Hazen *Technical Memorandum*

April 20, 2018

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CableRunner Technology Review
City of Miami Beach

Introduction

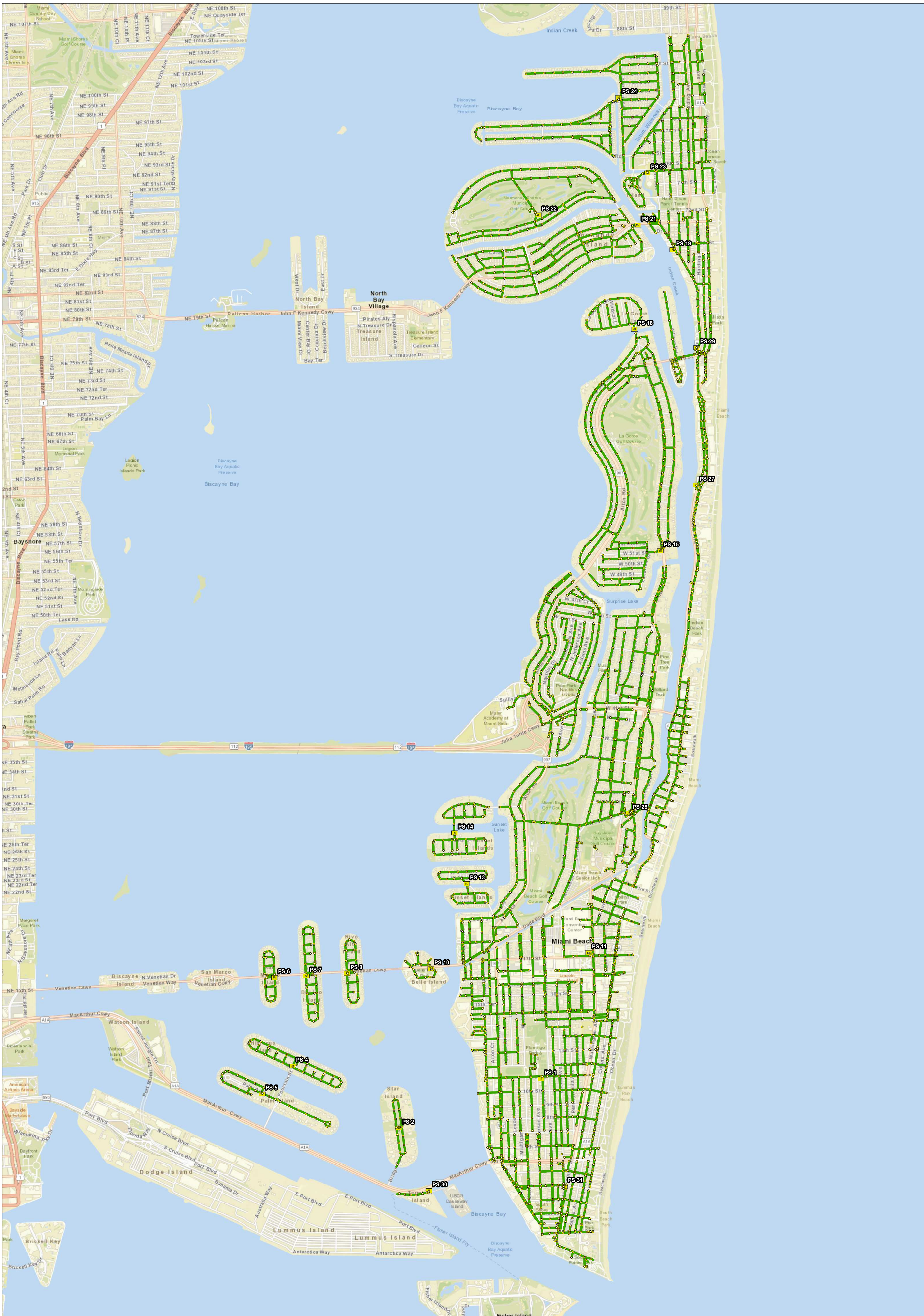
The City of Miami Beach owns and operates a gravity wastewater collection system that includes approximately 113 miles of gravity sewer and approximately 2,750 manholes. The majority of the sewer piping was installed circa 1950, as indicated by the major presence of vitrified clay pipe (VCP), also referred to as terracotta piping. Concrete, polyvinyl chloride (PVC), cast iron, and ductile iron piping are also present in the system. The size of piping ranges from 4-inches in diameter to 36-inches in diameter.

The sewer system collects wastewater from the City's service area and transmits that wastewater to 23 lift stations, which pump wastewater through the City's force main network. Flow converges at South Point Park, where wastewater is conveyed through a subaqueous 60-inch force main under Government Cut and is received by Miami-Dade Water and Sewer's (MDWASD) Central District Wastewater Treatment Plant (CDWWTP) for treatment and disposal. Refer to **Figure 1-1** for an overview of the City's sewer system.

CableRunner International (CableRunner) is a company based in Vienna, Austria. CableRunner offers a mechanism to install fiber optic conduits within gravity sanitary sewer systems, benefiting from the connectivity and proximity to homes. Stormwater systems can also be utilized for CableRunner technology. The company was founded in 1999 and has completed several projects in Europe. In recent years CableRunner has expanded to China, Russia, and the Americas. In 2013, CableRunner began work in the United States (US) with a large diameter sanitary sewer project in Cleveland, Ohio, which is the sole installation in the US to date.

The City of Miami Beach contracted Hazen and Sawyer to perform an evaluation of CableRunner technology and consider local conditions in Miami Beach to determine the suitability of installing an in-sewer fiber optic network.

Job no 49000-004



Legend

- Manhole
- Pump Station
- Gravity Sewer Main

N W E S

1 inch = 1,250 feet

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Figure 1-1: Sewer Network Overview

MIAMIBEACH

DATE: **APRIL 17, 2018**

Table of Contents

List of Tables

List of Figures

1. Broadband Availability in Miami Beach

Broadband in Miami Beach is currently provided by digital subscriber line (DSL), cable, fiber optic, and satellite. Cable and DSL are the most widely used broadband service method, with coverage across approximately 98% of the City.

DSL is a type of broadband connection that transmits data over telephone cables. Internet speed depends on how far the connection must travel from the provider, but speed is independent of the volume of users. DSL broadband is typically the slowest option, with speeds ranging in the hundreds of kilobytes per second (Kbps). However, many users choose DSL because it is typically the most cost-effective option.

Cable is a type of broadband connection that transmits data through coaxial copper cables. Each cable line services more than one home, so the speed of broadband depends on the volume of users. Cable internet speed is independent of distance to provider. Cable internet is typically faster than DSL, with speeds ranging in the hundreds of megabits per second (Mbps). Cable is typically more expensive than DSL but less expensive than fiber optic service.

Fiber optic service transmits data in the form of light waves through plastic or glass fiber optic cable. The speed of fiber optic broadband is independent of both distance from the provider and volume of users. Fiber optic service typically provides the fastest broadband speeds ranging in the thousands of Mbps into the gigabits per second (Gbps). Fiber optic service is not widely used in Miami Beach, as coverage is only available across approximately 3-4% of the City, and the cost per month in comparison to DSL and cable is high.

Satellite broadband works wirelessly through the interaction of geosynchronous satellites, and therefore is available essentially everywhere in the world. Satellite internet speeds fall between DSL and cable. Speed may be slowed down or interrupted by inclement weather. Satellite broadband is typically the most expensive in monthly fees, depending on the data usage cap chosen by the customer.

Table 1.1 summarizes the characteristics of the different broadband service types available in Miami Beach.

Table 1.1: Comparison of Broadband Service Types in Miami Beach

Parameter of Comparison	Broadband Service Method			
	DSL	Cable	Fiber Optic	Satellite
Speed of connection	Slowest	Fast	Fastest	Slow
Potential for lag in service	Common[1]	Common[2]	Uncommon	Common[3]
Availability	Wide	Wide	Limited	Wide
Price of monthly service	Lowest	Low	High	High

[1] Occurs when home connection is far from provider.
[2] Occurs when high volume of users are online.
[3] Occurs during inclement weather conditions.

2. Technology Review

2.1 Standard Installation Practices

Wired broadband infrastructure, including DSL, coaxial cable, and fiber optic cable, are traditionally installed separately from the sewer infrastructure. Broadband infrastructure may be installed above or below ground. Above ground, aerial cables are affixed to power or telephone poles. Below ground cables are most commonly installed via open trench and are protected by PVC or galvanized steel ducts. Underground installation may also be completed via horizontal directional drilling (HDD), which is the process of reaming an arced pathway which cables can be pulled through. Trenchless technology such as HDD is less disruptive to the public and environment. In Miami Beach, the broadband network provider is responsible for installation, operation, and maintenance of the system.

Sewer systems are installed below ground by open trench or through trenchless technology, such as tunneling or HDD, when necessary. The City of Miami Beach is responsible for installation, operation, and maintenance of its sewer system. Small diameter sewer pipes service homes and businesses while larger diameter pipes collect flow and are typically located closer to pump stations. Currently, the City's sewer network is comprised of approximately 113 miles of below ground gravity sewer and 2,750 manholes which allow access to the sewers at regular intervals.

2.2 CableRunner Installation

CableRunner's in-sewer fiber optic technology involves installation of fiber optic cables inside existing gravity sewer mains through manholes. Prior to installation, the CableRunner team performs an inspection via camera to assess the condition of the pipe. The pipe is then assigned a Damage Class, a number from 1 to 5 rating the condition of the pipe. 1 refers to a pipe in perfect condition while 5 refers to a pipe in very poor condition. CableRunner only installs their system on pipes with a Damage Class rating of 1 through 3, that is pipes that are not expected to need repair or replacement within the next 10 years.

If a pipe passes the Damage Class evaluation, the CableRunner team will proceed with installation. If there is settled sludge in the sewer pipe, the system must be cleaned before installation. The system may also need to be plugged and vacuumed in the case that more than 30% of the pipe is full of water, where vacuuming is possible. The CableRunner robot, discussed below, is not able to work in excessively dirty or inundated pipes.

Crew-accessible sewers are defined by CableRunner as sewers with a diameter of greater than 80 cm (30 in). A human crew enters the sewer and manually affixes cables to the wall of the pipe with mounting clips at pre-defined intervals. The depth that these clips are driven into the pipe wall depends on the pipe material and wall thickness. The mounting clips hold 8.2cm x 3.6 cm (3.2" x 1.4") rectangular cable trays in place. The cable trays run along the length of the pipe and are used as a conduit for fiber optic cables. **Figure 2-1** shows CableRunner technology installed in a crew accessible sewer.

Figure 2-1: CableRunner technology installed in an accessible sewer of diameter greater than 80 cm (30 in).

Non-accessible sewers are defined by CableRunner as sewers with a diameter of less than 80 cm (30 in). In non-accessible sewers, a robotic device on wheels enters the sewer and is guided by a wire connected to an installation vehicle above ground. The robot makes a series of punctures in the upper wall of the sewer pipe and affixes 6.8cm x 3.0cm (2.7” x 1.2”) rectangular cable trays at pre-defined intervals. Fasteners are driven completely or partially through the sewer pipe wall. The depth of puncture is determined by the material and wall thickness of the pipe. The robot exits the sewer and the cable tray remains in place along the top wall of the sewer. **Figure 2-2** shows CableRunner technology installed in a non-accessible sewer and **Figure 2-3** shows the current version of the robot used for installation.

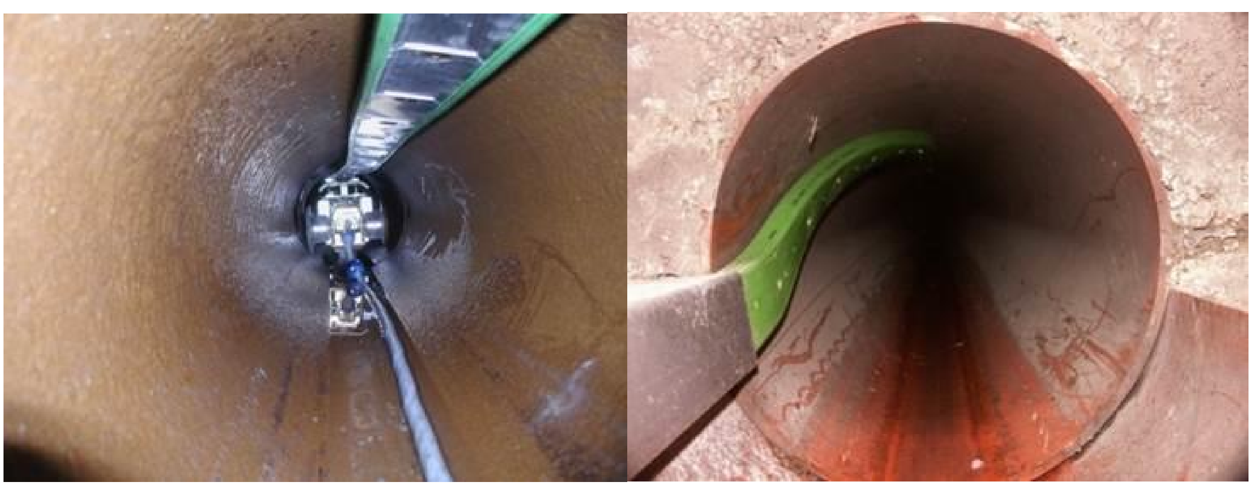


Figure 2-2: CableRunner technology installed in a non-accessible sewer of diameter less than 80 cm (30 in).

Figure 2-3: Current version of CableRunner robot used for installation of fiber optics in inaccessible sewers.

CableRunner has tested their system on various pipe materials including concrete, brick, PVC, and terracotta piping. Installation in PVC piping is most desirable because the fastener can be threaded completely through the PVC, and the plastic and the fastener create a watertight seal. Ductile iron and cast iron can similarly be drilled with minimal leakage. Drilling completely through a brittle material such as concrete, brick, or terracotta pipe is the least desirable, as a watertight seal is not created between the wall of the pipe and the bolt. Pipes of these materials may be partially drilled. Concrete and brick pipes in accessible sewers are typically thicker and may be partially drilled to affix mounting clips. Smaller pipes made of brittle material may be partially drilled if the wall thickness is adequate.

A key element to the functionality of the CableRunner system is redundancy. Ideally, the system would be very interconnected and have multiple pathways for each connection, to assure reliable uninterrupted service. CableRunner's intent is to install fiber optic connections through multiple pathways, so in case of an interruption in service along one pathway, there are backup pathways to maintain service. The interconnectivity of a sewer system to homes and businesses makes it a potential conduit for installation of a fiber optic network.

Table 2.1 summarizes the installation requirements for CableRunner technology, as discussed above.

Table 2.1: CableRunner Installation Requirements

Parameter	Capability of Installation
Condition of Pipe	
Damage Class 1-3	CableRunner may perform installation.
Damage Class 4-5	Pipe in too poor condition for CableRunner installation.
Pipe Diameter	
4-10"	Too small to access via robot or crew.
12-27"	Accessible via robot.
30-36"	Accessible via crew.
Pipe Material	
Concrete	Bolts are drilled partially through wall of pipe. The depth of the bolts depends on the thickness of the pipe.
Brick	Bolts are drilled partially through wall of pipe. The depth of the bolts depends on the thickness of the pipe.
PVC	Threaded bolts are drilled fully through wall of pipe. Threaded plastic creates a watertight seal.
Ductile or Cast Iron	Threaded bolts are drilled fully through wall of pipe.
Terracotta	Bolts are drilled partially through wall of pipe. The depth of the bolts depends on the thickness of the pipe.
Connectivity of Suitable Pipes	
Low	Minimal pathways for in-sewer fiber optic network.
High	Allows for redundancy and an expansive fiber optic network.

The single case of installation of CableRunner technology in the United States is in Cleveland, Ohio. The North East Ohio Regional Sewer District (NEORSD) contracted CableRunner to install a fiber optic system in the Heights Hilltop Interceptor, a sanitary sewer tunnel. The installation was performed by a local construction company, remotely supervised by CableRunner, within a 12-foot (144-inch) diameter, crew accessible concrete tunnel. The extent of the project was approximately 3,000 linear feet. According to phone correspondence with NEORSD, they have experienced no difficulties with the system and have no current plans for expanding the network. See **Figure 2-4** for photographs from the Cleveland installation.

Figure 2-4: CableRunner installation in Heights Hilltop Interceptor in Cleveland, Ohio.

3. Suitability Review

3.1 Size of Sewer System

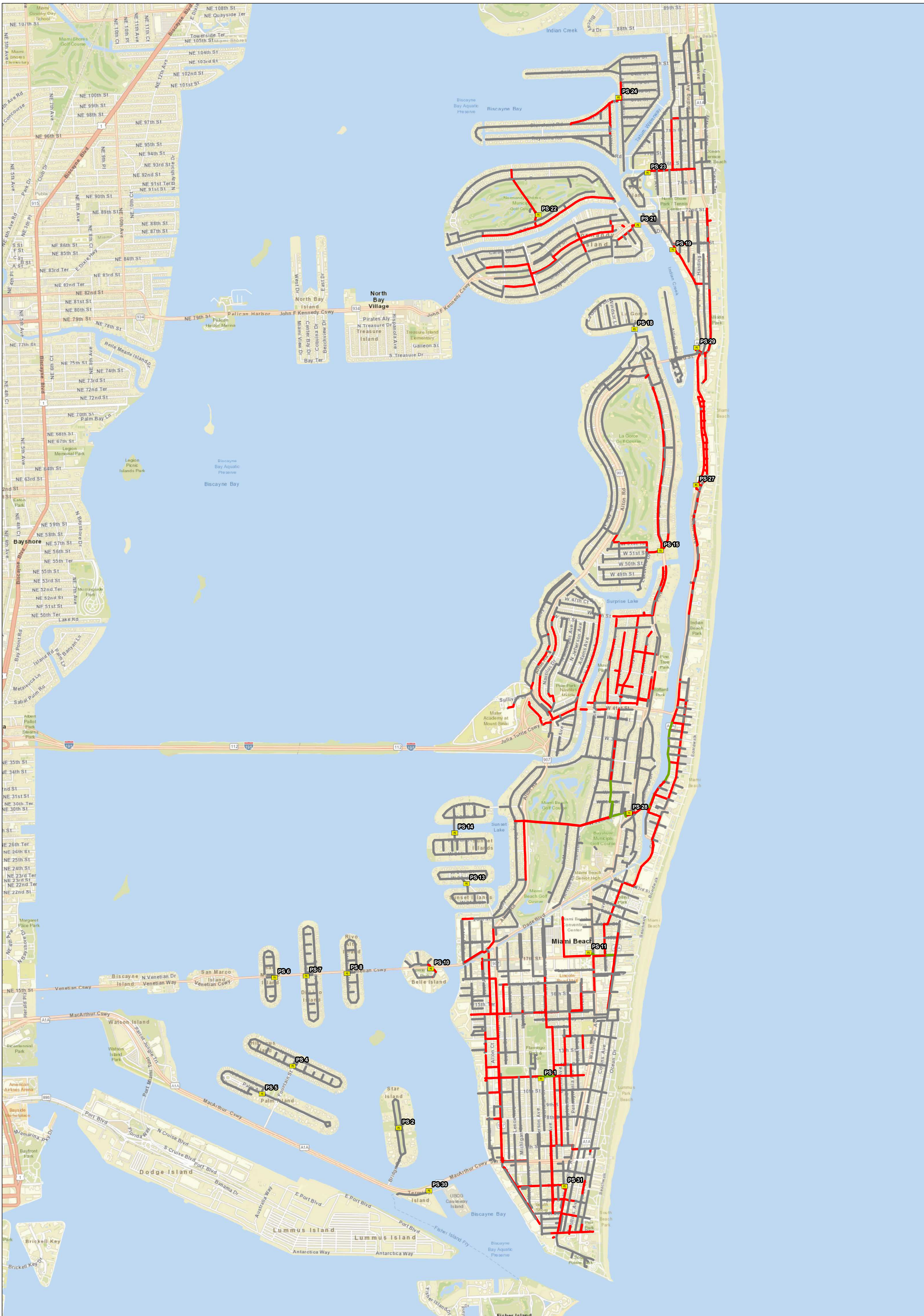
As discussed in Section 2.2, CableRunner classifies a crew-accessible sewer as one that is greater than 80 cm (30 in) in diameter. According to CableRunner's size classification, less than 1% of City's sewer system is crew-accessible. The current version of the CableRunner robot is able to install cable trays in sewers greater than 30 cm (12 in) in diameter. As presented in Table 3.1, approximately 23% of the City's existing gravity collection system is robot accessible. The remaining 75% of sewer system of known diameter is too small to be accessed via either crew or robot.

Table 3.1: Wastewater Collection System Gravity Sewer Distribution by Size

Diameter (Inches)	Pipe Length (Feet)	Percentage (%)	Accessibility
4 – 10	444,907	75%	Not accessible
12 – 27	139,470	23%	Accessible via robot
30 – 36	4,883	0.8%	Accessible via crew
Unknown	7,195	1.2%	N/A
Total	**596,455**		

Source: City of Miami Beach GIS database dated December 12, 2017.

Refer to **Figure 3-1** for the distribution of gravity mains between 4-10 inches (inaccessible), 12-27 inches (accessible by robot), and 30-36 inches (accessible by crew). As previously discussed, CableRunner technology depends on high connectivity of the sewer system and the proximity to homes. The large amount of 8-inch piping throughout the system severely limits the ability to install an integrated fiber optic network with redundant pathways, because of limited connectivity of accessible pipes.



Legend

- Pump Station
- 4 - 10" (non-accessible)
- 12 - 27" (robot-accessible)
- 30 - 36" (crew-accessible)

1 inch = 1,250 feet

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Figure 3-1: Gravity Main Diameter Distribution

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DATE: APRIL 17, 2018

3.2 Material of Sewer System

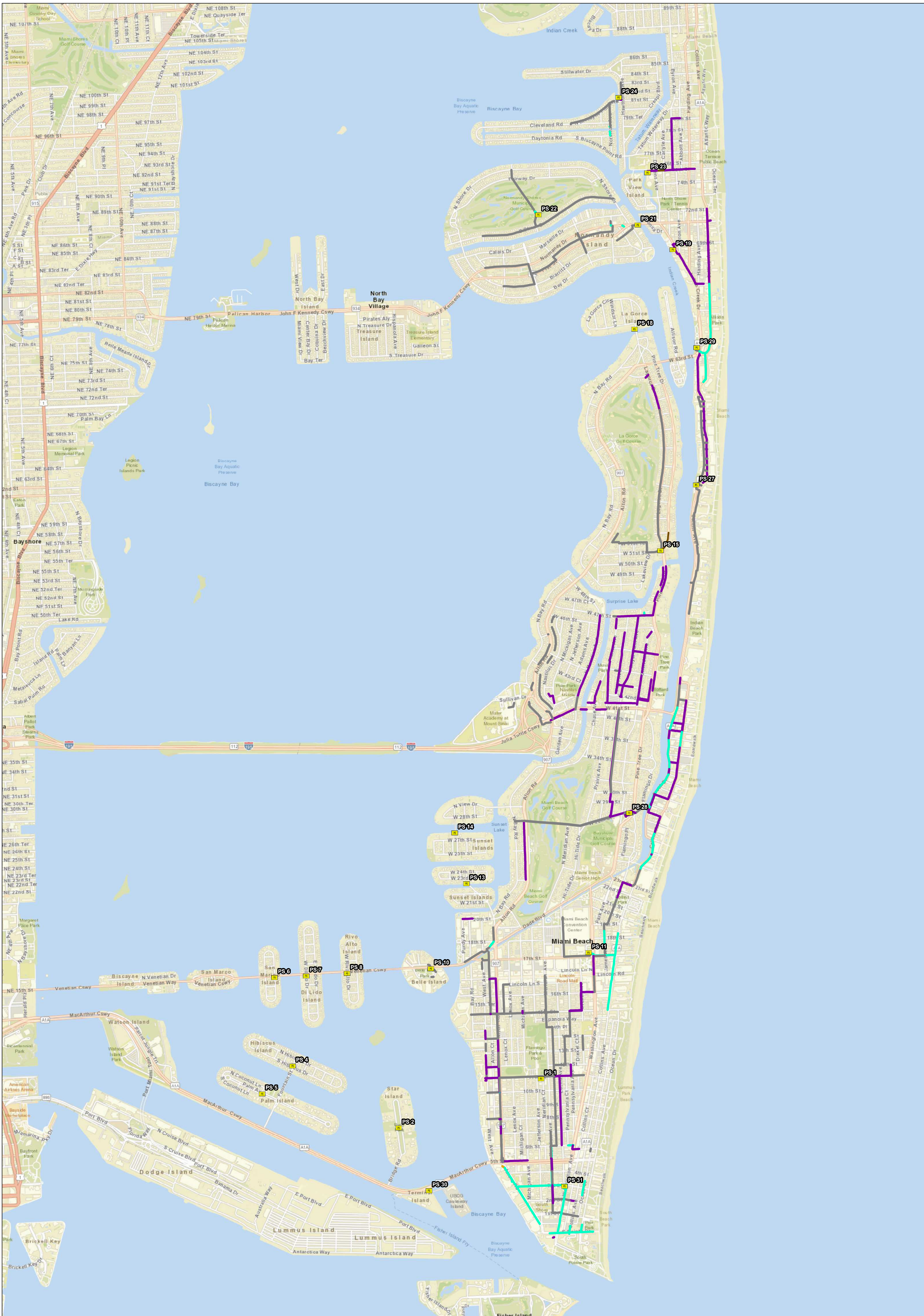
Table 3.2 presents a breakdown of the City's sewer system by material. A majority (approximately 54.5%) of the City's existing gravity sewer system is constructed out of terracotta pipe. Terracotta pipe is very susceptible to cracking once an initial fracture is made. Drilling bolts partially or fully into a terracotta sewer pipe for mounting of cable trays could compromise the structural integrity of the pipe and likely lead to leakage. The second most common material of construction for Miami Beach sewer is concrete (37.3%). CableRunner has previously successfully installed fiber optic cables in large diameter concrete tunnels and pipes. Other materials within the City's sewer system include PVC (7.6%) and Ductile or Cast Iron (0.3%), which can better structurally support CableRunner technology.

Table 3.2: Wastewater Collection System Gravity Sewer Distribution by Material

Material	Pipe Length (Feet)	Percentage (%)
Ductile or Cast Iron	1,896	0.3%
Concrete	221,721	37.3%
PVC	45,502	7.6%
Terracotta	325,326	54.5%
Unknown	2,010	0.3%
Total	**596,455**	

Source: City of Miami Beach GIS database dated December 12, 2017.

Figure 3-2 presents the distribution of sewer pipe by material in Miami Beach, for pipes greater than 12-inches, the portion that is accessible to CableRunner. Assuming that installation of CableRunner in terracotta pipe could potentially diminish the structural integrity of the pipe, the connectivity of the system will be further reduced. The portion of the sewer that is larger than 12-inches in diameter and not constructed out of terracotta piping amounts to approximately 12% of the entire sewer network, as shown in **Figure 3-3**.



Legend

- Pump Station
- Terracotta: 12 - 36"
- Concrete: 12 - 36"
- Iron: 12 - 36"
- PVC: 12 - 36"
- Unknown Material: 12 - 36"

N / S / E / W

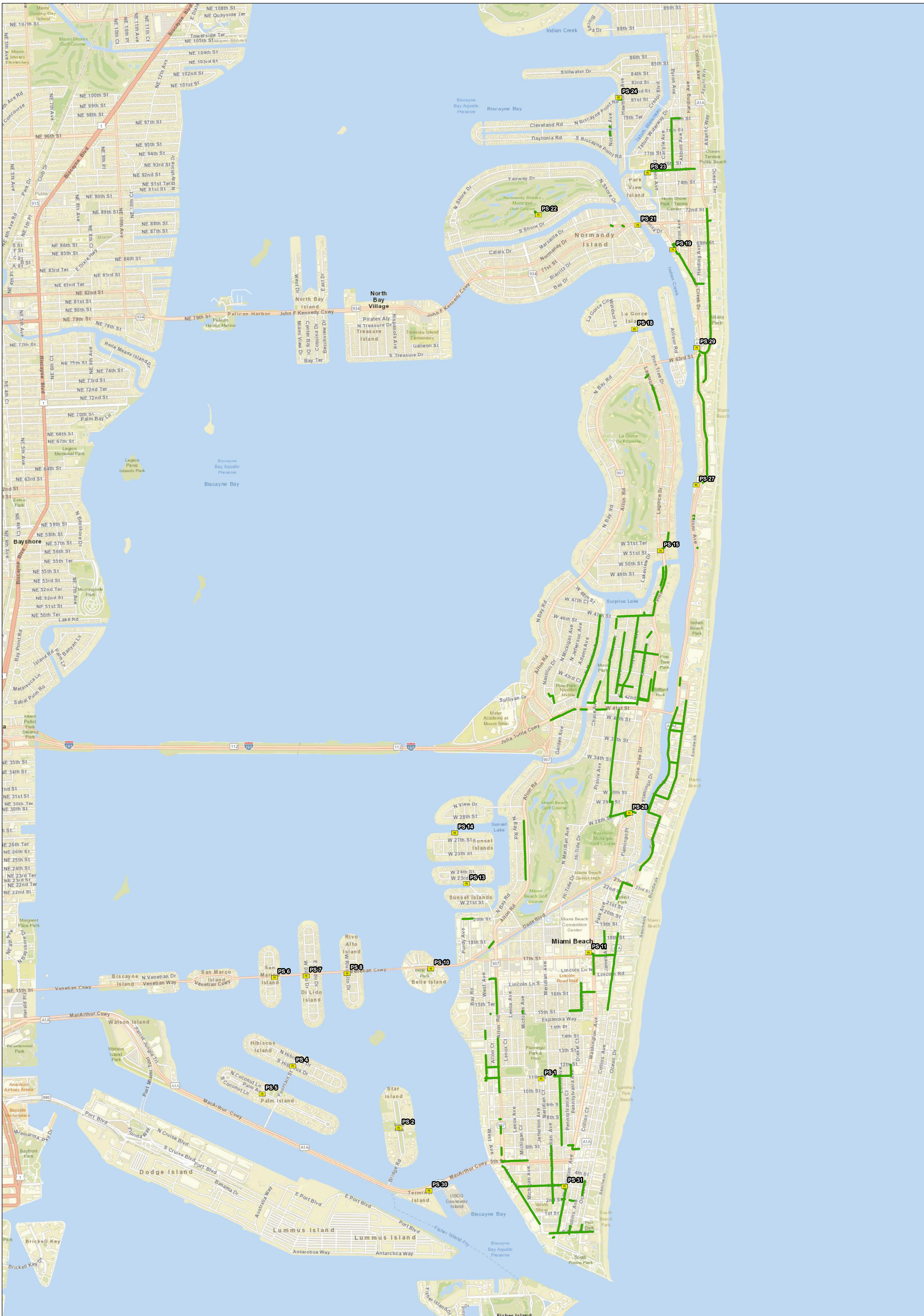
1 inch = 1,250 feet

CITY OF MIAMI BEACH

Figure 3-2:
12 - 36" Gravity Main Material Distribution

MIAMIBEACH

DATE: **APRIL 17, 2018**



Legend

Suitable portion of Sewer

Pump Station

1 inch = 1,250 feet

CITY OF MIAMI BEACH

Figure 3-3: Location of Gravity Mains Suitable for Installation of CableRunner based on Diameter and Material

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DATE: APRIL 17, 2018

3.3 Other Considerations

3.3.1 Age of Piping

As discussed in Section 2.2, prior to installation CableRunner performs a Damage Class evaluation and will not install on pipes assigned a Damage Class of 4-5, or a pipe that may need replacement within 10 years. Although the exact age distribution of the existing gravity sewer piping is unavailable, the major presence of terracotta piping indicates that a majority of the sewer system was installed circa 1950, making the system almost 70 years old.

The US Environmental Protection Agency (EPA) issued a document in September 2002 titled "Clean Water and Drinking Water Infrastructure Gap Analysis Report" (document no. 816-R-02-020). This report indicates that the average expected useful life of gravity sewer piping is in the range of 80-100 years. The majority of the City's sewer piping is approaching this age threshold and will likely need a great deal of replacement and repair within the next 10-20 years. Comprehensive repair and replacement of an aging sewer system takes many years and resources.

3.3.2 Repair

The CableRunner team is responsible for the maintenance of the CableRunner system. If the City must repair or replace a pipe where CableRunner is installed, the CableRunner team must be contacted to splice the cables as necessary and install a manhole to manhole cable bypass system to ensure that broadband customers do not lose service during the pipe repair. If enough redundancy exists, the CableRunner team may not need to install a bypass, but the system will still need to be removed for the City to perform the pipe repair. Following the repair, CableRunner must be present to reinstall the cable trays. The added step of coordinating with an additional crew can lead to longer repair times and potentially greater public disruption, which may be especially problematic in emergency repair situations.

3.3.3 Lining

One common maintenance technique used on failing sewer pipes is lining. Cracked or damaged sewer pipe may be internally lined through cured-in-place piping (CIPP) or similar trenchless methods. CIPP is the process by which a flexible lining material containing fiber glass particles is inserted into the sewer pipe. Water is pumped through the liner so that it expands to the walls of the sewer pipe. The water is heated, which causes the liner to harden, essentially forming a new internal wall of the pipe.

A pipe could not be lined with CableRunner technology present. The CableRunner crew would need to be contacted to install a bypass and remove the cable trays before lining could take place. This adds extra time and resources to a lining procedure.

Commonly, the liner material is thin, as not to impact the hydraulic carrying capacity of the sewer pipe. The thickness of a liner does not often exceed one inch, as presented in Table 3.3. Attaching cable trays to the liner may penetrate the surface of the liner, potentially resulting in leaks and possibly voiding the liner warranty. As presented in Table 3.4, half of all sewer piping in Miami Beach has been lined.

Table 3.3: Average Sewer Pipe Liner (CIPP) Thickness

Diameter of Pipe	Range of Normal Liner Thickness (mm)	Range of Normal Liner Thickness (in)
8” - 15"	6.0 - 9.0	0.236 - 0.354
18”	6.0 - 10.5	0.236 - 0.413
21”	6.0 - 12.0	0.236 - 0.472
24” - 30”	9.0 - 15.0	0.354 - 0.591
36”	10.5 - 18.0	0.413 - 0.709

Table 3.4: Wastewater Collection System Lining Status

Status	Pipe Length (Feet)	Percentage (%)
Lined	291,239	49%
Unlined	305,216	51%
Total	**596,455**	

Source: City of Miami Beach GIS database dated December 12, 2017.

3.3.4 Maintenance

Inspection and maintenance is necessary for all sewer systems. A single clogged sewer pipe can compromise the functionality of the entire system. If a blockage or build-up is suspected, the City uses robotic cameras on wheels to perform an in-sewer TV inspection of the line.

CableRunner technology may interfere with videoing of the system. Any cracks, fractures, or points of concern on the top wall of the pipe could be covered up by the cable tray and go undetected. If the CableRunner tray detaches from the wall of the pipe, it may physically obstruct the path of the camera, especially in smaller diameter pipes.

If excess debris is detected after videoing the line, the sewer pipe is flushed out by hydro-jetting. Jetting is the procedure of inserting high pressure water hoses into the pipe to clean the line and remove debris. The hose is inserted into the sewer through an upstream manhole and pulled back through the pipe while jetting high pressure water in its path.

The CableRunner system has been tested to withstand pressures in the range of 150 bars (2,200 psi). Jetting of a sewer line can use water pressures from 750 psi to 2,500 psi, depending on the condition and blockages within the pipe. If the CableRunner fastening system is compromised in any way, it could potentially be detached during high pressure cleaning and create blockages downstream.

3.4 Infiltration/Inflow (I/I)

I/I refers to infiltration and inflow of stormwater or groundwater into a sewer system. Groundwater may enter a sewer system when a pipe is damaged or cracked and installed below the water table. Miami Beach is very susceptible to I/I because of the depth of the pipes below the water table and the age of the sewer system.

The United States Geological Survey (USGS) records daily groundwater levels at various monitoring wells across the US. Well No. F-179 (254444080144801) is located at the intersection of SW 32 Avenue and SW 24 Terrace in Miami, Florida. The average wet season groundwater elevation for 2017 was 0.90 NAVD 88 and the average dry season groundwater elevation for 2017 was 0.75 NAVD 88.

Table 3.5 shows the range of invert elevations of the City's gravity sewer. Approximately 90.5% to 99.5% of the entire gravity sewer system is below the groundwater table for the entire year. 90.5% conservatively assumes that all pipes of unknown elevation are above the water table, while 99.5% assumes that all pipes of unknown elevation are below the water table.

Table 3.5: Wastewater Collection System Gravity Sewer Distribution by Elevation

Average Invert Elevation of Pipe (NAVD 88)	Pipe Length (Feet)	Percentage (%)
< -3	8,550	1%
-3 to -2	40,322	7%
-2 to -1	283,443	48%
-1 to 0	204,123	34%
0 to 0.75	2,756	0.5%
> 0.75	3,001	0.5%
Unknown	54,260	9%
Total	**596,455**	

Source: City of Miami Beach GIS database dated December 12, 2017.

Due to the City being surrounded by water and the age of infrastructure, the sewer pipes often flow full and the CableRunner system could be subject to almost constant inundation by saline groundwater. Saline conditions are harsh on infrastructure and cause premature corrosion of metal piping and ducting.

3.5 Security

The US Department of Homeland Security (DHS) Water and Wastewater Systems Sector aims to protect water and wastewater systems across the country. The EPA oversees the water and wastewater sector. Water and wastewater systems are vulnerable to a variety of attacks that could threaten public health and safety. Wastewater system attacks could target treatment plants or transmission system access points such as manholes. Pointed attacks could affect a large amount of the public, since the transmission system is connected to almost every house and business in a given service area.

In 2015, DHS released a Water and Wastewater Sector Specific Plan (SSP) to outline possible risks and describe how to make the water and wastewater systems more resilient. In the report, intentionally malicious acts; such as release of chemical or biological contaminants into a water or wastewater system, disruption of service by physically harming infrastructure, or breaches in cyber security; are classified as high risk.

The extent of security concerns that would arise by allowing a private company to enter and install broadband technology in a sewer network is unknown. The integration of sewer and fiber optic infrastructure make the systems dually vulnerable in the case of an attack.

3.6 Regulatory Compliance

Install of CableRunner would need to be approved by various regulatory agencies that oversee the wastewater collection system in Miami Beach including the Miami-Dade Department of Economic Resource Management (DERM) and the Florida Department of Environmental Protection (FDEP). Hazen and Sawyer has not consulted with either regulatory agency during this review to determine if this system would be permittable.

4. Conclusions

The following conclusions indicate the City's sewer system is not suitable for the installation of an in-sewer fiber optic network:

- The majority of the gravity sewer is too small in diameter for installation by either human crew or the CableRunner robotic device.
- It is not advisable to drill into terracotta piping due to the limited knowledge of its physical condition.
- Drilling into existing piping regardless of the material will increase the potential for I/I problems that Miami Beach already faces due to the depth of pipes below the water table and the age of its sewer infrastructure.
- Based on the estimated age of the City's sewer infrastructure, a large amount of the existing sewer piping will likely require repair in the next 10-20 years.
- Maintenance procedures such as emergency repairs, lining of the pipe, or cleaning operations become more complex with the presence of an in-sewer fiber optic system.
- It is unknown if the regulatory agencies will permit an in-sewer fiber optic system.
- The suitable piping that does appear acceptable for CableRunner installation does not provide enough connectivity for an expansive or redundant in-sewer fiber optic network.