PennPraxis

Project Name: Developing PWSA's Strategic Plan for Stormwater

Project No.: 2020-025-OPS

ACTION 4: Level of Service Recommendations

March 18, 2022

Introduction

One of the key elements of the PWSA Stormwater Strategic Plan for the city of Pittsburgh is outlining an appropriate Level of Service for the stormwater program. At its core, Level of Service sets a standard for the performance of the stormwater system with respect to such issues as water quality and flood conveyance, and by extension, the capital and operational investments needed to attain this level of performance. Level of Service integrates both regulatory obligations (e.g., reducing combined sewer overflows, achieving required pollutant load reductions in MS4 areas) and aspirational goals (e.g., preventing flooding) that relate to sustainability or public health objectives. Various levels of service are associated with different costs of service, so the selection of an appropriate Level of Service depends not only on what is physically feasible or desirable, but on the ability of PWSA (and city partners) to pay for system upgrades and maintenance.

Peer City Level of Service Review

Building on the Task 2 deliverable, which articulated broad principles around Level of Service policy development, the team has conducted a review of Level of Service policies and related design criteria for several peer cities. Briefly, the team reviewed Level of Service and related policies for 13 peer cities, including Atlanta, Cincinnati, Cleveland, Milwaukee, and Philadelphia. For each community, the team reviewed pertinent policies to understand sizing requirements (i.e., design storm events) for combined sewer and separate sewershed areas, as well as for stream channels and floodplains. Although design standards and approaches varied considerably, a few important trends and best practices emerged from the review:

- Although there were exceptions, design standards in combined sewer areas (typically older areas) tended to target smaller events than did corresponding policies in separate sewer areas. Several communities based their design requirements for combined sewers on a 5-year recurrence interval, while requirements in separate sewershed areas tended to be based on a 10- or 25-year recurrence interval event.

- New York City was notable for the use of a short duration "cloudburst" event in determining design standards for combined sewers. This could be an interesting model for incorporating higher levels of performance within combined sewer areas.
- Both Cleveland and Philadelphia established policies that allowed flexibility at the individual project level. While minimum standards are important, incorporating a flexible policy that recognizes both opportunities and constraints at the local scale could be an important point of emphasis for Pittsburgh.
- Greenville, South Carolina established both strategic and tactical Level of Service policies. The strategic Level of Service policy expressed overall program goals, while the tactical level of service focused on specific targets for individual asset types. This model provided a useful precedent for thinking about the relationship between the performance of PWSA's sewer system and larger City-wide infrastructure protection goals.
- Greenville's policy included an interim or short-term Level of Service goals, as well as long-term or ultimate Level of Service targets. This approach could be important for PWSA in building and maintaining public support by attaining significant improvements in Level of Service within priority areas over a short period of time, even as more ambitious longer-term investments are planned.
- PennDOT used a roadway classification-based Level of Service policy that provided more stringent design standards for certain types of roadways such as emergency routes, while using less stringent standards for other roadway types. This approach provides a potentially useful framework for organizing Level of Service policies in Pittsburgh, as is discussed below.

The results of the peer-city research are further summarized in Appendix 1.

Overview: Level of Service Recommendations

Building on peer-city work, the team has developed the following recommendations for the development of Level of Service policies for Pittsburgh. Additional insight into each recommendation is provided in the paragraphs below.

- **Establish distinct but related Level of Service policies for 1) flooding of surface infrastructure (City) and 2) performance of the PWSA sewer system.** Level of Service relating to how frequently surface flooding occurs should be established as a broad-based City-wide policy, with connections to a more narrowly focused and separate Level of Service policy for PWSA conveyance infrastructure.

- **Work with City-agencies via the Joint Task Force to establish roadway classification-based standard for surface flooding.** PWSA can and should play a leadership role in working with the city-wide Joint Task Force (JTF) to establish a City-

wide Level of Service policy for surface flooding. Classification systems that establish Level of Service by roadway classification are suggested as a framework for this policy.

- **Develop a Level of Service policy for PWSA infrastructure that balances affordability and public responsibility.** PWSA should seek a balanced approach to Level of Service that improves capacity over time, effectively balancing affordability and public responsibility, starting with priority sheds. PWSA should avoid using a "stand pat" approach that maintains the existing system over time and thus fails to provide enhanced levels of flood control, and also an aggressive approach that envisions a much higher Level of Service at the expense of affordability.

- **Focus modeling efforts and condition assessment efforts on priority sheds to identify capacity issues and identify root causes.** Detailed hydraulic modeling of PWSA's existing system and updated condition assessments will be critical to understanding where the system is capacity limited and what root causes are responsible. Ultimately this level of detailed analysis is needed to understand what Level of Service can be achieved given available resources. This work should begin with priority sheds, where resources are needed most.

- **Clearly and transparently communicate with the public around Level of Service issues as part of an integrated communications strategy for stormwater.** Level of Service can be a difficult issue to communicate with the public since it involves a technical understanding of sewer and infrastructure performance and challenging conversations around affordability. Clear and transparent communication is needed to build public trust and set expectations. Communications around Level of Service should clearly articulate the important tradeoffs between the level of performance stormwater infrastructure is able to provide and the available resources needed to upgrade the system. Communications should emphasize that meaningful increases in Level of Service are a whole-of-government responsibility that require generational investments in both stormwater and roadway infrastructure. Communications should also emphasize that the Level of Service that can be achieved is also limited by affordability concerns and specifically the need to limit increases to the stormwater fee. PWSA's goal is to leverage external funding such as FEMA BRIC and State Revolving Funds, which will help achieve a higher Level of Service while limiting rate increases. This recommendation will be further developed as part of the Communication Framework developed under Action 5.

Detailed Level of Service Recommendations for Pittsburgh

Establish distinct but related Level of Service policies for 1) flooding of surface infrastructure (City of Pittsburgh) and 2) performance of the sewer system (PWSA)

Level of Service is a broad and potentially misleading term that can encompass a wide array of performance objectives relating to stormwater infrastructure. For instance, some Level of Service policies may set a performance objective with respect to the conveyance capacity of the storm sewer network, while other policies may refer to Level of Service with respect to the frequency that surface infrastructure assets such as roadways. PWSA should establish a Level of Service policy that relates specifically to the infrastructure that it owns and operates, namely, the combined and separate storm sewer system. With respect to flooding in particular, this Level of Service policy should be then linked to and informed by a separate City-wide Level of Service policy that stipulates acceptable flood frequency/duration/depth for surface infrastructure such as roadways, buildings, parks, etc. Importantly, attainment of the target Level of Service for the sewer system does not allow the city to attain a particular Level of Service for surface flooding. Attaining a surface flooding Level of Service may require a host of other infrastructure investments relating to roadways, bridges, buildings, floodplains and other City-assets.

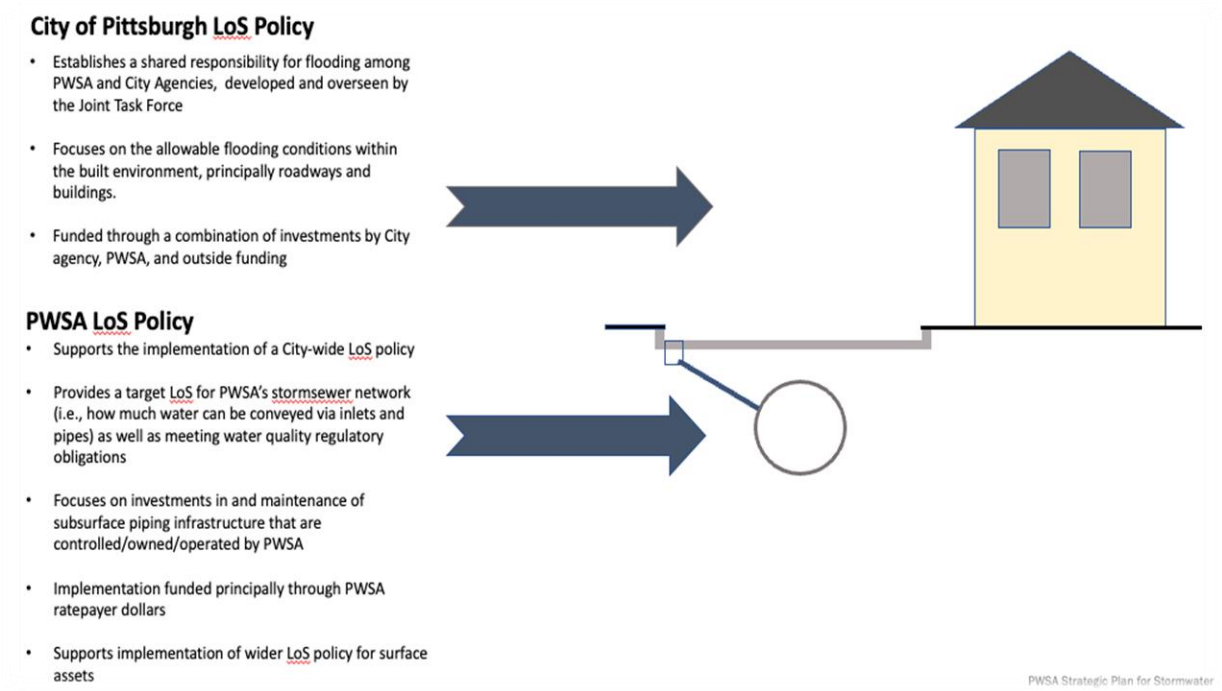

Figure 1. *Conceptual relationships between PWSA-specific and City-wide Level of Service policies*

Work with City-agencies via the Joint Task Force (JTF) to establish roadway classification-based standard for surface flooding

As described above, establishing and ultimately attaining a City-wide Level of Service policy for surface flooding is a whole-of-government responsibility that relies on a suite of related investments in sewer, roadway, and building infrastructure. Given the inherently cross-agency nature of this work, we see the development of this policy as best developed by the Stormwater/Flooding JTF proposed as Action 6 of the Stormwater Strategic Plan. Placing the City-wide Level of Service work in the hands of the JTF will help to ensure that surface flooding is viewed as a whole-of-government issue, rather than solely a PWSA problem. The Level of Service should directly influence and be influenced by capital and operational budgets for a range of city departments that will be involved in attaining the Level of Service, including City Planning, DOMI, Public Works, Parks etc. The JTF provides the most appropriate venue for this work. In fact, Level of Service policy development would provide a clear initial set of tasks for the JTF that would encourage a collective planning approach.

Although there are many conceptual frameworks around which to build a city-wide Level of Service for flooding, a roadway-based classification such as shown in Figure 2, seems the most useful and intuitive. Such a system establishes a target Level of Service (usually a particular depth and duration of flooding for a given recurrence interval event) for various roadway classifications. These classifications would range from roadways in which no street flooding would be allowed (Type A) for a particular flood, to roadways that act as intentional conveyance during a particular event (e.g., as with a cloudburst-type approach) (Type D). Figures 3a, b, and c. provide examples of roadway-based Level of Service schemes that have been implemented by other jurisdictions. These include PennDOT, whose Level of Service roadway classifications may provide a good starting point for locally-owned roadways in Pittsburgh.

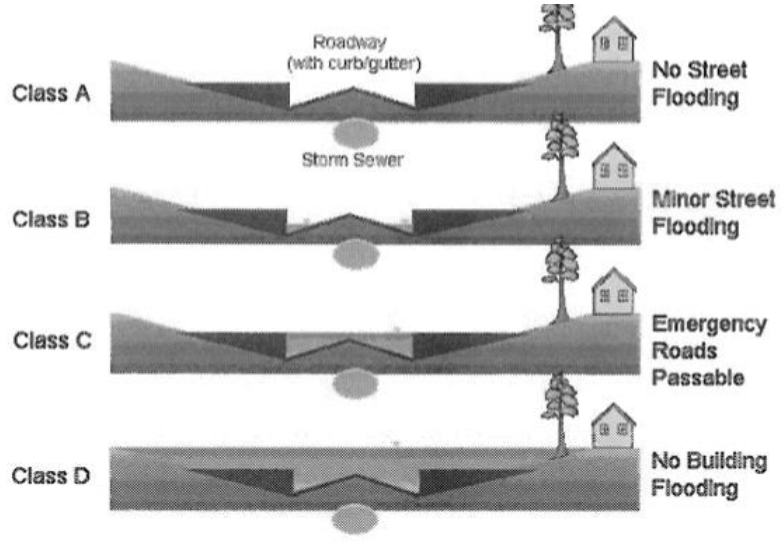

Figure 2. *Conceptual illustration of a roadway classification-based Level of Service framework.*

Gregory, M.M.F. Schmidt and Aldrich. 2003. "Level of Service Evaluations for Stormwater Assessments." *Journal of Water Management Modeling* R215-04.

A

Level of Service Category		Maximum Allowable Flooding Depths		
Category	Description	10-y/1-h event	25-y/24-h event	100-y/24-h event
A2	two-lane arterial	0 ft above inlet	no building flooding	no building flooding
A4	four-lane arterial	0.25 ft above inlet	no building flooding	no building flooding
A4/E	four-lane arterial/ emergency	0.25 ft above inlet	0.25 ft below crown	no building flooding
C2	two-lane collector	0 ft above inlet	no building flooding	no building flooding
C2/E	two-lane collector/ emergency	0 ft above inlet	0.25 ft below crown	no building flooding
C4	four-lane collector	0.25 ft above inlet	no building flooding	no building flooding
C4/E	four-lane collector/ emergency	0.25 ft above inlet	0.25 ft below crown	no building flooding
O	open channel	0 ft above top of bank	no building flooding	no building flooding
R	residential route	0.75 ft above inlet	no building flooding	no building flooding

B

DESIGN FLOOD SELECTION GUIDELINES

FUNCTIONAL CLASSIFICATION	MAXIMUM EXCEEDANCE PROBABILITY (%)	MINIMUM RETURN PERIOD (YEARS)
Interstate and Limited Access Highways	2	50
Principal Arterial System	2	50
Minor Arterial System	4	25
Rural Collector System, Major	4	25
Other Collector Systems	10	10
Local Road and Street Systems	10	10

C

Roadway Classification / Use	Design Storm	Flooding Depth
Emergency Access Routes	10-Year	8.0 ft Maximum Gutter Spread
Collector Roads	10-Year	8.0 ft Maximum Gutter Spread
Local Roads	10-Year	8.0 ft Lane Width Open
Roads with No Other Outlet	10-Year	8.0 ft Lane Width Open
Parking Lots (with a check of the 100-year storm flooding depth and maximum 1-foot depth)	10-Year	Maximum 0.5 ft Depth
Detention Areas utilized for other purposes with general public access (i.e. parking lot detention, etc.) with flood warning sign	10-Year	Maximum 1.5 ft Depth
Material Storage Areas / Landscape Areas with flood warning sign if area is utilized by the public (with a check of the 100-year storm flooding depth)	10-Year	Maximum 2.0 ft Depth

Figure 3. *Examples of roadway classification-based Level of Service policies from St. Petersburg, FL (A), Albany, NY (B), and PennDOT (C)*

Develop a Level of Service policy for PWSA infrastructure that balances affordability and public responsibility

A thoughtful Level of Service policy for PWSA infrastructure acknowledges PWSA's responsibilities to rate payers and the public as well as limitations on infrastructure spending imposed by affordability concerns, specifically the need to keep the stormwater fee affordable for all city residents. Within this framework, a wide range of potential Level of Service targets are possible (see Figure 4). At the low end, a baseline Level of Service target could consist of investments needed to 1) meet regulatory obligations for CSO and MS4, and 2) maintain the existing Level of Service for PWSA's conveyance and storage infrastructure, including maintenance and in-kind replacement.

A moderate Level of Service policy option would add to the baseline option investment in system upgrades in priority sheds to bring the system to provide conveyance for 5-year, 25-hour event (for combined sewer), 10-year, 24-hour event (for separate sewer) conveyance, and 100-year, 24-hour storm for floodplains, plus targeted investments in enhanced maintenance, backflow valves, buyouts, and other local flood mitigation measures.

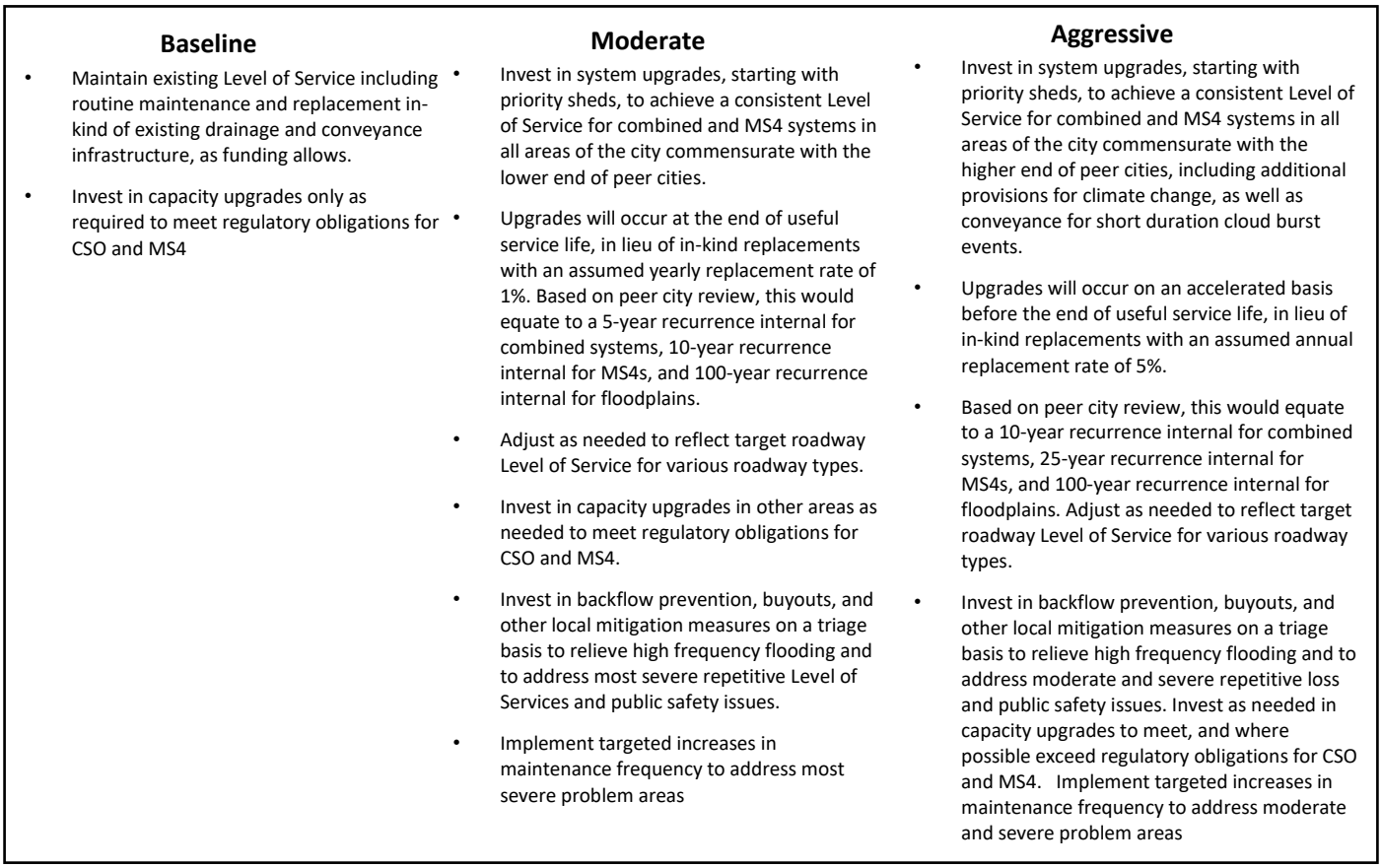

***Figure 4**. Potential baseline, moderate, and aggressive Level of Service policy options for PWSA infrastructure.*

More aggressive Level of Service policy options would invest in strategic upgrades to achieve a Level of Service commensurate with the higher end of peer-city range in all areas of the city (i.e., not just priority sheds), additional conveyance for short duration cloudburst events, and a more rapid replacement schedule.

In terms of homing in on a preferred policy option, it is likely that the Baseline option presented in Figure 4, while the most affordable, would present an unacceptable level of system performance particularly in terms of flood mitigation. On the other end of the spectrum, the Aggressive option, while providing superior levels of flood protection would likely represent an unaffordable target, even with substantial increases in the stormwater fee and significant external funding. The moderate option provides the best balance between affordability and performance, allowing PWSA to achieve a Level of Service in line with peer-cities while recognizing the limits of its financial resources.

Focus modeling and condition assessment efforts on priority sheds to identify capacity issues and identify root causes

Regardless of the Level of Service policy option selected, the development of a final Level of Service policy will need to be strongly informed by the detailed hydraulic and hydrologic (H&H) model that PWSA's Wet Weather Team is currently developing, in concert with condition assessments of PWSA infrastructure. This modeling will allow for a more precise understanding of the gap between the existing Level of Service and various Level of Service targets as well as root cause analysis through which PWSA can identify and evaluate the alternatives needed to attain a particular target Level of Service, and the associated investment level (Figure 5). The team recommends that these modeling efforts focus initially on priority sheds with documented capacity issues (as defined in this plan). Additional recommendations for modeling efforts to support Level of Service policy development include:

- Modeling collection and conveyance system at a level of detail needed to understand and predict overland flooding for a variety of events.
- Pairing modeling efforts with field inspections to identify maintenance and condition issues.
- Aggressively incorporating model calibration and verification via monitoring data, surveyed high water marks, etc.to ensure maximum model reliability
- Using modelling results to triage near term sewer capacity upgrades/watershed storage projects
- When interpreting model results to identify needed system upgrades, incorporating allowances for dry weather sanitary flow peaking factors and in-system surcharging in areas where deep sewers and high basement elevations exist.
- In combination with model results, using PWSA sewer system mapping and conservative estimates of adjacent basement elevations to determine potential locations of allowable system surcharge areas.

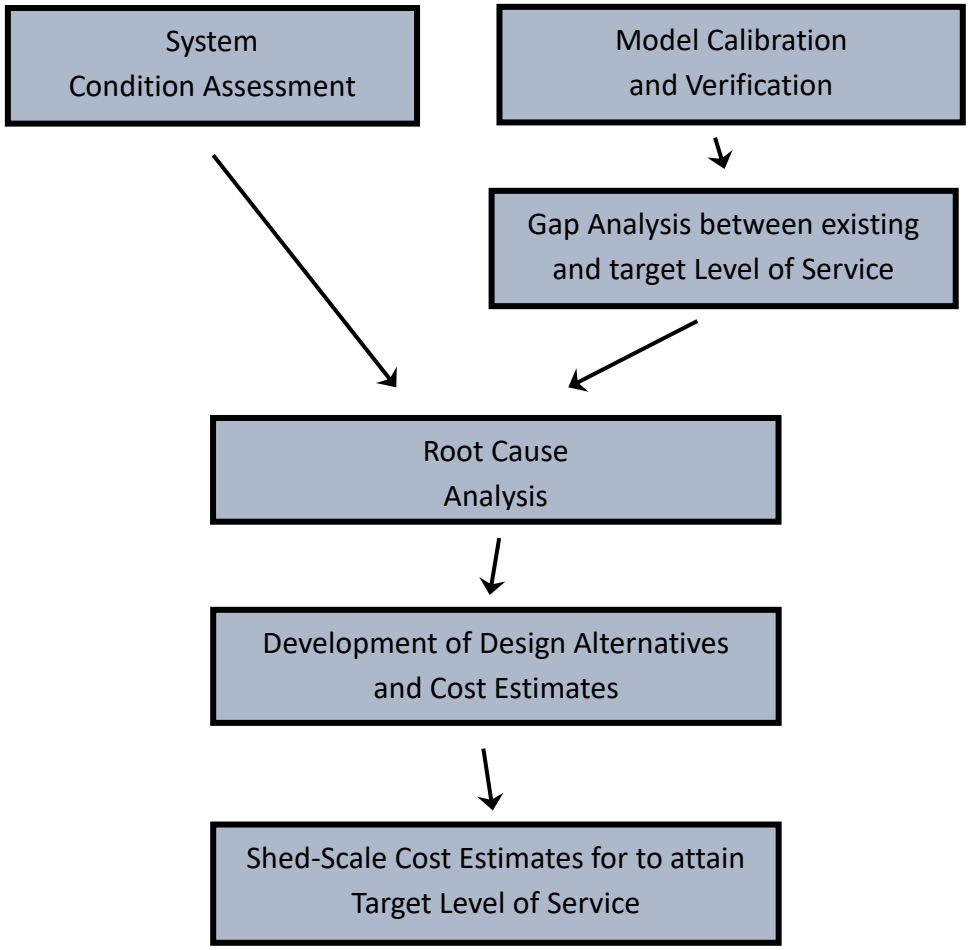

Figure 5. *Conceptual framework for evaluation of sewer capacity and flood mitigation projects in priority sheds.*

Clearly and transparently communicate with the public around Level of Service issues as part of an integrated communications strategy for stormwater.

Level of Service can be a difficult issue to communicate with the public since it involves a technical understanding of sewer and infrastructure performance and challenging conversations around affordability. The strategies below will help to share the conversation around Level of Service in ways that build public support and understanding while calibrating expectations.

Emphasize tradeoffs between Level of Service and affordability.
Integrating with PWSA's Outreach Plan for stormwater, communications around Level of Service should clearly articulate the important tradeoffs between the level of performance stormwater infrastructure is able to provide and the available resources needed to upgrade the system. Communications should also emphasize that the Level of Service that can be achieved is also limited by affordability concerns and specifically the need to limit increases to the stormwater fee. PWSA's goal is to leverage external funding such as FEMA BRIC and State Revolving Funds, which will help achieve a higher Level of Service while limiting rate increases.

Clearly explain the Level of Service issue as whole-of-government responsibility.
Communications should emphasize that meaningful increases in Level of Service are a whole-of-government responsibility that require generational investments in both stormwater and roadway infrastructure. Communication should include clearly explaining the relationships between the Level of Service for the PWSA sewer system and the City-wide Level of Service for surface infrastructure (as discussed above). Also important is the idea that, given PWSA's financial challenges and funding gaps, significant improvements to existing Level of Service will require a sustained effort over a long period of time and that, in the interim, investments will be strategically targeted where they are needed most. This targeting will ensure that the most vulnerable populations experiencing the most severe flooding and water quality problems are prioritized for investments in system upgrades.

Clearly explain the rationale for developing the Level of Service.
Transparency can help build the public's trust, so clearly explaining how the Level of Service for PWSA assets is being developed is key to bringing the public along. Specifically, the use of peer-city benchmarking helps the public understand PWSA's commitment to understanding and aligning with the current standard of practice. Investments in modeling, affordability studies, priority shed development and other components that support the Level of Service policy should be clearly explained so that the public understands the level of analysis and thoughtfulness underlying the policy.

Use accessible language.
The term Level of Service is challenging for the public (and some technical audiences) to understand. Conservations around Level of Service with the public and outside stakeholders would best be communicated using simple language that discusses the issue in terms of, for instance, "the amount of water that can be carried by PWSA's sewers" or "how often sewers back up and flood roadways". Similarly, the idea that

different types of roadways less suited to temporary flooding (like emergency routes) is an easy-to-understand concept that helps the public understand the drawbacks of a one-size-fits-all policy. The use of graphics, visualizations, and examples should be emphasized wherever possible. This can help to convey nuance around issues of flooding – for instance, how flood depth can vary across a roadway. Also, avoiding the use of technical terms and jargon (like "recurrence interval" or "conveyance", for instance) helps share the core ideas with the public in ways that are accessible to audiences of varied backgrounds.

This recommendation will be further developed as part of the Communication Framework developed under Action 5.

Appendix 1:Peer City Review of Level of Service Policies.

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Memorandum

To:	Ellen Neisis, PennPraxis and Shandor Szalay, University of Pennsylvania Water Center
From:	AKRF, Inc.
Date:	January 24, 2022
Re:	PWSA Strategic Plan for Stormwater Peer Cities Level of Service Review

As part of the Pittsburgh Water and Sewer Authority (PWSA) Strategic Plan for Stormwater, AKRF conducted a stormwater level of service peer city review of several major cities and related stormwater agencies primarily located in the eastern and mid-western portions of the United States. For this study, "level of service" is defined as the exceedance probability design storm rain event (i.e. the 10% annual chance rain event or 10-year storm) in which stormwater infrastructure is designed as part of public capital improvement projects. For this research, level of service for various types of stormwater conveyance infrastructure were researched and separated into the following types:

- Combined sewer systems (CSS) for combination stormwater and sanitary conveyance
- Municipal Separate Storm Sewer Systems (MS4) for separate stormwater conveyance
- Streams, open channels, and floodplain conveyance

The locations chosen for peer city review were based on several factors of which include: AKRF's direct working experience in the city, prevalence of mixed CSS/MS4 systems, focus on Pennsylvania communities for on-going PWSA/Public Utility Commission discussions, and similar geography/rainfall climate as appropriate. For each city, public capital improvement stormwater design regulations/design guidance manuals and wet weather consent order agreements were primarily reviewed. Private development design manuals were generally not reviewed as these guidelines do not always align with design objectives associated with government agencies. The findings of the peer city review are summarized in Table 1. Document reference sources with corresponding page numbers are provided in Attachment A.

Table 1. Level of Service Design Goals

City/Agency	Combined Sewers	MS4	Streams, Channels, and Floodplains
Atlanta, GA (GA SW Design Manual)	Not Found	Evaluate both 10-year, 24-hour (minimum) and 25-year, 24-hour (maximum)[1]	25-year, 24-hour (roadside open channels)[2]
Camden, NJ	LOS design goals pending. Street Flooding Mitigation Plan written into Camden County Municipal Utilities Authority 2020 Consent Order with EPA. Consent order requires to "Identify design standards and best practices for flooding mitigation for use on public and private redevelopment projects."[3]		
Cincinnati, OH (MSD)	Backflow valve program based on 5-year event (see discussion)	10-year[5]	100-year (major stream channels)[6]
Cleveland, OH (NEORSD)	5-year, 6-hour with HGL remaining 10 feet below rim within NEORSD's interceptor system.[7]	No NEORSD guidelines on local stormwater piping conveyance. Use best engineering judgement.[8]	100-year (floodplains)[9]
Greenville, SC (MS4 System Only)	N/A	10-year (everywhere) 25-year (collector and arterial roads) 500-year (critical facilities)[10]	Not Found
Harrisburg, PA	25-year[11]	25-year[11]	25-year (natural or manmade channels or swales)[11]
Lancaster, PA	Not Found	25-year, 24-hour[12]	Not Found
Milwaukee, WI (MMSD)	5-year[13]	Not Found	Not Found
New York City, NY (NYCDEP)	5-year, 6-minute[14]	Not Found	Not Found
PennDOT	Based on road classification (see discussion)		
Philadelphia, PA (PWD)	Not disclosed. Determined internally by PWD Planning Unit based on watershed specific analysis.[15]	Not disclosed. Determined internally by PWD Planning Unit based on watershed specific analysis.[15]	Not Found
Raleigh, NC (MS4 System Only)	N/A	10-year[16]	2 feet of freeboard in the 10-year in stream channel, 100-year storm in for floodplain[17]
Richmond, VA	Not Found	10-year[18]	2-year (stream channel)[19]

Table 1. Level of Service Design Goals

City/Agency	Combined Sewers	MS4	Streams, Channels, and Floodplains
Toledo, OH	Not Found	5-year design for pipe full and confirm 10-year HGL is below grade[20]	Not Found
Washington, DC (DC Water)	15-year, 24-hour[21]	15-year, 24-hour[22]	Not Found

Discussion of Results and Key Findings

Level of Service for Combined Systems

In general, level of service design goals for combined system communities are difficult to obtain within publicly available documents. For many the cities researched (including cities not on the above list that were researched such as Boston, Buffalo, and Chicago), combined system level of service goals were not found or not publicly disclosed. Key findings are summarized below for select cities.

- **Cleveland Ohio Northeast Ohio Regional Sewer District (NEORSD)**

  NEORSD combined system level of service goals are outlined in their Hydrologic and Hydraulic Modeling of Sewer Systems Standards and Protocols. Within these protocols NEORSD states that the "design level of service is to convey the 5-yr, 6-hr event with the peak hydraulic grade line (HGL) remaining 10 feet or more below rim elevation within the District's interceptor system." However, it is stated that the use of this event is "subject to change based on project specific conditions" and that "consultants should exercise sound engineering judgment in project specific situations where providing the targeted LOS should be relaxed based on benefit/cost balance." In general, the 5-year, 6-hour event sets a minimum baseline level-of-service goals for NEORSD but the policy leaves some flexibility in instances in which there may be need to deviate. The approach also provides allowances for system surcharging (10 feet) where deep sewers exist, presumably to account for additional pressurized system conveyance during modeling evaluations.

- **Cincinnati Metropolitan Sewer District (MSD)**

  Cincinnati MSD has a level of service goal tied to their sewer backup (SBU) response program which was included as part of their consent order mandates with the EPA. The details of this program are described in their consent order under Exhibit 6: Water in Basement Prevent Program Plan. Within this exhibit MSD states the following:

  "Subject to the requirements of this Plan, eligible property owners whose property experiences the backup of wastewater into buildings due to inadequate capacity in MSD's Sewer System (both the combined and the sanitary portions) can receive, at no cost to the property owner, the installation of systems or devices to prevent the backup of wastewater in the future. The Prevention Program is not intended to address water in buildings caused by: 1) overland flooding not emanating from MSD's Sewer System; or 2) blockages in lateral or public sewer lines. Blockages, whether in lateral or public sewer lines, generally are temporary conditions that are better addressed by rodding and other measures that are less permanent than the systems and devices offered by this Plan."

  Eligible property owners "apply to buildings that have suffered multiple reported capacity-related building back-ups in the five years immediately preceding the assessment of that building's eligibility." Certain buildings may be ineligible for the program due to several factors stipulated in the exhibit, of which include overland flooding areas not covered by the program. The program is solely focused on basement backups that are proven to be a result of known system capacity limitations. When it is demonstrated that a sewer backup as a result of MSD system capacity occurs on the same property more than once in a five-year window, that property is eligible for a backflow prevention device at the

cost of MSD. Essentially this means that one 5-year reoccurrence basement flooding event is permitted per the consent order, but the moment there is two occurrences the requirements kick-in. In a way the backflow prevention program is a de facto level-of-service benchmark for MSD's sewer system.

- **New York City Department of Environmental Protection (NYCDEP and Milwaukee Metropolitan Sewer District (MMSD)**

Both NYCDEP and MMSD have also selected a 5-year event for their system level of protection goals. Each city indicated that selection of this event takes into consideration known systemwide capacity challenges and hydraulic capacity assessment of the sewer system. NYCDEP selected a short-term event duration of 6-minutes to specifically address cloudburst rain events. MMSD does not specifically state the event duration of their 5-year event level of protection goal.

- **DC Water and Harrisburg, PA**

As seen above, of the cities found with combined system level of service goals most use a 5-year event for planning purposes. Two outliers found are DC Water (15-year) and Harrisburg (25-year). However, it should be noted that these values appear to be more related to new construction combined sewer infrastructure within their design guidance manuals and do not specifically speak to the issue of upgrading existing capacity limited/flood prone areas.

Sanitary Flow Allocation in Combined Systems

Cities with combined sewer systems have established varying approaches to accounting for sanitary flows as part of the sewer level of service conveyance design. Harrisburg requires that combined sewer systems convey both the design stormwater flows (from a 25-year storm, as noted in Table 1) and the peak sewage flows from the tributary area, which is defined as four times (4x) the average daily flow. New York City defines the combined sewer baseflow based on zoning and floor-area ratio within a given tributary area, and interceptor sewers must be sized to convey four times (4x) the sanitary flow in residential areas and two times (2x) the sanitary flow in industrial areas.

Level of Service for MS4

In general, MS4 level of service design goals are more readily available with some having more open and robust policies. This is likely due to the fact that MS4 capacity issues are less sensitive as compared to combined systems that contain public health ramifications with mixed sewage in habitable dwellings. Most cities reviewed have a consistent level of service of a minimum 10-year reoccurrence event with some cities evaluating a 15-year (Washington DC) or 25-year (Lancaster, PA and Harrisburg, PA). In general level of service goals for MS4 systems are higher than combined sewer level of service goals for the cities reviewed.

Tiered Level of Service for MS4 Approach (Greenville, SC and PennDOT)

While most of the subject cities apply a consistent level of service across a given infrastructure type, some apply varying levels of service standards based on geographic location or infrastructure characteristics. One notable example found is Greenville, SC which requires a higher level of service for certain infrastructure components and areas of the city, including critical infrastructure areas and major roadways. Level of service goals are further categorized according to strategic (citizen/customer) and tactical (asset unit) approaches. Greenville defines each of these categories as follows: "The strategic level of service goal is focused on the stormwater program as a whole as defined by the stormwater ordinance to include citizen needs, regulatory drivers, and environmental concerns of the City. The tactical level of service identifies the infrastructure goals for the maintenance, repair, rehabilitation, and replacement of the system components." Under the tactical level of service category there are two level of service sub-classifications: 1. Short-term LOS and 2. Desired LOS. The short-term level of service classification uses risk analysis likelihood of failure and consequence of failure. The city recognizes a complete inventory is required to establish the short-term LOS and states a complete inventory of the system to be completed in five years to accomplish this goal. The Desired LOS is defined as "the preferred level of service for the Stormwater 2.0 program, which is a proactive approach that will achieve regulatory compliance, water quality goals, and

citizen expectations while optimizing system functionality and minimizing repair and replacement costs: however, this LOS may require additional funding and/or resources beyond the Short-term LOS to achieve." However, as with the Short-term LOS the City is relying a complete inventory of the system to inform its Desired LOS goals.

Similarly, the Pennsylvania Department of Transportation (PennDOT) level of service standards also apply the same tiered approach to roadway drainage and associated stormwater conveyance piping. Figure 1, represents design flood selection guidelines from PennDOT based on road classification taken from PennDOT Publication 13M Highway Design Manual.

Figure 1. PennDOT Design Flood Level of Service Based on Road Classifications

DESIGN FLOOD SELECTION GUIDELINES

FUNCTIONAL CLASSIFICATION	MAXIMUM EXCEEDANCE PROBABILITY (%)	MINIMUM RETURN PERIOD (YEARS)
Interstate and Limited Access Highways	2	50
Principal Arterial System	2	50
Minor Arterial System	4	25
Rural Collector System, Major	4	25
Other Collector Systems	10	10
Local Road and Street Systems	10	10

Stream Flood Protection Level of Service

Healthy streams (i.e. streams not incised by excess peak flows) and are meant to overtop their banks and be connected with adjacent floodplains and wetlands. Typically, most healthy streams overtop the main channel banks and disperse into the floodplain around the 1 or 2-year flood event. Many cities and agencies (including FEMA) recognize that in order to adequately protect citizens from natural flooding from open streams, a much larger flood protection goal is necessary. Cities participating in the National Flood Insurance Program (NFIP) are mandated to regulate all activities and existing structures in the 100-year floodplain. Given this interaction between streams and floodplains its important to understand that level-of-service sizing requirements are often separated between these two stream channel flow regimes. The results in Table 1 are presented based on these stream flow regimes (streams, channels, and floodplains). Ultimately the floodplain level of service along open streams should adhere to FEMA minimum floodplain regulations set forth in the NFIP. This is the case in Northeast Ohio Regional Sewer District (NEORSD) in Ohio. NEORSD strives to provide protection for its regional stream floodplains to the 100-year flood event. However, NEORSD in its November 4, 2021 board meeting minutes recognized "that this is not possible in all areas." NEORSD further states that "NEORSD continues to incrementally raise the level of service as high as it can. In some areas the level of service cannot exceed a 10-year or 25-year storm level of service, however, the intent is to increase the level of service across the area in a comprehensive manner."

Climate Change Considerations

All of the level of service values in Table 1 do not reflect increased rainfall due to climate change, though some cities acknowledge that designing infrastructure in anticipation of future increased rainfall should be considered as part of on-going capital planning and climate resilience efforts. New York City is the furthest along in incorporating climate change into the stormwater design standard and will ultimately require use of the future yet to be determined 5-year storm at the end of the asset's useful life. The City of Pittsburgh recently passed updates to Title 13, which requires volume, rate, and conveyance sizing using climate change rainfall projections from Carnegie Mellon University/RAND. These rainfall estimates could be used for future PWSA sewer system level of service analysis.

Conclusions and Recommendations

This review of stormwater level of service standards and performance requirements reveals a range of standards based on infrastructure type. Generally combined systems are the lowest (typically 5-year),

followed by MS4 (10 to 25-year), and streams being the greatest (100-year). The duration of the design rain events are typically 24-hour or are not specified with the exceptions being NYCDEP (6-minute) and NEORSD (6-hour).

Based on our peer city review ARKF presents the following level of service recommendations for consideration as part of the PWSA Strategic Stormwater Masterplan.

- For combined systems, it is recommended that PWSA conduct a systemwide level of service system evaluation with the systemwide SWMM hydrologic and hydraulic model. For the cities reviewed, it is generally indicated that the level of service design storm selection was based on systemwide hydraulic capacity evaluation. Based on the results of the peer review it is anticipated that the level of service for Pittsburgh will likely be in the 5-year (minimum) to 10-year (maximum) range based on precedent elsewhere. Allowances for dry weather sanitary flow peaking factors and in-system surcharging should also be considered in areas where deep sewers and high basement elevations exist. The locations of allowable system surcharge areas should be determined using PWSA sewer system mapping and conservative estimates of adjacent basement elevations. Hydraulic gradeline results of the with a systemwide hydraulic capacity assessment should also be incorporated into this analysis
- Provide flexibility in the level of service policy with the following:
    - As part of the policy allow for flexibility in the ultimate level of service based on engineering on cost benefit analysis on a project-by-project basis (see language from NEORSD). Develop cost-benefit analysis modeling guidance approach for use by consultants using a range of design storms (including future climate change) and standardized cost metrics based on full lifecycle costs. Perform knee-of-curve analysis to determine most appropriate level of service design storm for the project area.
    - Consider a level of service policy similar to Greenville, SC based on Pittsburgh geographical risk analysis and short-term and desired level of service goals based on known system capacity challenges from the hydraulic model capacity evaluation. It is likely to take many years, if not decades, for PWSA to address all of its level of service capacity challenged areas. Development of a short term and long term level of service policy could provide useful flexibility for prioritizing its most capacity challenged geographical areas using metrics such as existing hydraulic capacity, environmental justice areas, roadway classification, and locations of critical emergency facilities. This could then be used for a level of service risk analysis for future PWSA capital investment. For consistency purposes in Pennsylvania, the PennDOT road classification system can be implemented for all City of Pittsburgh roads as a starting point as many PennDOT state-owned roads traverse flood prone areas in Pittsburgh (Saw Mill Run Boulevard, Banksville Road, Streets Run Boulevard, Washington Boulevard, to name a few). It is also recommended to identify emergency facilities in consultation with City of Pittsburgh.
- For open streams and stream flooding protection, it is recommended that the level of service policy be developed in collaboration between PWSA and City of Pittsburgh floodplain management departments. The level of service policy should consider both the main stream channel and floodplains as separate level of service metrics as healthy streams are meant to overtop its banks and engage floodplains, where appropriate and safe. It is recommended that PWSA engage City of Pittsburgh to develop a floodplain mitigation strategy to understand existing level of service of Pittsburgh flood prone open streams, identify repetitive loss NFIP properties (not collected as part of mapping task), and identify watershed mitigation strategies (willing homeowner buyout properties, locations of floodplain storage/restoration, capacity limited culverts/bridge decks, etc.) for increasing existing level of service around the 100-year regulatory floodplain.

- It is recommended that consideration should be given to future precipitation patterns due to climate change, either by selecting a higher level of service using the current design storms or by incorporating future precipitation projections into project alternatives cost benefit analysis. As part of the flood mapping exercise, AKRF collected dates and times of major flooding events for several years of flooding data. It is recommended that PWSA perform statistical rainfall analysis of these flooding events using 3RWW rainfall data to understand rainfall depths, intensities, durations, and rainfall temporal distribution of flooding events in Pittsburgh. The results should be then compared to existing NOAA Atlas 14 values. The implementation of climate change adjustment factors using future rainfall projection estimates from Carnegie Mellon University should also be considered.

Attachment A - Reference Materials for Table 1

Source Documentation:	Link:
1 Georgia Stormwater Management Manual Volume 2: Technical Handbook, 2016 (Page 9 of document and Page 22 of PDF)	https://cdn.atlantaregional.org/wp-content/uploads/gsmm-2016-edition-final-v2.pdf
2 Georgia Stormwater Management Manual Volume 2: Technical Handbook, 2016 (Page 402 of document and Page 420 of PDF)	https://cdn.atlantaregional.org/wp-content/uploads/gsmm-2016-edition-final-v2.pdf
3 CCMU Selection and Implementation of Alternatives Report (Page 93 of PDF)	http://www.ccmua.org/wp-content/uploads/2020/09/CCMUA-Camden-Gloucester-SIAR-09-30-20.pdf
4 Metropolitan Sewer District of Greater Cincinnati (MSDGC), Ohio, Global Consent Decree filed on June 9, 2004 in the matter of, United State of America, the State of Ohio, and Ohio River Valley Water and Sanitation Commission v. the Board of County Commissioners of Hamilton County, Ohio and the City of Cincinnati, U.S. District Court, Southern District of Ohio, Western Division, Case No. C-1-02-107 (Exhibit 6, Water-In-Basement Program)	https://www.epa.gov/sites/default/files/2014-09/documents/hamilton-cd2.pdf
5 City of Cincinnati Department of Public Works Stormwater Management Rules and Regulations Part 2 Stormwater Management Design Manual (Page 28 of PDF)	https://www.cincinnati-oh.gov/sites/stormwater/assets/File/SMU_Rules_Regs_Part_2.pdf
6 City of Cincinnati Department of Public Works Stormwater Management Rules and Regulations Part 2 Stormwater Management Design Manual (Page 28 of PDF)	https://www.cincinnati-oh.gov/sites/stormwater/assets/File/SMU_Rules_Regs_Part_2.pdf
7 Northeast Ohio Regional Sewer District PROJECT CLEAN LAKE | Green infrastructure project plans through 2018	https://www.neorsd.org/I_Library.php?SOURCE=library/GI-Project_Summaries.pdf&a=download_file&LIBRARY_RECORD_ID=6249
8 NEORSD Hydrologic and Hydraulic Modeling of Sewer Systems Standards and Protocols Version 4.1 (Page 55 of document, Page 64 of PDF)	https://neorsdpmo.org/ExternalUserPage/Pages/320_HydraulicModelingStandardsforCollectionSystems.pdf
9 NEORSD November 11, 2021 Board of Trustees Meeting Minutes (Page 7 of document, Page 6 of PDF)	https://www.neorsd.org/I_Library.php?SOURCE=library/BA-Minutes-110421.pdf&a=download_file&LIBRARY_RECORD_ID=7737
10 City of Greenville Public Works Deparment Stormwater Level of Service February 27, 2018 (Page 3 of document and PDF)	https://www.greenvillesc.gov/DocumentCenter/View/11255/Stormwater-Level-of-Service-Policy
11 Section § 9-903.5 "Downstream hydraulic capacity analysis"	https://ecode360.com/13783420

12 City of Lancaster Green Infrastrucutre Design Manual, February 2019 (Page 218 of Document and Page 225 of PDF)	https://cityoflancasterpa.com/wp-content/uploads/2014/03/Lancaster-GI-Design-Manual_Final_reduced_0.pdf
13 MMSD System Evaluation and Capacity Assurance Plan, (Page 97 of PDF)	https://www.mmsd.com/docs/2014_MMSD_CMOM_Program.pdf
14 New York City Stormwater Resiliency Plan, May 2021 (Page 5 of document and pdf)	https://www1.nyc.gov/assets/orr/pdf/publications/stormwater-resiliency-plan.pdf
15 Water/Sewer Design Manual Version 3.10.1, July 9 2019 (Page 5-1 of document and 32 of PDF)	https://s3.amazonaws.com/phillywaterdesign/Design+Manual/Water+Sewer+Design+Manual+V3.10.1.pdf
16 City of Raleigh Stormwater Management Design Manual, 2002 (Page 10 of document and PDF)	https://cityofraleigh0drupal.blob.core.usgovcloudapi.net/drupal-prod/COR16/StormwaterDesignManual.pdf
17 City of Raleigh Stormwater Management Design Manual, 2002 (Page 11 of document and PDF)	https://cityofraleigh0drupal.blob.core.usgovcloudapi.net/drupal-prod/COR16/StormwaterDesignManual.pdf
18 City of Richmond Stormwater Management Design Manual, 2002 (Page 5-3 of document and Page 30 of PDF)	https://www.rva.gov/sites/default/files/2021-06/Stormwater_Management_Design_and_Construction_Standards_Manual.pdf
19 City of Richmond Stormwater Management Design Manual, 2002 (Page 4-2 of document and Page 21 of PDF)	https://www.rva.gov/sites/default/files/2021-06/Stormwater_Management_Design_and_Construction_Standards_Manual.pdf
20 City of Toledo Infrastructure Design and Construction Requirements, May 2014 (Page 21 of PDF)	https://cdn.toledo.oh.gov/uploads/documents/Public-Utilities/Engineering-Services/2014-infrastructure-requirements.pdf
21 DC Water Project Design Manual Volume 3 - Linear Infrastructure Design, July 2018 (Page 3-5-5 of document, Page 55 of PDF)	https://www.dcwater.com/sites/default/files/engineering/PDM%20Vol%203%20-%20Linear%20Infrastructure%20Design_0.pdf
22 DC Water Project Design Manual Volume 3 - Linear Infrastructure Design, July 2018 (Page 3-4-5 of document, Page 54 of PDF)	https://www.dcwater.com/sites/default/files/engineering/PDM%20Vol%203%20-%20Linear%20Infrastructure%20Design_0.pdf