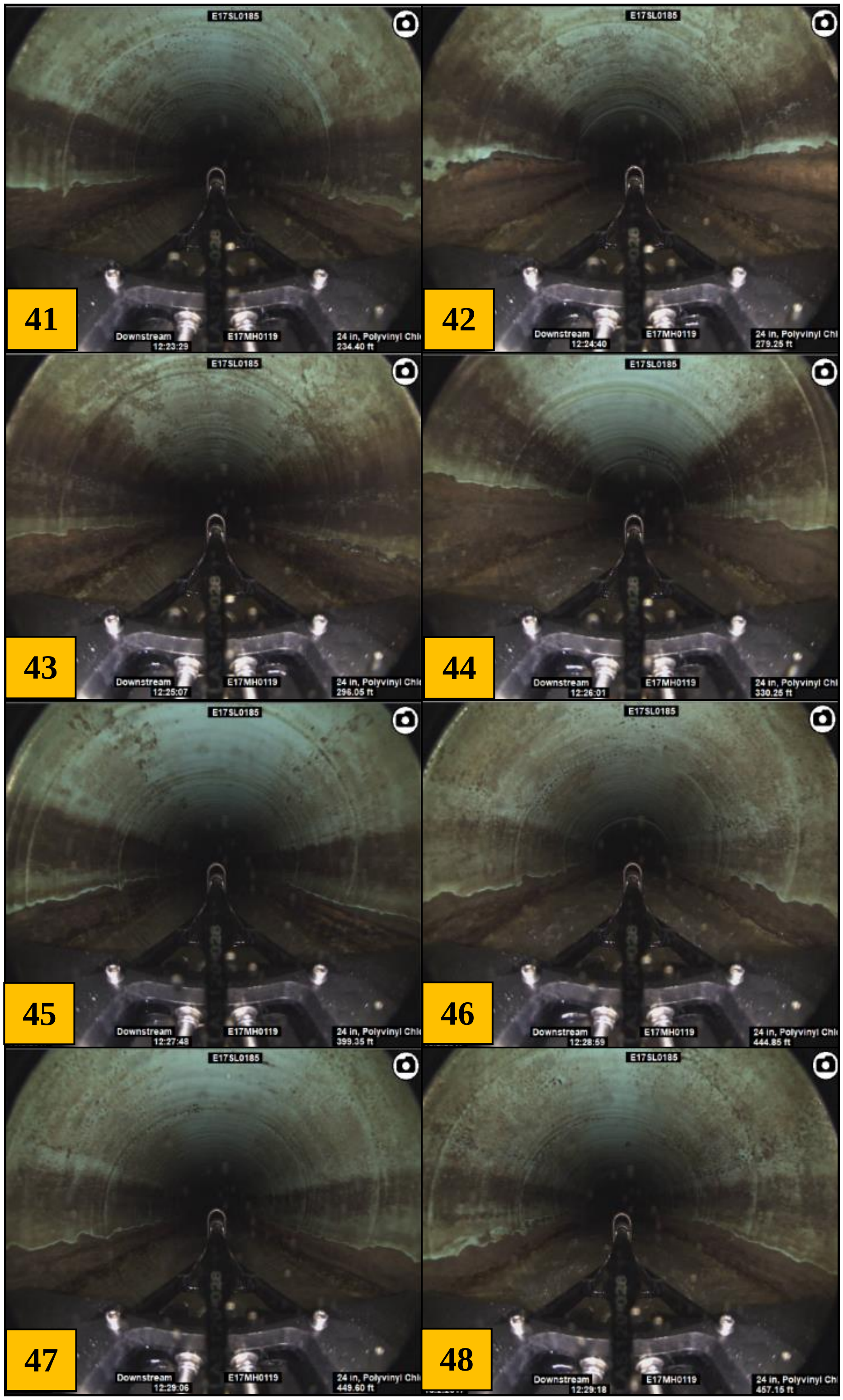


Figure A52-9 images from 40 through 48

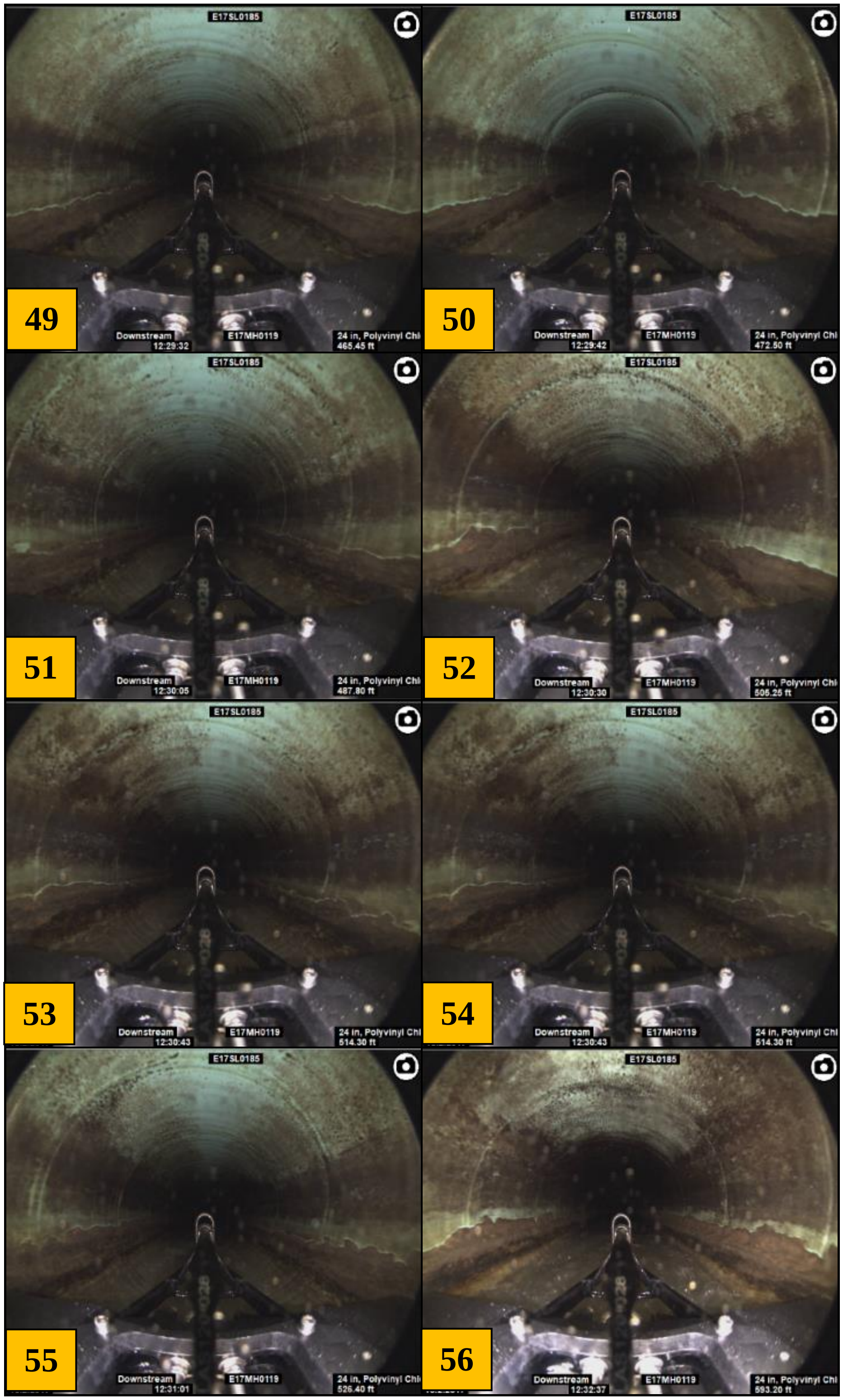


Figure A52-10 images from 49 through 56

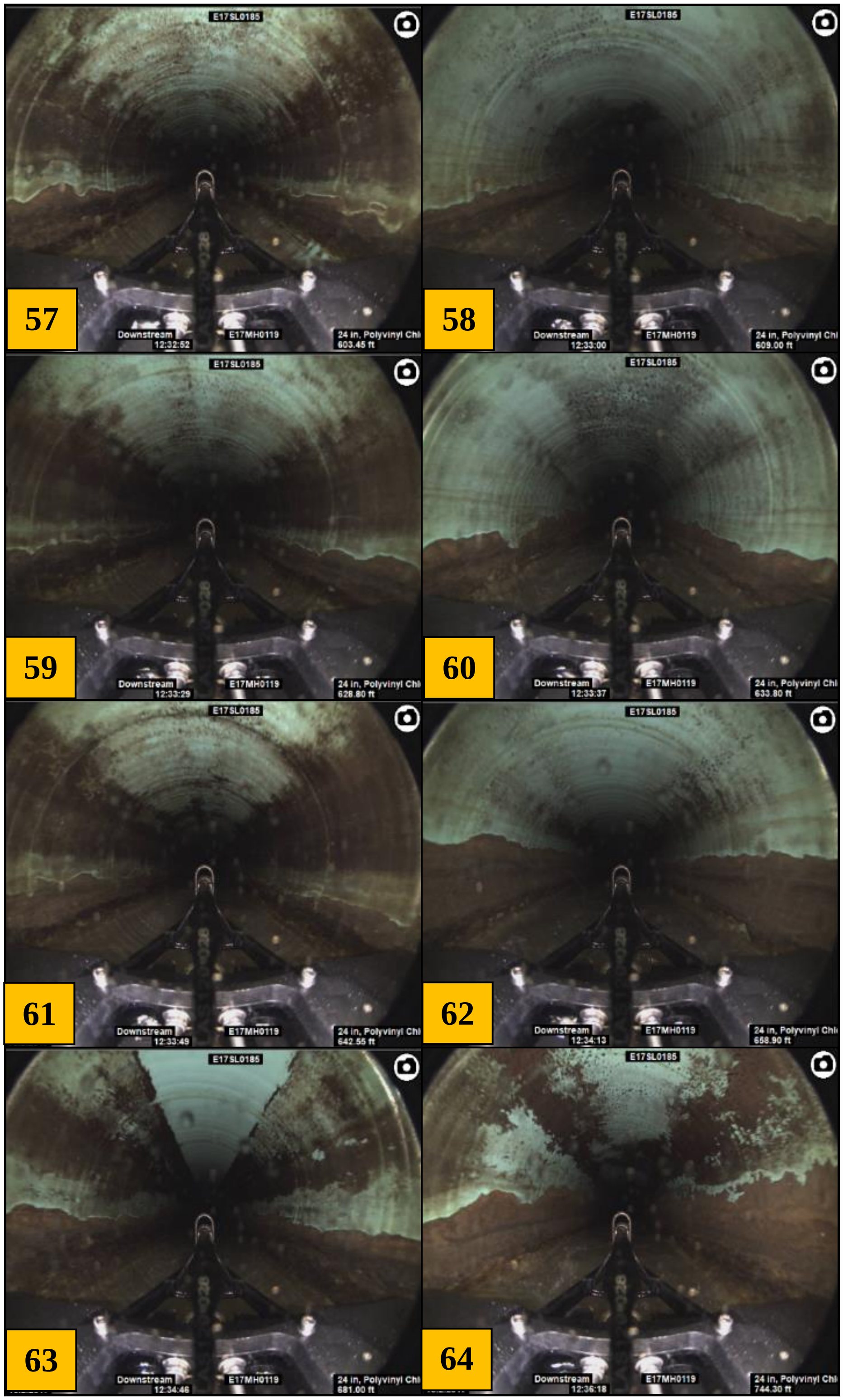


Figure A52-11 images from 57 through 64

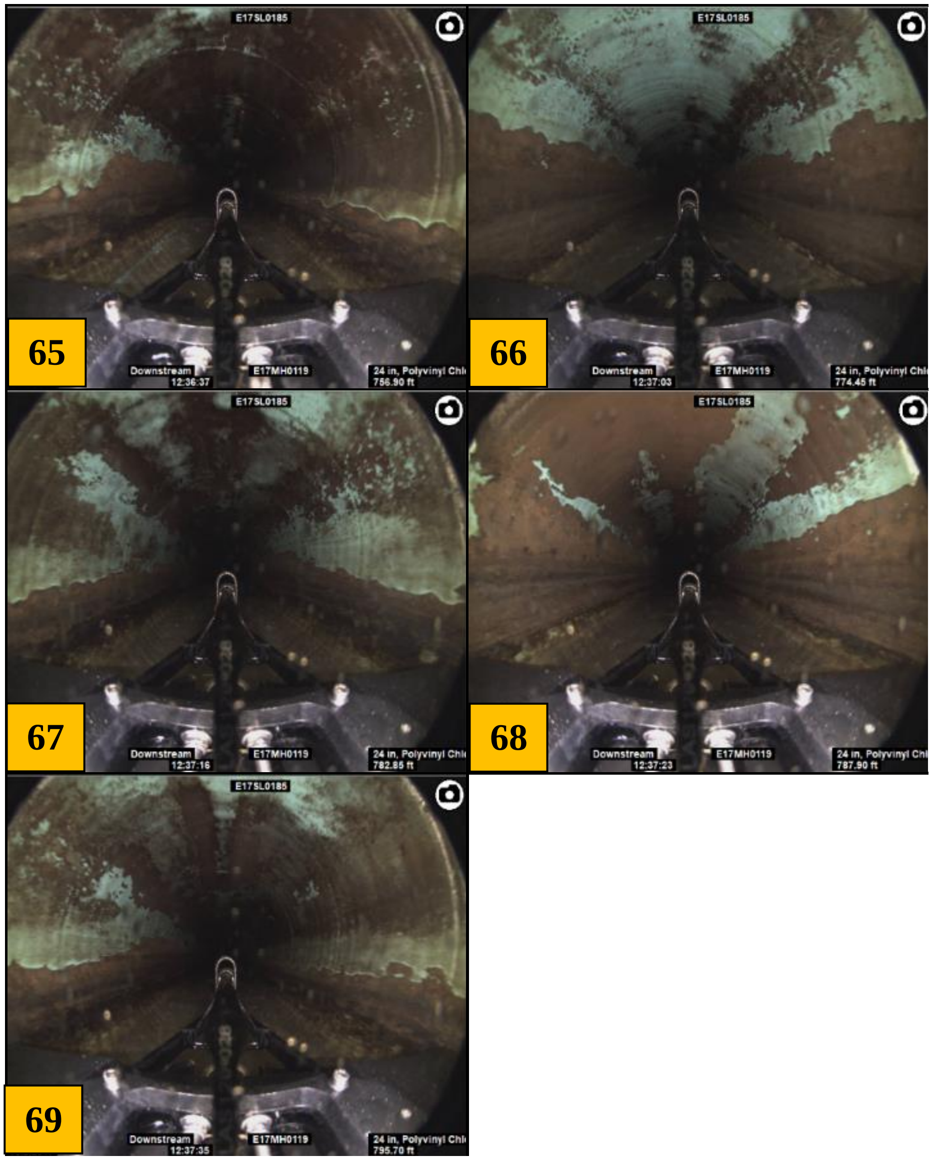


Figure A52-12images from 65 through 69

Line 53 Summary

Table A53-1 Results Summary of Sewer Line 53

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	588
Percentage of The Line Not Inspected	0 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	49
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	82284.9
Maximum Blockage (%)	5.5
Maximum Deposit Height (in)	2.4

Deposit Data

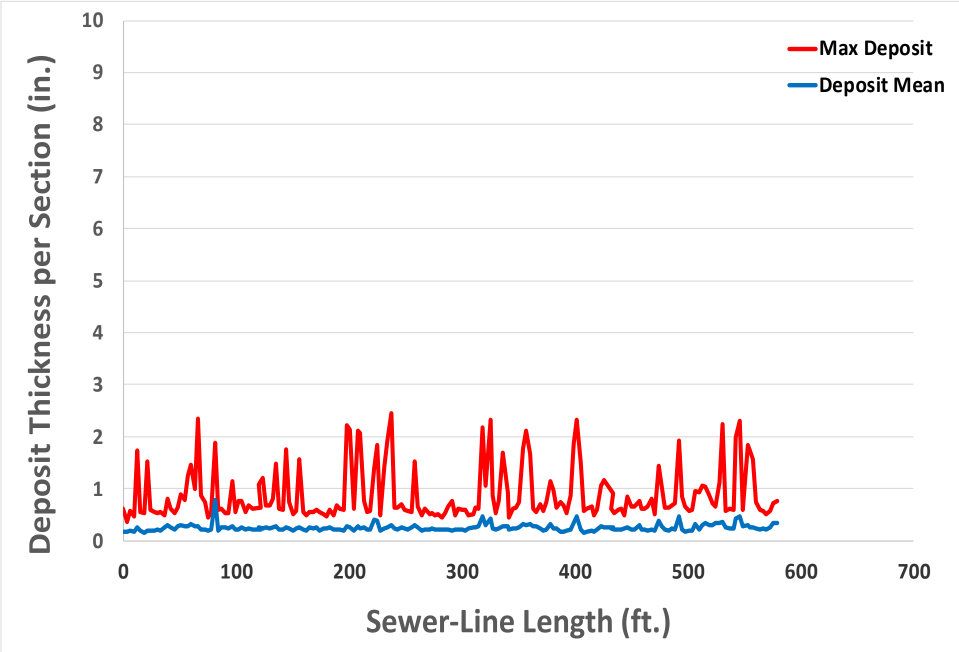


Figure A53-1 Deposit thickness per cross-section

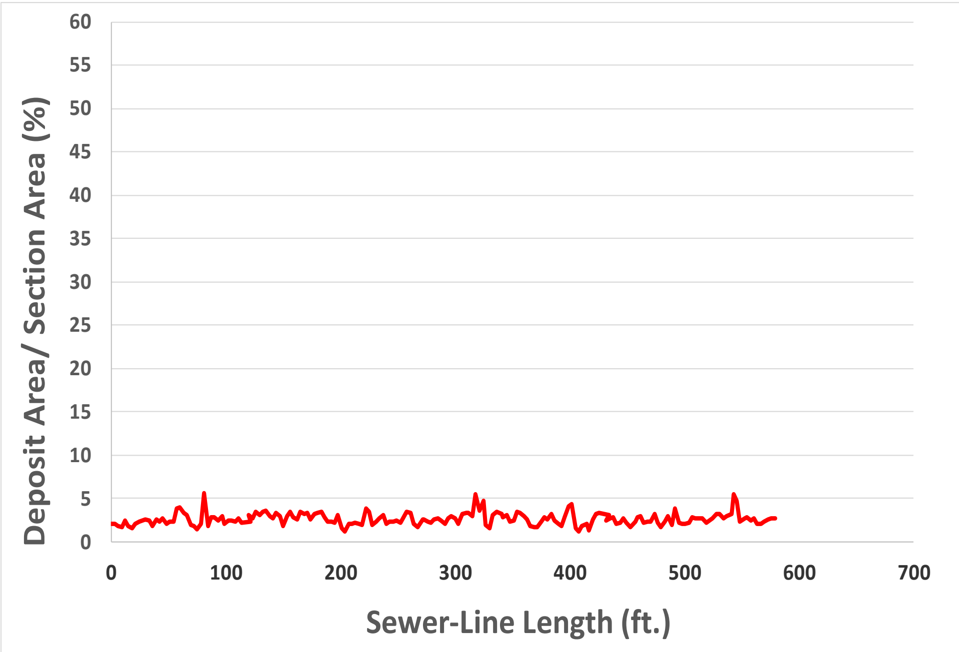


Figure A53-2 Deposit area percentage of the pipe cross section area

Blockage Data

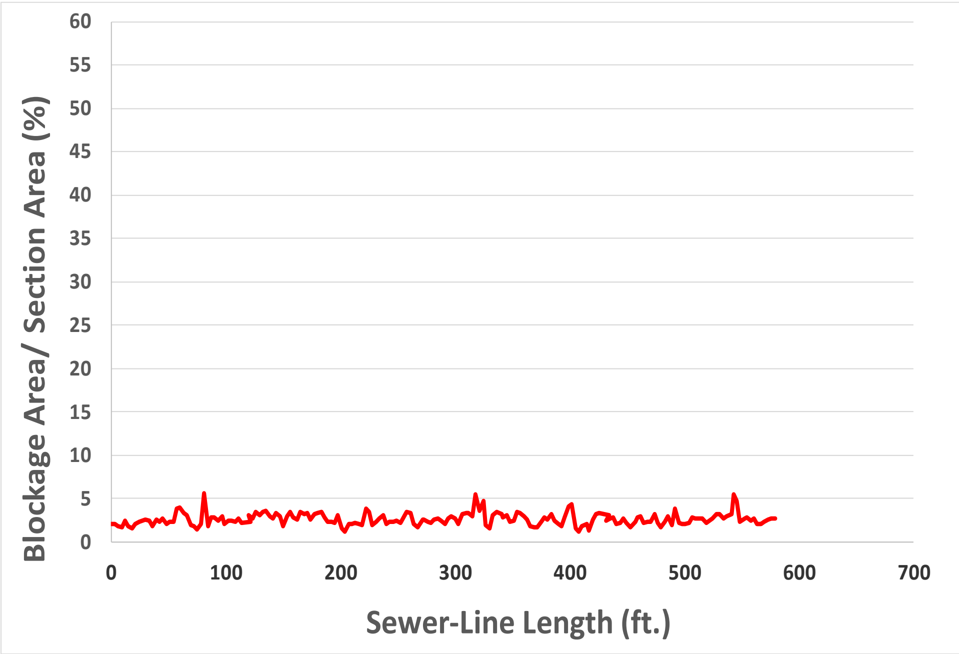


Figure A53-3 Blockage area (deposits and debris areas) percentage of pipe cross section area

Visual Observations

Table A53-1 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension 1st	Dimension 2nd	%		At/ From	To		
1	0		AMH									
2	0		MWL				10%					
3	0		DAE	S01			15%				1,2	
4	4.55		DAE	F01								
5	5.15		DAE	S02			5%				3	
6	10.4		MWL				5%				4	
7	55.2		DAE	F02								
8	55.2		DAE	S03			10%				5,6	
9	65		MWL				10%				7	
10	86.65		DAE	F03								
11	86.65		DAE	S04			5%				8,9,10	
12	86.8		MWL				5%				11	
13	117.9		DAE	F04								
14	117.9		DAE	S05			10%				12	
15	124.9		DAE	F05								
16	124.9		DAE	S06			5%				13	
17	146.5		MWL				10%				14	
18	150.2		DAG				<5%	J			15	
19	163.7		MWL				5%				16	
20	196.8		DAE	F06								
21	196.8		DAE	S07			10%				17	
22	198.6		MWL				10%				18	
23	203.85		DAE	F07								
24	203.85		DAE	S08			5%				19	
25	215.15		MWL				5%				20	
26	219.55		DAE	F08								
27	219.75		DAE	S09			10%				21,22	
28	228.3		MWL				10%				23	
29	239.5		DAE	F09								
30	239.85		DAE	S10			5%				24,25	

31	241.15		MWL				5%				26	
32	265.35		DAE	F10								
33	265.35		DAE	S11			5%				27,28	
34	315.75		DAE	F11								
35	315.75		DAE	S12			10%				29	
36	319.65		MWL				10%				30	
37	325.15		DAE	F12								
38	325.15		DAE	S13			5%				31	
39	343.5		MWL				5%				32	
40	350.55		DAE	F13								
41	350.55		DAE	S14			10%				33	
42	356.65		MWL				10%				34	
43	365.5		DAE	F14								
44	365.5		DAE	S15			5%				35,36	
45	367.7		MWL				5%				37	
46	377.35		MWL				10%				38	
47	393.3		MWL				5%				39	
48	396.45		DAE	F15								
49	396.45		DAE	S16			10%				40	
50	404.5		MWL				10%				41	
51	407.7		DAE	F16								
52	407.7		DAE	S17			5%				42,43	
53	432.15		MWL				5%				44	
54	472.55		DAE	F17								
55	472.55		DAE	S18			10%				45	
56	474.95		MWL				10%				46	
57	477.05		DAE	F18								
58	477.05		DAE	S19			5%				47	
59	484.7		MWL				5%				48	
60	490.75		DAE	F19								
61	490.75		DAE	S20			10%				49	
62	494.85		DAE	F20								
63	494.85		DAE	S21			5%				50	
64	504.6		DAE	F21								
65	504.6		DAE	S22			10%				51	
66	510.85		MWL				10%				52	
67	514.45		DAE	F22								
68	514.45		DAE	S23			5%				53	
69	522.5		MWL				5%				54	
70	540.9		DAE	F23								
71	540.9		DAE	S24			10%				55	
72	551.15		DAE	F24								
73	551.15		DAE	S25			5%				56,57	
74	552.6		MWL				10%				58	
75	572.45		MWL				5%				59	
76	583.1		DAE	F25								
77	583.1		MSA									

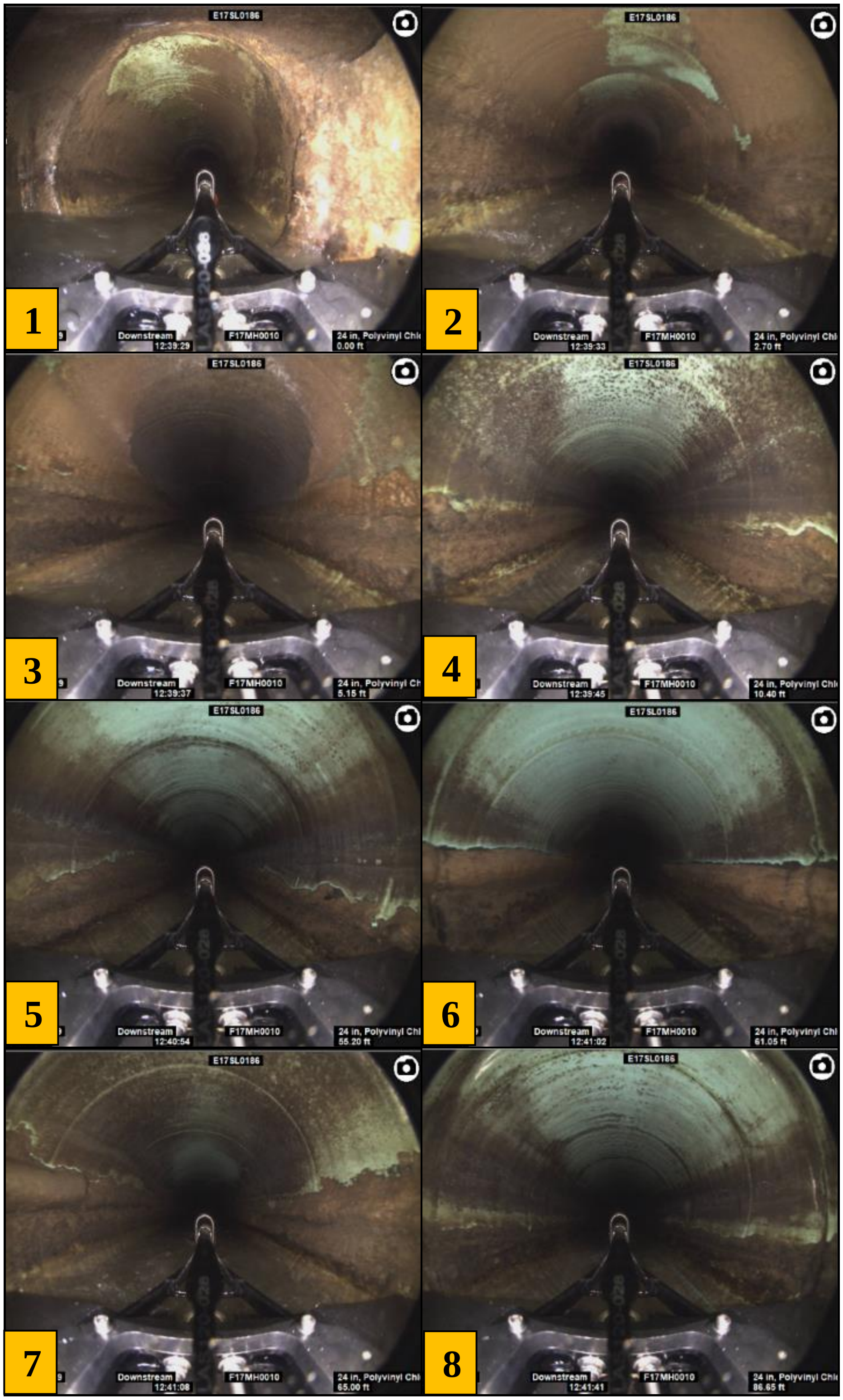


Figure A53-4 images from 1 through 8

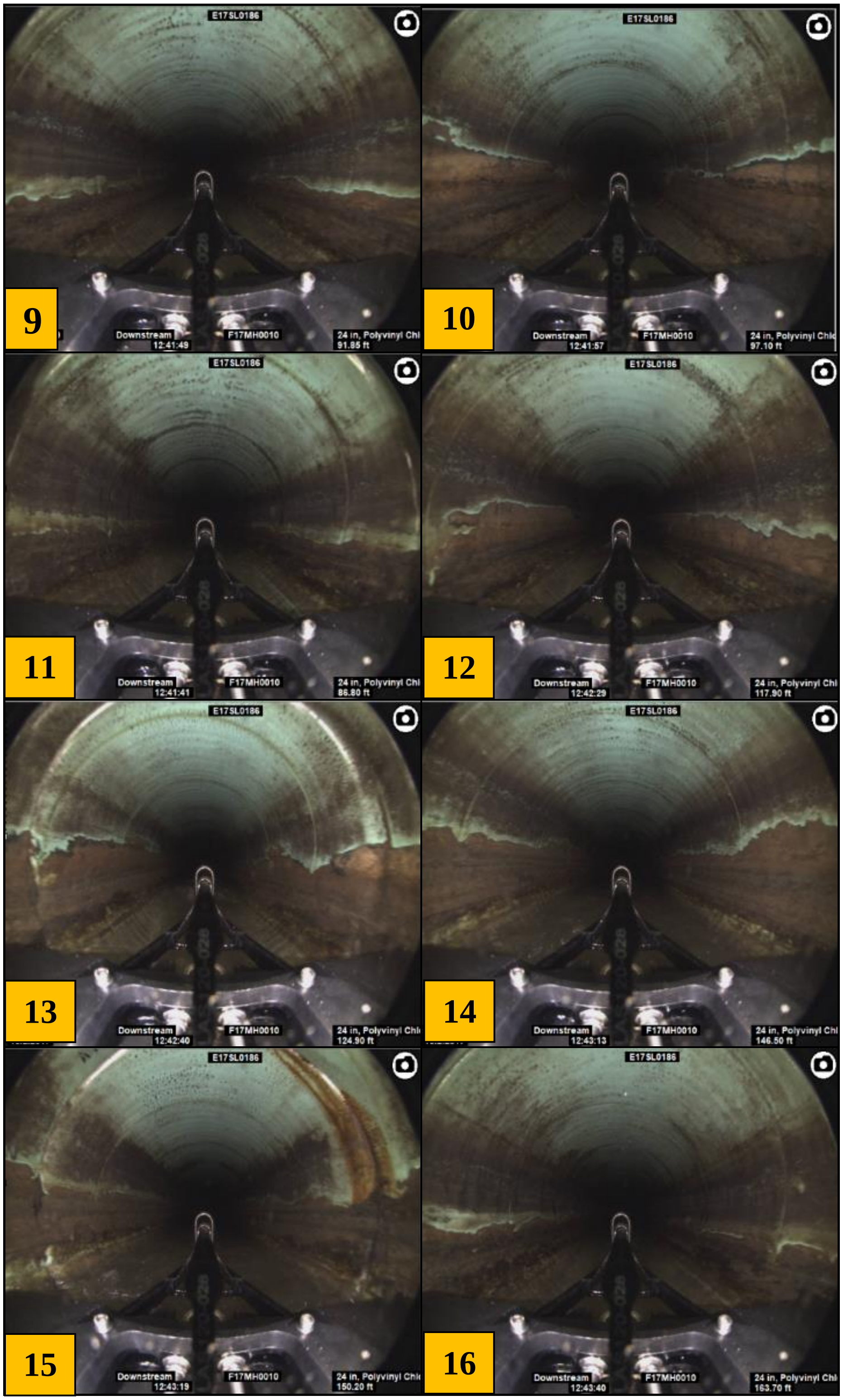


Figure A53-5 images from 9 through 16

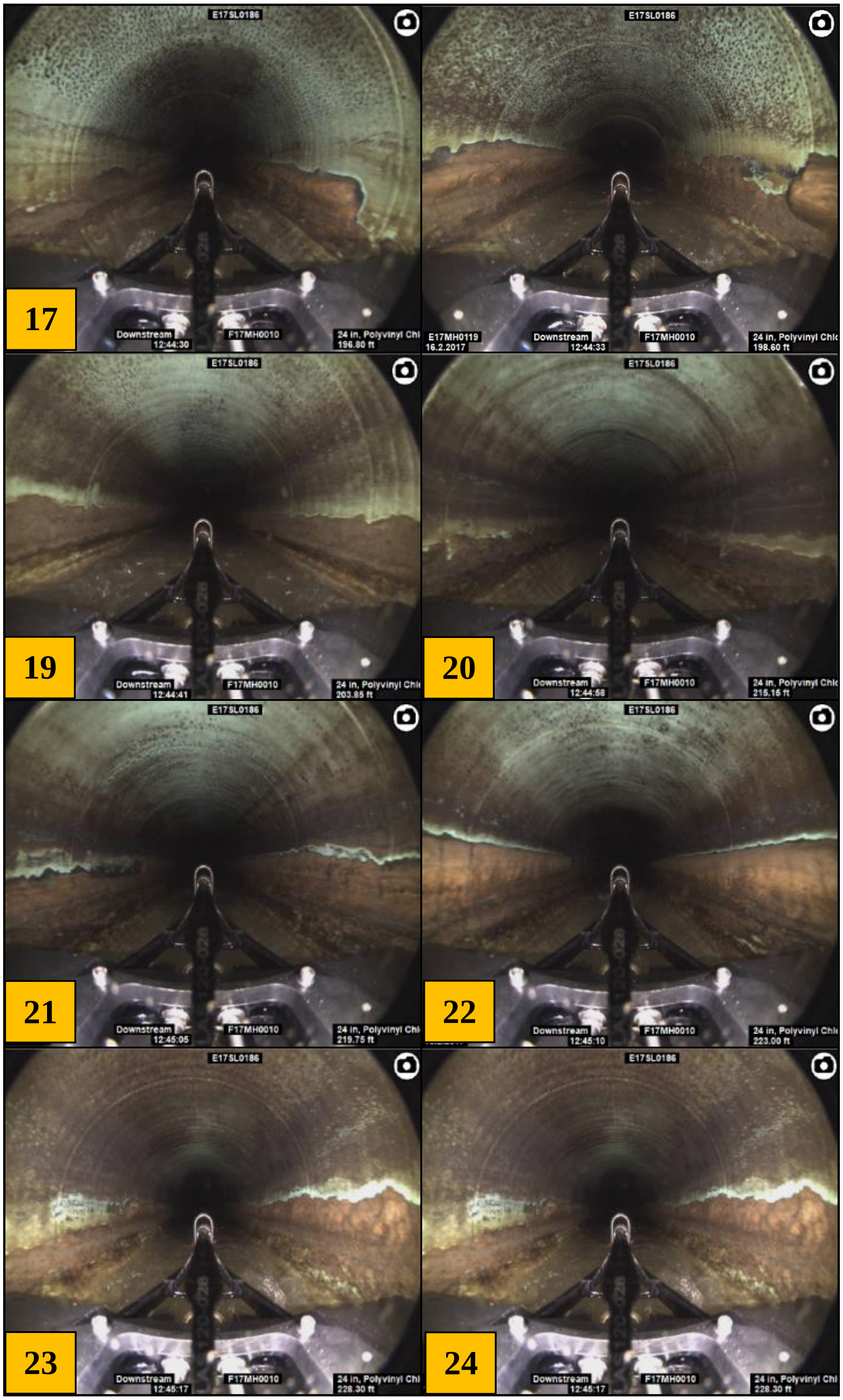


Figure A53-6 images from 17 through 24

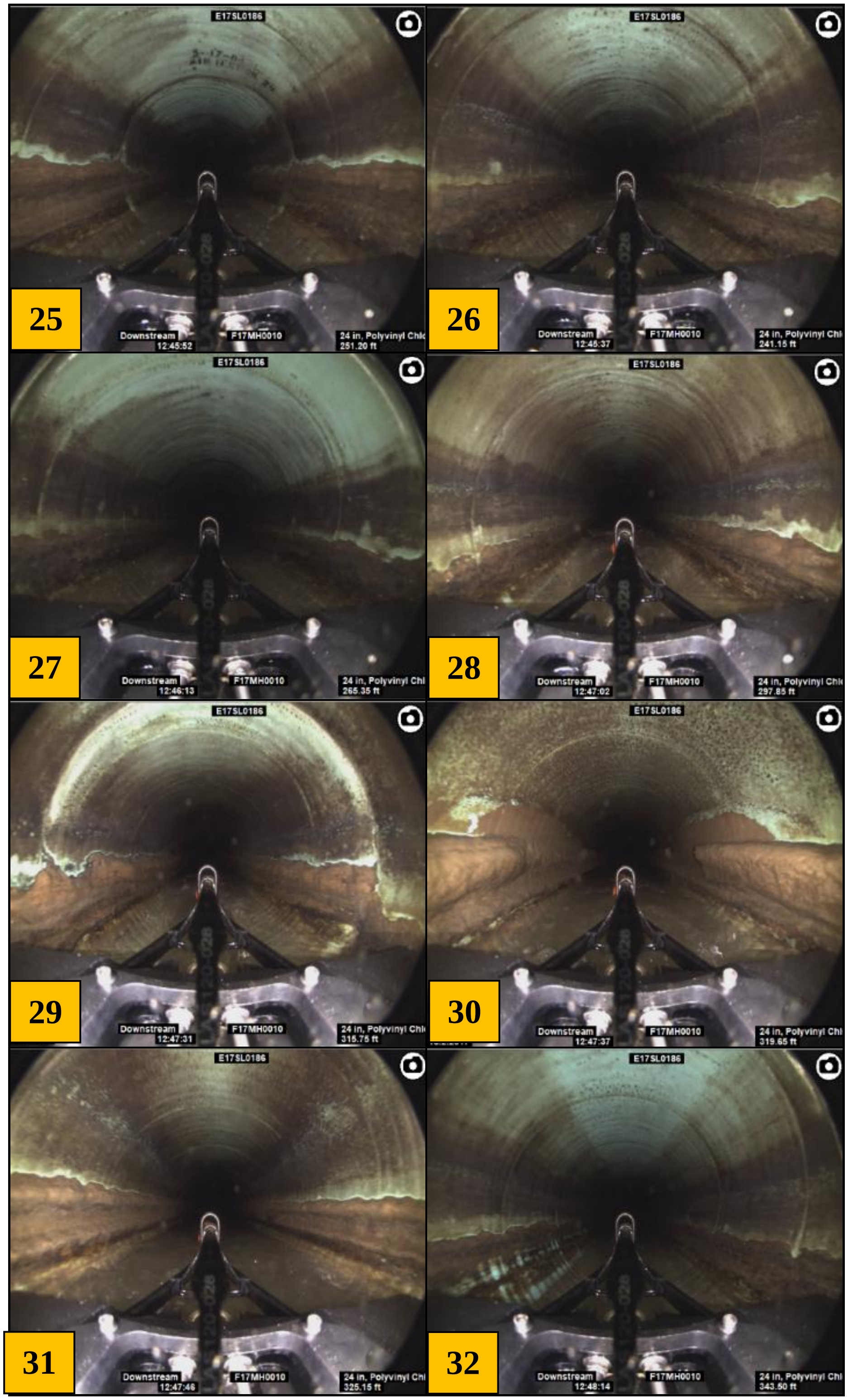


Figure A53-7 images from 25 through 32

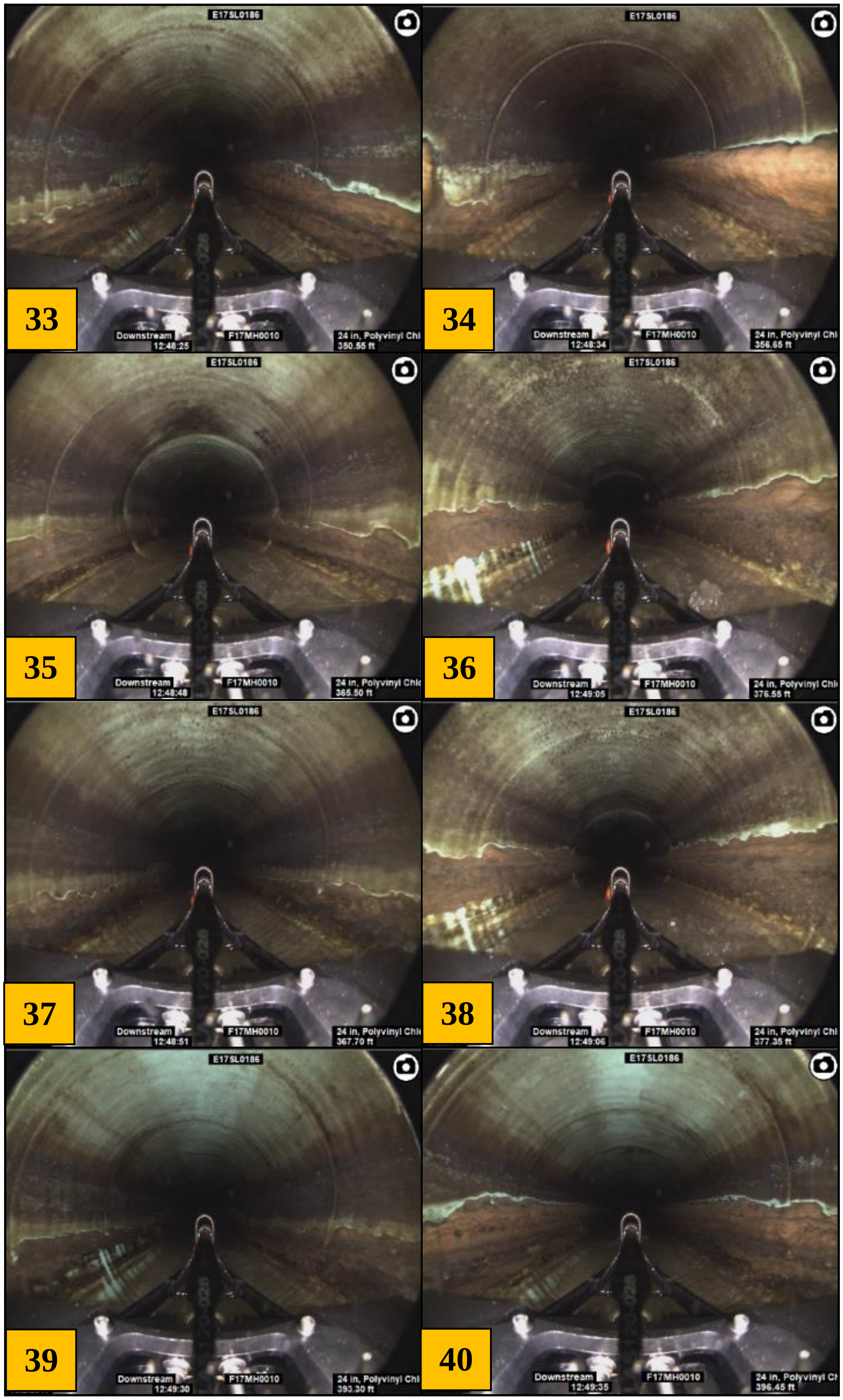


Figure A53-8 images from 33 through40

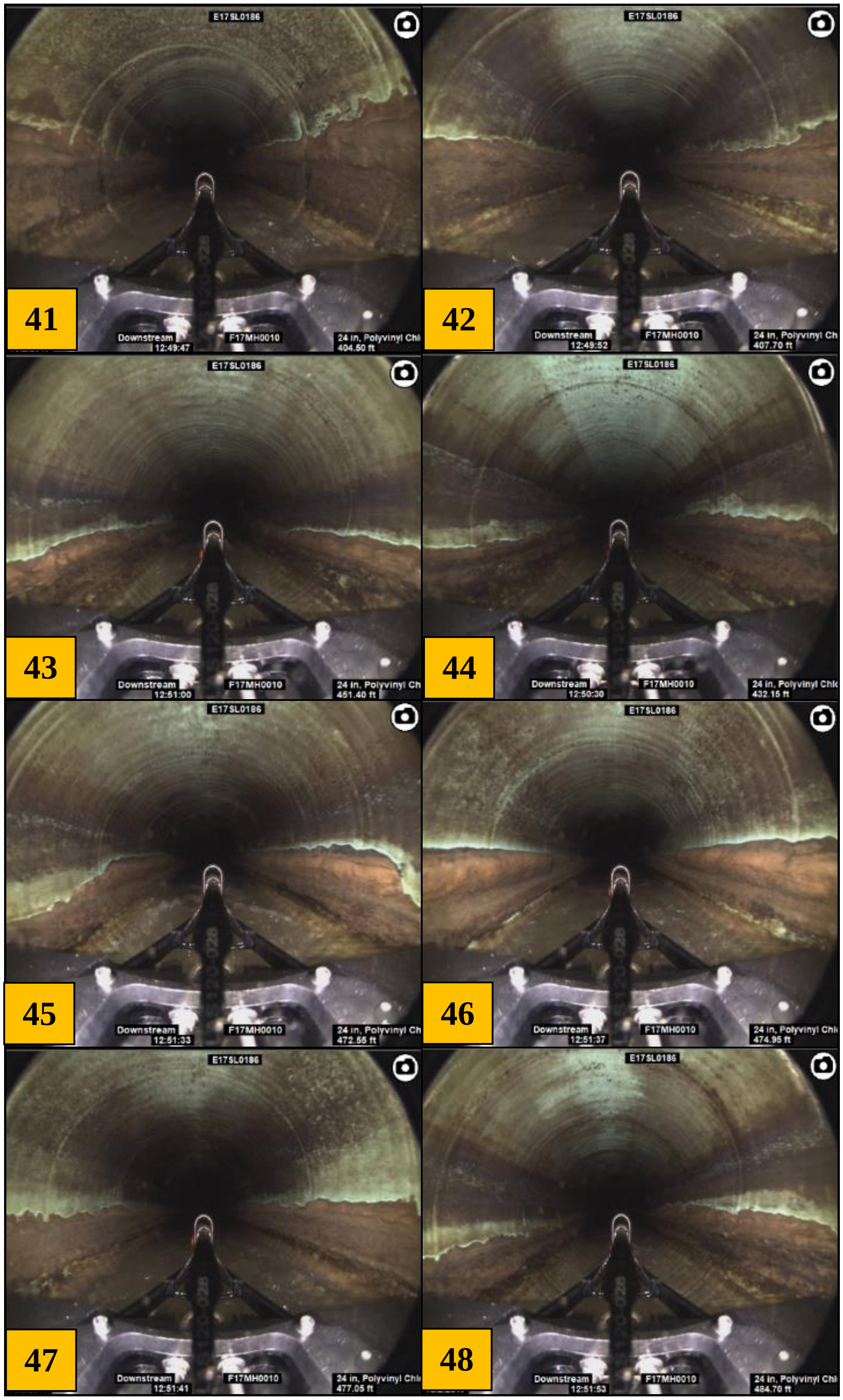


Figure A53-9 images from 40 through 48

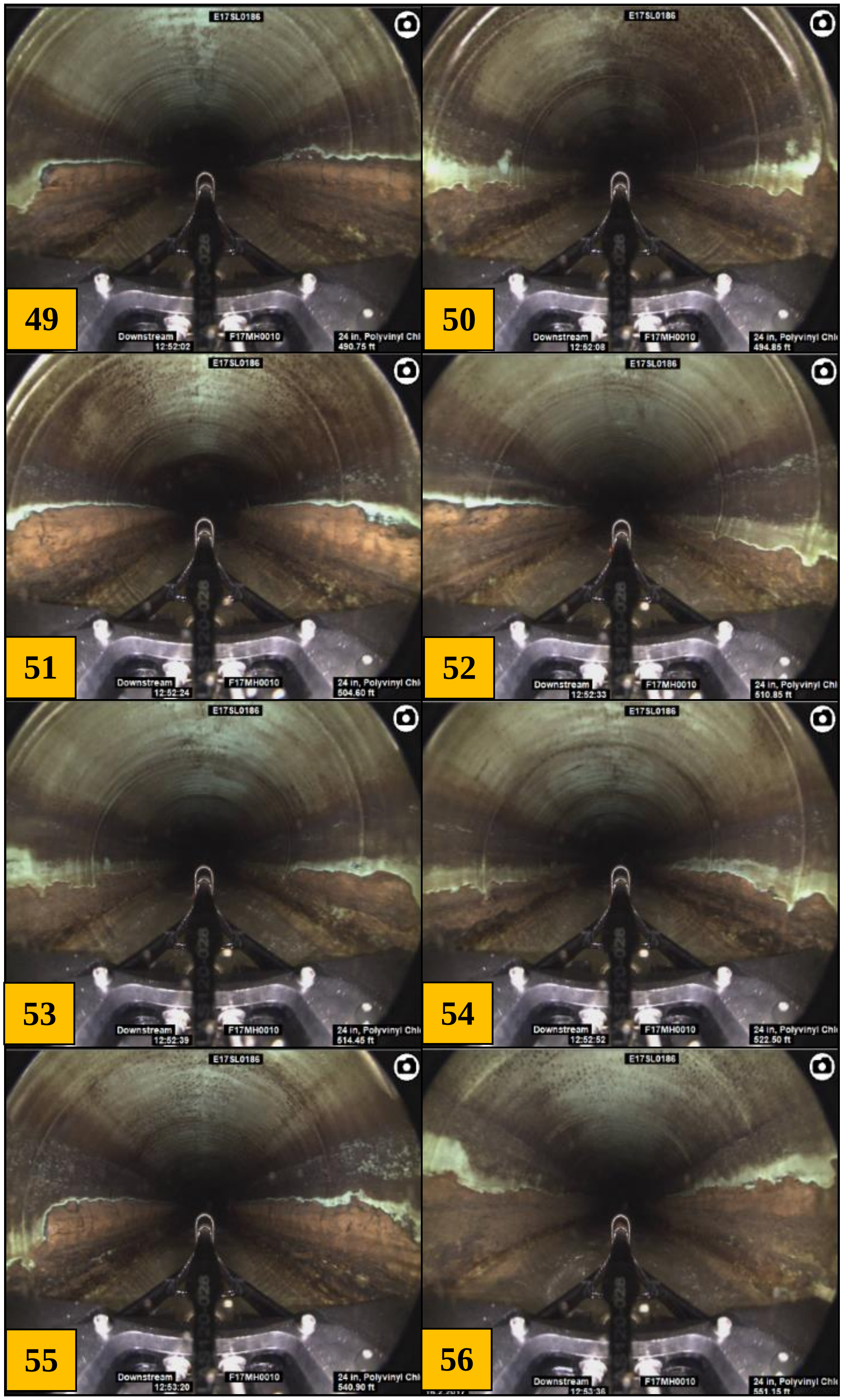


Figure A53-10 images from 49 through 56

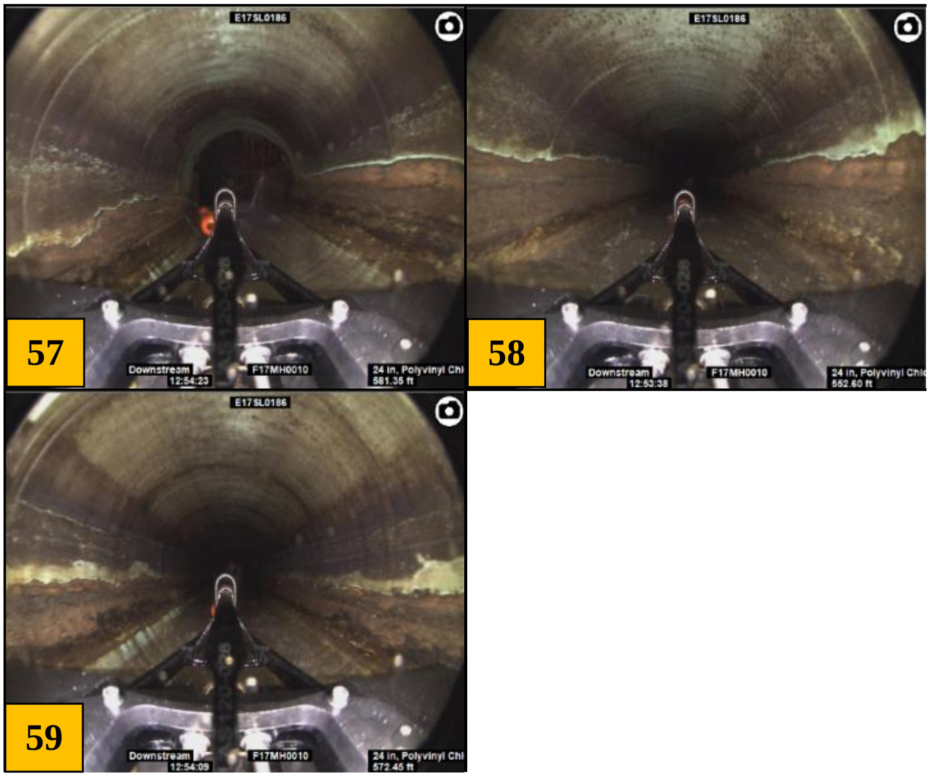


Figure A53-11 images from 57 through 59

Line 54 Summary

Table A54-1 Results Summary of Sewer Line 54

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	799
Percentage of The Line Not Inspected	17.6 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	3
Level 5 Defects	0
Level 4 Defects	1
Total Defects	61
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	61953.29
Maximum Blockage (%)	4
Maximum Deposit Height (in)	1.6

The device hit roots at 661 ft. Mud covered part of the laser ring. Video recording is obtained, and the laser profile is partially obtained.

Visual Observations

Table 54-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				5%					
3	1.15		DAE				10%				1,2	
4	4.1		DAE	S01			<5%				3	
5	5		MWL				10%				4	
6	12		MWL				5%				5	
7	30.05		DAE	F01								
8	30.05		DAE	S02			5%				6,7	
9	34.75		DAE	F02								
10	34.75		DAE	S03			5%				8,9	
11	35.45		MWL				10%				10	
12	48.25		MWL				5%				11	
13	137.2		DAG				<5%	J			12	
14	149.75		DAG				<5%	J			13	
15	153.4		MWL				10%				14	
16	176.35		MWL				5%				15	
17	207.4		DAE	F03								
18	207.4		DAE	S04			5%				16	
19	221.95		MWL				10%				17	
20	229.5		MWL				5%				18	
21	235.9		MWL				10%				19	
22	239.65		DAE	F04								
23	239.65		DAE	S05			<5%				20,21	
24	252.25		MWL				5%				22	
25	258.25		MWL				10%				23	

26	268		MWL				5%				24	
27	281.7		DAE	F05								
28	281.7		DAE	S06			5%				25,26	
29	289.75		DAE	F06								
30	289.75		DAE	S07			<5%				27	
31	294.85		MWL				10%				28	
32	309.1		MWL				5%				29	
33	319.05		DAE	F07								
34	319.05		DAE	S08			10%				30,31	
35	323		MWL				10%				32	
36	325.3		DAE	F08								
37	325.3		DAE	S09			5%				33	
38	343.1		MWL				5%				34	
39	359.4		DAE	F09								
40	359.4		DAE	S10			5%				35	
41	364.85		DAE	F10								
42	364.85		DAE	S11			5%				36	
43	377.55		MWL				10%				37	
44	380.15		DAG				10%	J			38	
45	384.1		DAE	F11								
46	384.1		DAE	S12			5%				39	
47	386.3		MWL				5%				40	
48	418.45		DAG				10%	J			41	
50	431.15		DAE	F12				J				
51	431.15		DAG				5%				42	
52	432.35		DAE	S13			5%				43	
53	456.7		RMJ					J			44	
54	500.1		DAE	F13								
55	500.1		DAE	S14			10%				45,46	
56	505.45		MWL				10%				47	
57	509.05		DAE	F14								
58	509.05		DAE	S15			5%				48	
59	534.55		MWL				5%				49	
60	538.15		DAE	F15								
61	538.15		DAE	S16			10%				50,51	
62	546.7		DAE	F16								
63	546.7		DAE	S17			5%				52	
64	552.35		DAE	F17								
65	552.35		DAE				5%				53	
66	556.25		DAE	S18			5%				54,55,56,57	
67	558.6		MWL				10%				58	
68	573.3		MWL				5%				59	
69	591.35		MWL				10%				60	
70	598.1		MWL				5%				61	
71	617.9		MWL				10%				62	
72	625.55		MWL				5%				63	
73	658.6		MWL				10%				64	
74	661.65		RLJ								65	
75	667.65		MWL				5%				66	
76	723.15		MWL				10%				67	
77	740.35		MWL				5%				68	
78	775.55		MWL				10%				69	
79	791.6		MWL				5%				70	
80	798.9		MWL				10%				71	
81	802.15		DAE	F18								
82	802.15		RMJ								72	
83	802.15		MSA									

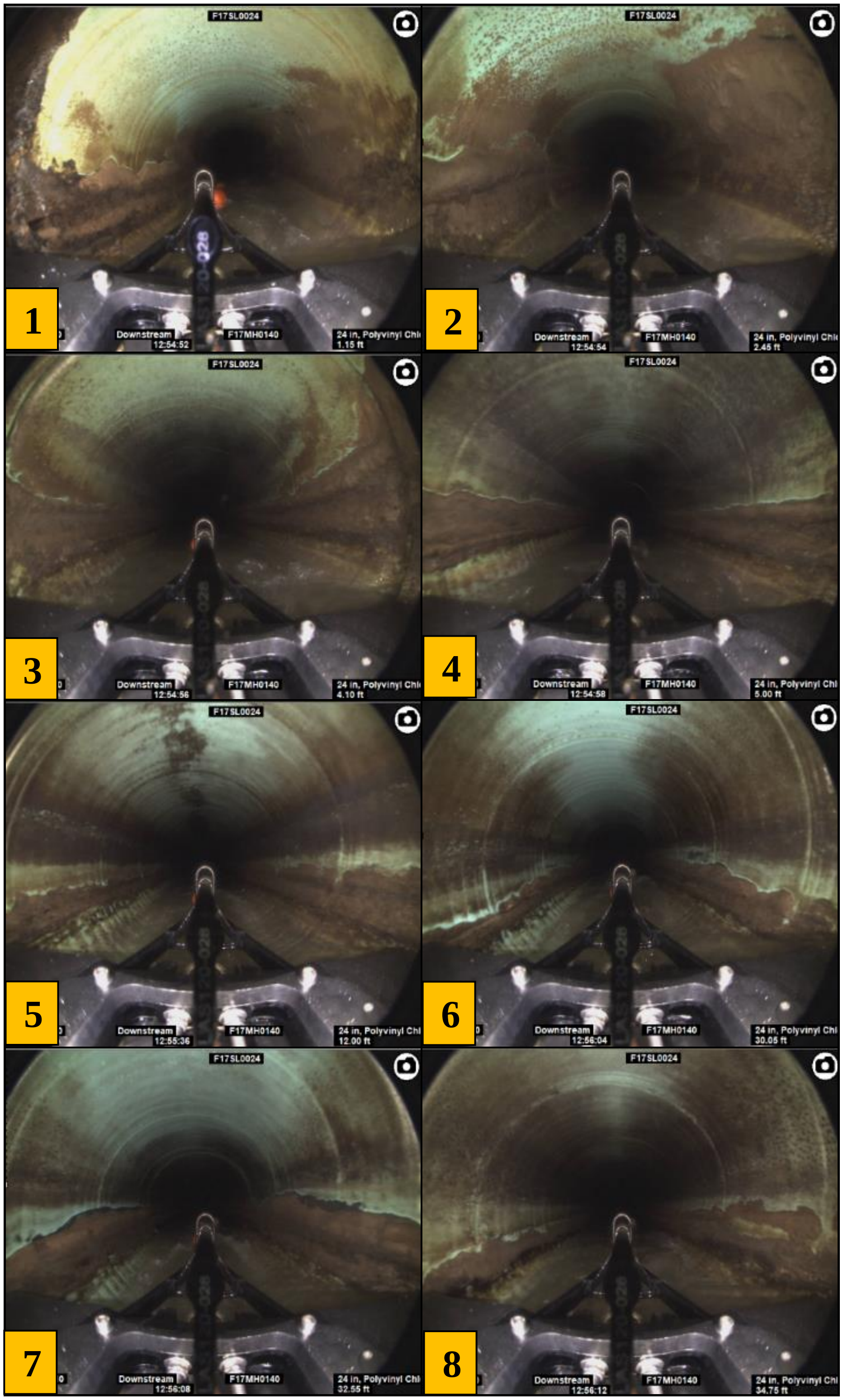


Figure A54-1 images from 1 through 8

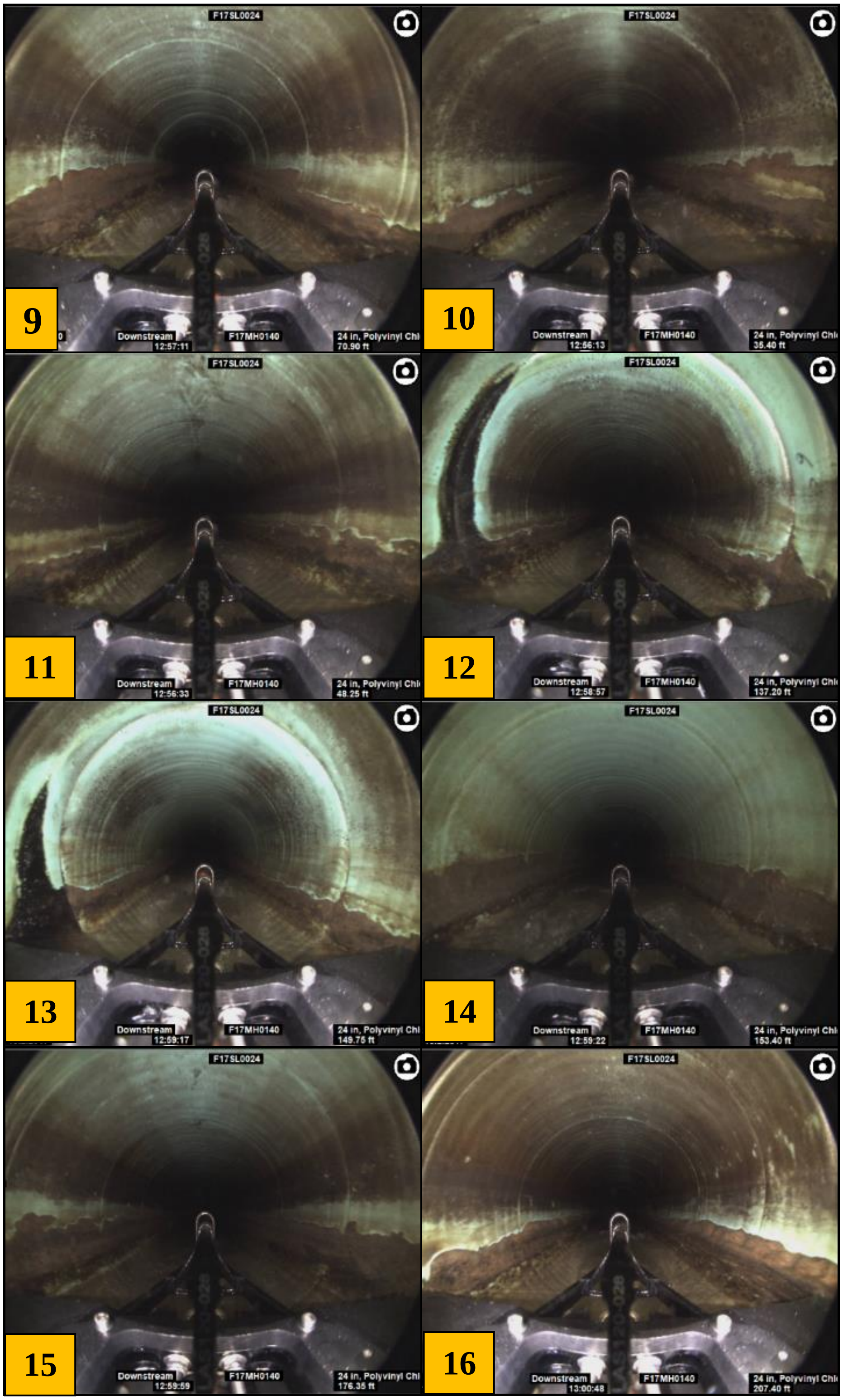


Figure A54-2 images from 9 through 16

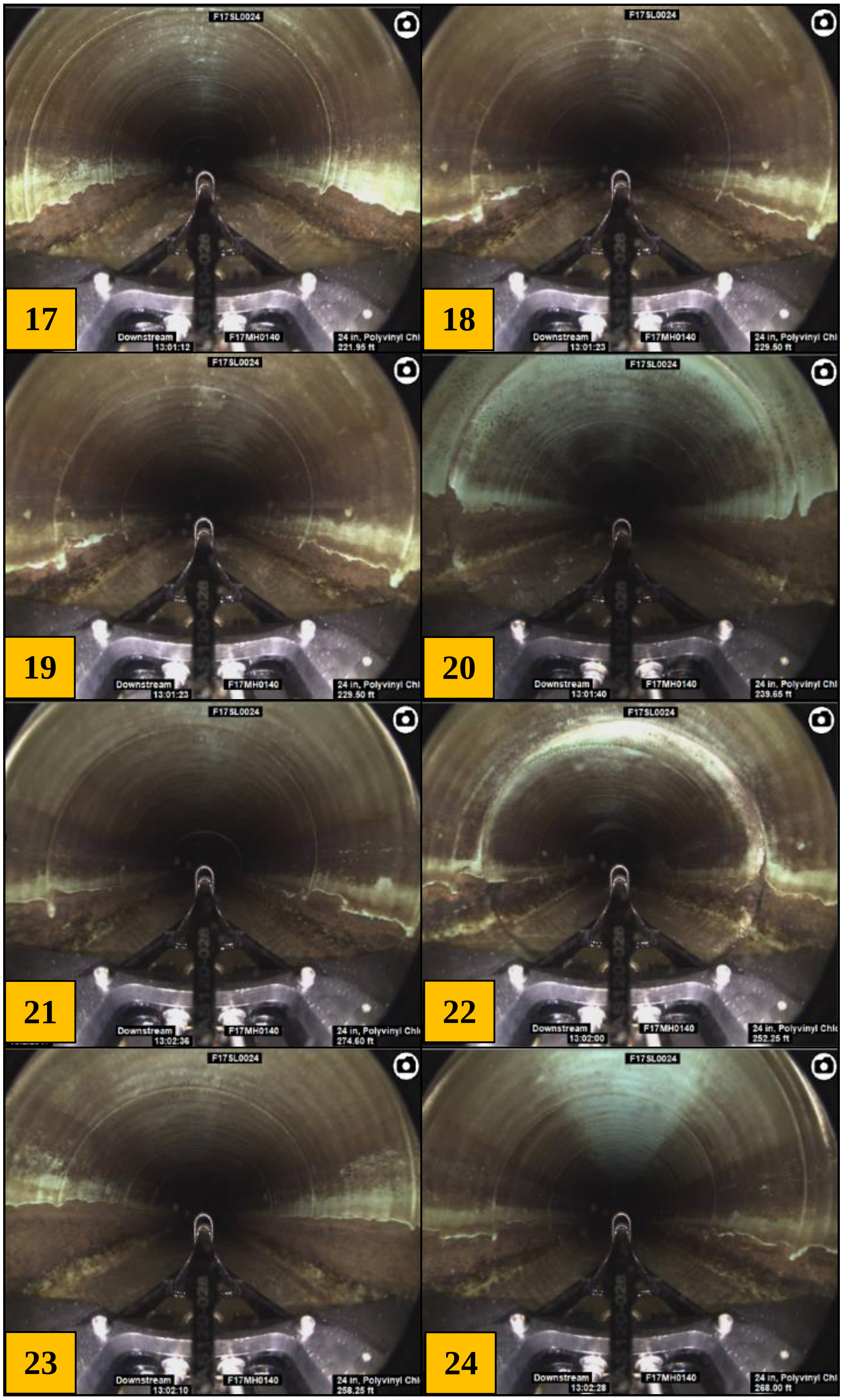


Figure A54-3 images from 17 through 24

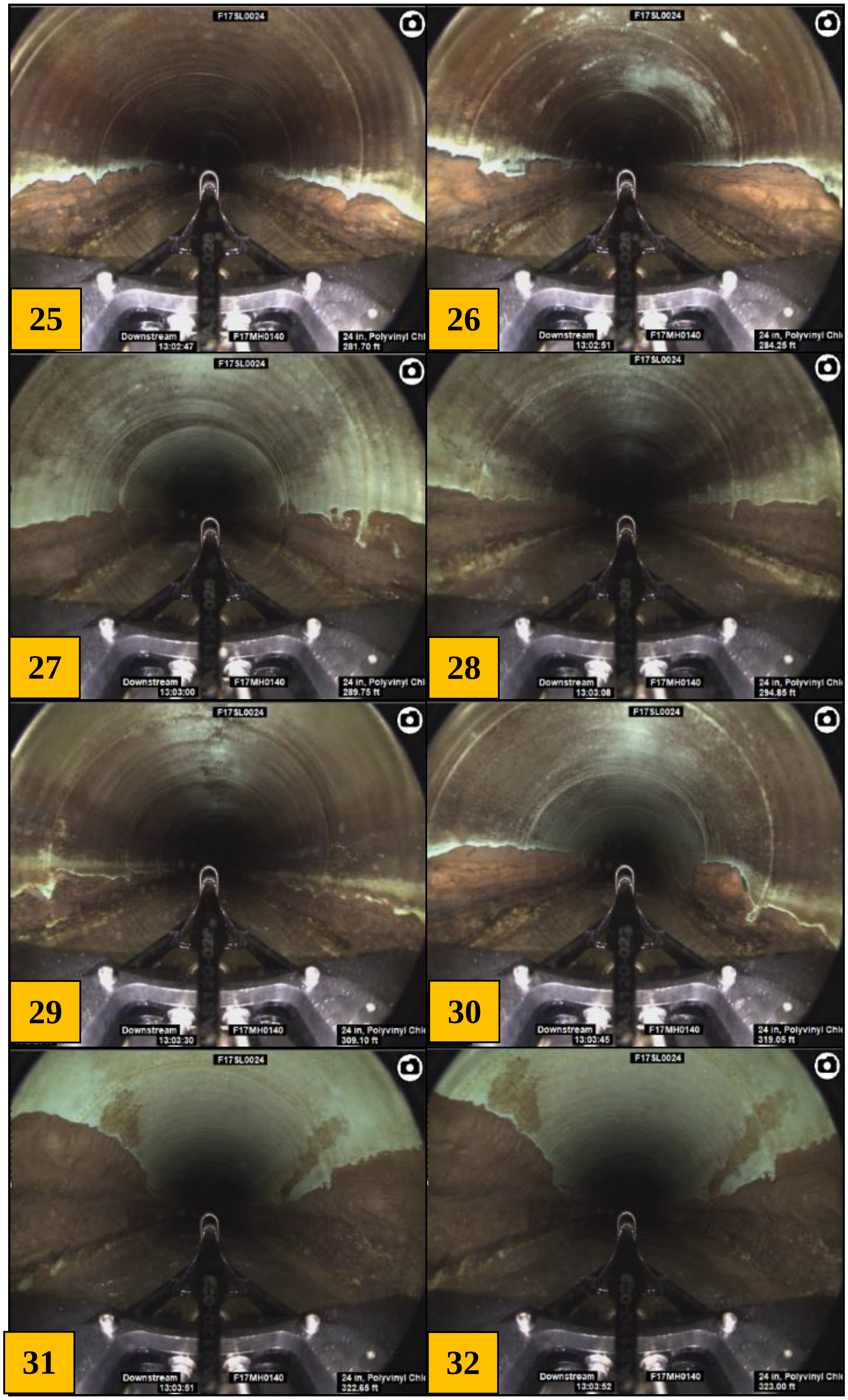


Figure A54-4 images from 25 through 32

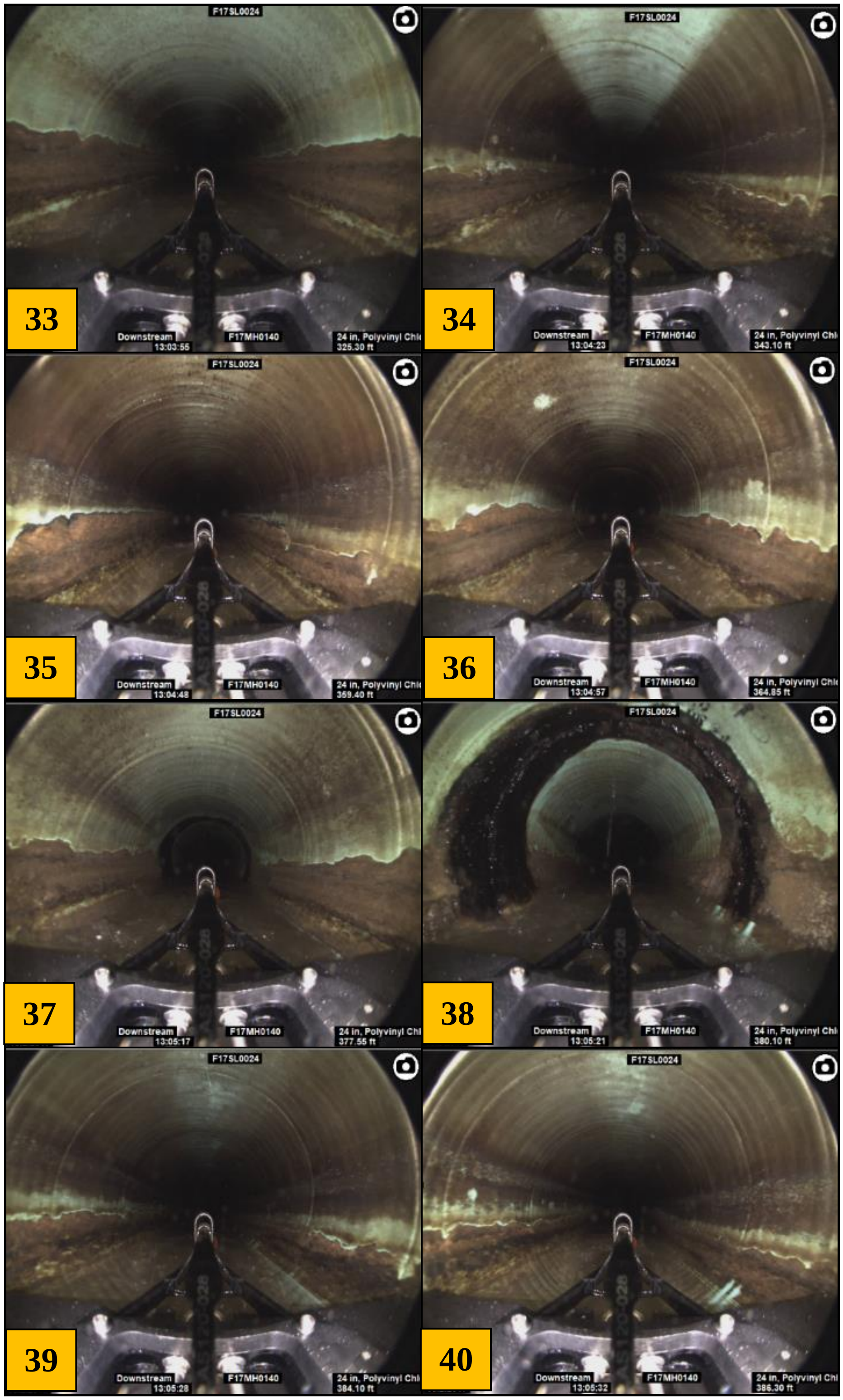


Figure A54-5 images from 33 through40

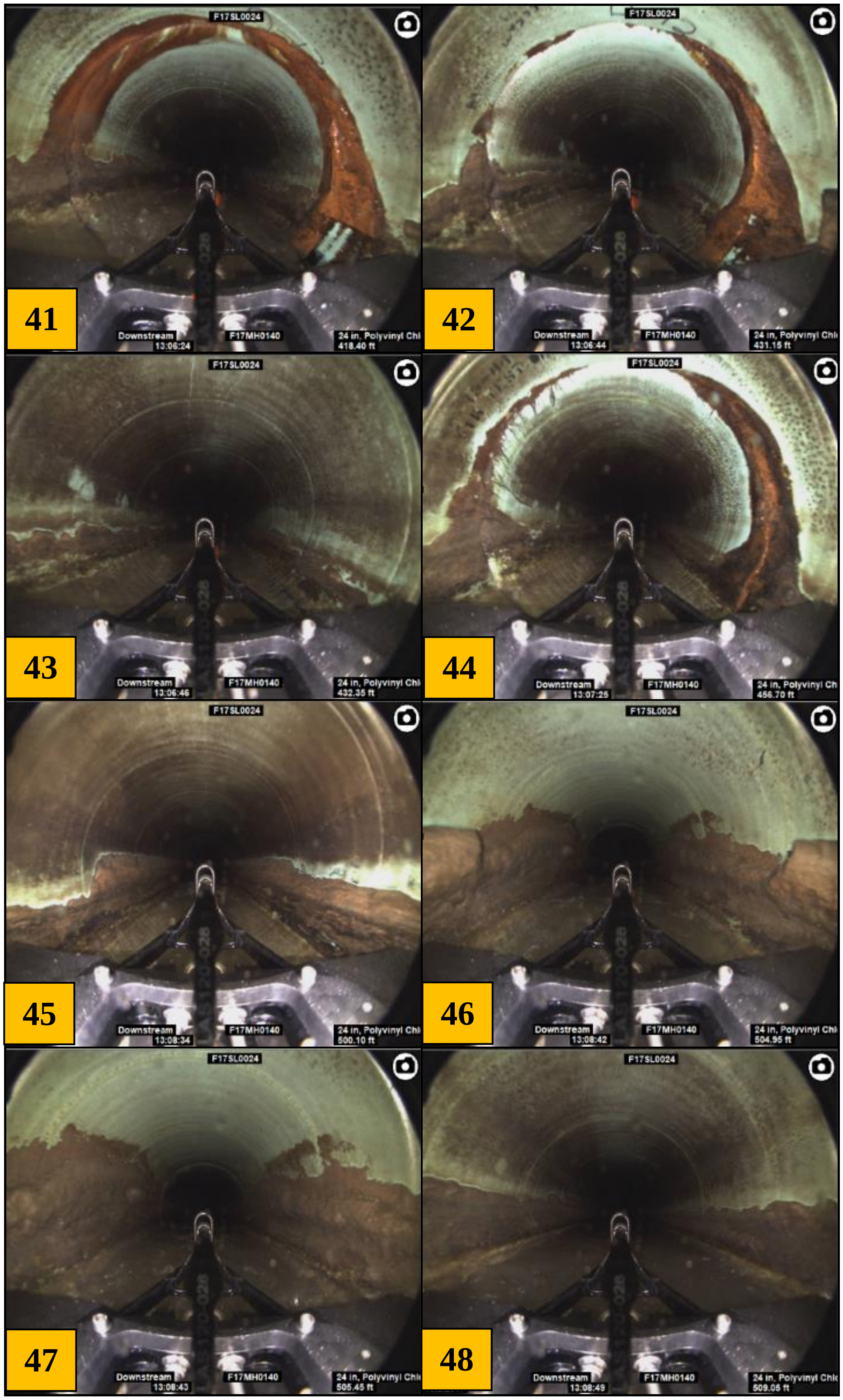


Figure A54-6 images from 40 through 48

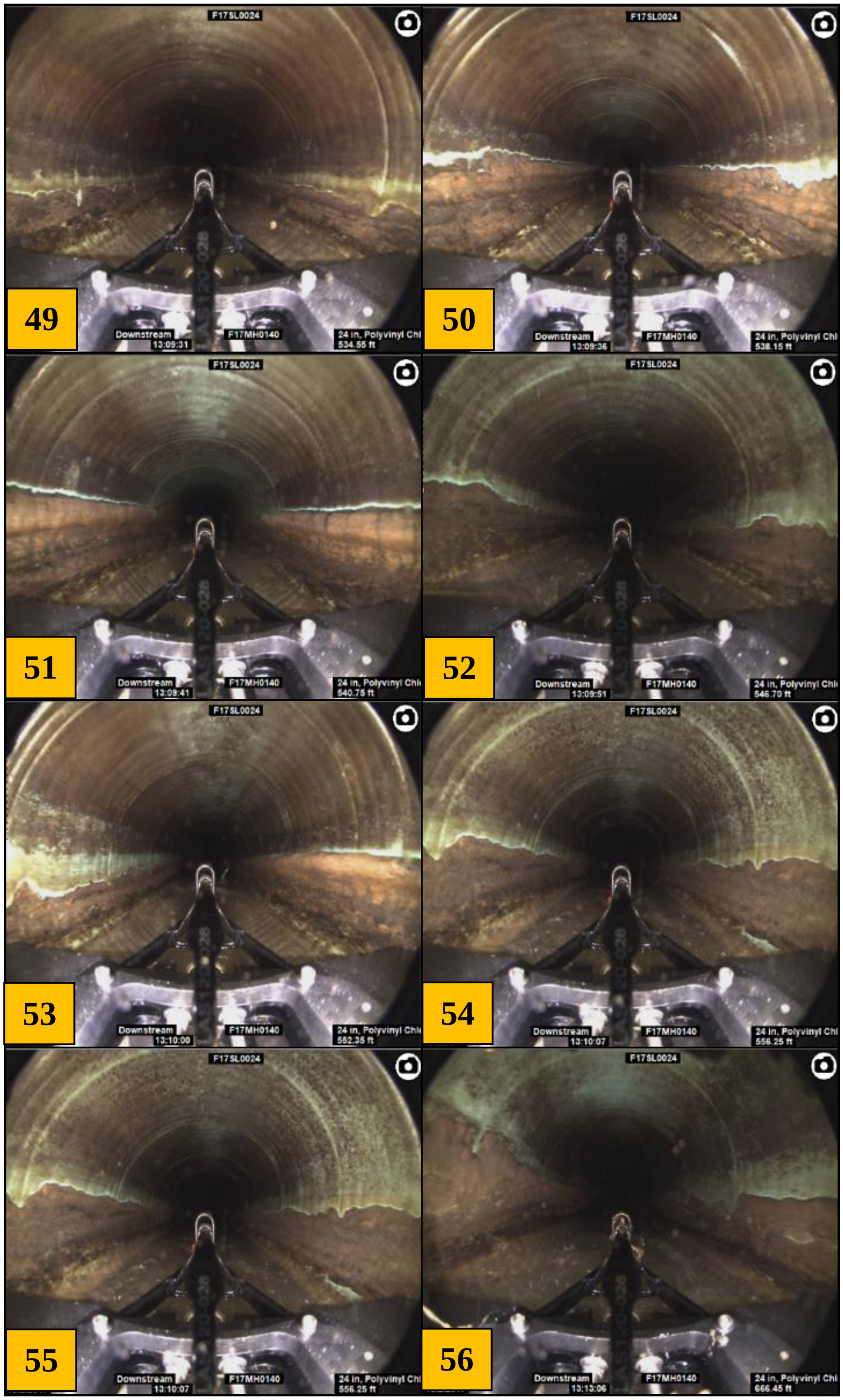


Figure A54-7 images from 49 through 56

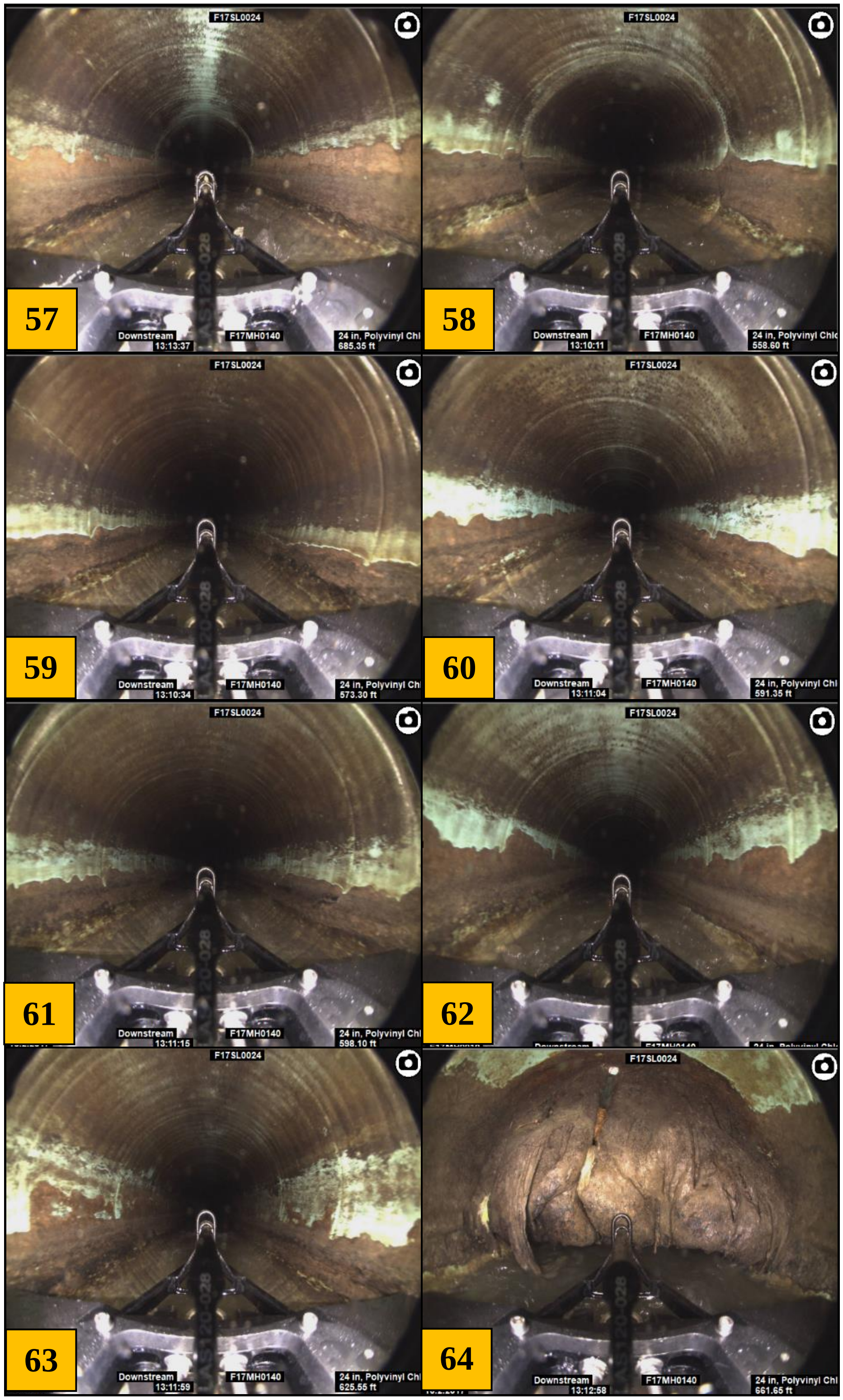


Figure A54-8 images from 57 through 64

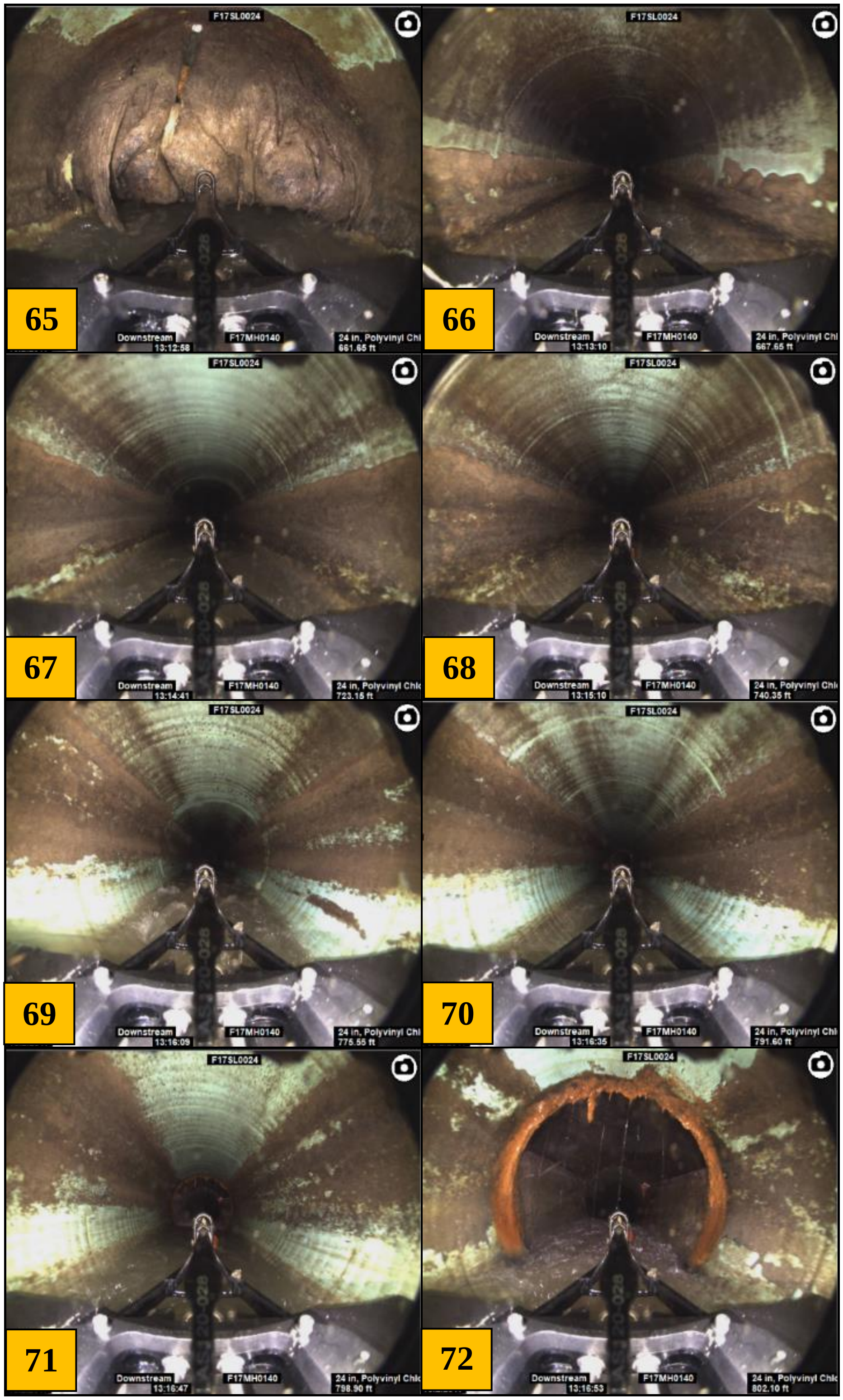


Figure A54-9 images from 57 through 72

Line 55 Summary

Table A55-1 Results Summary of Sewer Line 55

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	273
Percentage of The Line Not Inspected	100 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	7
Level 5 Defects	0
Level 4 Defects	0
Total Defects	25
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	0
Maximum Blockage (%)	0
Maximum Deposit Height (in)	0

Mud covered part of the laser ring. Video recording is obtained, and the laser profile is partially obtained.

Visual Observations

Table A55-1 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code: Group/ Descriptor/ Modifier	Continuous Defect	Value: Dimension 1st	Value: Dimension 2nd	Value: %	Joint	Circumferential Location: At/ From	Circumferential Location: To	Img Reference	Remarks
1	0		AMH									
2	1		MWL				5%					
3	1		DAG				<5%				1	
4	1		DAE	S01			10%				1,2	
5	11.1		DAE	F01								
6	11.1		DAE	S02			5%				3,4	
7	48.8		RMJ					J			5	
8	61.5		RMJ					J			6	
9	68.6		DAE	F02								
10	68.6		DAE	S03			5%				7	
11	74.3		DAE	F03								
12	74.3		RMJ								8	
13	74.3		DAE	S04			5%				8	
14	74.8		MWL				10%				9	
15	88.35		MWL				5%				10	

16	93.4		DAE	F04								
17	93.4		DAE	S05			5%				11,12	
18	99.7		RMJ								13	
19	101		MWL				10%				14	
20	112.9		DAE	F05								
21	112.9		DAE	S06			5%				15	
22	115.05		MWL				5%				16	
23	125.95		DAE	F06								
24	125.65		RMJ								17	
25	125.95		DAE	S07			5%				17	
26	130.4		MWL				10%				18	
27	166.85		MWL				5%				19	
28	214.85		RMJ								20	
29	216.6		DAE	F07								
30	216.6		DAE	S08			5%				21,22	
31	222.75		MWL				10%				23	
32	228.1		DAE	F08								
33	228.1		DAE	S09			5%				24	
34	253.6		RMJ								25	
35	256.65		MWL				5%				26	
36	271.55		DAE	F09								
37	271.55		MSA									

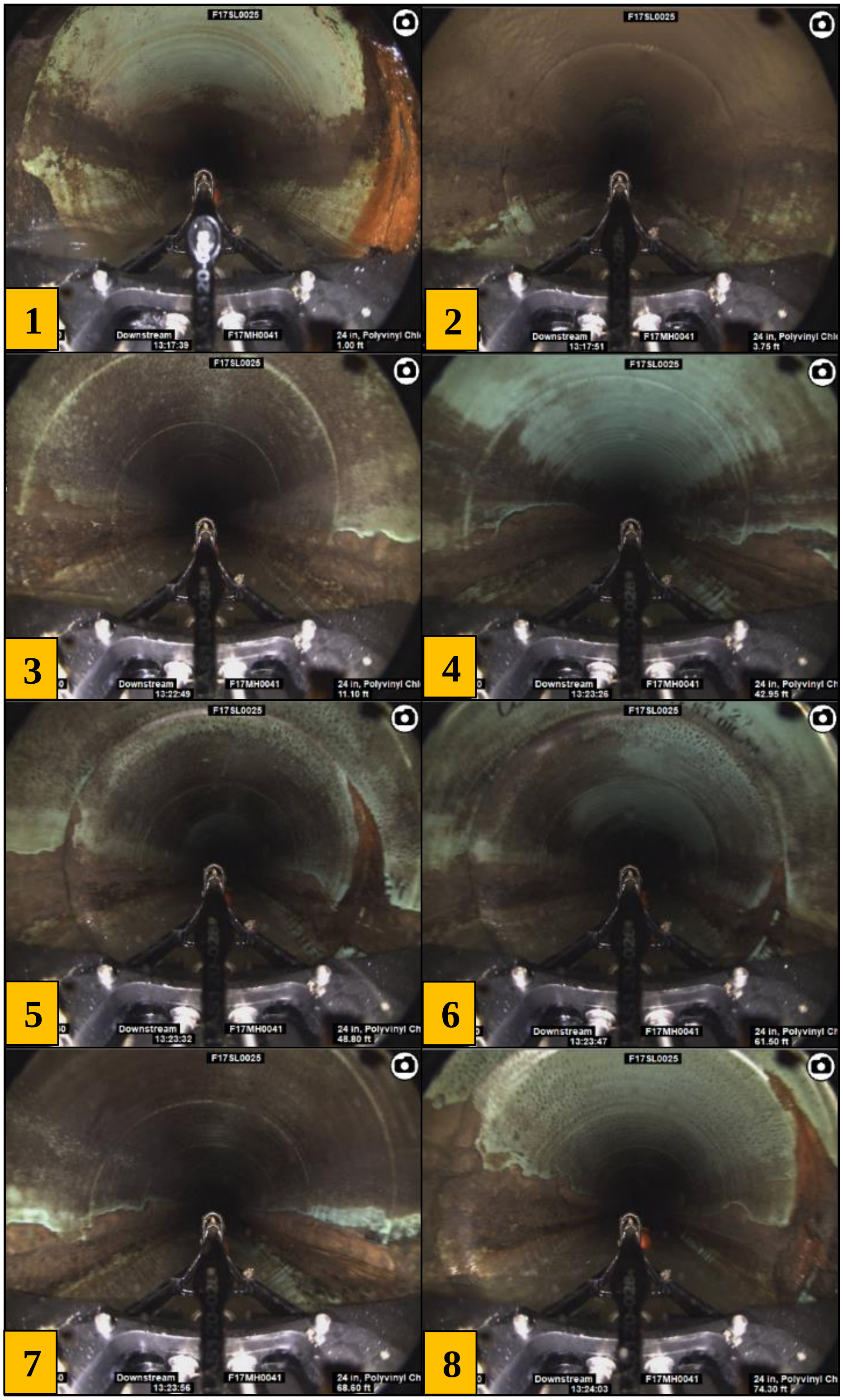


Figure A55-1 images from 1 through 8

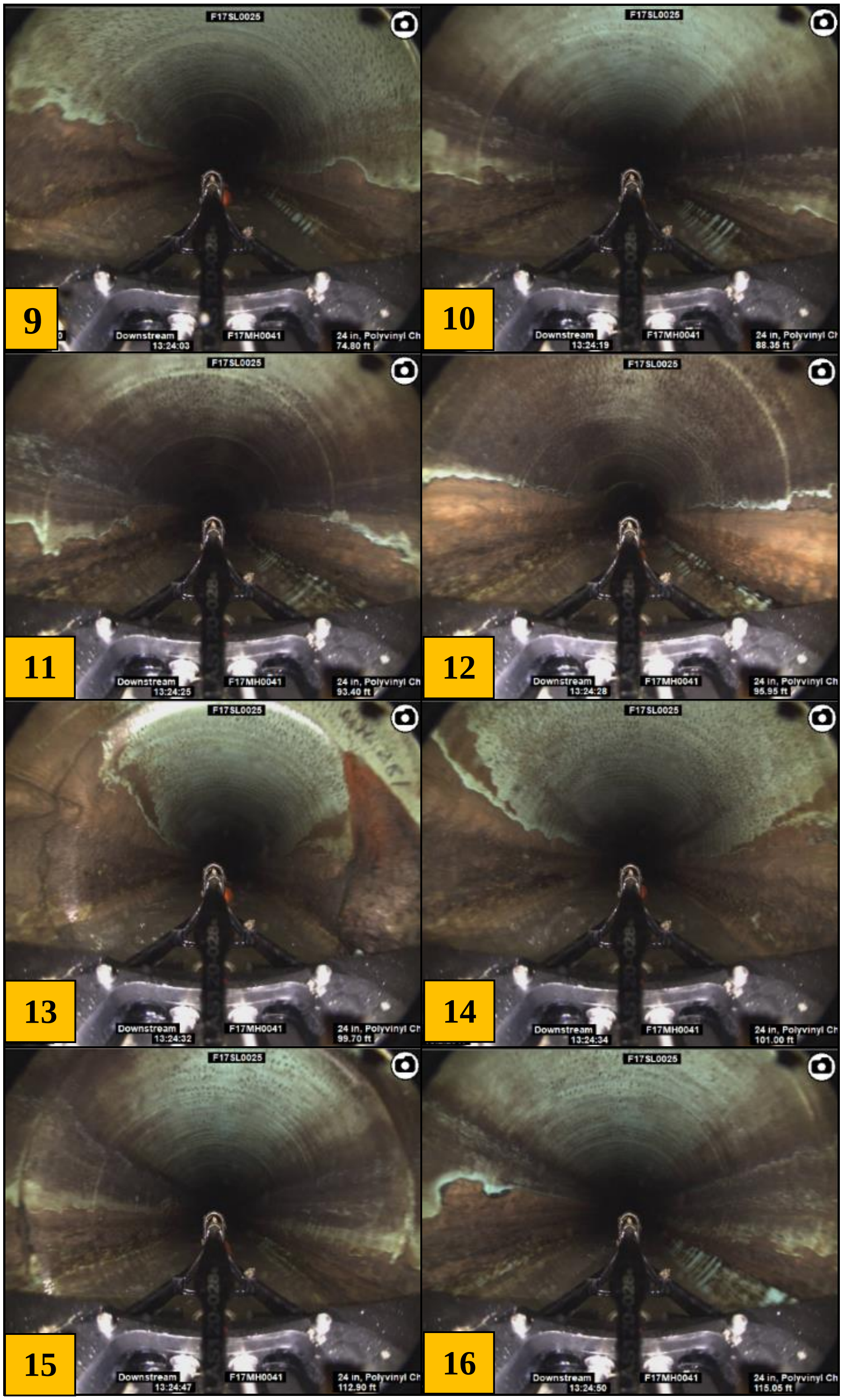


Figure A55-2 images from 9 through 16

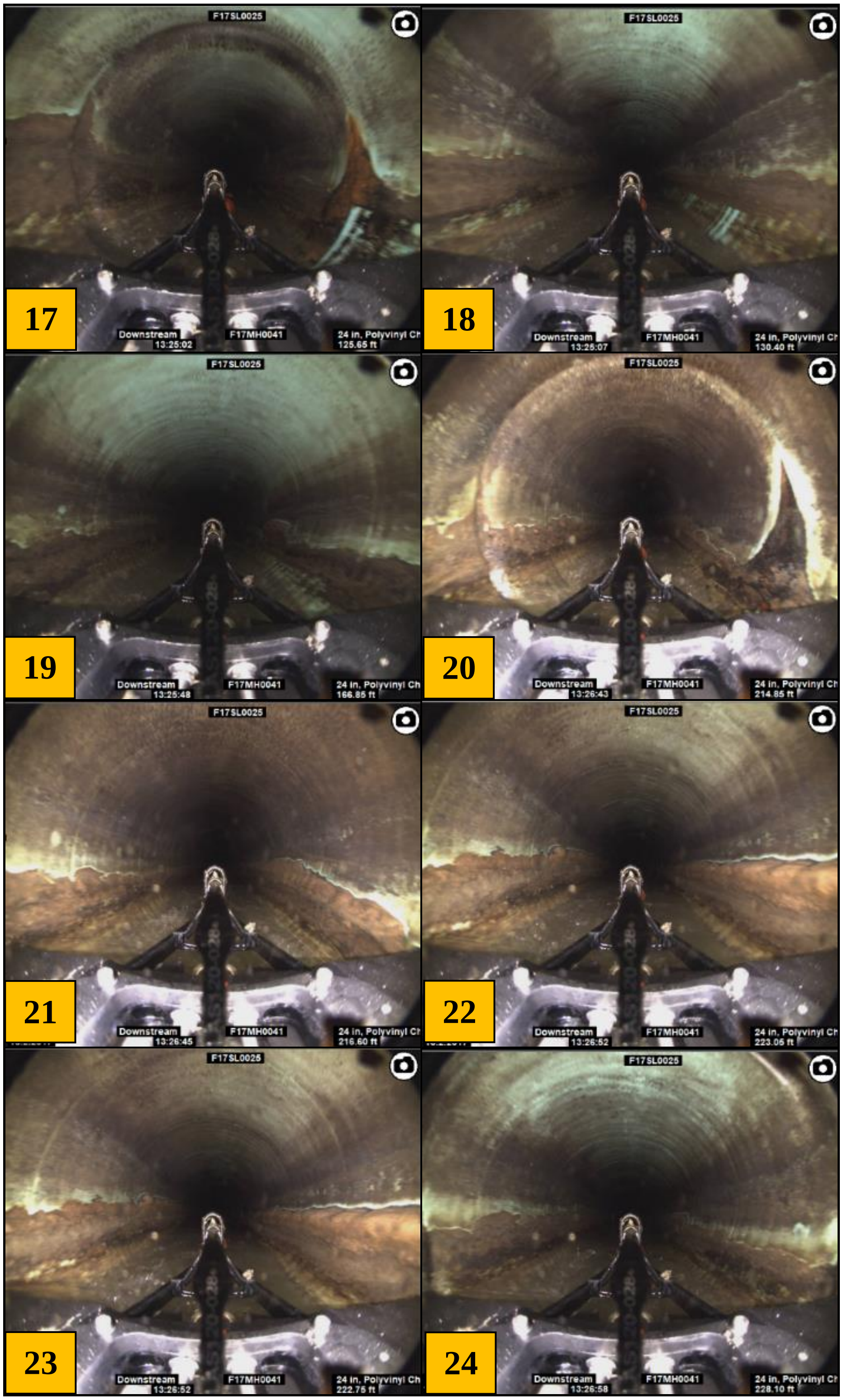


Figure A55-3 images from 17 through 24

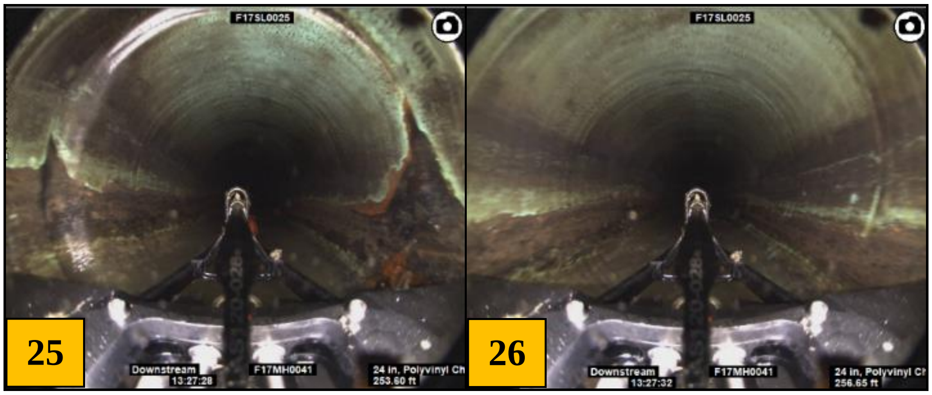


Figure A55-4 images from 25 through 26

Line 56 Summary

Table A56-1 Results Summary of Sewer Line 56

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	155
Percentage of The Line Not Inspected	100%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	1
Level 5 Defects	0
Level 4 Defects	0
Total Defects	5
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	0
Maximum Blockage (%)	0
Maximum Deposit Height (in)	0

Mud covered part of the laser ring. Video recording is obtained, and the laser profile is partially obtained.

Visual Observations

Table A56-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL					5%				
3	0		DAE	S01				<5%			1,2	
4	33.5		DAE	F01								
5	33.5		DAE	S02				5%			3	
6	41		DAE	F02								
7	41		DAE	S03				5%			4,5,6,7	
8	118.75		IDJ								8	
9	130.6		RMJ								9	
10	130.75		DAE	F03								
11	130.75		MSA									

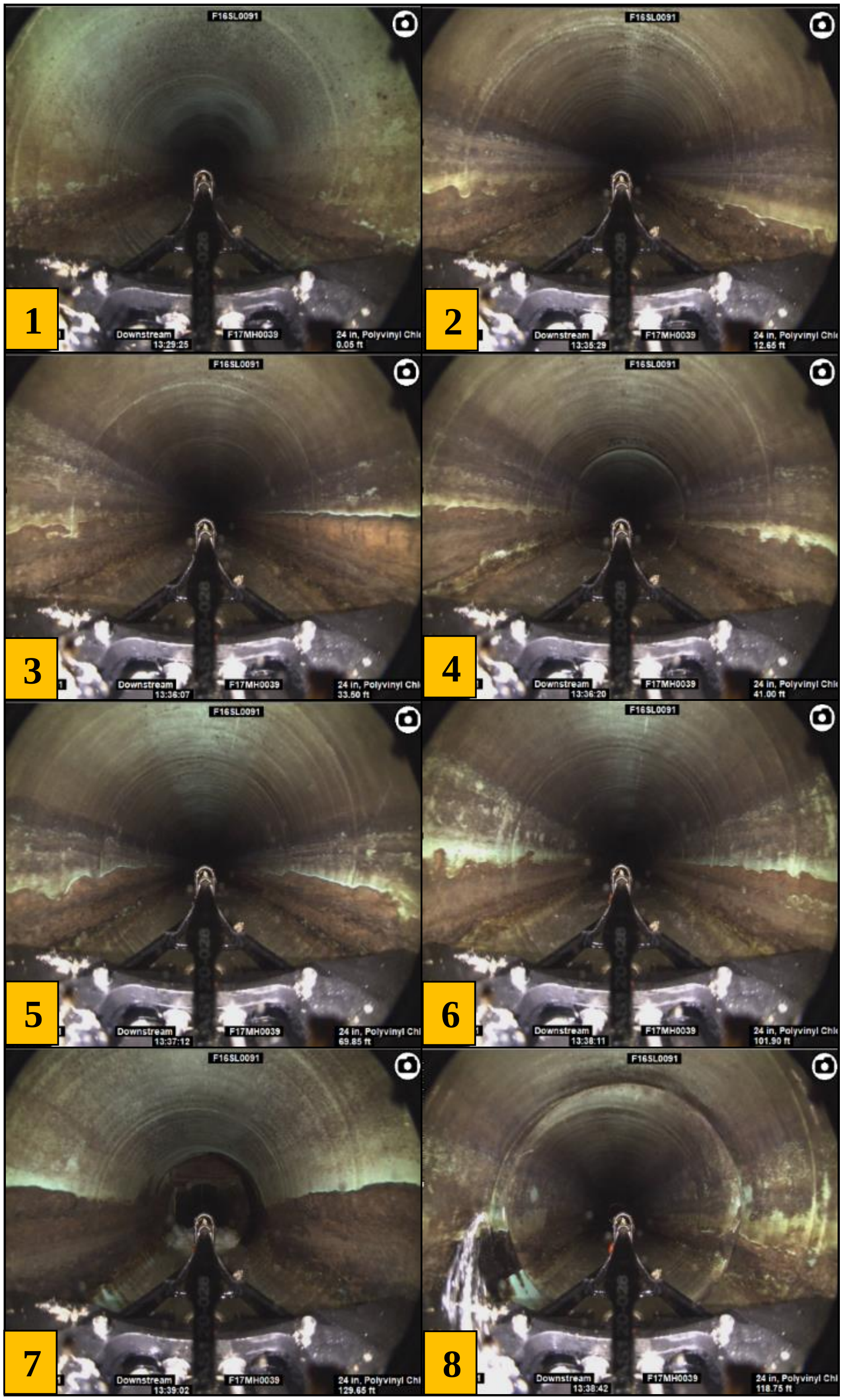


Figure A56-1 images from 1 through 8

Figure A56-2 image 9

Line 57 Summary

Table A57-1 Results Summary of Sewer Line 57

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	290
Percentage of The Line Not Inspected	100 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	21
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	0
Maximum Blockage (%)	0
Maximum Deposit Height (in)	0

Mud covered part of the laser ring. Video recording is obtained, and the laser profile is partially obtained.

Visual Observations

Table A57-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	0		MWL				10%					
3	0		DAE	S01			5%				1,2,3	
4	40.9		MWL				5%				4	
5	48.7		DAE	F01								
6	48.7		DAE	S02			10%				5	
7	55.4		MWL				10%				6	
8	58.3		DAE	F02								
9	58.3		DAE	S03			5%				7,8	
10	67.5		MWL				5%				9	
11	88		DAE	F03								
12	88		DAE				5%				10	
14	90.8		DAE	S04			5%				11,12	
15	105.85		MWL				10%				13	
16	116.75		DAE	F04								

17	116.75		DAE	S05			5%				14,15	
18	118.35		MWL				5%				16	
19	149.65		DAE	F05								
20	149.65		DAE	S06			5%				17	
21	151.2		MWL				10%				18	
22	154.45		DAE	F06								
23	154.45		DAE	S07			5%				19	
24	155.95		MWL				5%				20	
25	162.1		DAE	F07								
26	162.1		DAE	S08			5%				21	
27	165.15		MWL				10%				22	
28	167.75		DAE	F08								
29	167.75		DAE	S09			5%				23,24,25,26	
30	182.7		MWL				5%				27	
31	255.55		MWL				10%				28	
32	274.85		MWL				5%				29	
33	287.8		DAE	F09								
34	287.8		MSA									

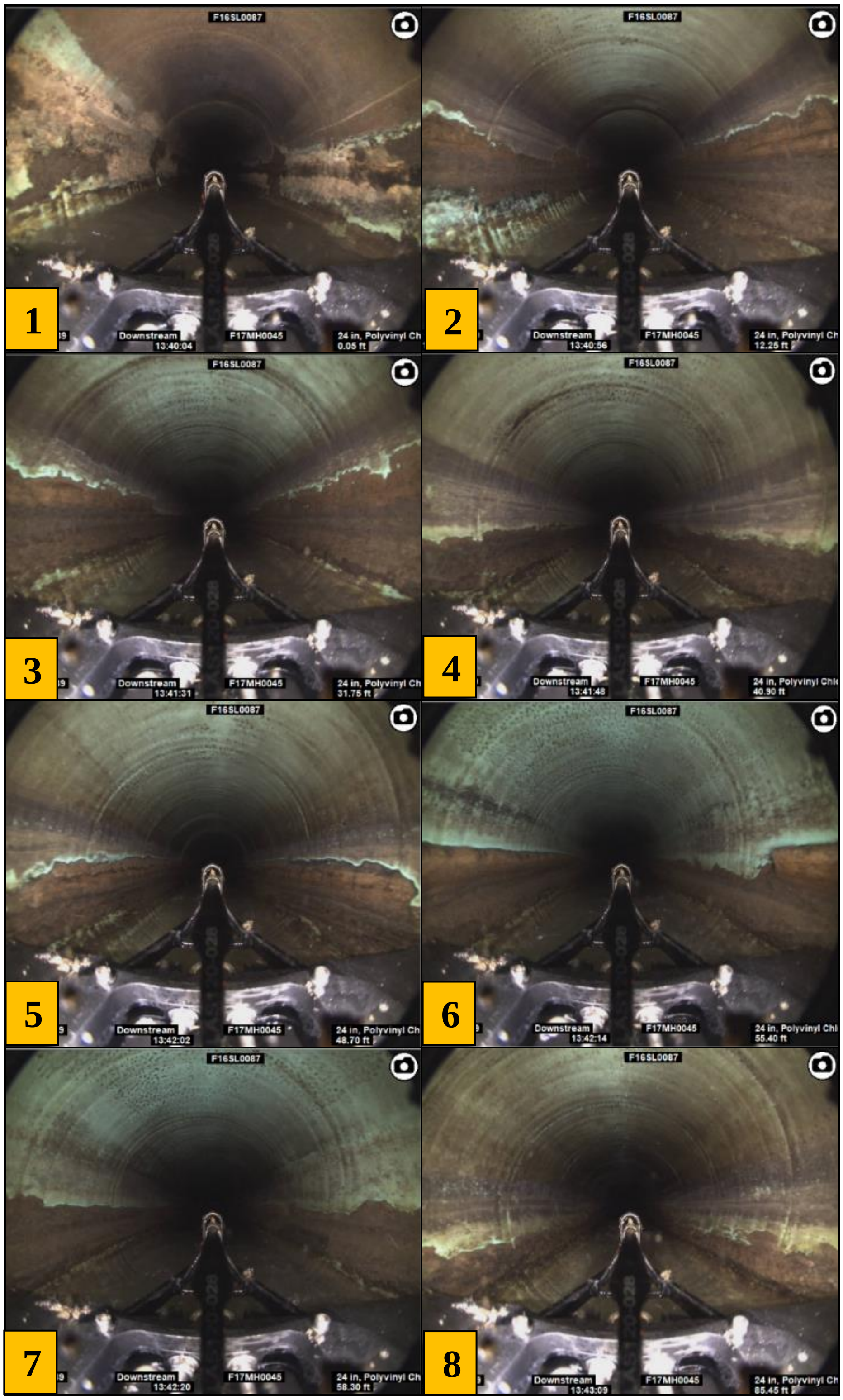


Figure A57-1 images from 1 through 8

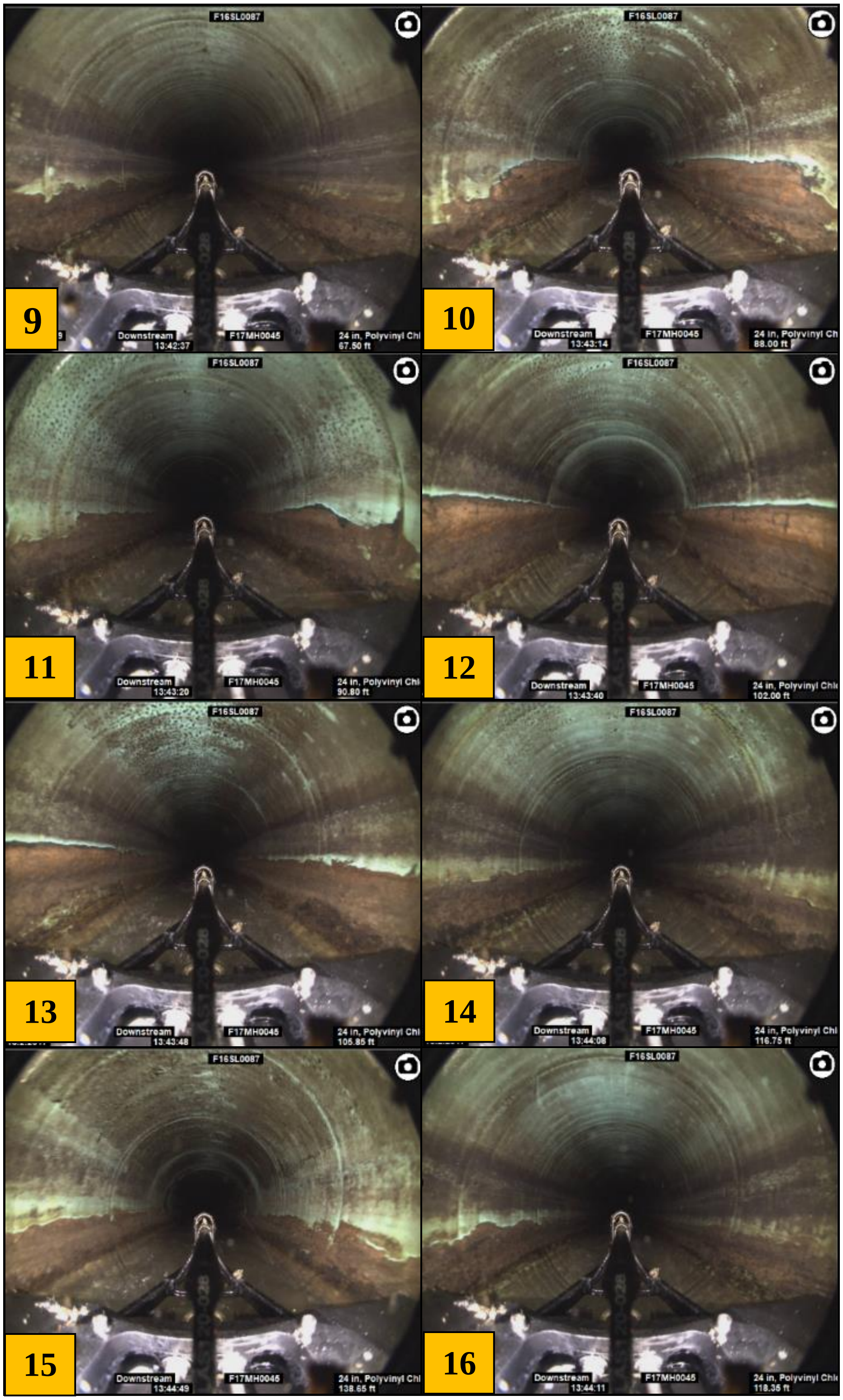


Figure A57-2 images from 9 through 16

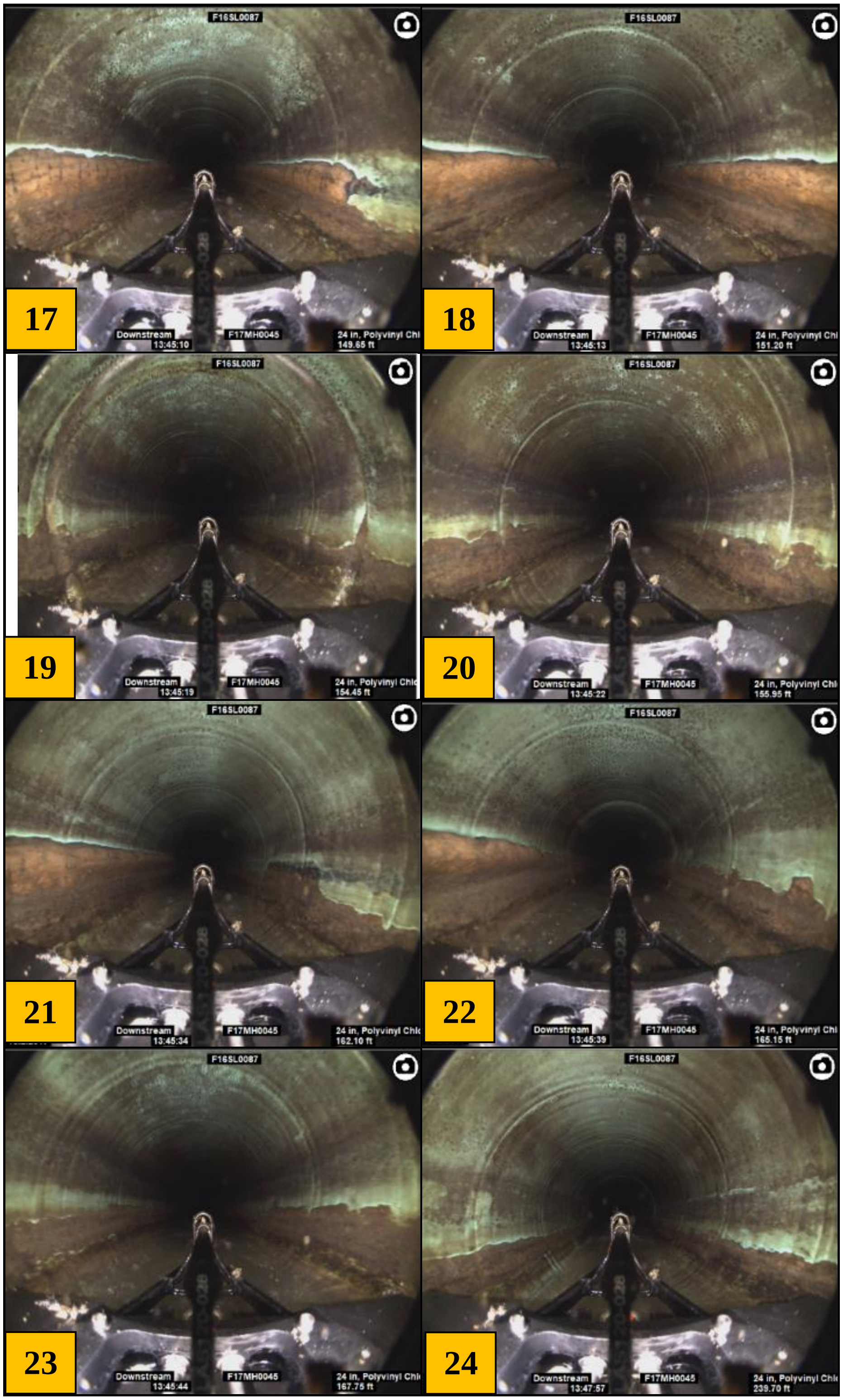


Figure A57-3 images from 17 through 24

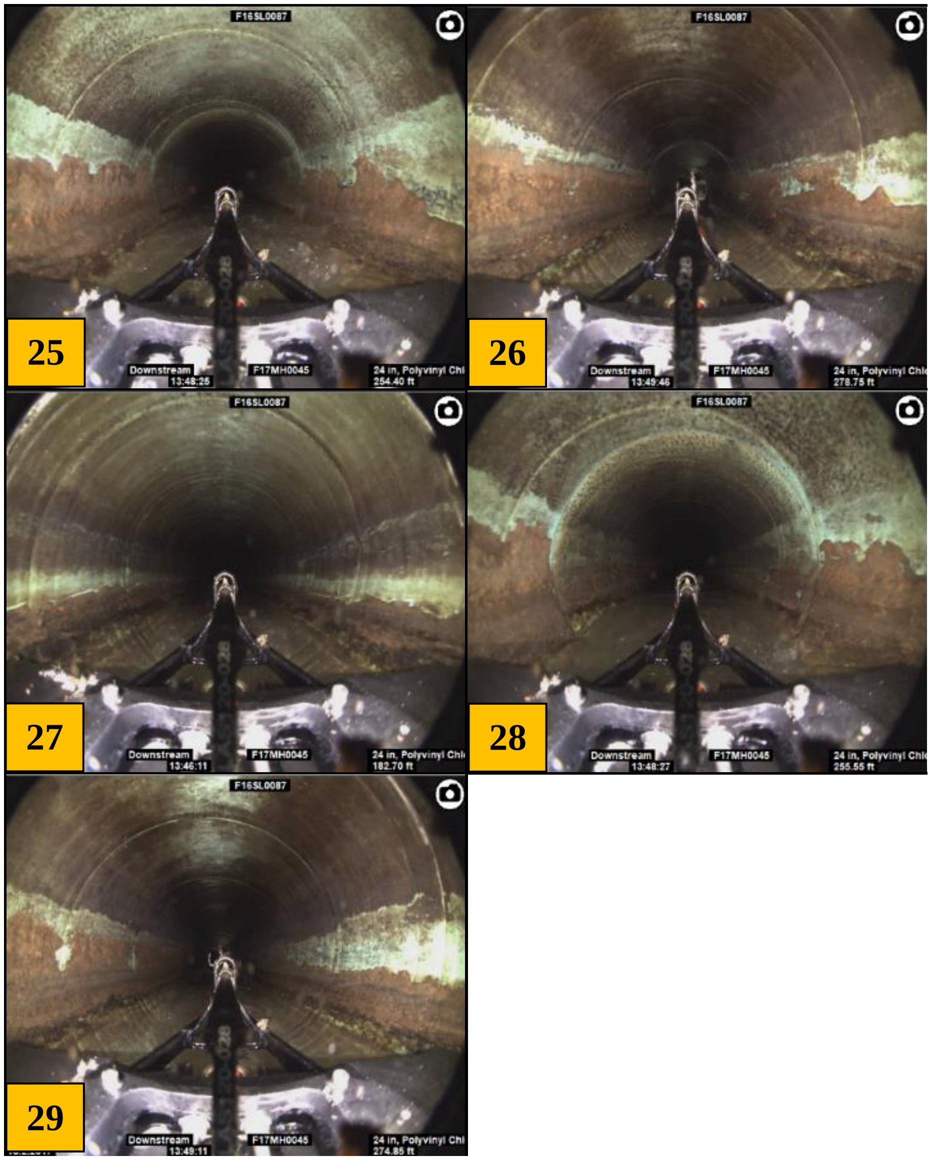


Figure A57-4 images from 25 through 29

Line 58 Summary

Table 58-1 Results Summary of Sewer Line 58

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	876
Percentage of The Line Not Inspected	100%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	2
Total Roots Occurrences	19
Level 5 Defects	0
Level 4 Defects	5
Total Defects	29
Total Debris Volume (ft^3)	0
Total Deposits Volume (in^3)	0
Maximum Blockage (%)	0
Maximum Deposit Height (in)	0

Video recording is obtained, but the laser and sonar are not clear to be analyzed due to the splashed water.

Visual Observations

Table A58-2 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension 1st	Dimension 2nd	%		At/ From	To		
1	0		AMH									PIPE IS OVAL IN SHAPE AT SOME PLACES AND COVERED WITH DEPOSITS THROUGH-OUT THE LENGTH OF THE PIPE
2	8		MWL				10%					
3	15.2		RMJ								1	
4	53.9		RMJ								2	
5	79.3		RMJ								3	
6	79.3		DAE				20%				3	
7	149.4		MWL				5%				4	
8	169.75		MWL				10%				5	
9	194.85		RMJ								6	
10	233.3		RMJ								7	
11	246.2		RMJ								8	
12	284.3		RLJ								9	
13	310.15		RMJ								10	
14	323.05		RMJ								11	
15	348.8		RMJ								12	
16	361.45		RLJ								13	
17	412.6		RMJ								14	
18	438.3		RMJ								15	
19	464.3		RMJ								16	
20	477.15		RLJ								17	

21	494.15		JSL								18	
22	498.65		JSM								19	
23	498.65		DAE				5%				19	
24	580.45		MWL				5%				20	
25	593.05		RMJ								21	
26	598.55		MWL				10%				22	
27	776.55		RLJ								23	
28	780.45		RLJ								24	
29	785		MWL				5%				25	
30	792.7		MWL				10%				26	
31	811.1		RMJ								27	
32	861.5		MSA									

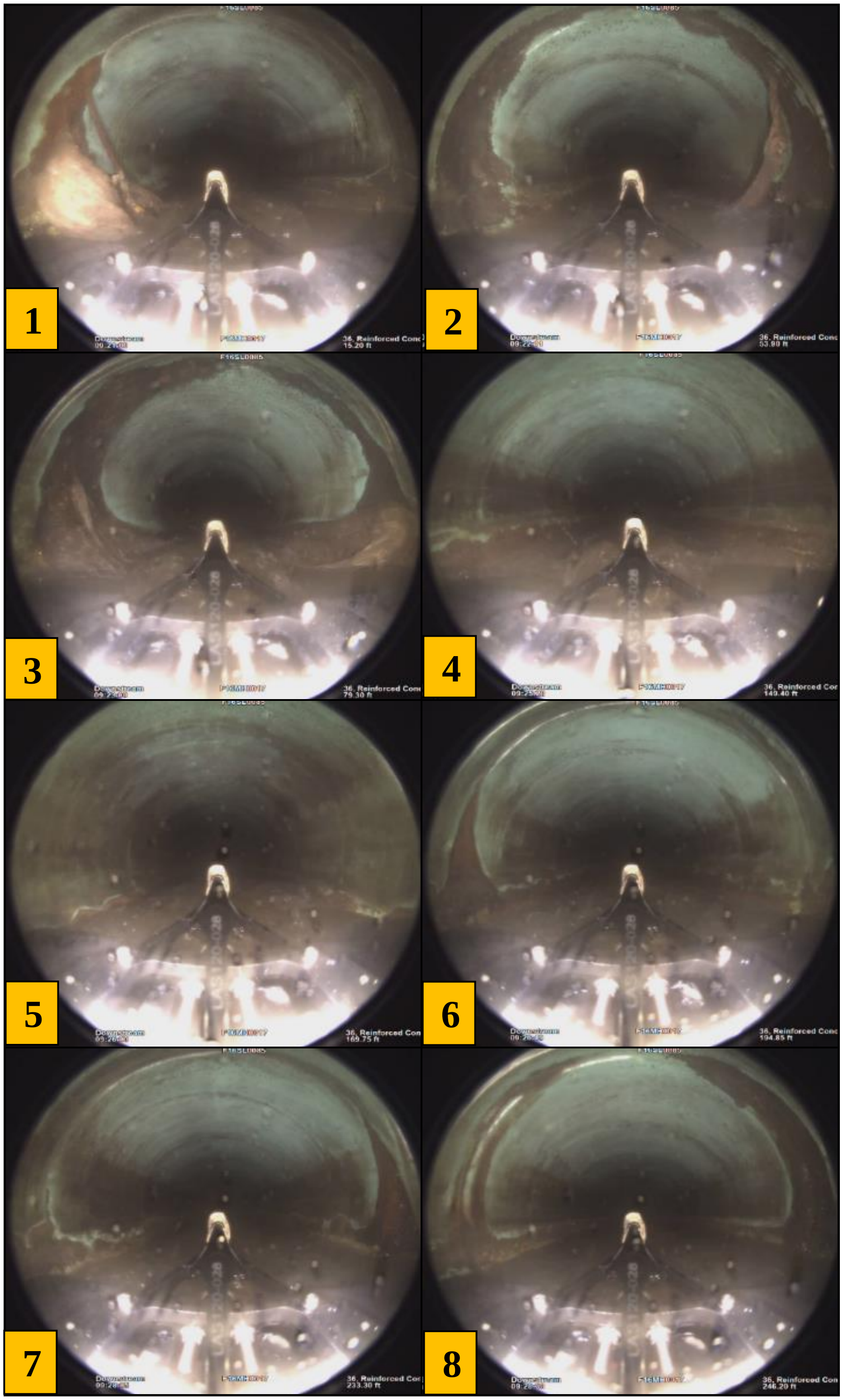


Figure A58-1 images from 1 through 8

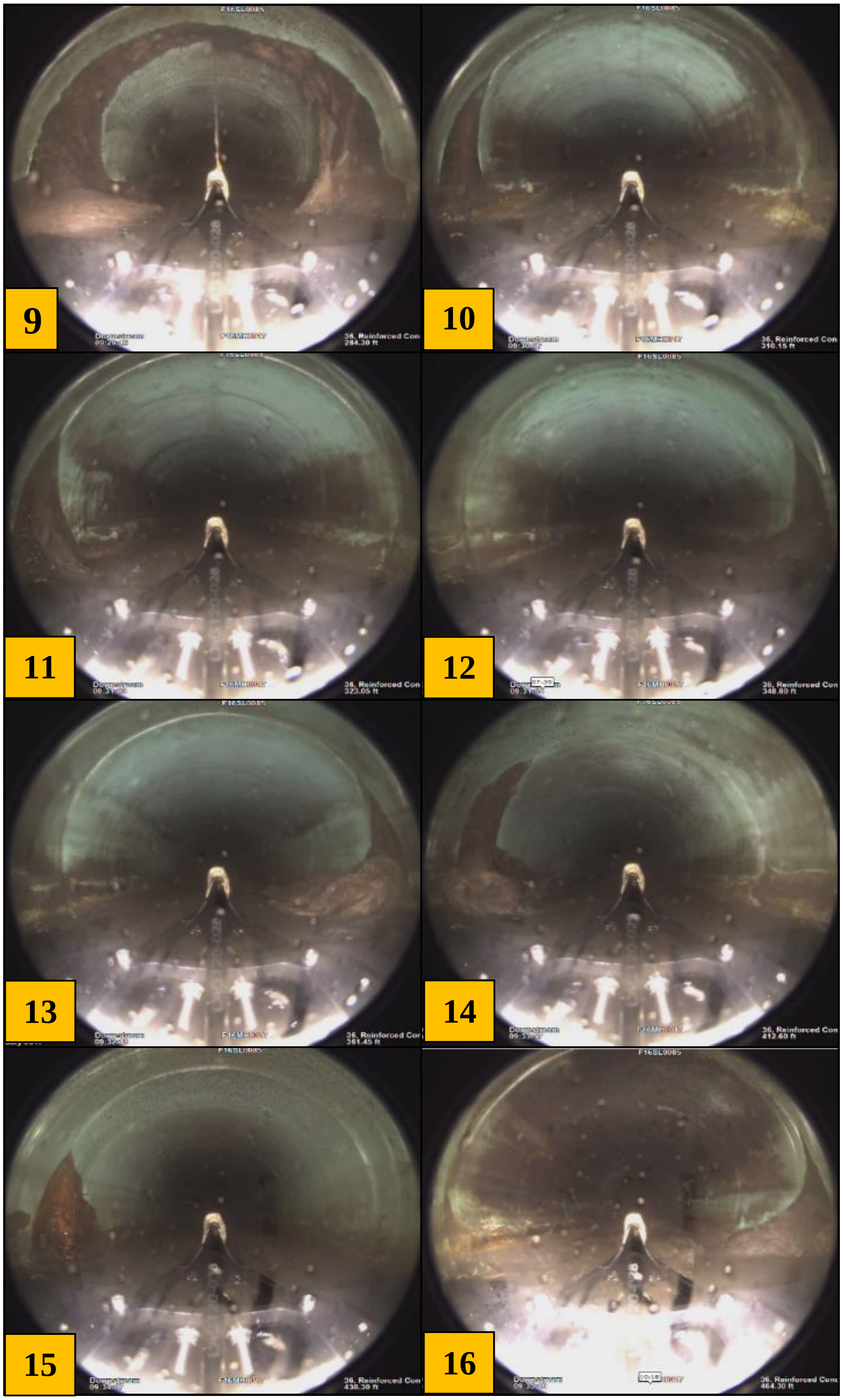


Figure A58-2 images from 9 through 16

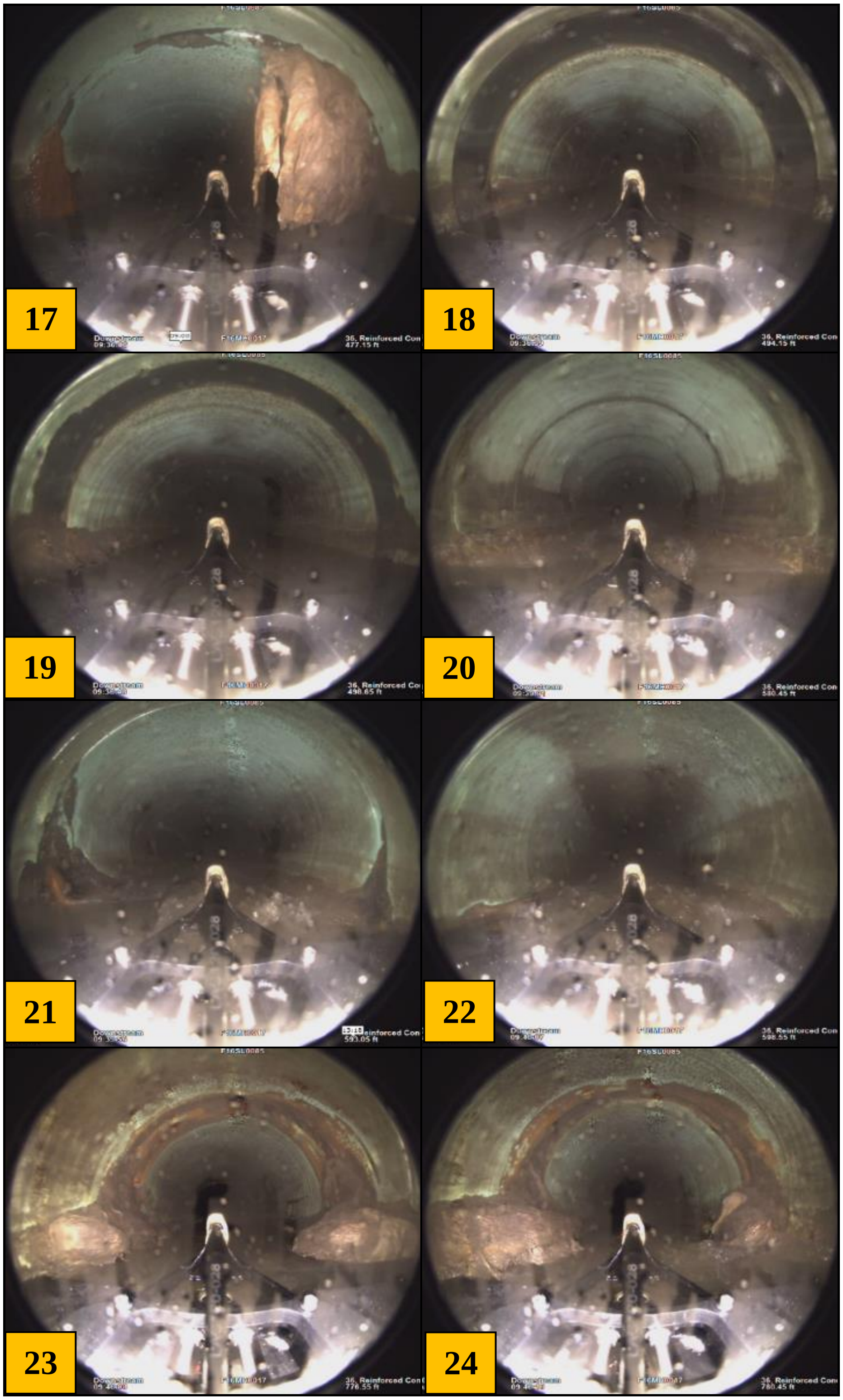


Figure A58-3 images from 17 through 24

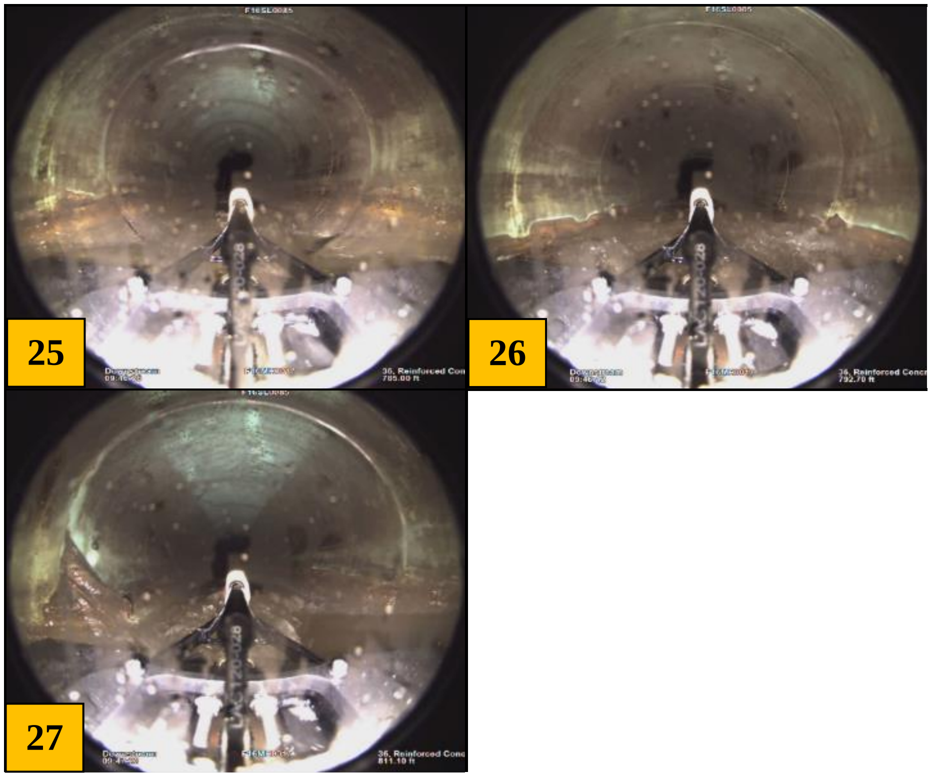


Figure A57-4 images from 25 through 27

Line 59 Summary

Table A59-1 Results Summary of Sewer Line 59

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	307
Percentage of The Line Not Inspected	0 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	8
Total Debris Volume (ft^3)	11.5
Total Deposits Volume (in^3)	26505.2
Maximum Blockage (%)	3.7
Maximum Deposit Height (in)	1.3

Deposit Data

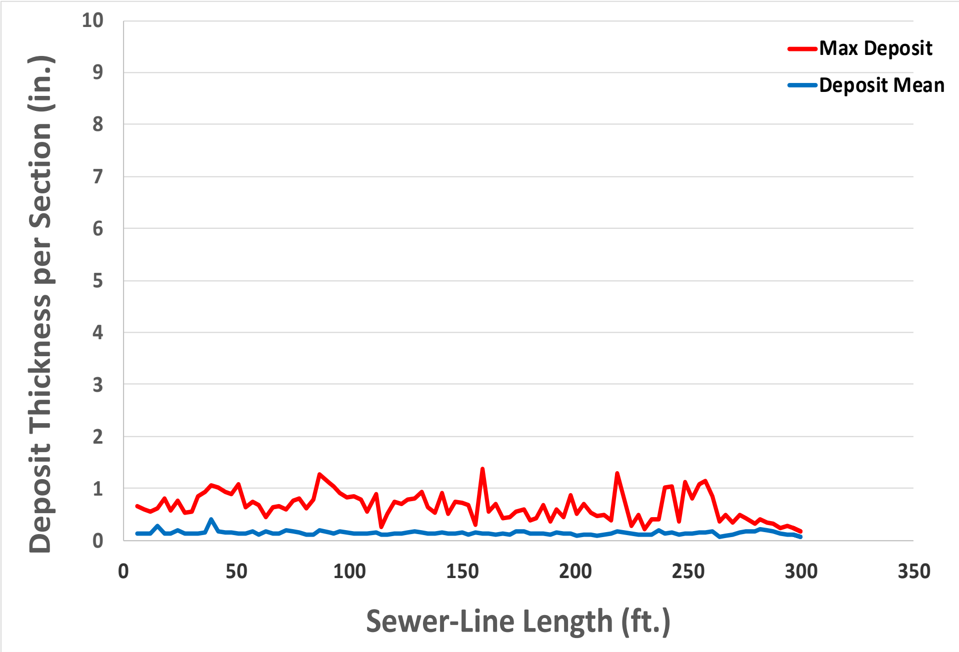


Figure A59-1 Deposit thickness per cross-section

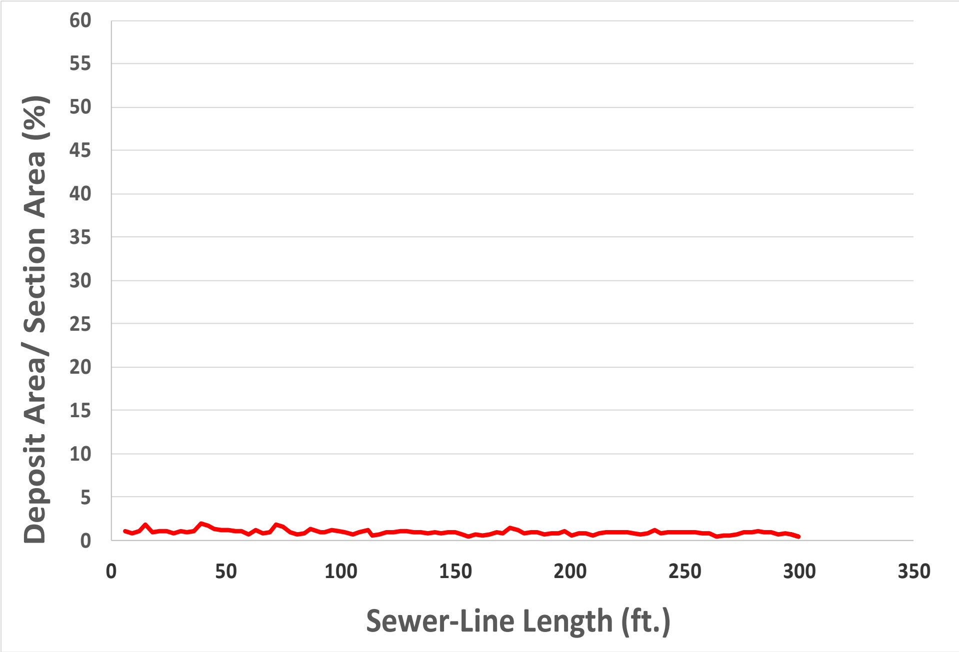


Figure A59-2 Deposit area percentage of the pipe cross section area

Debris Data

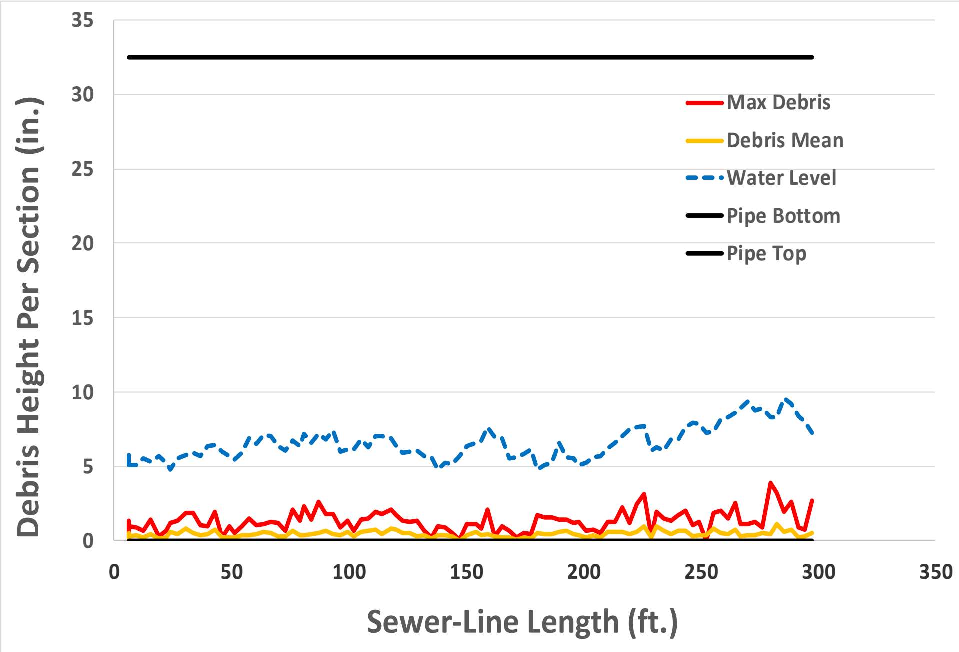


Figure A59-3 Debris height per cross-section

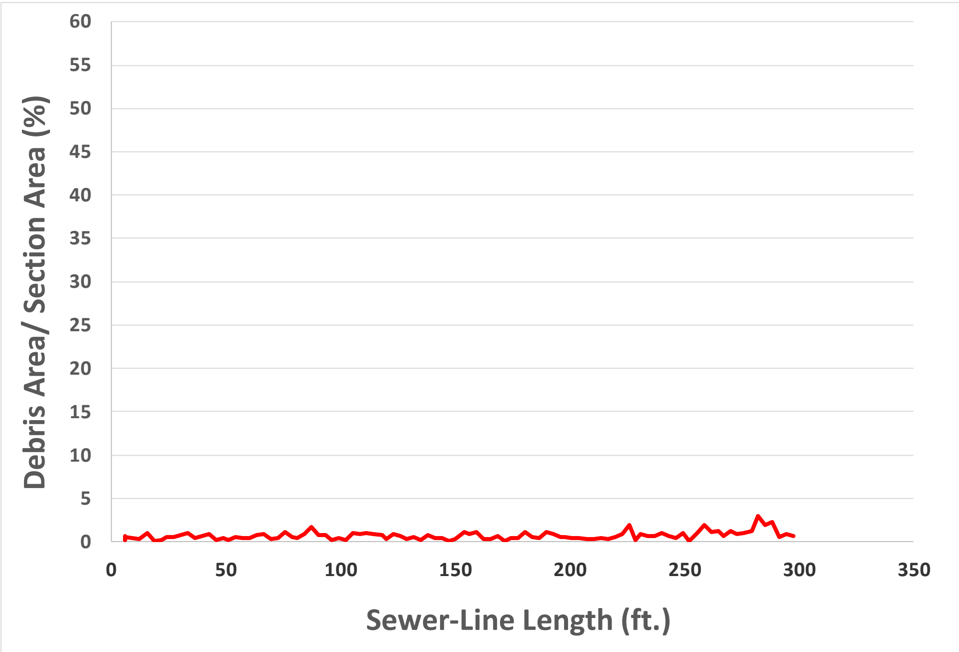


Figure A59-4Debris area percentage of the pipe cross-sectional area

Blockage Data

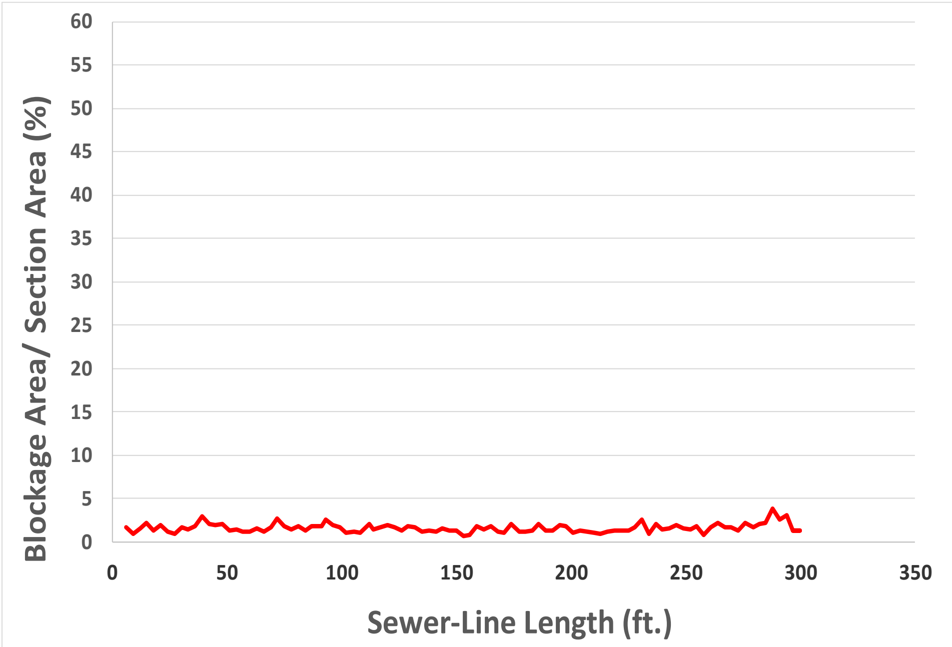


Figure A59-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion Data

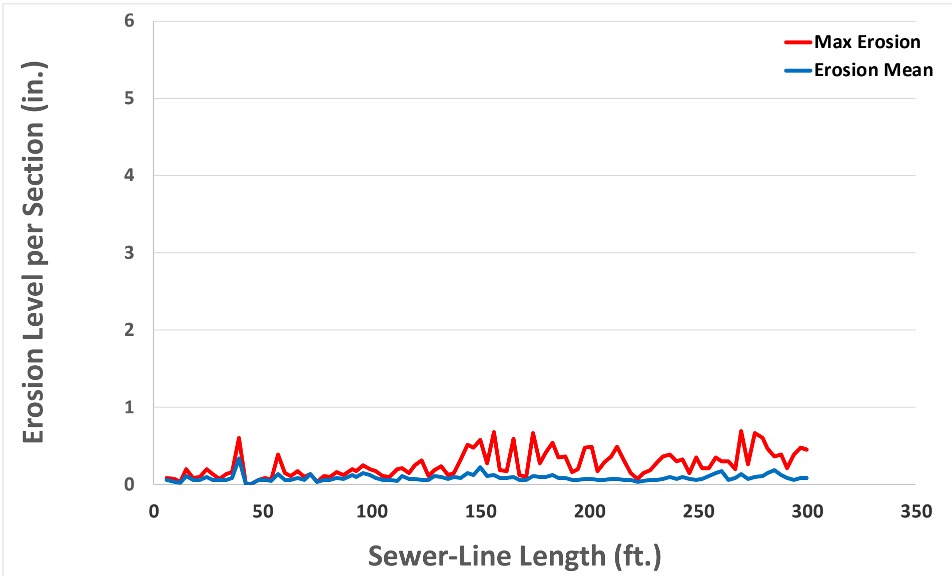


Figure A59-6 Erosion level per cross-section

Table A59-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	F15SL0146	RCP	33	32.5	0.6	0

Visual Observations

Table A59-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	6		MWL				5%					
3	54.5		DAG				5%	J			1	
4	81.5		MWL				10%				2	
5	94.3		DAG				20%	J			3	
6	157.5		MWL				5%				4	
7	207.55		MWL				10%				5	
9	234.45		MWL				5%				6	
10	250		MWL				10%				7	
11	253.05		DAG				20%	J			8	
12	300.8		MSA									

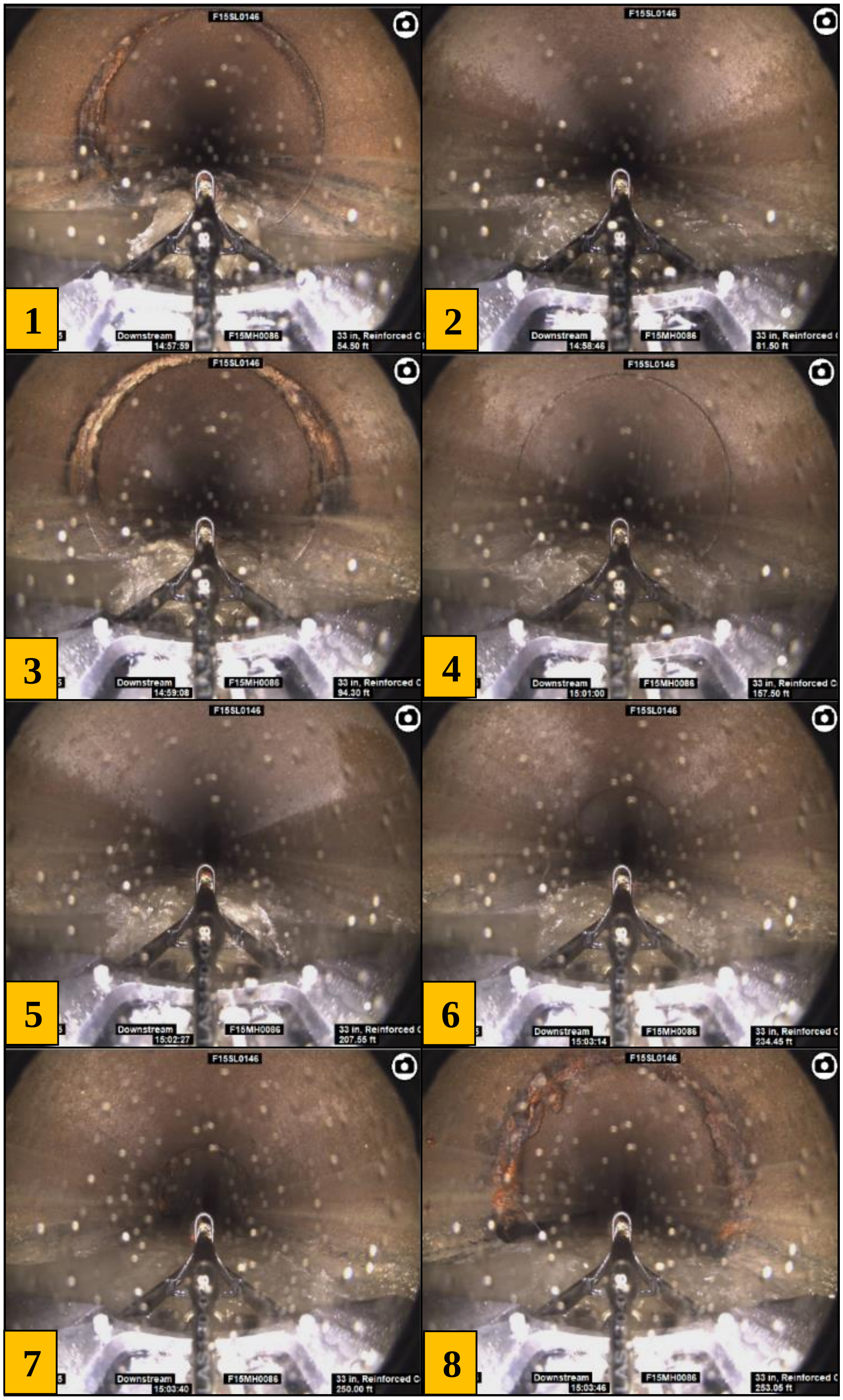


Figure A59-7 images from 1 through 8

Line 60 Summary

Table A60-1 Results Summary of Sewer Line 60

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	289
Percentage of The Line Not Inspected	0 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	7
Total Debris Volume (ft^3)	15.5
Total Deposits Volume (in^3)	34057.9
Maximum Blockage (%)	4.1
Maximum Deposit Height (in)	1.6

Deposit Data

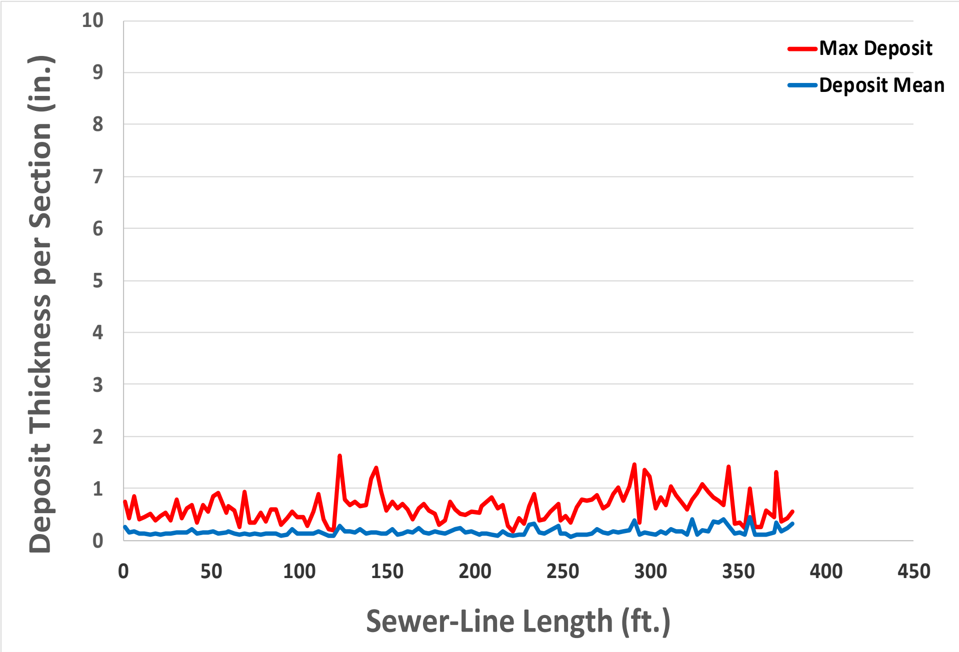


Figure A60-1 Deposit thickness per cross-section

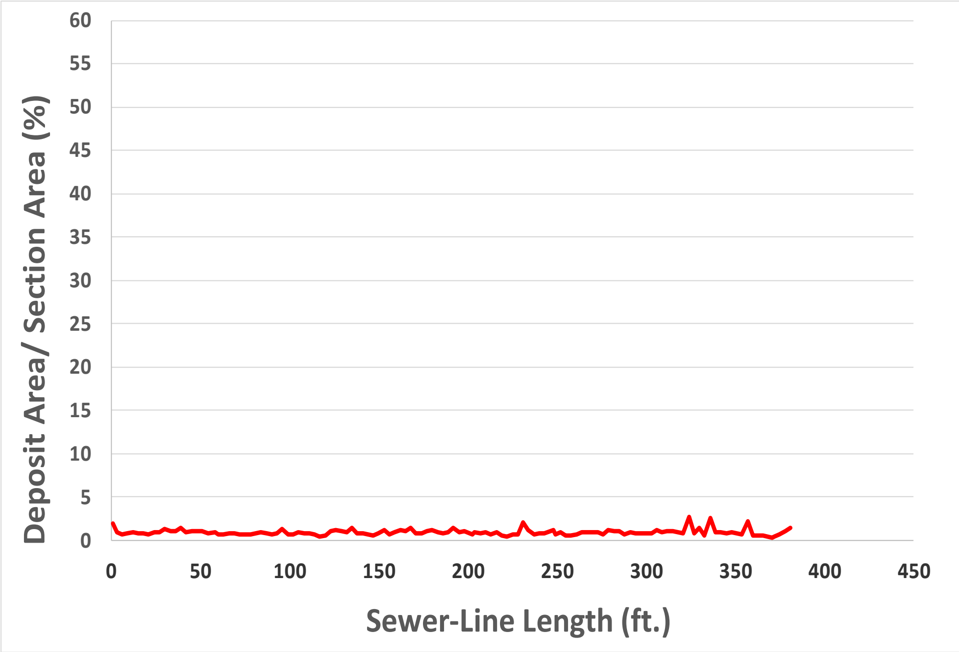


Figure A60-2 Deposit area percentage of the pipe cross section area

Debris Data

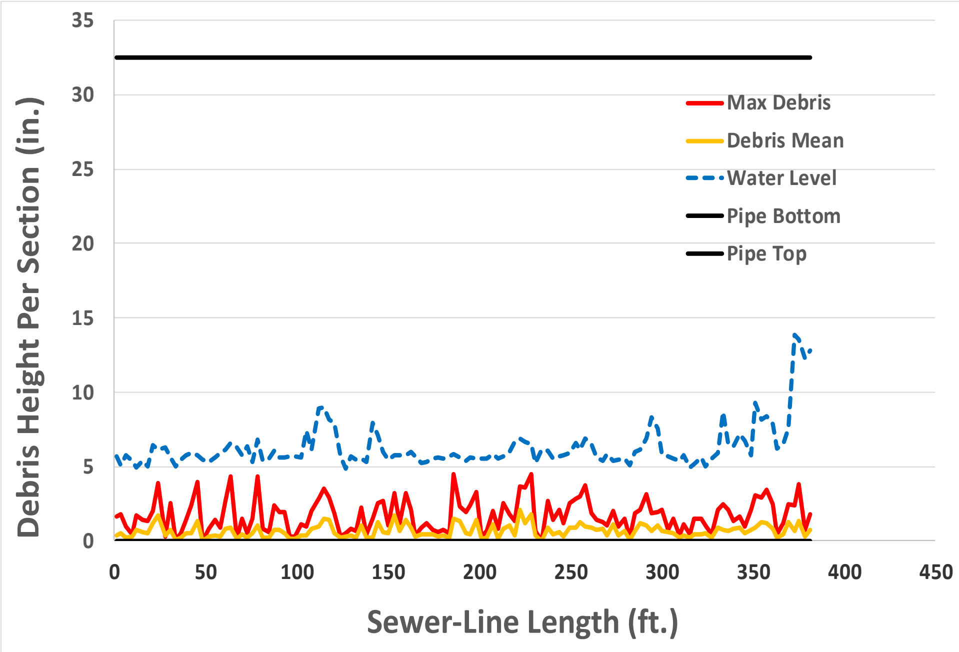


Figure A60-1 Debris height per cross-section

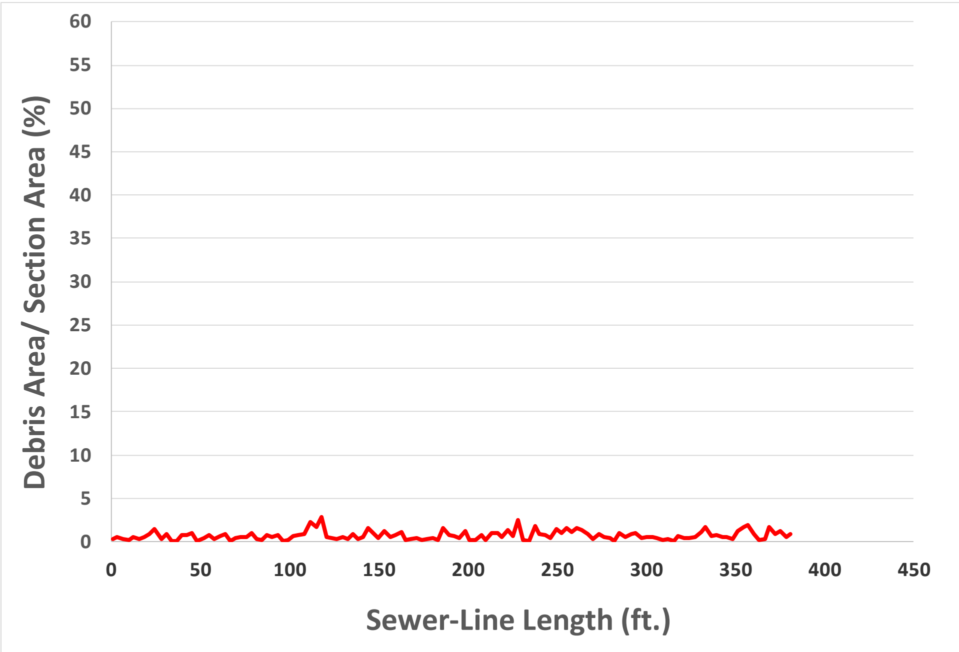


Figure A60-2 Debris area percentage of the pipe cross-sectional area

Blockage Data

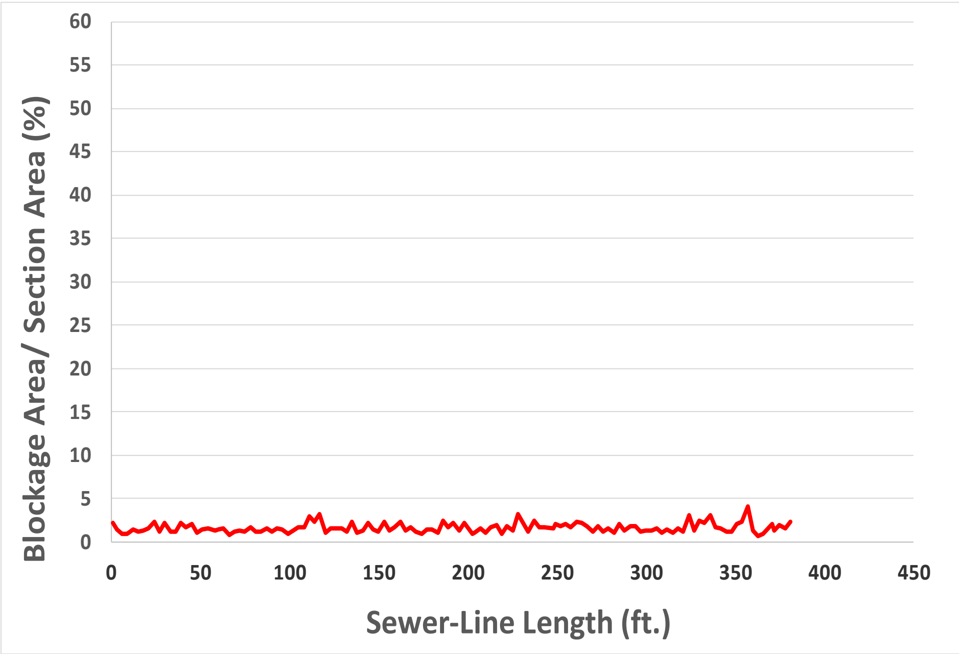


Figure A60-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion data

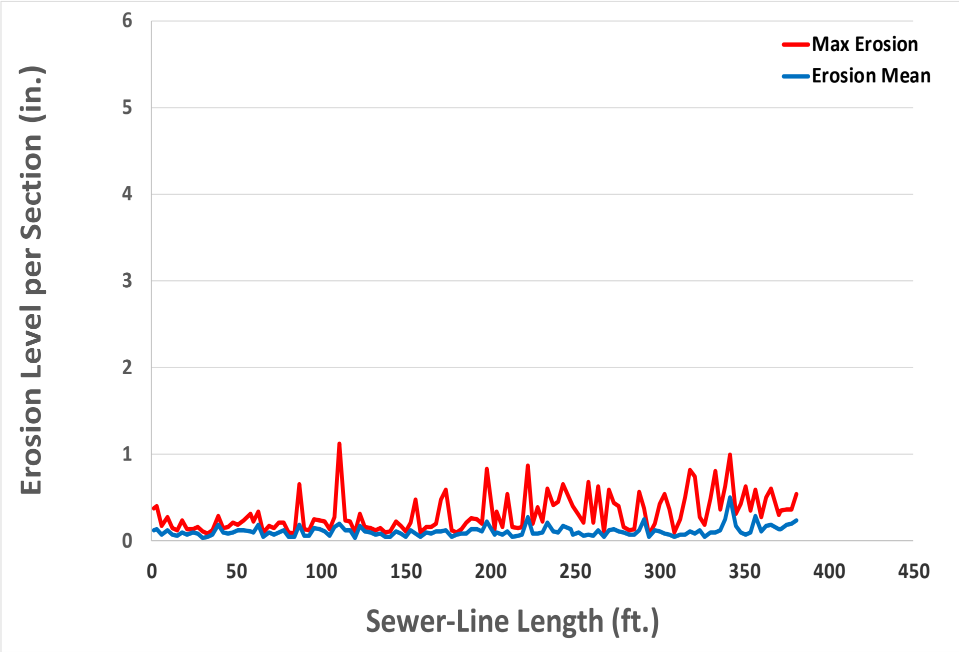


Figure A60-6 Erosion level per cross-section

Table A60-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	F15SL0161	RCP	33	32.5	1.1	0.1

Visual Observations

Table A60-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	1		MWL				5%					
3	110.3		MWL				10%				1	
4	124.9		MWL				5%				2	
5	255.2		MWL				10%				3	
6	269.25		MWL				5%				4	
7	289.85		MWL				10%				5	
8	303.85		MWL				5%				6	
9	326.25		MWL				10%				7	
10	384.8		MSA									

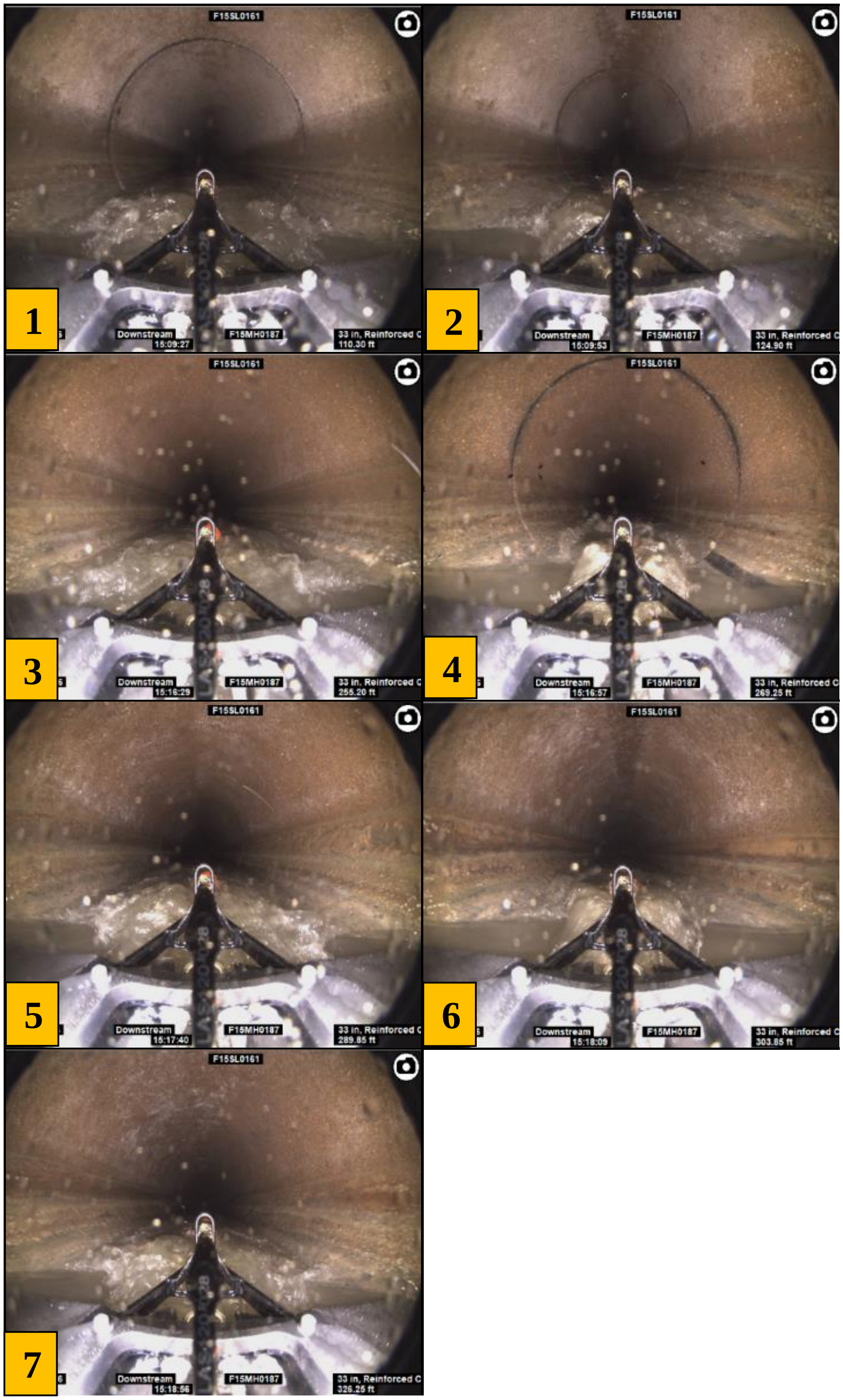


Figure A60-7 images from 1 through 7

Line 61 Summary

Table A61-1 Results Summary of Sewer Line 61

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	62.4
Percentage of The Line Not Inspected	22.2 %
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	1
Total Debris Volume (ft^3)	1.4
Total Deposits Volume (in^3)	6572
Maximum Blockage (%)	2.2
Maximum Deposit Height (in)	1.6

Deposit Data

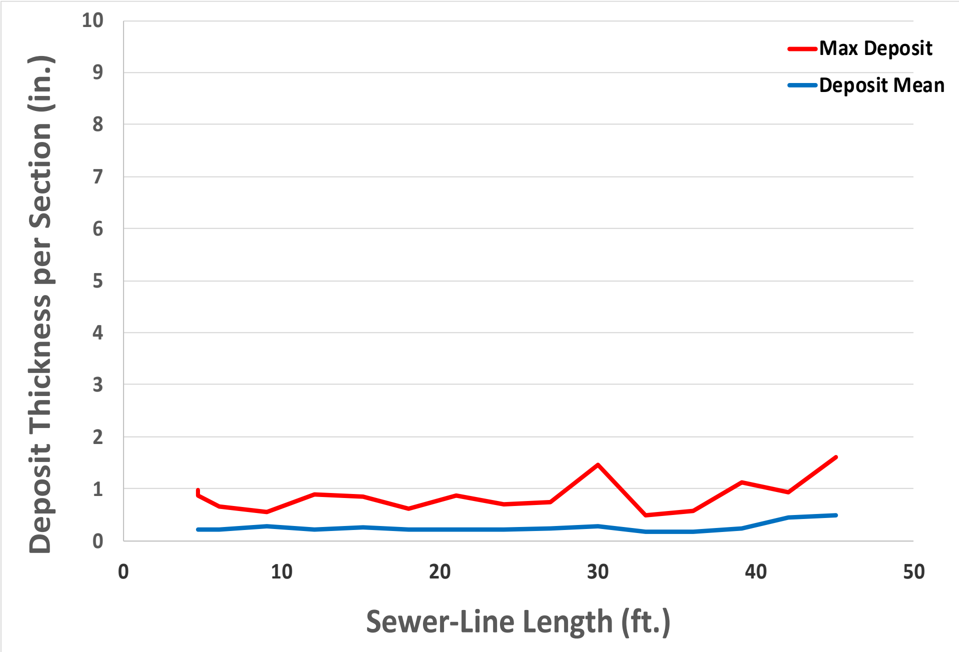


Figure A61-1 Deposit thickness per cross-section

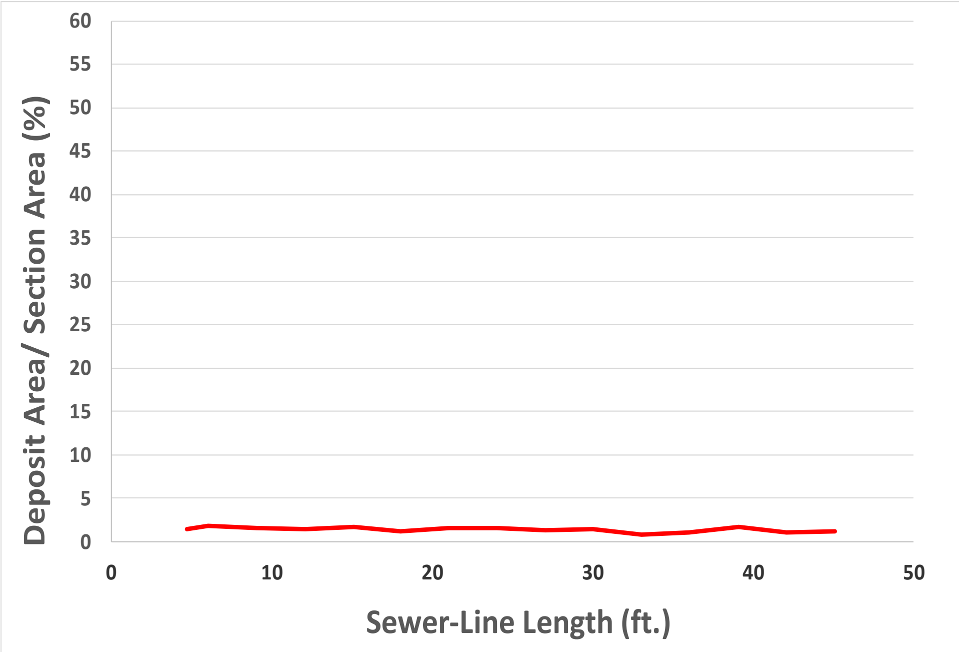


Figure A61-2 Deposit area percentage of the pipe cross section area

Debris Data

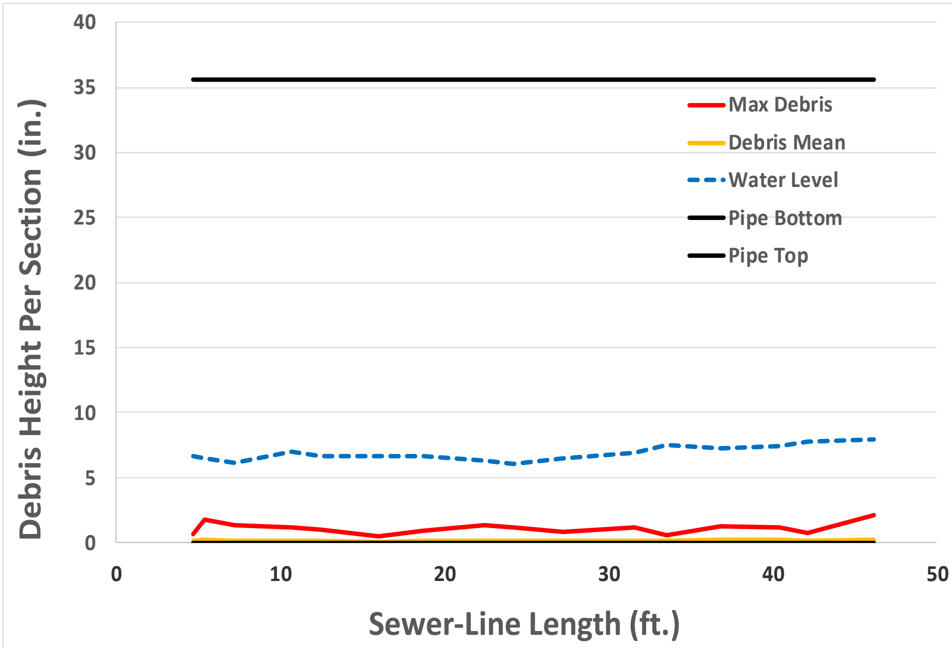


Figure A61-3 Debris height per cross-section

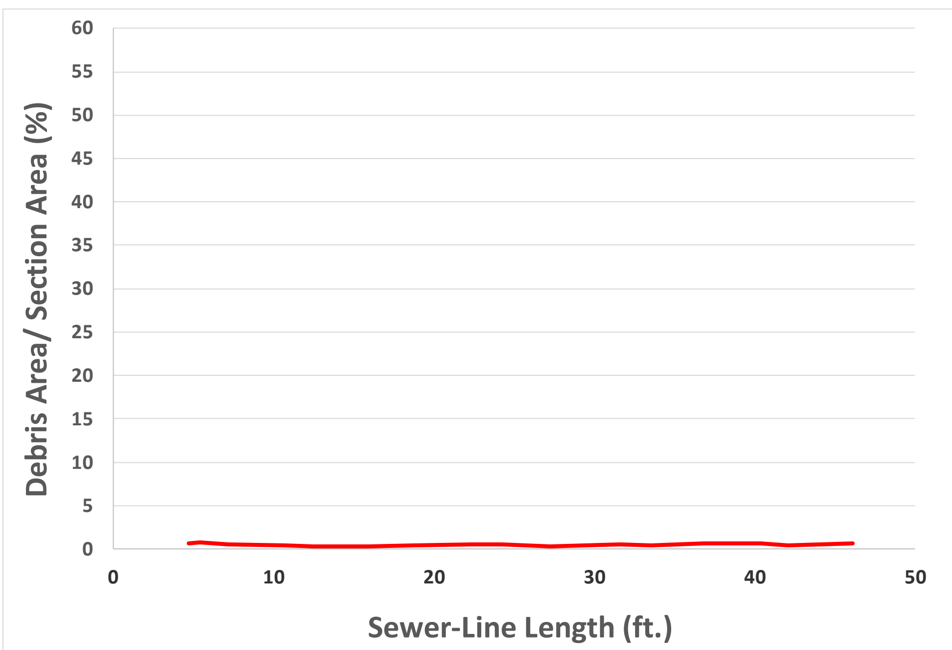


Figure A61-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

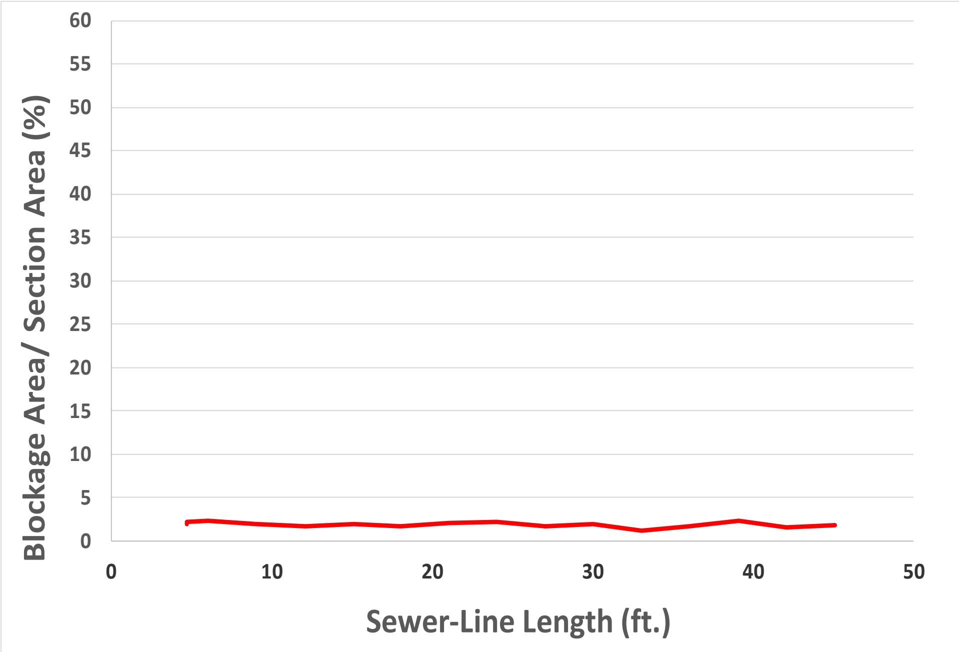


Figure A61-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion Data

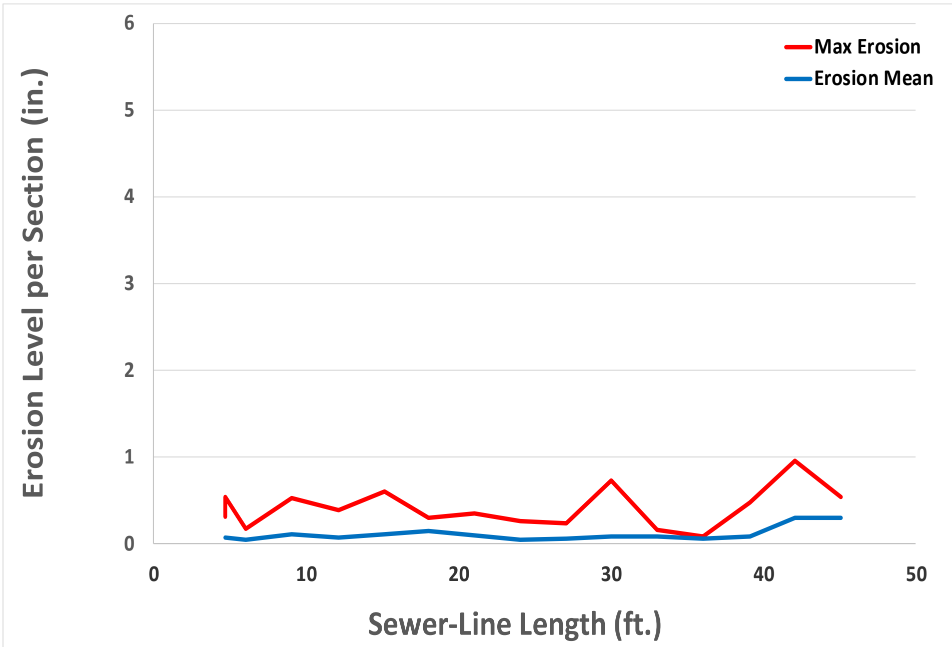


Figure A61-6 Erosion level per cross-section

Table A61-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	F15SL0346	RCP	36	35.6	0.9	0.1

Visual Observations

Table A61-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									NO MUCH DEFECTS
2	0.5		MWL				10%					
3	2.35		DAG				<5%				1	
4	48.5		MSA									

Figure A62-7 image1

Line 62 Summary

Table A62-1 Results Summary of Sewer Line 62

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	117.5
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	0
Total Debris Volume (ft^3)	1
Total Deposits Volume (in^3)	16142.0
Maximum Blockage (%)	3.8
Maximum Deposit Height (in)	1.5

Deposit Data

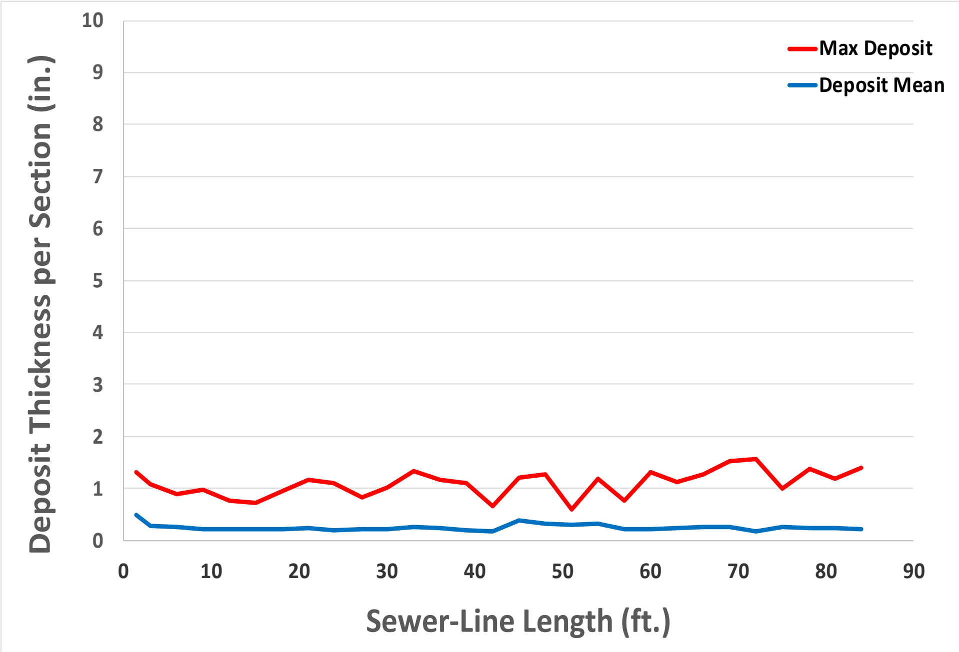


Figure A62-1 Deposit thickness per cross-section

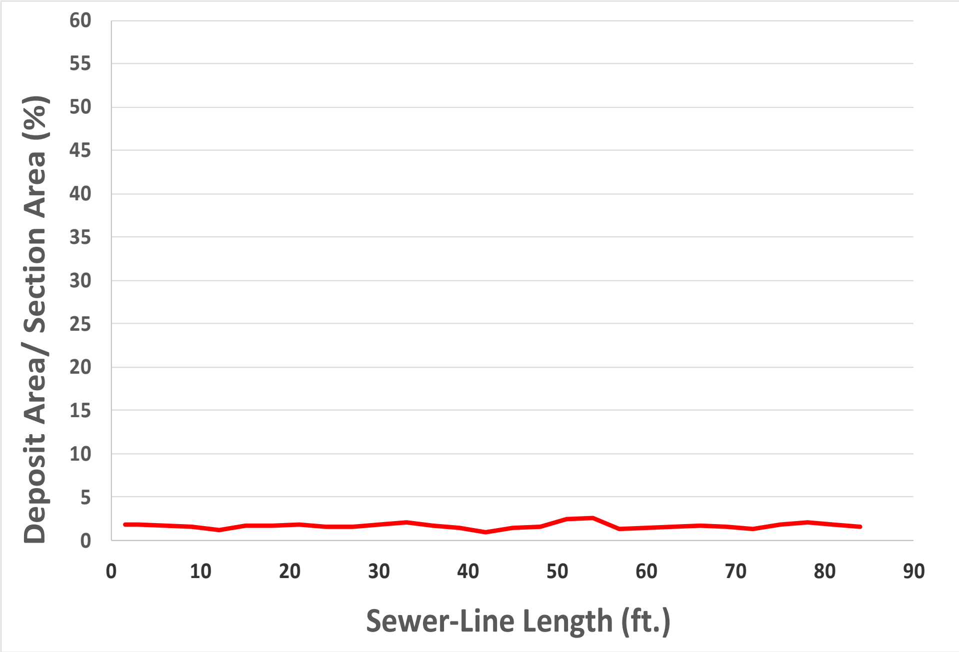


Figure A62-2 Deposit area percentage of the pipe cross section area

Debris Data

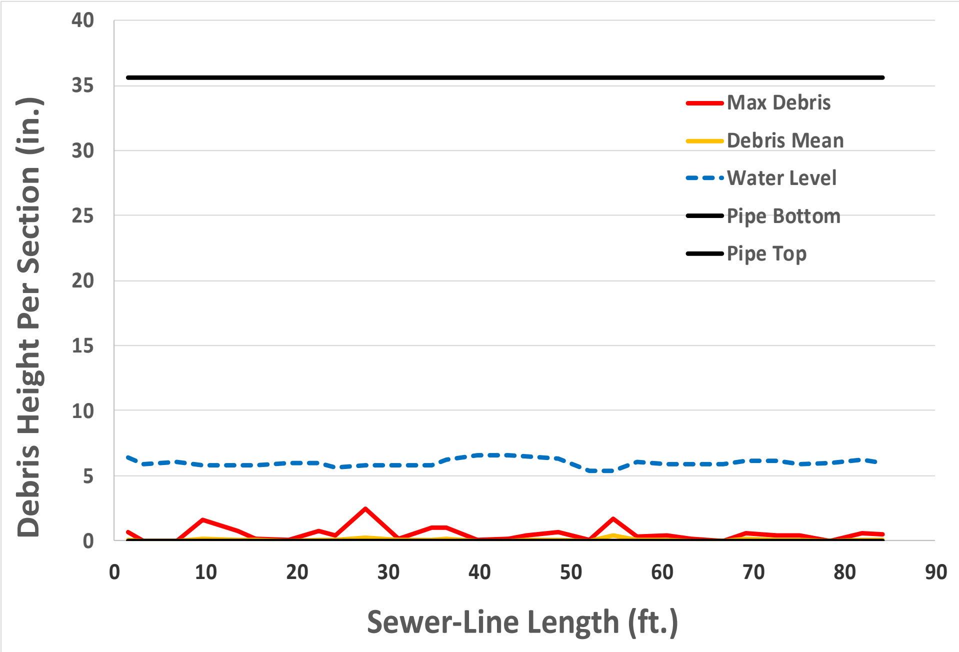


Figure A62-3 Debris height per cross-section

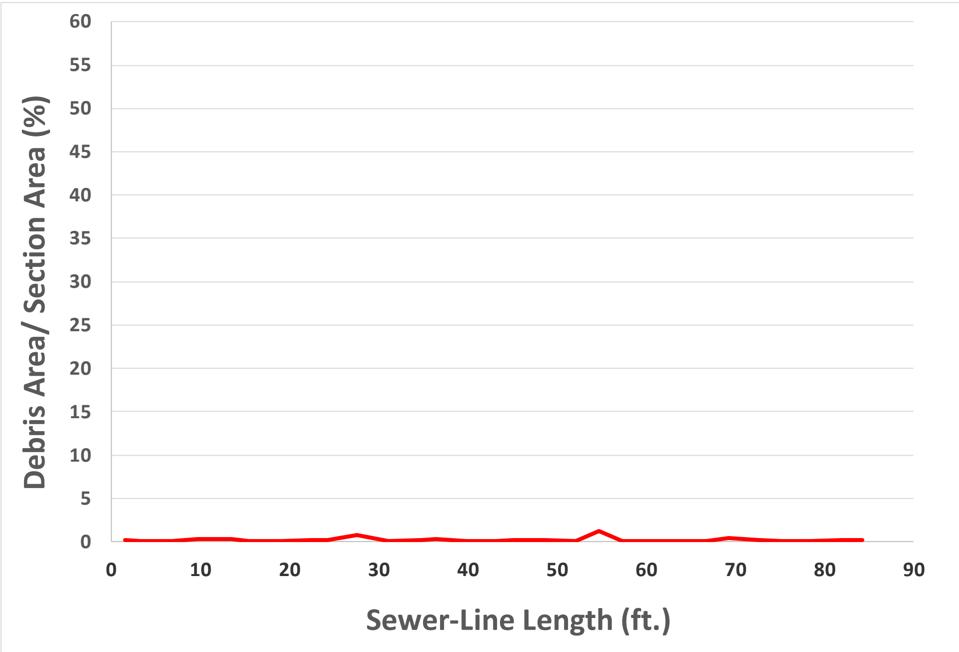


Figure A62-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

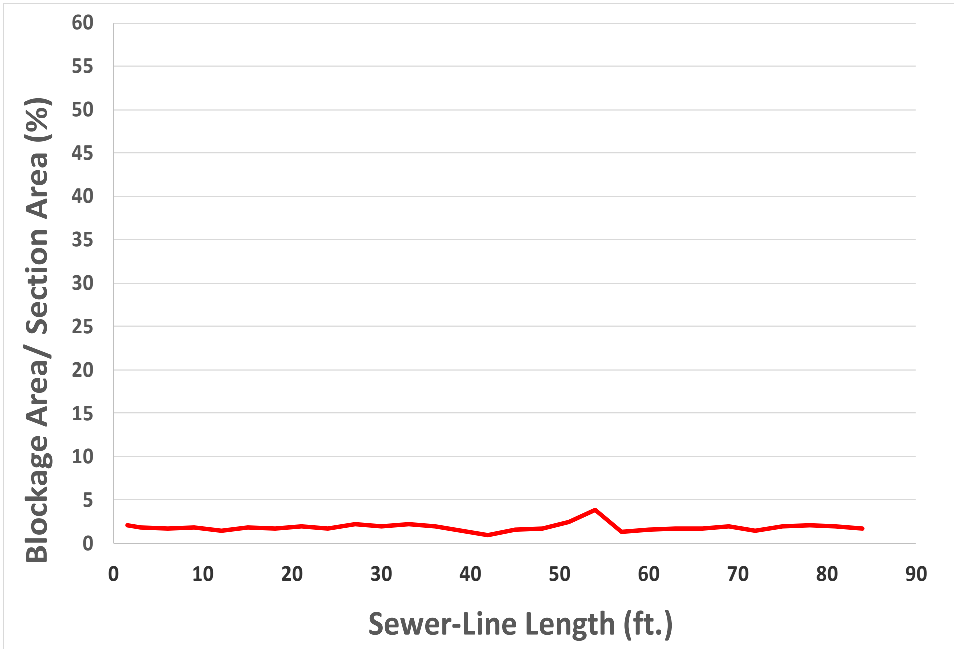


Figure A62-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion Data

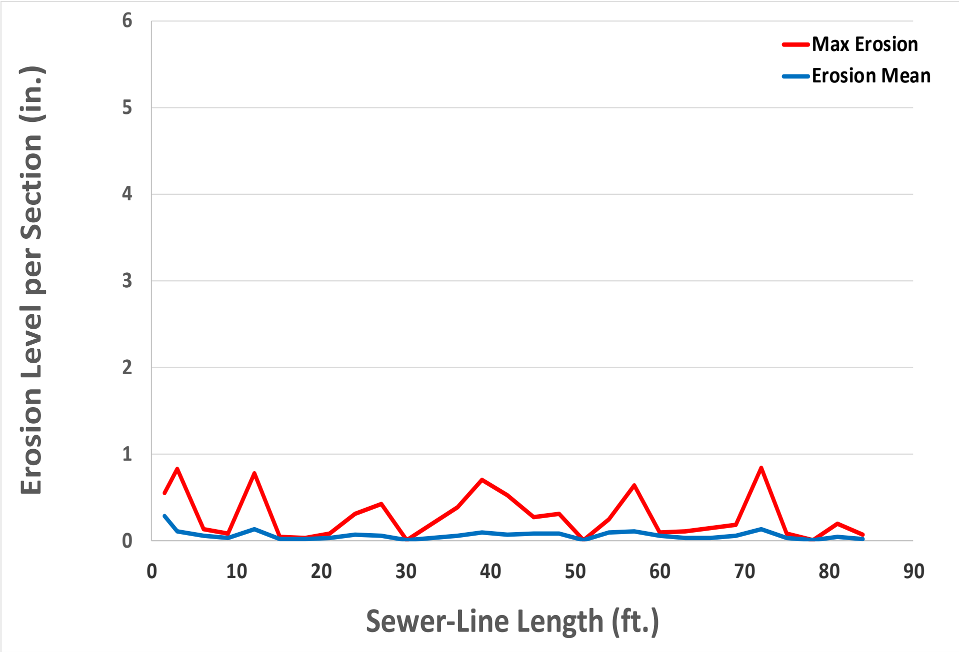


Figure A62-6 Erosion level per cross-section

Table A62-3 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	F15SL0146	RCP	33	32.5	0.6	0

Visual Observations

Table A62-3 Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									NO DEFECTS
2	1.5		MWL				5%					
3	87.4		MSA									

Line 63 Summary

Table A63-1 Results Summary of Sewer Line 63

LINE INSPECTION SUMMARY	
OBSERVATION METRIC	OBSERVATION
Distance Planned (ft.)	360
Percentage of The Line Not Inspected	0%
Total Collapsed	0
Total Fractures Multiple	0
Total Fractures Hinge	0
Total Fractures Longitudinal	0
Total Fractures Circumferential	0
Broken	0
Deformed Rigid	0
Joint Offsets	0
Total Roots Occurrences	0
Level 5 Defects	0
Level 4 Defects	0
Total Defects	11
Total Debris Volume (ft^3)	3.8
Total Deposits Volume (in^3)	40178.1
Maximum Blockage (%)	2
Maximum Deposit Height (in)	1.5

Deposit Data

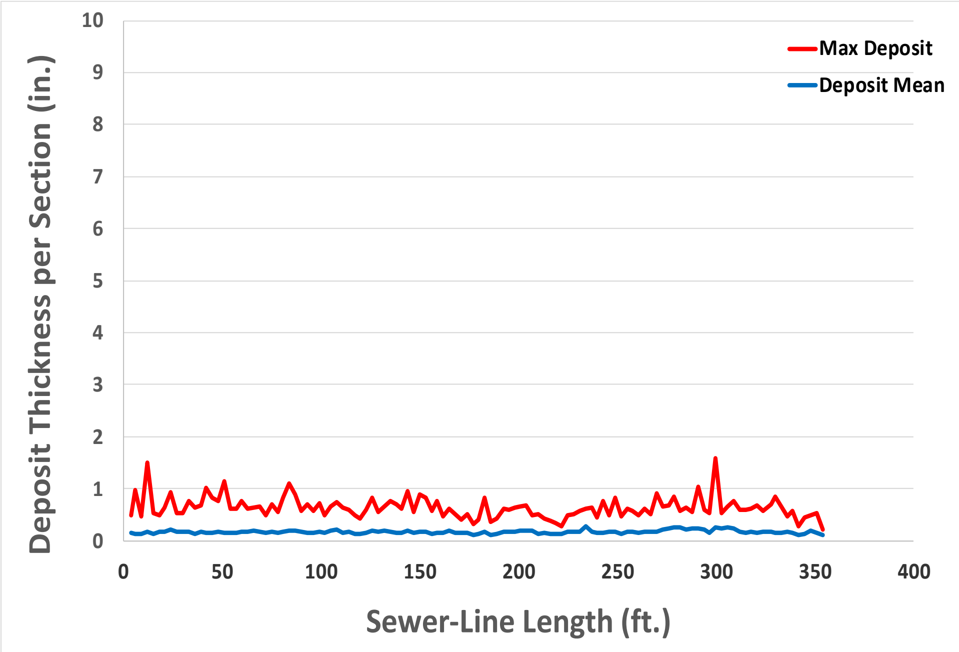


Figure A63-1 Deposit thickness per cross-section

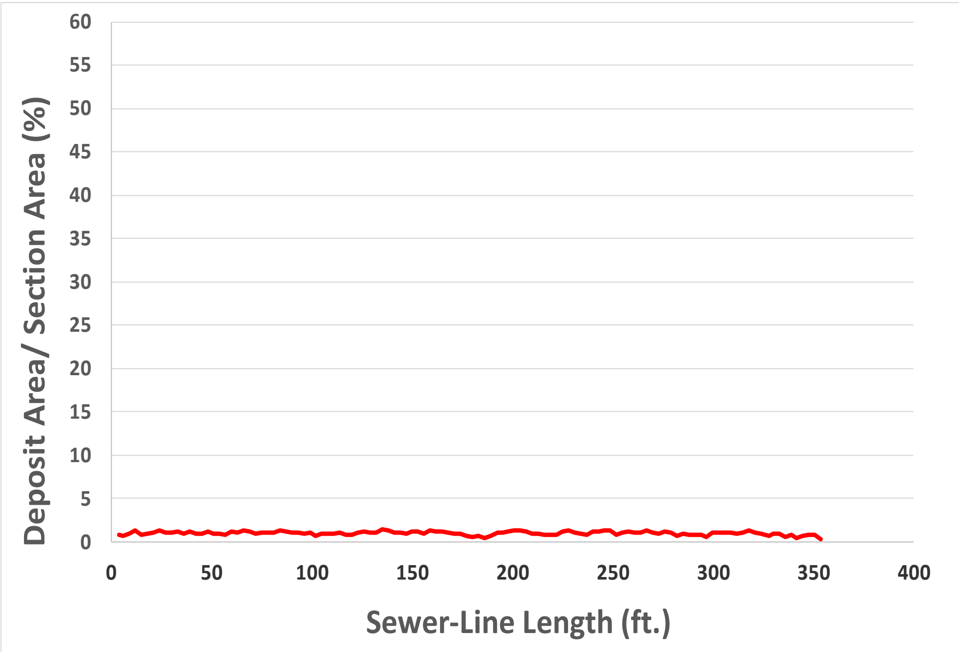


Figure A63-2 Deposit area percentage of the pipe cross section area

Debris Data

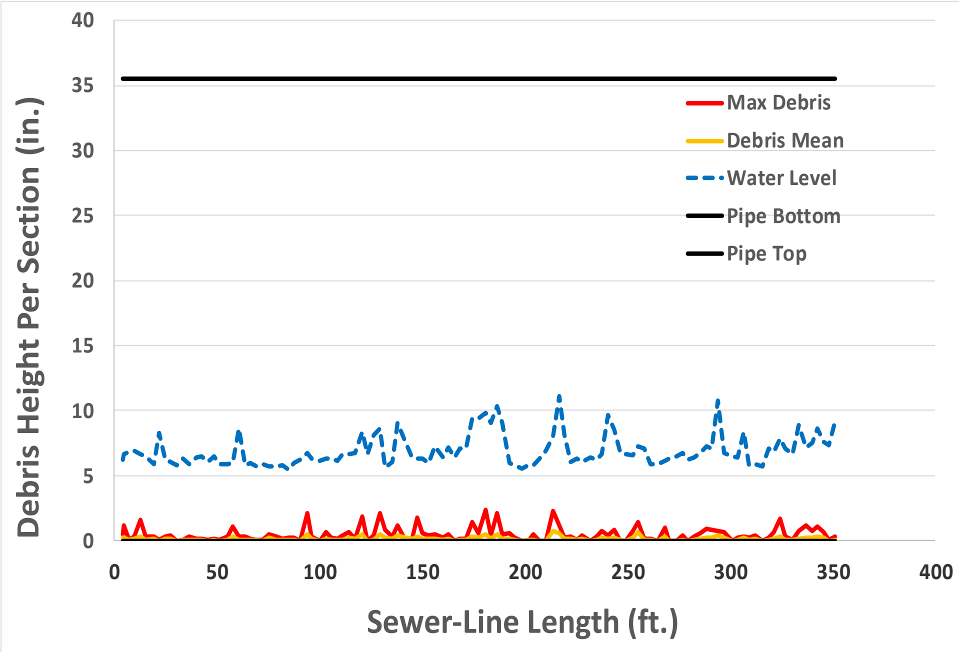


Figure A63-3 Debris height per cross-section

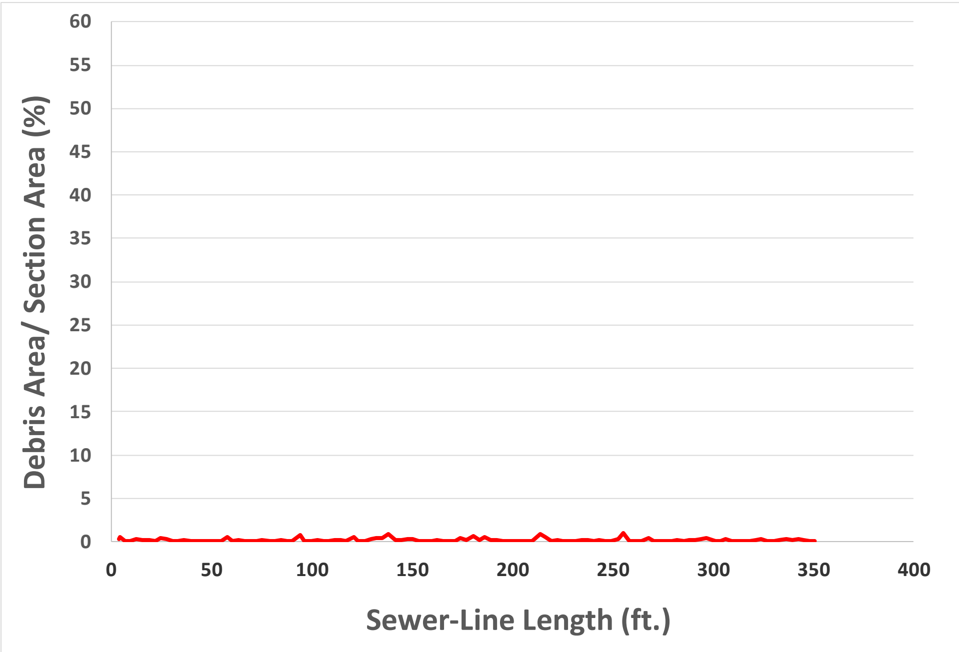


Figure A63-4 Debris area percentage of the pipe cross-sectional area

Blockage Data

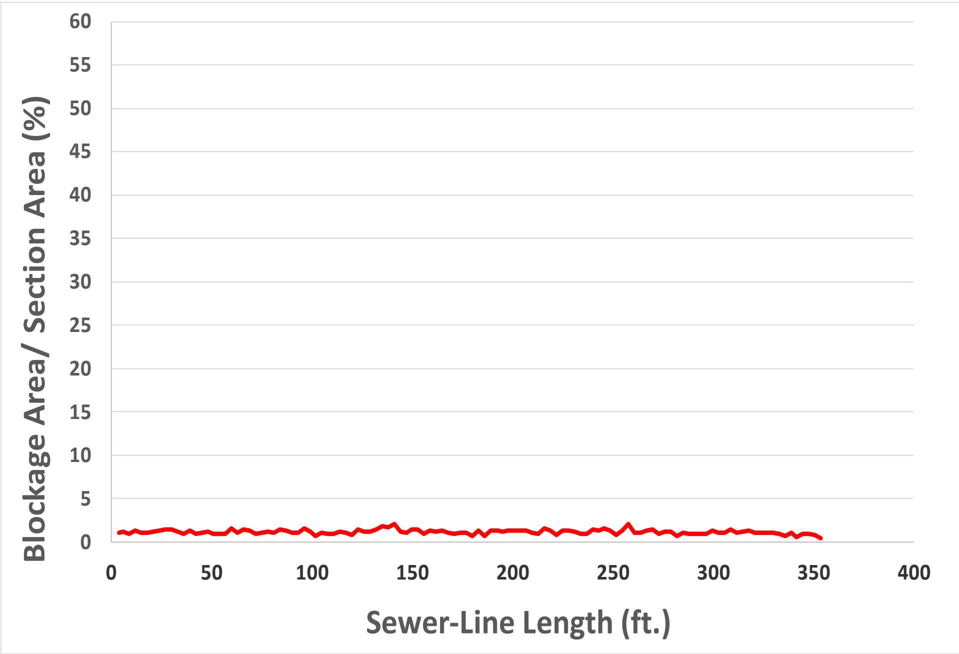


Figure A63-5 Blockage area (deposits and debris areas) percentage of pipe cross section area

Erosion Data

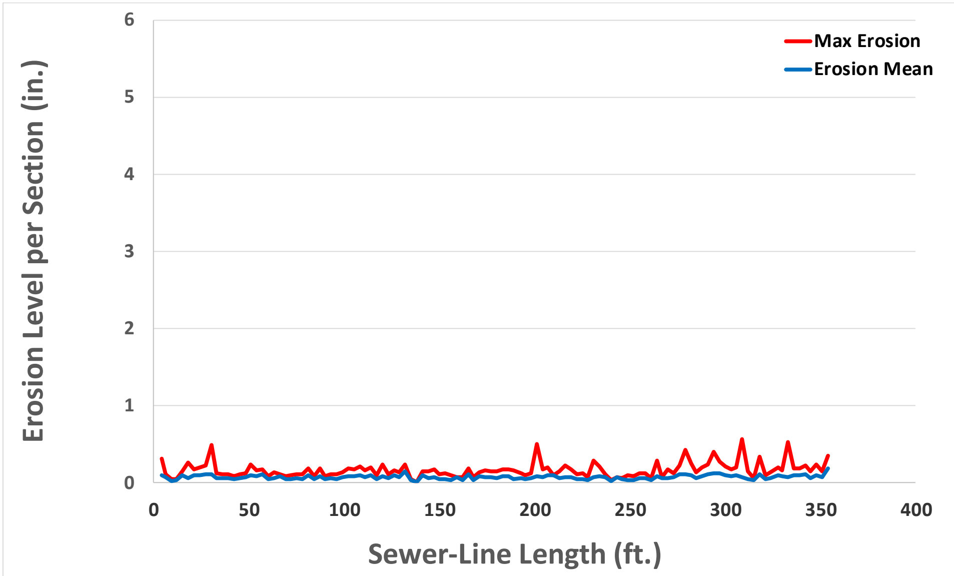


Figure A63-6 Erosion level per cross-section

Table A63-2 Erosion observations

Rank	Line ID	Observed Pipe Material	GIS Pipe Diameter (inches)	Observed Pipe Diameter (inches)	Approx. Max Erosion (Inches)	Approx. Mean Pipe Erosion (inches)
1	F15SL0146	RCP	33	32.5	0.6	0

Visual Observations

Table A63-3Visual inspection observations

SN	Distance (feet)	Video Ref.	Code	Continuous Defect	Value			Joint	Circumferential Location		Img Reference	Remarks
			Group/ Descriptor/ Modifier		Dimension		%		At/ From	To		
					1st	2nd						
1	0		AMH									
2	2.5		MWL				5%					
3	118.75		MWL				10%				1	
4	128.55		MWL				5%				2	
5	169.45		MWL				10%				3	
6	195.4		MWL				5%				4	
7	212.7		MWL				10%				5	
8	226.35		MWL				5%				6	
9	240.6		MWL				10%				7	
10	265.4		MWL				5%				8	
11	287.85		MWL				10%				9	
12	311.75		MWL				5%				10	
13	321.25		MWL				10%				11	
14	356.3		MSA									

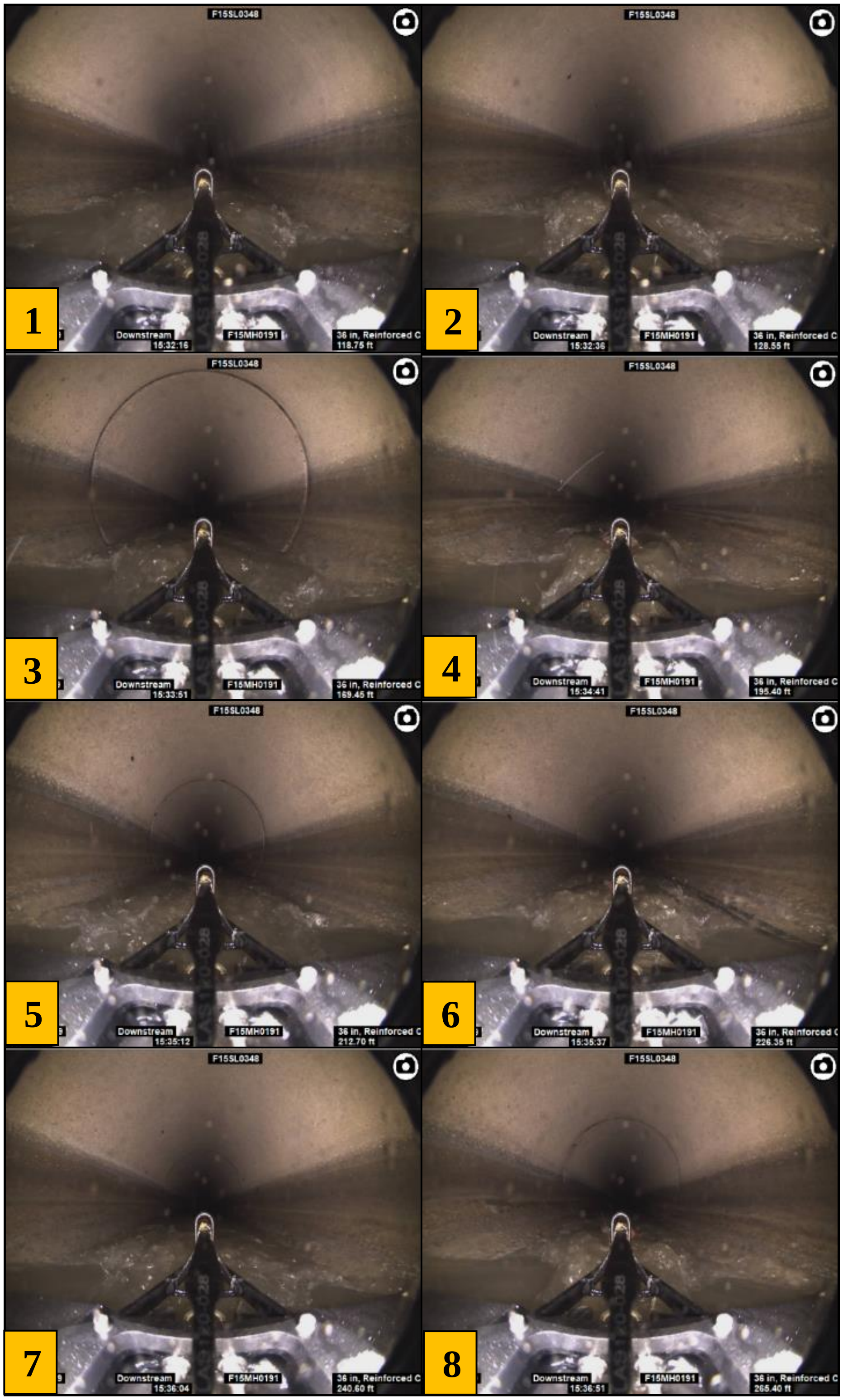


Figure A63-1 images from 1 through 8

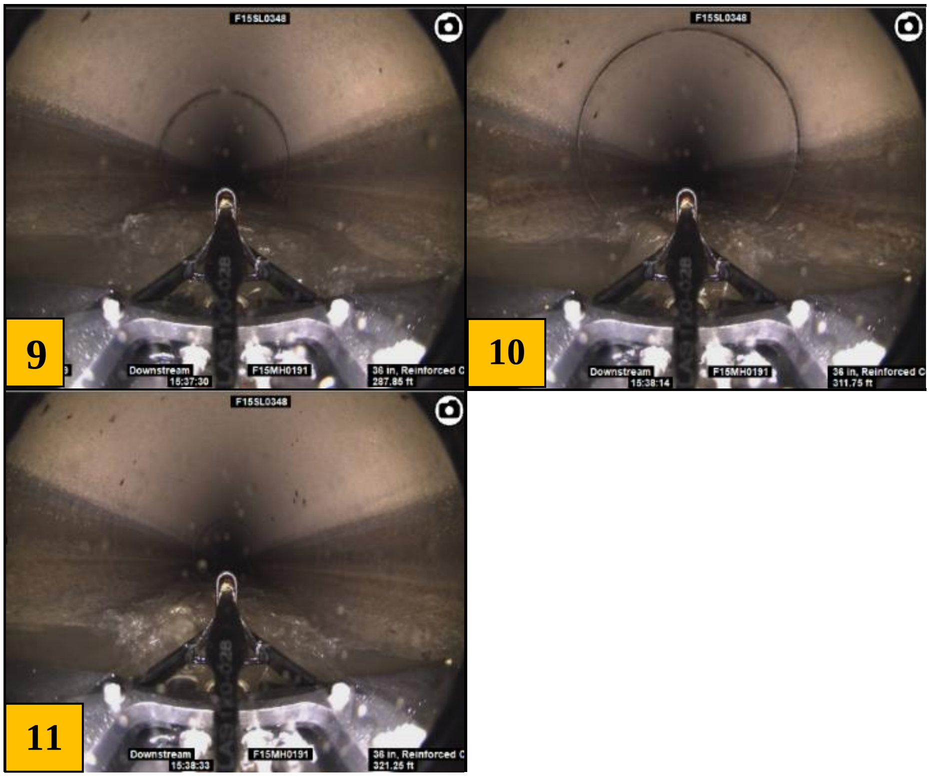


Figure A63-2 images from 9 through 11

Appendix B

Standard Operating Procedure (SOP)

MSI Equipment Assembly and Preparation

1) Have each person collect the needed items from the Morning Equipment Checklist and follow the initial instructions for their position unless otherwise specified by the crew chief or project manager.
2) Tagging the float from both sides will be necessary if there are several bends greater than 30 degree, there is low flow, not all manholes were located, or there are any other unknowns that could lead to the float becoming snagged. The float can be used with a single tag and a drift anchored for straight deployments with known manholes and a low probability of issues arising.
3) Winch 1
   a) During a morning briefing, go over any safety concerns, areas for improvement, specifics about the current deployment, and answer any questions related to the deployment. Make sure that everyone is on the same page before everyone begins their respective tasks.
   b) If a double tag deployment is chosen
      i) Go to the upstream manhole with all items outlined in the Morning Equipment Checklist
      ii) Set out a box of gloves, the field binder, and a trash bag
      iii) Install the pendent and turn on the generator
      iv) Check the winch to make sure it is set to the right settings.
      v) Assemble the counter bracket and run the plasma cable through the counter toward the manhole
      vi) Run the cable through the upstream end of the tiger tail
      vii) Tie the drift anchored to the cable using a bowline knot

viii) Set up the computer and connect it to the counter. This is to get an accurate known distance for the deployment phase

ix) Test the manhole for gasses and open the manhole

x) Insert the drift anchor and make sure it is catching the flow

xi) Insert the tiger tail and tie it off

xii) Begin sending the cable downstream as fast as the flow will allow.

xiii) Install the manhole pulley

xiv) The cable can be feed hand over hand into the manhole to help maintain speed. Tug on the manhole side of the cable periodically to make sure that the flow is effectively pulling the drift anchor and that it has not become snagged. As more cable is fed into the manhole, the hand over hand feeding will become less necessary. After this point continue to watch and tug on the line to ensure that the cable is still moving with the flow.

xv) Periodically provide an estimate time that the drift anchor will arrive to the downstream winch operator

xvi) Once the downstream wench has spotted the drift anchor, they will call an all stop and communicate with the upstream wench to aid in the drift anchor's retrieval. Copy the total deployment footage down when the all stop is called.

xvii) Once Winch 2 calls to pay in cable slowly, pay in at 20 to 30.

xviii) Monitor the line tension. If the line becomes too tight, the truck suspension will move. If the tension continues the winch will e-fail. If an e-fail occurs, reset the winch after calling an all stop. If too much tension occurs, call an all stop. The best practice is to call an all stop before the e-fail occurs. Communicate with Winch 2 to determine the problem

xix) If the wenches are operating smoothly communicate with Winch 2 and then speed up. This process can be running at up to 100 at the operators deaccession.

xx) Slow Winch 1 to a stop when the knot is visible. Pull in enough slack to work with from Winch 2 before stopping completely.

xxi) Close out of HDComms and reopen to program the pod. Use a battery that will not be used during the inspection to program the pod.

(1) Enter the following Information to program the pod:

(a) Project Name

(b) Inspection number

(c) Deployment number

(d) Start manhole identification

(e) End manhole identification

(f) Footage

(g) Conditions (dry, rain)

(h) Pipe size – always input a larger value than the expected largest pipe's OD

(i) Pipe type

(j) The inspection sensors to be used

(k) Press the green arrow

(l) Check the entered information – delete and re-enter if needed

(m) Make sure "Feet" not "Meters" is listed

(2) Give the pod to Float Support for installation

xxii) Remove the tiger tail leaving it still tied off to the same location

xxiii) Remove the manhole pulley

xxiv) Securely tie the Winch 2 line off near the manhole and then untie both cables from each other.

xxv) Tie the Winch 2 cable to the float using a bowline knot.

xxvi) Thread the Winch 1 cable through the tiger tail from its upstream side and tie the cable to the back end of the float using a bowline knot.

c) If a single tag deployment is chosen

i) Go to the upstream manhole with all items outlined in the Morning Equipment Checklist

ii) Set out a box of gloves, the field binder, and a trash bag

iii) Install the pendent and turn on the generator

iv) Check the winch to make sure it is set to the right settings.

v) Assemble the counter bracket and run the plasma cable through the counter toward the manhole

vi) Run the cable through the upstream end of the tiger tail

vii) Set up the computer and connect it to the counter.

viii) Test the manhole for gasses and open the manhole

ix) Open HDComms to program the pod. Use a battery that will not be used during the inspection to program the pod.

(1) Enter the following Information to program the pod:

(a) Project Name

(b) Inspection number

(c) Deployment number

(d) Start manhole identification

(e) End manhole identification

(f) Footage

(g) Conditions (dry, rain)

(h) Pipe size – always input a larger value than the expected largest pipe's OD

(i) Pipe type

(j) The inspection sensors to be used

(k) Press the green arrow

(l) Check the entered information – delete and re-enter if needed

(m) Make sure "Feet" not "Meters" is listed

(2) Give the pod to Float Support for installation

x) Thread the Winch 1 cable through the tiger tail from its upstream side and tie the cable to the back end of the float using a bowline knot.

xi) Attach an approximately 10' length of cable to the front of the float using a bowline knot. Tie the drift anchor to this cable and whined the cable around it.

xii) Tuck the drift anchor into the side of the camera guard.

4) Winch 2

a) If a double tag deployment is chosen

i) Go to the downstream manhole with all items outlined in the Morning Equipment Checklist

ii) Set out a box of gloves, the field binder, and a trash bag

iii) Set out the reaming equipment so that it can be easily accessible

iv) Install the pendent

v) Install the pendent and turn on the generator

vi) Check the winch to make sure it is set to the right settings

vii) Test the manhole for gasses and open the manhole

viii) Monitor the manhole for the drift anchor

ix) Once the drift anchor is spotted, call an all stop.

x) Communicate with Winch 1 to move the drift anchor into a position where it can be captured by the grappling hook.

xi) Once the drift anchor is captured, have Winch 1 pay out until enough of the cable has been retrieved and then call an all stop.

xii) Slide the tiger tail down the Winch 1 cable. Once in place, tie off the tiger tail.

xiii) Tie both Winch 1 and Winch 2 cables together using two bowline knots.

xiv) Set the Winch 2 to free spin.

xv) Install the manhole pulley.

xvi) Tell Winch 1 to pay in line slowly. Verify that there is not too much tension on the line and that Winch 2 is paying out in accordance with free spin.

xvii) Once satisfied that the cable retrieval is progressing as planned, ask Winch 1 to increase speed.

xviii) Continue monitoring the tension.

xix) Once Winch 1 has the knot they will call. Set the winch for normal operation and remain in an all stop mode until insertion is complete. The line may become slack. This is OK.

b) If a single tag deployment is chosen

i) Go to the downstream manhole with all items outlined in the Morning Equipment Checklist that apply to a single deployment

ii) Set out a box of gloves, the field binder, and a trash bag

iii) Set out the reaming equipment so that it can be easily accessible

iv) Test the manhole for gasses and open the manhole

v) Monitor the manhole for the drift anchor

5) Confined Space Supervisor

a) Supervise and support all positions as they collect their respective items from the Morning Equipment Checklist. Make a note of anything that is missing or will soon be running out. Report these Items to Kevin at the end of the day. Help staff members with any questions that they have and verify that everything from the checklist has been collected.

b) Drive the Entrant, Confined Space Support, and Float Support to Winch 1.

c) Support and guide the set-up process for the float and confined space entry.

d) Verify that the confined space equipment has been set up properly before entry

6) Entrant

a) Verify that the tanks are pressurized

b) Go to the upstream manhole with all items outlined in the Morning Equipment Checklist using the gator along with Float Support, Confined Space Support, and the Confined Space Supervisor

c) Prepare for the confined space entry and help with the set-up of the confined space equipment

d) Verify that the confined space equipment has been set up properly before entry

7) Confined Space Support

a) Go to the upstream manhole with all items outlined in the Morning Equipment Checklist using the gator along with Float Support, the Entrant, and the Confined Space Supervisor

b) Help unload the gator/trailer

c) Set up the tripod and 3 winches following all safety guidelines

d) Test for gasses at the manhole and give the values to the Confined Space Supervisor

e) Witness the confined space paperwork

f) Assist the Entrant or Confined Space supervisor. If all confined space tasks are complete, assist Float Support

8) Float Support

a) Ask which float/ float configuration will be used during the deployment

b) Inspect the camera, float, sonar, Antennae, cables, and all other equipment for any signs of damage.

c) Go to the upstream manhole with all items outlined in the Morning Equipment Checklist using the gator along with Confined Space Support, the Entrant, and the Confined Space Supervisor

d) Help unload the gator/trailer

e) Provide 1 battery and the pod to the Winch 1 operator for programming

f) Assemble the float.

g) Make sure the batteries are evenly spaced and their weight is distributed to reduce the potential for the float to capsize

h) If the MD sonar has been removed, make sure that it has been fully inserted and is lined up with the tabs so that it is correctly oriented.

i) Make sure that all guards on the MD profiler are oriented in the correct direction. The camera guard should have the flat side facing downstream. The pod guards should have the loop facing upstream.

j) Verify that all MD floats are installed correctly with the “spoilers” facing upstream.

k) If the wheels are used on the MD float, take the zip ties off of the wheel axels prior to installation. Put the zip ties back on after removing the wheels.

l) Once the pod is programmed, install the pod.

m) Install all cables to their respective ports except to the pod and sonar pod battery ports. Wait to connect the battery cables to both pods until instructed.

The pins on the cables and pods need to be protected. Take your time and insert the cables gently. Make sure that all cables are fully connected and that the O-rings on the camera and pod are completely covered by the cable

n) Remove the camera cover and clean both the lenses and the laser with a shop towel and rainX

o) Cover the lenses with a glove. Be careful not to smear the glove over the lenses. This will wipe of the thin coating of rainX

p) Verify that all parts are securely fastened

q) Help with confined space set-up if needed.

Equipment Insertion

Winch 1

(a) Verify that the camera and laser has been cleaned with rainX

(b) Have Float Support Connect the batteries and turn the pod on

(c) Click the counter icon within HDComms and make sure that the counter connects

(d) Once the pod is on, Float Support will wait for the laser to turn on and then turn on the tablet

(e) Once the tablet is connected to the CCTV pod Wi-Fi as limited, Float Support will open the tablet inspection software and connect to the pod. Once the CCTV is visible they will count down to sync the counter and the pod. Click the start button in the HDComms counter page when Float Support says 3. 2. 1. SET

(f) The float is then ready to insert. Float Support, Confined Space Support, the Entrant and The Confined Space Supervisor will now assist/enter the manhole and insert the float. Pay out line as needed.

(g) Once the back end of the float is in place, the Entrant will yell “Set” to the Confined Space Supervisor who will relay it to Winch 1. Set the counter at 6 feet.

(h) Give slack as needed.

(i) Do not help with the breakdown of equipment. Make sure that you are constantly monitoring the line for tension. Be prepared and in place to deal with potential problems as they arise.

Winch 2

Remain at all stop during the insertion. The cable will go slack. This is OK.

Confined Space Supervisor

a) Fill out the confined space paperwork

b) Have Confined Space Support Witness the paperwork

c) Help the Entrant don the confined space entry equipment. Verify that all equipment is in working order and has been donned properly.

d) Begin the entry while the pod is being synced to the counter.

e) Guide Confined Space Support.

f) Communicate with the Entrant and watch for anything that could become snagged or tangled.

g) When the Entrant is in position and has the appropriate slack, signal Float Support and Confined Space Support to begin lowering the float.

h) If a double tag inspection is being performed be sure to have then untie the Winch 2 cable and slowly allow the slack into the manhole.

i) Connect the float to the third winch using the line on the upstream side of the float

j) Communicate with the entrant as the float is lowered into place and in the case of the HD profiler the pontoons are installed.

k) Verify that the entrant wipes the lens prior to the camera entering the main. If there is any potential for the lens to have been splashed, have the entrant wipe the laser and camera lens again.

l) When the upstream end of the float is in line with the beginning of the main, have Winch 2 pay in all slack and set 6’ on the counter.

m) Send or have the tiger tail sent to the Entrant. If the Entrant needs slack to properly insert the tiger tail they will call for it. Communicate this with Winch 1

n) Extract the entrant while making sure that nothing is becoming tangled or snagged

o) Use Confined Space Support and Float Support to assist.

p) Supervise the breakdown of all confined Space equipment and head to the next manhole. If possible send either Confined Space Support or Float Support ahead with a hammer pick, radio, and meter to test the manhole for gas and look for the float. Winch 1 will slow the pace of the inspection if necessary to allow for everyone to be in place. To reduce splashing on the lens, stopping the float should be avoided unless the float has reached the next manhole.

Entrant

a) Be prepared for entry when the pod is being synced to the counter.

b) Before entry have the Confined Space, Supervisor double check your equipment to verify that it is in working order and verify that it is properly donned to prevent snags or tangles

c) Begin entry while being assisted by the Confined Space Supervisor and Confined Space Support.

d) Follow all safety guidelines for confined space entry.

e) Communicate with the Confined Space Supervisor.

f) Pay attention to all lines and cables so that you do not become tangled. If an emergency situation arises. Use your safety knife to cut yourself free if prudent.

g) If the HD profiler is being used, install the pontoons. This can be done while the float is still vertical unless the size of a bench or opening will not permit this.

h) Before the camera(s) is inserted into the pipe, wipe the camera and laser lenses. If there is any chance that the camera has been splashed before you are extracted, pull the float back and wipe the camera and laser lenses.

i) If a single tag deployment is being conducted, release the drift anchor prior to inserting the camera into the main.

j) Continue to insert the float until the upstream side is in line with the beginning of the main. Call to the Confined Space Supervisor to have the slack from Winch 1 pulled in and the counter set. Verify that the Winch 1 cable will not tangle with you when the slack is removed.

k) Once set, the Confined Space Supervisor will send down the tiger tail. Insert it in place. Call for slack if necessary.

l) Coordinate with the Confined Space Supervisor for your extraction.

m) Allow Confined Space Support, Float Support, and the Confined Space Supervisor to help you out of the manhole.

n) Remove your mask and doff your confined space equipment

o) Help break down the confined space equipment and load it onto the gator to move to the next manhole

Confined Space Support

a) Help the Entrant and Confined Space Supervisor during the entry. Follow their guidance and look out for anything potentially unsafe

Float Support

a) Visually and physically check the profiler for any loose components

b) When instructed, connect the battery cable, first to the main pod, followed by the sonar pod

c) Turn the main pod on. The ring will turn green

d) Wait for the laser to begin flashing and then turn on the tablet

e) In the lower right corner select the network icon and verify that the pod is connected as “Limited”

f) The pod will show up as it’s serial number

g) Connect to the CCTV pod 1st

h) If it is not connected, connect to it using the password: mdpass00

i) Turn on the inspection software on the tablet. Move close to the float and connect to the CCTV pod first. Ask Winch 1 if they are ready to sync. If so, loudly Count 3. 2. 1. SET! Press record on the word SET. Restart the count if the CCTV was not viewable during the count.

j) Verify in the top left that all sensors connected to that pod are recording.

k) If the HD float is being used, connect to the laser/sonar pod and select record.

l) Verify in the top left that all sensors connected to that pod are recording.

m) Help the Confined Space Supervisor and Confined Space Support.

n) Help insert the float when ready.

o) Watch for anything unsafe.

p) Do not handle the HD Profiler using the laser guard or the laser rod! This can damage the laser.

Inspection Operation

1) Winch 1

   a) If a double tag deployment is chosen

      i) When the Entrant is clear, tell Winch 2 to pay in all slack.

      ii) Once Winch 2 calls back, begin paying out cable at no more than 45 ft/s depending on flow.

      iii) If time is required, slow the float so that the Confined Space Crew can get into place at the next manhole.

      iv) Stopping the float unless in a manhole should be avoided to prevent splashing on the lenses.

      v) Give the Confined Space Crew an ETA before they leave especially if the radio is already at the next manhole.

vi) Make sure that you are constantly monitoring the line for tension. Be prepared and in place to deal with potential problems as they arise.

vii) Do not stop until Wench 2 has said “STOP STOP”

viii) Maintain constant speed. If the speed must be changed, notify Wench 2 and have them slow first if slowing. If speeding up, have Winch 2 speed up after you. Winch 2 will then fine tune their adjustment to the new speed while you stay constant.

ix) Give periodic ETAs over the radio. Notify when 300ft, 200ft, 100ft and 50ft out.

x) Unless there is an emergency limit communication over the radio to giving ETAs while the float is within 300ft of a manhole. The radio needs to remain clear for the Confined Space Supervisor or crew member monitoring the manhole to call an all stop.

xi) At each manhole, coordinate with the Confined Space Supervisor and Winch 2 to position the float so that its lenses can be cleaned, and so that it can float around bends.

xii) Coordinate with Winch 2 when the float is at the final manhole for extraction.

b) If a single tag deployment is chosen

i) When the Entrant is clear begin the inspection by paying out cable at no more than 45 ft/s depending on flow.

ii) If time is required, slow the float so that the Confined Space Crew can get into place at the next manhole.

iii) Stopping the float unless in a manhole should be avoided to prevent splashing on the lenses.

iv) Give the Confined Space Crew an ETA before they leave especially if the radio is already at the next manhole.

v) Make sure that you are constantly monitoring the line for tension. Be prepared and in place to deal with potential problems as they arise.

vi) Give periodic ETAs over the radio. Notify when 300ft, 200ft, 100ft and 50ft out.

vii) Unless there is an emergency limit communication over the radio to giving ETAs while the float is within 300ft of a manhole. The radio needs to remain clear for the Confined Space Supervisor or crew member monitoring to manhole the call an all stop.

viii) At each manhole, coordinate with the Confined Space Supervisor to position the float so that its lenses can be cleaned, and so that it can float around bends.

ix) Coordinate with Winch 2 when the float is at the final manhole for extraction.

2) Winch 2

a) If a double tag deployment is chosen

i) When the Entrant is clear, tell Winch 1 will tell you to pull in Winch 2's slack. When this is done, Call Winch one and tell them you are ready.

ii) Winch 1 will begin paying out cable at no more than 45 ft/s depending on flow. Winch 1 will tell you how fast they are paying out and when. After they begin, begin paying in at near their speed, and adjust to maintain light tension to light slack on the cable.

iii) If time is required, slow the float so that the Confined Space Crew can get into place at the next manhole.

iv) Stopping the float unless in a manhole should be avoided to prevent splashing on the lenses.

v) Make sure that you are constantly monitoring the line for tension. Be prepared and in place to deal with potential problems as they arise.

vi) Be ready to stop Winch 2 and call a "STOP STOP" the instant a call is made from either Winch 1 or the Confined Space Supervisor. Winch 1 will not stop until you stop so stop and communicate that you are stopped quickly!

vii) Winch 1 will maintain a constant speed. If the speed must be changed, Winch 1 will notify you to slow first if slowing. If speeding up, have Winch 1 speed up before you and then notify you to speed up. Winch 2 will then fine tune your adjustment to the new speed while you stay constant.

viii) Unless there is an emergency (a need to call all stop), do not speak into the radio while the float is within 300ft of a manhole. The radio needs to remain clear for the Confined Space Supervisor or crew member monitoring the manhole to call an all stop.

ix) At each manhole, coordinate with the Confined Space Supervisor and Winch 1 to position the float so that its lenses can be cleaned, and so that it can float around bends.

x) Coordinate with Winch 1 when the float is at the final manhole for extraction.

b) If a single tag deployment is chosen

i) Once the drift anchor is spotted, call an all stop.

3) Confined Space Supervisor

a) Supervise and gather all equipment onto the gator.

b) Move to the next manhole and watch for the float.

i) If time is short and it can be done, send Confined Space support ahead to call an All Stop when the float is spotted.

c) Guide both wenches through each manhole.

d) Clean the lens in every manhole.

e) Watch for a capsized float

f) Watch for the condition of the cameras

g) Make sure the pods are still on by checking for the green light on each pod

h) Determine if a confined space entry is needed.

4) Entrant

a) Support the Confined Space Supervisor and perform an entry if required

5) Confined Space Support

a) Support the Confined Space Supervisor

6) Float Support

a) Support the Confined Space Supervisor, Winch 1 or 2 depending on where you are located.

Obtaining Quality Data

1) Both wench operators should periodically feel the wench line to determine the state of the float. Vibrations in the line can be used to determine if the float is hung up or dragging. Slowly pull on the tether as it is feeding out to gauge the tension on the line and how “free” the float is floating.

2) Make sure that no debris is covering the sonar. If covered by rags or paper, the sound will have trouble travelling and this will affect the data

3) Wipe both camera lenses and the laser lenses at each manhole.

a) Use a glass water repellent one each lens prior to the inspection

4) Tethering the float at both ends will reduce float pitching and provides more options around bends and debris.
5) Make sure that any slack in the tether is between the wench and the counter, not the counter and the manhole
6) The ideal location for the profiler is in the center of the pipe. Choose the best configuration and profiler to achieve this where possible. Guidelines for this are in section 4.2 Flow Conditions.

Equipment Extraction

1) Winch 1
   a) Winch 2 will as Winch 1 to pay in or out to orient the float so that it can be retrieved. This will be done by either the grappling hook capturing the drift anchor, or by a manned entry.
   b) Pay out as directed when the float is captured.
   c) Once the float is free, Winch 2 will notify you.
   d) Turn off the counter by pressing stop and close HDComms
   e) Winch in the cable at up to 100.
   f) The cable will start to slack as the end approaches
   g) Once the end of the cable has exited the manhole slow the winch.
   h) Stop the winch when there is just enough cable length to secure the cable to the winch using 2 half hitches.
   i) Break down and secure any remaining equipment
   j) Travel back to the trailer/staging site
   k) Once the pod and batteries have been disinfected and removed from the float, begin downloading and reviewing the data.
      (1) Download the data to the computer
         (a) Create an inspection folder on the hard drive under Inspections

(i) Label the folder in the following format: Line ID –Deployment – Insertion Manhole – Extraction Manhole.

(b) Connect the pod to the battery and then to the computer

(c) Place a bag of ice onto the pod during the download in summer temperatures

(d) Start HD Communications

(e) Turn on the pod and wait for cycle of hard drive

(f) Select download

(g) Select file to download (HiRes, Laser, sonar)

(i) HiRes is CCTV downloaded from one pod

(ii) Laser and Sonar are downloaded from the other pod

(h) Select the file to download inspection folder created above

(i) Download the file

(j) Do not view the data

(k) Do not download slowly

(l) Repeat for remaining files (HiRes, Laser and sonar)

(2) Delete IDT, IDX and IST files from Laser and CCTV files before viewing

(a) The sonar does not have files to delete

(3) Copy the counter file for that deployment from the C:/ drive/Inspections over to the inspection folder

(a) The counter file will have been made at the same time that the inspection began.

(4) Review the data using Fly Contractor and loading data from the Inspection Folder created above

l) Copy the distance between each manhole into the field notes

m) Make sure the field notes are completed.

i) Date

ii) Total Distance

iii) Upstream or downstream

iv) Deployment number

v) Material

vi) Notes

2) Winch 2

a) If a double tag deployment is chosen

i) Communicate with the Confined Space Supervisor during the retrieval manned entry. Work with him to pay in or out.

ii) Work with Winch 1 letting them know when to pay in or out

iii) Once the float is removed and the Confined Space Supervisor gives the OK, begin untying the cables from both sides of the float.

iv) Tell Winch 1 that they are free once they are untied.

v) Reel in your slack once Winch 2 is free.

vi) Help with the retrieval of the Entrant and then begin the breakdown and sanitation of all equipment.

vii) If the trailer/staging site is at another location move to that location once feasible.

viii) Help and Guide the replacement of all equipment into their respective locations.

ix) Take note of anything that is damaged or low and give a list to the Confined Space Supervisor once completed.

b) If a single tag deployment is chosen

i) Communicate with Winch 1 to move the drift anchor into a position where it can be captured by the grappling hook.

ii) Once the drift anchor is captured, have Winch 1 pay out until the float has been retrieved and then call an All Stop.

iii) Untie the cable and tell Winch 1 that they are free.

iv) Begin the breakdown and sanitation of all equipment.

v) If the trailer/staging site is at another location move to that location once feasible.

vi) Help and Guide the replacement of all equipment into their respective locations.

vii) Take note of anything that is damaged or low and give a list to the Confined Space Supervisor once completed.

3) Confined Space Supervisor

a) If a double tag deployment is chosen

i) Communicate with the Winch 1 and 2 during the retrieval manned entry. Tell them when they need to pay in or out.

ii) Once the float is removed notify personnel to untie the cables so that they can be reeled out of the way and reduce the potential for tangling the Entrant.

iii) Begin the retrieval of the Entrant.

iv) Once the Entrant is retrieved, have the support staff begin breaking down and sanitizing the equipment.

v) If the trailer/staging site is at another location move to that location once feasible.

vi) Help and Guide the replacement of all equipment into their respective locations.

vii) Take note of anything that is damaged or low.

b) If a single tag deployment is chosen

i) Untie the cable and tell Winch 1 that they are free.

ii) Lead the breakdown process. Begin the breakdown and sanitation of all equipment.

iii) If the trailer/staging site is at another location move to that location once feasible.

iv) Help and Guide the replacement of all equipment into their respective locations.

v) Take note of anything that is damaged or low

4) Entrant

a) Before entry have the Confined Space Supervisor double check your equipment to verify that it is in working order and verify that it is properly donned to prevent snags or tangles

b) Begin entry while being assisted by the Confined Space Supervisor and Confined Space Support.

c) Follow all safety guidelines for confined space entry.

d) Communicate with the Confined Space Supervisor so that the winches can orient the float where you need it.

e) Pay attention to all lines and cables so that you do not become tangled. If an emergency situation arises. Use your safety knife to cut yourself free if prudent.

f) If the HD profiler is being used, remove the pontoons and send them up via ropes.

g) Attach the Winch to the float and assist its removal.

h) Coordinate with the Confined Space Supervisor for your extraction.

i) Allow Confined Space Support, Float Support, and the Confined Space Supervisor to help you out of the manhole.

j) Remove your mask and doff your confined space equipment

k) Help break down the confined space equipment and load it onto the gator to move to the next manhole

5) Confined Space Support

a) Help the Entrant and Confined Space Supervisor during the entry. Follow their guidance and look out for anything potentially unsafe

b) Once the Entrant has been removed, make sure that they are OK and then begin breaking down and sterilizing the equipment.

c) If the trailer/staging site is at another location, load the equipment for travel.

d) Replace all equipment

e) Take note of all low or damaged equipment and supplies and notify Winch 1 who will make a list.

6) Float Support

   a) Help the Entrant and Confined Space Supervisor during the entry. Follow their guidance and look out for anything potentially unsafe

   b) When the float is removed and the Confined Space Supervisor tells you to, untie the cables from the float and turn off the float using the tablet to stop the recording. Turn off the pod by pressing the button for several seconds.

   c) Return to supporting the Entrant and Confined Space Supervisor.

   d) Once the Entrant has been removed, make sure that they are OK and then begin breaking down and sterilizing the equipment.

   e) Once the pod(s) are sterilized and removed, bring them, a battery cable, and a fresh battery to the Winch 1 operator for download.

   f) If the trailer/staging site is at another location, load the equipment for travel.

   g) Replace all equipment

   h) Take note of all low or damaged equipment and supplies and notify Winch 1 who will make a list.

Post Inspection Field review

1) Open Fly Contractors

2) Download the video files from the directory

3) Select the deployment file that you want to view

4) When complete, view Laser, HiRes, Sonar

   a) You can switch between each while viewing

   b) Press the arrow multiple times to increase speed

   c) The progress bar at bottom can be used to select what point to watch

d) The counter shows the footage and can be used to mark and notify the Project Manager of problem locations.

Safety Considerations

Daily Pre-Inspection Safety Briefing

The Daily Pre-Inspection Briefing will include information about the main that will be inspected that day, possible hazards and complications, accessibility, special considerations, and general safety reminders.

Policy/General Provisions – Sections 109.01 & 109.02 of the COA Personnel Manual

109.01 POLICY/PURPOSE

The City is committed to providing a safe workplace. Employees are expected to take an active role in promoting workplace safety by reporting unsafe working situations. Management support is one of the crucial elements of a Risk Management program.

Additionally, employees are required to report accidents in order to help management identify and correct the underlying causes of accidents, and thereby prevent similar accidents. Accident reporting is also required to verify that injuries in the course and scope of employment qualify for compensation under the Workers' Compensation system.

The City sets minimum qualification standards for vehicle drivers and for vehicle operation in an effort to minimize human injury, lost working time, and property damage costs.

109.02 GENERAL PROVISIONS

A. Employee Responsibilities. Employees are responsible for exercising care and good judgment in preventing accidents and for observing safety rules when performing job duties. Employees are required to:

1. Report all accidents to their supervisor and seek first aid for all injuries, however minor they may be. Employees shall complete accident report forms and report to their supervisor no later than 24 hours after the occurrence;

2. Report any unsafe work conditions, equipment, or practices to their supervisor as soon as possible;

3. Attend scheduled safety meetings and activities; and

B. Employees shall not alter, repair, or in any way change, add to, or remove any parts or accessories of any City owned or leased property without the permission of the department head and the City department officially charged with maintenance of the property (such as Information Technology for computers, Fleet for vehicles). This includes buildings, office equipment, machines, clothing, tools, and other equipment.

C. Employees who operate vehicles or equipment in the course and scope of employment with the City will be instructed, where applicable, in the use of that equipment.

D. Supervisor Responsibilities - It is the responsibility of all City supervisors to adhere to the occupational safety and health programs, accident reporting, and supervisory investigation responsibilities. Supervisors are required to:

1. Reporting accidents/injuries to the appropriate risk management department using City accident reporting forms. Supervisors have 48 hours from the time the employee notifies them of the accident to complete their initial investigation and submit the accident forms.

2. Train staff under their supervision and ensure that staff understands how to accomplish their work assignments in a safe manner.

3. Ensure that scheduled, periodic inspections of workplaces are conducted to identify, evaluate, and correct workplace hazards, sanitation deficiencies, security concerns, and unsafe work practices. Findings shall be documented and corrective action outlined for all deficiencies.

4. Ensure adequate personal protective equipment (PPE) is available and enforce its use as required.

**** View section 109 in its entirety in the COA Personnel Manual located on the COA portal

Personal Protective Equipment– Section 109.06 of the COA Personnel Manual

A. The City will provide, directly or through an allowance, as determined by management, items of personal protection, including clothing, as specified in this Chapter.

B. Supervisors will direct use of personal protective items when warranted. Employees will comply with such direction. Examples are:

1. Hard hats will be provided and used by all employees working in areas where possible danger of head injury from impact, falling or flying objects, or from electrical shock and burns exist.

2. Hearing protection devices will be provided and worn by all employees working in areas where a danger of noise exposure exceeds accepted safe limits.

3. Eye and face protection equipment will be provided and used by all employees when machines or operations present potential eye or face injury from physical, chemical, or radiation agents.

4. Respiratory protective devices will be provided and used by all employees when working in atmospheres immediately dangerous to life and health, or where there is an immediate threat of exposure to contaminants which are likely to have adverse effect on the health of the employee.

5. Protective footwear will be used by all employees when working in areas where equipment operation, or the movement of heavy materials, or construction situations could cause injury to the feet.

6. Protective gloves will be worn by all employees when work-site operations could cause injury to the hands.

7. Outer garments marked with or made from reflective or high-visibility material will be provided and will be worn by all employees when exposed to vehicular traffic in alleyways, roads, streets, highways, or when working within 15 feet of a street or roadway.

8. Appropriate fall-arrest equipment will be provided and used by all employees when working in an overhead position which may require use of both hands and/or when there is a danger of falling.

9. Life jackets or buoyant work vests will be provided and used by all employees when working over or near water where the danger of drowning exists.

10. Confined-space work rules will be followed for all work in confined spaces.

**** View section 109 in its entirety in the COA Personnel Manual located on the COA portal

Inspection Contingencies

Weather

I&I

Inflow and Infiltration can occur due to heavy storms. This may suddenly increase flow within the pipe being inspected. Because of this, the inspection must be postponed at the start of any potentially heavy storm until the flow has returned to an Inspectable depth.

Lightning

If lightning has been sighted, the inspection will be placed on hold until there has been at least 30 minutes since the last lightning strike.

Flow Conditions

Expected pipe flows from the sewer model are included in this field manual for each line to be inspected along with a recommendation for which profiler in what configuration is likely to be needed. However, this is only an estimate. The profiler configuration should always be chosen based on the actual field conditions. Note lines where actual flow does not match the model predictions.

The profiler provides the best data when floating in the center of the pipe. Choose the profiler and configuration that best accomplishes this. Options for different flows are discussed below:

High Flow

If the flow is too high or has the potential to become too high, the camera and laser system can be damaged by submersion or by impact with the top of the pipe. This can also potentially lead to pipe collapse if the pipe is in poor condition. If a pipe has high flow, (most likely in the morning before most people leave for work, and in the afternoon when the return home) wait to inspect that segment for a non-peak time. If the pipe cannot be inspected during the day, a night inspection may have to be performed when flows are at their lowest. If the top of pipe is completely surcharged. The MD Profiler can be used with only the sonar. Remove the camera, laser and associated module and pull the profiler through the pipe using a double tether.

Low Flow

If the flow is too low for the appropriate profiler, wait to inspect that segment of pipe until a peak flow period (generally in the morning before most people leave for work, and in the afternoon when the return home). If there is still not enough flow use the MD profiler with wheels.

The Profiler gets Stuck in the Pipe

If the profiler is stuck in the pipe attempt to dislodge it by alternating the winch slowly feed out and take line. Feel the tether to pick up any vibrations and make sure that the tether does not get too taught. From the vibrations try to assess to what degree the profiler is able to move and how smoothly. If possible and the profiler is near to a manhole, release the tension on the tether and attempt to get a visual from within the manhole. If the profiler shows no sign of working free, note the distance measured by the counter and notify the Project Manager and Ops Assistant Director.

Damage to Equipment

Equipment troubleshooting

Leak in the pontoons

The two pressure testing nozzles on the curved side of each of the main pontoon can be used to locate potential leaks. Lightly pressurize the suspected pontoon and either submerge the pontoon in water or spray soap water onto the pontoon. Look for bubbles and listen for escaping air. If a minor leak is found, it can be fixed temporarily with epoxy or sealed with a soldering iron. Notify the project manager so that a replacement can be coordinated.

If the crack is in the fisheye lenses, any data accumulated since the crack will be compromised. Remove the camera and notify the project manager so that the camera can be repaired and recalibrated.

If the crack is located near the LED ring, then the crack can be temporarily repaired by clear epoxy. The camera will need to be sent in for repair and recalibration at the end of the inspection cycle.

Sonar

Check the sonar to see if oil is leaking from its housing. The most likely location is near the screws. If oil is leaking, the data is compromised. Notify the project manager so that the sonar can be replaced.

The Laser

Under normal operating conditions, the laser is eye safe. If the housing is compromised, this may no longer be the case. Do not look at the laser light in this case without protective eyewear. Notify the project manager so that the unit can be replaced.

The Lens Cover has a Scratch

1) Blead the bleeder valve
2) Angle the camera so that it is pointed directly skyward.
3) Secure the camera so that it cannot move
4) Take out the screws around center bezel
5) Do not move the led lens cover
6) After removal of the bezel, remove the center lens cover.
7) Make sure the o rings remain in their groves.
8) Place a small dab of O ring lube or di-electric grease onto each o ring.
9) Check to make sure that the lens has not been smudged.

a) If it has been, clean with glasses cleaner and a microfiber cloth

10) Place the new lens cover into the groves.

11) Replace the bezel and insert a thread all screws until they are just starting to thread.

12) Tighten ¼ turn at a time in a star pattern

13) Tighten until all screws are tight but no more than two finger tight.

14) Wait 5 minutes.

15) Tighten again clockwise and then counter clockwise

a) Tighten no more than two-finger tight

16) Using a Nitrogen Kit, pressurize the camera to between 3 to 8psi for nitrogen

The Pipe Needs Cleaning

If the float is dragging, check the video. If the sonar shows sedimentation the line may require cleaning prior to inspection. View the video to see how close the float was to clearing the debris. If it was close, plan a re-inspection during a peak flow period. If this inspection does not succeed, tell the Project Manager.

The Profiler Capsized

If the Profiler has capsized, remove the profiler from the current manhole if possible. If not, re-orient the float into its upright position and remove it from the following manhole. Once the float is removed, check to make sure all onboard components are functioning. Review the video to determine the cause of the capsized float, and the last manhole from where good inspection data was collected. If the equipment is operational and the risk is acceptable, continue the inspection from this location. If the equipment is not functional or the float is likely to capsize again when sent through the same section of pipe, contact the Project Manager.

The Pipe Collapses

Shut down inspection operations. Call the Operations Assistant Director followed by the Project Manager

Personnel Injury

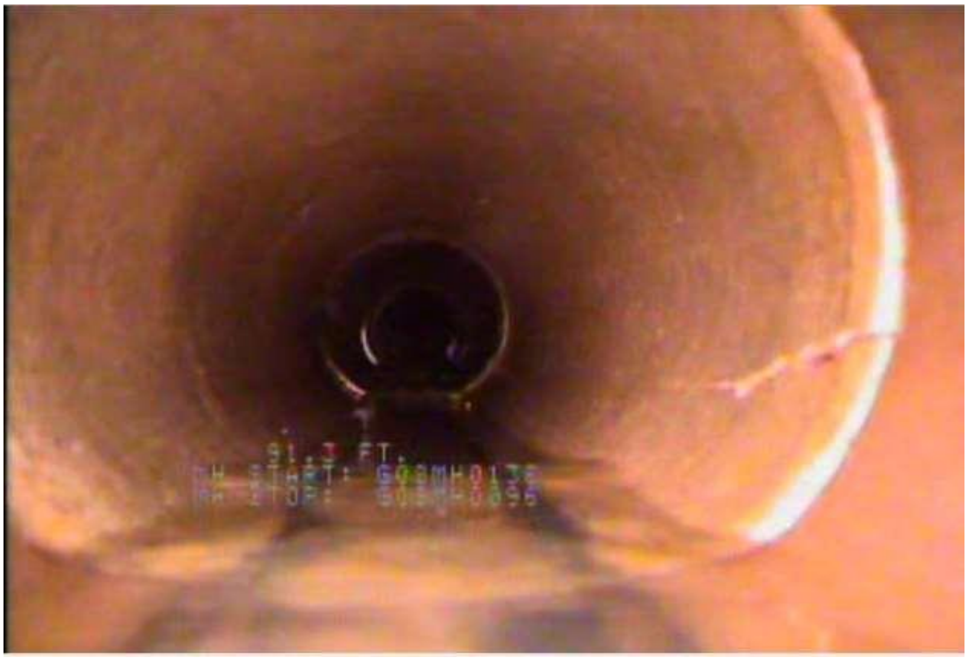
See section 3.6.3 - Policy/General Provisions – Sections 109.01 & 109.02 of the COA Personnel Manual

Appendix C

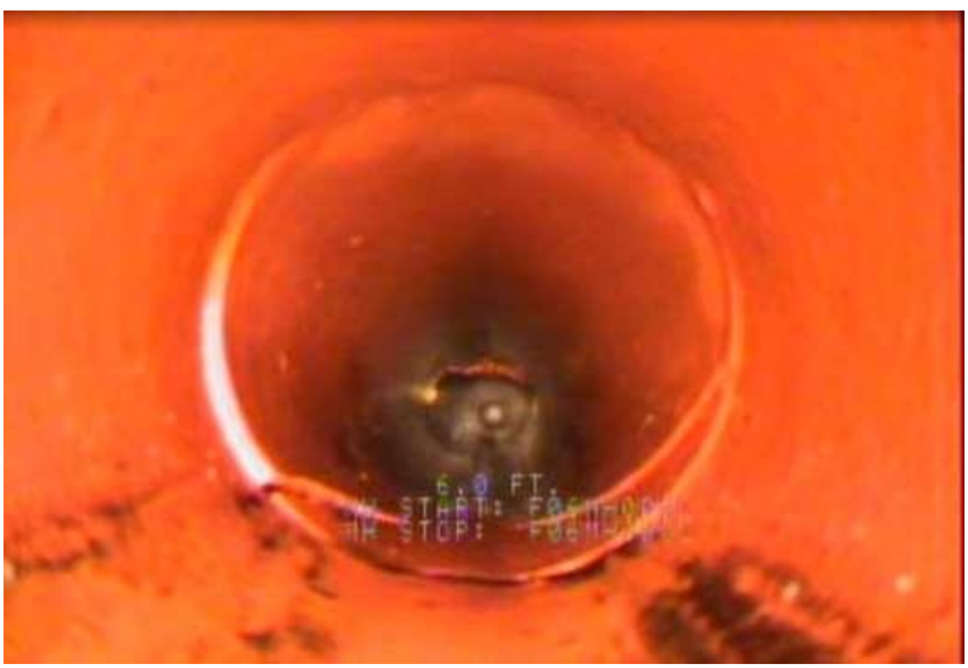
Pipe Coding System

Fracture (F)

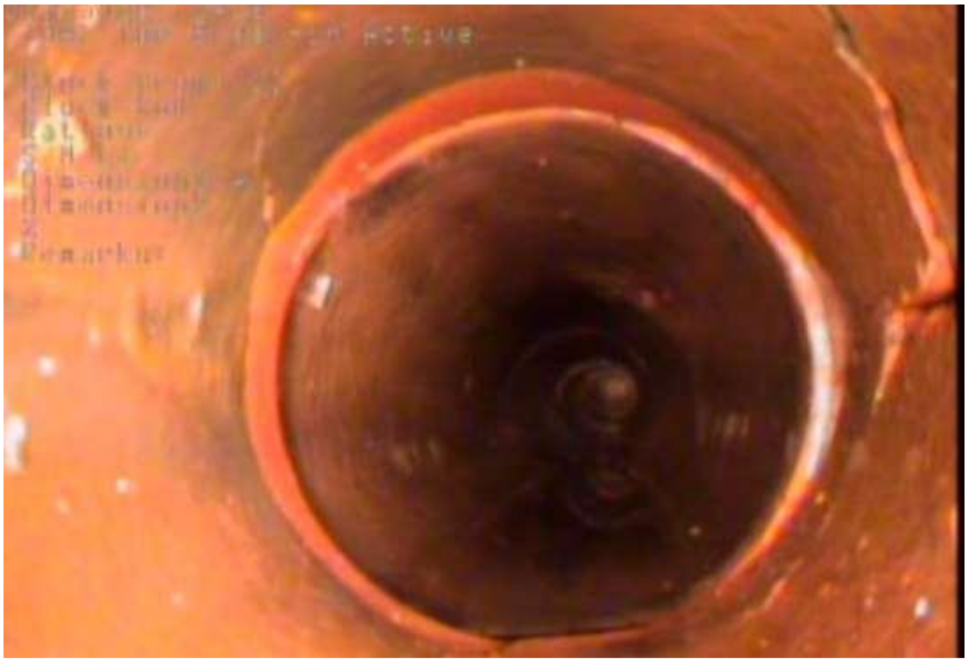
Fracture Longitudinal (FL)



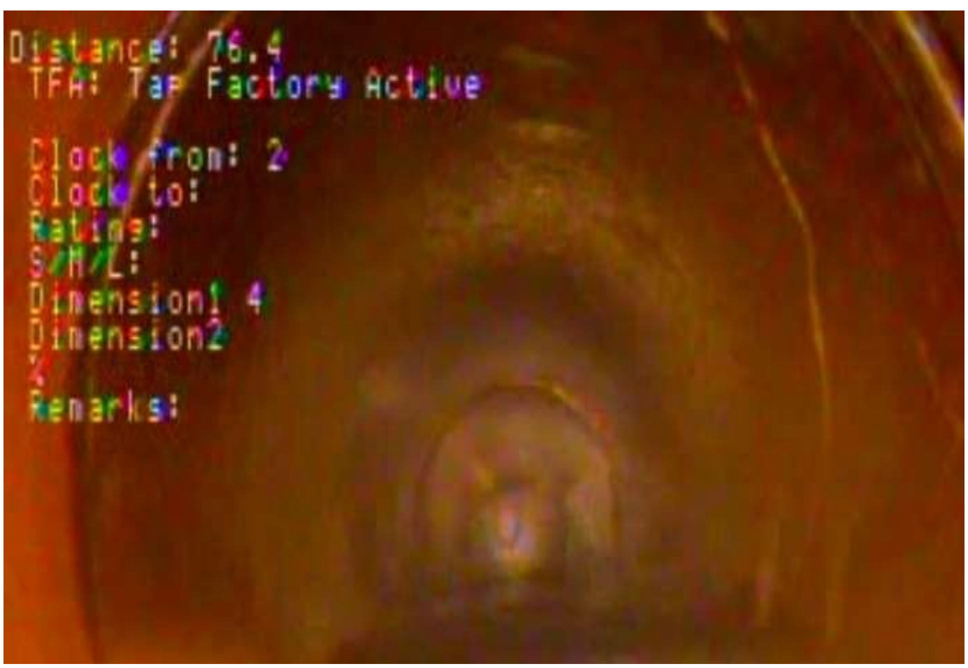
Fracture Circumferential (FC)



Fracture Multiple (FM)



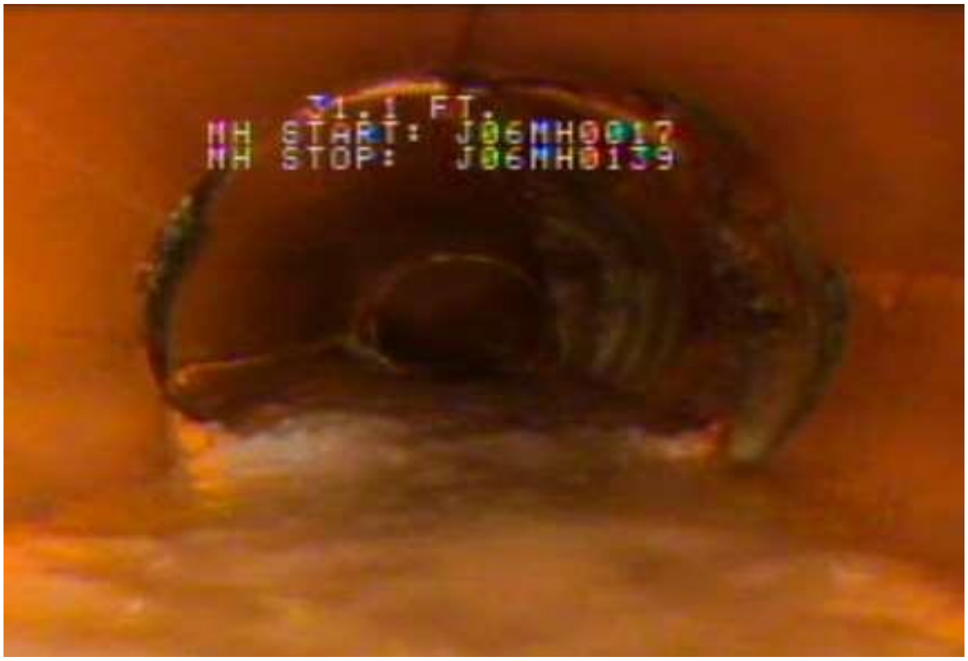
Fracture Spiral (FS)



Fracture Hinge (FH)

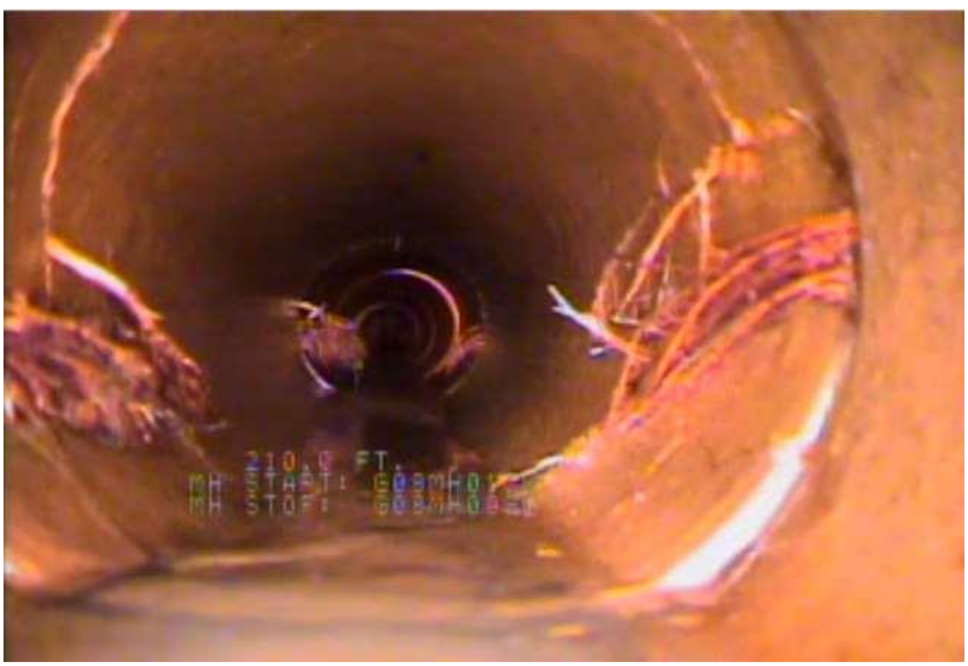
Fracture Hinge 2 (FH2)

Fracture Hinge 3 (FH3)

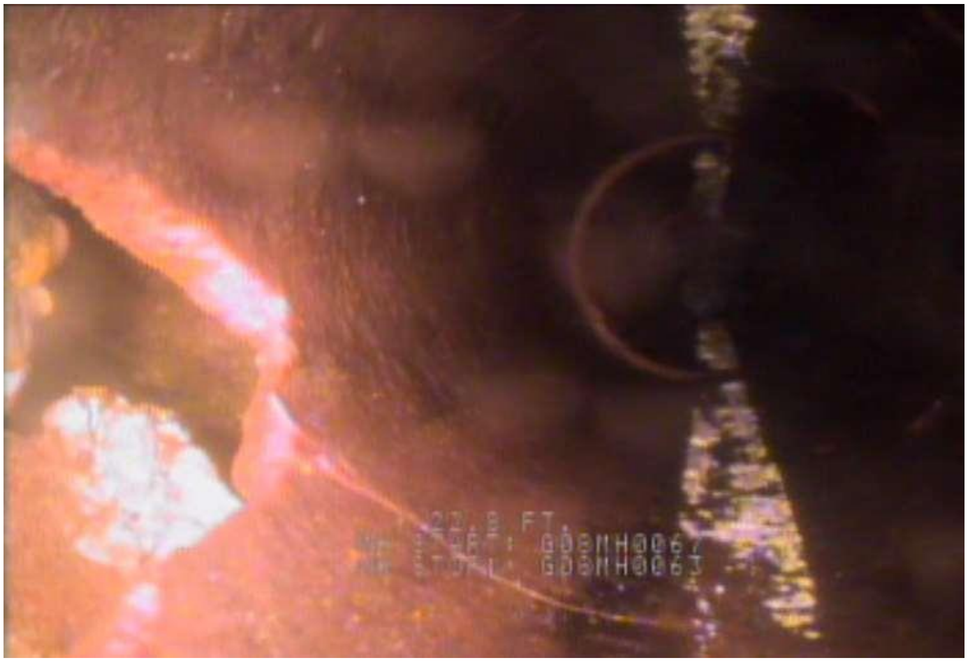


Fracture Hinge 4 (FH4)

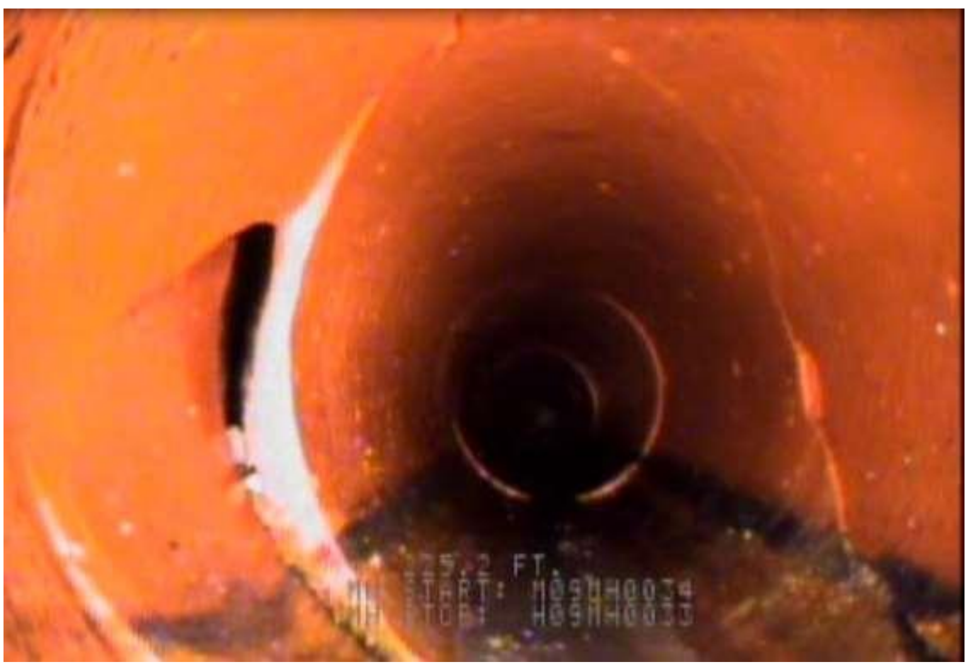
Broken (B)



Broken Soil Visible (BSV)



Broken Void Visible (BVV)



Hole (H)

Hole Soil Visible (HSV)

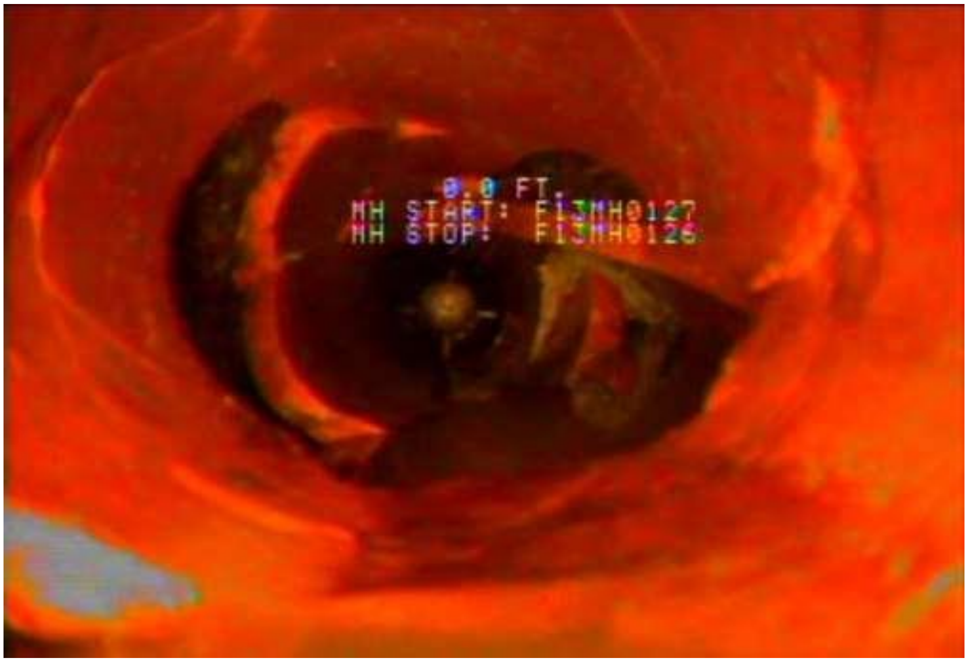
Hole Void Visible (HVV)

Deformed (D)

Deformed Rigid (DR)

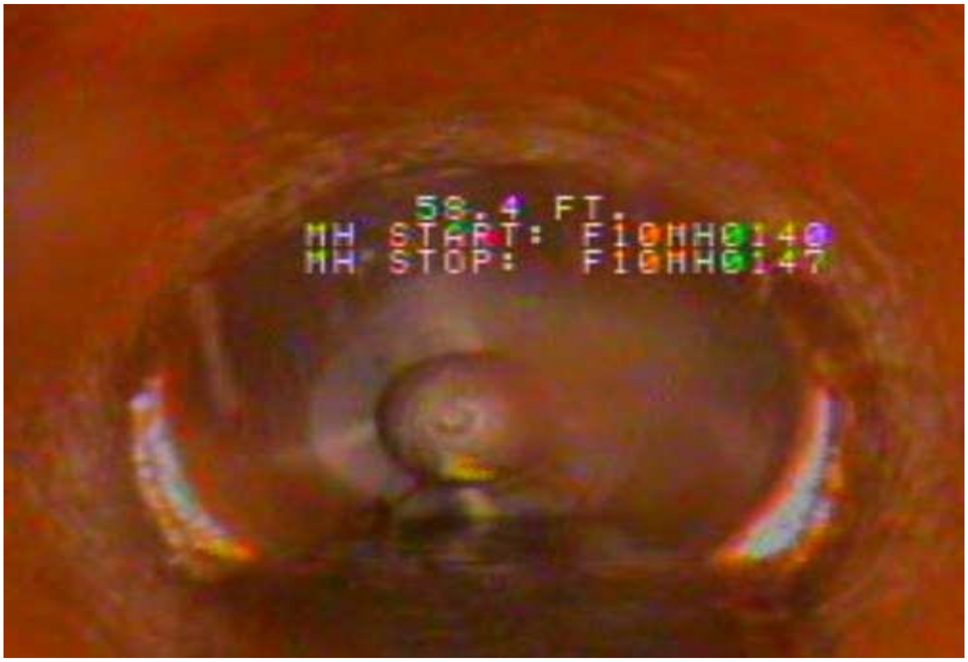
Deformed Flexible (DF)

Collapse (X)

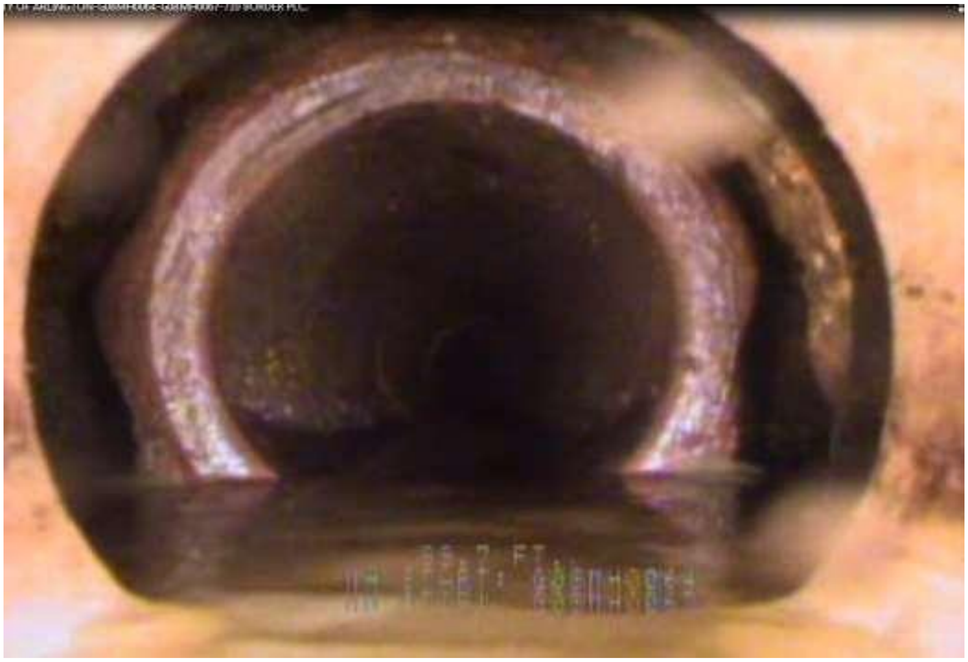


Joint (J)

Joint Offset (JO)



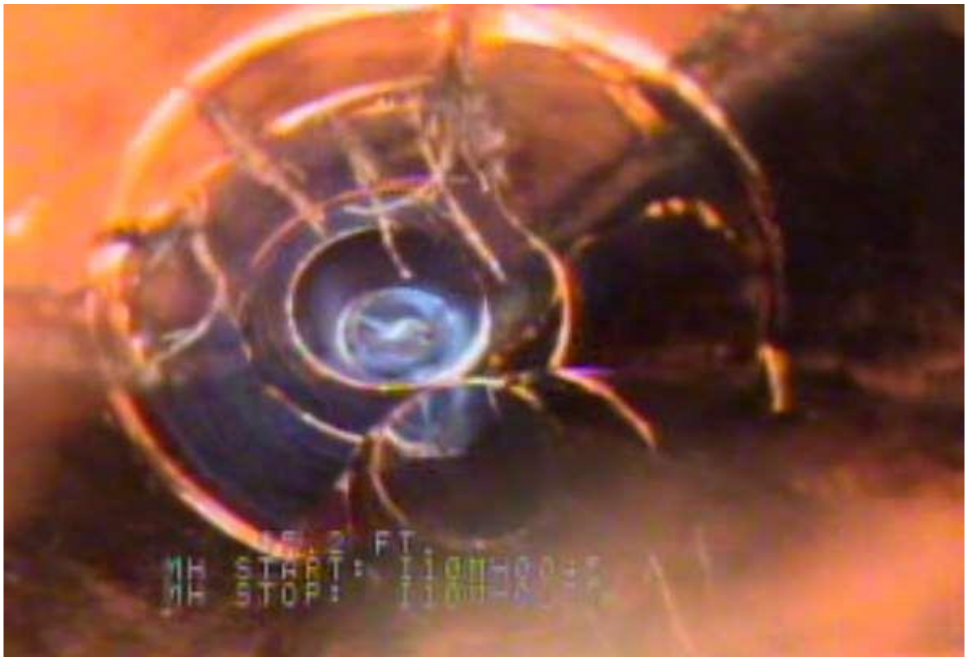
Joint Separation (JS)



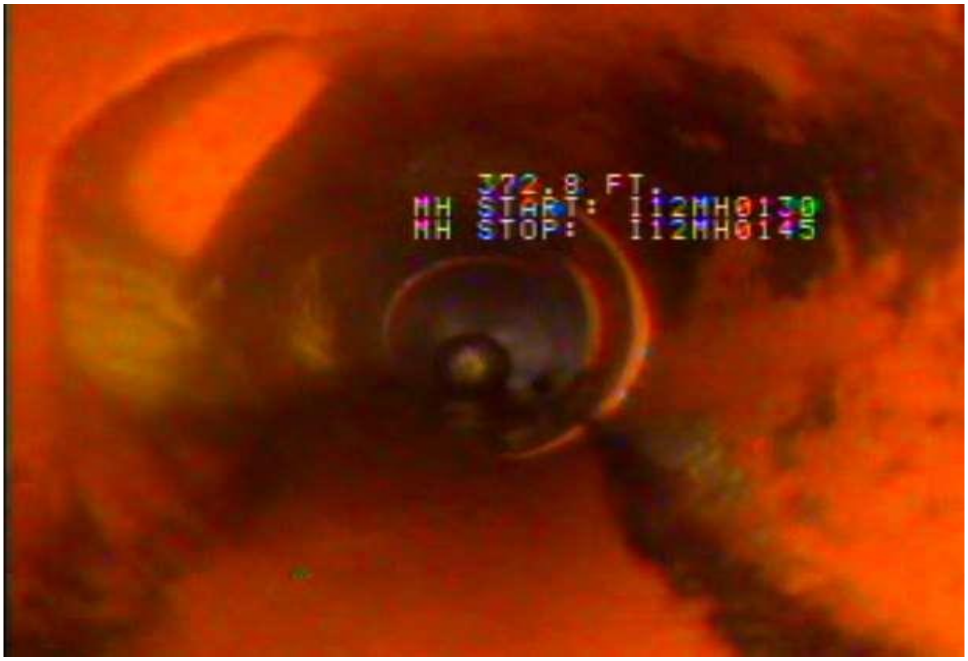
Joint Angular (JA)

Roots (R)

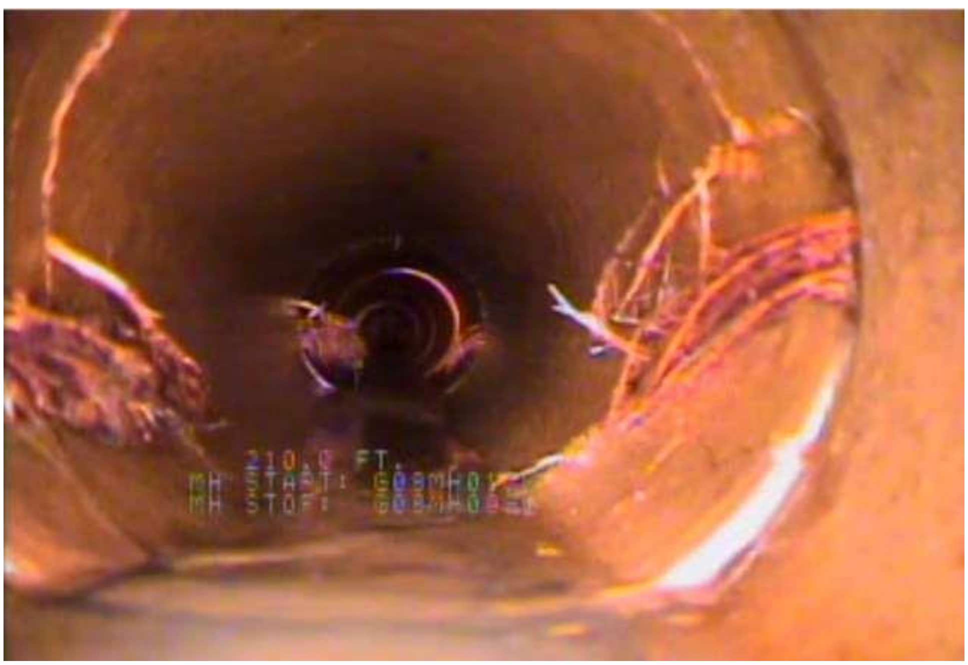
Roots Medium Barrel (RMB)



Roots Medium Connection (RMC)



Roots Medium Joint (RMJ)



Large (L)

Roots Large Barrel (RLB)

Roots Large Connection (RLC)

Roots Large Joint (RLJ)

Infiltration (I)

Dripper (D)

Infiltration Dripper Barrel (IDB)

Infiltration Dripper Connection (IDC)

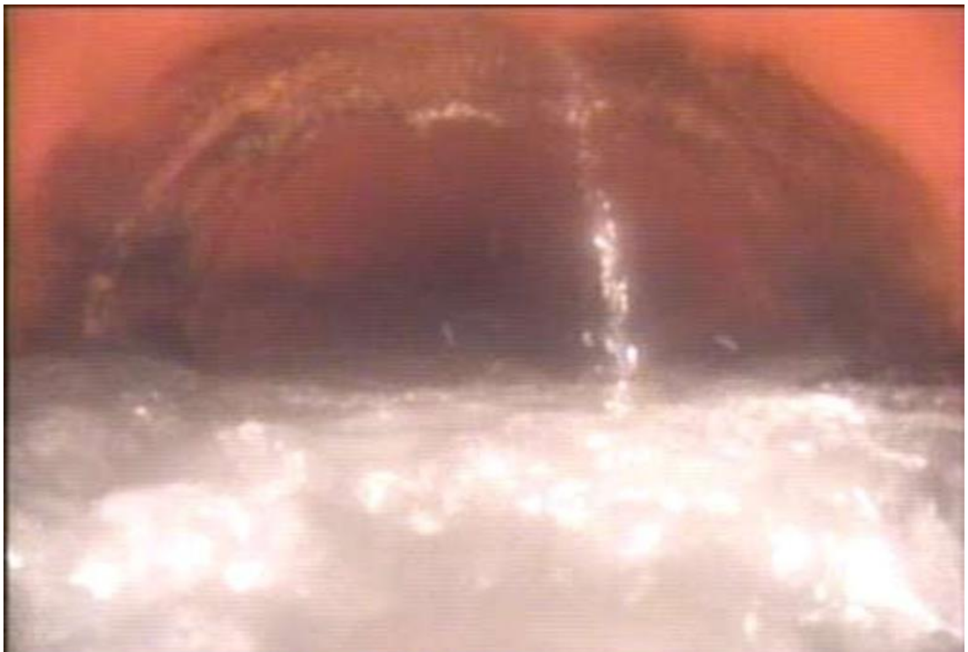
Infiltration Dripper Joint (IDJ)

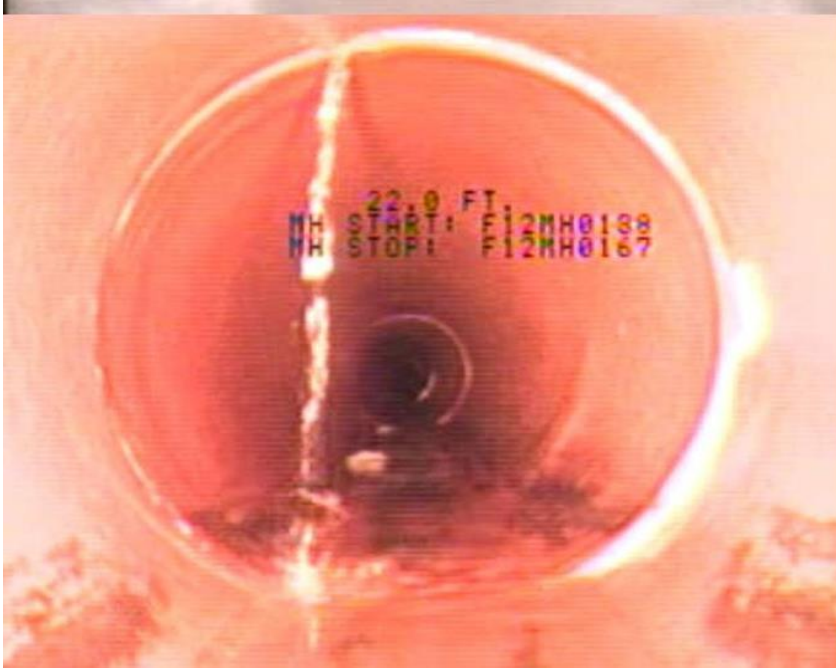
Runner (R)

Infiltration Runner Barrel (IRB)

Infiltration Runner Connection (IRC)

Infiltration Runner Joint (IRJ)



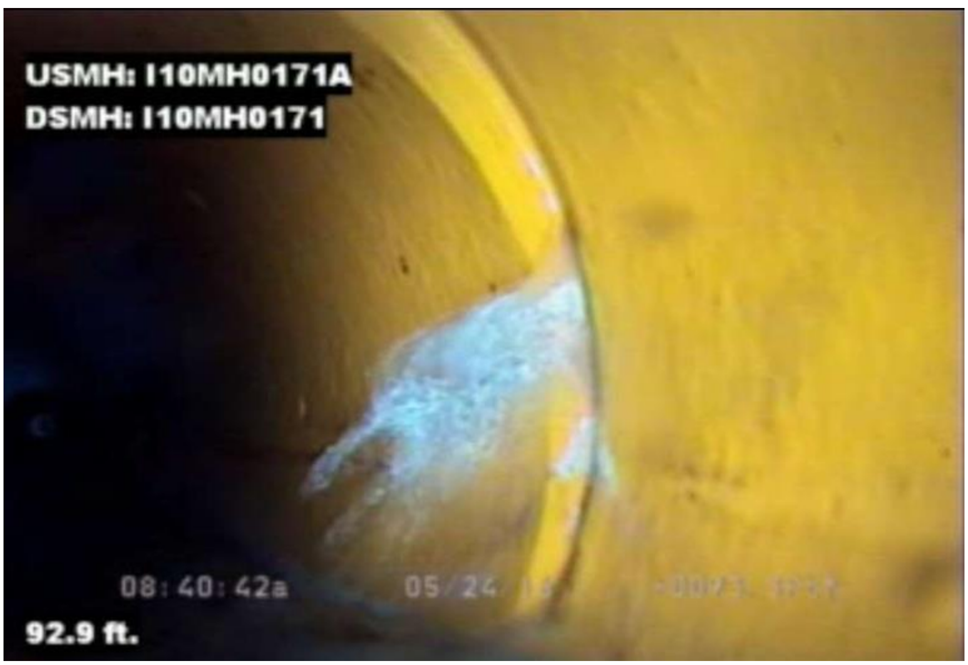


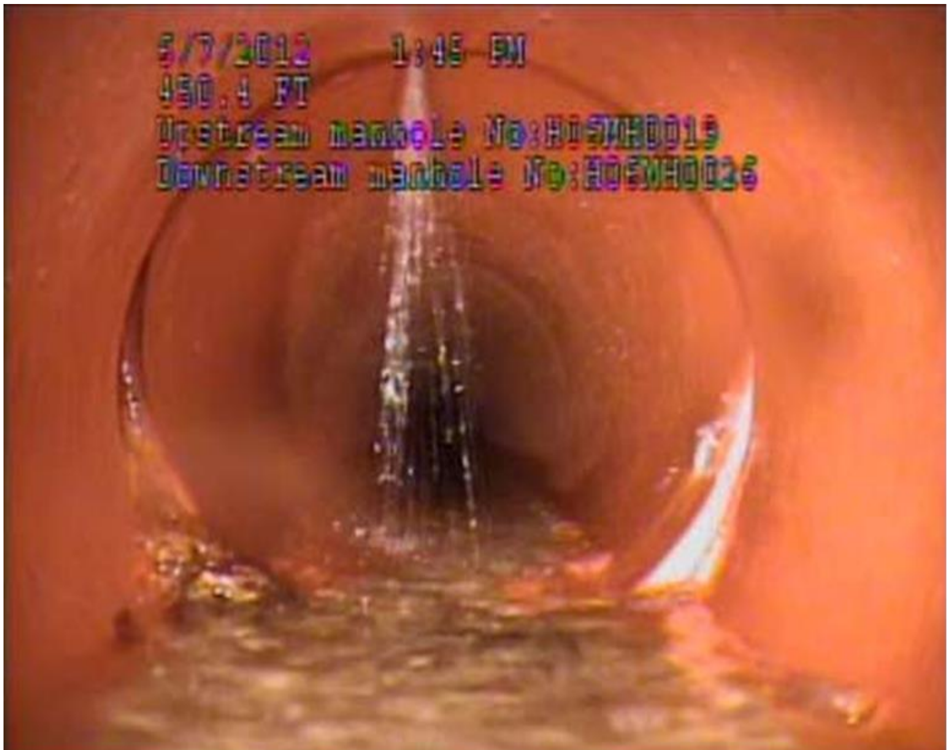
Gusher (G)

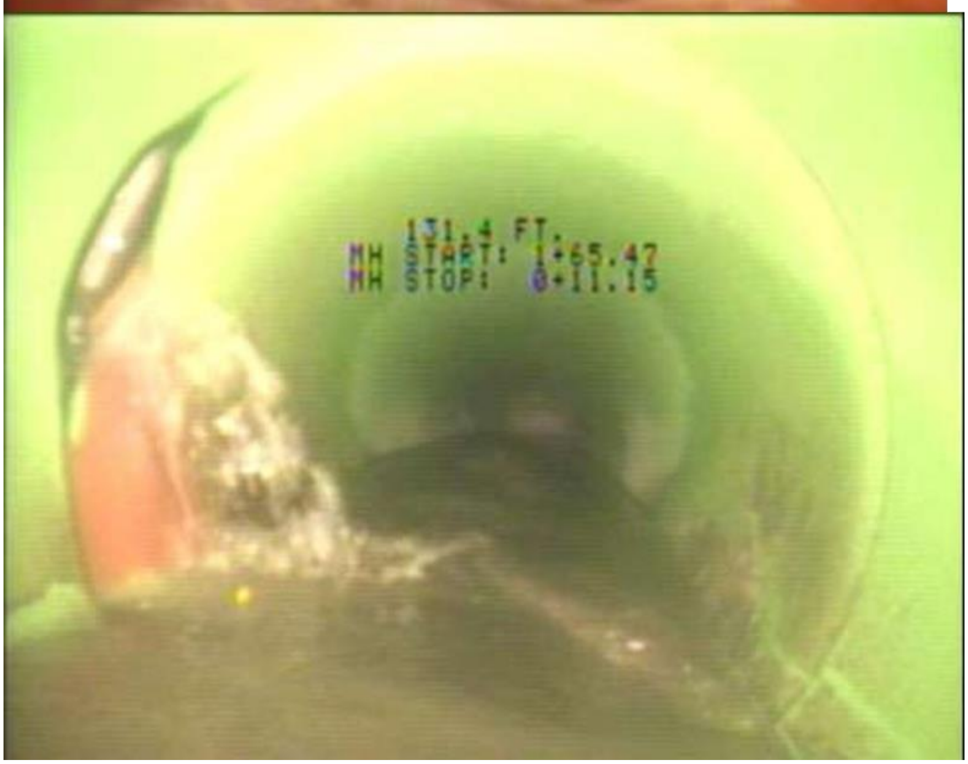
Infiltration Gusher Barrel (IGB)

Infiltration Gusher Connection (IGC)

Infiltration Gusher Joint (IGJ)



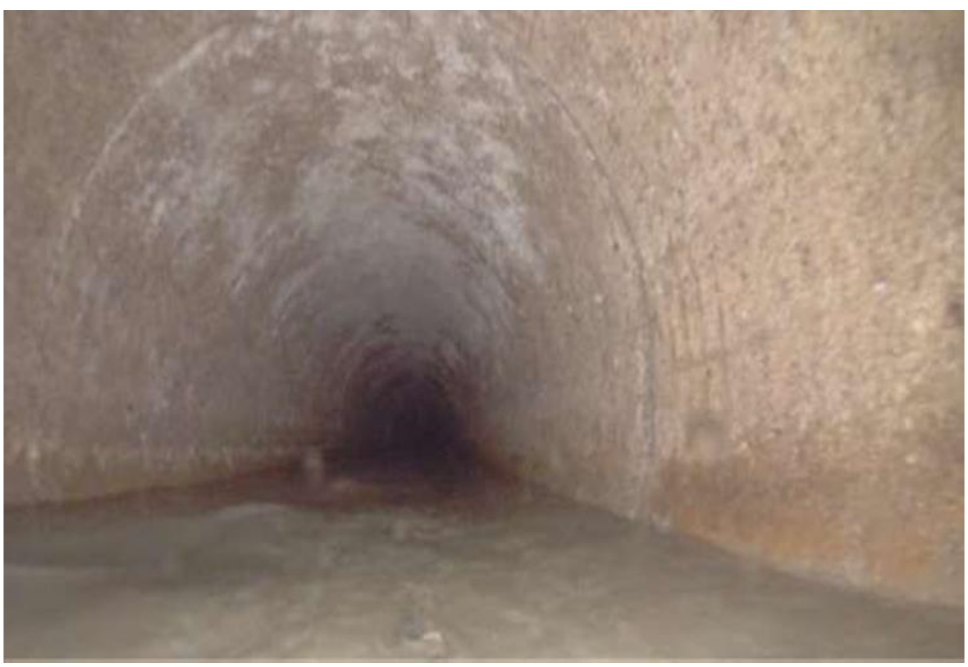

5/7/2012 1:45 PM
450.4 FT
Upstream manhole No:H05MH0019
Downstream manhole No:H05MH0026


131.4 FT.
MH START: 1+65.47
MH STOP: 0+11.15

Surface Damage (S)

Surface Damage Aggregate Visible (SAV)

Surface Damage Reinforcement Visible (SRV)

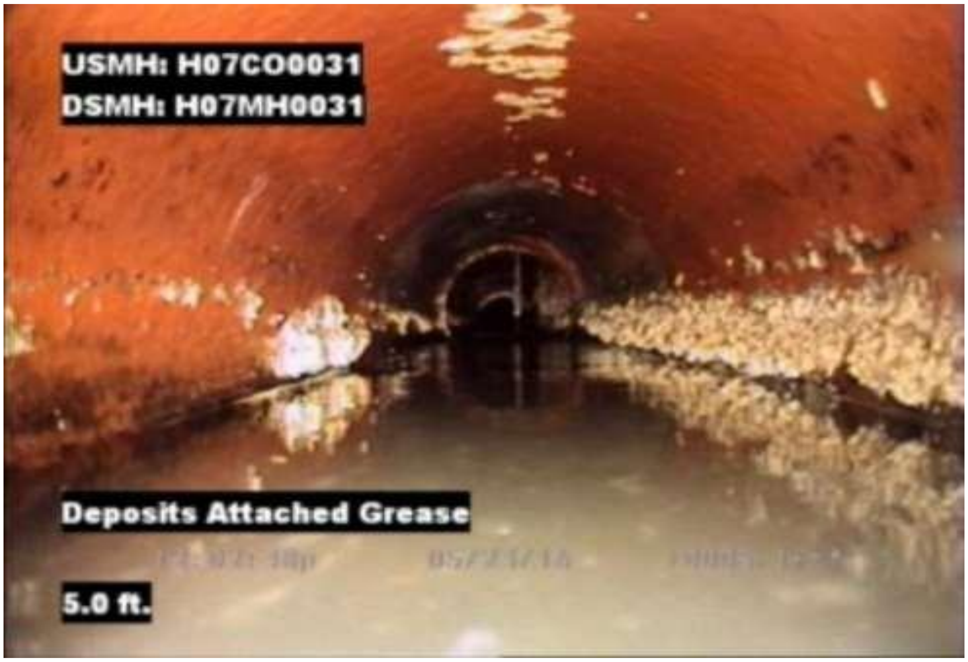


Surface Damage Missing Wall (SMW)

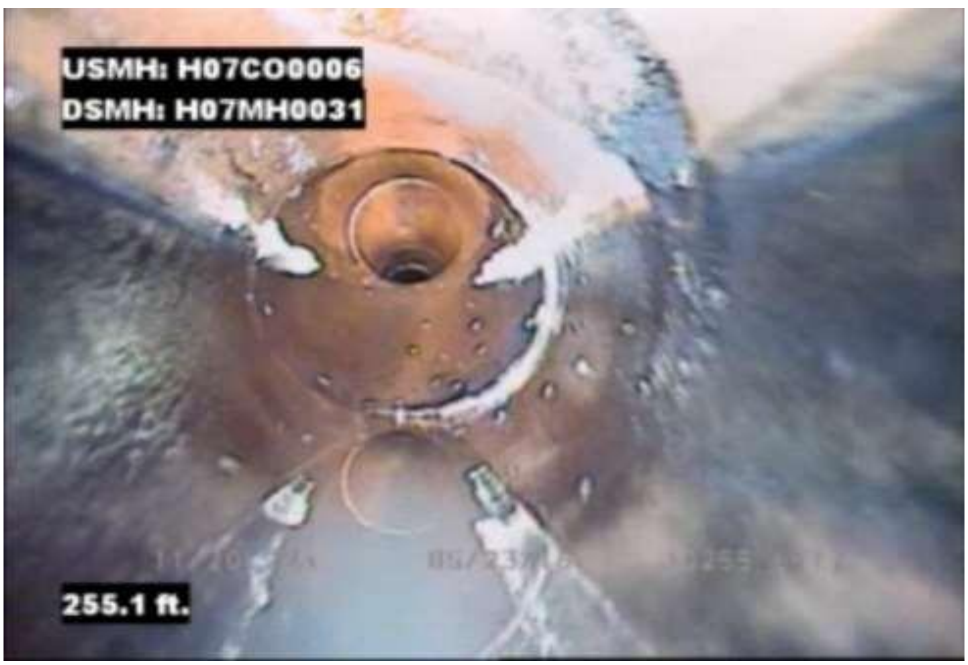
Deposits Attached (DA)

Deposit Attached Encrustation (DAE)

Deposits Attached Grease (DAG)



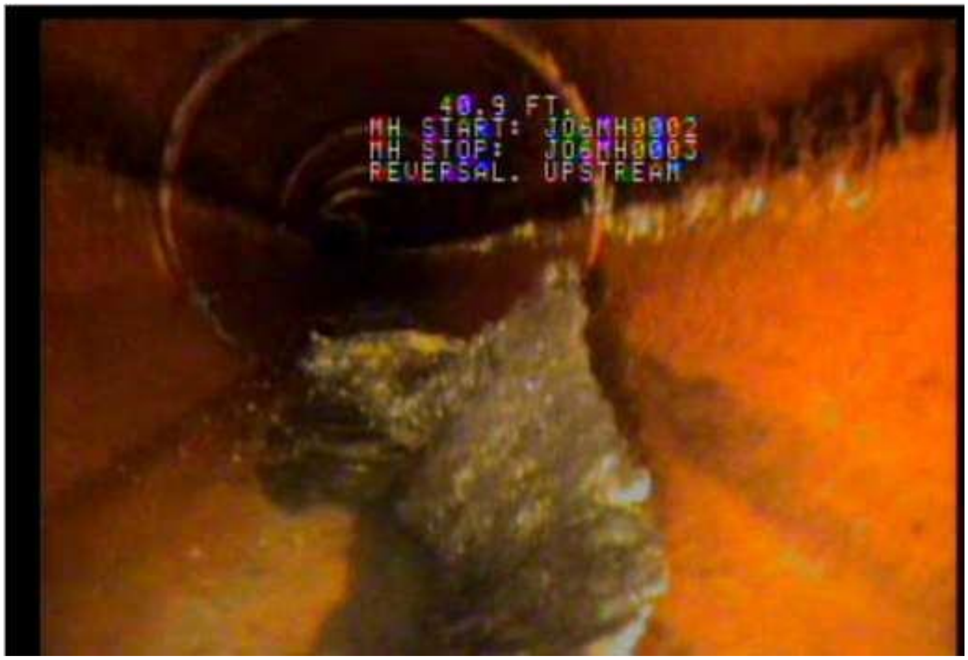
Deposits Attached Ragging (DAR)



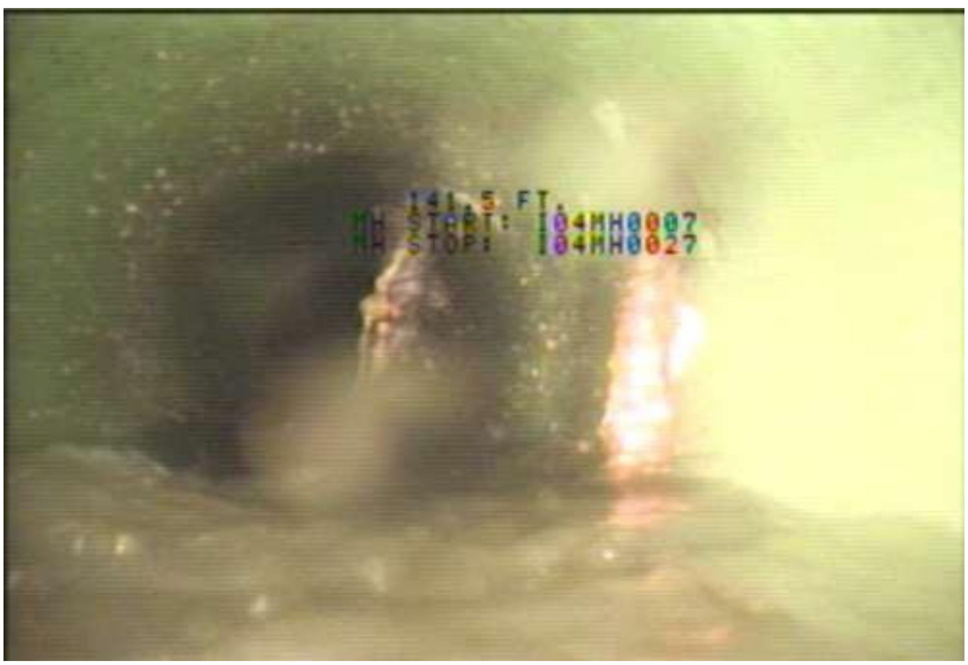
Obstacles / Obstruction (O)

Obstruction Brick/Masonry (OBB)

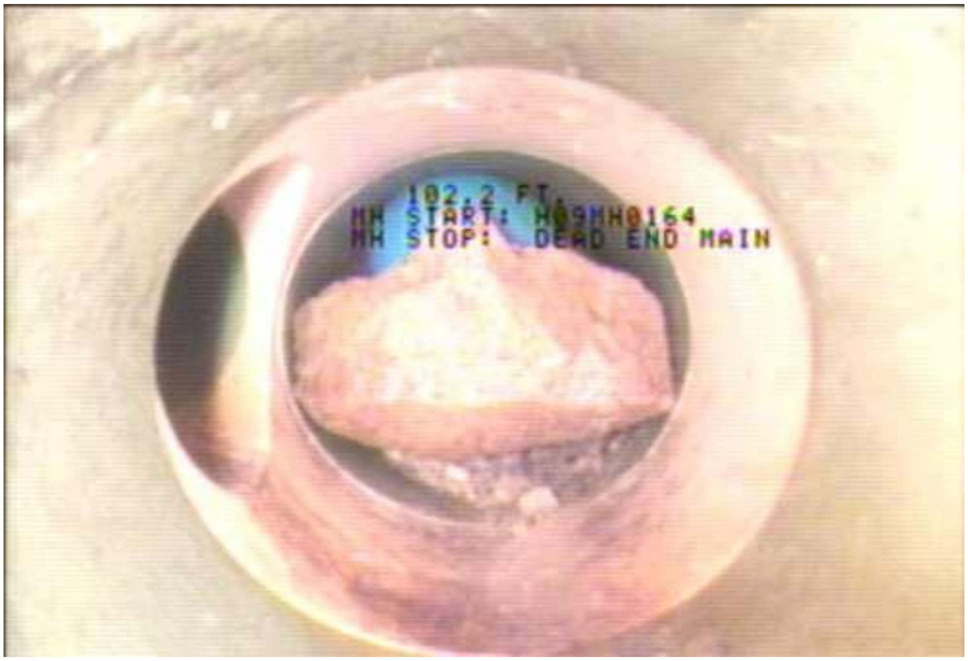
Obstruction Construction Debris (OBN)



Object Intruding Through Wall (OBI)

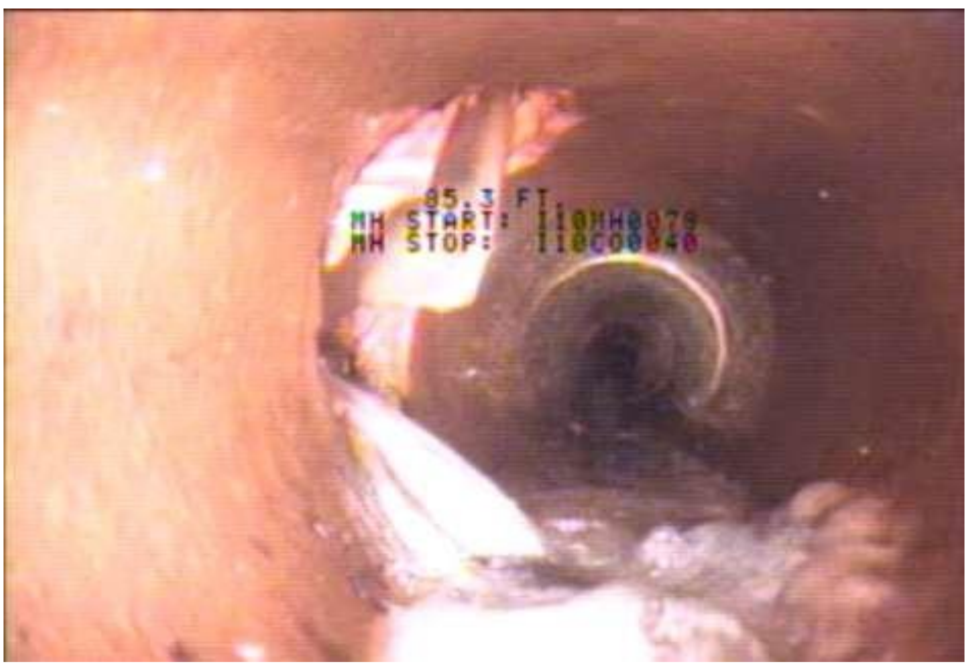


Obstruction Rock (OBR)



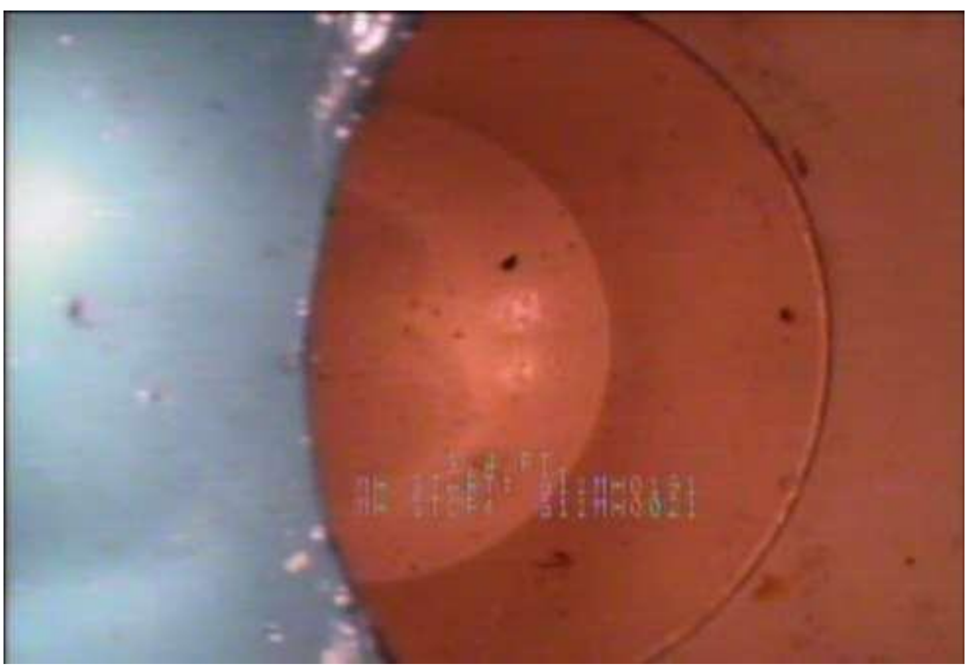
Tap (T)

Tap Break-In/Hammer Intruding (TBI)



Tap Break-In/Hammer Defective (TBD)

Tap Break-In/Hammer Capped (TBC)



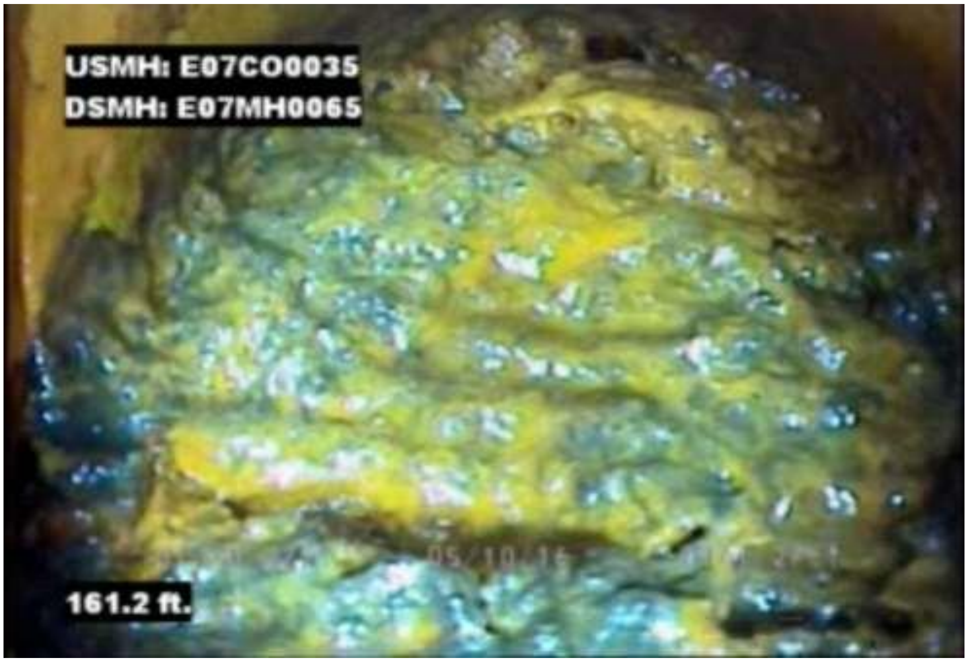
Tap Break-In/Hammer Active (TBA)

Factory Made (F)

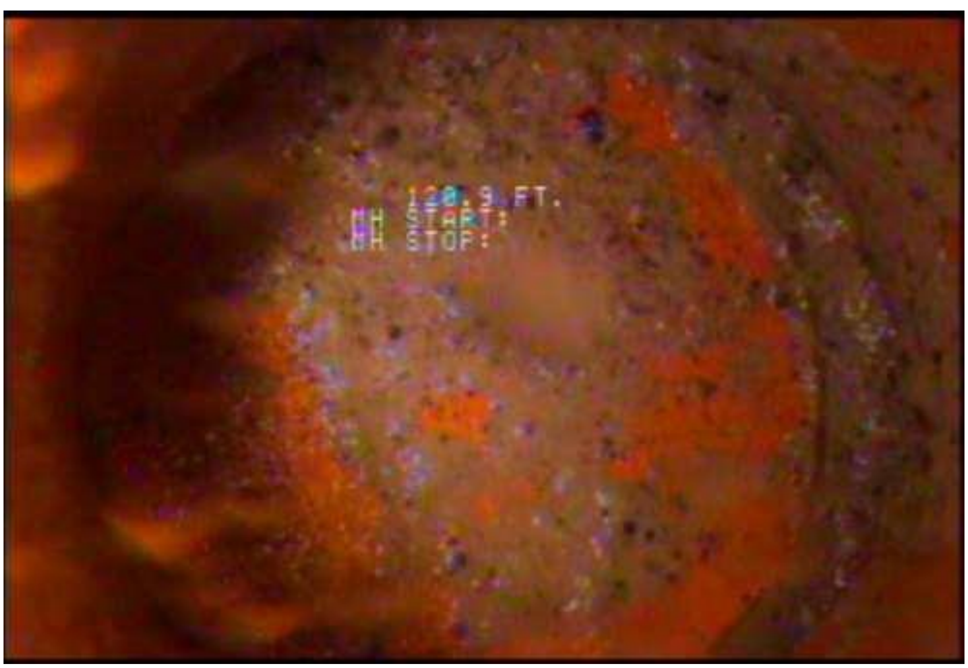
Tap Factory Made Intruding (TFI)


Distance: 63.0
Material Change
Clock from:
Rating:
Dimension1
Dimension2
Remarks:

Tap Factory Made Defective (TFD)



Tap Factory Made Capped (TFC)



Tap Factory Made Active (TFA)

Rehabilitated (R)

Tap Rehabilitated Intruding (TRI)

Tap Rehabilitated Defective (TRD)

Tap Rehabilitated Capped (TRC)

Tap Rehabilitated Active (TRA)

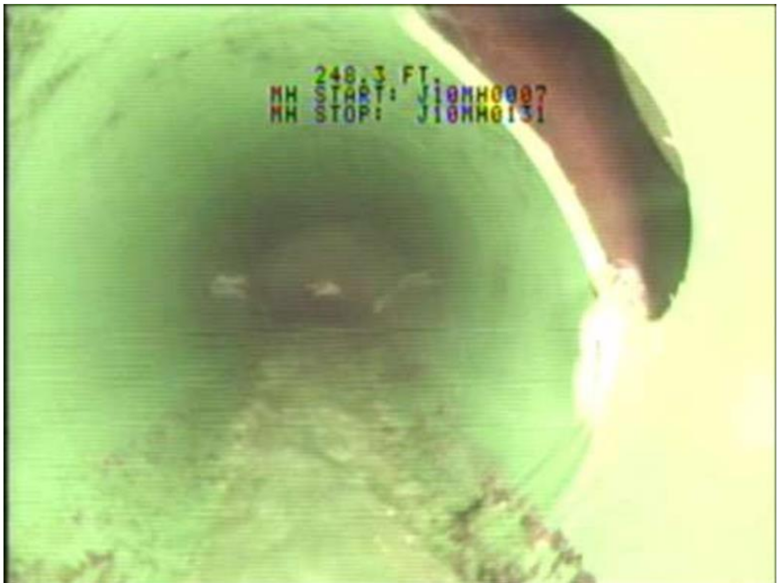
Saddle (S)

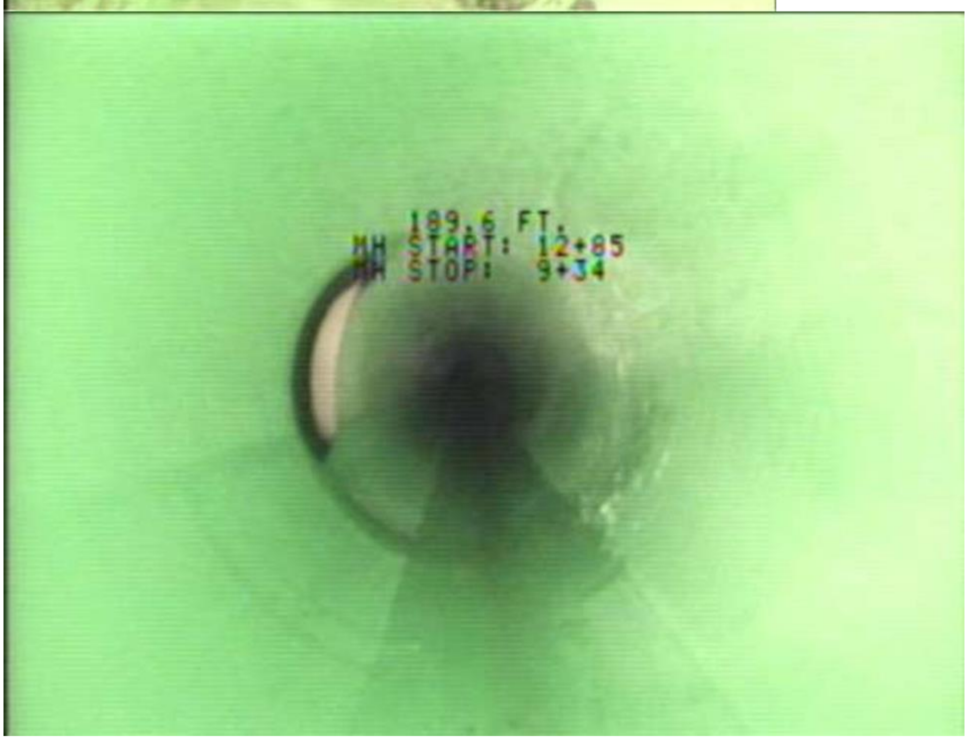
Tap Saddle Intruding (TSI)

Tap Saddle Defective (TSD)

Tap Saddle Capped (TSC)

Tap Saddle Active (TSA)

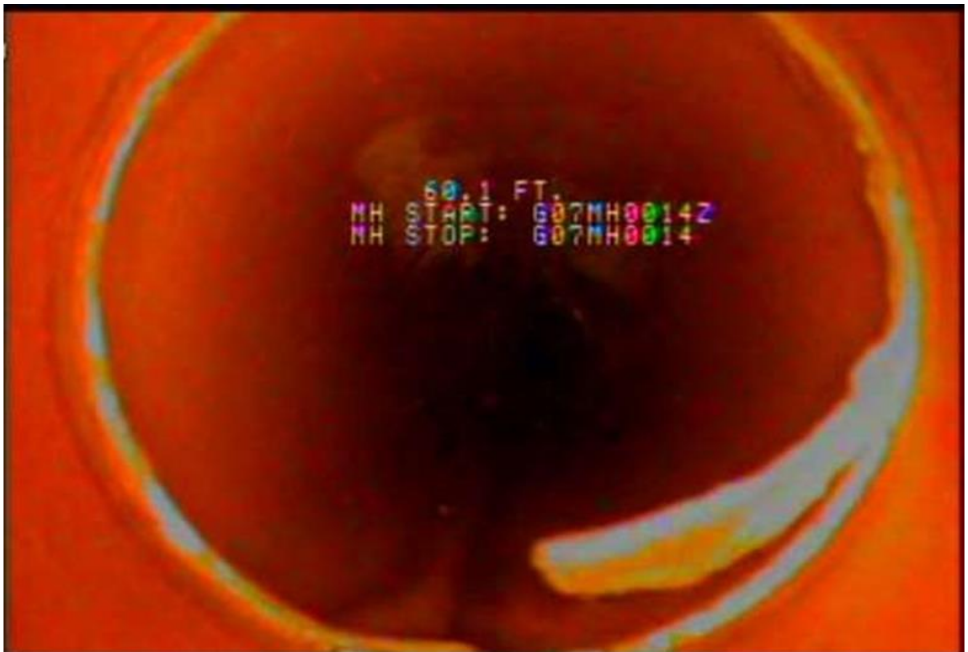

248.3 FT.
MH START: J10MH0007
MH STOP: J10MH0131


189.6 FT.
MH START: 12+85
MH STOP: 9+34

Intruding Sealing Material (IS)

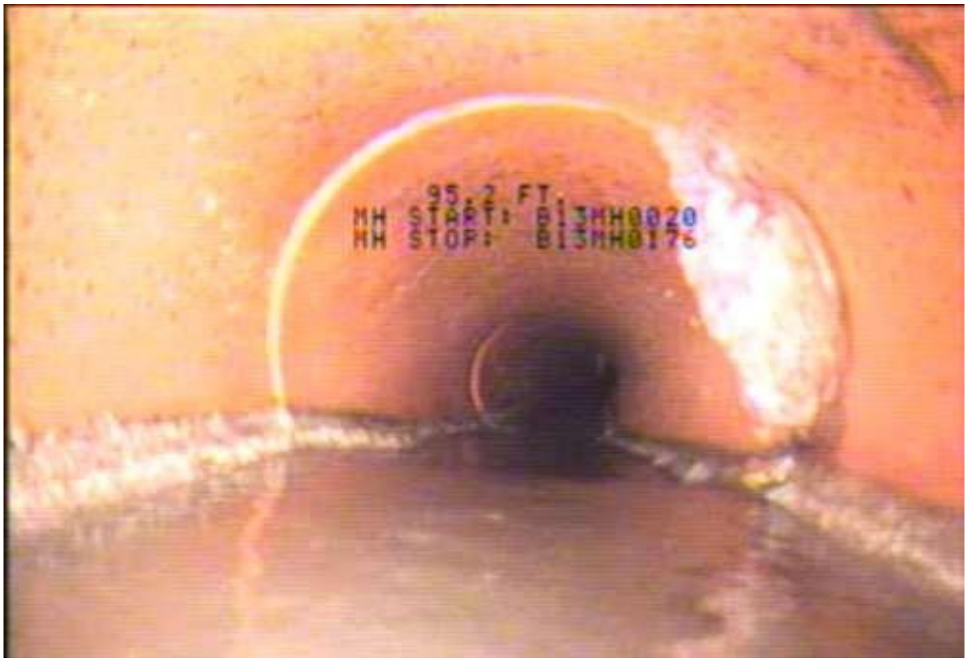
Intruding Sealing Ring Hanging (ISSRH)

Intruding Sealing Ring Broken (ISSRB)

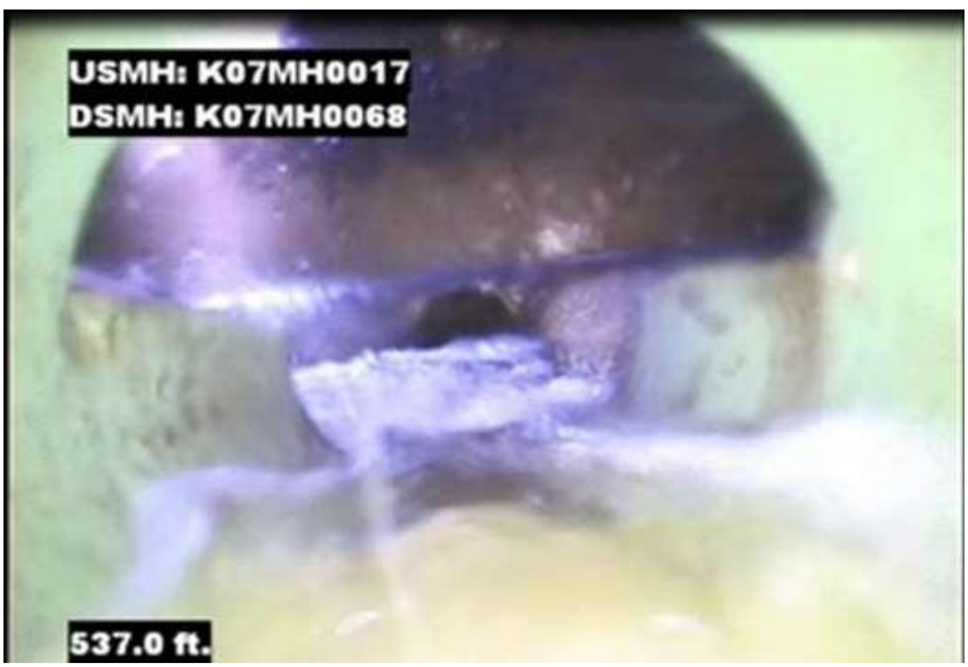

60.1 FT.
MH START: G07MH0014Z
MH STOP: G07MH0014


7/18/2013 10:01 AM
337.5 FT

Intruding Sealing Material Grout (ISGT)

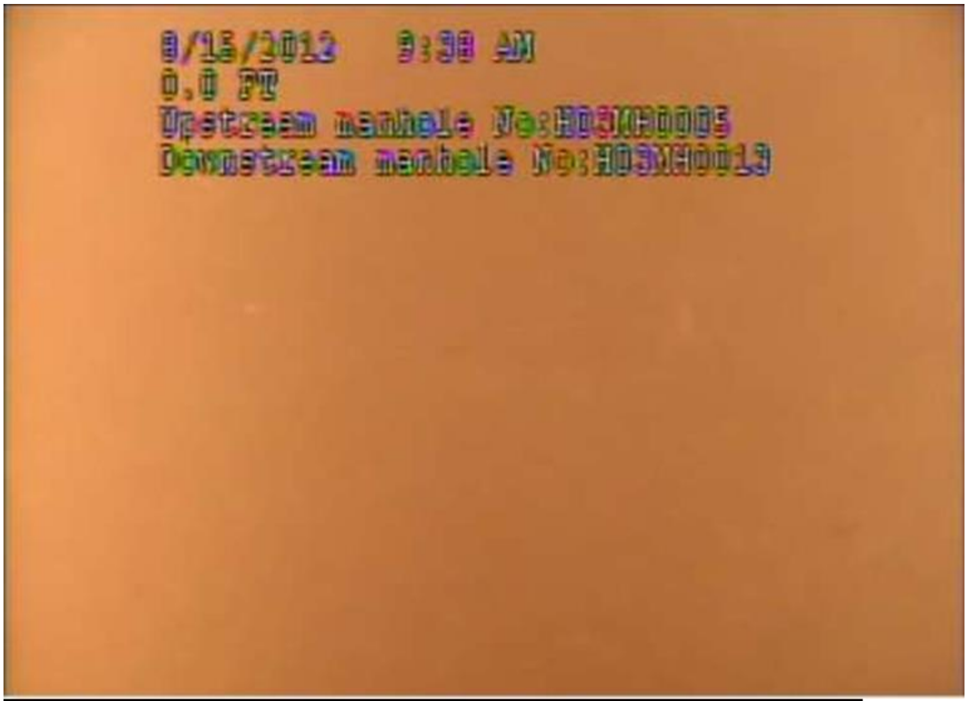


Access Manhole (AMH)



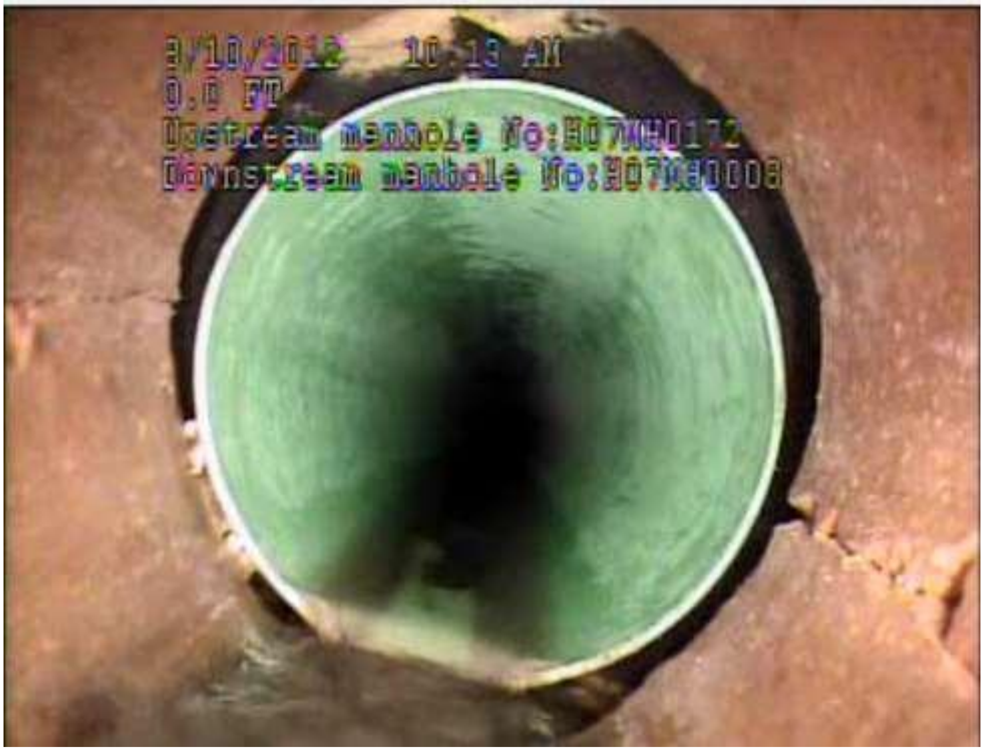
Miscellaneous (M)

Miscellaneous Camera Underwater (MCU)



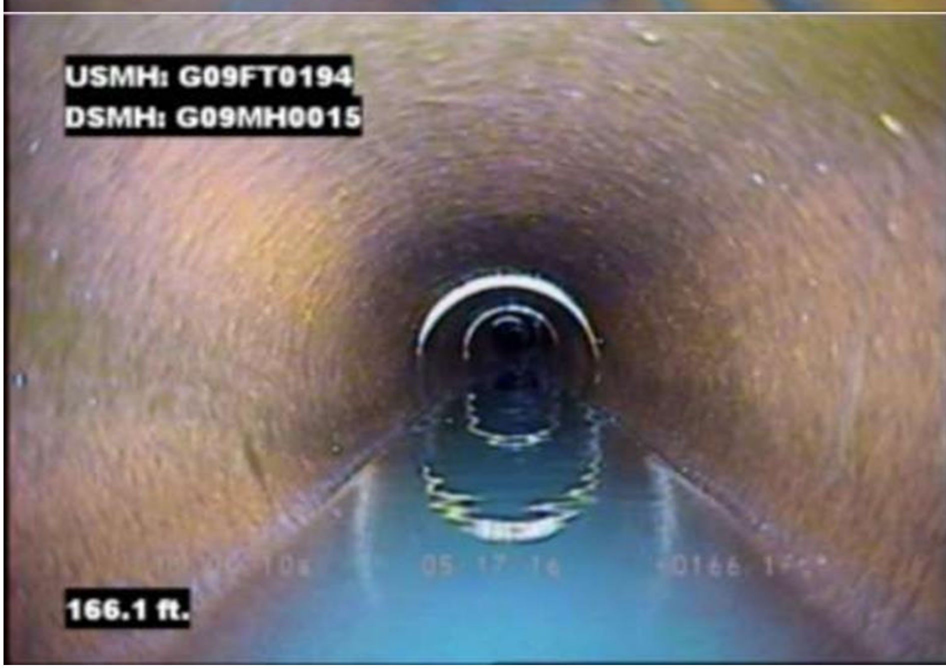
Miscellaneous General Observation (MGO)

Miscellaneous Material Change (MMC)



Miscellaneous Survey Abandon (MSA)

Miscellaneous Water Level Sag (MWLS)



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Biographical Information

Mr. Mohammed Al Asadi is a civil engineer with an experience of more than 10 years combined in research, teaching, non-destructive evaluation of superstructures and infrastructure, project planning and scheduling, project estimating, reinforced concrete design, steel design, concrete mix design, ready mix concrete quality control, pipe inspection and evaluation and pipes long term performance.

Mr. Mohammed Al Asadi has three degrees in Engineering, Bachelor degree in Civil Engineering from UOB in Asia, Post-Graduate diploma in Construction and Project Management and a Master's Degree in Construction and Building Engineering From AASTM in Africa and a current PhD. candidate in Structural Engineering in UTA in North America.