Hydraulic Capacity Analysis of the New York City Sewer System

The City of New York
Department of Environmental Protection
Bureau of Wastewater Treatment

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1.0 Background

The SPDES BMP Consent Order of 2010 requires the NYCDEP (DEP) to deliver to NYSDEC (DEC) an "Evaluation of the Hydraulic Capacity of the NYC Sewer System (Combined and Sanitary) by Wastewater Treatment Plant (WWTP) Drainage Area (Excluding Oakwood Beach)." Four components fall under this requirement. The first was the delivery to the DEC by December 31, 2010 of a report complying with the following:

> "*Using the existing INFOWORKS Models and available data develop a report that evaluates the hydraulic capacity of the existing sewer system in accordance with BMP#2 for the entire New York City combined and sanitary collection systems by WWTP drainage areas."*

Compliance with the first component of this hydraulic analysis was met with the submission to DEC of the requested report on December 30, 2010. This report was entitled "Hydraulic Capacity Analysis of the New York City Sewer System".

The second and third components under the SPDES BMP Consent Order, due in 2012, require: (a) updating the calibration of the InfoWorks (IW) models using new impervious cover data, interceptor inspections and cleaning results; and (b) submission of the updated IW modeling reports to DEC. Both the second and third components have also been completed with the submission of the report entitled, "INFOWORKS, Citywide Recalibration Report, Updates to and Recalibration of October 2007 NYC Landside Models" to DEC on June 30, 2012.

The fourth component related to the Hydraulic Evaluation, is the subject of this report, which was defined as follows:

> "*Using updated INFOWORKS Models for each WPCP drainage basin, complete and submit the evaluation of the current hydraulic capacity of the entire New York City combined and sanitary sewer collection systems by WPCP drainage basin.*
>
> *Determination of hydraulic capacity is to be verified in all drainage basins by comparison to the TV/Sonar inspection results from Item 1(a) above."*

CSO BMP #2 noted in the first component in the Order above contains the following wording:

> "*Maximize the Use of the Collection System for Storage: The permittee shall optimize the collection system by operating and maintaining it to minimize the discharge of pollutants from CSOs. It is intended that the maximum amount of in-system storage be used (without causing service backups) to minimize CSO*

> *and convey the maximum amount of combined sewage to the treatment plant in accordance with Item 4 below. This shall be accomplished by an evaluation of the hydraulic capacity of the system but should also include a program of flushing or cleaning to prevent deposition of solids and the adjustment of regulators and weirs to maximize storage."*

This report was compiled to fulfill the fourth requirement for the submission of a Hydraulic Capacity Evaluation by December 2012.

In reviewing this submission, it should be recognized that the New York City sewer system is a complex system, with hundreds of interconnections, relief points, and control structures. It has been designed and constructed over the past 100(+) years, and has undergone a variety of modifications from its genesis to its current state but overall the system operates as it was designed.

Furthermore, its behavior is dynamic for a variety of reasons, one of which is that the majority of the combined sewer outfalls have tide gates that prevent the flow of sea water into the system. These tide gates impact the way the sewer systems function, in that they temporarily hold water within the upstream collection system when the harbor is at or near high tide. The impact of allowing the water levels to rise in wet weather creates additional head on the regulator orifices that convey flow to the interceptors. The result is that more water is forced through the regulators and interceptors in this high tide condition. At lower tides, the system functions as designed and overflows when the regulator capacity is exceeded.

As a result, when evaluating the hydraulic capacity of the sewer system, it is critical to define the meaning of the word "capacity" as well as the conditions for which the capacity is being assessed. The ability of pipes and regulating structures to convey flow through the system can and will change with tide, rainfall intensity, and other factors. The ability of conveyance pipes to carry flow will depend on whether they are flowing by gravity; whether they have a downstream driving head on them, or whether they are in a backwater condition.

The DEP has prepared this report in response to the CSO BMP Consent Order requirement as an initial examination of the conveyance of the sewer system. The DEP will use the information contained in this report but will also continue to advance the analysis over time as required by the Order and as part of its development of the CSO Long Term Control Plan (LTCP) for the sewersheds impacting individual waterbodies.

2.0 Methodology

The DEP has developed much of the information contained in this report based on the use of the thirteen InfoWorks models as the primary data sources. These existing IW models were previously updated, calibrated, and documented in the June 2012 recalibration report. While there are various potential approaches to develop information on the system's capacity, using the IW models as a basis for this evaluation is a reasonable approach, since the models are being utilized as part of the LTCP planning process, and are the most sophisticated and useful tools representing the sewer system characteristics to date. As such, the information on capacity will be consistent with the LTCP analyses. It should also be noted that the SPDES BMP Consent Order specifically calls for the hydraulic analysis to be based on the existing IW models.

The IW models used herein were originally documented under a series of Landside Modeling Reports dated October 2007. There is one model and an associated report for each of the WWTP sewershed, with the exception of the Oakwood Beach sewershed, which is a separately sewered area of the City. Each model contains a system of pipes and nodes (i.e., manholes or junction points) that include interceptors, major combined sewers and certain other trunk and combined sewers. The models do not contain each and every sewer or manhole instead, they consolidate the system into "modeled pipes" that represent pipe lengths with common sizes, shapes, and slopes that allow for sewer system analysis at an appropriate resolution for planning purposes. The models are planning tools, not operational tools or design-based tools, and as such represent the system in a simplistic fashion. For example, where an actual combined sewer segment may have manholes located every 200 to 400 feet, the IW model may have a node (*i.e.*, manhole) every 1,000 feet. For hydraulic modeling purposes, a node is only needed each time there is a change in pipe slope, pipe size or catchment inflow. Lengths of a combined sewer or interceptor where the slope and size of the pipe do not change would be represented in the model by a single pipe element, irrespective of the actual segment lengths. In reality, however, the actual system may have several sections of pipe separated by several manholes and inflow points within this single model pipe element.

Generally, the models contain combined sewer conduits ranging in size from large, multiple-barrel combined sewers near regulators and outfalls, down to single 48-inch combined sewers, located more upstream. However, in certain locations, the models do contain sewers as small as 12 inches. The level to which the sewers in the IW modeling system have been constructed depends on many factors. Generally, the models only contain these smaller pipes in areas of the City where a site-specific evaluation was performed, requiring a more refined representation, or where very small catchments feed single regulators. Over time, the models continue to get more refined with the addition of more detailed and up to date sewer information, with additional flow monitoring for model calibration/verification, and with advances in the computational capacity of the software and hardware that allows DEP to add small sewers into the model.

While combined sewers are represented in the models as described above, the diversion structures (weirs and orifices) and interceptor sewers are represented more accurately. Spatially referenced interceptor sewers are explicitly included to convey flow to the WWTP. Throttling gates and WWTP pumping operations are included to the extent information is available. For example, WWTP pumping operations are generally not the same for each and every storm event. As such, during continuous simulations a single pump curve is applied to every storm event during the simulation.

In the 2010 Hydraulic Capacity Analysis Report submission (the first phase of the hydraulic analyses), DEP provided spatially-referenced maps of the IW model combined sewer piping networks. Full-pipe flow capacities were identified for each segment of the modeled system. In short, these capacities represented the amount of water that could be conveyed through the pipes under the following conditions:

- Steady, uniform gravity flow
- Clean interceptors and sewers
- Pipes flowing full under non-surcharged conditions
- Typical pipe surface roughness values.

This December 2012 Hydraulic Analysis Report provides additional information. Much of the information uses an analysis that is dynamic, as opposed to the 2010 static evaluation, and provides further insight into the hydraulic capacities of key system components and system response to various wet weather conditions. The information provided in this Report is organized into the following sections.

- Delivery and Treatment of Combined Sewage
- Capacity of Conveyance System

The objective of each evaluation and its specific approach is briefly described in the following paragraphs. A more detailed analysis of each drainage area is provided in the Appendices.

3.0 Delivery and Treatment of Combined Sewage

This section of the Report provides information and analyses results that provide insight into the amount of time at which the WWTPs operate at twice the Design Dry Weather Flow (2xDDWF). This information is based on measured data as well as model calculations (i.e., simulations). Model simulations were performed for a variety of different rainfall scenarios and for different sewer system conditions (existing and future). These modeling simulations also include interceptor sediment data from the recently completed TV and sonar inspections of all of the City's interceptors as required under the SPDES BMP Consent Order. In summary, information is provided on the number of hours for which each of the WWTPs attains the target maximum wet weather flow capacity, using both measured data and model results for existing and future conditions.

InfoWorks model simulations were conducted for two different precipitation years – 2008, which contained a total precipitation of 46.26 inches as measured at the JFK Airport, and 2011, which contained a total precipitation of 55.78 inches - an amount 20% higher than was observed in 2008, thus providing a comparison of a wetter rainfall year. These simulations were conducted using projected 2040 DWFs for two model input conditions: a) the 2011 re-calibrated models for each service area; and b) the Cost-Effective Grey (CEG) alternative defined for each service area, if applicable. The CEG elements for each service area, where applicable, are listed in the respective service area summaries later in this report (Appendices). However, the CEG elements generally represent the CSO controls that became part of the recent 2012 amended CSO Consent Order. The simulations provide the calculated amount of flow treated at the WWTPs and the number of hours for which each WWTP was processing 2xDDWF (i.e., the permitted peak rate), for each WWTP service area for current (existing) and CEG conditions. For these simulations, the primary input conditions that applied were as follows:

- Projected 2040 DWF conditions
- 2008 or 2011 tides and precipitation data
- WWTPs at 2xDDWF capacities
- No sediment in the combined sewers
- Sediment in interceptors representing the post-interceptor sediment conditions after completion of the inspection and cleaning program completed in 2011 and 2012
- No green infrastructure

During any given period, the amount of wet weather flow delivered to and treated at the WWTPs can vary for a variety of reasons including the following:

- Amount of construction occurring at the WWTP associated with upgrades
- Volume, intensity and distribution of rainfall
- Presence or absence, and amount of sediment/debris in the interceptor system
- Capacity of the conveyance system, specifically interceptors
- Whether tides were high or low during rainfall events

Table 1 below summarizes the number of hours that each WWTP received and processed 2xDDWF, based on measured data. As noted, the number of hours varies by WWTP and by year. Year-to-year variability in the hours a WWTP operates at 2xDDWF can, to a certain extent, be attributed to the changes in the spatial distribution of rainfall volume, as well as the frequency and intensity of that rainfall. In addition, in more recent years WWTP operating conditions, most of which are associated with various construction activities (Biological Nitrogen Removal upgrades, Newtown Creek reconstruction, etc.), are responsible for any reduced hours of processing flow at the target 2xDDWF maximum operating levels. As shown in the table, there is a wide range in the amount of wet weather flow, as measured by the number of hours plants receive and treat wet weather flow. Variation in the hours operating at 2xDDWF between WWTP's that are not associated with construction is more likely due to the macro scale modeling assumptions such as the population density that was evenly distributed throughout the drainage area and the fact that only large sewers are accounted in the model for so the travel time in which the runoff reaches the WWTP may not be accurately representative but overall wet weather flows captured are accounted for.

The differences between the six-year average frequency of treating 2xDDWF range from a low of 6 hours per year (Tallman Island WWTP) to a high of 159 hours per year (Owls Head), for the period 2005 through 2011, excluding the Rockaway WWTP. As DEP has acknowledged in the Waterbody/Watershed Facility Plans and the SPDES BMP and CSO Consent Order obligations, both the Tallman Island and the Jamaica WWTPs, although fully capable of delivering 2xDDWF to the treatment plants, have conveyance system features that limit the frequency at which those facilities receive 2xDDWF.

Table 1: Observed Durations of Peak Flow Treatment (2005-2011)

Appendix	WWTP	2xDDWF (MGD)	Number of hours of flow equal to or exceeding 2xDDWF							
			CY-2005	CY-2006	CY-2007	CY-2008	CY-2009	CY-2010	CY-2011	Average (2005-2011)
A	26th Ward [2]	170	91	44	4	16	0	1	0	68
B	Bowery Bay [2]	300	26	15	25	0	0	0	6	22
C	Coney Island	220	143	87	42	107	130	87	276	125
D	Hunts Point	400	60	54	77	79	43	63	116	70
E	Jamaica	200	25	3	18	0	0	3	19	10
F	Newtown Creek[1]	700	163	171	116	75	82	14	78	100
G	North River	340	124	137	134	75	59	39	93	94
H	Owls Head	240	125	261	206	215	158	26	125	159
I	Port Richmond [2]	120	9	42	45	28	8	25	2	31
J	Red Hook	120	141	186	156	121	88	113	179	141
K	Rockaway	90	0	0	0	0	0	2	0	0
L	Tallman Island	6	5	0	5	0	0	3	29	150
M	Wards Island [2]	550	21	66	8	0	4	0	1	44

[1] Actual hours for Newtown Creek is only for 2010 and 2011 when comparing to 700 MGD.
[2] Actual hours for the following WWTPs only include years in which wet weather flows were not impacted by construction at the WWTPs, that is, flow limitations were not
26th Ward - 2005, 2006
Bowery Bay - 2005, 2006, 2007
Port Richmond - 2005, 2006, 2007, 2008
Wards Island - 2005, 2006

The IW models were used to simulate both existing conditions and future conditions (implementation of CEG controls) to further assess the frequency at which WWTPs will receive 2xDDWF upon completion of 2012 amended CSO Consent Order required controls. **Table 2** provides a summary of the number of hours the IW models predicted that the WWTPs will be at 2xDDWF for existing infrastructure conditions and for the future infrastructure conditions (CEG elements as per the CSO Consent Order). It should be noted that for the existing infrastructure conditions, it was assumed that all WWTPs were treating to a maximum flow of 2xDDWF. In using the IW model to calculate the number of hours that each WWTP would operate at 2xDDWF, the WWTP capacities used in the simulations were set exactly at 2xDDWF. As such, the model was constrained from allowing the influent pumps to pump at a rate greater than the 2xDDWF rate. Thus, the flow rate to the plant in many cases approached very close to the 2xDDWF and in reality may have achieved 2xDDWF but were restricted from doing so by the constraint placed on the model as the maximum allowable flow. To fairly count the number of hours that the plants were modeled to be at or near their required wet weather capacity, an hour was counted if the modeled flow to the plant was calculated to be within 3% of 2xDDWF.This value of 3% is representative of the flow differential above 2xDDWF observed in actual data from WWTP operations. As noted in this table, for most of the treatment facilities, there is an increase in the overall model-predicted number of hours that the WWTPs would be expected to reach 2xDDWF for the CEG conditions. In particular, the Tallman Island and Jamaica WWTPs are projected to receive 2xDDWF much more regularly, once CEG controls are in place.

Table 2: Model-Predicted Durations of Peak Flow Treatment

Appendix	WWTP	2xDDWF (MGD)	Number of hours of flow equal to or exceeding 2xDDWF				
			Actual Hours	InfoWorks Model Results (hours)			
			Average (2005-2011)[1]	2008 w/o CEG	2008 w/ CEG	2011 w/o CEG	2011 w/ CEG
A	26th Ward [2]	170	68	133	132	162	161
B	Bowery Bay [2]	300	22	58	74	109	130
C	Coney Island	220	125	99	161	99	195
D	Hunts Point	400	70	49	59	99	107
E	Jamaica	200	10	12	68	33	87
F	Newtown Creek[1]	700	46	24	53	35	56
G	North River	340	94	101	101	185	185
H	Owls Head	240	159	105	98	85	82
I	Port Richmond [2]	120	31	27	27	37	37
J	Red Hook	120	141	136	152	146	147
K	Rockaway	90	0	0	0	0	0
L	Tallman Island	160	6	49	99	99	150
M	Wards Island [2]	550	44	35	35	74	74

[1] Actual hours for Newtown Creek is only for 2010 and 2011 when comparing to 700 MGD.

[2] Actual hours for the following WWTPs only include years in which wet weather flows were not impacted by construction at the WWTPs, that is, the averages included data from the following years:

26th Ward - 2005, 2006
Bowery Bay - 2005, 2006, 2007
Port Richmond - 2005, 2006, 2007, 2008
Wards Island - 2005, 2006

Also noted in Table 2, the IW model predictions show that, for the Owls Head WWTP, there will be a slight decrease in the frequency that 2xDDWF will be attained. This decrease is associated with the CEG components of the increased Avenue V Pump Station capacity and the new force main, which conveys peak wet weather flows toward the treatment plant more quickly under the CEG condition than the conveyance system could under pre-CEG conditions, primarily due to reduced travel time in the system. As a result, the peaks from the upstream areas may be reaching the plant slightly in advance of the prior situation, thus causing a slight reduction in the time that the plant is at the 2xDDWF level. The decrease in hours, however, is more than offset by the benefits gained by the decrease in CSO discharges to Coney Island Creek and the total increase in wet weather volume being treated at the Owls Head treatment plant under the CEG condition. As shown in **Table 3**, the annual volume of flow treated at the Owls Head WWTP increases slightly. With respect to the Tallman Island WWTP, DEP's regular cleaning of the

Flushing and Whitestone Interceptors appears to be responsible for the calculated increase in hours operating at 2xDDWF for the simulations.

Table 3: Model-Predicted Volumes of Flow Delivered to the WWTPs

Appendix	WWTP	Actual Annual Volume Treated (MG)		Total Annual Projected Volume Treated (MG)			
				2008		2011	
		2008	2011	w/o CEG	W/ CEG	w/o CEG	W/ CEG
A	26th Ward	18,384	20,110	20,056	20,163	20,186	20,350
B	Bowery Bay	38,042	43,252	47,289	47,471	47,121	47,281
C	Coney Island	30,783	34,659	34,196	38,081	33,658	37,433
D	Hunts Point	48,416	51,178	49,787	49,805	50,348	50,835
E	Jamaica	31,347	30,111	32,354	33,077	32,427	33,188
F	Newtown Creek	87,626	91,178	92,845	92,981	93,522	93,680
G	North River	46,251	46,091	49,223	49,223	50,026	50,026
H	Owls Head	35,771	35,441	38,064	38,074	37,289	37,301
I	Port Richmond	11,119	11,615	11,784	11,784	11,920	11,920
J	Red Hook	10,705	11,166	12,944	13,096	12,889	13,052
K	Rockaway	8,237	6,420	9,092	9,092	9,210	9,210
L	Tallman Island	20,672	22,476	24,038	24,301	23,686	23,902
M	Wards Island	77,857	77,353	81,358	81,358	81,961	81,961

Note: Model projections may differ somewhat from actual values for a number of reasons, such as: the model assumes uniform precipitation over the entire sewershed whereas actual values may vary significantly; the models approximate the normal operations at the plants whereas manual control may practiced frequently; various processes and influent pumping may be affected by construction projects that are not accounted for in the models.

4.0 Capacity of Conveyance System

The conveyance capacity of the interceptors and combined sewers represented in the IW models was examined. The Appendices of this Report provide an overview of the conveyance systems in each WWTP service area. The discussions that follow focus mainly on delivery of flow to the WWTP, but also provide insight into the conveyance capacity and the potential to temporarily store water within the modeled sewers in each WWTP area. In each Appendix, an IW sewer system map shows the components of the modeled conveyance system, as follows:

- piping network, with interceptors shown as solid lines;
- regulating structures, including actual regulators as well as major internal relief structures shown as green pentagons;
- pump stations, shown as blue squares while outfall terminal points are shown as blue circles;
- model nodes (manholes) shown as black circles;
- hydrologic subcatchment area boundaries, which represent the land surface components of runoff generation during wet weather, shown to the extent of illustrating the types of drainage areas included in the system according to various color codes on the maps; and
- major force mains, shown as black dashed pipe segments.

Where appropriate, the maps include an enlargement around the area of the WWTP, allowing a more detailed view of the modeled pipes leading to the WWTP. Even though the sewer lines and other features shown in the maps have been geo-referenced to the best extent possible, they may notportray the exact location of the actual sewer infrastructure. The precise geographic location of the infrastructure does not affect hydraulic calculations within the model which depend solely on physical inputs such as length, slope and size independent of their locations in space.

The sewer system maps provided in the December 30, 2010 initial submittal contained labels that identified the full pipe flow capacities in the main sewer segments. For this 2012 submittal, the sewer system components shown on the maps were updated to reflect any recent changes made to the IW models. These maps also differ from the 2010 maps in that each sewer segment represented in the model and placed on the system map is labeled with an alpha-numeric or numeric label - not the full pipe flow capacity. These labels refer directly to corresponding sewer segments provided in the detailed tabulations accompanying each map in the Appendices, in which the specific characteristics of the sewer segments are provided. These characteristics include length, width, height, and theoretical (calculated) full-pipe capacity.

The full-pipe flow capacities provided in the Appendix tables do not represent any actual operating condition, but are approximated theoretical values based on hydraulic equations similar to those used in the design of sewer systems (e.g. Manning's equation). The equations used to generate this information in the IW models were the same as those equations used by the New York City DEP Bureau of Water Sewer Operations (BWSO) in the development of drainage plans and sewer designs, with one difference. The full pipe flow was used instead of the typical maximum pipe flow used by DEP in drainage planning and sewer design. BWSO prescribes the use of full pipe flow calculations for circular or oval sewers; therefore, for these pipes, the capacities provided were exactly the same as those prescribed by BWSO. However, for pipes with flat tops, BWSO prescribes a slightly different approach, which results in the maximum flow capacity being developed. For rectangular or flat-topped sewer designs for example, BWSO calculates the flow capacity based on setting the flow depth at 95% of the pipe height, with a minimum freeboard of 3 inches. This calculation methodology provides a higher flow capacity value than provided in this report (10 to 15% higher), since this condition results in less internal friction at the water/pipe interface near the top of the pipe.

It is important to note that theoretical full pipe capacity (or maximum pipe capacity) based on Manning's equation can differ significantly from the quantity of flow that a given sewer reach is capable of conveying. Manning's equation assumes that the friction or energy slope of the flow is approximately the same as the bottom slope of the pipe or channel. It is also applicable under steady, uniform flow conditions – which rarely occur within the sewer network. In reality, the sewers often experience unsteady, non-uniform flow (e.g. they vary in both time and space) due to variation in rainfall location and intensity, changes in channel cross-section and slope, in addition to other dynamic factors. Under certain conditions, sewers surcharge (i.e. the hydraulic grade line is above the sewer crown), which causes the friction or energy slope in the Manning's equation to rise and increases the flow.

A variety of conditions and variables have an impact on when, where, and why a sewer may operate under such a surcharged condition: the unique characteristics (i.e., duration, intensity, distribution, volume, etc.) of a given rainfall event, runoff coefficients, original sewer design criterion used in the past, topography and depression storage; WWTP headworks operation; CSO regulator configuration; receiving water tides (tide gates); the depth of the sewer -particularly relevant for interceptors- and the specific configuration and connectivity of the sewers and manholes at any given location in the system. Any or all of these factors may play a role in the dynamic behavior of the City's sewer system, which can change from hour to hour during a single event, and certainly can vary from event to event. A thorough understanding of the above factors is required in order to calculate flow reaching the combined sewers at manholes, flow entering interceptor segments from each regulator, flow conveyed through interceptor segment, flow leaving via CSO, and flow reaching each WWTP.

During the development of the Waterbody/Watershed Facility Plan (WWFP) for each WWTP area and/or during sewer design projects, efforts were made to understand field conditions as well as local, specific operational controls in each system; and apply such knowledge in the development and use of detailed, calibrated, dynamic hydrologic/hydraulic models, coupled with and the application of detailed engineering calculations. An evaluation of full-pipe capacity is merely a first step in the development of any sewer system evaluation.

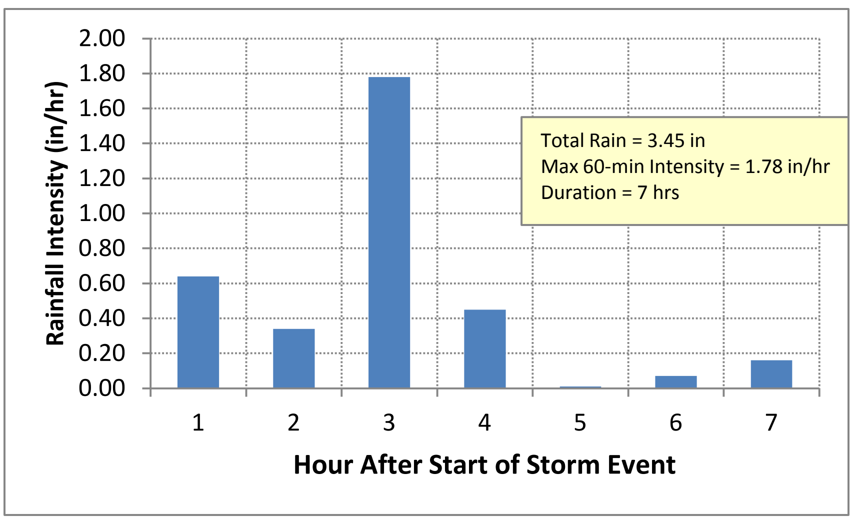
As noted above, the presence of surcharged conditions during a storm event can increase the amount of flow that passes through any point in the sewer system, specifically the interceptors. Some of the interceptors operate in surcharged conditions on a frequent basis, as is evidenced by the fact that the WWTPs that receive those interceptor flows often measure influent flow rates at 2xDDWF. The fact that these same interceptors may have full-pipe capacities that do not indicate the ability to deliver flow at the 2xDDWF rate, is indicative of the surcharged and dynamic flow conditions that can and do occur in each of the sewer systems. As such, the full-pipe flow capacities and/or maximum un-surcharged pipe flow capacities being provided in this hydraulic capacity analysis will indicate lower flow rates than those that are typically observed in the system. By contrast, the presence of surcharge conditions during a storm event can reduce the amount of flow that passes through a given point in the sewer system. As an example, high tide causes a decrease in the differential head between upstream sewers and the outfalls, which would reduce flows in the combined sewers upstream of the outfalls, possibly to levels well below full pipe capacity.

The full-pipe flow capacities provided herein sometimes show results that are not indicative of the amount of flow that can pass through an individual pipe segment for other reasons. For example, there are many locations in the collection and conveyance systems where a pipe segment was constructed with a very shallow slope. This reduced slope may have been the result of the need to pass under another utility or for a variety of other reasons. In these cases, the upstream and downstream pipe segments may present themselves with a full pipe capacity flow of “X” while the segment in question may end up with a calculated flow of 20% of “X” or even with zero flow. That in and of itself does not mean there is a hydraulic restriction, or that the pipe can only convey 20% of the flow being conveyed into it. The pipe may in fact be able to convey 100% of the flow coming into it because of the systemic nature of sewer systems. The friction or energy slope of the system as a whole is what drives flow through individual pipe sections and will therefore increase flows beyond their theoretical full-pipe values, which are based on individual pipe slope alone. The additional columns provided in the Appendix tables, which are discussed further in this section, provide a much better estimate of the actual pipe flow capacity for these types of situations.

In each of the Appendices, tables are provided showing pipe/conduit dimensions and pipe/conduit capacities sorted into interceptors and major combined sewer trunks/branches, to facilitate referencing. The IW model networks are complex and interconnected, and thus the sorting of the data into continuous segments from upstream to downstream, with all of the various combined sewer segments along the way, is not practical. Thus, within the groups of interceptors and major branches listed in the table, the sewer segments have been sorted alphanumerically. This provides some ease with which to refer to the tables for detailed information pertaining to a sewer segment when viewing the map.

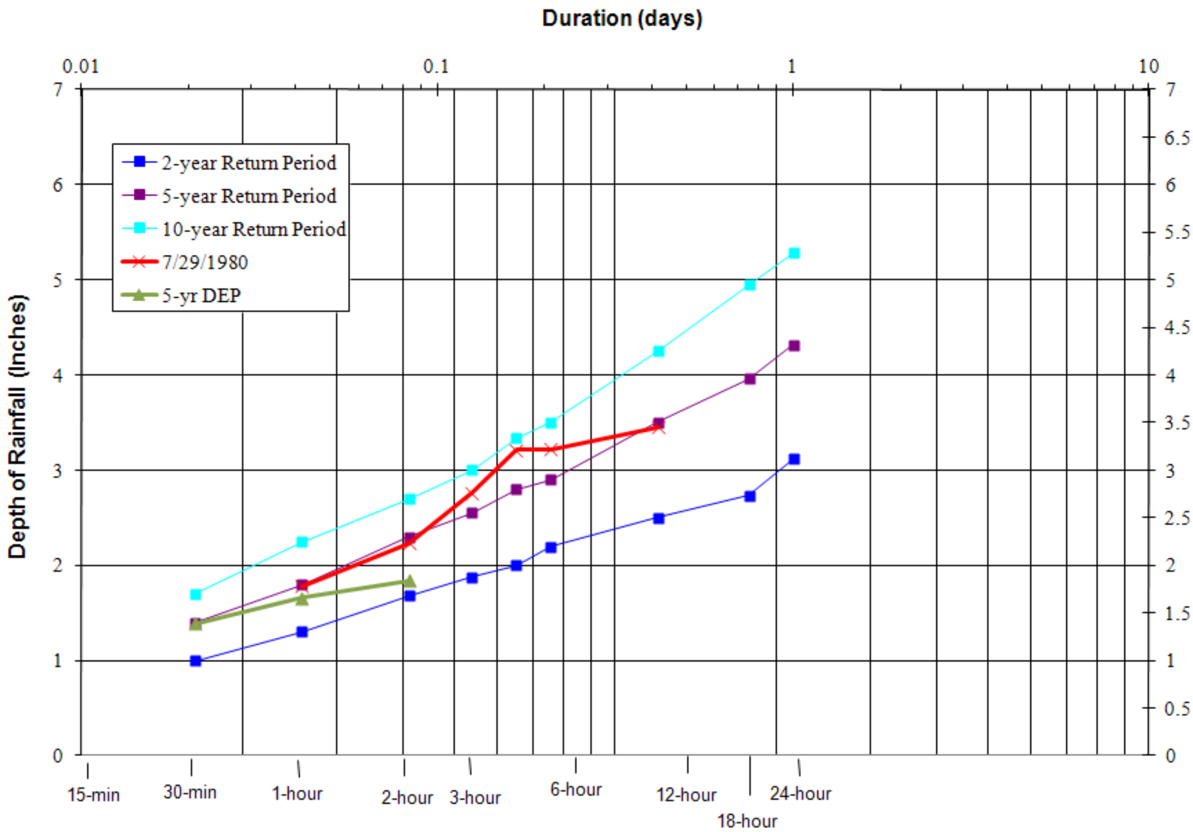
In addition to the physical characteristic data and full pipe flows presented in the tables for each sewer segment, additional columns include the peak flows that are predicted to occur in each conduit during a single, historical wet weather event. For this analysis, a real storm was selected to simulate the runoff entering the conveyance system. The selected storm had characteristics that were found to approximate a 5-year return frequency with respect to maximum 1-hourly, 2-hour, etc., intensities. The storm event selected for this particular analysis was the storm event of July 29, 1980. **Figure 1** provides a summary of the hourly rainfall for this event. This event contained a total volume of 3.45 inches of rain, had a peak intensity of 1.78 in/hr, and duration of 7 hours.

Figure 1: Single-Event Storm - July 29, 1980



The one hour, 2-hour, 3-hour, etc., average rainfall intensities for this June 1980 event are compared to the rainfall intensities with 2-year and 5-year recurrence intervals on **Figure 2**. As noted this June event closely tracks the properties of all the average intensities that have a 5-year recurrence frequency, with the exception of the 4- and 5-hour average intensities that appear to track those less frequently occurring.

Figure 2: Rainfall Intensities for 2- and 5-year Recurrence Intervals



It should be noted that DEP currently designs its sewers to convey runoff from events with intensities that have a return frequency that approximates a 5-year return period. Using, the DEP 5-year rainfall intensity equation noted below, the 60-minute intensity would be 1.67 inches per hour:

$$I \;=\; 125 / (T + 15)$$

Where: "I" is the rainfall in inches per hour and

"T" is the time in hours.

Two scenarios were simulated using this actual storm; each representing differing conditions for the WWTP conveyance systems.

- Scenario 1 (S-1): Post-cleaning interceptor sediments and no combined sewer sediments
- Scenario 2 (S-2) Post-cleaning interceptor sediments and no combined sewer sediments with CEG controls

The model-predicted peak flow rates are presented for each of the scenarios simulated. An indication is also provided of whether the resulting peak flow rates for each scenario resulted in a flow greater than ("Y") or less than ("N"), the full-pipe peak flow rate for that sewer segment. The predicted peak flow rates when compared to the full-pipe flow rate for each sewer segment provide a better understanding of the potential for sewers to be surcharged throughout the system and what impact the surcharge has on the ability to convey flow. These analyses were conducted using the 2040 DWFs. These simulations were also examined to determine which pipe conduits within the model were flowing full; and if not, to assess the fraction of water depth (i.e., percent full) within the pipe during the event. These portions of the conduits occupied by water would not be available for inducing any in-line storage now or in the future, since those portions of the pipes must remain free to carry the flow toward the treatment plants.

Comparison of peak flow rates in the various sewer segments under the storm condition, with the full-pipe flow capacity of the sewer segments, sheds some light on how well the system is able to convey flows beyond just the full-pipe flow. In addition, these results were used to examine the ability of the interceptor systems and regulators to deliver at least 2xDDWF to the plants and under what hydraulic conditions.

5.0 Capacity to Deliver 2xDDWF

Table 4 summarizes the interceptor segments that feed directly into each WWTP. The information provided in the table is taken directly from much larger tables provided within each Appendix. Shown in the table are the full-pipe flow capacities of these key conduits, as well as the maximum flows that are predicted to be conveyed by the conduits during the June 1980 storm event simulations for the current condition (S-1) and for the CEG conditions (S-2). The table also contrasts these predicted flows to the requirements of the SPDES that generally indicated that the conveyance systems should be capable of conveying 2xDDWF.

As noted in this table, some of the pipe conduits (Hunts Point, Jamaica, Wards Island, Coney Island and Tallman Island) are calculated to have a full-pipe flow capacity less than that required to convey 2xDDWF to the WWTP. However as shown in the table, the results of the model simulations for both existing and CEG conditions indicate that these conduits, for the June 1980 rainfall event, actually convey 2xDDWF. The reason for these changes is related to the fact that the WWTP regulators are allowing more than 2xDDWF into the interceptors. This action adds head to the upstream ends of the system and thereby effectively increasing the slope of the hydraulic gradeline; i.e. water surface. Effectively, the water surfaces at the upstream portions of the system are elevated above the crowns of the conduits where in contrast the full-pipe flow calculation assumes the slope of the water surface to be parallel to the crown of the pipes.

Regarding Wards Island, the two conduits from which the 495 MGD influent capacity was obtained are actually the deep siphons that enter the wet well at the plant. The full-pipe capacity shown in the link table is, of course, what the capacity would be if they were not under a surcharged condition. But because these links represent siphons, they are always under surcharge. No other conduits have been modeled that are upstream of the siphons and downstream of the Manhattan and Bronx Grit Chambers.

Table 4: Comparison of Peak Flows Delivered to each WWTP

	IW Model results			SPDES Permit Requirements		IW Model Results		
		S-1	S-2				S-1	S-2
WWTP	Full Pipe Flow (MGD)	Max Flow (MGD)	Max Flow (MGD)	DDWF (MGD)	Multiple of 2xDDWF	Full Pipe Flow (MGD) multiple of 2xDDWF	Max Flow (MGD) multiple of 2xDDWF	Max Flow (MGD) multiple of 2xDDWF
Hunts Point	244	408	413	200	2.0	**0.61**	**1.02**	**1.03**
26th Ward	215	192	192	85	2.0	**1.27**	**1.13**	**1.13**
Jamaica	178	218	220	100	2.0	**0.89**	**1.09**	**1.10**
Wards Island	495	663	668	275	2.0	**0.90**	**1.20**	**1.21**
Coney Island [1]	157	181	195	110	2.0	**0.85**	**0.96**	**1.02**
Owls Head	303	321	313	120	2.0	**1.26**	**1.34**	**1.31**
Newtown Creek	688	783	785	310	2.25	**0.98**	**1.12**	**1.12**
Port Richmond	178	133	135	60	2.0	**1.48**	**1.11**	**1.12**
North River	601	348	348	170	2.0	**1.77**	**1.02**	**1.02**
Red Hook	264	207	190	60	2.0	**2.20**	**1.73**	**1.58**
Tallman Island	131	165	182	80	2.0	**0.82**	**1.03**	**1.14**
Bowery Bay	242	293	300	150	2.0	**0.81**	**0.98**	**1.00**

The Coney Island full-pipe flow rates and peak flow rates shown in the table are based only on the CSO sewer system contribution and do not include the separately sewered area influent pipe capacity. For the simulations conducted for the hydraulic analysis, a separately sewered flow rate of 30 MGD was applied as a point load to the plant. For computing the IW model results ratios, therefore, 30 MGD was added to the CSO peak flow rates modeled to arrive at the multiples of 2xDDWF.

For Newtown Creek, the 688 MGD full-pipe flow noted in the table represents the combined interceptor capacities of the Newtown Creek Brooklyn and Newtown Creek Manhattan interceptors. The peak flow rate totals shown for the IW simulations (783 and 785 MGD) represent the sum of the capacities of the north and south interceptors approaching the Manhattan Pump Station (MPS) plus the capacity of the Brooklyn influent sewer to the Brooklyn Pump Station (BPS). Each of the MPS and BPS has the capacity to pump 400 MGD, yielding some flexibility for how much flow can be delivered to the plant under varying storm event conditions. For the model simulations conducted for this hydraulic analysis, the BPS was assigned a maximum capacity of 400 MGD and the MPS was assigned a maximum capacity of 300 MGD, with the resulting maximum flow to the plant of about 700 MGD.

6.0 Capacity for In-System Interceptor Storage

The ability of ***interceptors*** to store additional water within them was examined through the evaluation of the IW model outputs for the two simulation conditions. **Table 5** provides a summary for each WWTP sewershed, the portion of the interceptors in the IW models that are predicted by the models to flow with water up to the crown (100%) or up to 75% of the crown. As shown in this table, the interceptors to all WWTPs with the exception of the Port Richmond interceptor flow full for greater than 94% of their length, with most flowing full for 100% of their length. This is a clear indication that the interceptors are currently either using their full depth for conveyance or for a combination of conveyance and in-system storage. As such, there would not be any additional CSO reduction benefit that could be obtained through further use of interceptors for storage of combined sewage during storm events.

Table 5: Summary of Pipe Storage Utilization

Sewershed		Interceptor				Combined Sewers			
		S1 - 100%	S1-75%	S2 - 100%	S2-75%	S1 - 100%	S1-75%	S2 - 100%	S2-75%
26th Ward		100.0%	100.0%	100.0%	100.0%	64.1%	72.6%	62.6%	72.5%
Bowery Bay[1]	HLI	100.0%	100.0%	100.0%	100.0%	56.0%	69.8%	60.4%	70.7%
	LLI	100.0%	100.0%	100.0%	100.0%	67.8%	76.4%	85.1%	89.9%
Coney Island		100.0%	100.0%	100.0%	100.0%	92.5%	96.6%	95.0%	96.7%
Hunts Point		94.3%	100.0%	94.1%	98.4%	53.5%	76.3%	55.2%	76.4%
Jamaica		95.5%	99.1%	93.1%	99.2%	74.3%	85.9%	74.7%	85.0%
Newtown Creek	BPS	100.0%	100.0%	100.0%	100.0%	43.0%	55.9%	45.2%	56.5%
	MPS	100.0%	100.0%	100.0%	100.0%	81.8%	90.9%	81.8%	90.9%
North River		100.0%	100.0%	100.0%	100.0%	71.0%	81.7%	71.0%	81.7%
Owls Head		100.0%	100.0%	100.0%	100.0%	76.1%	83.6%	78.9%	85.2%
Port Richmond		70.3%	81.4%	70.3%	81.4%	60.7%	65.5%	60.7%	65.5%
RH		100.0%	100.0%	100.0%	100.0%	55.3%	77.1%	70.3%	79.8%
Tallman Island		78.1%	90.4%	93.0%	99.7%	56.5%	72.0%	58.8%	71.7%
Wards Island		99.1%	100.0%	99.1%	100.0%	65.4%	81.6%	65.4%	81.6%

Notes: 1 - HLI is the high level interceptor side of the system and LLI is the low level interceptor side of the system
2 – BPS is the Brooklyn Pump Station side of the system and MPS is the Manhattan Pump Station side of the system

7.0 Capacity for In-System Combined Sewer Storage

The ability of ***combined sewers*** to store additional water within them was examined through the evaluation of the IW model outputs for the two simulation conditions. Table 5 also provides a summary for each WWTP sewershed, of the portion of the combined sewers in the IW models that are predicted to flow with water depths up to the crown (full pipe). As shown in this table, the combined sewers in all WWTP service areas, with the exception of the Coney Island sewershed, do not flow full for their entire length. This is an indication that some combined sewers, which flow less than 100% full depth, could potentially have some excess capacity that could be used for in-system storage. Many of the combined sewers that exhibit a depth of flow less than full are located far up in the system, away from the interceptors, and generally smaller than 60 inches in height.

Utilization of any storage in these conduits can involve numerous distributed inline controls that can be extremely challenging from a system operations standpoint and can increase the potential for upstream flooding. Thus, the potential for significant availability of in-line storage volume is likely to be limited.

However, where the combined sewers are located immediately upstream from regulators, the partially-filled pipes could provide opportunities for employing CSO control technologies, such as raising weirs, using bending weirs, and using real-time control (RTC) control systems (e.g., inflatable dams or outfall/combined sewer gates). The DEP will use the information generated herein to further evaluate these opportunities during the development of the Long Term CSO Control Plans and ensure such modifications don’t cause upstream flooding.