Borough of Caldwell

Phase II Inflow and Infiltration Investigation

December 28, 2021

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Borough of Caldwell
Wastewater Collection System

Phase II Inflow and Infiltration Investigation
Extraneous Flow Evaluation

December 28, 2021

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Issue and revision record

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01	February 11, 2021	ESS	JJS	JJS	Draft Report - Flow Monitoring
02	February 19, 2021	JFM	JJS	JJS	Draft Report - Hydraulic Model
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07	Nov 2, 2021	JFM MKW	JJS	JJS	Final Draft Report Smoke Testing and CCTV Inspection Results
08	Dec 28, 2021	JFM	JJS	JJS	Final Issue

Information class: Standard

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Executive Summary

The Borough of Caldwell (Borough) owns, operates and maintains the sanitary sewer collection and interceptor system and Wastewater Treatment Plant (Caldwell WWTP) that serves the residents of five adjoining municipalities: Borough of Caldwell, Township of West Caldwell, Borough of North Caldwell, Borough of Roseland, and Borough of Essex Fells. The Caldwell WWTP has a permitted average daily treatment capacity of 4.5 million gallons per day (MGD) with a peak hydraulic capacity of 15.0 MGD.

In a letter dated November 8, 2018 from Gautam R. Patel, Chief, Bureau of Environmental Engineering and Permitting, New Jersey Department of Environmental Protection (NJDEP), the Borough was alerted to the fact that the Caldwell WWTP had reached or exceeded ninety-five (95%) percent of its New Jersey Pollutant Discharge Elimination System (NJPDES) permitted discharge flow limit over a twelve (12) month consecutive average.

When a wastewater treatment facility exceeds its permitted capacity it can fail to meet its NJPDES discharge permit limits, which can adversely impact the waterbody into which the treatment facility discharges its effluent, potentially threatening drinking water supplies and the habitat of aquatic plants and animals. In order prevent further harm to the discharge waterbody, a temporary sanitary sewer connection ban is one option that can be implemented to limit new flow contributions within the sanitary sewer drainage area served by the affected treatment facility, until additional capacity becomes available.

To avoid the potential requirement of a sanitary sewer ban, prior to a treatment facility reaching its permitted discharge flow, a Capacity Assurance Program (CAP) Report is required to be prepared. The CAP Report provides guidance to the treatment facility owner / operator (permittee) in determining how a treatment facility's remaining flow capacity will be utilized and in deciding whether an upgrade to the treatment facility and / or the sanitary sewer collection system is necessary to ensure future capacity.

To meet the requirements as given in the NJDEP CAP Checklist, and as authorized by the Borough, Mott MacDonald completed an evaluation of the Borough's sanitary sewer collection system and wastewater treatment plant (Capacity Assurance Report). This Capacity Assurance Report (dated August 30, 2019) was submitted to the NJDEP on September 3, 2019.

Upon issuance of the Capacity Assurance Report, the NJDEP responded in a letter (dated September 18, 2019), commenting that "this office would like to see the Borough take the lead and get the cooperation and participation of those communities in their service areas that are suspected of contributing excessive flows to develop an I/I reduction plan, provide a specific schedule, financial plan and certification for initiatives that would eliminate I/I."

To that end, the Borough contracted with Mott MacDonald to conduct an Inflow / Infiltration Investigation to focus on the drainage areas that exhibit the greatest amount of (extraneous) Inflow / Infiltration (I/I), further identify specific defects and infiltration / inflow sources within the sanitary sewer collection and interceptor system, and prepare a plan and provide recommendations for corrective measures (along with an opinion of probable construction costs) to reduce I/I so as to comply with the Borough's Capacity Assurance Program.

This Inflow / Infiltration Investigation resulted in recommendations for a variety of system repairs to reduce leakage rates within the Borough's sanitary sewer collection and interceptor system. An estimated total of 54,418 gallons per day (gpd) of inflow / infiltration (I/I) was identified, including their sources, under this investigation within the study areas under various weather and groundwater conditions present at the time of inspection. An additional 69,000 gpd of suspected extraneous flow within four (4) sewer reaches were identified (although the direct sources could not be identified due to required limited accessibility).

This Report summarizes the procedures used for each of the project tasks, the results of the inspections, database reports, findings and recommendations for rehabilitation and maintenance with associated opinions of probable construction costs.

The cost to repair the identified defects and sources of I/I is estimated to be **$127,050**. The total project cost (including engineering and legal costs) is estimated to be **$198,200**.

1 Introduction

The Borough of Caldwell (Borough) owns and operates a sanitary sewer collection and interceptor system and a Wastewater Treatment Plant (Caldwell WWTP - located at 25 Pine Tree Place, West Caldwell, Essex County, New Jersey) that serves the residents of five adjoining municipalities: Borough of Caldwell, Township of West Caldwell, Borough of North Caldwell, Borough of Roseland, and Borough of Essex Fells, as well as minor sections of Fairfield, Livingston, Verona, and West Orange. The Borough is charged with the responsibility of managing the Caldwell WWTP and the Caldwell sanitary sewer collection and interceptor system and continuing to provide adequate and reliable sanitary sewer service to its customers and the public in general. The Borough's wastewater collection system includes over 133 miles of gravity sanitary sewer and force main with pipe diameters ranging from 8-inch to 24-inch. The Borough's wastewater collection system conveys sewage to the Caldwell WWTP (which currently serves approximately 31,800 customers).

In a letter dated November 8, 2018 (**Appendix A**) from Gautam R. Patel, Chief, Bureau of Environmental Engineering and Permitting, New Jersey Department of Environmental Protection (NJDEP), the Borough was alerted to the fact that the Caldwell Wastewater Treatment Plant had reached or exceeded ninety-five (95%) percent of its New Jersey Pollution Discharge Elimination System (NJPDES) permitted discharge flow limit over a twelve (12) month consecutive average.

When a wastewater treatment facility exceeds its permitted capacity it can fail to meet its NJPDES discharge permit limits, which can adversely impact the waterbody into which the treatment facility discharges its effluent, potentially threatening drinking water supplies and the habitat of aquatic plants and animals. In the event that a treatment facility exceeds its discharge permit limits, in order prevent further harm to the discharge waterbody, a sanitary sewer ban would be implemented within the sanitary sewer drainage area served by the affected treatment facility. A sanitary sewer ban protects the receiving water from further damage (by halting additional connections to the sanitary collection and treatment infrastructure) until the discharge permit limit exceedance issue can be properly evaluated and addressed.

To avoid the potential requirement of a sanitary sewer ban, prior to a treatment facility reaching its discharge permit limit, a Capacity Assurance Program (CAP) Report is typically prepared. A CAP Report is an evaluation performed by the owner / operator of wastewater infrastructure (i.e.: collection and interceptor system and / or treatment facility) to ensure that its collection system and / or treatment facility infrastructure will not exceed its permitted design flow capacity. A CAP is required when a wastewater treatment facility's average flow over a twelve (12) consecutive month period (as reported in the facility's Discharge Monitoring Report (DMR)) reaches or exceeds ninety-five (95%) percent of the facility's permitted design flow capacity.

The CAP provides guidance to the treatment facility owner / operator (permittee) in determining how a treatment facility's remaining flow capacity will be utilized and in deciding whether an upgrade to the treatment facility or sanitary sewer collection and interceptor system is necessary to ensure future capacity.

Amendments to the Capacity Assurance Program (CAP) rule were adopted and appeared in the May 15, 2017 issue of the New Jersey Register (49 NJR 1191(a)). The amendments modified the threshold of when a CAP is triggered (from eight (80%) percent of permitted flow based on committed flow to ninety-five (95%) percent of permitted flow based on reported flow from the Discharge Monitoring Reports (DMRs)).

The amendments also clarified and expanded analysis and certification requirements as part of the CAP; included a 180-day timeframe for submission of the CAP; clarified that the requirements can be imposed on owners/operators of a sanitary collection / conveyance system; included a requirement to have the CAP posted to the entity's website (with a copy maintained at the treatment facility and / or conveyance system owner's offices); and revised the requirements for when an owner / operator (permittee) can be relieved from the CAP.

Due to flows at the Caldwell WWTP exceeding 95% of the permitted flow of 4.50 MGD over a twelve (12) consecutive month period, the Borough was required by its NJPDES Permit to participate in the New Jersey Department of Environmental Protection (NJDEP) Capacity Assurance Program (CAP).

To meet the requirements as given in the NJDEP CAP Checklist, and as authorized by the Borough, Mott MacDonald completed an evaluation of the Borough's sanitary sewer collection system and wastewater treatment plant (Capacity Assurance Program Report). This Report (dated August 30, 2019) was issued to the NJDEP on September 3, 2019. As part of the Report issued to the NJDEP, Mott MacDonald recommended that the Borough conduct an extraneous flow investigation (within various sub-basins that demonstrated the highest amounts of extraneous flows) to identify specific defects and I/I sources within the sanitary sewer collection system and provide recommendations for corrective measures to reduce I/I to comply with the Borough's Capacity Assurance Program.

The NJDEP issued a response letter to the Report on September 18, 2019 (**Appendix B**). In the NJDEP's response letter, the NJDEP specifically directed the Borough to take the lead in gaining cooperation from the communities that contribute wastewater flow to the Caldwell WWTP to develop an Infiltration and Inflow Reduction Plan.

In order to meet the requirements given in the NJDEP's response letter, the Borough contracted with Mott MacDonald to perform the next phase of evaluation of the sanitary sewer collection and interceptor system (Inflow / Infiltration Investigation (Phase II)). The Phase II - Inflow / Infiltration Investigation focused on the three (3) drainage sub-basins that the Capacity Assurance Report determined to contain excessive I/I by dividing these three (3) drainage sub-basins into mini-basins (for subsequent investigation and analysis).

US Environmental Protection Agency (USEPA) guidance states that a drainage sub-basin containing between 10,000 - 100,000 linear feet of pipe contains excessive flow if the flow per inch-mile of pipe is above 4,000 gallons per day (gpd), and that a drainage sub-basin containing greater than 100,000 linear feet of pipe demonstrates excessive flow if the flow per inch-mile of pipe is above 3,000 gpd. The drainage sub-basins within the Caldwell WWTP sanitary sewer service area that demonstrated excessive I/I were Drainage Basin A, Basin C1 and Basin D.

Mott MacDonald's work for the Phase II - Inflow / Infiltration Investigation was performed under six (6) tasks in accordance with Mott MacDonald's scope of work (dated January 21, 2020):

Task 1 - Temporary Flow Monitoring / Evaluation of Extraneous Flow

Under this Task, Mott MacDonald divided the three (3) aforementioned drainage sub-basin collection systems into "mini-basins" for additional focused temporary flow monitoring. Upon paring the sub-basins into mini-basins (of 10,000 - 15,000 linear feet each) twenty-one (21) mini-basins were established for additional temporary flow monitoring. Temporary flow monitoring devices were installed at key locations and were maintained for an eight (8) week period in order to capture sufficient flow data during at least one (1) significant rainfall event (approximately one (1") inch of rainfall within a twenty-four (24) hour period).

Mott MacDonald utilized a sub-consultant (Flow Assessment Services (FAS)) for the installation of the temporary flow monitoring devices to record wastewater flow during dry and wet weather conditions. Continuous flow monitoring was performed to obtain information necessary to accurately analyze each mini-basin for infiltration during high groundwater periods and for rainfall derived inflow (RDI/I) during wet weather periods. FAS also installed one (1) rain gauge (at the WWTP) which recorded rainfall data (in five (5) minute increments). The rainfall data was useful to correlate the monitored wastewater flow rates against rainfall intensity, duration, and volume for the purpose of identifying inflow and its components.

The Wastewater Treatment Plant Flow versus Rainfall Graphs (**Appendix C**) demonstrate the difference between the typical wastewater flow to the Caldwell WWTP on a dry weather day (range of 4 - 5 MGD) versus the flow received at the Caldwell WWTP during a wet weather event (range of 10 - 15 MGD).

The drainage area tributary to each mini-basin and the corresponding municipally-owned sanitary sewer systems that contribute flow to each mini-basin are shown on the Inflow / Infiltration Mini-Basin / Meter Location Mapping (**Appendix D**).

Upon completion of the flow monitoring, Wastewater Flow Hydrographs were prepared for each of the twenty-two (22) mini-basin to show the flow recorded during dry weather periods versus the flow recorded during wet weather periods, as well as providing minimum, average and peak daily flows (**Appendix E**) hourly flows (**Appendix F**) and probability of maximum flows (**Appendix G**). Comparing the flows during a wet weather event versus the flows during a dry weather period provided the ability to analyze the effect of wet weather on the mini-drainage area, thus providing the extent of Rainfall Derived Infiltration/Inflow (RDI/I) within each mini-basin. The extraneous flow within each mini-basin was then determined and evaluated against United States Environmental Protection Agency's (USEPA) criteria. The mini-basins determined to have excessive extraneous flow were the subject of further investigation and evaluation (under Task 4 and Task 6 described below).

Task 2 - Interceptor GIS Enhancement

To further understand the Borough's existing interceptor sewer system (which conveys wastewater to the Caldwell WWTP in three (3) interceptor lines (15" / 20" / 24") that travel along Passaic Avenue and Pine Tree Place) Mott MacDonald developed a comprehensive Hydraulic Model of the interceptors. Mott MacDonald enhanced the Borough's existing sanitary sewer system GIS database for the three (3) interceptor lines, which included research and review of the existing GIS database / mapping as well as all available record and as-built drawings of the interceptors. Mott MacDonald also performed an "as-built" field survey of the existing interceptor manholes to obtain data of the rim elevations, pipe size, pipe inverts and pipe slopes.

Task 3 - Hydraulic Modeling of Interceptors

Under this task, Mott MacDonald created a Hydraulic Model of the interceptors that convey wastewater to the Caldwell WWTP along Pine Tree Place, Passaic Avenue, and Westville Avenue (between Deerfield Road and Passaic Avenue, including the manholes where the temporary flow monitoring devices were installed for the Phase I Capacity Assurance Report).

The hydraulic model was built in SewerGems® utilizing the record plans and data from the "as-built" survey (performed under Task 2) in order to create the model's geometry. Due to the extensive size of the WWTP drainage system, time of concentrations were estimated in order to determine the lag time from metering sites located upstream of the modeled interceptor sewers.

The temporary flow monitoring data (collected under Task 1 above) was analyzed in spreadsheets using EPA Sanitary Sewer Overflow and Planning (SSOAP) to develop dry weather flows and diurnal patterns, and Real Time Kinematic (RTK) methodology was used to evaluate infiltration and inflow during wet weather events. A Capacity Analysis of the existing interceptor lines was performed to locate any hydraulic bottlenecks (choke points) in the system and determine what type of storm event (duration and intensity) causes surcharging within the interceptor sewer system. The hydraulic capacity analysis includes a summary of the analysis and the evaluation of the sanitary sewer interceptor lines; and any interceptor reaches with capacity limitations within the study area were identified.

Task 4 - Instantaneous Flow Measurements

Instantaneous Flow Measurements were conducted under the Capacity Assurance Report and are included in the Phase II I/I Investigation Report for additional follow-up by the Borough.

Task 5 - Smoke Testing / Dyed Water Testing

Smoke testing consists of the injection of smoke into a sanitary sewer collection system. Once within the sanitary sewer system, the smoke will travel along the path of least resistance until it reaches the open atmosphere. If a sewer system is "tight" (properly constructed) the smoke will travel through the sanitary sewer system, through residential connections (laterals), and will vent to the open atmosphere through the residence's vent stack. However, if there are any defects in the sanitary sewer system (i.e.: faulty plumbing, faulty connections or fixtures, cleanout caps, or dry traps) the smoke will exit through these defects. If unauthorized connections were made to the sanitary sewer system (sump pumps, yard drains, roof leaders, inlets, etc.), the smoke will exit through these illicit connections.

The smoke testing process is as follows: a blower with a motor (approximately the size of a lawnmower) is placed over an open access point (i.e.: manhole). The blower is turned on, and a paraffin oil is heated on the blower exhaust. The oil heats and turns to smoke, and the smoke is in turn blown into the sanitary sewer system. Technicians then walk the length of the sanitary sewer, observing where the smoke vents from the system, documenting each occurrence. Each set-up consists of roughly 1,500 - 2,000 linear feet of sanitary sewer and each set-up takes approximately 20-45 minutes (dependent on how many sources are located and documented).

The smoke is paraffin wax based and is odorless, non-toxic and is non-staining. When smoke enters a residence (through faulty piping), it typically dissipates within a few hours (the dissipation period is shorter if windows are opened).

Mott MacDonald contracted with Flow Assessment Services (FAS) to conduct the smoke testing under this Task. Mott MacDonald and FAS met with the affected municipalities and their local emergency responders (fire / police / first aid) to discuss the smoke testing procedure and provided advance notification to affected property owners (through individually posted door-hangers and municipal-wide posting through each municipality's website and via Nexis Alerts).

A Flow Assessment representative was on-site during the smoke testing procedure to record occurrences of unauthorized connections to the Borough's sanitary sewer system.

Approximately 143,560 linear feet of sanitary sewer collection pipe were smoke tested within the three (3) drainage sub-basins under the Phase II I/I Investigation.

Mott MacDonald personnel performed dyed water testing in areas of suspected stormwater / sanitary sewer cross-connections. This testing consisted of the inclusion of dyed water into a storm water sewer line which crosses over a sanitary sewer line that was suspected of leaking.

Personnel monitored the sanitary sewer line to determine whether dyed water exfiltrated from the storm water line and infiltrated into the sanitary sewer line. Any occurrences of dyed water infiltration into the sanitary sewer line were noted for future rehabilitation / repair.

Phase 6 - Closed-Circuit Television (CCTV) Internal Sewer Inspection

Internal video inspections were conducted utilizing Mott MacDonald personnel and a color, pan-and-tilt camera system during and / or immediately after significant rainfall events or high groundwater periods (within sewers identified under Task 3 and Task 4 field investigations to be suspected source(s) of extraneous flows).

Thirty-seven (37) sanitary sewer reaches totaling approximately 6,844 linear feet were internally inspected. Mott MacDonald reviewed all of the video inspections, and input our observations (including defects, estimated quantity of I/I, suspected illicit connections, obstructions, hydraulic and maintenance problems, etc.) into tabular format. Our recommendations for rehabilitation / repair and opinions of probable construction costs were also included.

The data collected during the video inspections was also entered into a sewer inspection database, which provides comprehensive data, profile schematics and summary reports which can be linked to the Borough's GIS database.

Task 7 - Inflow / Infiltration Investigation Findings Report

This Inflow / Infiltration Investigation Findings Report summarizes the tasks that were performed and provides our findings and recommendations (including results of the temporary flow monitoring, hydraulic capacity analysis of the interceptor sewer lines, smoke testing / dyed water testing and the closed-circuit television inspections).

This Findings Report also includes opinions of probable construction costs for all of the repair / rehabilitation / replacement recommendations given herein. The expected quantity of extraneous flows to be removed is 0.123 MGD.

2 Temporary Flow Monitoring / Evaluation of Extraneous Flows

2.1 Temporary Flow Monitoring Program (2020)

This report focuses on the three (3) drainage sub-basins determined to contain excessive I/I by dividing these sub-basins into mini-basins for subsequent investigation and analysis. US Environmental Protection Agency (USEPA) guidance states a drainage basin between 10,000 - 100,000 linear feet of pipe demonstrates excessive flow if the flow per inch-mile of pipe is greater than 6,000 gallons per day, and a drainage sub-basin containing greater than 100,000 linear feet of pipe demonstrates excessive flow if the flow per inch-mile of pipe is greater than 3,000 gallons per day. The sub-basins that demonstrated excessive I/I are given in **Table 1**:

Table 1: Drainage Sub-Basin Designation

	Length	GPD/In-mile
Drainage Sub-Basin A	114,154	4,208
Drainage Sub-Basin C1	51,005	4,592
Drainage Sub-Basin D	115,157	5,411

Source: Borough of Caldwell WWTP Capacity Assurance Report (August 30, 2019)

Under the Flow Monitoring task in this Report, Mott MacDonald further divided the three (3) aforementioned sub-basins into "mini-basins" (of approx. 10,000 - 15,000 linear feet of sanitary sewer pipe per mini-basin) for additional focused temporary flow metering. Upon dividing the sub-basins, twenty-one (21) mini-basins were established for additional temporary flow monitoring. The temporary flow monitoring devices and their locations are given in **Table 2**.

Table 2: Drainage Mini-Basin Designation and Locations

Meter	Site Name	Location
A 1	A Gould Avenue	right-of-way off Gould Avenue
A 2	MH A2	31 White Oak Drive
A 3	MH A31	14 Sunset Drive
A 4	MH A61	Meadow Lane
A 5	MH A67	55 Grandview Place
A 6	MH A68	Deer Trail Road / Brookside Terrace
A 7	MH A88	11 Birchwood Road
A 8	A East Greenbrook Road	East Greenbrook Road (brook)
A 9	A Grandview Avenue	14 Grandview Avenue
A 10	A1	39 East Greenbrook Road
A 11	A6 Timber Drive	6 Timber Drive
A 12	Cald A10	22 Sunset Drive
C 1	C-1	645 Bloomfield Avenue
D 1	D Washburn Place	29 Washburn Place
D 2	D Sunnie Terrace	Sunnie Terrace and Westville Avenue
D 3	D Ryerson	Ryerson Avenue @ Fells Manor Road
D 4	D Elm	Elm Road @ Bloomfield Avenue
D 5	D Brookside	135 Brookside Avenue
D 6	D Roseland	54 Roseland Avenue
D 7	D Forest	13 Forest Avenue
D 8	MHD-1	72 Smull Avenue

Mott MacDonald contracted with Flow Assessment Services (FAS) to conduct the temporary flow monitoring program within strategic locations within each of the designated mini-basins. Temporary Flow Monitoring Devices were installed and maintained in each mini-basin for an eight (8) week period to capture flow data during at least one (1) significant rainfall event (approximately one (1”) inch of rainfall within a twenty-four (24) hour period). (Refer to **Appendix D** for the Inflow / Infiltration Mini-Basin / Meter Location Mapping in for the extents of the mini-basins and the locations of the temporary flow monitoring devices.)

Wastewater flow data was obtained during dry and wet weather periods over an eight (8) week period. The results of the temporary flow monitoring program are provided as Wastewater Flow Hydrographs (**Appendix E, Appendix F and Appendix G**).

For sewage collection systems the extent and type of Infiltration and Inflow in the system is an indicator of prior maintenance efforts but is also an indicator of system age and available capacities. Several indices exist to compare quantitative calculations of Infiltration and Inflow and its severity in the system. As discussed above, NJDEP guidance criteria is typically published in two forms, gpd / capita and gpd / capita / inch mile.

Table 3 compares the Theoretical Flows (utilizing parcel information multiplied by the NJDEP Design Flow Criteria for a 3-bedroom dwelling - 300 gpd) expected from each sub-basin versus the Measured Flow from each sub-basin drainage area.

Table 3: Theoretical Flows vs. Flow Assessment Services Metered Flow

Flow Meter (Sub-Basin)	FAS Meter Name	Total Parcels	Parcels served	Flow / Parcel (NJDEP CRITERIA)	Flow - Projected (GPD)	Flow - Projected (MGD)	Flow - Metered by FAS (MGD)
A1	A Gould Ave	52	52	300	15600	0.0156	0.021
A9	A Grandview Ave	85	85	300	25500	0.0255	0.0359
A8	A Greenbrook Road	43	43	300	12900	0.0129	0.0237
A10	A1	168	168	300	50400	0.0504	0.0543
A11	A6 Timber Dr	119	119	300	35700	0.0357	0.0356
C1	C1	259	259	300	77700	0.0777	0.403
A12	Cald A10	37	37	300	11100	0.0111	0.0084
D5	D Brookside	137	0*	300	0*	0*	0*
D4	D Elm	96	96	300	28800	0.0288	0.051
D7	D Forest	375	375	300	112500	0.1125	0.162
D6	D Roseland	317	317	300	95100	0.0951	0.066
D3	D Ryerson	49	49	300	14700	0.0147	0.0153
D2	D Sunnie Terr	321	321	300	96300	0.0963	0.1057
D1	D Washburn Pl	610	610	300	183000	0.183	0.4083
A2	MH A2	248	248	300	74400	0.0744	0.06
A3	MH A31	29	29	300	8700	0.0087	0.0073
A4	MH A61	125	125	300	37500	0.0375	0.0239
A5	MH A67	36	36	300	10800	0.0108	0.0088
A6	MH A68	111	0**	300	0**	0**	0**
A7	MH A88	219	219	300	65700	0.0657	0.0897
D8	MHD 1	250	0***	300	0***	0***	0***
					Total Flow	**0.957**	**1.58**

Source: Mott MacDonald / Essex County GIS Database
*Sub-basin D5 included as part of sub-basin D2
**Sub-basin A6 included as part of sub-basin A2
***Sub-basin D8 included as a part of sub-basin D1

The mini-basins subject to this Report had been identified as having potential excessive Infiltration and Inflow. (It should be noted that the summation of the flows from the twenty-one (21) mini-basins **does not** represent the total flow received at the wastewater treatment plant.)

The Measured Flow (**Table 4**) represents the average measured flow in each mini-basin for the monitoring period in question (May - September 2020):

Table 4: Measured Flows - Temporary Flow Monitoring Devices

Flow Meter (Mini-Basin)	FAS Meter Designation	Flow - Measured (MGD)
A1	A Gould Ave	0.021
A9	A Grandview Ave	0.0359
A8	A Greenbrook Road	0.0237
A10	A1	0.0543
A11	A6 Timber Dr	0.0356
C1	C1	0.403
A12	Cald A10	0.0084
D5	D Brookside	0.0286
D4	D Elm	0.051
D7	D Forest	0.162
D6	D Roseland	0.066
D3	D Ryerson	0.0153
D2	D Sunnie Terr	0.1057
D1	D Washburn Pl	0.4083
A2	MH A2	0.06
A3	MH A31	0.0073
A4	MH A61	0.0239
A5	MH A67	0.0088
A6	MH A68	0.0273
A7	MH A88	0.0897
D8	MHD 1	0.076

The data obtained from the temporary flow monitoring devices will be the data utilized for this Report. However, Mott MacDonald performed Theoretical Flow calculations to allow for a comparison point (i.e.: to evaluate whether the data obtained from the flow monitoring devices is reasonable). For the Theoretical Flow evaluation, a wastewater daily flow of 300 gpd per parcel was utilized, under the theory that the majority of the mini-basins are in residential areas, and that 300 gpd per parcel would be a conservative assumption (i.e.: based on each parcel having a 3-bedroom residence). Even with this conservative approach, the total Theoretical Flow is 0.956 MGD versus the total Metered Flow of 1.58 MGD. When performing direct comparisons within each of the mini-basins, the Metered Flow is greater than the Theoretical Flows, which can be explained as the presence of Infiltration and Inflow into the sanitary sewer system.

Based upon the results above, Mott MacDonald developed data from the available flows to compare it to the published criteria. Flow data was compared against area precipitation data (rain gauge installed by Flow Assessment Services at the Caldwell WWTP) to identify trends in flow increases compared to distinct rainfall events. The data was collected and plotted on graphs to allow for specific flow patterns to be visualized.

Table 5 through **Table 25** provide a Monthly Summary of the minimum, average and maximum flows recorded at each of the twenty-one (21) temporary flow monitoring devices installed throughout the Caldwell WWTP sanitary sewer collection system.

It should be noted that Meter A6 is a sub-basin of Meter A2, that Meter D8 is a sub-basin of Meter D1, and that Meter D5 is a sub-basin of Meter D2. Additionally, the tables below have a letter and a number in each title, these represent Mott MacDonald's designation for the mini-basins, the remaining text in the tiles represents Flow Assessment's designation for the meters.

These flow monitoring devices were installed in mini-basins that were identified as having potential Infiltration and Inflow issues. (It should be noted that the summation of the flow measured by these temporary flow monitoring devices **does not** represent the total flow conveyed to the Caldwell WWTP.)

Table 5: A Gould Ave (A1) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.010	0.021	0.032	0.020	0.028	0.032

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 6: A Grandview Ave (A9) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.0268	0.0359	0.0484	0.0364	0.0417	0.0484

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 7: A Greenbrook Road (A8) - Monthly

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to August 2020	0.0178	0.0237	0.0412	0.0274	0.0328	0.0412

Source: Flow Assessment Services Flow Monitoring Program May – August 2020

Table 8: A1 (A10) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
June 2020 to September 2020	0.0459	0.0543	0.0870	0.0559	0.0658	0.0870

Source: Flow Assessment Services Flow Monitoring Program June – September 2020

Table 9: A6 Timber Dr (A11) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.0206	0.0356	0.0663	0.0414	0.0504	0.0663

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 10: C1 (C1) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
June 2020 to September 2020	0.265	0.403	0.496	0.423	0.453	0.496

Source: Flow Assessment Services Flow Monitoring Program June – September 2020

Table 11: Cald A10 (A12) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.0047	0.0084	0.0226	0.0076	0.0138	0.0226

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 12: D Brookside (D5) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
June 2020 to September 2020	0.0202	0.0286	0.0512	0.0335	0.0385	0.0512

Source: Flow Assessment Services Flow Monitoring Program June – September 2020

Table 13: D Elm (D4) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
June 2020 to September 2020	0.033	0.051	0.137	0.058	0.080	0.137

Source: Flow Assessment Services Flow Monitoring Program June – September 2020

Table 14: D Forest (D7) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
June 2020 to September 2020	0.135	0.162	0.294	0.174	0.220	0.294

Source: Flow Assessment Services Flow Monitoring Program June – September 2020

Table 15: D Roseland (D6) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
June 2020 to September 2020	0.052	0.066	0.119	0.069	0.083	0.119

Source: Flow Assessment Services Flow Monitoring Program June – September 2020

Table 16: D Ryerson (D3) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
June 2020 to September 2020	0.0104	0.0153	0.0251	0.0152	0.0206	0.0251

Source: Flow Assessment Services Flow Monitoring Program June – September 2020

Table 17: D Sunnie Terr (D2) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.0887	0.1057	0.1857	0.1080	0.1379	0.1857

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 18: D Washburn Pl (D1) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to August 2020	0.3391	0.4083	0.5722	0.4031	0.4797	0.5722

Source: Flow Assessment Services Flow Monitoring Program May – August 2020

Table 19: MH A2 (A2) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.033	0.060	0.129	0.056	0.089	0.129

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 20: MH A31 (A3) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.0052	0.0073	0.0116	0.0072	0.0094	0.0116

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 21: MH A61 (A4) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.0171	0.0239	0.0648	0.0215	0.0367	0.0648

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 22: MH A67 (A5) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to August 2020	0.0060	0.0088	0.0146	0.0083	0.0106	0.0146

Source: Flow Assessment Services Flow Monitoring Program May – August 2020

Table 23: MH A68 (A6) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.0155	0.0273	0.1318	0.0310	0.0607	0.1318

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 24: MH A88 (A7) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
May 2020 to September 2020	0.0545	0.0897	0.2913	0.1052	0.1700	0.2913

Source: Flow Assessment Services Flow Monitoring Program May – September 2020

Table 25: MHD 1 (D8) - Monthly Summary

Time	Monthly Average			Daily Maximum Average		
Time Period	Min (MGD)	Average (MGD)	Max (MGD)	Min (MGD)	Average (MGD)	Max (MGD)
June 2020 to September 2020	0.0631	0.0760	0.2227	0.0859	0.1261	0.2227

Source: Flow Assessment Services Flow Monitoring Program June – September 2020

The data obtained from the temporary flow monitoring program was collected and plotted graphically to allow dry and wet weather flow patterns to be visualized. The Wastewater Flow Hydrographs - Daily Flows (**Appendix E**) provide the summaries of Daily Flow recorded at each of the twenty-one (21) temporary monitoring devices for its corresponding mini-basin. For each of the mini-basins evaluated, there is a direct correlation between the Average Daily Flow and the Daily Precipitation. The highest peaks of Average Daily Flow within each of the mini-basins tend to appear slightly after wet weather events, revealing an obvious and consistent reaction to wet weather. The temporary flow monitoring data demonstrates that the sanitary sewer system is responding to rainfall derived infiltration and inflow (RDI/I).

The data given in the Wastewater Flow Hydrographs **-** Hourly Flows (**Appendix F**) are from the temporary flow monitoring devices and demonstrate the fluctuation in flow due to the diurnal pattern. This pattern is typical for humans (who are typically awake during daylight hours and asleep during the nighttime hours) and is seen in the fluctuation of high flows (morning and early evening) to low flows (overnight hours) throughout the span of a day. The high peaks in the graphs are potentially caused by infiltration and / or inflow into the sanitary sewer system.

The graphs showing the Probability of Maximum Flows (**Appendix G**) demonstrate the probability that the maximum flow will occur within each of the twenty-one (21) mini-basins. The extraneous flow in each mini-basin is typically demonstrated by the 90% / 95% through 100% Probability of Maximum Daily Flow.

The graphs given in **Appendix E**, **Appendix F** and **Appendix G** demonstrate that Infiltration and Inflow are prevalent within the majority of the selected mini-basins. In order to select the mini-basins that exhibit the greatest response to RDI/I (and in order to focus further investigation on the mini-basins whose remediation will provide the most benefit for the most economic cost), the USEPA Criteria will be utilized to determine the mini-basins with excessive extraneous flow versus the mini-basins with non-excessive extraneous flow.

2.2 Extraneous Flow - Definitions

Extraneous flow is water (other than wastewater) within a sanitary sewer collection system. The presence of extraneous flow contributes to increased wastewater treatment and pumping costs, increased hydraulic pressure within the sanitary sewer collection system (including pumping stations), and reduced capacity of the sanitary sewer collection system to convey wastewater flows.

Extraneous flows are characterized as follows:

- *Infiltration* - water flow entering the sanitary sewer system through such means as defective pipes, joints, cracks / fractures, and manhole walls.
- *Inflow* - water flow entering the sanitary sewer system through illicit sources such as sump pumps, roof leaders, area drains, foundation drains, manhole covers and storm sewer cross-connections.
- *Rainfall-derived infiltration/inflow* (RDI/I) - occurs during and immediately after a wet weather event. It exerts the greatest hydraulic pressure on a sanitary sewer system and its volume and intensity may cause sanitary sewer overflows.
- *Wet weather infiltration/inflow* (I/I) - occurs during periods of high groundwater, i.e. those of seasonal high groundwater for 7-14 days (exclusive of *significant* rainfall days), which may be caused by rainfall and snowmelt. Wet weather I/I is less intense, but is more prolonged than RDI/I.
- *Dry weather infiltration* (DWI) - occurs during periods of dry weather and low groundwater. While less intense than wet weather-related extraneous flows, DWI can contribute significant volume since it may be present every day of the year. (A common DWI source is potable water main leakage into the sanitary sewer system).

2.3 Quantifying Extraneous Flows within Sanitary Sewer Systems

The process of quantifying extraneous flow rates involves reviewing the temporary flow monitoring data obtained and comparing the typical dry weather flow measured versus the peak (wet weather) flow measurements.

Based on the results obtained from the Temporary Flow Monitoring program, an extraneous flow evaluation was performed to determine which mini-basins demonstrated extraneous flow, based on the US Environmental Protection Agency's (USEPA) extraneous flow guidelines.

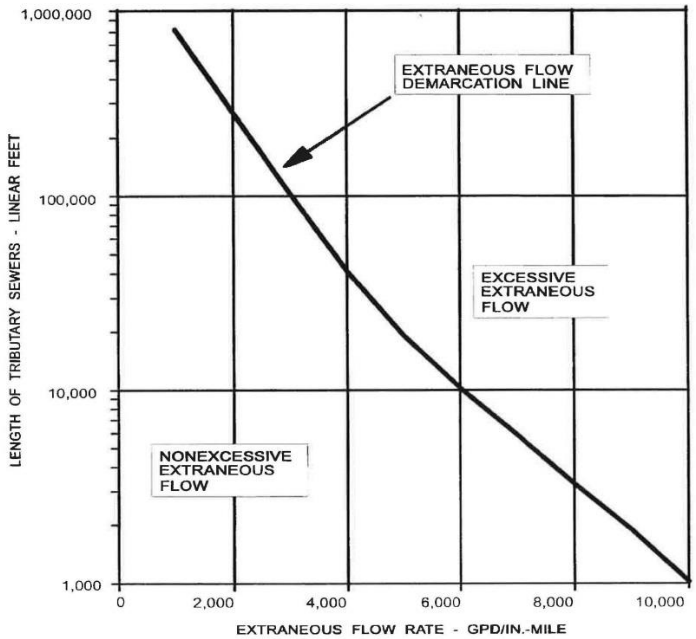
The severity of apparent extraneous flow in each mini-basin was evaluated relating the amount of extraneous flow within a mini-basin to the length of the pipe present in the corresponding mini-basin. The results from the temporary flow monitoring were compared to projected permissible extraneous flow parameters, adapted from the USEPA guidelines.

The USEPA guidelines compare the extraneous flow in a given basin to the length of the pipe in the basin and the diameter of the pipes in the basin in order to compute a metric known as the gallons per day per inch-mile of pipe (gpd/in-mi). This metric is used in conjunction with the tributary sewer length to determine if extraneous flows are excessive or non-excessive.

The USEPA has established limits for estimating whether extraneous flows within sanitary sewer systems are excessive, as follows:

Length of Pipe (l.f.)	**Non-Excessive Extraneous Flow (gpd/in-mi)**
Less than 10,000	6,000 to 10,000
10,000 to 100,000	3,000 to 6,000
Greater than 100,000	2,000 to 3,000

In order to evaluate extraneous flows for specific segments of a sanitary sewer collection system, the USEPA developed a graph to which a comparison can be made of the length of sewer pipes in the appropriate basin versus the extraneous flow.



The dark line shown in **Figure 1** generally follows the USEPA guidelines discussed above. (A minimum value of 10,000 gpd/in-mile is used for any mini-basins with less than 1,000 linear feet of sanitary sewer piping.) Any point which lies to the left of the USEPA line represents a sanitary sewer system which contains non-excessive extraneous flows, while a point to the right of the USEPA line represents a sanitary sewer system which contains excessive extraneous flows.

Figure 1: USEPA Guideline for Excessive v. Non-Excessive Flow

Upon plotting the flow results for the twenty-one (21) mini-basins verse their corresponding in-mile values (**Figure 2**), the sub-basins with excessive extraneous flow are given below:

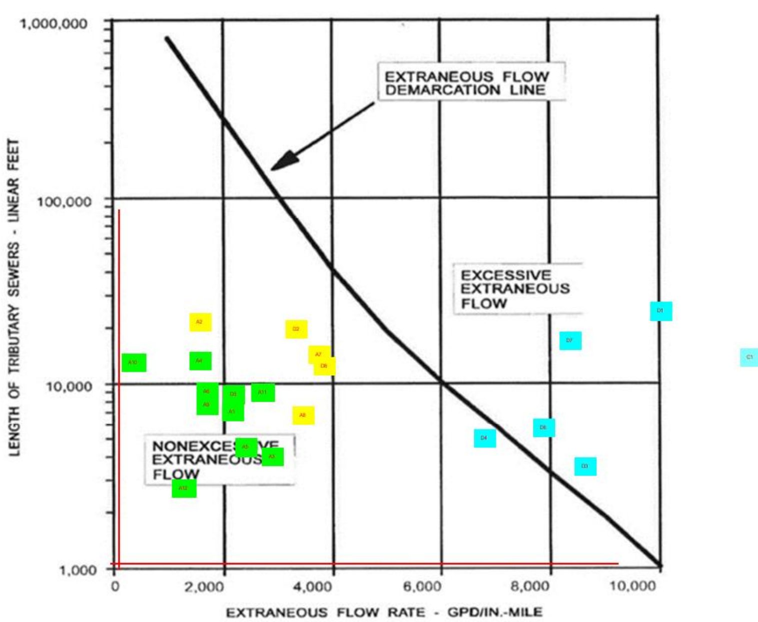


Figure 2: Mini-Basins with Excessive v. Non-Excessive Flow

Table 26: Excessive versus Non-Excessive Mini-Basins

Meter	Meter Designation	Location	Average Flow (gpd)	Pipe Dia.	Length of sewer (miles)	in-mile	GPD/in-mile (x-axis)	Feet of sewer (y-axis)	Excessive?
A 1	A Gould Avenue	right-of-way off Gould Avenue	19,000	8"	1.16	9.31	2041.68	6142.00	No
A 2	MH A2	31 White Oak Drive	56,000	8"	4.14	33.11	1691.09	21855.77	No
A 3	MH A31	14 Sunset Drive	13,000	8"	0.57	4.53	2871.49	2988.00	No
A 4	MH A61	Meadow Lane	25,000	8", 2"		16.01	1561.52	11019.47	No
A 5	MH A67	55 Grandview Place	12,000	8"	0.66	5.27	2279.14	3475.00	No
A 6	MH A68	Deer Trail Road / Brookside Terrace	25,000	8"	1.76	14.11	1772.10	9311.00	No
A 7	MH A88	11 Birchwood Road	87,000	2", 8", 10"		23.26	3740.33	15462.90	No
A 8	A East Greenbrook Road	East Greenbrook Road (brook)	30,000	8"	1.10	8.78	3417.12	5794.35	No
A 9	A Grandview Ave	14 Grandview Ave	22,000	8"	1.51	12.09	1818.99	7982.45	No
A 10	A1	39 East Greenbrook Road	8,000	8"	2.53	20.21	395.92	13336.00	No
A 11	A6 Timber Drive	6 Timber Drive	37,000	2", 8", 10"		13.91	2659.96	9410.03	No
A 12	Cald A10	22 Sunset Drive	5,000	8"	0.55	4.42	1130.14	2920.00	No
C 1	C-1	645 Bloomfield Avenue	444,000	8", 10", 12"		24.00	18500.00	14808.33	Excessive
D 1	D Washburn Place	29 Washburn Place	422,000	8", 10"		39.94	10565.85	25919.04	Excessive
D 2	D Sunnie Terrace	Sunnie Terrace and Westville Avenue	106,000	8", 10"		31.32	3384.42	19779.93	No
D 3	D Ryerson	Ryerson Avenue @ Fells Manor Road	46,000	8"	0.67	5.33	8627.45	3519.00	Excessive
D 4	D Elm	Elm Road @ Bloomfield Avenue	52,000	8"	0.98	7.82	6649.72	5161.12	No
D 5	D Brookside	135 Brookside Avenue	28,000	8"	1.67	13.39	2090.64	8839.41	No
D 6	D Roseland	54 Roseland Avenue	70,000	8"	1.10	8.80	7958.81	5804.89	Excessive
D 7	D Forest	13 Forest Avenue	228,000	8"	3.42	27.36	8332.70	18058.98	Excessive
D 8	MHD-1	72 Smull Avenue	80,000	8"	2.53	20.28	3945.25	13383.18	No

Utilizing the data as plotted against the USEPA Guideline for Excessive versus Non-Excessive Flow **(Figure 2),** Mott MacDonald focused further investigations (smoke testing / dyed water testing / closed-circuit television inspections) in the six (6) mini-basins that demonstrated excessive extraneous flow (B1 / C1 / D3 / D4 / D7 / D8) as well as five (5) mini-basins that demonstrated borderline excessive extraneous flow (A2 / A7 / A8 / B2 / D8).

2.3.1 Pipeline Defects

Extraneous flow rates are assigned to pipeline defects identified from the internal CCTV video inspections primarily based on the inspector's visual observation of the defect and their knowledge of the techniques used in quantifying the extraneous flow. When observing an extraneous flow defect, the extraneous flow rate is equal to the steady clear flow rate recorded during the observation.

2.3.2 Private Building Service Connection (PBSCs)

Leakage rates from private building service connections (PBSCs or laterals) fluctuate dramatically in response to periods of intense rainfall. Very high extraneous flow rates typically occur when intense rainfall saturates the ground. Private building service connection trenches are typically much shallower than municipal sanitary sewer trenches, and private building service connections typically have porous lawn coverings; these factors tend to lend to activating leakage within private building service connections much more rapidly than leakage into municipal sanitary sewers. As some private building service connections may be identified as having minimal leakage when discovered during a period of low extraneous flows, these private building service connections may discharge very high extraneous flows when RDI/I levels are near maximum levels, therefore noting the data and time of all inspections is very important. It is worthwhile returning to key identified service connection leaks to perform additional investigate when RDI/I has been activated and / or when Sanitary Sewer Overflows and / or pump station high water alarms activate, leading to the chance of recording significant amounts of extraneous flows. When these leaks are identified and quantified, eliminating the extraneous flow should become a high priority.

3 Hydraulic Modeling of Interceptors

3.1 Description of Sanitary Sewer Collection and Interceptor System

As stated previously in this Report, the Borough's sanitary sewer collection system and WWTP provide wastewater conveyance and treatment services to the Borough of Caldwell, the Township of West Caldwell, the Borough of North Caldwell, the Borough of Roseland, and the Borough of Essex Fells as well as sections of Fairfield, Livingston, Verona, and West Orange.

The Caldwell WWTP receives wastewater flow via approx. 133 miles of sanitary sewer lines located throughout the WWTP's sanitary sewer collection system. Flow enters the WWTP through three (3) gravity sanitary sewer interceptors (15-inch / 20-inch / 24-inch diameter pipes) and one (1) force main (14-inch diameter) that conveys wastewater from the Borough of Roseland. The WWTP is rated for an average daily wastewater flow of 4,500,000 gpd (4.5 MGD). The daily diurnal maximum design wastewater flow is 6,800,000 gpd (6.8 MGD), the daily peak design wastewater flow is 12,000,000 gpd (12 MGD) and the instantaneous maximum (peak) hydraulic capacity is 15,000,000 gpd (15 MGD).

3.2 Objective and Scope of Work

The goal of the sewer modeling process was to create a mathematical model of the sanitary sewer interceptor system that is capable of accurately simulating the operating characteristics of the interceptor system over a broad range of conditions. Mott MacDonald developed a computer Hydraulic Model of the Caldwell WWTP sanitary sewer interceptor system that will serve as a tool to evaluate the "baseline" conditions within the sanitary sewer interceptor system and will aid in understanding the operation of the interceptor system and the impacts of future sanitary sewer capital projects.

The scope of work for this Task included the following elements:

- Update and enhance the existing Geographic Information System (GIS) database to develop the physical framework for use in SewerGEMS software (i.e.: hydraulic model)
- Calibrate the Hydraulic Model for dry weather flow
- Analyze dry and wet weather flows verse rainfall data
- Utilize the Hydraulic Model to estimate the sanitary sewer collection interceptor's capacity by stressing the system under a variety of simulated wet weather events

Each of these elements (along with supporting calculations) are discussed in greater detail throughout this section of the Report.

3.3 Data Sources

As part of an overall GIS Upgrade and Enhancement Program, Mott MacDonald conducted an As-Built Survey along the three (3) sanitary sewer interceptor lines leading to the WWTP (Pine Tree Place / Passaic Avenue / Westville Avenue). Record Plans of the WWTP were used to define the boundary conditions for the Hydraulic Model, and the Borough of Caldwell Sewerage District Sub-Area Maps (circa 1992) were used for sanitary flow distribution analysis and routing adjustments. Based on the information obtained during the As-Built Survey, the sanitary sewer interceptor hydraulic model includes approximately seventy (70) manholes. The extents of the Hydraulic Model are demonstrated in **Figure 3**.

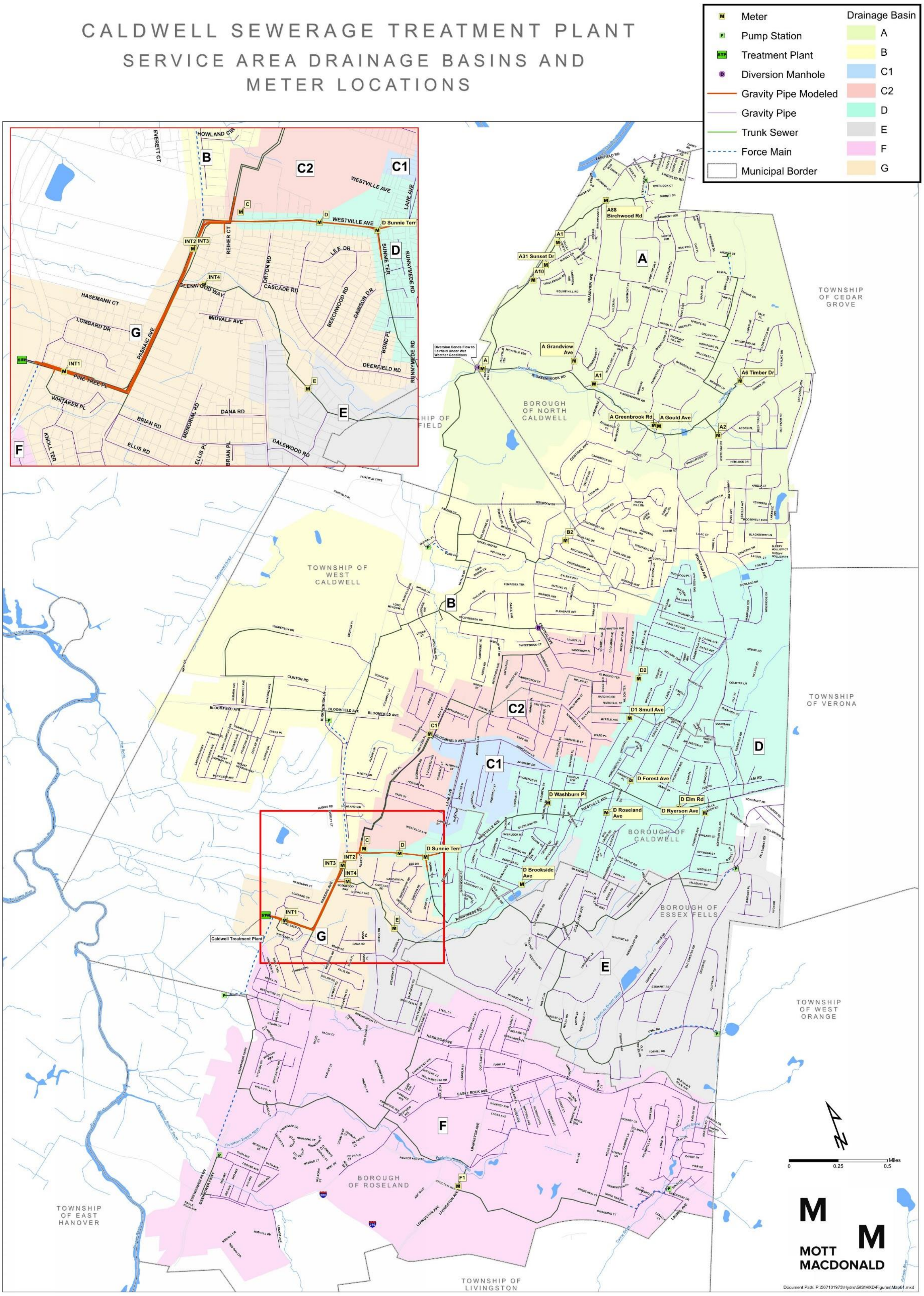


Figure 3: Caldwell WWTP Service Area System Map

3.4 Geographic Information System Upgrade and Enhancement

The physical information used in the Hydraulic Model is based on the Borough's existing Geographic Information System (GIS) files, which were field verified during the performance of the As-Built Survey. The majority the pipe data (i.e.: pipe diameter, material, inverts, etc.) was based on research of previous as-built drawings and was supplemented with the information obtained during the As-Built Survey (as required). A breakdown of the modeled system (by pipe diameter and length) is given below in **Table 27**:

Table 27: Hydraulic Model Gravity Pipe Inventory

Diameter (in)	Length (ft)	% in Model
8	978	6.5%
10	437	2.9%
12	2,464	16.4%
15	3,744	25.0%
18	295	2.0%
20	2,470	16.5%
21	176	1.2%
24	4,207	28.1%
42	185	1.2%
26" x 30" Box	34	0.2%
Grand Total	**14,990**	**100.0%**

3.5 Temporary Flow Monitoring Program

3.5.1 Background

Mott MacDonald contracted with Flow Assessment Services (FAS) to conduct a temporary flow monitoring program within the Caldwell WWTP sanitary sewer collection system. A total of twenty-seven (27) flow monitoring devices and one (1) rain gauge were installed in the collection system for the duration of study, between June 18, 2020 and September 22, 2020.

The general discussion and results from the twenty-one (21) temporary flow monitoring devices installed in the service area mini-basins are given in Section 2.1 of this Report. The below discussion concerns the six (6) temporary flow monitoring devices that were installed within the interceptor sewer lines and at the Caldwell WWTP (**Appendix H**).

The flow monitoring devices recorded the depth and velocity of the wastewater flow in five (5) minute intervals. The devices utilized pressure and/or ultrasonic sensors to measure depth, and a continuous wave Doppler sensor to measure velocity. The temporary flow monitoring devices that were utilized have a typical field accuracy rating of ± 5% within systems with good hydraulic conditions (i.e.: minimal flow turbulence and the absence of significant physical obstructions). The location of the temporary flow monitoring devices that were utilized for the interceptor model calibration are shown on **Figure 4** and are summarized in **Table 28**.

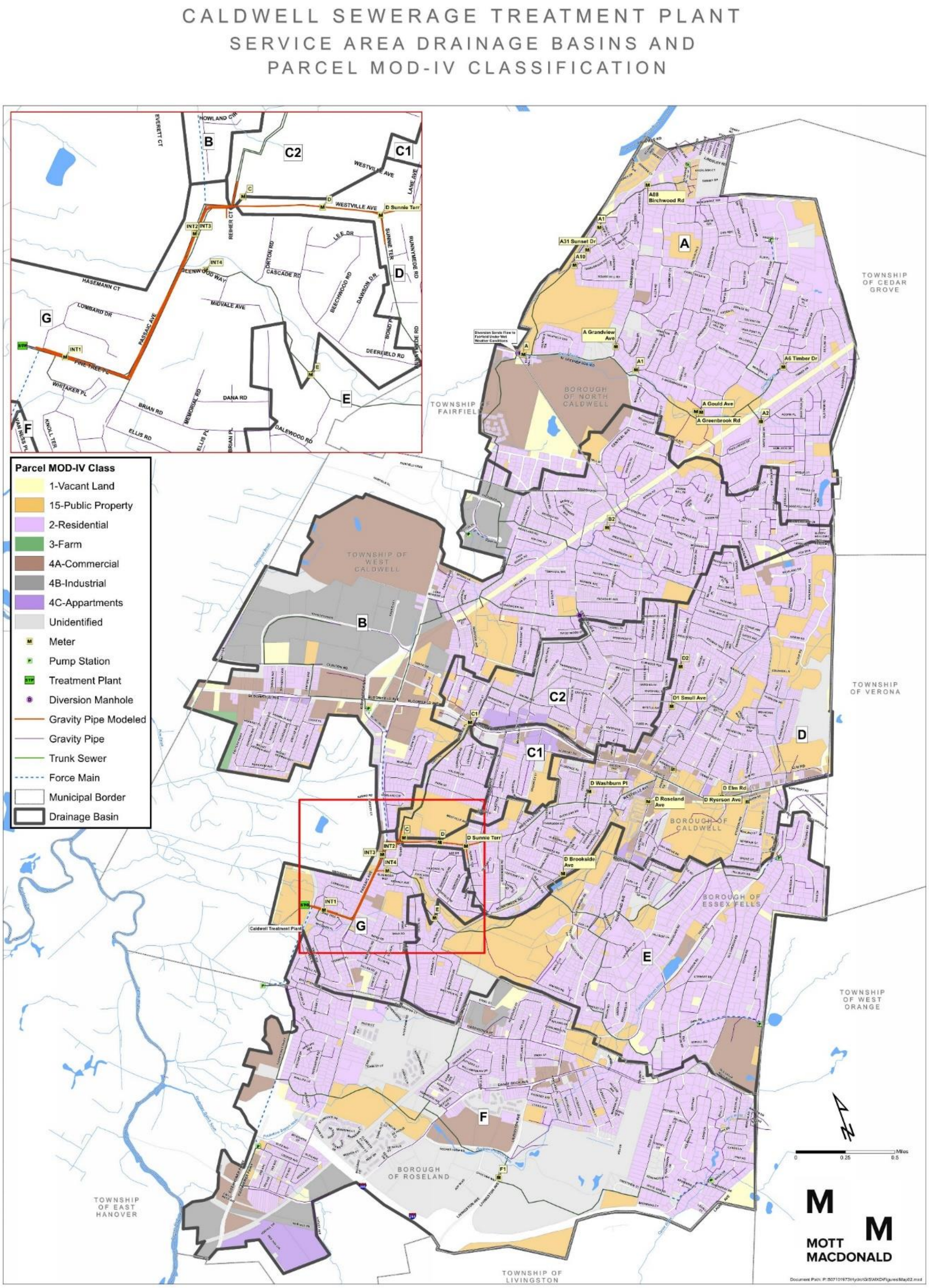


Figure 4: Temporary Flow Monitoring Device Locations

Table 28: Temporary Flow Monitoring Device Locations and Mini-Basins

Meter ID	Structure ID (GIS)	Sensor Installation Description	Location
Interceptor 1	69	Upstream 15" pipe	14 Pine Tree Place
Interceptor 2	44	Upstream 20" pipe	408 Passaic Ave
Interceptor 3*	45	Upstream 19" pipe	408 Passaic Ave
Interceptor 4	8	Upstream 16" pipe	5 Glenwood Way
D Sunnie Terrace	1	Upstream 10" pipe	Sunnie Terrace at Westville Avenue
WWTP	N/A	Influent Channel	Caldwell WWTP

*Record plans indicate this interceptor is fifteen (15") inches in diameter, while the portion of the sewer where the temporary flow monitoring device was installed has undergone rehabilitation (i.e.: cured-in-place liner). The field measured size was nineteen (19") inches, it is not known if this was due to localized improvement or if a greater portion of the sewer has been improved.

3.5.2 Rainfall Data Analysis

Precipitation data was reviewed to identify the dry weather periods and wet weather events which contribute to Rainfall Derived Inflow and Infiltration (RDI/I). RDI/I is dependent on the amount and intensity of precipitation and the condition of the sanitary sewer collection system.

The wet weather events were identified using the following criteria:

- Minimum six (6) hours inter-event time
- Minimum 0.1" total depth of rain

The start and end times of rainfall identified from the measured rainfall data are summarized in **Table 29**. To further classify the rainfall data, the maximum one (1) hour intensity was also determined for each wet weather event.

Table 29: Wet Weather Event Summary

Event No.	Event Start	Event End	Depth (in)	Duration (hrs)	Average Intensity (in/hr)	Max 5-min Intensity (in/hr)	Max 1-hr Intensity (in/hr)
1	6/28/20 5:25 PM	6/28/20 5:55 PM	0.45	0.50	0.90	2.88	0.45
2	7/1/20 11:00 AM	7/2/20 12:30 AM	0.36	13.50	0.03	1.56	0.33
3	7/3/20 6:40 PM	7/3/20 7:55 PM	0.43	1.25	0.34	1.44	0.42
4	7/8/20 3:20 PM	7/8/20 3:55 PM	0.28	0.58	0.48	0.96	0.28
5	7/10/20 6:45 AM	7/11/20 1:30 AM	3.17	18.75	0.17	1.92	1.23
6	7/11/20 5:40 PM	7/11/20 6:55 PM	0.11	1.25	0.09	0.48	0.06
7	7/21/20 11:25 PM	7/22/20 12:00 AM	0.12	0.58	0.21	0.36	0.12
8	7/22/20 5:50 PM	7/22/20 7:25 PM	0.47	1.58	0.30	2.16	0.45
9	7/31/20 12:35 AM	7/31/20 7:15 AM	0.11	6.67	0.02	0.24	0.06
10	8/3/20 8:05 PM	8/4/20 2:25 PM	1.81	18.33	0.10	3.24	0.63
11	8/7/20 3:35 AM	8/7/20 7:05 AM	0.23	3.50	0.07	0.60	0.15
12	8/7/20 6:15 PM	8/7/20 7:05 PM	0.14	0.83	0.17	0.24	0.14

Furthermore, these wet weather events were then classified into four (4) categories based on their maximum one (1) hour intensity and storm duration, namely:

- Short Duration, Low Intensity
- Short Duration, High Intensity
- Long Duration, Low Intensity
- Long Duration, High Intensity

The distinction between low intensity and high intensity and short duration and long duration was made by assuming the data collected was typical of local rainfall and taking the arithmetic average of the peak hourly intensities and durations.

Two (2) rainfall events of notable magnitude that contributed to RDI/I were selected as representative events of short duration-high intensity and long duration-high intensity. As shown in **Table 29** (above) these two (2) significant rainfall events took place on June 28, 2020 and July 10, 2020, respectively. Due to its duration and intensity, the July 10, 2020 event will be considered as an extreme event in the wet weather flow analysis.

Figure 5 shows an intensity-duration-frequency (IDF) plot comparing NOAA Atlas 14 Precipitation Frequency (PF) estimates of the July 10, 2020 precipitation event. From the chart, the event can be approximated as a two (2) year storm.

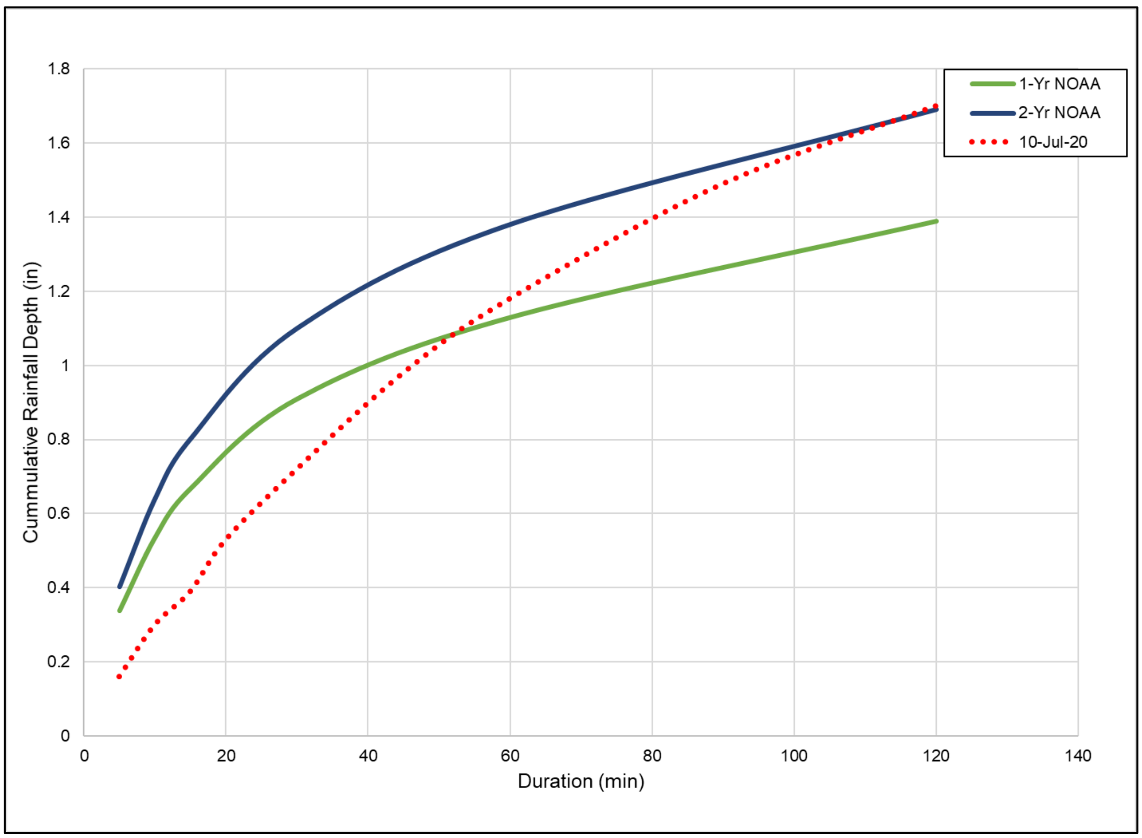


Figure 5: July 10, 2020 Rainfall Return Period Comparison

3.5.3. Flow Monitoring Data Review

Wastewater flows for analysis and design of sanitary sewers can be divided into three (3) main categories as shown in **Figure 6**:

1. Base wastewater flow (BWF)
2. Groundwater infiltration (GWI)
3. Extraneous flow associated with flows from wet weather events i.e.: Rainfall Derived Inflow and Infiltration (RDI/I)

Base wastewater flow (BWF) is the wastewater flow associated with contribution from residential, commercial, industrial and institutional water users.

Groundwater infiltration (GWI) is a portion of typical dry weather flow and depends on several factors: groundwater and surface water hydraulic heads, pipe diameter and the condition of the sanitary sewer collection system. As sewer systems age and deteriorate, the pipes will experience an increase in GWI flow. GWI can be seasonally influenced, and GWI issues can be substantial in areas where sewer pipes are installed below the groundwater table.

Rainfall Derived Inflow and Infiltration (RDI/I) is the portion of a wastewater flow hydrograph above the normal dry-weather base flow pattern (as shown in **Figure 6**). RDII is a sanitary sewer's flow response to rainfall or snowmelt within that sewer line's drainage basin.

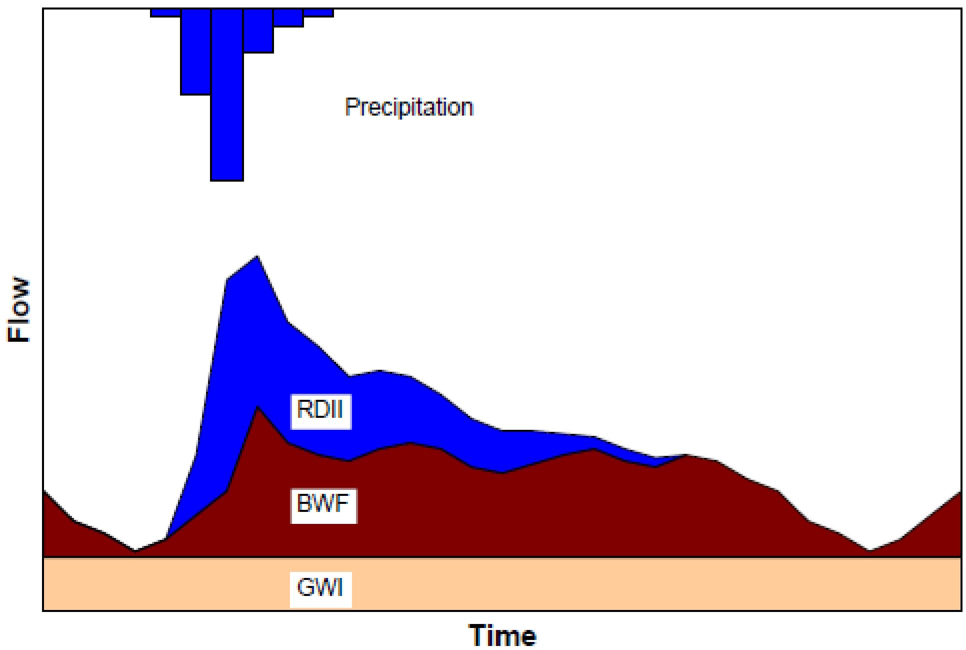


Figure 6: Wet Weather Flow Components in a SAMPLE Wastewater Flow Hydrograph

The data obtained from the temporary flow monitoring program was initially reviewed with the USEPA Sanitary Sewer Overflow Analysis and Planning Toolbox (SSOAP) software. The goal of this initial review was to confirm data completeness of the monitored flow and determine if there are any flow anomalies present which could affect further analysis.

During the initial data review, it was determined that the data monitored between June 18, 2020 and September 22, 2020 was complete, with all flow monitoring devices reporting one-hundred (100%) percent uptime. However, a number of data sets contained a certain degree of high frequency data noise, potentially due to the operation of a pump station within the drainage basin (which tend to contribute wastewater flow to a collection system in “slugs”) or due to flow monitoring anomalies. It was noted that the meter noise was higher for the smaller mini-basins that have a lower base flow. The DWF analysis of data attempted to center the modeled flows around the mean of these flow oscillations so as to more accurately represent the average flow and volume.

3.5.3.1 Hydraulic Model Groundwater Infiltration Basis

As stated previously, the Caldwell WWTP sewer service area encompasses five (5) municipalities within Essex County. There are approximately 1,325 parcels within Essex Fells, 2,525 parcels within North Caldwell, 4,425 parcels within West Caldwell, 2,275 parcels within Roseland, and 2,500 parcels within Caldwell. The population of the five (5) municipalities has been relatively constant since 2010. The US Census 2010 population estimate of 31,808 people within the sanitary sewer collection system drainage area was used in wastewater flow analysis. **Table 30** provides the US Census 2010 population for the sub-basins that are predominately serviced by the Caldwell WWTP. There are approximately 1,200 inch-miles of sewers contributory to the Caldwell WWTP, this figure was utilized to distribute the GWI flows throughout the Hydraulic Model.

Table 30: US Census 2010 Population

Sub-Area	Area, ac	Population (US Census 2010)
A	1,370	4,100
B	1,665	4,916
C1	146	1,630
C2	406	3,992
D	1,090	7,548
E	959	2,584
F	1,766	5,578
G	313	1,460
Grand Total	**7,714**	**31,808**

3.6 Sanitary Sewer Collection System Elements

The Hydraulic Model geometry consists of structures, manholes and pipes that convey wastewater flow in a sanitary sewer collection system. Mott MacDonald built the Hydraulic Model Utilizing SewerGEMS Version 10.01.01.04 (using GIS integrated utilities). The shapefiles were utilized to introduce groundwater infiltration and wastewater loads to the collection system. The database and all utility shapefiles were projected in the North American Datum of 1983 (NAD83).

SewerGEMS executes a dataset field matching routine through a ModelBuilder tool that allows the model to be updated from a source file. Thus, data analysis and input are accomplished in the GIS and imported into the SewerGEMS analysis software.

Model data tables and profiles were visually scanned for missing geometry, physical data values defaulted to null and adverse (i.e.: negative or flat) pipe slopes. The model was also reviewed for likely points of early failure. For example, **Figure 7** and **Figure 8** show a potential surface overflow location along Passaic Avenue.

Figure 7: 15-inch dia. Passaic Avenue Interceptor Plan - Peak DWF Model

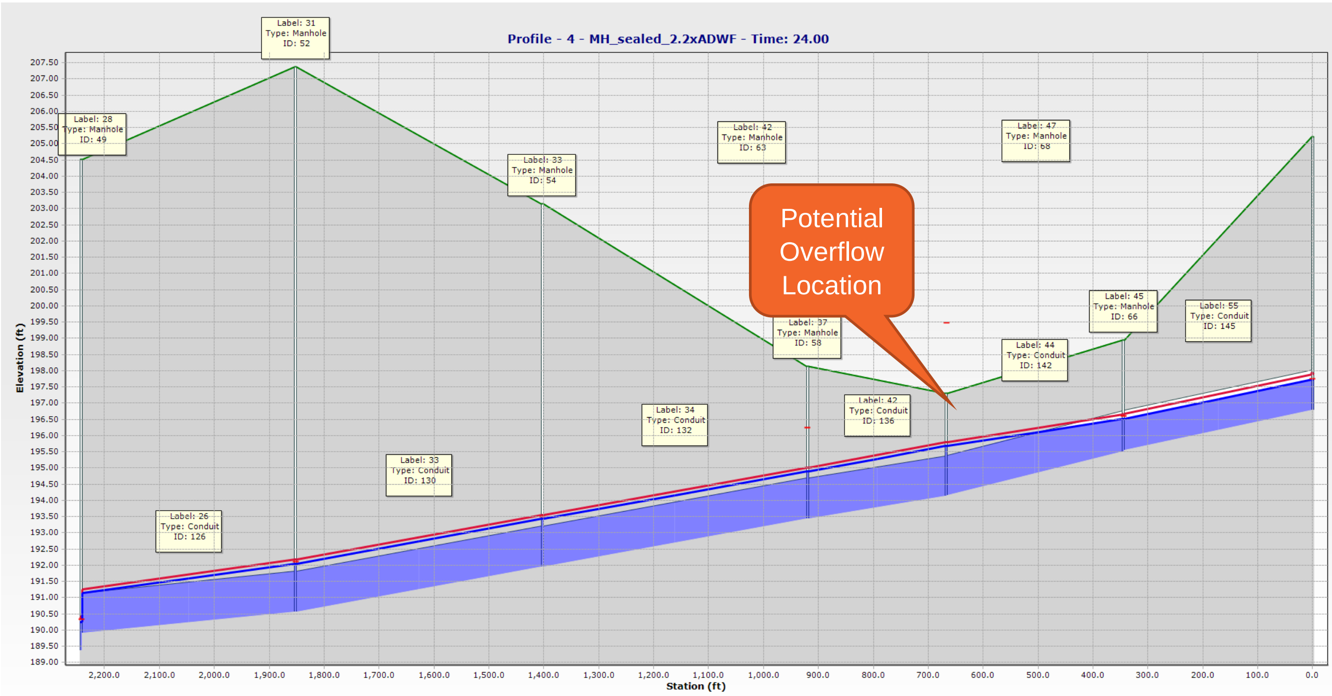


Figure 8: 15-inch dia. Passaic Avenue Interceptor Profile - Potential Overflow Location

Review of the initial Hydraulic Model showed that most of the missing invert data consisted of isolated smaller diameter pipes. There were instances when no elevation data could be obtained due to inaccessible structures; under such circumstances, the pipe inverts were interpolated based on known data (which is common practice in sewer system modeling provided sufficient data is available in the vicinity of the inverts to be inferred). Any structures that contain such interpolated inverts were tagged in a model as “Inferred” (INF). LiDAR elevation data was used to estimate rim elevation in cases where this data was not available in the GIS data file.

Manholes were entered in as node objects, and pipes were entered in as links that connect the nodes (manholes). Sanitary sewer loads (wastewater flow) were assigned in the SewerGEMS model using the Load Builder tool, which assigns sanitary loads and diurnal patterns to nodes or links. Load Builder performed the routine of spatially adding and assigning sanitary loads to the closest node. Distributed sanitary loads were reviewed to verify that there were no significant mis-assignments. Sanitary loads from areas upstream of the modeled portion of the system were calculated and assigned to the various upstream model nodes. In some cases, “dummy” pipes were assigned to replicate the travel time from areas located well upstream of the modeled portion of the system.

3.7 Pipe Roughness Coefficients

Hydraulic roughness (represented by the Manning’s roughness coefficient - “n”) is a means of accounting for the effect on the resistance to flow of pipe materials, irregularities, debris, and other obstructions. Flow through pipes can incur a higher or lower head loss depending on the roughness of the pipe, which impacts the interceptor system’s capacity. As such, it is important to capture the roughness accurately in a system to properly identify the flow patterns.

Pipe roughness was assigned based on pipe materials identified during the GIS dataset upgrade as summarized in **Table 31**:

Table 31: Summary of Manning's Roughness Coefficients Used in the Hydraulic Model

Pipe / Lining Material	Label	Manning's "n" used in Hydraulic Model	Source
Clay/ Terracotta	VCP	0.014	NJDOT Drainage Design Manual
Cast Iron	CI	0.013	NJDOT Drainage Design Manual, VT Chow
Ductile Iron (Cast Iron)	DI	0.013	NJDOT Drainage Design Manual, VT Chow
Poly Vinyl Chloride	PVC	0.011	HEC-22
Concrete Lining	CON	0.012	VT Chow

3.8 Dry Weather Flow Analysis

Dry Weather Flow (DWF) (also referred to as base flow) is wastewater flow without any rainfall derived (RDI/I) flow contribution. An analysis is necessary to separate the DWF flow into Base Sanitary Flow (BSF) and Groundwater Infiltration (GWI) flow. This analysis is performed using the temporary flow monitoring data collected during periods of dry weather.

To facilitate the separation of GWI flow and BSF, the temporary flow monitoring data was cross examined with the rain gage data to identify dry weather days. For the purposes of this study, dry weather days were defined as: 1) a minimum of three (3) consecutive days of no precipitation following a day with rainfall more than 0.25 inches, or 2) a minimum two (2) consecutive days of no precipitation following a day with rainfall less than 0.25 inches and greater than 0.1 inches, and no rainfall on that day itself. Days with less than 0.1 inches of precipitation were considered dry. The general methodology was to identify flow monitored days that satisfied the dry weather classification used for this study.

Using the above-described methodology, a total of thirty-five (35) days were identified as dry weather days between the June 18, 2020 and September 22, 2020 flow monitoring period. Rainfall and wastewater flow data were analyzed using Microsoft Excel software.

3.8.1 Flow Monitoring Data Analysis

The dry weather days were identified using the criteria described above. The data was divided into weekday and weekend categories. The assumption is that weekday flow patterns are effectively identical to each other and that weekend day flow patterns are different from weekdays, but effectively identical to other weekend days. Once the two categories of data were verified, the monitored flows for the dry weather days were combined by averaging similar time steps together throughout a day. Dry weather days with significant irregularities were excluded from analysis. These days were identified by visually inspecting the data and evaluating days with missing data or data grossly different from the typical trends (refer to **Figure 9**). Upon completion of data screening process, average DWF were established for the typical weekday and weekend for each flow monitoring device.

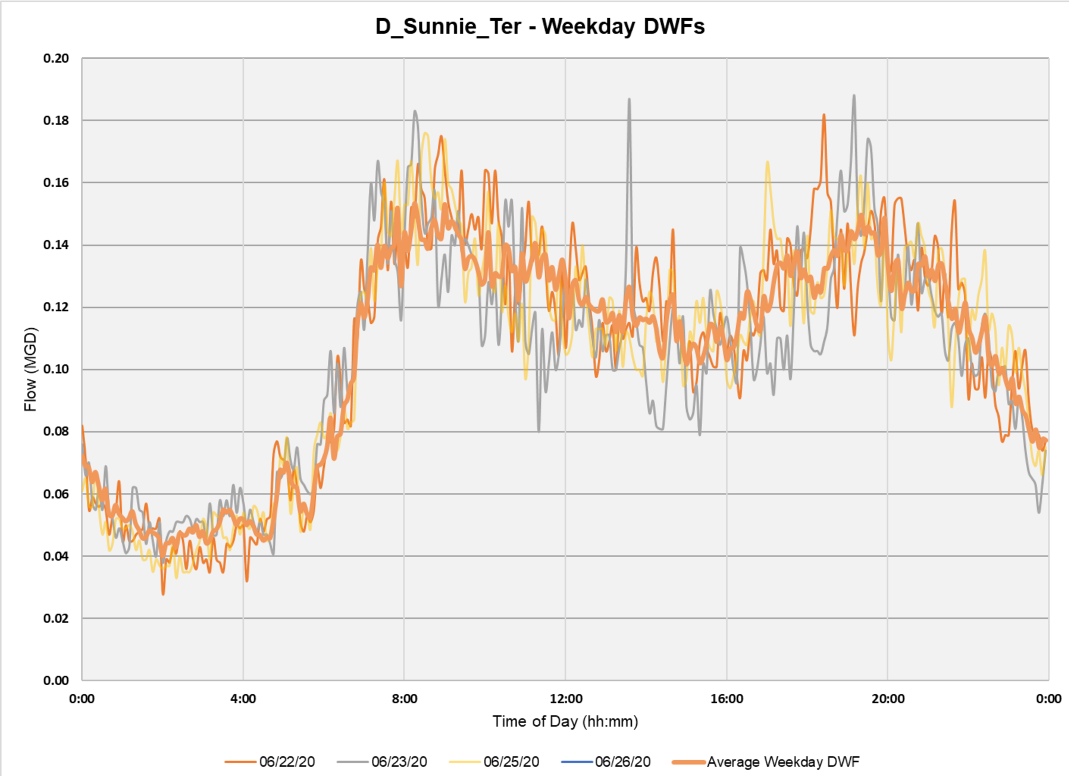


Figure 9: Typical Weekday Dry Weather Flow Comparison

The next step was to extract the GWI (groundwater infiltration) component of the overall DWF. Infiltration enters a sanitary sewer collection system through openings in the pipe (i.e.: displaced or open pipe joints, cracks, fractures and breaks in the fabric of the main sewer and lateral connections and / or manhole chambers). This usually occurs when the groundwater level is above the sewer invert level and may be seasonally influenced. It is typically modeled as a constant inflow, when sufficient seasonal data is available it can be adjusted with monthly coefficients.

The groundwater infiltration component of DWF was extracted by deducting groundwater infiltration flow using Stevens and Schutzbach empirical equation for estimating groundwater infiltration. This equation used curve fitting technique to increase the reliability of the graphical estimation at flow metering locations with very low or very high flows and in basins heavily influenced by pump station flow.

Stevens-Schutzbach Equation:

$$GWI = \frac{0.4(MDF)}{1 - 0.6(MDF/ADF)\hat{}ADF^{0.7}}$$

Where:

MDF - minimum daily flow
ADF - average daily flow

The difference of the overall DWF and the GWI yields the sanitary flows (population input). After the sanitary flows were separated, diurnal patterns for these flows were calculated, each for weekday and weekend. The diurnal patterns are represented by hourly peaking flow factors that were calculated by the ratio of the flow value for an individual time step to the average value of the entire day. Once hourly peaking factors were calculated for all flow meters, these were input into SewerGEMS model, along with the calculated sanitary flows and baseflows, for dry weather flow generation (refer to **Figure 10** for an example from a flow montoring location).

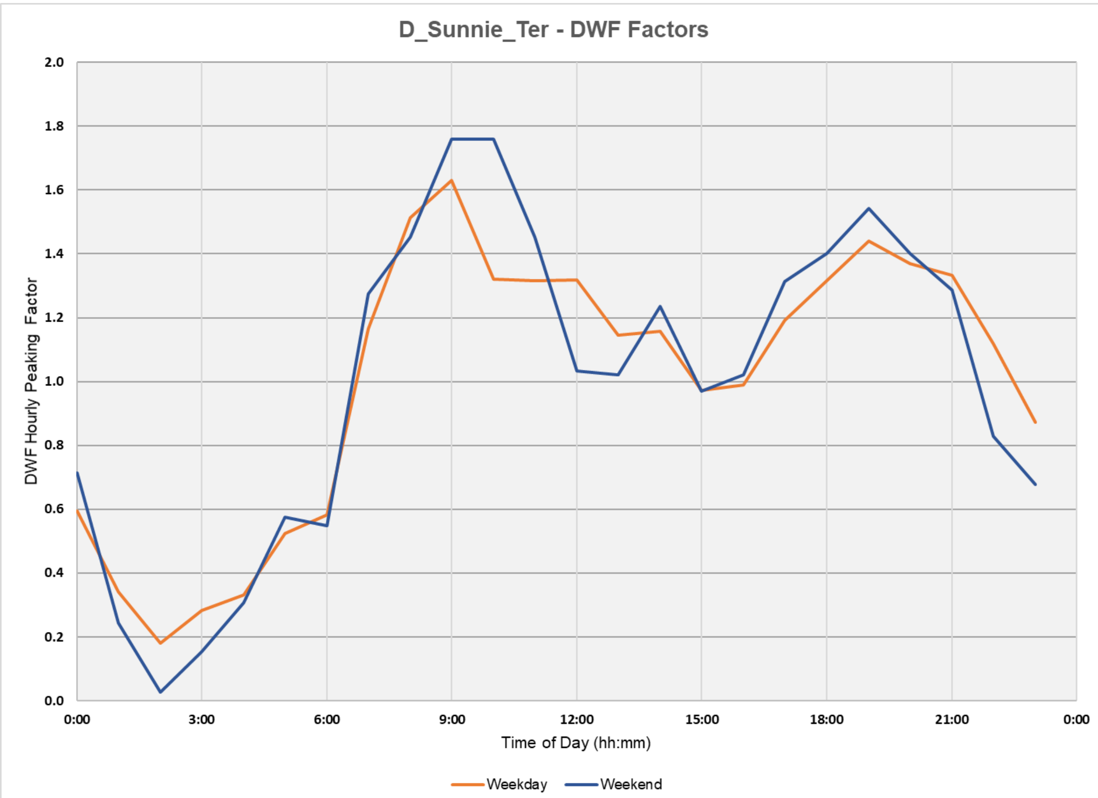


Figure 10: Typical Weekly Diurnal Pattern

Dry weather flow per metershed is summarized in **Table 32**. The average flow rate is one-hundred (100) gallons per capita per day (gpcpd), which is consistent with literature values for residential areas.

Table 32: Calculated Dry Weather Flow by Metershed

Meter ID	Average DWF (MGD)	Population (US Census 2010)	Average DWF (gpcpd)
Interceptor 1(1)	0.03	Unknown	N/A
Interceptor 2	1.01	11,061	91.4
Interceptor 3	0.98	10,646	92.0
Interceptor 4	0.25	3,559	69.1
D Sunnie Terr(2)	0.11	359	294.2
WWTP	3.28	31,808	103.1

Notes:

(1) The sewer line services a smaller community located to the south of Pine Tree Place.

(2) Average flows show greater deviation from system average, possibly due to small area metered and inaccuracies in low flow measurements.

3.8.2 Metershed Delineation

Digitized Sewerage District 1992 Sub-Area Maps were used as a basepoint for metershed delineation. These areas were processed further using GIS tools to correlate the sewersheds physical characteristics to the corresponding temporary flow monitoring data, from which population-based flow parameters (wastewater flows expressed as gallons/capita/day) can be estimated. For the unmetered areas of the collection system, the flow characteristics were extrapolated from areas with similar characteristics (e.g.: flow characteristics of a flow monitoring device located in a primarily residential area can be extrapolated to another area of the collection system that is residential).

3.8.3 Population Analysis and Per-Capita Sanitary Flows

Due to minimal population growth, the US Census 2010 population GIS data for Essex County, New Jersey was used in this Report. This data is maintained and published by the US Census Bureau. Census block level population data is publicly available from the US Census Bureau's American Fact Finder web platform. The population count is available for download in table format, while the census blocks are available in GIS format. The blocks were normalized by their acreage to derive population density for each census block. This GIS dataset was then compared with the delineated metersheds to calculate total population at each metershed level (Population Density in Population/Acre x Metershed Acre = Population of Metershed).

Once the population counts by metershed were available, this data was correlated with the flow monitoring data. Recall that as part of the flow meter data analysis, the wastewater component of the overall DWF was extracted (in million gallons/day (MGD)) from the recorded meter data. This value divided by the metershed population provides an estimate of the average wastewater flow loading rate at each metershed level in gallons per capita per day (gpcpd).

Six (6) unique wastewater profiles were created, one (1) for each metershed. Each wastewater profile had the gallons per capita per day (gpcpd) flow estimate as the average sanitary flow, coupled with the diurnal peak factors for weekday and weekends calculated earlier.

3.9 Wet Weather and Rainfall Derived Infiltration and Inflow Analysis

There are several methods used to quantify response to Infiltration and Inflow (I/I). Since the Hydraulic Model was intended for interceptor capacity assessment, the peaking factor approach was used to gauge the system's wet weather response. The instantaneous peaking factor is calculated by dividing the peak flow by the average daily flow. In general, a sanitary system with a peaking factor of more than five (5) is considered to be I/I stressed. The maximum observed peaking factor at WWTP influent under existing conditions was 8.5, this was during the July 10, 2020 storm which is discussed in subsequent sections of this report. **Table 33** provides DWF summary statistics: minimum, average, peak flow and DWF peaking factors.

Table 33: Dry Weather Flow Summary

Meter ID	Average DWF MGD	Minimum DWF MGD	Peak DWF MGD	DWF Peaking Factor
Interceptor 1[(1)]	0.03	0	0.1	3.3
Interceptor 2	1.01	0.54	1.35	1.3
Interceptor 3	0.98	0.57	1.3	1.3
Interceptor 4	0.25	0.13	0.4	1.6
D Sunnie Terr	0.11	0.03	0.17	1.5
WWTP	3.28	1.33	4.88	1.5

Table 34 summarizes the WWF statistics of peak flow and event peaking factors for the three calibration storm events.

Table 34: Wet Weather Flow Summary

Meter ID	June 28, 2020 Event		July 10, 2020 Event	
	Peak Flow MGD	Peaking Factor	Peak Flow MGD	Peaking Factor
Interceptor 1(1)	0.18	6.1	1.96	65.4
Interceptor 2	2.01	2.0	6.17	6.1
Interceptor 3	1.27	1.3	5.39	5.5
Interceptor 4	0.52	2.1	1.73	6.9
D Sunnie Terr	0.21	1.9	0.64	5.8
WWTP	7.14	2.2	27.87	8.5

Notes:

(1) The peaking factor is exaggerated during wet weather event due to interconnection with 24” trunk sewer line within Pine Tree Place.

Peaking factors calculated for the six (6) interceptor meter locations are estimated to exceed acceptable industry range during a two (2) year recurrence precipitation event (the wet weather event on July 10, 2020 was classified as a two (2) year event).

3.9.1 Analysis of Excessive RDI/I at the WWTP during the July 10, 2020 Event

It is noted that the WWTP flow was unexpectedly high during the July 10, 2020 wet weather event when compared to the flow recorded on the temporary flow monitoring devices. Interceptor Flow Monitoring Devices 1, 2, and 3 account for approx. seventy-five (75%) percent of the WWTP’s service area, with much of the remaining area conveyed by the Roseland pumping station. During the July 10, 2020 wet weather event, the peak flow from these three (3) meters totaled 13.3 MGD (less than half the peak flow at the plant). Since the Roseland pumping station alone does not have the capacity to account for the remaining flow, it was assumed there was a large inflow source located upstream of the WWTP and downstream of the temporary flow monitoring devices installed on Passaic Avenue (near Westville Avenue). The most likely location of this inflow source is theorized to be in the vicinity of the Pine Brook crossing of Passaic Avenue. It is theorized that surface waters from the Pine Brook enter the interceptor system at this location and are conveyed under surcharged conditions to the WWTP.

3.10 Model Calibration Procedures

Model calibration refers to input criteria modifications within acceptable ranges by which a model is adjusted to achieve an acceptable agreement between modeled and observed flows. The sewer model consists of a number of hydrologic and hydraulic components in a dynamic relationship, and calibration relies on proper adjustment of these components.

The goal of model calibration is to create a model of the sanitary sewer collection system that is capable of representing dry weather conditions, demonstrates the probable responses to wet weather conditions, and provides an accurate hydraulic grade lines within the collection system. The calibration / validation guidelines from the Chartered Institution of Water and Environmental Management (CIWEM) Urban Drainage Group (Code of Practice for Hydraulic Modeling of Sewer Systems, 2017) were targeted during model simulation comparison to monitoring data. Dry weather flows are represented in the model using extrapolations of monitored data.

3.11 Dry Weather Flow Calibration

The dry weather flow at the temporary flow monitoring device locations was reviewed, and significant variations from average conditions were reviewed to determine if there was an error in the dry weather flow input or an incorrect set-up with the model hydraulics. A period of seven (7) continuous dry weather flow days (June 20-27, 2020) was selected as the dry weather calibration period. During the initial calibration run, the calculated volume had a small deviation for the majority of metersheds. This came as a result of GIS spatial flow distribution to the closest manhole structure. It primarily affected the metersheds with highest population density. Therefore, the volumes were recalculated and distributed back into the model. Modeled flow depths were consistently lower than recorded, but the flow depths were within acceptable limits. Targeted statistical values, based on the CIWEM Urban Drainage Group, formerly known as WaPUG (Code of Practice for the Hydraulic Modeling of Sewer Systems version 3.001) were applied to give a numerical evaluation of each flow meter used for model calibration.

Table 35 summarizes the CIWEM Urban Drainage Group criteria for DWF calibration:

Table 35: CIWEM Urban Drainage Group - Dry Weather Flow Calibration and Validation Criteria

Criteria	Calibration Range	Notes
Peak Flow Rate	±10% or 0.1MGD	Use of actual value instead of percentage applied to meters with very small flows
Volume	±10% or 0.1MGD	Use of actual value instead of percentage applied to meters with very small flows
Unsurcharged Depth	± 4 in	The flow depth at locations under unsurcharged conditions.
Timing of Peaks	±1 Hour	For both peaks (high flows) and troughs (low flows)
Shape	The shape of the measured and simulated curves should be similar for flow and depth	

Figure 11 is an example comparison of measured vs. simulated flows for Dry Weather Flow calibration. Similar plots for all meters are provided in **Appendix I**. As per the CIWEM criteria, the timing and shape of the modeled flow matches well with the monitored flow.

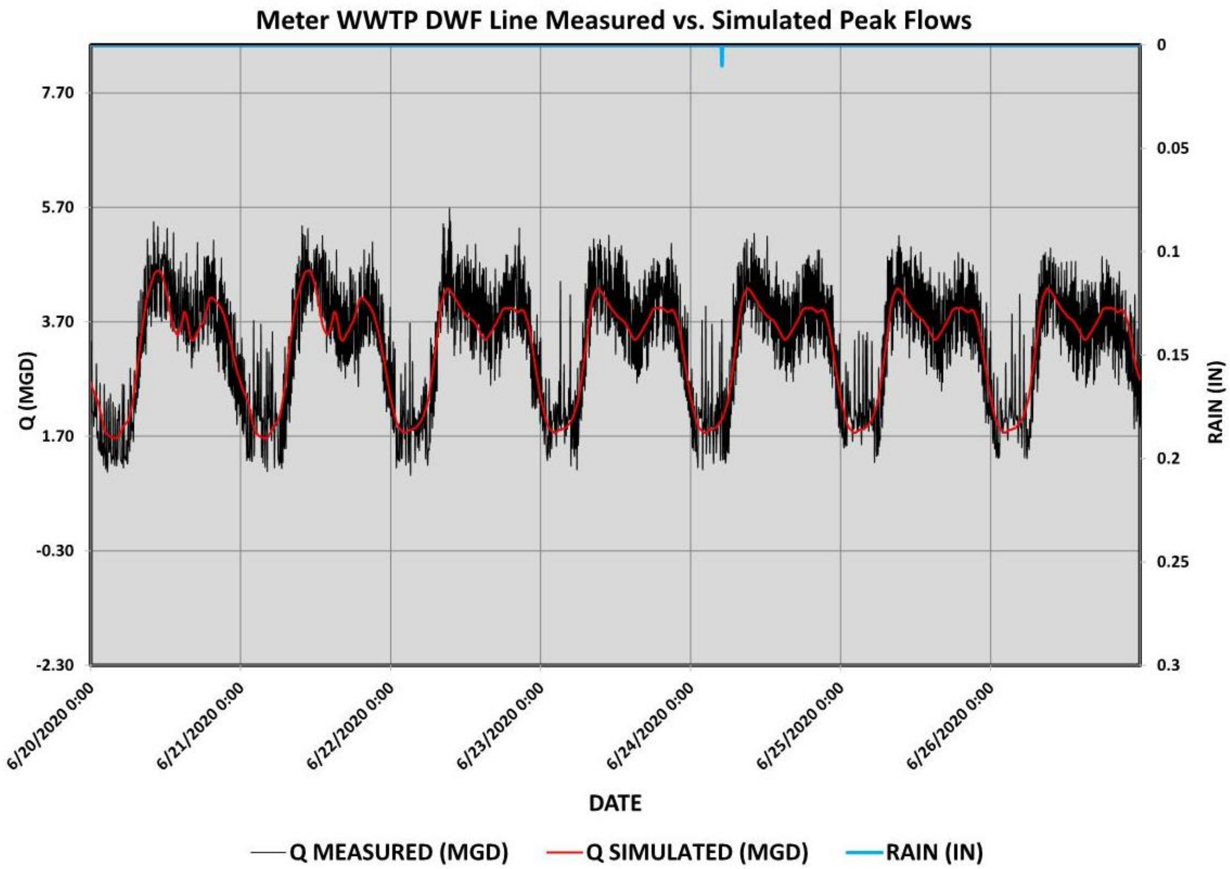


Figure 11: Comparison of Metered and Modeled Dry Weather Flows at WWTP Inflow

Excessive peak flow deviations between the modeled and metered flow were noted for five (5) of the six (6) meters. As previously mentioned in this Report, the metered data noise is associated with lower flow magnitude and the presence of pump stations, and when the noise if filtered out the agreement is much improved. The results of dry weather flow calibration are presented in **Table 36.**

Table 36: Dry Weather Flow Calibration Summary

Meter ID	Metered Volume (MG)	Modeled Volume (MG)	Volume Difference %	Peak Flow (MGD)	Modeled Peak (MGD)	Peak Difference %[1]	Meter Depth (in)	Modeled Depth (in)	Depth Difference (in)	CIWEM Urban Drainage Group Compliance for Volume and Depth
Interceptor 1	0.23	0.20	-13%	0.21	0.07	-67%	1.5	0.9	0.6	N
Interceptor 2	7.04	7.54	7%	1.53	1.57	3%	6.7	6.3	0.4	Y
Interceptor 3	6.93	6.79	-2%	1.75	1.27	-27%	6.3	6.4	-0.1	Y
Interceptor 4	1.73	1.75	1%	0.51	0.45	-12%	3.4	3.3	0.1	Y
D Sunnie Terr	0.75	0.77	3%	0.21	0.18	-14%	2.9	2.0	0.9	Y
WWTP	23.03	22.64	-2%	5.69	4.6	-19%	3.2	7.1	-3.9	Y

Notes:

(1) Calculated peak flow difference percentages were impacted by system noise, possibly due to pumping station activity. The volume differences are a better indicator of the model performance during dry weather.

3.12 System Capacity Assessment

The existing interceptor system appears adequately sized for its service area for the typically daily and peak dry weather flows. Since the 2020 temporary flow monitoring program indicated that excessive wet weather events could generate excessive extraneous flows within the interceptor system, the capacity of the interceptor system was evaluated with respect to a wet weather flow event. Wet weather model alternatives were prepared using average dry weather flow (ADWF) peaking factors that provide a range of the system's response throughout a typical year.

The following list of multipliers was used:

- 2.2 x ADWF - approximates the response from the June 28, 2020 wet weather event
- 5.0 x ADWF - approximates typical excess I/I impacts
- 8.5 x ADWF - approximates the response from the July 10, 2020 wet weather event (classified as a two (2) year wet weather occurrence)

The results demonstrate that the trunk sewer lines along Passaic Avenue and Pine Tree Place operate under surcharge conditions during rainfall events of more than 2.2 x ADWF. There is a potential for a manhole overflow during less frequent (longer return period) events.

The results from the Hydraulic Model were mapped in GIS (**Appendix J**) to show the sanitary system's performance. There are two evaluation criteria that are based on the level of surcharge:

- maximum flow depth relative to pipe dimeter
- manhole maximum hydraulic grade line elevation relative to rim elevation

Based on the model runs, the peak flow condition was determined for each pipe, and the performance of each pipe was color coded. No capacity deficiencies were identified for dry weather conditions. Depending on the magnitude of the storm, portions of the system were found to have inadequate capacity for wet weather flows. A factor of 5.0 x ADF was taken as representative of a majority of wet weather conditions and was used as the design condition.

In general, the modeled portion of the interceptor system has capacity for the design wet weather conditions, with exception of the 15-inch interceptor on Passaic Avenue (which showed surcharging to surface grade). However, this result is suspect since higher flows were metered in this line with only minor surcharging recorded. If this interceptor were to undergo excessive surcharging, surface flooding would result, alleviating the pressure and flow volume in the pipe. The line was "sealed" in the model to evaluate impacts downstream assuming all flow was conveyed through the 15-inch pipe.

Overall, under most conditions the sanitary interceptor system appears to have capacity to convey expected flows to the WWTP for treatment without overflowing. The system is impacted by RDII which can cause excess flows during extreme events. The 15-inch interceptor line on Passaic Avenue (in the vicinity of the Pine Brook) seems particularly vulnerable to excess RDI/I flows, with potential entry of significant volumes of surface flows into the interceptor system. Since the field measured data for the interceptor in question revealed both a different size than record plans and that undocumented rehabilitation was performed, it is recommended that additional investigations be done on this line to confirm its size and condition along Passaic Avenue. It is also recommended that the low point on Passaic Avenue be monitored or visually observed during extreme events to detect potential overflows or large-scale interactions between the sanitary sewer system and surface.

4 Flow Measurements

4.1 Instantaneous Flow Measurements

During performance of the Capacity Assurance Program, it was determined that sub-basin A, sub-basin C1 and sub-basin D exhibited excessive extraneous flows and were candidates for additional investigation. As such (during performance of the Capacity Assurance Program) Mott MacDonald performed additional tasks to further investigate these drainage sub-basins.

4.1.1 Dry Weather Flow Measurements

Dry weather instantaneous flow measurements were taken by placing a portable, calibrated weir into the pipe(s) tributary to a manhole. Field personnel noted the time of the measurement, the weather conditions, flow rate and flow clarity. Flow clarity is an important factor in extraneous flow investigations, as wastewater is typically cloudy with visible suspended sewage solids, and clear flow is usually an indication of extraneous flows.

Mott MacDonald identified key junction manholes within sub-basins A, C1 and D and obtained instantaneous flow measurements under dry weather conditions utilizing available mapping and manhole numbering system[1]. Instantaneous flow measurements were taken by placing portable weirs in the pipe(s) tributary to a manhole during the late night / early morning low-flow period (so that dry weather infiltration into the system would be obvious). Dry weather measurements were also used as base flow rates for comparison to subsequent instantaneous flow measurements performed under the Wet Weather Flow Measurements (discussed below).

Sanitary Sewer Instantaneous Flow Measurements (**Appendix K**) lists the dry weather instantaneous flow measurements taken during the CAP investigation. The table contains several columns that list information relevant to each instantaneous flow measurement.

A brief explanation of the columns is provided below:

- *Drainage Basin* - refers to the collection system drainage basin in which the sanitary sewer is located
- *Sewer Reach* (three headings)
  At MH - manhole in which the flow rate was recorded
  From MH - upstream manhole of the sewer being measured
  Location/Vicinity - applies to the *at* manhole
- *Tributary Sewer Data* (three headings, applicable to the pipe from which the measurement is being taken):
  Dia. - internal diameter of the sewer pipe (in inches)
  LF - total linear feet of upstream sewer pipe
  In.-Mi. - total inch diameter miles of the sewer pipes in the tributary area, where the inch diameter miles is calculated as follows: for each diameter of pipe, the total length of pipe tributary to the manhole is multiplied by the diameter in inches; then all of the calculated inch diameter foot values are summed; and then the sum is divided by 5,280 feet per mile.
- *Date* and *Time* - when the measurement was obtained.

[1] The existing manhole numbering system was used for drainage basin A; Mott MacDonald-designated manhole numbers were used for drainage basins C1 and D.

- *Flow* (two headings)
  Flow Clarity - clarity of the wastewater at the time of measurement (abbreviations):
  - *CLR* = clear (extraneous flow); sometimes noted as *CCLR* for crystal clear
  - *MCLR* = mostly clear flow (with minimal wastewater)
  - *PCLDY* = partly cloudy (wastewater with possible extraneous flow)
  - *CLDY* = cloudy (wastewater discharge)

  Rate - instantaneous flow measurement in gallons-per-day (gpd).
- *gpd/in.-mi.* (three headings)
  Calc. Value - calculated gpd per in.-mi. for the measured flow
  Ceiling Value - non-excessive ceiling value projected for the tributary sewer system. The Ceiling Value is a USEPA guideline used to evaluate the excessiveness of *wet weather* extraneous flows (represented in **Table 26**). If the calculated gpd per in-mi. values exceed the ceiling values during a high groundwater period, it may be cost-effective to locate and rehabilitate extraneous flow sources in the tributary sewer system. (It should be noted that this is only a guideline and in general, sources of I/I should be located and repaired based on the specific site conditions and engineering considerations for the overall sanitary sewer system.)
  Difference - difference between the *Calc. Value* and *Ceiling Value*.
- The *DWF*, *WWF* and *RDI/I* column lists prevalent weather and sewer flow conditions when the flow measurements were recorded.
  - *DWF* - dry weather flow - during the late night/early morning low flow period
  - *WWF* - wet weather flow - during a light rain, a period of high groundwater, or the period after a moderate to significant rainfall
  - *RDI/I* - rainfall-derived infiltration / inflow - during and shortly following a significant wet weather event

The light blue highlighting indicates instantaneous flow measurements where the flows were clear or mostly clear (indicative of extraneous flow) and where the calculated gpd/in.-mi. exceeded the ceiling value.

Dry weather flow measurements were completed on seventy-five (75) sanitary sewer reaches. Maps providing the locations of these sanitary sewer reaches (as investigated as part of the Capacity Assurance Program Report) are given in **Appendix L** (sub-basin A) and **Appendix M** (sub-basin C and sub-basin D).

4.1.2 Wet Weather Flow Measurements

Instantaneous flow measurements were taken using calibrated weirs within the sanitary sewers reaches listed on the Sanitary Sewer Instantaneous Flow Measurements (**Appendix K**) during wet weather conditions. The wet weather measurements were compared to the baseline data obtained during the dry weather investigations to determine the presence and extent of upstream extraneous wet weather extraneous flows (i.e.: Rainfall-Derived Infiltration/Inflow (RDI/I)) within the drainage basin upstream from the measurement manholes

Additional weir measurements were obtained within successive upstream manholes in an effort to pinpoint the leakage source(s) to single sewer reaches. The investigation also identified any observed manhole leakage sources. Those sewers identified with suspected leakage sources were noted and recommended for internal video inspections during a future wet weather event.

The purpose of the dry and wet weather investigations was to determine specific reaches of sanitary sewer within the prioritized drainage basins with the highest amounts of extraneous flows to be recommended for investigation through internal closed-circuit television (CCTV) inspection to pinpoint areas documented with high extraneous flows.

This section of the Report contains the methodology, findings and recommendations from the Capacity Assurance Program Report, and the appropriate maps of the field inspections, summary tables of the instantaneous flow measurements; photographs of observed manhole defects; photos of instantaneous weir measurements; and a list of the sanitary sewer reaches recommended for CCTV inspection (further discussed in Section 6 of this Report) to pinpoint sources of excessive extraneous flow. **Appendix L** and **Appendix M** include maps of the sub-basins, demonstrating manholes with identified infiltration or covers that could not be opened; weir measurement manholes; dry and wet weather weir measurements; and sanitary sewers recommended for CCTV inspection (highlighted in yellow).

4.2 Phase I Field Investigations

4.2.1 Instantaneous Flow Measurements

The main intent of the field investigations was to identify specific sanitary sewer reaches with sources of extraneous flows. The work was conducted by taking instantaneous flow measurements during dry weather and again during wet weather conditions within identified key junction manholes throughout the sub-basins that were anticipated to activate extraneous flows.

Instantaneous flow measurements were taken by placing a portable, calibrated weir in the pipe(s) tributary to a manhole. Instantaneous flow measurements taken during dry weather serve two purposes: 1) to detect dry weather infiltration and 2) to establish dry weather base flow rates (for comparison to subsequent instantaneous flow measurements taken during (or immediately after) wet weather). A significant increase in flow, particularly if it the flow is clear, indicates extraneous flows entering the sewer system upstream of the measurement point.

Field personnel noted the time of the measurement, the weather conditions, the flow rate and the flow clarity. Flow clarity is an important factor in extraneous flow investigations. Wastewater is typically cloudy, with visible suspended sewage solids. Clear flow, however, is usually an indication of extraneous flow within the sanitary sewer system**.** (Refer to **Appendix N** for photos of typical instantaneous flow measurements.)

Mott MacDonald recorded instantaneous flow measurements on the following dates:

2019		
Dry Weather*	**Wet Weather***	**RDI/I***
August 20	October 9	October 27
August 23	October 16	November 01
August 26		
August 28		
September 19		

The Sanitary Sewer Instantaneous Flow Measurements (**Appendix K)** lists the instantaneous dry and wet weather flow measurements taken during this investigation. In order to determine extraneous flows for specific segments of a sewer system, these parameters were graphed. The light blue highlighting on the Sanitary Sewer Instantaneous Flow Measurements indicates instantaneous flow measurements where the flows were clear or mostly clear (indicative of extraneous flow) and where the calculated gpd/in.-mi. exceeded the ceiling value.

* Dry weather flow - dry weather conditions during and for at least a few days prior to measurement; wet weather - during a light rain, a period of high groundwater, or the period after a moderate to significant rainfall; RDI/I (rainfall-derived infiltration / inflow) during and immediately after a moderate to significant rainfall

Appendix L and **Appendix M** contain the sub-basin maps of Areas A, C1 and D (as investigated in the Capacity Assurance Program) and show the following:

- Manhole with Identified Infiltration or Inflow Sources
- Manhole Covers that Couldn't be Opened
- Instantaneous Flow Measurement Manholes
- Instantaneous Flow Measurements for Dry Weather (green)
- Instantaneous Flow Measurements for Wet Weather (blue)
- Sanitary Sewers Recommended for Further Investigation (yellow)

The purpose of the Instantaneous Flow Measurements was to determine specific reaches of the sanitary sewer within the sub-basins that contained the highest amounts of extraneous flows. Upon comparing the wet weather instantaneous flow measurements to the baseline dry weather measurements, the presence of extraneous flows upstream of the measurement manholes were noted for further investigation; the sewer reaches identified with suspected leakage sources will be investigated via internal closed-circuit television video inspections (CCTV) during wet weather events to identify the source(s). Based on the dry weather instantaneous flow measurement results and analysis, fifty-six (56) sanitary sewers (totaling approximately 11,820 linear feet) were recommended for CCTV to locate and identify suspected DWI source(s).

4.2.2 Inspection of Sewer Trunk Line Manholes in Flood-Prone Areas

Manholes provide access points to a sanitary sewer system for monitoring flow conditions and for quantifying extraneous flows. Manholes are an important part of the sanitary sewer collection system as they are the primary means of access to pipes for maintenance, inspection, and rehabilitation. Manholes are necessary at pipe junctions, slope transitions, and horizontal alignment changes.

Over time, manholes in a sanitary sewer collection system can develop cracks and offsets at pipe joints and riser sections; these deficiencies can become sources of infiltration or roots/sediment/debris that can cause blockages, potentially resulting in surcharging and/or sewer overflows. For example, once a root penetrates a manhole it will grow down the walls and to the manhole channel pipe to feed. The initial tap roots may expand and wedge open the cracks and the tail roots will fan into the pipe (causing toilet paper and solid materials within the wastewater flow to snag).

Manholes (particularly those along or near watercourses) must be structurally watertight so as to not allow the entrance of inflow from surface runoff or infiltration from groundwater into the sanitary sewer system. In addition, the manhole interior must be resistant to powerful deterioration mechanisms such as erosion, abrasion, and hydrogen sulfide-induced corrosion that occur naturally or may be introduced into the system from various activities.

Periodic manhole inspections should be conducted to identify sources of inflow and infiltration, assess the extent of structural deterioration, evaluate issues affecting the operational function of the sanitary sewer, and determine is manhole remediation is required.

Mott MacDonald performed visual field inspections of select sanitary sewer manholes along each of the interceptor lines within the Borough of Caldwell WWTP service area. Several of the interceptor lines are within easement areas and are adjacent to watercourses. The purpose of the investigation was to identify manholes that are potential inflow sources to the sanitary sewer collection system. The inspections included walking the alignments of the interceptors to confirm the location of accessible manholes based on available mapping and to note evidence of possible inflow to the sanitary sewer system.

The interceptors inspected as a part of the Capacity Assurance Program Report included:

- East Brach Fullerton Brook Interceptor
- Green Brook Interceptor
- Pine Brook Interceptor
- York Avenue Interceptor

Please refer to **Appendix O** through **Appendix R** for the mapping of each interceptor (with manhole numbers for reference).

A total of sixty-nine (69) trunk line manholes along watercourses (based on available mapping) were located and inspected. The Interceptor Inspection Summary (**Appendix S**) provides a summary of the manholes inspected. The summary provides the manhole's corresponding interceptor, the (Mott MacDonald-designated) manhole number, the location / vicinity of the manhole, any notable observations (including leaks, defects or covers that are deemed flood-prone) remediation recommendations and the estimated construction costs.

Digital photographs were also taken during the inspections to document surface conditions, topside or ground level photo of the interior; and additional photos of internal components and various observations (e.g. infiltration sources and defects). Photographs of the more notable observed manhole conditions are shown in the discussion below.

4.2.3 Uninspected Manholes

During the manhole inspections there were forty (40) manholes along the selected interceptors (based on available mapping) that could not be located. It is recommended that these manholes be located and inspected to verify that they do not contain any potential inflow sources to the sanitary sewer collection system as well as for general sewer maintenance purposes.

4.2.4 Interceptor Manhole Inspection Findings

The findings regarding our interceptor manhole inspections include the following:

East Brach Fullerton Brook Interceptor: Interior inspections were conducted at 17 of the 22 manholes. Refer to **Appendix O -** East Branch Fullerton Brook Interceptor.

- Five (5) manholes are in satisfactory condition with no recommended rehabilitation.
- Five (5) manholes were found to be leaking with defects/infiltration sources and are recommended for chemical grouting.
    - One (1) manhole with large void due to root intrusion that is a potential source of significant inflow and is recommended for rehabilitation
- Nine (9) manhole covers are deemed flood-prone and recommended for installation of inflow-prevention insert covers.
- Five (5) manholes could not be located; three (3) of these manholes are located away from the East Brach Fullerton Brook.

Figure 12: East Branch Fullerton Interceptor MH FB-7

Arrow points to inflow source (void wedged-open by tree root) below ring section. Inset shows internal view of tree root through void.

Green Brook Interceptor: Interior inspections were conducted at 33 of the 54 manholes. Refer to **Appendix P** - *Green Brook Interceptor*.

- Twenty-eight (28) manholes are in satisfactory condition with no recommended rehabilitation; eighteen (18) of these manholes are within paved roadway away from any watercourse.
- Five (5) manhole covers are deemed flood-prone and recommended for installation of inflow-prevention insert covers.
    - One (1) manhole cover was observed to be two (2") inches below grade and is prone to inflow from surface ponding.
- Twenty-one (21) manholes could not be located.

Figure 13: Green Brook Interceptor MH GB-38

View of cover two (2") inches below grade; susceptible to inflow from surface ponding.

<u>Pine Brook Interceptor</u>: Interior inspections were conducted at 15 of the 28 manholes. Refer to **Appendix Q** - Pine Brook Interceptor.

- Thirteen (13) manholes are in satisfactory condition with no recommended rehabilitation.
- Two (2) manhole covers are deemed flood-prone and recommended for installation of inflow-prevention insert covers.
- Thirteen (13) manholes could not be located.

<u>Figure 14: Pine Brook Interceptor MH PB-9</u>

View of flood-prone cover (susceptible to inflow) near Pine Brook.

<u>York Avenue Interceptor</u>: Interior inspections conducted at 4 of the 5 manholes near a watercourse. Refer to **Appendix R -** York Avenue Interceptor.

- Three (3) manholes are in satisfactory condition with no recommended rehabilitation.
- One (1) manhole cover observed with concrete slab atop it suggesting that sanitary sewer overflow (SSOs) occur at this location.
- One (1) manhole could not be located.

<u>Figure 15: York Avenue Interceptor MH YA-4</u>

View of flood-prone cover (susceptible to inflow) with concrete slab atop cover suggesting SSOs have occurred.

4.2.5 Manhole Infiltration and Inflow

Over time, manholes in the sanitary sewer collection system can develop cracks and openings at pipe / manhole joints and at riser sections that can become sources of infiltration. Periodic manhole inspections should be conducted to identify potential sources of inflow and infiltration at manholes for elimination. While conducting the sewer trunk line inspections, recording instantaneous flow measurements and internal CCTV inspections, any defects observed during these investigations (such as manhole leaks and root intrusions) were recorded.

Overall, the manholes appeared to be in good structural condition. The Manhole Infiltration and Inflow spreadsheet (**Appendix T**) lists leaking defects, as inspected under dry and wet weather conditions, in nineteen (19) manholes. The Manhole Infiltration and Defects (**Appendix U**) provides images of the extraneous flows observed during the inspections.

Extraneous flow, in the form of groundwater, was detected entering from twenty-eight (28) sources within the following nineteen (19) manholes:

- Drainage Basin A: Manhole **NC-1-58** Brookside Terrace and Deer Trail Road - Sleeve of influent pipe; void around pipe/wall interface
- Drainage Basin A: Manhole **NC-1-62** Old Farm Road - Wall defect
- Drainage Basin A: Manhole **NC-1-65** Brookside Terrace - Wall joint
- Drainage Basin A: Manhole **NC-1-73A** Brookside Terrace ROW - Sleeve of effluent pipe; wall joint
- Drainage Basin A: Manhole **NC-1-78**Brookside Terrace ROW - Roots from wall joint
- Drainage Basin A: Manhole **NC-1-87** Deer Trail Road - Wall/bench interface
- Drainage Basin A: Manhole **NC-1-108** Lakeside Avenue - Inflow from manhole cover
- Drainage Basin A: Manhole **NC-1-109** Lakeside Avenue - Sleeve of influent pipe
- Drainage Basin A: Manhole **NC-1-103** Lakeside Avenue and Amelia Street - Wall defect
- Drainage Basin A: Manhole **NC-1-119** Fox Run - Sleeves of both pipes
- Drainage Basin A: Manhole **NC-1-120** Fox Run and Blackberry Lane - Sleeves of both influent pipes
- Drainage Basin A: Manhole **NC-2** Allen Road near Grandview Place - Pressurized leak from hole above influent pipe; wall joint
- Drainage Basin A: Manhole **NC-2-97** Pine Place - Sleeves of both influent pipes
- Drainage Basin A: Manhole **NC-3-140** Pressurized leak from wall joints
- Drainage Basin A: Manhole **NC-4-16** Longview Avenue and Tanglewood Road - Sleeves of effluent and influent pipes
- Drainage Basin A: Manhole **NC-4-134** Beachmont Terrace - Sleeve of influent pipe
- Drainage Basin D: Manhole **D-09** Brookside Avenue and Bowers Road - Roots from sleeves of influent and effluent pipes
- Drainage Basin D: Manhole **D-74** Harrison Street and Hillside Avenue - Wall defect
- Drainage Basin D: Manhole **D-76** Forest Avenue and Redman Terrace - Pressurized leak from channel defect

Infiltration is groundwater that enters a sanitary sewer collection system through defects in manholes (i.e.: holes, breaks, joint failures, connection failures and other openings). The Interceptor Inspection Summary (**Appendix S**) lists the following five (5) East Fullerton Brook Interceptor manholes, inspected under dry weather conditions.

The suspected infiltration sources or root intrusions that might be infiltration sources:

- East Fullerton Brook Interceptor: **FB-1**
- East Fullerton Brook Interceptor: **FB-7**
- East Fullerton Brook Interceptor: **FB-8**
- East Fullerton Brook Interceptor: **FB-9**
- East Fullerton Brook Interceptor: **FB-11**

4.2.7 Manhole Covers that could not be Opened

The following four (4) manhole covers could not be opened by Mott MacDonald field technicians using a standard manhole hook (due to sealed covers):

- Drainage Basin A: Manhole **NC-2-80** Mountain Ave & Colony Drive
- Drainage Basin A: Manhole **NC-2-85** Mountain Ave & Spruce Road
- Drainage Basin A: Manhole **NC-2-91** Spruce Road
- Drainage Basin A: Manhole **NC-4-75** Grandview Place

It is recommended that the Borough open the manhole covers to provide access to the sewer interceptor for operation and maintenance purposes.

5 Smoke Testing / Dyed Water Testing

5.1 Smoke Testing

5.1.1 Smoke Testing Methodology

Smoke testing consists of the injection of smoke into a sanitary sewer collection system. Once within the sanitary sewer system, the smoke will travel along the path of least resistance until it reaches the open atmosphere. If a sewer system is "tight" (properly constructed) the smoke will travel through the sanitary sewer system, through residential connections (laterals), and will vent to the open atmosphere through the residence's vent stack. However, if there are any defects in the sanitary sewer system (i.e.: faulty plumbing, faulty connections or fixtures, cleanout caps, or dry traps) the smoke will exit through these defects. If unauthorized connections were made to the sanitary sewer system (sump pumps, yard drains, roof leaders, inlets, etc.), the smoke will exit through these illicit connections.

The smoke testing process is as follows: a blower with a motor (approximately the size of a lawnmower) is placed over an open access point (i.e.: manhole). The blower is turned on, and a paraffin oil is heated on the blower exhaust. The oil heats and turns to smoke, and the smoke is in turn blown into the sanitary sewer system.

Technicians then walk the length of the sanitary sewer, observing where the smoke vents from the system, documenting each occurrence. Each set-up consists of roughly 1,500 - 2,000 linear feet of sanitary sewer and each set-up takes approximately 20-45 minutes (dependent on how many sources are located and documented).

The smoke is paraffin wax based and is odorless, non-toxic and is non-staining. When smoke enters a residence (through faulty piping), it typically dissipates within a few hours (the dissipation period is shorter if windows are opened).

5.1.2 Smoke Testing Field Investigations

Preliminary flow metering data was used to analyze the mini-basins for extraneous infiltration / inflow (I/I). Eleven (11) mini-basins showed signs of extraneous I/I and were smoke tested; these included sub-basins A2, A7, A8, C1 D1, D2, D3, D4, D6, D7 and D8. Smoke testing was conducted between December 2020 and January 2021 (with smoke testing in C1 conducted in May 2021, due to delays due to weather).

Mott MacDonald and Flow Assessment Services coordinated with each municipality prior to performing the smoke test investigations. During the field work, Flow Assessment Services noted any smoke emanating from other than plumbing vent stacks, which indicate sources of infiltration and/or inflow, including the following:

- Broken or missing private building service connection (PBSC) cleanouts
- Suspected sanitary sewer pipeline defects
- Suspected building plumbing defects
- Suspected indirect connections to catch basins
- Pavement and sidewalk cracks
- Broken or unsealed manhole frames
- Unfilled building plumbing traps

Such observations are documented, and those readily identified as inflow sources (e.g. roof downspouts) are recommended for the appropriate rehabilitation. The remaining, not so readily identified smoke sources (e.g. ground emanations), are recommended for further investigation to pinpoint the of infiltration and/or inflow source.

A total of 143,564 linear feet (LF) of sanitary sewer pipes were smoke tested, distributed as shown in **Table 37**.

Table 37: Smoke Testing Basin Breakdown

Sub-Basin	Linear Feet (LF)
C1	19,928
A2	22,010
A7	14,947
A8	5,796
D1	13,398
D2	19,792
D3	3,868
D4	5,162
D6	5,807
D7	19,402
D8	13,454
Total	**143,564**

5.1.3 Smoke Test Findings

Table 38 below shows the sanitary sewer lengths that had defects or other field observations. In total, 14,593 linear feet of sewer throughout 63 reaches had defects. A full report (prepared by Flow Assessment Services) including sketches of locations, and photos of the smoke testing are located in **Appendix V**.

The most common *identified* defects are cleanout (CO) caps along the PBSCs that are missing, loose or broken. Fifty-one (51) such CO caps were observed. These open or partially open COs can be sources of inflow, particularly when the PBSC riser is at or below grade. All have been recommended for installation or replacement.

The smoke test also revealed seven (7) direct connections and ten (10) indirect connections that could be sources of inflow. These situations are also recommended to be repaired or investigated further to eliminate I/I sources.

Table 38: Smoke Test Findings

Sub System	Inspection Date	From MH	To MH	Line Section Address	Line Footage	Finding Street No	Finding Street	Findings
A2	1/21/2021	NC-1-101	NC-1-87	Deer Trail Road	389	9	Deer Trail Road	Smoke from cleanout 0.5" above grade, missing cap
A2	1/21/2021	NC-1-107	NC-1-106	Amelia Street	136	32	Amelia Street	Smoke from cleanout 0.5" below grade, missing cap
A2	1/21/2021	NC-1-108	NC-1-103	Lakeside Avenue	249	22	Lakeside Avenue	Smoke from cleanout 0.5" above grade, missing cap
A2	1/21/2021	NC-1-113	NC-1-112	Roosevelt Boulevard	320	50	Roosevelt Boulevard	Smoke from cleanout 0.5" above grade, broken cap
A2	1/21/2021	NC-1-117	NC-1-116	Roosevelt Boulevard	337	66	Roosevelt Boulevard	Smoke from cleanout 0.5" above grade, missing cap
A2	1/21/2021	NC-1-118	NC-1-117	Roosevelt Boulevard	154	65	Roosevelt Boulevard	Smoke from broken (CO top coupling) cleanout 0.5" above grade
A2	1/20/2021	NC-1-14	NC-1-13	White Oak Drive	220	35	White Oak Drive	Smoke from cleanout 1" above grade, broken cap
A2	1/20/2021	NC-1-15	NC-1-14	White Oak Drive	107	2	Acorn Place	Smoke from cleanout 3" above grade, broken cap
A2	1/20/2021	NC-1-17	NC-1-16	White Oak Drive	254	36	White Oak Drive	Smoke from cleanout 1" above grade, broken cap
A2	1/20/2021	NC-1-17	NC-1-16	White Oak Drive	-	45	White Oak Drive	Smoke from cleanout 0.5" above grade, broken cap
A2	1/20/2021	NC-1-18	NC-1-17	White Oak Drive	219	40	White Oak Drive	Smoke from cleanout 1" above grade, broken cap
A2	1/20/2021	NC-1-20	NC-1-19	Acorn Place	334	8	Acorn Place	Smoke from cleanout 2" above grade, broken cap
A2	1/20/2021	NC-1-20	NC-1-19	Acorn Place	-	6	Acorn Place	Smoke from cleanout 5" above grade, broken cap
A2	1/20/2021	NC-1-22	NC-1-21	Acorn Place	275	12	Acorn Place	Smoke from cleanout 3" above grade, missing cap
A2	1/20/2021	NC-1-24	NC-1-23	Deer Trail Road	89	16	Deer Trail Road	Smoke from cleanout 0.5" above grade, missing cap
A2	1/20/2021	NC-1-41	NC-1-40	Deer Trail Road	299	45	Deer Trail Road	Smoke from cleanout 1" above grade, missing cap
A2	1/20/2021	NC-1-46	NC-1-45	Brookside Terrace	139	7	Brookside Terrace	Smoke from cleanout 0.5" above grade, missing cap
A2	1/20/2021	NC-1-64	NC-1-63	Old Farm Road	282	7	Old Farm Road	Smoke from cleanout 3" above grade, broken cap
A2	1/20/2021	NC-1-76	NC-1-75	Brookside Terrace R.O.W.	263	50	Deer Trail Road	Smoke from cleanout 1" above grade, broken cap
A2	1/21/2021	NC-1-91	NC-1-90	Amelia Street	150	16	Amelia Street	Smoke from cleanout #1; 0.5" above grade, broken cap

Sub System	Inspection Date	From MH	To MH	Line Section Address	Line Footage	Finding Street No	Finding Street	Findings
A2	1/21/2021	NC-1-91	NC-1-90	Amelia Street	-	16	Amelia Street	Smoke from cleanout #2; 0.5" above grade, broken cap
A2	1/21/2021	NC-1-98	NC-1-97	Estella Avenue	314	53	Estella Avenue	Smoke from cleanout 0.5" above grade, missing cap
A7	1/21/2021	NC-4-121B	NC-4-121A	Hamilton Drive East	331	51	Hamilton Drive East	Smoke from broken (CO top coupling) cleanout 1" above grade
A7	1/21/2021	NC-4-122	NC-4-121	Hamilton Drive East	77	45	Hamilton Drive East	Smoke from cleanout 0.5" above grade, missing cap
A7	1/21/2021	NC-4-124	NC-4-123	Hamilton Drive East	81	38	Hamilton Drive East	Smoke from cleanout 1" above grade, broken cap
A7	1/21/2021	NC-4-127	NC-4-126	Hamilton Drive East	133	34	Hamilton Drive East	Smoke from cleanout 1" above grade, missing cap
A7	1/21/2021	NC-4-129	NC-4-128	Hamilton Drive East	165	28	Hamilton Drive East	Smoke from cleanout 1" above grade, broken cap
A7	1/21/2021	NC-4-130	NC-4-119	Beach Mont Terrace	110	38	Beachmont Terrace	Smoke from cleanout 0.5" above grade, broken cap
A7	1/21/2021	NC-4-158	NC-4-157	Oak Place	183	31	Oak Place	Smoke from cleanout 0.5" above grade, broken cap
A7	1/21/2021	NC-4-162	NC-4-161	Oak Place	76	24	Oak Place	Smoke from cleanout 0.5" above grade, broken cap
A7	1/21/2021	NC-4-162	NC-4-161	Oak Place	-	24	Oak Place	Smoke from under rock patch in driveway - direct connection
A7	1/21/2021	NC-4-170	NC-4-169	Fairview Drive	162	15	Fairview Drive	Smoke from cleanout 3" above grade, broken cap
A7	1/21/2021	NC-4-82	NC-4-83	Beachmont Terrace	296	67	Beachmont Terrace	Smoke from driveway drain, at grade - direct connection
A7	1/21/2021	NC-4-83	NC-4-84	Beachmont Terrace	278	58	Beachmont Terrace	Smoke from cleanout 3' above grade, missing cap
A7	1/21/2021	NC-4-85	NC-4-86	Beachmont Terrace	145	46	Beachmont Terrace	Smoke from cleanout 1" below grade, missing cap
A7	1/21/2021	NC-4-91	NC-4-90	Birchwood Road	174	18	Birchwood Drive	Smoke from broken cleanout (missing CO top coupling) 2" below grade
A8	12/16/2020	NC-24	NC-23	Farmstead Road	266		Brentwood Road	Light smoke from catch basin - indirect connection
A8	12/16/2020	NC-24	NC-23	Farmstead Road	-	10	Farmstead Road	Light smoke from catch basin - indirect connection
C1	6/23/2021	C1-14	C1-13	Lane Avenue	272	35	Lane Avenue	Smoke from cleanout 0.75" above grade, broken cap
C1	6/23/2021	C1-15	C1-14	Lane Avenue	569	69	Park Terrace	Smoke from cleanout 0.25" above grade, missing cap
C1	6/23/2021	C1-23	C1-22	Lane Avenue	185	94	Lane Avenue	Smoke from cleanout 0.5" above grade, broken cap

Sub System	Inspection Date	From MH	To MH	Line Section Address	Line Footage	Finding Street No	Finding Street	Findings
C1	6/23/2021	C1-27	C1-26	Park Terrace	164	10	Park Terrace	Smoke from broken cleanout (missing CO top coupling) 0.5" below grade
C1	6/23/2021	C1-39	C1-38	Bloomfield Avenue	292	501	Bloomfield Avenue	Smoke from cleanout 2" above grade, broken cap
C1	6/23/2021	C1-H	C1-G	Dodd Road	145	6	Dodd Street	Smoke from left front roof leader - direct connection
C1	6/23/2021	C1-H	C1-G	Dodd Road	-	6	Dodd Street	Smoke from left front roof leader - direct connection
D1	12/10/2020	D-2-3	D-2-2	Grover Lane	279	19	Grover Lane	Smoke from right front roof leader - direct connection
D1	12/8/2020	D-3-8.2	D-3-8.1	West Grover Lane R.O.W.	182			No defects observed (New sewer in D1 boundry that flows to D8 - see sketch)
D1	12/8/2020	D-3-8.3	D-3-8.2	West Grover Lane R.O.W.	345			No defects observed (New sewer in D1 boundry that flows to D8 - see sketch)
D1	12/8/2020	D-3-8.4	D-3-8.3	West Grover Lane R.O.W.	154			No defects observed (New sewer in D1 boundry that flows to D8 - see sketch)
D1	12/8/2020	D-3-8.5	D-3-8.4	West Grover Lane	80			No defects observed (New sewer in D1 boundry that flows to D8 - see sketch)
D2	12/10/2020	D5-4	D5-3	Bowers Road	390	28	Bowers Road	Smoke from cleanout 2" above grade, broken (hole) cap
D2	12/10/2020	D5-5	D5-4	Bowers Road	254	14	Bowers Road	Light smoke from catch basin - indirect connection
D2	12/10/2020	D5-6	D5-5	Bowers Road	177	19	Bowers Road	Light smoke from catch basin - indirect connection
D3	12/11/2020	D3-9	D3-7	Ryerson Avenue	196	4	Hawthorne Road	Light smoke from catch basin - indirect connection
D3	12/11/2020	D3-3.1	D3-3	Ashland Street	348	8	Ashland Street	Smoke from cleanout 0.5" above grade, broken cap
D3	12/11/2020	D3-3.1	D3-3	Ashland Street	-			D3-3.1 is an unmapped manhole - see revised map
D4	12/15/2020	D4-3	D4-2	Crane Street	168	87	Elm Road	Smoke from ground - indirect connection
D6	12/15/2020	D6-15	D6-13	Parkway East	385	20	Parkway East	Smoke from cleanout 2" above grade, broken cap
D7	12/10/2020	D7-1B-1A	D7-1B-1	Hillside Avenue	43	53	Hillside Avenue	Homeowner stated smoke came from sump pump area in home (direct connection, if confirmed)
D7	12/10/2020	D7-1B-1A	D7-1B-1	Hillside Avenue	-	53	Hillside Avenue	Light smoke from catch basin - indirect connection

Sub System	Inspection Date	From MH	To MH	Line Section Address	Line Footage	Finding Street No	Finding Street	Findings
D7	12/10/2020	D7-1B-6	D7-1B-5	Hillside Avenue	152		Hillside Avenue	Heavy smoke from catch basin - indirect connection
D7	12/10/2020	D7-1E-1B	D7-1E-1A	Forest Avenue	241	100	Forest Avenue	Smoke from drain manhole - indirect connection
D7	12/10/2020	D7-1E-1B	D7-1E-1A	Forest Avenue	-	88	Forest Avenue	Light smoke from catch basin - indirect connection
D7	12/9/2020	D7-1E-33	D7-1E-31	Mountain Avenue	275	157	Mountain Avenue	Smoke from cleanout 0.5" above grade, missing cap
D7	12/9/2020	D7-1E-43	D7-1E-41	Mountain Avenue	445	194	Mountain Avenue	Smoke from broken cleanout (CO top coupling) 6" above grade
D7	12/9/2020	D7-1E-43	D7-1E-41	Mountain Avenue	-	186	Mountain Avenue	Smoke from cleanout 2" above grade, broken cap
D7	12/9/2020	D7-1E-45	D7-1E-44	Hickory Drive	212	9	Hickory Drive	Smoke from cleanout 1" below grade, missing cap
D7	12/9/2020	D7-1E-45	D7-1E-44	Hickory Drive	-	10	Hickory Drive	Smoke from cleanout 3" above grade, broken cap
D7	12/9/2020	D7-1E-48	D7-1E-47	Mountain Avenue	222	200	Mountain Avenue	Smoke from cleanout 3" below grade, loose cap
D7	12/9/2020	D7-1E-56	D7-1E-54	Windridge Drive and Mountain Avenue R.O.W.	531			No defects observed. Could not locate MH D7-1E-55, footages combined
D7	12/9/2020	D7-1E-62	D7-1E-59	Windridge Drive	235	1	Norwood Terrace	Smoke from cleanout 1" below grade, broken cap
D7	12/10/2020	D7-8	D7-7	Hillside Avenue	321	36	Hillside Avenue	Smoke from cleanout 1" below grade, missing cap
D8	12/8/2020	D-3-31	D-3-23	Smull Avenue	146	179	Smull Avenue	Smoke from cleanout 0.5" above grade, broken (hole) cap
D8	12/8/2020	D-3-65	D-3-57	Hickory Drive	178	24	Hickory Drive	Smoke from driveway drain - direct connection

Based on the aforementioned findings, Mott MacDonald recommends the following including a breakdown of the estimated costs:

- Install new caps for the seventeen (17) COs with missing (uncapped) caps; in addition to inflow elimination, these caps will prevent the introduction of debris (leaves, grass, dirt, sticks) and foreign objects (balls, small toys) into the service connection lateral**. The estimated cost for this work is $1,500.**
- Replace or tighten caps for twenty-nine (29) COs with loose or broken caps. **The estimated cost for this work is $3,000.**
    - Install or replace five (5) of these COs with top couplings that are broken or missing. **The estimated cost for this work is $7,000.**

- Internally television inspect with a push camera two (2) COs to 24 Oak Place and 87 Elm Road to identify possible breaks or other structural defects allowing smoke to escape up through the ground. **The estimated cost for this work is $2,500.**

- Contact the owner of 53 Hillside Avenue where smoke was stated to come from the sump pump area in home. Further investigation is recommended to confirm any prohibited (illegal) sump pump discharges to the sanitary sewer and for redirection of such discharges. The costs associated with the redirection should be borne by the property owner. **The estimated cost for this work is $1,000.**

- Contact the owners of 6 Dodd Street and 19 Grover Lane where smoke was observed emanating from roof leaders (3 total). Further investigation is recommended to confirm any prohibited (illegal) connection to the sanitary sewer and for redirection of such discharges. The costs associated with the redirection should be borne by the property owner. **The estimated cost for this work is $8,000.**

- Conduct dye testing of two (2) driveway drains of 67 Beachmont and 24 Hickory Drive to confirm a cross-connection with the sanitary sewer. Redirect connection if confirmed. The costs associated with the redirection should be borne by the property owner. **The estimated cost for this work is $10,500.**

- Conduct dye testing of the nine (9) storm sewer catch basins (or inlets) with observed emanating smoke to confirm a cross-connection with the sanitary sewer. Eliminate (seal) connection if confirmed. **The estimated cost for this work is $8,500.**

The estimated costs of the smoke test recommendations, not including soft costs such as administration, legal or engineering fees, is approximately **$42,000**.

6 Closed Circuit Television (CCTV) Video Inspections

6.1 Assessment Inspection Database

Mott MacDonald utilizes the PipeSmart!™ pipe inspection database to store and process video inspection information. PipeSmart!™ (a programming overlay to the Microsoft Access database) produces a variety of reports and summary information. The database was created by reviewing the closed-circuit television inspection videos that constitute a visual record of the inspected sewers. Site conditions (weather / temperature / location of manhole / crew / etc.) at the time of the inspections were also entered into the database.

Two types of data are entered into the database. The first type of data consists of general inspection and site information, including site conditions, sewer location and material, date of inspection and video identification. The second type of data includes all observations for inspected sewer pipes and manholes.

PipeSmart!™ generates the following reports of the information contained in the database:

- Pipe Database Directory
- Pipe Inspection Summary Report
- Detailed Pipe Data Report and Schematic Cross-Section.

The Pipe Database Directory and Pipe Data and Schematic Cross-Section are included in **Appendix W** and **Appendix X**.

6.2 Pipe Database Directory

The Pipe Database Directory lists all inspected sewers reaches alphanumerically by the number of the upstream manhole. One (1) sewer reach has *Drop* appended to the downstream manhole number to indicate that the inspected influent pipe enters the downstream manhole through an external drop connection pipe. Specific sewer reaches are identified by the numbered manholes at either end of the sewer and by the street or ROW designation. The inspection date and the digital video file designation and index are also listed. The Pipe Database Directory is included in **Appendix W**.

6.3 Pipe Inspection Summary Report

The Pipe Inspection Summary Report (located at the end of this section) is a compilation of pipe information and conditions extracted by PipeSmart!™. The Pipe Inspection Summary Report tabulates overall pipe inspection findings; catalogues the inspected sanitary sewers by pipe material and diameter; and summarizes the assigned condition ratings.

6.3.1 Inspection Summary

A summary report was compiled for the 37 sewer lines listed in the pipe database directory, totaling 6,844 linear feet. These sewers consist of asbestos cement (5,250 linear feet); polyvinyl chloride (1,304 linear feet); and vitrified clay (290 linear feet) pipe, totaling 6,844 linear feet, of which all but 489 linear feet was internally inspected.

6.3.2 Frequency Count by Observation

The *Frequency Count by Observation* section of the Pipe Inspection Summary Report notes the frequency of the various inspection observations. There are six (6) basic observation categories into which all of the specific observations, used to particularly describe various conditions, problems and defects, are divided.

- Structural Defects
  - Broken, chipped, corroded, cracked, crushed, depressed, eroded, punctured or sheared pipes, or pipes with missing pieces or deteriorated wall coating
  - Broken, chipped, corroded, cracked, eroded, misaligned, offset or separated joints, or joints with deposits, exposed gaskets or missing pieces
  - Pipe sags and ponded flow
- Structural Observations
  - Changes in pipe direction, diameter, material, shape or joint-spacing
  - Buried manholes
  - Spot repairs
  - Stubs, meter chambers, crossing pipes
- Operation and Maintenance Issues
  - Debris / sediment
  - Foreign objects
  - Roots
  - Grease
- Inspection Notes
  - Reversals, impassable obstructions, uninspected portions, inspection end points
  - Pauses for cleaning, dewatering, root-cutting
  - Camera submersion
- Sources of Inflow and / or Infiltration
  - Staining
  - Weepers
  - Drippers
  - Runners
  - Gushers
- Service Connections
  - Description - capped, inactive, bolt-on, pre-cast, plumber’s tap, unclassified
  - Condition - defects, leakage, roots, debris, grease, protruding

The existence or severity of problems can be assessed by the frequency count of observations and the comments section of the individual Pipe Data Reports. Low frequency counts indicate very few problems or conditions of that type were observed; higher frequency counts indicate more problems or conditions of that type were observed; and observation types not listed indicate that no such observations were noted.

6.3.3 Pipe Count and Footage by Condition Rating

The final section of the Pipe Summary Report, *Pipe Count and Footage by Condition Rating*, is a breakdown of the inspected sewers based on overall structural, hydraulic, infiltration and maintenance conditions as described above.

6.4 Pipe Data Reports

PipeSmart!™ creates a Pipe Data Report for each of the inspected sewer reaches. These reports are a complete record of all inspection details and provide an insight into sewer conditions without having to review the videotape of the inspection. The Pipe Data Reports and Schematic Cross-Sections are included in **Appendix X**.

The first page of each Pipe Data Report lists the general pipe and site data, including sewer reach designation and location; date and time of inspection; direction of camera; weather/surface conditions; digital video file reference data; and pipe data including material, shape and length. Following is the comments section (which contains a rating of overall pipe conditions) which includes a description of noteworthy problems with recommendations for maintenance and / or rehabilitation.

Following the main page of each Pipe Data Report is a detailed record of all observations within the inspected sewer reach listed in eight (8) columns as follows:

- Ftg - footage of an observed feature from the camera deployment manhole
- End - ending footage of features that extend along the sewer for several feet, such as pipe sags, structural damage, grease accumulations, etc.
- Offset - estimate of the deflection or offset alignment of a defect (i.e.: pipe joints)
- Observation - a brief description of a pipe feature or inspection activity
- Leak - estimated rate (in gallons per minute (gpm) of any suspected infiltration
- Rtng - may include defect / condition grading (Grade 1 to 5), depth of flow, or the percentage of pipe cross-sectional area obstructed by sediment, grease, water, etc.
- Clk - clock position indicating location of service connections or other observations
- Video - Video time index where the observed feature was recorded

Any supplementary comments associated with an observation are included on the line immediately below the observation itself. These comments may include service connection data (diameter, tributary building number, and conditions observed in the service connection when viewed with the pan-and-tilt camera), apparent sources of extraneous flows, and any other necessary clarifying information.

6.5 Schematic Cross Sections

PipeSmart!™ also creates a Schematic Cross-Section for each inspected sewer reach. Each Schematic Cross Section contains a plan view and a profile view which graphically depict conditions and findings observed during the inspection.

The plan view shows the apparent direction of all service connections; stubs note those entering from the left or right, while circles note those at the crown of the pipe. The total pipe length is noted, as is the measurement method (i.e. pipe end-to-end, structure lid centers or structure base centers). The latter method, measuring structure bases center-to-center, was used for this Report.

The profile view shows the inspected pipe and the starting and ending manholes for the sewer reach. Each observation is depicted along the pipe in proportion to its location. For observations that span along the pipe, a dashed line indicates the beginning and ending points. Uninspected pipe portions are cross-hatched in red indicating the length along the pipe that was not video inspected. Some schematics show observations digitally captured from the video inspections.

It should be noted that the manholes and pipes are not drawn proportionally, and all observations are noted along only the pipe portion of the profile view; thus, for the typical four (4’) foot diameter manhole, any observation within 1-1/2 to 2-feet of a manhole center, though actually situated in the manhole itself, is depicted in the pipe on the schematic.

PipeSmart!™ proportions the space between the manholes to indicate the relative location of the sewer features, defects and problems listed on the pipe data reports. If space permits, all observations are printed on a single page. When numerous observations are recorded, the computer creates two or more pages (as necessary).

While the Schematic Cross-Sections repeat some of the general inspection and site information listed on the Pipe Data Reports, they do not list defect / condition ratings or clock positions, infiltration rates, or video file information, which are contained on the Pipe Data Reports only. The Pipe Data Reports and Schematic Cross Sections are included in **Appendix X**.

6.6 Internal Sewer CCTV Inspections

Internal video inspections were conducted utilizing Mott MacDonald's color, pan-and-tilt camera system and staff within sanitary sewer lines with suspected extraneous flow sources. A list of sewers to be video-inspected during wet weather conditions was developed from the fieldwork outlined within this Report. Within these sanitary sewer lines, either individual reaches or a number of reaches were the likely sources of the extraneous flows measured by the instantaneous flow measurements. **Table 39** lists the sanitary sewers video inspected under this project.

Table 39: Video Inspected Sanitary Sewers

U/S Manhole Number	D/S Manhole Number	Location	Pipe Material	Diameter (in)	Length (LF)
D-71-D	D-71C	Hillside Avenue	VCP	8	290
NC-1-60	NC-1-58	Brookside Terrace	ACP	8	171
NC-1-61	NC-1-60	Brookside Terrace	ACP	8	159
NC-1-62	NC-1-61	Old Farm Road	ACP	8	40
NC-1-63	NC-1-62	Old Farm Road	ACP	8	242
NC-1-64	NC-1-63	Old Farm Road	ACP	8	242
NC-1-65	NC-1-61	Brookside Terrace	ACP	8	231
NC-1-69	NC-1-68	Brookside Terrace	ACP	8	79
NC-1-70	NC-1-68	Brookside Terrace	ACP	8	247
NC-1-71	NC-1-70	Brookside Terrace	ACP	8	250
NC-1-72	NC-1-71	Brookside Terrace	ACP	8	275
NC-1-73	NC-1-72	Brookside Terrace ROW	ACP	8	200
NC-1-73A	NC-1-73	Brookside Terrace ROW	ACP	8	40
NC-1-78	NC-1-73A	Brookside Terrace ROW	ACP	8	120
NC-1-84	NC-1-58	Deer Trail Road	ACP	8	124
NC-1-85	NC-1-84	Deer Trail Road	ACP	8	360
NC-1-86	NC-1-85	Deer Trail Road	ACP	8	189
NC-1-108	NC-1-107	Lakeside Avenue	ACP	8	210
NC-1-109	NC-1-108	Lakeside Avenue	ACP	8	196
NC-1-111	NC-1-109	Lakeside Avenue	ACP	8	219
NC-1-112	NC-1-111	Lakeside Avenue	ACP	8	140
NC-1-114	NC-1-112	Roosevelt Boulevard	ACP	8	205
NC-1-119	NC-1-114	Fox Run	ACP	8	164
NC-1-120	NC-1-119	Fox Run	ACP	8	170
NC-2-43	NC-2-39	Brookside Terrace	ACP	8	295
NC-2-45	NC-2-43	Willow Brook Drive	ACP	8	200

U/S Manhole	D/S Manhole	Location	Pipe Material	Diameter (in)	Length (LF)
NC-2-46	NC-2-45	Brookside Terrace	ACP	8	203
NC-2-47	NC-2-46	Brookside Terrace	ACP	8	148
NC-2-48	NC-2-47	Brookside Terrace	ACP	8	236
NC-3-138	NC-3-137	Evergreen Drive	ACP	8	216
NC-3-139	NC-3-138	Evergreen Drive	ACP	8	120
NC-3-140	NC-3-139	Evergreen Drive	ACP	8	157
NC-4-15	NC-4-14	Tanglewood Drive	ACP	8	155
NC-4-16	NC-4-15	Tanglewood Drive	ACP	8	216
NC-4-17	NC-4-16	Longview Avenue	ACP	8	68
NC-4-18	NC-4-16	Longview Avenue	ACP	8	81
NC-4-19	NC-4-18	Longview Avenue	ACP	8	186
				Total	**6,844**

Abbreviations: VCP = Vitrified Clay Pipe; ACP = Asbestos Cement Pipe; PVC = Polyvinyl Chloride Pipe; ROW = Right-of-Way

The completed project consists of the internal video inspection of sewers as follows:

- Total number of pipes: 37
- Total pipe footage: 6,844 LF
- Total *inspected* pipe footage: 6,355 LF
- Total *un-inspected* pipe footage: 489 LF
- Range of pipe diameters: All pipe = eight (8") inch diameter

The video inspections were conducted and reviewed by Mott MacDonald personnel certified by the National Association of Sewer Service Companies (NASSCO) under the Pipeline Assessment and Certification Program (PACP), which sets standardized procedures for the coding of sewer defects and the assessment of sewer condition.

Mott MacDonald focused its observations on defects, estimated quantity of I/I, suspected prohibited connections, obstructions, hydraulic and maintenance problems, etc. in tabular format including our recommendations for rehabilitation/repair and their estimated costs.

The data collected during the video inspections was also entered into our PipeSmart!™ sewer inspection database. PipeSmart!™ provides comprehensive data and summary reports, profile schematics, and can be linked to the Borough's GIS sewer maps.

6.6.1 Partially Video Inspected Sewers

The following six (6) sanitary sewers that were *partially* video inspected due to either a protruding S/C, sediment/debris accumulations or camera malfunction:

- **D-71D to D-71C Hillside Avenue** - Impassible protruding S/C
- **NC-1-72 to NC-1-71 Brookside Terrace** - Impassible debris accumulation.
- **NC-1-73 to NC-1-72 Brookside Terrace ROW** - Camera malfunction.
- **NC-1-120 to NC-1-119 Fox Run** - Camera wheel slipping on scum, cannot advance.
- **NC-2-43 to NC-2-39 Brookside Terrace** - Impassible sediment accumulation.
- **NC-2-45 to NC-2-43 Willow Brook Drive** - Impassible debris accumulation.

It is recommended that these sewers be included in a future cleaning and inspection project since they were slated for video inspection due to the presence of suspected extraneous flow sources. Prior to the video inspection of these sewers, the conditions that precluded complete inspections need to be addressed in order to pinpoint the source(s) for subsequent repair and reduction of leakage into the collection system.

6.7 Evaluation of Condition of Sanitary Sewer

The Video Inspection of the existing sanitary sewer was reviewed and evaluated by Mott MacDonald's NASSCO PACP/MACP/LACP certified personnel. The condition of the existing sanitary sewer lines, as observed from the Video Inspection, was evaluated. In general, the overall condition of the Borough's sanitary sewer collection system evaluated under this project is satisfactory and in fairly good structural condition.

Mott MacDonald evaluated the condition of the sanitary sewers video inspected based on overall structural, hydraulic, infiltration and maintenance conditions as follows:

- **Structural** - The physical condition of the pipe itself. The rating is based on the quantity and severity of pipe defects along the reach. These defects include chipped, cracked, offset, and broken joints; and cracked and broken pipe segments.

- **Hydraulic** - The ability of the pipe to convey tributary flows as designed. The hydraulic rating for a sewer pipe is determined by conditions in the pipe, conditions in the downstream manhole and conditions in the downstream effluent sewer. Reverse slopes, severe sags, foreign objects, obstructions, invert obstructions - all reduce a pipe's hydraulic capacity, which results in a poor rating.

- Manhole conditions such as missing inverts, inverts higher than influent pipes, the absence of channeling to contain sewage flow and cascading influent flows that impede sewage flow are all examples of manhole conditions that reduce a pipe's hydraulic capacity.

- Finally, conditions in the downstream or effluent sewer can decrease a pipe's capacity. These conditions create a backwater condition, which impedes the discharge from a tributary sewer.

- **Infiltration** - The presence and quantity of extraneous flows, whether from pipes, manholes or tributary service connections.

- **Maintenance** - The presence and extent of debris/sediment, grease and roots in the sewer reach. This rating is based on an assessment of (1) the conditions observed prior to any cleaning, (2) during the internal television inspections and (3) the apparent tendency of the sewer reach to become a maintenance problem.

Mott MacDonald utilized a condition rating system with a range of 1 to 5 to assess the sanitary sewer line conditions. The rating matrix is listed in **Table 40**.

Table 40: Sewer Condition Rating Table

Rating/Grade	Grade Description	Defect Description
1	Excellent	No defects; condition like new
2	Good	Minor and few moderate defects; pipe unlikely to fail for at least 20 years
3	Fair	Moderate defects that will continue to deteriorate, at a ten to twenty- year timeframe
4	Poor	Sewer defects that will continue to degrade with likely failure in next 5 to 10 years
5	Immediate attention	Pipe segment has failed or will likely fail in next 5 years; requires immediate attention

Comments, which clarify and summarize the detected conditions in each inspected sewer, appear in the comments section on both the Pipe Database Directory and on the Pipe Data Reports Schematic Cross-Section of the Video Inspection Reports. All sewers in good condition have a grade 1 rating and all sewers with defects were assigned a rating of 2, 3, 4 or 5 to describe the severity of pipe damage. The defect rating numbers are noted on the pipe data reports (Rating) column opposite each identified structural defect.

Sewers that were incompletely inspected were given an **Unknown** rating since the condition is unknown along the *uninspected* pipe portion; these sewers would need to permit camera advancement in order to determine the overall pipeline condition.

The assigned SHIM condition ratings of the project sewers are summarized in **Table 41**.

Table 41: Sewer Condition Grade Distribution

Condition	Rating	Pipe Count	Footage
Structural			
	Grade 1	**23**	**3,814.0**
	Grade 2	**6**	**1,357.0**
	Grade 3	**1**	**40.0**
	Grade 4	**1**	**203.0**
	Unknown	**6**	**1,430.0**
Hydraulic			
	Grade 1	**31**	**5,414.0**
	Unknown	**6**	**1,430.0**
Infiltration			
	Grade 1	**18**	**3,289.0**
	Grade 2	**13**	**2,125.0**
	Unknown	**6**	**1,430.0**

Maintenance			
	Grade 1	**30**	**5,266.0**
	Grade 3	**1**	**148.0**
	Unknown	**6**	**1,430.0**

6.8 Pipe Infiltration and Defects

The 5-level grading system for structural defects was applied to the video inspected sanitary sewers. Each sewer was assigned an overall rating based on the observed conditions. **Table 41** indicates 18 of the 31 (56%) completely inspected sewers are rated as Grade 1

Table 6.8.1, *Pipe Defects and Infiltration* (which follows this page) lists six (6) leaking pipe defects within five (5) sanitary sewers (one had multiple extraneous flow sources) observed during the video inspections. The table also indicates the recommendations for the defect repair/rehabilitation. The leaking defect were observed with a combined infiltration rate of approximately 1,326 gpd.

The breakdown of the observed pipe defects and infiltration is as follows:

- Five (5) sewers with a combined 750 gpd from punctures
- One (1) sewer with an estimated 576 gpd from a hole

The Township's sanitary sewer system consists of asbestos cement (ACP) pipes that date back to the 1960s. ACP pipe, like vitrified clay (VCP) pipe, is a rigid pipe but its tensile strength due to the asbestos fibers results in more punctures than longitudinal and spiral cracking as can occur in VCP. The video inspected sanitary sewers are in overall satisfactory condition within the study areas.

Images of Observed Infiltration Sources (digitally captured from the internal video inspections) are included in **Appendix Y**.

6.9 Private Building Service Connection (PBSC) Inspections

Extraneous Flows from Private Building Service Connections (**Appendix Z**) lists four (4) suspected I/I sources from Private Building Service Connections (PBSC or S/C). The total estimated PBSC leakage rate was 5,184 gallons per day (gpd), with a range between 288 to 2,160 gpd.

- The leakage sources within four (4) S/Cs, with a combined infiltration rate of 5,184 gpd, could not be pinpointed from the mainline sewer and are recommended for additional investigation and eventual repair. The additional inspection required would be by video inspection with a push camera or lateral launcher during a significant rain event to locate the I/I source(s).

Private S/Cs are typically more susceptible to infiltration compared to sewer mains because the lateral trenches are much shallower than sewer main trenches and the surface cover above the laterals are typically porous lawn areas. Some service connections identified as having minimal leakage when discovered during a period of low extraneous flows may discharge very high extraneous flows when RDI/I levels are near maximum levels.

6.10 Hydraulic Conditions of Inspected Pipes

The hydraulic condition of a sewer pipe refers to its ability to adequately convey the wastewater tributary to it. This includes maintaining velocity (i.e.: equal to or greater than two (2') feet per second) to keep solids from settling, but without high velocities as to cause excessive wearing on pipes and manhole channels. Causes of adverse hydraulic conditions include slopes that are too great or too slight, mortar dams, excessive sediment or debris, blockages, and pipe sags.

All 31 completely inspected sewers are in Grade 1 hydraulic condition.

6.11 Maintenance Conditions of Inspected Pipes

Maintenance problems are conditions in a sewer that may obstruct wastewater flow and may require more frequent sewer cleaning than normal. Some typical sewer maintenance problems include intruding roots, grease accumulations, and sediment/ debris depositions.

The overall maintenance condition of 30 of the completely inspected sewers is Grade 1. Only 1 one (1) *completely* inspected sewer is in Grade 3 maintenance condition due to a S/C protruding three (3") inches into the mainline (this protrusion may cause rags/debris/solids to accumulate). It is recommended to cut the protruding S/C to prevent obstruction of wastewater and restore full pipeline conveyance capacity.

6.12 Yearly Impact of Identified Extraneous Flow Sources

Infiltration and inflow is estimated in gallons per minute (gpm), with one (1) gpm being small but noticeable and five (5) to ten (10) gpm considered significant. **Table 42** lists the identified defect sources and flow rates based on statistically derived total flow values that would be contributed by each during a *standard* rain event into the Township's wastewater collection system, assuming the leaks are constant throughout the day and steady through the year.

Table 6.12.1 - Yearly Impact of Identified Extraneous Flow Sources

Defect Source	Source Description	Quantity	Flow per Defect (gpm)[1]	Total Flow (gpd)	Total Yearly Flow
Manholes	Wall/bench/pipe seals	28	0.5	20,160	7,358,400
Manholes	Inflow through covers	1	1.0	1,440	525,600
Pipelines	Breaks/fractures/holes	6	0.1	864	315,360
S/Cs	Breaks/fractures/holes	4	2.0	11,520	4,204,800

[1] Amount of Flow per defect varies based on severity

7 Findings and Recommendations

7.1 Findings

This Inflow / Infiltration Investigation included temporary flow monitoring, hydraulic modeling of the interceptors, smoke testing / dyed water testing and closed-circuit television internal sanitary sewer inspections within the sub-basins which demonstrated the greatest extraneous flow (as documented in the Capacity Assurance Report).

The Inflow / Infiltration Investigation identified numerous sources and suspected sources of extraneous (I/I) flow within the project areas. The findings are summarized below:

- Smoke testing findings **(Table 38)**
  - Fifty-one (51) cleanout caps that are missing, loose or broken.
  - Seven (7) direct connections
  - Ten (10) indirect connections that could be sources of inflow

- Manhole inflow/infiltration and defects (**Appendix T**)
  - Twenty-seven (27) defects with infiltration were identified within eighteen (18) manholes. The total estimated leakage was 47,9085 **gpd**, with defect infiltration rates ranging from 150 to 11,000 gpd.
  - One (1) manhole with inflow through the cover. The total estimated inflow rate was 2,880 **gpd.**

- Pipe defects and infiltration (**Table 6.8.1)**
  - Seventeen (17) defects within ten (10) sewers were identified.
  - Six (6) pipe defects with infiltration were identified. The total estimated leakage was **1,326 gpd**, with defect infiltration rates ranging from 150 to 576 gpd.

- Private building service connection extraneous flows (**Table 6.9.1)**
  - PBSC leakage - source not identified
    - Four (4) PBSCs were observed with leakage, though the exact source/s could not be determined because they were not visible from the mainline pipe. The combined estimated observed leakage rate was **5,184 gpd**.

8 Summary and Recommendations

The purpose of the Instantaneous Flow Measurements was to determine specific reaches of sanitary sewer within the project drainage basins with extraneous flows to be investigated further.

Recommendations for the reduction of leakage rates, repair of appurtenance defects, and additional private building service connection investigations are summarized below. ***Tables 8.1 through 8.5***, which follow this Section, provide tabulations of the recommended repairs, including a breakdown of the estimated costs.

- Twenty-seven (27) identified manhole defects are recommended for grouting and patching. The estimated construction cost for this work is $46,650, as indicated in **Table 8.1, *Recommendations for Grouting and Patching of Manhole Defects.***

- Nineteen (19) manholes have been recommended for the installation of inflow-prevention inserts. The estimated construction cost is $2,500, as indicated in **Table 8.2, *Manholes Recommended for Installation of Inflow-Prevention Inserts.***

- Ten (10) sanitary sewers are recommended for partial CIPP lining over identified defects. The estimated construction cost for this work is $28,500, as indicated in **Table 8.3, *Recommendations for Partial CIPP Lining of Sanitary Sewers.***

- Two (2) S/Cs (laterals) protruding into mainline sewer are recommended to be cut to restore full pipe capacity. The estimated construction cost for this work is $2,400, as indicated in **Table 8.4, *Recommendations for Cutting Protruding S/Cs.***

- The four (4) S/Cs with observed extraneous flows but unidentified leakage sources are recommended for additional investigation using a lateral launcher camera from the sewer main or a push camera from the building cleanout. The internal inspection of the entire building sewer lateral is recommended. The estimated construction cost for this work is $5,000. **Table 8.5, S/*Cs Recommended for Additional Leakage Investigation***, provides a list of the lateral locations.

- Clean and CCTV inspect all sewers that were partially inspected for a thorough evaluation and to identify suspected I/I sources.

- Conduct further internal CCTV inspections of sewer reaches identified with suspected leakage sources based on the Instantaneous Flow Measurements as outlined in **Section 4.**

In summary, a total estimated **54,418 gpd** of I/I have been identified including their source under this investigation. The estimated construction costs to repair the identified defects and sources of I/I based on the smoke testing results and from the internal video inspections (listed on **Tables 8.1 through 8.5)**, not including soft costs such as administration, legal or engineering fees, is approximately $127,050, as summarized on **Table 8.6.** The total project cost is approximately $198,200.