Appendix A

Service Area System Characterization Report
and
NJDEP approval letter dated April 12, 2019

State of New Jersey

PHIL MURPHY
Governor

SHEILA OLIVER
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Mail Code – 401-02B
Water Pollution Management Element
Bureau of Surface Water Permitting
P.O. Box 420 – 401 E State St
Trenton, NJ 08625-0420
Phone: (609) 292-4860 / Fax: (609) 984-7938

CATHERINE R. McCABE
Commissioner

April 12, 2019

To: Distribution List

Re: Review of Revised "Service Area System Characterization Report"

Passaic Valley Sewage Commission, NJPDES Permit No. NJ0021016
Bayonne City Municipal Utilities Authority, NJPDES Permit No. NJ0109240
Borough of East Newark, NJPDES Permit No. NJ0117846
Town of Harrison, NJPDES Permit No. NJ0108871
Town of Kearny, NJPDES Permit No. NJ0111244
City of Newark, NJPDES Permit No. NJ0108758
North Bergen Municipal Utilities Authority, NJPDES Permit No. NJ0108898
City of Paterson, NJPDES Permit No. NJ0108880

Dear Permittees:

Thank you for your submission dated March 28, 2019 which contains a revised version of the "Service Area System Characterization Report" as well as a "Summary of Changes" document. The original submission was dated June 2018 and was in response to Part IV.D.3.b.ii of the above referenced NJPDES permit. The New Jersey Department of Environmental Protection (the Department) provided technical comments on your original submission on October 9, 2018 and February 26, 2019 where this most recent submission is in response to those comments. The Department acknowledges that both the original and revised submissions were made in a timely manner. This letter is written to provide a determination on your most recent submission.

As you know, the System Characterization Report was preceded by a work plan, as required by Part IV.D.3.b.i of your NJPDES permit, where this work plan was approved by the Department on March 30, 2016 (Newark, East Newark, Harrison, Kearny, Paterson, PVSC) and August 1, 2016 (Bayonne, North Bergen, PVSC). The Department is also in receipt of continued quarterly progress reports which provide periodic progress updates on the System Characterization Report, as well as other aspects of the NJPDES permit.

In accordance with Part IV.G.1.a of the NJPDES CSO permit, the purpose of the System Characterization Report is to provide a "comprehensive characterization of the CSS as developed through records review, monitoring, modeling and other means as appropriate to establish the existing baseline conditions, evaluate the efficacy of the CSO technology based controls, and determine the baseline conditions upon which the LTCP will be based." As described in the October 9, 2018 and February 26, 2019 letters, the Department noted that Section I.6.3, Table I-13 of the reports depicts percent capture for the 2004 Typical Year. Additionally, in both technical comment letters, the Department objected to inclusion of this information in the July 2018 submission as well as the calculation method. As a result, the Department would like to meet with you to discuss this topic and will provide technical documentation regarding the percent capture

calculations under a separate cover letter. Please contact Jenna Immordino of the Bureau of Surface Water Permitting to arrange this meeting.

While the Department is in disagreement with the calculation method and inclusion of percent capture in the System Characterization Report, the Department has determined that the System Characterization Report meets the intent of the NJPDES permit condition. **In sum, the Department has determined that the System Characterization Report requirement is hereby approved and that this permit condition is now satisfied.**

The Department looks forward to submission of the Development and Evaluation of Alternatives for the LTCP as due on July 1, 2019. Please let us know if you have any questions regarding submission of that report.

Thank you for your continued cooperation.

Sincerely,



Susan Rosenwinkel
Bureau Chief
Bureau of Surface Water Permitting

C: Marzooq Alebus, Bureau of Surface Water Permitting
Teresa Guloy, Bureau of Surface Water Permitting
Dwayne Kobesky, Bureau of Surface Water Permitting
Joe Mannick, Bureau of Surface Water Permitting
Tim Ebersberger, Bureau of Nonpoint Pollution Control
Richard Haytas, Jersey City Municipal Utilities Authority

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Town of Kearny
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Frank Pestana, Executive Director
North Bergen Municipal Utilities Authority
6200 Tonnelle Avenue
North Bergen, NJ 07047

SERVICE AREA SYSTEM CHARACTERIZATION REPORT

Submitted on behalf of the following participating Permittees
By the Passaic Valley Sewerage Commission:

Passaic Valley Sewerage Commission (NJ 0021016)
Bayonne City (NJ0109240)
East Newark Borough (NJ0117846)
Harrison Town (NJ0108871)
Kearny Town (NJ0111244)
Newark City (NJ0108758)
North Bergen MUA (NJ0108898)
Paterson City (NJ0108880)

Passaic Valley Sewerage Commission
Essex County
600 Wilson Avenue
Newark, New Jersey

"Protecting Public Health and the Environment"

June 2018
Revised 01/21/19
Revised 03/28/19

SECTION A - INTRODUCTION AND BACKGROUND

A.0 SUMMARY OF CHANGES

This Report is for the Service Area System Characterization Report to be utilized by the Passaic Valley Sewerage Commission (PVSC) and the entities who own and operate combined sewer collection systems within the PVSC service area, with the exception of the Jersey City Municipal Utilities Authority. This Report describes the rainfall monitoring, wastewater sampling, collection system monitoring, modeling and other work necessary to characterize the CSO discharges from the participating municipalities and for development of a collections system model for the purposes of evaluating CSO control alternatives and development of a CSO Long Term Control Plan (LTCP). The history of this document and changes made to it are summarized below:

- June 29, 2018: Submitted Service Area System Characterization Report in fulfillment of the LTCP Permit requirement.
- Revised January 21, 2019: Modified the Service Area System Characterization Report to address comments made by NJDEP in letter dated October 9, 2018. A 45 day extension was granted on December 6, 2018. A copy of the October 9, 2018 letter and the 45 day extension email are included in Appendix E of this document. The June 29, 2018 submitted Service Area System Characterization Report was 228 pages including Appendix A. This version includes updates that resulted in a page total of **739** pages including the report, appendices and cover page. Table of Contents and page number updates are not reflected with redline-strikeout in this document. The following pages in this document have been changed to address NJDEP comments, with changes shown in redline-strikeout throughout the document:
    a. DEP Comment 1 – Pages **127 and 130** Modified.
    b. DEP Comment 2 – Pages **146 to 148** Modified.
    c. DEP Comment 3 – Pages **170-172** Modified. A new Appendix B has been added to the Report.
    d. DEP Comment 4 – Page **178** Modified. A new Appendix C has been added to the Report.
    e. DEP Comment 5 – Pages **227 to 231** Modified.
    f. DEP Comment 6 – Page **233** Modified.
    g. DEP Comment 7 – Although the 2004 Newark Airport annual precipitation volume is lower than the 1988 JFK Airport annual precipitation volume, overflow volumes are dependent on a number of additional factors. Rainfall intensity and inter-event time can influence overflows. River elevations can have a significant impact on overflows as well. Furthermore, the monitoring data collected under the current QAPP focused largely on overflow monitoring. The results of that overflow monitoring were used to further calibrate and validate the landside models that were used during the prior permit cycle. The models were updated to reflect more current information. For example, the control rules for the regulating gates in the City of Newark were updated based on operational logs from 2015. The model configuration for regulating chambers were updated based on record drawings. Also, dry weather flows to PVSC have been declining over the last decade, which allows more wet weather flow to be captured and sent to the plant.

It should be expected that the updated model results will differ from those historic studies.
Performing a 1988 simulation and a comparison analysis would require a significant amount of time and effort that is not commensurate with the value obtained from this analysis when considering the overall objective of preparing a LTCP. Given these factors and the monitoring and modeling work that was recently performed to improve the model from those historic studies, performing the suggested analysis is not warranted. No changes made to the Report.

h. DEP Comment 8 – Pages 82 to 86 Modified. A new Section D.2.10 has been added to the Report.
i. DEP Comment 9 – InfoWorks ICM software does not have the function to provide the water budget for the simulation period. The Innovyze technical team indicated that to generate a pie-chart of water budget, a specific SQL will be needed to get runoff, evaporation etc. for each subcatchment and each time step, and post data processing is needed, as well. This will require a significant amount of time and effort that is not commensurate with the value obtained from this analysis when considering the overall objective of preparing a LTCP. No changes made to the Report.
j. DEP Comment 10 – DWF values for individual flow meters were included in Figure E-4, page 92 (Dry Weather Flow). No changes made to the Report.
k. DEP Comment 11 – Pages 93 to 96 Modified. A new Appendix D has been added to the Report.
l. DEP Comment 12 – Page **102** Modified.
m. DEP Comment 13 – Pages **98 to 99** Modified.
n. DEP Comment 14 – Page **101** Modified.
o. DEP Comment 15 – Pages **98 to 103** Modified.
p. DEP Comment 16 – Page **106** Modified.
q. DEP Comment 17 – Page **110** Modified.
r. DEP Comment 18 – Page **122** Modified.
s. DEP Comment 19 – Pages **127, 130 and 131** Modified.
t. DEP Comment 20 – The System Characterization and Landside Modeling QAPP goals were:

- Supplement and update, as appropriate, the site specific dry and wet weather data to be used to recalibrate and verify the InfoWorks collections system model of those collections systems tributary to the PVSC WPCF.
- Define the combined sewer systems' hydraulic response to rainfall.
- Supplement the existing dry weather water quality and quantity data to be used in the representation of each CSO drainage basin.
- Determine the CSO flows and pathogen concentrations/loadings being discharged to the receiving streams as a result of varied rainfall events.
- Supplement the stormwater quality data for various land use applications.

These goals support the objectives of the Work Plan as stated in the NJDEP comment letter, which are:
- To predict overflow occurrence, volume, and, in some cases, quality for rain events other than those which occurred during the monitoring phase. These can

include a storm event of large magnitude (long recurrence period) or numerous storm events over an extended period of time.
- To predict the performance of portions of the CSS that have not been extensively monitored.
- To develop CSO statistics, such as annual number of overflows and percent of combined sewage captured as described in the CSO Control Policy.
- To optimize CSS performance as part of Nine Minimum Control (NMC) implementation. In particular, modeling can assist in locating storage opportunities and hydraulic bottlenecks and demonstrate that system storage and flow to the POTW are maximized.
- To evaluate and optimize control alternatives, from simple controls described under the NMC to more complex controls proposed in a municipality's LTCP. An example of a simple control would be to raise weir heights to increase in-line storage. The model can be used to evaluate the resulting reductions in CSO volume and frequency.

No changes made to the Report.

u. DEP Comment 21 – Pages **131 and 132** Modified.
v. DEP Comment 22 – Page **131** Modified.
w. DEP Comment 23 – Pages **148 to 153** Modified.
x. DEP Comment 24 – Page **178** Modified. A new Appendix C has been added to the Report.
y. DEP Comment 25 – Pages **194** Modified.
z. DEP Comment 26 – Pages **194 to 237** Modified. A new Appendix D has been added to the Report.
aa. DEP Comment 27 – As stated in the EPA's Guidance for Long-Term Control Plan (EPA 832-B-95-002), and as referenced by NJDEP's Technical Comments on the "Service Area System Characterization Report, one of the primary objectives of the combined sewer system modeling study is:

To develop CSO statistics, such as annual number of overflows and percent of combined sewerage captured as described in the CSO Control Policy.

The Percent Capture provided in Table I-12, page **237** is for existing conditions and is appropriate for the System Characterization Report. No changes have been made to the Report in response to this comment.
bb. DEP Comment 28 – The combined sewer overflow and stormwater sampling results in excel format have been provided under separate cover.

- Revised March 28, 2019: Modified the Service Area System Characterization Report to address comments made by NJDEP in a letter dated February 26, 2019 and by the MEG in a letter dated February 15, 2019. A copy of the February 26, 2019 letter is included in Appendix F of this document**.** A copy of the February 15, 2019 letter is included in Appendix B of this document. The January 21, 2019 submitted Service Area System Characterization Report included 739 pages including the report, appendices and cover page. This version includes updates that resulted in a page total of 797 pages including the report, appendices and cover page. Table of Contents and page number updates are not

reflected with redline-strikeout in this document. The following pages in this document have been changed to address NJDEP comments, with changes shown in redline-strikeout throughout the document:

a. DEP Comment 1 – The DWFs in Figure E-4 correspond to the temporary flow monitoring period: April 1, 2016 to August 31, 2016. Page 96 modified.
b. DEP Comment 2 – The July 31st, 2016 rainfall event was not replaced. Table E-2 of the report submitted on June 28, 2018 presented the four Calibration and Validation Rainfall Events based upon the Newark Airport gage. When considering only the Newark Airport gage, the precipitation that occurs on June 30th, 2016 and the precipitation that occurs on July 31st, 2016 are two separate events because they have an interevent time exceeding 6 hours. In response to Former NJDEP Comment 13, that analysis was updated to include all eight gages used in the calibration and validation of the landside model. For some of these gages the precipitation occurring on July 30th and July 31st are considered to be a single event because the interevent time does not exceed 6 hours. Therefore, on a system wide basis, the precipitation occurring on these two days is considered a single event. The updated table, now Table E-5, reflects that this events starts on July 30th and ends on July 31st. No changes required.
c. DEP Comment 3 – Appendix B has been updated to include the final MEG Memorandum. Pages 100, 174, 182, 211, and 255 – 263 modified.
d. DEP Comment 4 – Two different types of manning's N are mentioned in this comment:
    1. Subcatchment Manning's "n", roughness coefficient for the runoff surface in the combined area.
    2. Sewer mains Manning's "n", roughness coefficient for the conveyance pipe

    The Manning's "n" on Page 188 and Appendix C is for Subcatchments, with a standard value of 0.05 for pervious surfaces and 0.02 for impervious surfaces. This was not adjusted during calibration/validation process.
    The Manning's "n" on Page 194 cited in the comments (Section I.3.3), is referring to sewer mains. Most of these values were imported from the previous models. The values for new sewer lines were assigned based on available GIS information or with appropriate assumptions. No changes required.
e. DEP Comment 5 – Pages 245 through 248 Modified.
f. DEP Comment 6 – The inclusion of existing conditions Percent Capture is appropriate for the Service Area System Characterization Report. As provided in the response to former NJDEP Comment 27, as stated in EPA's Guidance for Long-Term Control Plan (EPA 832-B-95-002), and as referenced by NJDEP's Technical Comments on the "Service Area System Characterization Report, one of the primary objectives of the combined sewer system modeling study is:

    "To develop CSO *statistics, such as annual number of overflows and percent of combined sewerage captured as described in the CSO Control Policy."* To that end, the percent capture is a part of the CSO statistics and is relevant for the system characterization.

Furthermore, the Evaluation of Alternatives Report, which is to be submitted on July 1, 2019, will consider a range of CSO control alternatives predicted to accomplish the requirements of the CWA using either the Presumption Approach or the Demonstration Approach. As acknowledged in the Department's comment, the elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis is one of the criteria for the Presumption Approach. It is therefore necessary to establish the existing Percent Capture prior to the July 1st, 2019 Evaluation of Alternatives Report so that that alternatives for achieving 85% capture can be identified and evaluated for inclusion in that report.

The Permittees do not agree with the portion of Department's comment which states "….. *any percent capture calculation that includes separately sewered communities is in direct conflict with the NJPDES".* The 83.8% Percent Capture for the PVSC Interceptor Communities includes the portion of the hydraulically connected system that conveys flow to the PVSC WWRF through the PVSC interceptor. This includes municipalities comprised of both combined and separate sewers. The PVSC Interceptor Communities are a smaller inter-connected system of the hydraulically connected system, as defined by the NPDES permit. The flows from these communities enter the PVSC WWRF by gravity. The remaining flows from Bayonne, Jersey City, North Bergen and South Kearny are conveyed to the PVSC WWRF via a force main originating at the Jersey City West pump station. The NJPDES permit Part IV.B.1.c defines the Hydraulically Connected System as:

> *"Hydraulically connected system" means the entire collection system that conveys flows to one Sewage Treatment Plant (STP). On a case-by-case basis, the permittee, in consultation with the Department, may segment a larger hydraulically connected system into a series of smaller inter-connected systems, based upon the specific nature of the sewer system layout, pump stations, gradients, locations of CSOs and other physical features which support such a sub area. A hydraulically connected system could include multiple municipalities, comprised of both combined and separate sewers".* To that end, the combined sewer systems and the separate sanitary systems are both a part of the hydraulically connected system of the PVSC WWRF.

Furthermore, the inclusion of flows from the municipalities served by separate sewers for the purposes of the calculation of percent capture is supported by the USEPA CSO Post Construction Compliance Monitoring Guidance (May 2012) document. Based on this document, it is clear that the USEPA considers upstream separate sewer areas to be part of the total combined sewage and should be used "*to evaluate compliance with CSO volume control targets."* Furthermore, the document states that separate sanitary flow to the combined sewer system from non-combined sewer systems should be accounted for "*to ensure that the flow volumes represent the CSS and all its contributing areas*" and that the "*combined sewage in the CSS during precipitation events is the sum of runoff plus sanitary*

sewage entering the CSS." Therefore, the flow from the separate sanitary sewer systems is part of the combined sewage in the CSS and the flow from the separate sanitary sewer systems should be included in the percent capture calculation. Relevant portions of that document are included below for reference, including Figure 5 which portrays a situation similar to the PVSC Interceptor Communities:

(Excerpts from USEPA CSO Post Construction Compliance Monitoring Guidance (May 2012) :

4.1.2.1 Identifying Flows to the CSS

Permittees should ensure that the flow values used to evaluate compliance with CSO volume control targets include appropriate contributions of the various parts of the CSS and that the remaining CSO volumes are calculated correctly. For example, permittees should be sure to account for flows from upstream from separated areas, plus any infiltration and inflow that can be expected during critical periods (e.g., during rainfall events). Examples of the types of flows that should be accounted for to ensure that the flow volumes represent the CSS and all its contributing areas include the following:

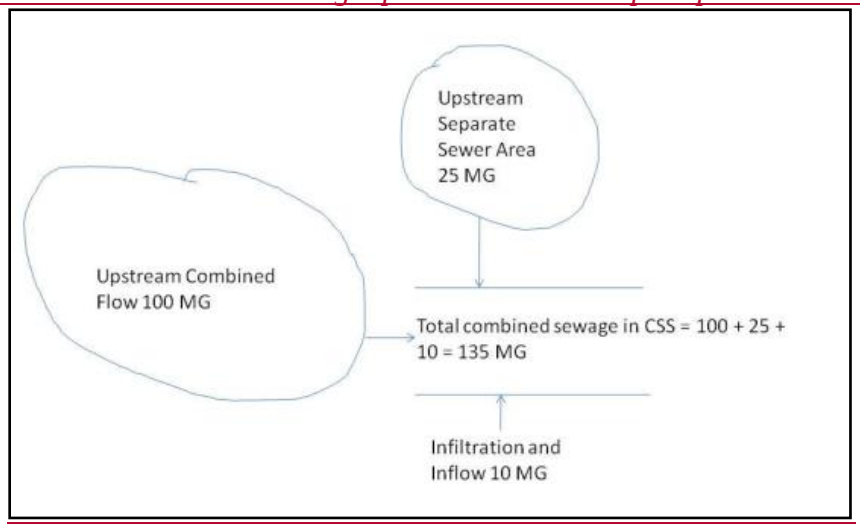
- *Flows from satellite communities that contribute to the CSS.*
- *Separate sanitary flow to the CSS from non-CSS areas.*
- *Infiltration and inflow in separate sanitary areas that contribute flow to the CSS.*
- *Flow in key interceptors in the CSS.*
- *Flow at key hydraulic control points (i.e., pump stations) in the CSS.*
- *Flow at treatment facilities within the CSS.*
- *Flow at the headworks of the publicly owned treatment works wastewater treatment plant (POTW WWTP).*
- *Flow at POTW WWTP outfalls, including allowable CSO-related bypasses.*
- *Flow at CSO outfalls.*

4.1.2.4.1 Volume of Combined Sewage in the CSS during Precipitation Events

The "combined sewage in the CSS during precipitation events" is the sum of runoff plus sanitary sewage entering the CSS (or dry-weather flow). Runoff should either be modeled or calculated as the combined sewage entering the CSS during precipitation events. Sanitary sewage should either be metered or apportioned from the sanitary sewage in CSS during precipitation events. Delineating what should be included in the "sanitary sewage" component should be negotiated between the permittee and the NPDES authority. For example, NPDES authorities may expect systems with high I/I to reduce baseline sanitary sewage flow levels to account for excessive I/I.

4.1.2.4.3 Calculating a Volume Balance

Figure 5. Flows to the CSS during a particular 24-hour precipitation event.



In summary, the Permittees believe that the calculation for Percent Capture should be included in the Service Area System Characterization Report, and that the wet weather flows from the municipalities served by separate sewers should be included in that calculation.

g. Since the prior report submission, the baseline model was refined based on feedbacks from individual CSO permittees including Paterson, Newark, North Bergen, and Bayonne. The typical year overflow statistics (Section I.6.2, Table I-11 and Figure I-66 to Figure I-68) and percent capture (Section I.6.3, Table I-12) were updated accordingly in this report. Appendix C - Subcatchment Characteristics (Baseline Model) has been updated and included in this revised report. Appendix D - H&H Modeling Calibration Plots will be updated and submitted with the Final LTCP.

In future versions, this section will be further updated to include summaries of changes and when they were incorporated as appropriate.

A.1 TITLE OF PLAN AND APPROVAL

Title: Service Area System Characterization Report for Passaic Valley Sewerage Commission LTCP

Preparer:

Project Officer: _____ 6/20/18
Michael J. Hope, P.E., Greeley and Hansen LLC — Date

QA Officer: _____ 6/20/18
Timothy J. Dupuis, P.E., CDM Smith — Date

Passaic Valley Sewerage Commission:

PVSC Program Manager: _____ 06/20/2018
Bridget McKenna, Chief Operating Officer, PVSC — Date

PVSC QA Officer: Marques Eley 6/19/18
Marques Eley, PVSC — Date

New Jersey Department of Environmental Protection

DEP Permits: _____
Joseph Mannick, CSO Coordinator — Date

DEP QA: _____
Marc Ferko, Office of Quality Assurance — Date

Service Area System Characterization Report

Submitted by
Passaic Valley Sewerage Commission:

NJPDES Number NJ0021016 (Passaic Valley Sewerage Commission)

Approval of this submittal:

Permittee: _____ 06/20/2018
Bridget McKenna — Date
Chief Operating Officer, Passaic Valley Sewage Commission

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _____ 06/20/2018
Bridget McKenna — Date
Chief Operating Officer, Passaic Valley Sewage Commission

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0109240 (Bayonne City)

Approval of this submittal:

Permittee: _____ 6.19.18

Timothy Boyle — Date
Superintendent, City of Bayonne Department of Public Works

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _____ 6.19.18

Timothy Boyle — Date
Superintendent, City of Bayonne Department of Public Works

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0117486 (East Newark)

Approval of this submittal:

Permittee: _____ 6/25/18

Frank Pestana — Date
Licensed Operator, Borough of East Newark

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _____ 6/25/18

Frank Pestana — Date
Licensed Operator, Borough of East Newark

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0108871 (Harrison)

Approval of this submittal:

Permittee: _____ 6/19/18

Rocco Russomano — Date
Town Engineer, Town of Harrison

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _____ 6/19/18

Rocco Russomano — Date
Town Engineer, Town of Harrison

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0111244 (Kearny)

Approval of this submittal:

Permittee: _____ 6/20/18

Robert J. Smith — Date
Town Administrator, Town of Kearny

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _____ 6/20/18

Robert J. Smith, — Date
Town Administrator, Town of Kearny

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0108758 (Newark)

Approval of this submittal:

Permittee: _____ 6-18-18

Ras J. Baraka — Date
Mayor, City of Newark

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _____ 6-18-18

Ras J. Baraka — Date
Mayor, City of Newark

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0108988 (North Bergen Municipal Utilities Authority)

Approval of this submittal:

Permittee: _____ 6/25/18

Frank Pestana — Date
Executive Director, North Bergen Municipal Utilities Authority

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _____ 6/25/18

Frank Pestana — Date
Executive Director, North Bergen Municipal Utilities Authority

Service Area System Characterization Report

Submitted on behalf of the following participating Permittee by Passaic Valley Sewerage Commission:

NJPDES Number NJ0108880 (Paterson)

Approval of this submittal:

Permittee: _____ 6/20/18.
Manny Ojeda — Date
Director of Public Works, City of Paterson

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law that this document and all attachments were prepared either: (a) under my direction or supervision; or (b) as part of a cooperative performed by members of the NJ CSO group effort in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

Permittee: _____ 6/20/18
Manny Ojeda — Date
Director of Public Works, City of Paterson

SERVICE AREA SYSTEM CHARACTERIZATION REPORT

Submitted on behalf of the following participating Permittees By the Passaic Valley Sewerage Commission:

Passaic Valley Sewerage Commission (NJ 0021016)
Bayonne City (NJ0109240)
East Newark Borough (NJ0117846)
Harrison Town (NJ0108871) Kearny Town (NJ0111244) Newark City (NJ0108758)
North Bergen MUA (NJ0108898)
Paterson City (NJ0108880)

Approval of Report Submission:

Permittee: Richard Haytas November 5 2018

Richard Haytas Date
Senior Engineer, Jersey City Municipal Utilities Authority

NJPDES Certification:

Without prejudice to any objections timely made to permit conditions, I certify under penalty of law, to the best of my knowledge and belief, that the Passaic Valley Sewerage Commission ("PVSC") and the all Permittees in the list above, with the assistance of a professional engineering consultant, prepared this document and all attachments. JCMUA is engaged with PVSC and the all Permittees in the list above in order to coordinate planning to achieve NJDEP's objective of having one (1) long term combined sewer overflow control plan for all NJPDES permittees that are hydraulically connected to PVSC. PVSC has represented to me that this document and all attachments hereto are complete, accurate, and truthful.

I further certify that JCMUA's professional engineering consultant has performed a cursory review of this document and attachments and has not found any obvious elements that would conflict with the approach taken by PVSC and the remaining hydraulically-connected NJPDES permittees to long term control planning. I have also certified the reports prepared by PVSC and their engineering consultant entitled, "Typical Hydrologic Year Report", "Baseline Compliance Monitoring Report", and "Identification of Sensitive Areas Report" on 12/5/2017, 6/4/2018, and 6/13/2018. Since I have previously certified these 3 reports, I also certify Sections F.8, G.6, and H of the Service Area System Characterization Report which are based upon these 3 reports and except for these sections of the Service Area System Characterization Report I do not certify as to the accuracy of any data contained in this document or any attachments hereto, nor to any conclusions drawn by PVSC and/or its consultant. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for purposely, knowingly, recklessly, or negligently submitting false information.

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Richard Haytas Date
Senior Engineer, Jersey City Municipal Utilities Authority

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Marques Eley, Process Control Engineer III, PE

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East Newark:	Frank Pestana, Licensed Operator
Harrison:	Rocco Russomano, Town Engineer
Kearny:	Robert J. Smith, Town Administrator
Newark:	Ras J. Baraka, Mayor of Newark
North Bergen:	Frank Pestana, Executive Director
Paterson:	Manny Ojeda, Director of Public Works

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Appendix A - Combined Sewer Overflow and Stormwater Sampling Results
Appendix B - MEG Group Meeting Summary with comments, MEG Memorandum and Meeting Presentations., ~~Comments~~
Appendix C - Subcatchment Characteristics (Baseline Model)
Appendix D - H&H Modeling Calibration Plots
Appendix E - NJDEP Comment Letter dated October 9, 2018 and Email from NJDEP to PVSC Dated December 6, 2018 Granting 45 Day Extension
Appendix F – NJDEP Comment Letter dated February 26, 2019.

A.5 SIGNIFICANT BACKGROUND

Passaic Valley Sewerage Commission (PVSC) provides wastewater treatment service to 48 municipalities within Bergen, Hudson, Essex, Union and Passaic Counties in the Passaic Valley Service District located in northeast New Jersey. In total PVSC services approximately 1.5 million people, 198 significant industrial users and 5,000 commercial customers. The PVSC District covers approximately 150 square miles from Newark Bay to regions of the Passaic River Basin upstream of the Great Falls in Paterson. PVSC's main interceptor sewer begins at Prospect Street in Paterson and generally follows the alignment of the Passaic River to the PVSC WRRF in the City of Newark.

PVSC does not own or operate any of the combined sewer overflow outfalls but has assumed a lead role in the development of the System Characterization and Landside Modeling Program on behalf of these permittees. The extent of the PVSC Service District and the combined sewer areas within the study area are illustrated in **Figure A-1** .

Eight of the municipalities within the PVSC District have combined sewer systems (CSSs) and have received authorization to discharge under their respective New Jersey Pollutant Discharge Elimination System (NJPDES) Permits for Combined Sewer Management. The eight PVSC CSO Permittees are listed below:

- Paterson City
- Newark City
- Kearny Town
- Harrison Town
- East Newark Borough
- City of Bayonne (Bayonne MUA was dissolved in 2016 and the City of Bayonne now own its CSS)
- Jersey City Municipal Utilities Authority (MUA)
- North Bergen MUA

A general schematic of the PVSC sewer system is included in **Figure A-2** .

Jersey City MUA is included in the list above, however it will submit its own System Characterization report separately. Any mention in this report of the infrastructure owned and operated (in part or in full) by Jersey City MUA is due to its hydraulic connection to the PVSC Water Resources Recovery Facility (WRRF) and is only included where it is necessary in order to properly characterize the PVSC system.

North Bergen Township has two combined sewer areas that are owned and operated by the North Bergen Township Municipal Utilities Authority (NBMUA) under two separate NJPDES permits; NBMUA and NBMUA (Woodcliff). The Woodcliff STP service area is separate from the PVSC service area and is covered in a separate System Characterization Report. Any mention in this

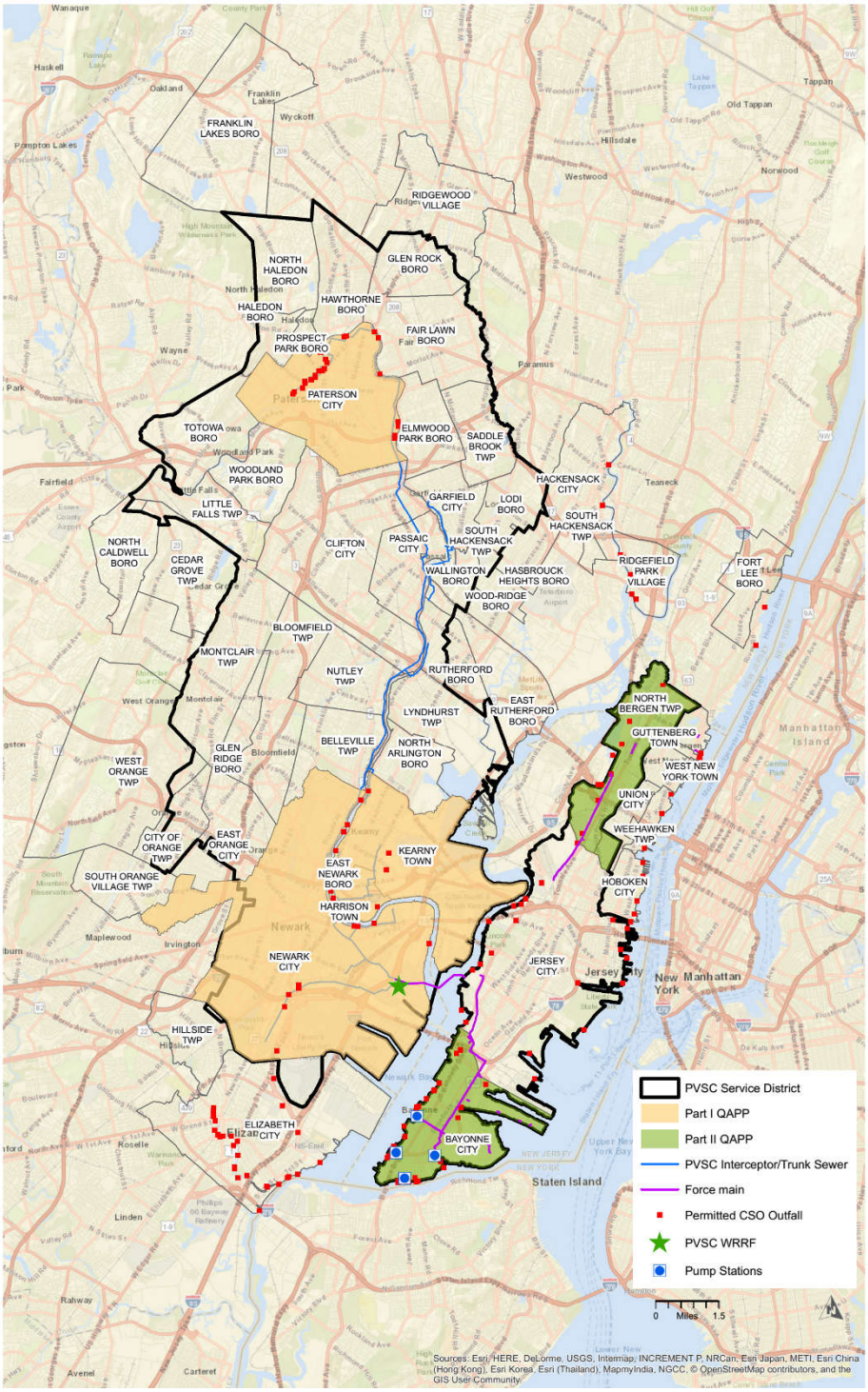


Figure A-1: The PVSC Service District[1]

[1] QAPP listed in above legend refers to the "System Characterization and Landside Modeling Program Quality Assurance Project Plan (QAPP)," which have been previously approved by NJDEP.

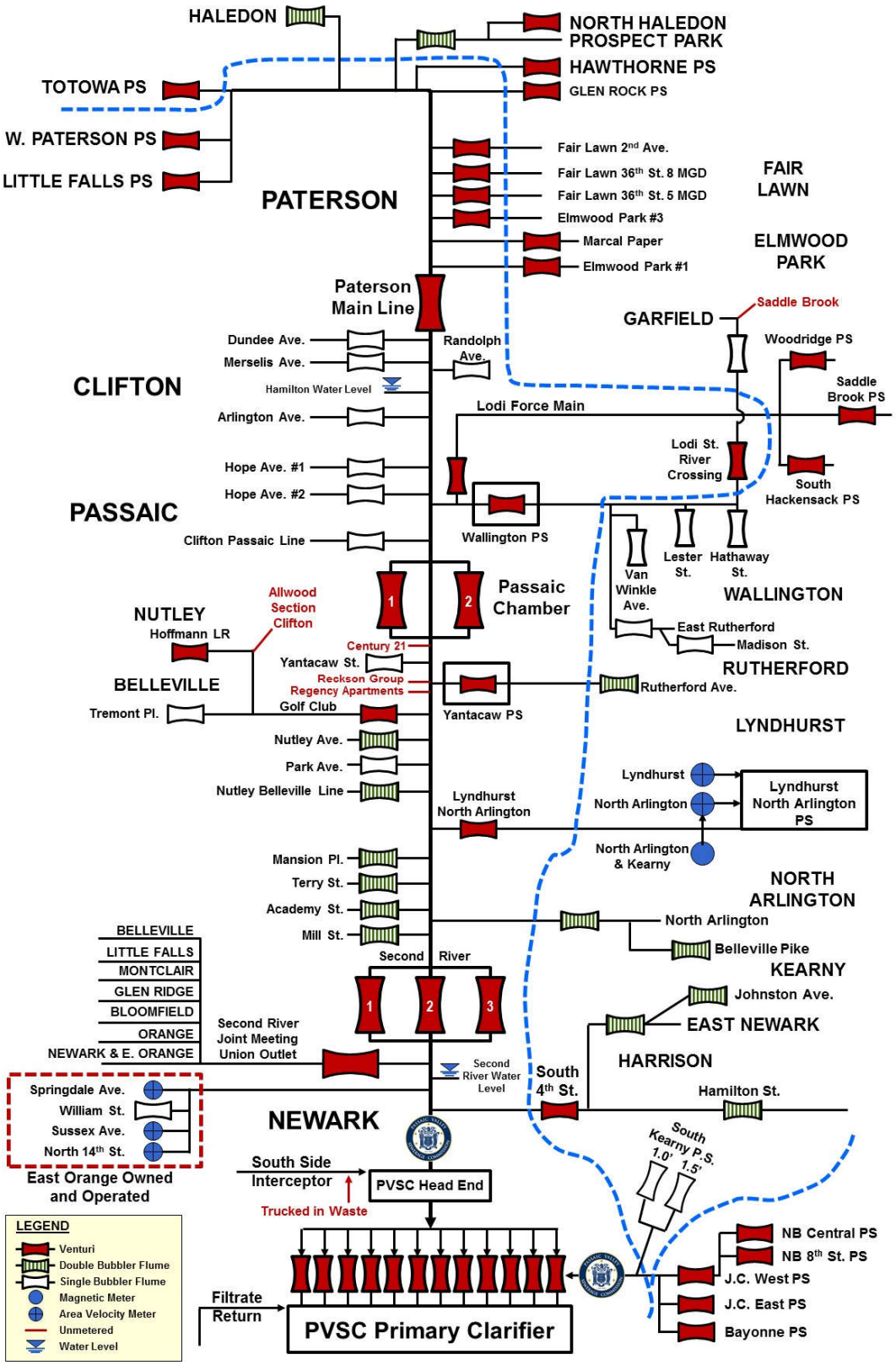


Figure A-2: The PVSC Sewer System Schematic

report of the infrastructure owned and operated (in part or in full) by North Bergen MUA (Woodcliff) is only included where it is necessary in order to properly characterize the North Bergen MUA system.

Permit Requirements

The NJPDES permits issued to PVSC and each CSO Permittee include requirements for PVSC and the CSO Permittees to cooperatively develop a CSO Long Term Control Plan (LTCP). To facilitate the CSO LTCP development, PVSC has undertaken the development of the System Characterization Report on behalf of these permittees.

Historical Characterization Reports

Between 1998 and 2003, PVSC conducted a Combined Sewer Overflow Discharge Characterization Study for all regulators and interceptor sewers owned and operated by the PVSC. This study was prepared by PVSC on behalf of the Borough of East Newark, the Towns of Harrison and Kearny and the City of Paterson. Jersey City, North Bergen MUA, and the Cities of Newark and Bayonne prepared their own separate reports in response to these NJPDES General Permit requirements. The following four reports were developed under this study:

- *Rainfall Monitoring Study Report* (December 1998): This study was conducted to develop an understanding of the rainfall characteristics in the combined communities in the PVSC service area, develop a correlation between rainfall characteristics and frequency of occurrence that causes a discharge, and develop rainfall monitoring for use in monitoring and modeling of CSO drainage basins.
- *CSO Monitoring Report* (December 1998): This effort was intended to quantify and qualify dry weather and wet weather wastewater flow and pollutant concentration variations at key CSO drainage basins so that this information can be used to calibrate and verify hydrologic and hydraulic models of the CSSs for the combined communities within the PVSC service area.
- *CSO Characterization Study Modeling Report* (December 2003): This study developed a refined US EPA approved Storm Water Management Model of the PVSC interceptor sewer system and tributary collections systems. This report presents the data collection efforts, describes the model, discusses characterization of CSOs and presents an approach for estimating pollutant loads from drainage areas that were not monitored within the study area.
- *Combined Sewer System Modeling Study* (February 2004): This study succeeded the 2003 Characterization and was intended to calibrate and verify the combined sewer overflow model to represent the response of the PVSC combined sewer system to historical precipitation events using a US EPA approved Storm Water Management Model.

Between 2003 and 2007, the Bayonne MUA and North Bergen MUA conducted individual Combined Sewer Overflow Discharge Characterization Studies for all regulators and interceptor sewers owned and operated within their respective systems. The reports were developed under the following studies:

City of Bayonne

- *CSO Characterization Study Final Modeling Report Volumes I and II (November 2005);* Bayonne performed continuous rainfall monitoring; long-term flow monitoring at 8 stations both in-stream and at outfalls; and performed dry and wet weather monitoring and overflow water quality sampling at 3 locations. This effort informed the current sampling and modeling program effort by providing suitable locations to characterize the Bayonne system and will aid in calibration and verification of previously developed SWMM models of each Bayonne CSO drainage basin. It will also provide a baseline to compare dry and wet weather quality and quantity as well as a comparison of CSO flows and pollutant concentrations/loadings since the 2005 study.
- *CSO Discharge Characterization Study - Rainfall Monitoring Study Report (August 2006);*
  Bayonne conducted its rainfall monitoring program to develop an understanding of the rainfall characteristics of its service area, determine any correlation between rainfall characteristics and frequency of occurrence of CSO discharges, and establish a rainfall monitoring network. This information will supplement other rainfall data collected in as part of this characterization study to correlate the hydraulic and hydrologic response to rainfall of the combined sewer system.

North Bergen Municipal Utilities Authority

- *CSO Characterization Study Group 2 Dry Weather Quality and Quantity Monitoring Report (June 2003);*
- *CSO Characterization Study Water Quality and Quantity Monitoring Report (March 2005)*

These studies developed background information on the combined sewer systems tributary to each regulator as well as the analysis of historical rainfall patterns, overflow volumes and pollutants contained in the CSO discharges. The information collected and the modeling tools developed under these previous studies were supplemented and updated as part of the System Characterization and Landside Modeling Program Quality Assurance Project Plan (QAPP). Each section of the QAPP summarized the data collected under previous studies (performed under past QAPPs) and outlined the supplemental data collected under the most recent QAPP. Baseline Compliance Monitoring and Receiving Water Quality Modeling of the receiving waters were also addressed under separate QAPPs.

A.6 PURPOSE OF REPORT

Section D.3.b.i of the NJPDES permit indicates that as part of the LTCP requirements a System Characterization Work Plan must be completed and submitted to the NJDEP 6 months from the effective date of the permit. To meet this requirement, two System Characterization and Landside Modeling Program QAPPs were submitted for all eight CSO Permittees and PVSC to be executed and performed by the PVSC. See **Table A-1** for each Municipality and associated QAPP. The System Characterization and Landside Modeling Program includes the rainfall monitoring, wastewater sampling, collections system monitoring, modeling and other work necessary to characterize the CSO discharges from the participating municipalities and for

development of a collections system model for the purposes of evaluating CSO control alternatives and developing a CSO LTCP.

Table A-1: Municipality and associated QAPP submissions

Municipalities and Permittees	QAPP Submission
PVSC; East Newark Borough; Town of Harrison; Town of Kearny; City of Newark; City of Paterson	PVSC QAPP Part 1
Bayonne City; Jersey City MUA; North Bergen MUA	PVSC QAPP Part 2

NOTE: NBMUA (Woodcliff) and Guttenberg was included under separate QAPP.

In accordance with the PVSC and the eight CSO Permittee NJPDES Permits' LTCP requirements, a System Characterization Report shall be submitted by July 1, 2018. This System Characterization Report (SCR) has been developed to meet these permit requirements and incorporates the results of the Quality Assurance Project Plans (QAPPs) for the System Characterization and Landside Modeling Program, a summary of the Baseline Monitoring and Modeling Plan program, and the System Characterization mapping of the combined and separate sewer areas within the PVSC CSO Service District. Details of the Baseline Compliance Monitoring Program will be submitted under a separate Report. This System Characterization Report constitutes the PVSC CSO District Service Area *System Characterization Report* (SCR) developed on behalf of the following CSO Permittees:

- Paterson City
- Newark City
- Kearny Town
- Harrison Town
- East Newark Borough
- Bayonne City
- North Bergen MUA

Section G.1 of the PVSC NJPDES Permit Number NJ0021016 outlines the requirements of the System Characterization Monitoring and Modeling of the Combined Sewer system study that will provide a comprehensive characterization of the CSS.

The objective of the SCR is to provide NJDEP, PVSC, and the municipalities with a comprehensive and empirical understanding of the physical nature and hydraulic performance of

their respective sewerage systems for use in optimizing the performance of the current systems and in the development of CSO control alternatives

A.7 SUMMARY OF WORK PLANS/QAPP

In accordance with consultation with NJDEP as NJPDES permitting authority, the following QAPPs have been developed for PVSC to meet the permitting requirements to cover sampling and analysis of the stormwater, wastewater and receiving water of the service area.

1. **System Characterization and Landside Modeling Program QAPP,** which includes wastewater collection system sampling and analysis as well as landside modeling. The System Characterization and Landside Modeling Program QAPP outlines the program necessary to address this requirement of the Permit. **The results of the System Characterization Wastewater Collection System Sampling and analysis program are included in this System Characterization Report.**

2. **Baseline Compliance Monitoring QAPP,** which includes sampling and analysis of the receiving waters. **The results of the sampling and analysis of the Baseline Compliance Monitoring of the Receiving Waters will be included under a separate report; the *Compliance Monitoring Program Report.***

3. **Pathogen Water Quality Modeling QAPP;** which includes the computational model of the receiving waters **(Not a permit requirement).**

The project goals and objectives for the System Characterization and Landside Modeling Program included:

- Supplement and update, as appropriate, the site specific dry and wet weather data to be used to recalibrate and verify the InfoWorks collections system model of those collections systems tributary to the PVSC WRRF.
- Define the CSSs' hydraulic response to rainfall.
- Supplement the existing dry weather water quality and quantity data to be used in the representation of each CSO drainage basin.
- Determine the CSO flows and pathogen concentrations/loadings being discharged to the receiving streams as a result of varied rainfall events.
- Supplement the stormwater quality data for various land use applications.

PVSC and the eight CSO Permittees developed a monitoring program that collected dry and wet weather data that was used to calibrate and verify a hydraulic model for CSO basin upstream of the PVSC WRRF. This data also defined the combined sewer system response to rainfall and determined the quality and quantity of dry weather flow in the system as well as determine CSO flow quantities and pollutant concentrations/loadings discharged to receiving streams.

The purpose of the monitoring program was to quantify and qualify dry weather and wet weather wastewater flow and pathogen concentration variations at key CSO and stormwater drainage

basins to calibrate and verify hydrologic and hydraulic models (InfoWorks) of the CSSs within the Borough of East Newark, the Township of North Bergen, Towns of Harrison and Kearny, and the Cities of Bayonne, Newark and Paterson. This work was used to update the mathematical tool (sewer system model) used to assess residual storage and maximum hydraulic conveyance capacity in the PVSC, Bayonne and North Bergen interceptor system, pathogen concentrations and loading distributions during storm events and among CSO discharge points, calculate pathogen loads from CSOs and stormwater to the receiving water, and for the development and evaluation of long term control alternatives and/or modifications to the water quality standards (WQS) during wet weather events.

Data collected under the QAPPs was used to supplement the data from the 2003 CSO Characterization Study Modeling Report and the February 2004 CSO Modeling Study. The flow metering and CSO laboratory analytics were utilized in performing the following LTCP development tasks:

- Rainfall-Overflow Correlation Analysis
- Rainfall Event Characterization
- Collection System Model Validation
- Characterization of Sanitary, Stormwater and CSO Wastewater Quality

Wastewater quality sampling and flow metering were conducted in order to characterize the CSO quantity and quality for each of the combined sewer drainage areas. The characterization of the CSOs included determination of relationships between rainfall, runoff/overflow volume and pathogen loads. The data obtained was used in the validation of the InfoWorks Collections System Model for all the combined sewer drainage basins tributary to the PVSC control facilities, main interceptor sewer and force mains.

A.7.1 Receiving Waters Description

The receiving waters include the receiving waterbody of the combined sewer service area of the PVSC Sewer District and expand from this service area to include all receiving and adjacent downstream waters that may be potentially affected by CSOs from the various combined sewer service areas of the NJ CSO Group. Impacted waters include the Passaic River, Hackensack River, Newark Bay, Hudson River, Kill Van Kull, Arthur Kill, Raritan River and Raritan Bay, as well as their tributaries.

A.8 CONTENTS OF THIS REPORT

This report provides a comprehensive characterization of the CSS developed through records review, monitoring, modeling establishing the existing baseline conditions to evaluate the efficacy of the CSO technology based controls, and determine the baseline conditions upon which the LTCP will be based.

PVSC and the municipal permittees have developed a thorough understanding of their respective sewerage systems, the systems' responses to precipitation events of varying duration and

intensity, the characteristics of system overflows, and water quality issues associated with combined sewer overflows (CSOs) emanating from the systems and is presented in this report.

An overview of the organization and contents of this system characterization report are provided on **Table A-2**.

Table A-2: System Characterization Report Contents and Organization

Section		Topics Covered
A	Introduction and Background	Documents the problem definition, background, project description, summary and table of contents.
B	Regulatory Requirements	Describes the scope, purpose and regulatory context of the System Characterization Report.
C	Overview of Wastewater Facilities and Service Area	Characterizes the service area comprising the PVSC combined sewered municipalities that are the subject of this system characterization report and current wastewater treatment facilities within the service area.
D	Characteristics of the Combined Sewer System	Characterizes the municipal collection sewers, sewer mains, interceptors and appurtenances such as pump stations, existing CSO control facilities, regulator structures, and CSO outfalls.
E	Collection of Precipitation and Sewer Flow Monitoring	Documents the precipitation and flow monitoring programs, data analyses, integration of wastewater treatment plant operational data, data validation and QA/QC and presents the results of the analyses.
F	Characteristics of the Receiving Waters	Describes the watersheds, physical characteristics, and hydrodynamics of the receiving streams. Also describes the designated uses and current water quality compliance (e.g. 303(d) listings) and achievement of designated use status.
G	Collection of Water Quality Data	Documents the regulatory requirements for water quality data collection, historic water quality data collection, the water quality monitoring program and related QAPP and receiving water quality results.
H	Typical Hydrologic Period	Documents the requirements for and selection of the typical year and summarizes the hydrologic characteristics of the typical year.
I	Hydrologic and Hydraulic Modeling	Documents the development and scope of the H&H model used in this system characterization and to be used in the development of CSO control alternatives. The documentation includes model inputs, sensitivity analyses, model calibration and validation and modeling results.
J	References	
K	Abbreviations	

SECTION B - REGULATORY REQUIREMENTS

B.1 INTRODUCTION

This document constitutes the PVSC SCR developed by PVSC on behalf of the municipalities and municipal authorities served by PVSC that are listed below in **Table B-1**. The SCR provides a "Characterization Monitoring and Modeling of the Combined Sewer System" under Part IV Section G.1 of the municipalities' respective New Jersey Pollutant Discharge Elimination System (NJPDES) permit.

Table B-1: Permittees Covered Under this System Characterization Report

Municipality	NJPDES #
PVSC	NJ0021016
Borough of East Newark	NJ0021016
Town of Harrison	NJ0108871
Town of Kearny	NJ0111244
City of Newark	NJ0108758
City of Paterson	NJ0108880
City of Bayonne	NJ0209240
North Bergen MUA	NJ0108898

B.2 REGULATORY CONTEXT

B.2.1 NJPDES Permit Requirements

Under Section 402 of the CWA, all point source discharges to the waters of the United States must be permitted. USEPA Region II has delegated permitting authority in New Jersey to the New Jersey Department of Environmental Protection (NJDEP). The permits are reissued on a nominal five-year cycle. All twenty-one New Jersey municipalities and municipal authorities with CSSs were issued new permits in 2015 that set forth requirements for the completion of the system characterization and the development of LTCPs on the following schedule:

- System Characterization Work Plan (QAPP) must be completed and submitted to the NJDEP 6 months from the effective date of the permit – January 1, 2016
- Submittal of the System Characterization Report to NJDEP - July 1, 2018;
- (LTCP Report 1) Development & Evaluation of CSO Control Alternatives - July 1, 2019; and
- (LTCP Report 2) Selection and Implementation of Alternatives - July 2020.

The System Characterization Reports are to be updates to and to utilize where applicable, previous system inventories and evaluations such as the *Sewage Infrastructure Improvement Act Planning Studies* conducted in the late 1990s. The municipalities documented their implementation of the nine minimum controls under an earlier NJPDES permit cycle. With minor exceptions such as lists of applicable previous studies, the 2015 permits are standardized. The 2015 major elements to be included in the System Characterization Report are outlined in Part IV (Specific Requirement: Narrative) paragraphs G.1.d.i through G.1.d.v. of the

permits. These requirements are reproduced on **Table B-2** along with the section of this SCR in which the requirements are addressed.

Table B-2: Review of Major Elements of the System Characterization Report

Permit Section	Permit Requirement	SCR Section
Part IV G.1.a	"The permittee, as per D.3.a and G.10, shall submit an updated characterization study that will result in a comprehensive characterization of the CSS developed through records review, monitoring, modeling and other means as appropriate to establish the existing baseline conditions, evaluate the efficacy of the CSO technology based controls, and determine the baseline conditions upon which the LTCP will be based. The permittee shall work in coordination with the combined sewer communities for appropriate Characterization, Monitoring and Modeling of the Sewer System."	Entire SCR
Part IV G.1.b	"The characterization shall include a thorough review of the entire collection system that conveys flows to the treatment works including areas of sewage overflows, including to basements, streets and other public and private areas, to adequately address the response of the CSS to various precipitation events"	Section C: ***Overview of Wastewater Treatment Facilities and Service Areas***
		Section D: ***Characteristics of the Combined Sewer System***
	"The characterization shall identify the number, location, frequency and characteristics of CSOs"	Section I ***Hydrologic and Hydraulic Modeling***
	"The characterization shall identify water quality impacts that result from CSOs"	Section G: ***Collection of Water Quality Data***
		Section F: ***Characteristics of the Receiving Waters***
Part IV G.1.c	"The permittee may use previous studies to the extent that they are accurate and representative of a properly operated and maintained sewer system and of the currently required information"	Applicable data from the cited references have been utilized throughout the appropriated sections of this SCR.

Permit Section	Permit Requirement	SCR Section
Part IV G.1.d.i	Rainfall Records Analysis	Section E: ***Collection of Precipitation and Sewer Flow Monitoring***
		Section H: **Typical Hydrologic Period**
Part IV G.1.d.ii	Combined Sewer System Characterization	Section D: ***Characterization of the Combined Sewer System***
Part IV G.1.d.iii	CSO Monitoring	
Part IV G.1.d.iv	System Hydrologic & Hydraulic Modeling	Section I: ***Hydrologic & Hydraulic Modeling***
Part IV G.1.d.v	The permittee shall identify sensitive areas where CSOs occur	Section F: **Characteristics of Receiving Waters**

B.2.2 USEPA's CSO Control Policy

USEPA's CSO Control Policy (Policy) was issued in April of 1994[2] to elaborate on the 1989 National CSO Control Strategy and to expedite compliance with the requirements of the Clean Water Act (CWA). The Policy provided guidance to municipal permittees with CSOs, to the state agencies issuing National Pollution Discharge Elimination permits (e.g. NJDEP and NJPDES permits) and to state and interstate water quality standards authorities (e.g. the Interstate Environmental Commission).[3] The Policy establishes a framework for the coordination, planning, selection and implementation of CSO controls required for permittee compliance with the Clean Water Act (CWA).

2 59 FR 18688 et seq.

3 The Interstate Environmental Commission (IEC) is a tri-state air and water pollution control agency—that is, a joint agency—serving the states of New York, New Jersey, and Connecticut.

The Policy includes three major activities required of municipalities with CSO related permits:

- ***System Characterization*** – The identification of current combined sewer system assets and current performance characteristics;
- ***Implementation of the Nine Minimum Controls***[4] – identified in the Policy to ensure that the current combined sewer system is being optimized and property maintained; and
- ***Development of a Long-Term Control Plan (LTCP)*** – The analysis and selection of long term capital and institutional improvements to the combined sewer system that once fully implemented will result in compliance with the CWA.

The Policy includes provisions for public and stakeholder involvement (e.g. the CSO Supplemental Committees), the assessment of affordability (rate-payer impacts) and financial capability (permittee ability to finance the long-term controls) as a driver of implementation schedules and two CSO control alternatives. The "presumption" approach is premised on the presumption that the achievement of certain performance standards, e.g. no more than an average of four overflow events per year; or the elimination or capture of at least 85% by volume of the combined sewage collected in the CSS during precipitation events; or the elimination or removal of no less than the mass of the pollutants for the volumes that would be eliminated or captured, would result in CWA compliance subject to post-implementation verification. Under the "demonstration" approach, permittees demonstrate that their proposed controls do not preclude the attainment of water quality standards.

The Policy includes regulations for the collection of water quality data required of municipalities with CSO related permits. Section II.C.1 of the CSO Control Policy "Characterization, Monitoring and Modeling of the Combined Sewer System" states:

> *"In order to design a CSO control plan to adequately meet the requirements of the CWA, a permittee should have a thorough understanding of its sewer system, the response of the system to various precipitation events, the characteristics of the overflows, and the water quality impacts that result from CSOs. The permittee should adequately characterize through monitoring, modeling, and other means as appropriate, for a range of storm events, the response of its sewer system to wet weather events including the number, location and frequency of CSOs volume, concentration and mass of pollutants discharged and the impacts of the CSOs on the receiving waters and their designated uses."*

[4] The nine minimum controls include: 1) proper operation and regular maintenance; 2) maximizing the use of the collection system for storage where feasible; 3) review and modification of the Industrial Pretreatment Program to minimize CSO impacts; 4) maximization of flow to the wastewater treatment plant; 5) the prohibition of CSOs during dry weather; 6) control of solids and floatables (addressed by NJDEP's requirement of screening or other facilities in the late 2000s); 7) pollution prevention; 8) public notification; and 9) monitoring CSO impacts and controls. 59 FR 18691.

The CSO Control Policy states that the major elements of a sewer system characterization include:

Rainfall Records

"The permittee should examine the complete rainfall record for the geographic area of its existing CSS using sound statistical procedures and best available data. The permittee should evaluate flow variations in the receiving water body to correlate between CSOs and receiving water conditions."

Combined Sewer System Characterization

"The permittee should evaluate the nature and extent of its sewer system through evaluation of available sewer system records, field inspections and other activities necessary to understand the number, location and frequency of overflows and their location relative to sensitive areas and to pollution sources in the collection system, such as indirect significant industrial users."

CSO Monitoring

"The permittee should develop a comprehensive, representative monitoring program that measures the frequency, duration, flow rate, volume and pollutant concentration of CSO discharges and assesses the impact of the CSOs on the receiving waters."

Modeling

"Modeling of a sewer system is recognized as a valuable tool for predicting sewer system response to various wet weather events and assessing water quality impacts when evaluating different control strategies and alternatives. EPA supports the proper and effective use of models, where appropriate, in the evaluation of the nine minimum controls and the development of the long-term CSO control plan."

B.2.3 USEPA CSO Guidelines

The data collection, analyses and this characterization report were written and conducted in conformance with the applicable USEPA guidance documents as shown in **Table B-3**.

Table B-3: USEPA Guidance Documents Used in the Preparation of the System Characterization Report

	Title	Date	Document Number
1	Combined Sewer Overflows Guidance for Long-Term Control Plan	1995	EPA 832-B-95-002
2	Combined Sewer Overflows Guidance for Screening and Ranking	1995	EPA 832-B-95-004
3	CSO Post Construction Compliance Monitoring Guidance	2011	EPA-833-K-001

	Title	Date	Document Number
4	Guidance for Quality Assurance Project Plans	2002	EPA/240/R-02/009
5	Guidance: Coordinating CSO Long-Term Planning with Water Quality Standards Reviews	2001	EPA-833-R-01-002
6	Manual: Combined Sewer Overflow Control	1993	EPA/625/R-83-007
7	NPDES Permit Writer's Manual	2010	EPA-833-K-10-001
8	Sewer System Infrastructure Analysis & Rehabilitation	1991	EPA/625/6-91-030
9	Water Quality Standards Handbook: Second Edition	1994	EPA 823-B-94-005
10	Water Quality Standards Handbook: Second Edition	2007	

B.2.4 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

Section 303(d) of the federal Clean Water Act or "CWA" (33 USC § 1251 et seq.) requires each state to identify those waters for which effluent limitations are not stringent enough to attain applicable water quality standards; establish a priority ranking for such waters based on extent of water quality impairment and designated use non-support; establish a total maximum daily load (TMDL) for each pollutant causing water quality impairment, based on their priority ranking, at a level necessary to attain applicable water quality standards; and submit a list to USEPA of all impaired waters and their pollutant causes (i.e., the 303(d) List).

The New Jersey Department of Environmental Protection (NJDEP) has established the 2014 New Jersey Integrated Water Quality Assessment Report. The primary source of information regarding causes of impairment, and the Total Maximum Daily Load (TMDL) status of the water bodies (if any) is the 2014 New Jersey Integrated Water Quality Assessment Report, which satisfies New Jersey's requirement of both Section 303(d) and 305(b) of the Clean Water Act (CWA). The NJDEP Website explains the categories as shown in **Table B-4**.

Table B-4: Components of New Jersey's Integrated List of Water (Integrated List)

Sublist	Component
Sublist 1	An assessment unit is fully supporting all applicable designated uses and no uses are threatened. (The Department does not include the fish consumption use for determining placement on this sublist.)
Sublist 2	The assessment unit is fully supporting the designated use but is not supporting all applicable designated use(s).
Sublist 3	Insufficient data and information are available to determine if the designated use is fully supported.
Sublist 4	One or more designated uses are not supported or are threatened but TMDL development is not required because of one of the following reasons:

Sublist	Component
Sublist 4A	A TMDL has been completed for the parameter causing designated use non-support.
Sublist 4B	Other enforceable pollutant control measures are reasonably expected to result in fully supporting the designated use in the near future.
Sublist 4C	Non-support of the designated use is caused by something other than a pollutant.
Sublist 5	One or more designated uses are not supported or are threatened by a pollutant(s) that requires development of a TMDL.
Sublist 5A	Arsenic does not attain standards, but concentration are below those demonstrated to be from naturally occurring conditions.
Sublist 5L	Designated use impairment is caused by a "legacy" pollutant that is no longer actively discharged by a point source.
Sublist 5R	Water quality impairment is not effectively addressed by a TMDL, such as nonpoint source pollution that will be controlled under an approved watershed restoration plan or 319(h) Watershed Based Plan.

The Sublist 5 list constitutes the Section 303(d) list that the USEPA will approve or disapprove under the CWA. For the purposes of the determination of Pollutants of Concern, Sublists 4A and 5 are the relevant categories as they indicate the need for a TMDL in the receiving water body and the limiting of additional loadings for those parameters.

B.2.5 Interstate Environmental Commission Requirements

With the exception of the City of Paterson, the municipalities and authorities covered by this System Characterization Report fall within the jurisdiction of the Interstate Environmental Commission (IEC). The Interstate Environmental Commission (IEC) is a tri-state air and water pollution control agency serving the states of New York, New Jersey, and Connecticut. The Commission and its area of jurisdiction were established in 1936 under a instate compact, with the consent of Congress. The IEC establishes the receiving stream water quality standards to which NJPDES permittees are subject under the federal Clean Water Act[5] and the New Jersey Water Pollution Control Act.[6]
The IEC has specified two classes of waters:[7]

Class A Waters - Class A waters are suitable for all forms of primary and secondary contact recreation and for fish propagation, including shellfish harvesting in designated areas. There are no Class A waters within the receiving waters of the PVSC combined sewered municipalities.

Class B Waters – IEC identified two sub-classes:

- **Class B-1** – the IEC water quality standards specify that Class B-1 waters remain "Suitable for fishing and secondary contact recreation. They shall be suitable for the

5 33 U.S.C. Chapter 26
6 N.J.S.A 58:10A-1 et seq.
7 Source: IEC website: http://www.iec-nynjct.org/wq.regulations.htm

growth and maintenance of fish life and other forms of marine life naturally occurring therein, but may not be suitable for fish propagation."

- **Class B-2** – the IEC water quality standards specify that Class B-2 waters remain: "Suitable for passage of anadromous fish and for the maintenance of fish life in a manner consistent with the criteria established by the general regulations."

The IEC water quality standard classification zones applicable to the PVSC combined sewered municipalities are shown on **Figure B-1**.

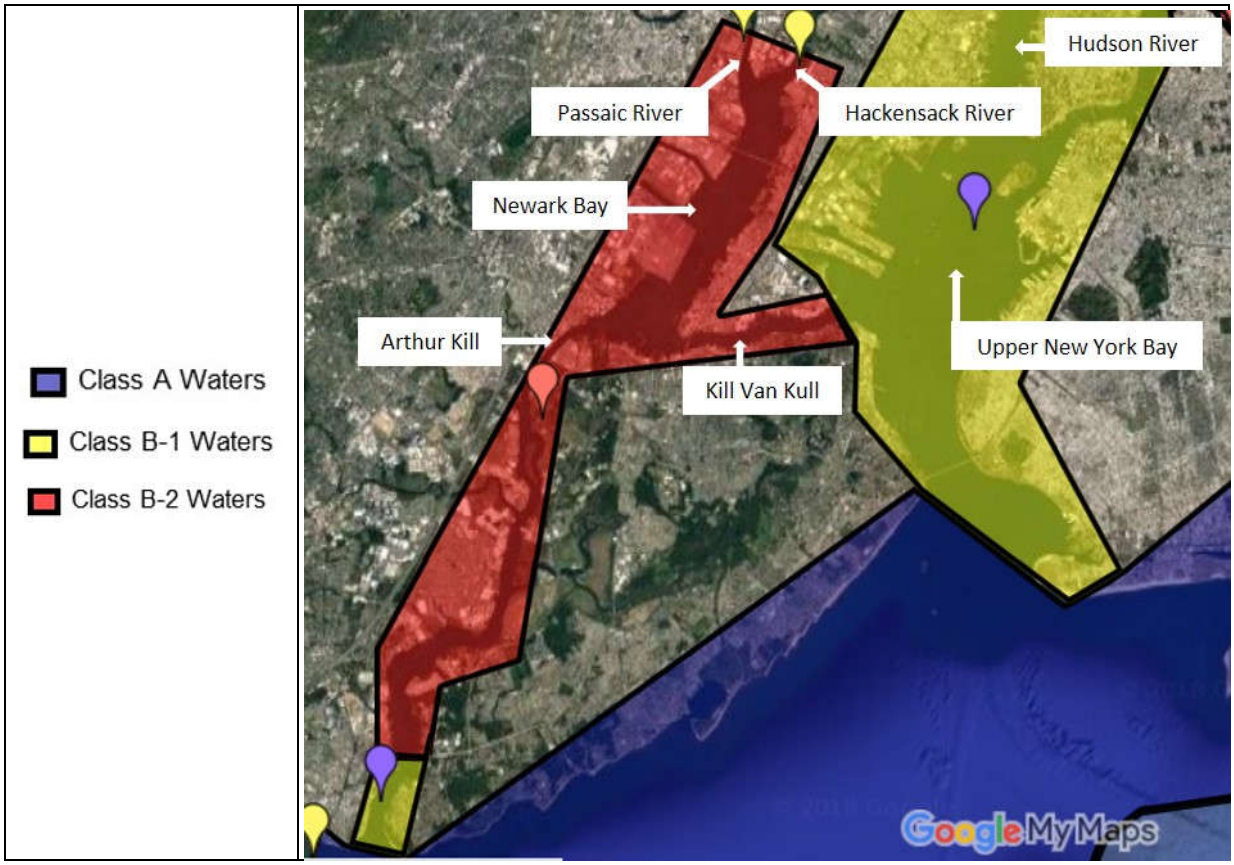


Figure B-1: Interstate Environmental Commission Water Quality Classifications

As shown on **Figure B-1**, the mouth of the Passaic River, the mouth of the Hackensack River, Newark Bay and the Kill Van Kull are classified as B-2 waters and the Upper Bay (Hudson River) is classified as B-1. Water quality standards applicable to Class B-1 and Class B-2 waters relevant to CSO discharges are provided in **Table B-5** below.

Table B-5: IEC Water Quality Standards for IEC Class B Waters

Water Quality Parameter	Value
Dissolved Oxygen	
Class B-1	≥ 4 milligrams per liter
Class B-2	≥ 5 milligrams per liter
Classes B-1 & B-2	Further, all sewage or other polluting matter discharged or permitted to flow into waters of the District shall first have been so treated as to effect a reduction in the oxygen demand of the effluent sufficient to maintain the applicable dissolved oxygen requirement in the waters of the District and also maintain the dissolved oxygen content in the general vicinity of the point of discharge of the sewage or other polluting matter into those waters, at a depth of about five feet below the surface.
Fecal Coliform (effluent discharges)	• 200 per 100 ml on a 30 consecutive day geometric average; • 400 per 100 ml on a 7 consecutive day geometric average; • 800 per 100 ml on a 6 consecutive hour geometric average; and • no sample may contain more than 2400 per 100 ml.
General Requirements	
• All waters of the Interstate Environmental District (whether of Class A, Class B, or any subclass thereof) shall be of such quality and condition that they will be free from floating solids, settleable solids, oil, grease, sludge deposits, color or turbidity to the extent that none of the foregoing shall be noticeable in the water or deposited along the shore or on aquatic substrata in quantities detrimental to the natural biota; nor shall any of the foregoing be present in quantities that would render the waters in question unsuitable for use in accordance with their respective classifications.	
• No toxic or deleterious substances shall be present, either alone or in combination with other substances, in such concentrations as to be detrimental to fish or inhibit their natural migration or that will be offensive to humans or which would produce offensive tastes or odors or be unhealthful in biota used for human consumption.	
• No sewage or other polluting matters shall be discharged, permitted to flow into, be placed in, or permitted to fall or move into the waters of the District, except in conformity with these regulations.	

The IEC website states:

> *"An effluent discharge which does not satisfy the requirements of the Commission shall not be considered to be in violation thereof if caused by temporary excess flows due to storm water conveyed to treatment plants through combined sewer systems, provided that the discharger is operating the facility with reasonable care, maintenance, and efficiency and has acted and continues to act with due diligence and speed to correct the condition resulting from the storm water flow.*

Unless there has been rainfall in greater than trace amounts or significant melting of frozen precipitation during the immediately preceding 24 hours, no discharges to the waters of the Interstate Environmental District shall occur from combined sewer regulating devices."

Additional information relating to the applicable water quality standards and the current use attainment status of the receiving waters is provided in Section F of this report.

B.2.6 New Jersey Administrative Code

New Jersey Administrative Code (NJAC) Section 7:9B Surface Water Quality Standards lists the classifications, designated uses, and water quality criteria for all New Jersey water bodies. The classification and water quality standards for the CSO receiving waters within the PVSC CSO Sewer District are shown in **Table B-6** below.

Table B-6: The NJ Administrative Code Classifications of PVSC Sewer District CSO Receiving Waters

Waterbody	Reach	Classification
Passaic River	Paterson - Outlet of Osborn Pond to Dundee Lake dam	FW2-NT
	Little Falls - Dundee Lake dam to confluence with Second River	FW2-NT/SE2
	Newark (@ Second River)	SE3
Hackensack River	Kearny Point	SE3
Hudson River	Englewood Cliffs	SE2
Kill Van Kull	Kill Van Kull	SE3
Newark Bay	Newark Bay	SE3

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 ml)
FW2-NT (Fresh Water Non Trout)	1. Maintenance, migration and propagation of the natural and established biota; 2. Primary contact recreation; 3. Industrial and agricultural water supply; 4. Public potable water supply after conventional filtration treatment (a series of processes including filtration, flocculation, coagulation, and sedimentation, resulting in substantial particulate	E. Coli	126 GM, 235 SSM

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 ml)
	removal but no consistent removal of chemical constituents) and disinfection; and 5. Any other reasonable uses.		
SE2 (Saline Water)	1. Maintenance, migration and propagation of the natural and established biota; 2. Migration of diadromous fish; 3. Maintenance of wildlife; 4. Secondary contact recreation; and 5. Any other reasonable uses.	Fecal Coliform	770 GM
SE3 (Saline Water)	1. Secondary contact recreation; 2. Maintenance and migration of fish populations; 3. Migration of diadromous fish; 4. Maintenance of wildlife; 5. Any other reasonable uses.	Fecal Coliform	1500 GM

* *"The geometric mean shall be calculated using a minimum of five samples collected over a thirty-day period"*

A map showing the NJAC classifications for all of the waterbodies is found below as **Figure B-2**.

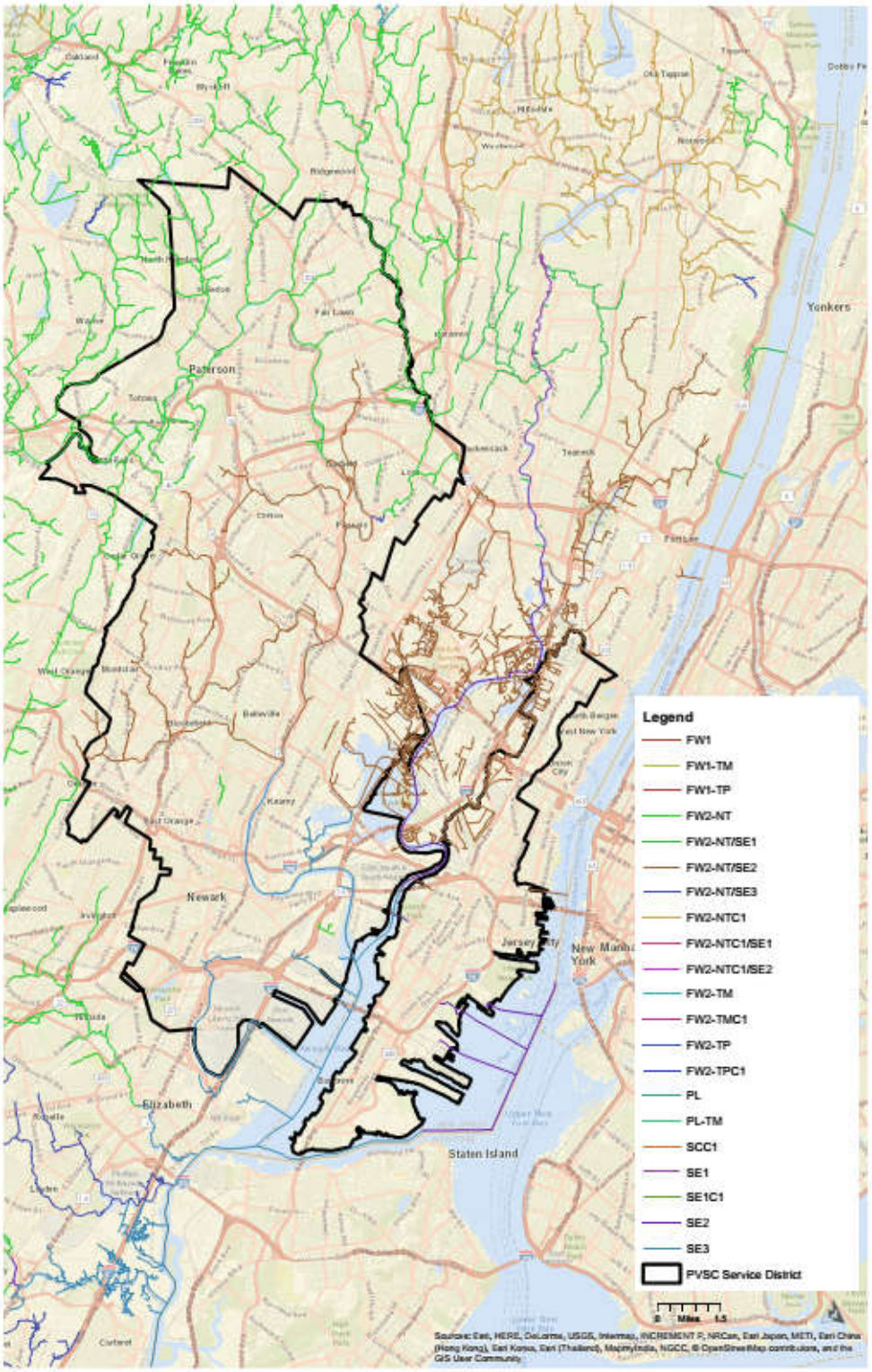


Figure B-2: NJAC Classifications of PVSC Sewer District Waterbodies

SECTION C - OVERVIEW OF WASTEWATER TREATMENT FACILITIES AND SERVICE AREAS

C.1 WASTEWATER TREATMENT FACILITIES

Passaic Valley Sewerage Commission

PVSC owns and operates a 330 million gallons per day (MGD) WRRF that covers approximately 142 acres and is located in an industrial area of Newark, NJ. A detailed schematic of the PVSC Service Area can be seen in **Figure C-1**.

The PVSC Facility receives flow from three sources: the Main Interceptor Sewer, the South Side Interceptor, and flow from Hudson County. The Main Interceptor is approximately 22 miles long and is routed from the City of Patterson in Passaic County to the WRRF in the City of Newark in Essex County, generally following the west bank of the Passaic River. The South Side Interceptor is approximately six (6) miles long and is located entirely within the City of Newark. The Main and South Side Interceptor's direct flow to the Headworks that includes a channelized Forebay that divides flow between six (6) grit channels. Wastewater is screened and degritted and moved through an effluent channel to the Influent Pumping Station. Flow is then lifted by six (6) Archimedes screw pumps to Primary Clarifiers. The Hudson County flow, which includes flow from the cities of Jersey City, Bayonne, North Bergen and South Kearny, enters the plant downstream of the Forebay just before the Primary Clarifiers. The combined flows then enter secondary treatment consisting of Aeration Tanks which utilize a pure oxygen activated sludge process and Final Clarifiers. Treated wastewater is disinfected with sodium hypochlorite as it enters the Effluent Pumping Station and is pumped to one of two outfalls. The main outfall discharges to Upper New York Bay, and flow in excess of the capacity of the main outfall flows to a chlorine contact tank prior to reaching the Newark Bay secondary outfall

Solids Treatment at the WRRF takes primary sludge from the Primary Clarifiers and Waste Sludge from the Aeration Tanks and transports them to gravity Sludge Thickeners. Thickened sludge then enters the Thickening Centrifuges to reduce its liquid volume. A wet-air oxidation process, known as Zimpro, conditions the sludge for dewatering before it is further reduced in volume in Decant Tanks. Sludge enters the final processing steps in filter presses and storage in cake silos prior to beneficial use.

North Bergen Municipal Utilities Authority

The North Bergen Township MUA owned and operated a small wastewater treatment plant called the Central Treatment Plant until its closure in October of 2010. The Central Treatment Plant was replaced with the Central Pump Station. The Township's wastewater from the original service area of the Central Treatment Plant, about 7 MGD, is now pumped to JCMUA's collection system for treatment at the PVSC WRRF. The remainder of the Township's wastewater that is generated outside of the service area of the Central Treatment Plant flows to the Woodcliff Sewage Treatment Plant (STP). The NBMUA also owns and operates the Woodcliff Sewage Treatment Plant (STP) and hold a separate NJPDES permitted for this plant discharge. The Woodcliff STP plant receives flow from the northeastern portion of North Bergen service area, and from the Town of Guttenberg. Approximately 3 MGD is treated at the

Woodcliff Sewage Treatment Plant (STP) in North Bergen and discharged into the Hudson River. Details regarding the NBMUA Woodcliff STP and its service area can be found in the report titled *Service Area System Characterization Report: NBMUA Woodcliff STP and Guttenberg (WCGB), dated June 2018*.

C.2 PVSC SEWER DISTRICT SERVICE AREA

The PVSC Sewer District service area is comprised of combined sewer areas and separate sewer areas that contribute flow to the PVSC WRRF. The combined sewer areas include several different municipalities who own and operate the CSSs and the combined sewer outfalls located within their jurisdiction. Separate sewer areas comprise the majority of the drainage area but only contributes approximately 40 percent of the flow to the PVSC WRRF. **Figure C-1** shows the municipalities and the type of sewer network they operate.

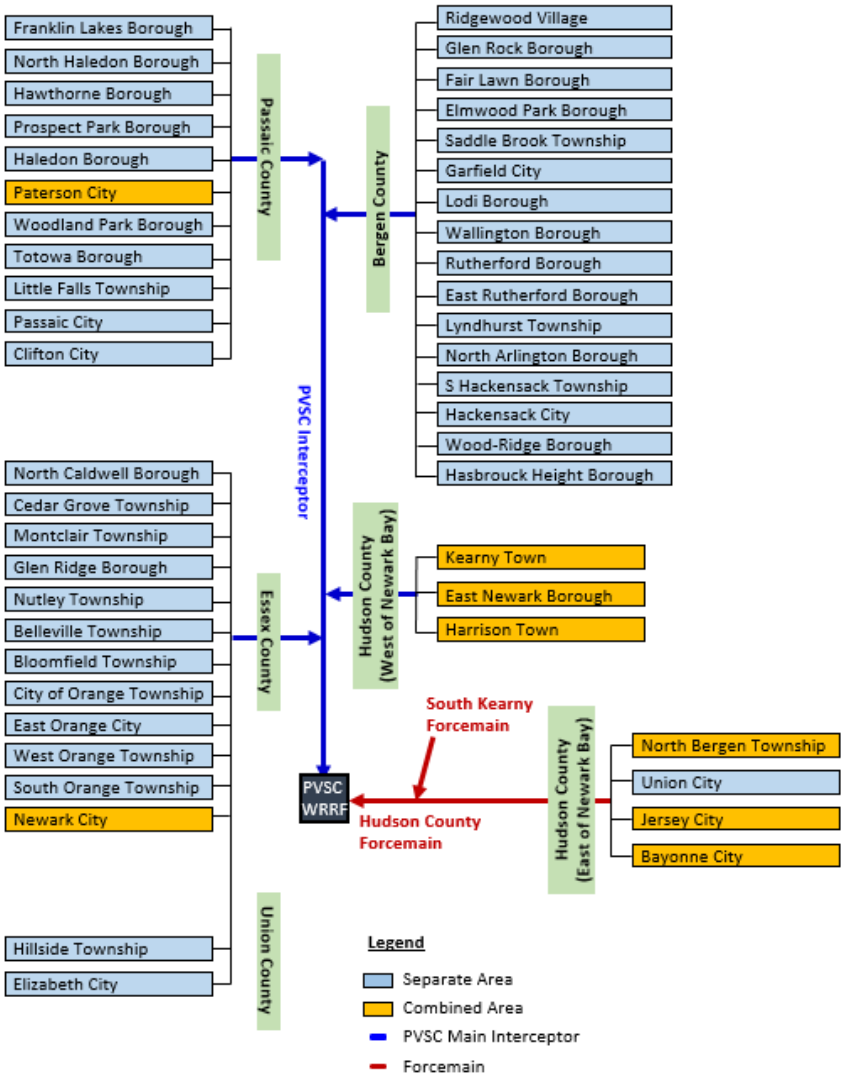


Figure C-1: PVSC Municipalities

C.2.1 Combined Sewer Service Area

Combined sewers, which serve eight of the municipalities within the PVSC Sewer District and collect surface runoff from the combined sewer service area. The total combined area is approximately 22,099 acres and makes up approximately 26 percent of the Total Contributing Area. The eight municipalities, their service area acreage and the number of CSO outfalls are listed in **Table C-1** below. All eight municipalities are authorized to discharge under their respective NJPDES Permits for Combined Sewer Management. PVSC does not own or operate any combined sewer outfalls. PVSC owns and operates CSO Facilities such as regulators, and netting facilities but the combined sewer outfalls are owned by other permittees.

Table C-1: Combined and Separate Sewer Service Area Municipalities

Municipality	Contributing area (acres)		Total Contributing Area (acres) [1]	Number of CSOs Located within Service Area
	Combined	Separate & Storm		
Bayonne City	1,706	36	1,742	28
East Newark Borough	62	0	62	1
Harrison Town [2]	423	354	771	6
Jersey City [3]	5,365		5,365	21
Kearny Town	1,243	2,763	4,006	5
Newark City	7,153	2,883	10,036	18
North Bergen MUA [4]	1,552	39	1,591	9
Paterson City	4,595	600	5,195	23
Subtotal	22,099	6,675	28,774	111
40 Separate Sanitary Communities		55,214	55,214	--
Total	22,099	61,889	83,988	111

Note:

1. The total acreage in the table above includes only the subcatchment areas in the model that contribute flow to the PVSC WRRF. The acreage does not include rivers, creeks or unsewered areas within a municipality.
2. Harrison's NJPDES permit currently includes 7 outfalls. NJDEP will be issuing Harrison a minor modification NJPDES permit action to remove Dey Street outfall 004A in the near future.
3. Jersey City will provide details of this information separately as part of its System Characterization Report.
4. NBMUA (Woodcliff) and Guttenberg will provide this information separately as part of its System Characterization Report.

The combined sewer municipalities on the east side of Newark Bay include the Cities of Jersey City and Bayonne, and the Township of North Bergen. These municipalities deliver their combined sewage through the Hudson County force main into the PVSC primary clarifiers at the PVSC WRRF. Two of the combined sewer municipalities, the City of Bayonne and Jersey City MUA, own their own CSSs, interceptors, CSO control facilities, and pumping stations. Bayonne and Jersey City jointly own the force main used to transport wastewater from the CSO area east of the Newark Bay in Hudson County, to the primary clarifiers at the PVSC WRRF in Newark. PVSC does not own or operate any of the combined sewer overflow control or transportation facilities which service this section of the District. Jersey City MUA is included in the above description, however it will submit its own System Characterization report separately.

The other five municipalities with CSSs are located on the west side of Newark Bay include the Borough of East Newark, the Towns of Harrison and Kearny, and the Cities of Newark and Paterson. These municipalities all own and operate their CSS and permitted by the NJDEP to discharge CSOs. All of these municipalities are tributary to the PVSC Main Interceptor. A portion of the CSSs are tributary to CSO control facilities owned and/or operated by the individual Permittees/Municipalities and a portion of the CSO control facilities are owned and/or operated by PVSC. PVSC owns and operates 45 of the regulator chambers in these communities that control the sewer flow to the PVSC trunk system.

These combined sewer municipalities collectively own and operate a total of 111 CSO outfalls in PVSC's existing Service Area, which ultimately discharge to the waterbodies shown in **Figure C-2**.

City of Bayonne

The City of Bayonne is located in Hudson County and has an approximate population of 63,024 (2010 US Census Bureau). The City is located on a peninsula within the New Jersey – New York Metropolitan Area. It is surrounded by Jersey City to the North, Newark Bay to the west, Kill Van Kull Channel to the south, and the Upper New York Bay, which separates it from the Borough of Manhattan, to the east. The City consist of a land area of approximately 3,200 acres of which approximately 1,742 acres are serviced by the combined sewer system.

The industrial section on the East side of the City at Constable Hook, is serviced primarily by a separate sewer system. Wastewater flows from the City of Bayonne, the Town of Kearny and Jersey City are conveyed to the Passaic Valley Sewerage Commissioners (PVSC) by a force main owned partially by PVSC and jointly by the City of Bayonne and the Jersey City MUA. The flow from the force main enters directly into the primary treatment facility at the PVSC WRRF. Under the current service agreement, wastewater flows from the City of Bayonne are restricted to an average daily flow of 11 MGD and a Peak flow of 17.6 MGD. The City of Bayonne entered into a forty (40) year agreement with United Water, now SUEZ, for operations and maintenance of the City's water and wastewater collection and transport facilities in December 2012. The Bayonne MUA was dissolved in 2016 as a result of this new agreement with United Water.

Township of North Bergen

The Township of North Bergen is located in Hudson County and has an approximate population of 60,773 (2010 US Census Bureau). The Township.is located between the Hackensack and Hudson Rivers, and is bordered by Ridgefield, Cliffside Park, Secaucus, Guttenberg, Union City and Jersey City. The total area of the Township is approximately 2,060-acres, where approximately 1,130 acres is serviced by the CSS and the balance is serviced by separate systems for sanitary and storm flows.

North Bergen consists of two combined sewer areas, Central and Woodcliff area. North Bergen Township owns and operates the manholes and sewer systems in both of these areas. The North Bergen Municipal Utilities Authority (MUA) owns and operates the regulators, interceptors, outfalls, CSO facilities and the Woodcliff STP under two separate NJPDES permits; NBMUA and NBMUA (Woodcliff). The largest combined sewer area is located in the central and western portions of the Township of North Bergen. The combined sewage in the Central/ Western section of North Bergen Township is conveyed via a pump station and force main to the Jersey City MUA where the flow is then pumped to PVSC's WRRF via the Hudson County force main. The second combined sewer area is generally located on the northeast side of North Bergen, to the east of Bergenline Avenue, and is connected to the North Bergen MUA's Woodcliff STP. The Woodcliff STP service area is separate from the PVSC service area and is covered in a separate System Characterization Report.

Borough of East Newark

East Newark is located in the western section of Hudson County and has an approximate population of 2,406 (2010 US Census Bureau). The Borough is bounded by the Passaic River and Newark to the west, the Town of Harrison on the southeast and the Town of Kearny on the northeast. The Borough encompasses approximately 72.5-acres and its land use is varied. East Newark mainly consists of high density residential and industrial areas primarily located along the Passaic River. According to the Service Area Drainage and Land Use Report prepared by Killam Associates in February of 1996 the municipality consists of 58% of industrial and 42 *%* of residential. Impervious surfaces (such as rooftops, driveways, parking lots, and roadways) encompass roughly 77% percent of the Borough.

Town of Harrison

The Town of Harrison is located in Hudson County and has an approximate population of 13,620 (2010 US Census Bureau). The Town is bounded by the Town of Kearny and the Borough of East Newark to the north and the Passaic River to the south. Harrison comprises an area of approximately 1.3 square miles.

Town of Kearny

The Town of Kearny is located in the northwest corner of Hudson County and has an approximate population of 40,684 (2010 US Census Bureau). Kearny is bounded by the Hackensack River and Jersey City on the east, East Newark and Harrison on the south, the Passaic River and Belleville on the west, and North Arlington on the north.

The total area of Kearny is approximately 10.19 square miles, of which 9.14 sq. mi. is land area and 1.05 sq. mi is water area. The 9.14 square miles within the Town's boundaries are divided into three- (3) broad sections, referred to locally as the "Uplands", the "Hackensack Meadowlands" and "South Kearny". Of the total land area, an estimated 21% is residential and commercial and 20% is industrial. The Hackensack Meadowlands area covers approximately 59%, or 5.5 square miles, of the Town's land area.

City of Newark

The City of Newark is located in Essex County and has a approximate population of 277,140 (2010 US Census Bureau). The City is situated to the west of the Passaic River and Newark Bay, and to the north of the Peripheral Ditch which flows into the Elizabeth Channel of Newark Bay. The City covers an area of approximately 24 square miles and presently owns and maintains approximately 298 miles of sanitary and combined sewers. The City is mostly served by the Passaic Valley Sewerage Commissioners with approximately 5% of the city served by the Joint Meeting of Union and Essex Counties.

City of Paterson

The City of Paterson is located within Passaic County and has an approximate population of 146,199 (2010 US Census Bureau). The City is bounded on the west by the Boroughs of West Paterson and Totowa, on the north by the Passaic River and the Boroughs of Haledon and Prospect Park, on the east by the Passaic River and the Boroughs of Elmwood Park and Fairlawn, and the south by the City of Clifton. The City consists of approximately 5,290 acres.

C.2.2 Separate Sewer Service Area

In addition to the municipalities with combined systems, separately sewered municipalities convey their flow to the Main Interceptor Sewer through 13 branch intercepting sewers and various direct sewer connections. Forty of the 48 municipalities in the service area have separate sewer systems (does not include storm water), and, therefore, do not own or operate any CSOs. Separate sewer systems make up 61,889 acres of the PVSC service area which is approximately 74 percent of the Total Contributing Area. In all but one municipality with a separate sewer system, sewage discharges to the PVSC Main Interceptor and is conveyed to the PVSC WRRF via this interceptor; Union City's sewage flow is conveyed through the Hudson County Force Main and is discharged upstream of the Primary Clarifiers at the PVSC WRRF. See **Table C-1** above for details regarding separate and combined sewer area.

The following Passaic County towns and boroughs listed in **Table C-2** below contribute separate sewage flow to the PVSC WRRF through the Main Interceptor.

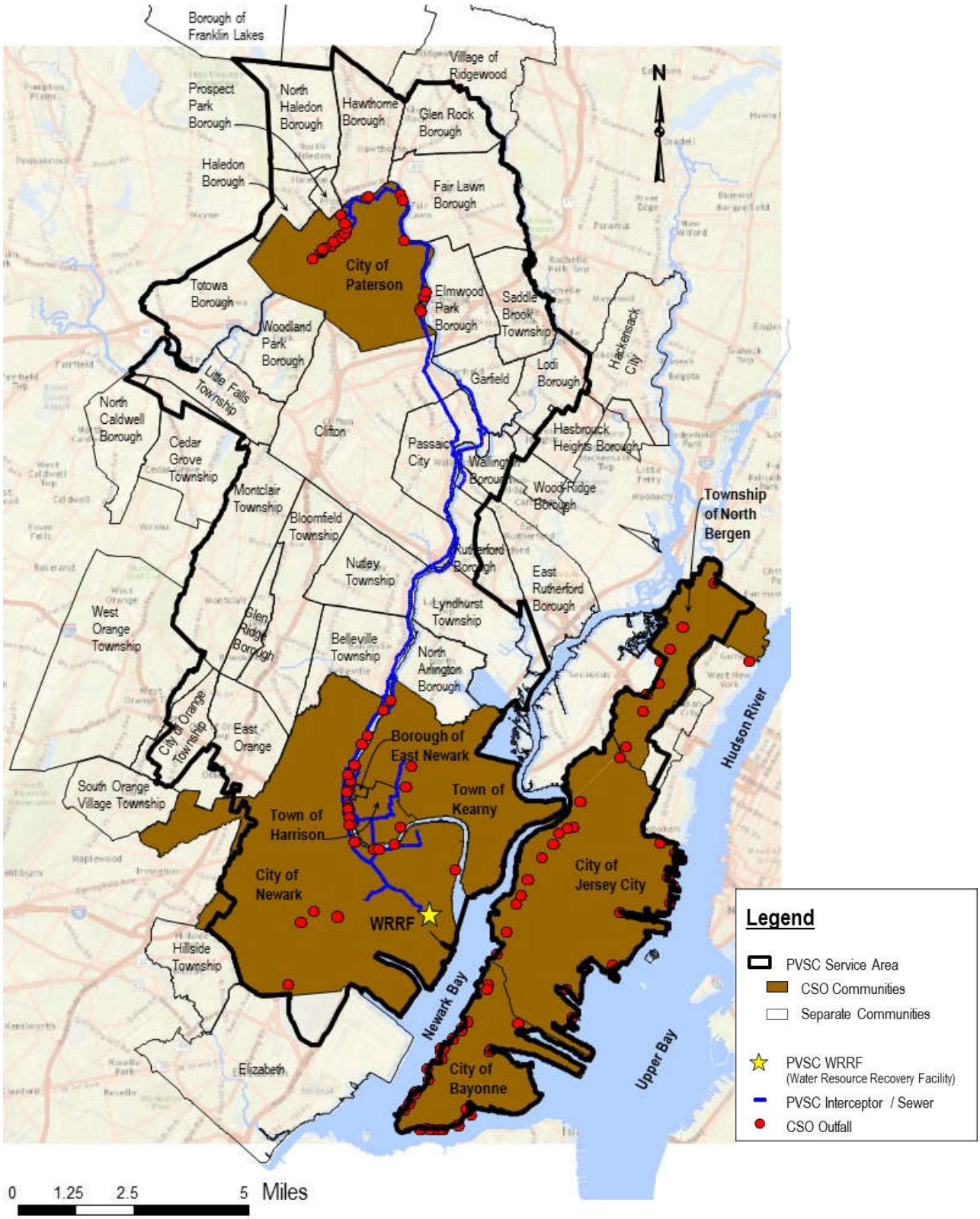


Figure C-2: PVSC Service Area with CSO Outfall Location

Table C-2: Passaic County Separate Sewer Areas

Passaic County	
Franklin Lakes	Woodland Park
North Haledon	Totowa
Hawthorne	Townships of Little Falls
Prospect Park	Cities of Passaic
Haledon	Clifton City

The following towns, boroughs and cities listed in **Table C-3** are located in Bergen County with separate sewage networks are generally located east of the Passaic River and drain into the PVSC Main Interceptor.

Table C-3: Bergen County Separate Sewer Areas

Bergen County	
Ridgewood Village	North Arlington
Glen Rock	Wood Ridge
Fair Lawn	Hasbrouck Heights
Elmwood Park	Saddle Brook
Lodi	Lyndhurst
Wallington	South Hackensack
Rutherford	Hackensack
East Rutherford	Garfield

Table C-4 lists the Essex County towns, boroughs and cities which are located towards the south end of the PVSC Main Interceptor and contribute separate sewage flow to the PVSC WRRF via the Main Interceptor.

Table C-4: Essex County Separate Sewer Areas

Essex County	
Montclair	West Orange
Nutley	South Orange
Belleville	City of East Orange
Bloomfield	Glen Ridge Borough
City of Orange	North Caldwell
Cedar Grove	

The township and city listed in **Table C-5** are in Union County and are located towards the south end of the PVSC Main Interceptor. They contribute separate sewage flow to the PVSC WRRF via the Main Interceptor.

Table C-5: Union County Separate Sewer Areas

Union County	
Hillside Township	Elizabeth City

Union City is the only separate sewerage municipality located in Hudson County and contributes flow directly to the WRRF through the Hudson County Forcemain.

Most CSO Communities have both separate sewer sections and combined sewer areas. The contributing separate sanitary sewer system area for each CSO community is shown in Table C-1. A portion of the City of Bayonne includes a separate sewer system, which serves a small industrial area. Sewage is conveyed separately in the area between Pulaski Street and Constable Hook along the Hudson River and is discharged directly to the Eastern Interceptor Sewer. All wastewater within the City flows to the City of Bayonne Oak Street Pumping Station, which transports wastewater to the PVSC WRRF.

SECTION D - CHARACTERISTICS OF THE COMBINED SEWER SYSTEM

D.1 SOURCES OF COLLECTION SYSTEM DATA

In order to characterize the CSS in the PVSC Service Area, the following previous reports were reviewed and utilized as sources of collection system data:

- North Bergen MUA CSO Characterization Study (March 2005)
- Bayonne Municipal Utilities Authority Facilities Inventory and Assessment Analysis (Sep 2013)
- Bayonne Municipal Utilities Authority CSO Discharge Characterization Report (Nov 2005)
- Bayonne Municipal Utilities Authority CSO LTCP Vol 1 Cost & Performance Analysis Report (Mar 2007)
- PVSC Report on Maximization Flows to WWTP (Oct 2003)
- PVSC Maximization of Wastewater to PVSC (Dec 1996)
- PVSC CSO Modeling Study (Feb 2004)
- PVSC CSO LTCP Vol 1 Cost & Performance Analysis Report March 2007-HMM

D.2 CHARACTERISTICS OF COMBINED SEWER SYSTEM

D.2.1 Description of CSO System

PVSC's sewer system consists of approximately 25 miles of intercepting sewers, eleven (11) branch interceptors with a total length of approximately 13 miles, thirteen (13) lateral sewers, river crossings, regulators, metering equipment, manholes and two (2) pump stations. Flow to the treatment facility is conveyed via two (2) primary interceptors and one primary force main: the Main Interceptor, the South Side Interceptor and the Hudson County Force Main. There are about 2,000 miles of lateral sewers which are owned by the various contributing municipalities which connect to the PVSC Main Interceptor.

The following is a basic summary of the Combined Sewer System Characterization Records submitted to NJDEP on July 1, 2016.

City of Bayonne

Bayonne's combined sewer system consists of approximately 81 miles of pipe with diameters generally ranging from 6 to 84 inches.

Town of North Bergen

North Bergen's combined sewer system consists of approximately 59 miles of pipe with diameters generally ranging from 4 to 30 inches.

Borough of East Newark

East Newark's combined sewer system consists of approximately 2 miles of pipe with diameters generally ranging from 8 to 48 inches.

Town of Harrison

Harrison's combined sewer system consists of approximately 17 miles of pipe with diameters generally ranging from 8 to 48 inches.

Town of Kearny

Kearny's combined sewer system consists of approximately 52 miles of pipe with diameters generally ranging from 6 to 30 inches.

City of Newark

Newark's combined sewer system consists of approximately 520 miles of pipe with diameters generally ranging from 3 to 153 inches.

City of Paterson

Paterson's combined sewer system consists of approximately 164 miles of pipe with diameters generally ranging from 8 to 84 inches.

D.2.2 Trunk Sewers

The PVSC service district includes over 1,000 miles of combined sewer gravity pipes and trunk sewers. These sewers are owned and maintained by the individual municipalities or authorities. Sewer data was collected from prior reports and GIS to develop and update the system inventory. Most of the pipe characteristics, including upstream and downstream nodes, dimension, shape, number of barrels, and flap gate information, were found or estimated from prior studies, record drawings, design drawings and sewer gravity main GIS shapefiles. If sewer main information was not available, sewer length was estimated in GIS geometry measurement. Manhole information, including invert and rim elevations, were found or estimated from record drawings, design drawings, and existing collection system models.

D.2.3 Flow Diversion Structures and CSO Regulators

There are 59 active regulating chambers tributary to the PVSC interceptors: 27 in Paterson, 17 in Newark, 1 in East Newark, 6 in Harrison, and 8 in Kearny. These regulating chambers are equipped with sandcatcher chambers to collect grit prior to flow entering the flow regulating structure. Under dry weather flow conditions, the flow passes through the sandcatcher and is diverted to the regulator chamber through a regulator gate or an orifice and then to the interceptor. Under wet weather conditions, as the height of the wet weather flow rises in the regulator, it overflows the weir and the excess flow is diverted to the overflow chamber and discharged to the receiving waters as combined sewer overflow. Typically, a tide gate chamber is located between the receiving waters and sandcatcher chamber to prevent the backflow of extraneous river waters into the interceptor. As originally designed, the regulating gate was equipped with a float mechanism to regulate the wastewater flow to the interceptor based on the interceptor levels. However, over a period of time, all of these regulators have been converted to passive control or equipped with sluice gates controlled from the WRRF.

PVSC owns and operates a total of 43 regulators throughout the PVSC sewer service district. PVSC owns and operates all of the regulators in East Newark, Harrison, and Kearny, 12 total, 11

regulators in Newark and 20 regulators located in Paterson. Newark and Paterson own and operate the remaining regulators located in their service area. **Table D-1** below lists permittees, regulator owner / operator and the number of regulators within the permittee's service areas. Harrison recently separated the drainage area for the Dey Street CSO and removed the regulator and outfall from service. Harrison now has 6 CSO outfalls and regulators. NJDEP will be issuing a minor modification NJPDES permit action to remove Dey Street outfall 004A in the near future.

Table D-1: Permittees and Their Regulators

Permittee	Owner / Operator	Number of Regulators
Bayonne*	Bayonne - 18	18
East Newark	PVSC - 1	1
Harrison**	PVSC - 6	6
Kearny	PVSC - 5	5
Newark	PVSC – 11; Newark - 7	18
North Bergen MUA*	North Bergen - 33	33 (Central)
Paterson	PVSC – 20; Paterson - 7	27
Total		**108**

* Do not contribute to the PVSC interceptors

** Harrison's NJPDES permit currently reflects 7 Outfalls. NJDEP will be issuing Harrison a minor modification permit action to remove Dey Street Outfall 004A in the near future and they will remove equipment from regulator.

The City of Bayonne has over the years constructed a combined sewer overflow control facilities and relief sewer to provide hydraulic relief to the CSS. The City's combined sewer system currently includes 17 active regulator structures. The Bayonne regulating chambers do not include a sandcatcher chamber. Under dry weather flow conditions, flow is directed through an opening to the regulator valve and then to the interceptor. Under wet weather conditions, when the height of the wet weather flow rises, it overflows the weir and excess flow is discharged to the receiving waters as a CSO. Typically, a tide gate chamber is located between the receiving waters and diversion chamber to prevent the backflow of extraneous river waters into the interceptor.

The North Bergen MUA has 33 active regulator structures in the central service area. All 33 regulating chambers drain to the Jersey City MUA sewer network. Of the thirty three regulators in the Central Area which is part of the PVSC service area, there are 8 dynamic and 25 static regulators. There are multiple regulators that serve single CSO outfalls. Categories of dynamic regulators include gate, float, gate/float, overflow and bar rack.

D.2.4 Interceptors

The PVSC interceptor sewers consist of two interceptor systems: Main Interceptor Sewer and South Side Intercepting Sewer owned and operated by the City of Newark. For flow measurement purposes, the system has three Venturi meter chambers on the Main Interceptor.

All but four municipalities, Jersey City, Bayonne, North Bergen and the South Kearny section of Kearny, are serviced by the PVSC interceptor system as shown in **Figure A-2.**

A total of 11 branch interceptors convey flow to the Main Interceptor. The 11 branch Interceptors are approximately 14.6 miles long. Five of the branch interceptors service combined sewer areas and the remaining six service separately sewered areas. They are identified as follows:

Combined Sewer Area Branch Interceptors

- Lawrence Street Branch Interceptor
- Kearny-East Newark-Harrison Branch Interceptor
- Kearny-Harrison-Newark Branch Interceptor
- Brown Street Branch Intercepting Sewer

Separate Sewer Area Branch Interceptors

- Jabez Street Branch Intercepting Sewer
- Prospect Street Branch Intercepting Sewer
- Warren Street Branch Interceptor
- Garfield-Passaic-Wallington Branch Interceptor
- Rutherford-East Rutherford Branch Intercepting Sewer
- Rutherford-Lyndhurst Branch Intercepting Sewer
- Kearny-North Arlington Branch Interceptor

The City of Bayonne's combined sewer system has three major interceptor sewers: Westerly Interceptor Sewer, Easterly Interceptor Sewer and Southerly Interceptor Sewer.

Each of the interceptors is described in further detail below.

Main Interceptor

The main intercepting sewer is approximately 112,000 feet long and extends from the Passaic Valley Sewerage Commissioners Sewage Treatment Facility in Newark to Prospect Street in Paterson. Between Newark and Paterson, the Main Interceptor connects to 11 branch interceptors, 13 lateral sewers, 2 pump stations (Wallington Pump Station at Passaic and Yantacaw Pump Station at Clifton), and a Main Pump Station and the union Outlet Joint Meeting Interceptor, which is jointly owned and operated by the municipalities of Montclair, Bloomfield and Glen Ridge. The system has 59 active regulators. The Main Interceptor generally follows the west bank of the Passaic River through Newark, Belleville, Nutley, Clifton, Passaic and Paterson. Flows enter the Main Interceptor from branch interceptors, regulators and local sewers, and are conveyed to the PVSC WRRF. There are a total of 257 manholes on the Main Interceptor, including the manholes of three Venturi meter chambers and two river siphons.

The Main Interceptor is constructed of poured in place concrete and its shape and size vary depending on location and construction methods (tunnel or open cut) employed in a given reach. At its downstream end in Newark, it is semi-elliptical and 12.5 ft. high, reducing to 10.5 ft. high semi-elliptical at the north Newark boundary. The Main Interceptor's slope varies from 0.0002 to 0.0003. The crossing under Second River at the Newark/Belleville boundary consists of two 7-ft. diameter siphons. At the siphon outlet, there is a Venturi meter chamber with three 36-inch diameter Venturi tubes and a bypass conduit. The siphon inlet is also a sand catcher chamber. At Academy Street in Belleville, the size of the Main Interceptor reduces to 10.0 ft. high semielliptical. Through Nutley, the Main Interceptor has a uniform 10-ft high semi-elliptical cross-section. The slope is 0.0003. At the northern boundary of Nutley, the Third River crossing consists of two 6.5-ft. diameter siphons. The siphon inlet is also a sand catcher chamber. Through the southern portion of Clifton, the sewer has a 9.0-ft. high semi-elliptical cross section, and a constant slope of 0.00035. An emergency by-pass is located in Clifton just north of Clifton-Nutley boundary at Yantacaw Street. Immediately upstream of the southern Passaic boundary, the flow passes through the Passaic Venturi Meter chamber which consists of two 36-inch diameter Venturi tubes and a meter bypass conduit. In Passaic, the interceptor cross section varies from 9 ft. to 7.5 ft. semi-elliptical. Slopes vary from 0.00035 to 0.00042. Through the northern section of Clifton, the interceptor cross section varies from 7.5 ft. semielliptical, to 6.75 ft. circular and subsequently to 6.75 ft. semi-elliptical. Slopes vary from 0.00049 to 0.00042. At the Clifton-Paterson boundary, flow passes through the Paterson meter chamber at Market Street, which includes a single 36-inch diameter Venturi tube and a meter bypass pipe. Through its reach in Paterson to the end, on the western and southern banks of the Passaic River, the cross section of the Main Interceptor changes from 6.75 ft. semi-elliptical to 3.75 ft. circular. Slopes through the Paterson reach vary from 0.00042 to 0.00073.

South Side Interceptor

The South Side Interceptor carries wastewater from the south portions of the City of Newark to the PVSC WRRF in Newark. Constructed in the mid 1960's of reinforced concrete pipe, it is approximately 21,000 feet long and extends from the Main Interceptor just upstream of the head end of the Passaic Valley Sewerage Commissioners Sewage Treatment Plant on Wilson Avenue to Waverly Street Regulator in Newark. It is owned and operated by the City of Newark.

The interceptor transports flows from three regulators owned by the City of Newark, Peddie, Queen and Waverly Street Regulators. At the Main interceptor it is an 84-inch diameter pipe, changes to 66 inch diameter pipe upstream of Peddie Street regulator, and terminates as a 54-inch diameter circular pipe between the Queen and Waverly Street regulators.

Lawrence Street Branch Interceptor

The Lawrence Street Branch Interceptor is approximately 2,839 feet long and extends from the Main Interceptor at the intersection of River and Lawrence Streets to the Northwest Street Regulator in Paterson. The interceptor generally follows Presidential Boulevard, Hudson Street, under the Passaic River onto Lawrence Street, to the intersection of River Street. Flows enter the interceptor through local sewers, the Northwest Street Regulator, Arch Street Regulator, Jefferson Street Regulator, Stout Street Regulator, North Straight Street Lateral Sewer, Hudson

Street Regulator and the Lawrence Street Regulator and are conveyed via a direct connection to the Main Interceptor just upstream of Manhole MI-239 as per the FIAA.

There are a total of 21 manholes on the Lawrence Street Branch Interceptor. The interceptor is constructed of poured in place concrete and is 30 inches in diameter at its upstream end. The size increases to 36-inch diameter at the intersection of Presidential Boulevard and Freeman Street. Its slope varies from 0.0009 to 0.00144.

Kearny-East Newark-Harrison Branch Interceptor

The Kearny-East Newark-Harrison Branch Interceptor is approximately 8,948 feet long and extends from the Kearny-Harrison-Newark Branch Interceptor upstream of KHN-5 on Frank E. Rogers Blvd. in Harrison, to the Nairn Street Regulator in Kearny. The Kearny-East Newark-Harrison Branch Interceptor generally follows Essex Street, First Street, Bergen Street, Dey Street, Passaic Avenue and Nairn Avenue.

Flows enter the interceptor through the local sewers, the First Street Lateral Sewer, Bergen Street Lateral Sewer, Dey Street Regulator, Harrison Avenue Regulator, Cleveland Avenue Regulator, New Street Regulator, Central Avenue Regulator, Johnston Avenue Regulator, Marshall Street Regulator and the Nairn Avenue Regulator and are conveyed to the Kearny-Harrison-Newark Branch Interceptor upstream of KHN-5. Flows are metered at two separate locations along the route, the East Newark Meter Chamber and the Johnston Avenue Meter Chamber.

There are a total of 41 Manholes on the Kearny-East Newark-Harrison Branch Interceptor. The interceptor is an 18-inch diameter concrete encased vitrified clay pipe at its upstream end. The size increased to 24-inch diameter poured in place concrete pipe downstream of the Marshall Street Regulator. The pipe size increased again to 33 inches in diameter near the Johnston Avenue Regulator.

The final pipe size change tasks place upstream of the Central Avenue Regulator to 36 inches in diameter. Over the length of the interceptor, the slope varies from 0.00354 to 0.00075.

Kearny-Harrison-Newark Branch Interceptor

The Kearny-Harrison-Newark (KHN) Branch Interceptor is approximately 15,355 feet long and extends from the Main Interceptor at the intersection of Ferry Street and Van Buren Street to north of King Street on Schuyler Avenue in Kearny. The Kearny-Harrison-Newark Branch Interceptor generally follows Van Buren Street and Raymond Boulevard in Newark, South Fourth Street, Essex Street, 7th Street, Bergen Street, Manor Avenue, Ann Street, Worthington Avenue, Kingsland Avenue in Harrison and Hamilton Avenue and Schuyler Avenue in Kearny.

Flows enter the Kearny-Harrison-Newark Branch Interceptor from the Brown Street Branch Interceptor, Kearny-East Newark-Harrison Branch Interceptor, Bergen Street Lateral, Duke and Tappan Street Lateral, local Sewers and service connections and are conveyed to the Main Interceptor upstream of Manhole MI-15. Flows entering the Kearny-Harrison-Newark Branch Interceptor are regulated by five regulators: the Bergen Street Regulator, Worthington Avenue Regulator, Duke Street Regulator, Tappan Street Regulator and Ivy Street Regulator.

There are a total of 43 manholes on the Kearny-Harrison-Newark Branch Interceptor including the manholes of one combined sewer overflow chamber, one flume type meter chamber, and one venturi type meter chamber. Also included are the inlet and outlet siphon chamber manholes.

The Kearny-Harrison-Newark Branch Interceptor is constructed of poured in place concrete pipe. The downstream end of the pipe is 64 inches in diameter and has a slope of 0.0038. The pipe size reduces to 54-inch diameter at a slope of 0.00049 in the vicinity of Passaic Avenue. The interceptor crosses the Passaic River under the Jackson Street Bridge as a 48 inch circular siphon at a slope of 0.00066. Through the southern portion of Harrison, the pipe size is 56 inches in diameter at a slope of 0.00039 to upstream of the intersection with Kearny-East Newark-Harrison Branch Interceptor, where, the diameter changes to 48 inches at a varying slope of approximately 0.00054. At manhole KHN-19, the pipe size changes to 42-inch diameter at a slope of 0.00065 and changes again at Manhole KHN-26 to 36-inch diameter at a slope of 0.00118.

Brown Street Branch Intercepting Sewer

The Brown Street Branch Intercepting Sewer is approximately 6,867 feet long and extends from the Kearny-Harrison-Newark Branch Intercepting Sewer at the intersection of Van Buren Street and Raymond Boulevard to the inactive Brown Street Regulator in Newark. The Interceptor generally follows Raymond Boulevard, Passaic Avenue, Cornelia Street, Lister Street and Brown Street. Flows enter the interceptor through the local sewers, the Freeman Street Regulator and the Polk Street Regulator and are conveyed via a direct connection to the Kearny-Harrison-Newark Branch Interceptor between Manholes KHN-1 and KHN-2.

There are a total of 29 manholes on the Brown Street Branch Intercepting Sewer. The interceptor is constructed of poured in place concrete and is a 24-inch diameter circular pipe at its upstream end. Its size increases to 48 inch at Raymond Boulevard and Freeman Street. Its slope is 0.0014.

Jabez Street Branch Intercepting Sewer

The Jabez Street Branch Intercepting Sewer is approximately 3,340 feet long and extends from the Main Interceptor at the intersection of Jabez Street and Wilson Avenue to the South Bay Avenue Regulator in Newark. The South Bay Regulator is currently inactive. The interceptor generally follows Jabez Street, Backus Street and Wheeler Point Road to South Bay Avenue. Flows enter the Interceptor through the South Bay Street Regulator and local sewers and are conveyed through a direct connection to the Main Interceptor between MI-13 and MI-14.

There are a total of 4 manholes on the Jabez Street Branch Intercepting Sewer including one manhole of the South Bay Avenue Regulator.

The Interceptor is a 57-inch circular poured in place concrete pipe over its entire length. Its slope varies from 0.001 to 0.002733.

Prospect Street Branch Intercepting Sewer

The Prospect Street Branch Intercepting Sewer is approximately 1,377 feet long and extends from the Main Interceptor at the intersection of River and Prospect Streets to the S.U.M. Park Regulator on Ryle Avenue in Paterson. The Interceptor generally follows the Passaic River in an easterly direction and crosses underneath the Passaic River by gravity. Flows enter the interceptor from the S.U.M. Park Regulator and local sewers and are conveyed to the Main Interceptor via a direct connection between MI-247 and MI-248.

There are a total of nine manholes on the Prospect Street Branch Intercepting sewer including manholes of the S.U.M. Park Regulator. The interceptor is a 16-inch diameter cast iron pipe at its upstream end, changes to a 24-inch x 16-inch elliptical concrete pipe before reaching its terminal size of 15 inches. Its slope varies from 0.0022 to 0.0080.

Warren Street Branch Interceptor

The Warren Street Branch Intercepting Sewer is approximately 1,967 ft. long and extends from the Main Interceptor at the intersection of Warren and River Streets to the Short Street Regulator in Paterson. The interceptor generally follows the west bank of the Passaic River form Short Street to East Holsman Street. At East Holsman Street, the interceptor crosses under the Passaic River and follows Warren Street to the Main Interceptor. Flows enter the interceptor from the Short Street Regulator, Warren Street Regulator, Bergen Street Regulator and local sewers and are conveyed to the Main Interceptor at Manhole MI-234.

There are a total of 15 manholes on the Warren Street Branch Interceptor, including the regulator manholes. The interceptor is a 24-inch diameter poured in place concrete pipe from its upstream end to East Holsman Street. The siphon at East Holsman Street is an 18-inch diameter cast iron pipe. At the siphon outlet, the interceptor increases to its terminal size of 30 inches in diameter.

Garfield-Passaic-Wallington Branch Interceptor

The Garfield-Passaic-Wallington (GPW) Branch Interceptor is approximately 12,387 feet long and extends from the Wallington Pumping Station in Passaic to the intersection of River Drive and Outwater Lane in Garfield. The interceptor generally follows Lester Avenue, Lodi Street, Eighth Street, Passaic Street, Tenth Street and River Drive. Flows enter the interceptor through local sewers, the Passaic-Tail Race Regulator (inactive), Dundee Lateral Sewer, Passaic Street Lateral Sewer, Wall Street Lateral Sewer, and are conveyed via a direct connection to the Main Interceptor, 87 feet upstream of MI-122. Flows are metered at two locations along the route, Garfield Meter Chamber and the Lodi Street Meter Chamber.

There are a total of 54 manholes on the Garfield-Passaic-Wallington Branch Interceptor. The Interceptor is typically constructed of poured in place concrete. A small section is concrete encased vitrified clay pipe. The concrete encased vitrified clay pipe located at the upstream end is 18 inches in diameter with a slope of .00170.

The interceptor size and slope change to 27-inch diameter with a slope of 0.00110 at Manhole GPW-48. At Manhole GPW-44, the pipe size changes to 30-inch diameter at a slope of 0.0014. The pipe size changes to 33-inch diameter with a slope of 0.0010 at Manhole GPW-33. One

manhole upstream of the Garfield Meter Chamber, GPW-22, the pipe size changes to 36-inch diameter. At the outlet of the Garfield siphon, the pipe becomes 42 inches in diameter and continues at that size to Manhole GPW-10, where it changes to 48 inches. The slope is approximately 0.00085. The outlet pipe at the Lodi Meter Chamber is 54 inches in diameter at a slope of 0.00085 and terminates at the Wallington siphon inlet chamber. The siphon has a 30-inch diameter and a 48-inch diameter pipe running in parallel under the Passaic River.

The last stretch of pipe runs from the outlet siphon to the Wallington Pumping Station and is 54 inches in diameter.

Rutherford-East Rutherford Branch Intercepting Sewer

The Rutherford-East Rutherford (RER) Branch Intercepting Sewer is approximately 4,943 feet long and extends from the Wallington Pumping Station Regulator in Wallington to Memorial Park in East Rutherford. The interceptor generally follows Madison Street, Carlton Avenue, Paterson Avenue and VanWinkle Avenue to the Wallington Pump Station Regulator. Appurtenances on the Interceptor include the East Rutherford and the Rutherford Meter Chambers. Flow enters the Interceptor through local sewers, house connections, and the VanWinkle Meter Chamber.

There are a total of 25 manholes on the Rutherford-East Rutherford Branch Intercepting Sewer. The sewer is constructed of 24-inch diameter poured in place concrete at its upstream end. Its size increases to 27-inch diameter at RER-8 and to 36-inch by 27-inch semi-elliptical and then to 36-inch circular near the intersection of Main Avenue and VanWinkle Avenue in Wallington. Small segment of the 36-inch pipe and the 36-inch by 27-inch semi-elliptical pipe along VanWinkle Avenue are constructed of brick.

Rutherford-Lyndhurst Branch Intercepting Sewer

The Rutherford-Lyndhurst Branch Intercepting Sewer is approximately 5,893 ft long and extends from the Yantacaw Pumping Station in Clifton to the Woodward Avenue Regulator in Rutherford. The sewer generally follows Riverside Avenue and conveys flows from the Rutherford, Pierrepont and Woodward Avenue Regulators, local sewers and service connections to the Yantacaw Pumping Station.

There are a total of 25 manholes on the Rutherford-Lyndhurst Branch Intercepting Sewer including the manholes of one meter chamber and the three aforementioned regulators. The interceptor is an 18-inch diameter concrete cradled vitrified clay pipe at its upstream end and increases to a 24-inch diameter poured in place concrete pipe at its downstream end. Its slope varies from 0.0012 to 0.0013. Appurtenances along the interceptor include a meter chamber, the Rutherford Avenue Regulator, the Pierrepont Avenue Regulator and the Woodward Avenue Regulator.

Kearny-North Arlington Branch Interceptor

The Kearny-North Arlington (KNA) Branch Interceptor is approximately 5,330 feet long and extends from the Main Interceptor on Academy Street in Belleville to North Midland Avenue in Kearny. The Kearny-North Arlington Branch Interceptor generally follows the east bank of the

Passaic River through North Arlington and Kearny. Flows enter the Kearny-North Arlington branch Interceptor through the Stewart Avenue and Washington Avenue Regulators, local sewers and a number of house connections and are conveyed to the Main Interceptor through the North Arlington Siphon.

There are a total of 31 manholes on the Kearny-North Arlington Branch Interceptor, including the manholes of the two meter chambers and the North Arlington Branch Regulator.

The Kearny-North Arlington Branch Interceptor is constructed of poured in place concrete pipe and concrete encased vitrified clay pipe. The siphon is 20-inch diameter cast iron pipe. Between the siphon outlet chamber and KNA-4, the sewer is a 24-inch diameter concrete pipe with a slope of 0.0011. At KNA-4, the pipe changes to an 18-inch diameter concrete encased vitrified clay pipe with a slope of 0.0014. At KNA-12, the size of the pipe changes to 12-inch diameter concrete encased vitrified clay pipe to the upstream end of the branch interceptor. Throughout the 12-inch diameter section, the slope of the pipe varied from 0.000068 to 0.00089.

Westerly Interceptor Sewer

Bayonne's Westerly Interceptor Sewer generally runs along Newark Bay and ranges from 12 inches to 48 inches in diameter. The interceptor discharges to the West 22nd Street Sewage Pumping Station which sends flow to the Easterly Interceptor.

Easterly Interceptor Sewer

Bayonne's Easterly Interceptor Sewer generally runs along Route 440 and Avenue F, and ranges from 42 inches to 72 inches in diameter. The interceptor discharges to the Oak Street Pumping Station.

Southerly Interceptor Sewer

Bayonne's Southerly Interceptor Sewer is generally routed along the Kill Van Kull and ranges from 24 inches to 54 inches in diameter. The interceptor discharges to the Oak Street Pumping Station.

D.2.5 Pump Stations

PVSC's Main Interceptor has two pump stations – the Wallington Pump Station and the Yantacaw Pump Station. Both pump stations were built in the year 1924 and have undergone several interim modifications since.

The Wallington Pump Station is located in the Borough of Wallington within Bergen County and serves the municipalities of Wallington, Garfield, East Rutherford, and portions of Passaic, Rutherford, and Saddle Brook. The pump station is equipped with two 75 HP and one 125 HP dry pit submersible pumps, with a wet well and dry well arrangement. Wastewater enters the pump station through a 54-inch diameter pipe (Lodi Force Main) and passes through screening equipment. The pump station discharges flow through a 36-inch diameter force main. The station has an emergency generator, electrical power distribution equipment, HVAC equipment, and instrumentation.

The Yantacaw Pump Station is located in the City of Clifton in Passaic County and serves portions of Lyndhurst and Rutherford. The Pump Station is equipped with three 50 HP dry pit submersible pumps, with a wet well and dry well arrangement. Wastewater enters the Pump Station through a 24-inch diameter pipe and passes through screening equipment. The pump station discharges flow through an 18-inch diameter force main. The station has an emergency generator, electrical power distribution equipment, HVAC equipment, and instrumentation.

City of Bayonne

The City of Bayonne operates four pumping stations; West 22nd St, Oak St, West 1st St and 5th Street Pumping stations, two on the combined sewer system and two on the relief sewer system.

- The West 22nd Street Sewage Pumping Station is located at the end of West 22nd Street, near Newark Bay. This Pumping Station pumps flows between the Westerly Interceptor and the Easterly Interceptor. The station is equipped with two pumps, and has a pumping capacity of 25 MGD.
- The Oak Street Pumping Station is located at Oak Street and 5th Street. This Pumping Station pumps flows from the Easterly and Southerly Interceptor Sewers to PVSC. The station is equipped with four (4) pumps, and has a pumping capacity of 57.6 MGD. 17.6 MGD of that flow can be pumped to PVSC, and the remaining 40 MGD is pumped to an outfall.
- The West 1st Street Pumping Station is located on West 1st Street near Humphreys Avenue. This Pumping Station relieves the Southerly Interceptor when hydraulic head increases beyond the crown of the pipe. This station is equipped with two pumps and has a pumping capacity of 6 MGD.\
- The 5th Street Pumping Station is located at 5th Street and Ingraham Avenue. This Pumping Station accepts stormwater and combined sewer overflows, and discharges to an inlet tributary to the Kill Van Kull. This station is equipped with eight pumps and has a pumping capacity of 300 MGD.

North Bergen MUA

North Bergen MUA owns and operates three pumping stations; Central PS, 8th Street PS, and 61st Street Pumping Stations. Approximately 7 MG dry weather flow of combined sewage per day is pumped from North Bergen to Jersey City MUA's CSS for ultimate conveyance to the PVSC WRRF via the Hudson County force main.

Town of Kearny

The South Kearny Pump Station that has a maximum capacity of 17.5 MGD. This pump station discharges directly the PVSC WRRF. There are four smaller sanitary pumping stations located throughout the Town of Kearny: Quincy Place, Gunnel Oval, East Midland and King Street.

D.2.6 Force Mains

The Hudson County force main ranges in size from 54 inches to 72 inches and is primarily comprised of prestressed concrete cylinder pipe. The force main was installed in the late 1980s and was relocated in two locations in Jersey City in 1997. PVSC maintains approximately 10,000 feet of the force main from the Jersey City emergency overflow structure, which is

located under Newark Bay, to the connection into PVSC's influent pumping station just prior to PVSC's primary clarifiers.

City of Bayonne

Bayonne's West 22nd Street Sewage Pumping Station pumps to a 30-inch force main which discharges to the Westerly Interceptor. Bayonne's Oak Street Pumping Station pumps to a 36-inch force main which discharges into the Hudson County force main in Jersey City.

D.2.7 CSO Control Facilities

Of the regulators to the PVSC interceptors, ten in Newark have been retrofitted and equipped with motorized sluice gates, which are remotely controlled from the plant via a telemetered control signal. PVSC operates the ten Newark sluice gates with radio transmission through Phoenix contact and Elpro™ transmitters back to PVSC's SCADA system. The gates can be utilized during rain events to prevent overloading the WRRF. The appropriate gates may be controlled to bypass the combined sewer from the regulator to the Passaic River.

City of Newark

Newark has 16 CSO Control Facilities, 12 Netting Facilities and 4 Screening Facilities. The South Side Interceptor has a gate that can be manually closed in the event of an emergency situation, causing a diversion of the entire flow to the Newark Airport Peripheral Ditch.

Borough of East Newark

The Borough of East Newark owns and operates 1 CSO Floatable Control Facility.

Town of Harrison

The Town of Harrison owns and operates 6 CSO Floatable Control Facilities. Harrison formerly owned and operated an additional CSO Floatables Control Facility on outfall 004A. This drainage area has been separated and NJDEP will be issuing Harrison a minor modification NJPDES permit action to remove Dey Street outfall 004A in the near future.

Town of Kearny

The Town of Kearny owns and operates 5 CSO Floatable Control Facilities.

City of Paterson

The City of Paterson owns and operates 19 CSO Floatable Control Facilities.

City of Bayonne

The City of Bayonne owns and operates 17 CSO control facilities and 17 discharge points originating at regulator chambers to the interceptor sewers. In addition to the CSO points originating at regulators to the interceptor, the City has constructed new CSO control facilities to provide hydraulic relief to the CSS. While catch basins in the area of the relief sewer were directly connected, catch basins in upstream areas remain connected to the combined sewer system. Control facilities, such as overflow pipes or weirs, divert excess wastewater flow from the combined sewer collection system to the receiving waters. Overall the relief sewer system

contains 37 control facilities tributary to 13 CSO discharge pipes. As construction of solids/floatables control facilities were undertaken, several of the outfalls were combined to reduce the number of individual facilities.

Township of North Bergen

The North Bergen MUA has 8 netting facilities and 1 bar screen in the Central Service Area.. While several of the CSO outfalls receive flows from only one control facility, the other systems contain multiple control points.

D.2.8 CSO Outfalls

Table D-2 lists all of the CSO outfalls, associated permittees, permit numbers and the waterbodies into which they discharge in the PVSC Service Area. PVSC CSO Sewer District receiving waters include the Passaic River, Newark Bay, Upper New York Bay, Hackensack River, Hudson River, Kill Van Kull, as well as their tributaries. There are a total of 90 outfalls within the PVSC Service District located in the Towns of Harrison and Kearny, Borough of East Newark, the Township of North Bergen and the Cities of Bayonne, Newark and Paterson.

City of Bayonne

Overall the City of Bayonne has 28 CSO outfall pipes that are all equipped with solids/floatables removal equipment. Sixteen of the CSO points discharge to Newark Bay. Nine flow to the Kill Van Kull and three drain to the Hudson River. All facilities are currently owned and operated by the City of Bayonne.

CSO – 001A

CSO – 001A is located at Bayonne Pump Station on East 15th Street and discharges in to the Kill Van Kull. The outfall is a 54" diameter cast-in-place pipe equipped with a floating net and mechanical bar screens.

CSO – 002A

CSO – 002A is located at the 5th Street Pump Station and discharges in to the Kill Van Kull. The outfall is an 84" diameter reinforced concrete pipe equipped with mechanical bar screens.

CSO – 003A

CSO – 003A is located at the 1st Street Pump Station and discharges in to the Kill Van Kull. The outfall is a 12" diameter pipe equipped with inline netting.

CSO – 004A

CSO – 004A is located at Lord Avenue and discharges in to the Kill Van Kull. The outfall is a 30" diameter reinforced concrete pipe equipped with a static overflow weir.

CSO – 006A

CSO – 006A is located at East 30th Street and discharges in to the Upper New York Bay. The outfall is a 54" diameter corrugated metal pipe equipped with inline netting.

CSO – 007A
CSO – 007A is located at East 34th Street and discharges in to the Upper New York Bay. The outfall is a 72" diameter reinforced concrete pipe equipped with end of pipe netting.

CSO – 008A
CSO – 008A is located at East 5th Street and discharges in to the Kill Van Kull. The outfall is a 48" diameter corrugated metal pipe equipped with inline netting.

CSO – 009A
CSO – 009A is located at Broadway and East 1st Street and discharges in to the Kill Van Kull. The outfall is a 24" diameter reinforced concrete pipe equipped with inline netting.

CSO – 010A
CSO – 010A is located at Avenue C and East 1st Street and discharges in to the Kill Van Kull. The outfall is a 24" diameter reinforced concrete pipe equipped with inline netting.

CSO – 011A
CSO – 011A is located at West 3rd Street and discharges in to the Newark Bay. The outfall is a 24" reinforced concrete pipe equipped with inline netting.

CSO – 012A
CSO – 012A is located at West 5th Street and discharges in to the Newark Bay. The outfall is a 24" diameter vitrified clay pipe equipped with inline netting.

CSO – 013
CSO – 013A is located at Edwards Court and discharges in to the Newark Bay. The outfall is a 12" diameter cast-in-place pipe equipped with a static bar screen.

CSO – 014A
CSO – 014A is located at West 16th Street and discharges in to the Newark Bay. The outfall is a 30" diameter reinforced concrete pipe equipped with inline netting.

CSO – 015A
CSO – 015A is located at West 22nd Street and discharges in to the Newark Bay. The outfall is a 36" diameter cast-in-place pipe equipped with end of pipe netting.

CSO – 016A
CSO – 016A is located at West 24th Street and discharges in to the Newark Bay. The outfall is a 16" diameter vitrified clay pipe equipped with inline netting.

CSO – 017A
CSO – 017A is located at West 25th Street and discharges in to the Newark Bay. The outfall is a 36" diameter cast-in-place pipe equipped with inline netting.

CSO – 018A
CSO – 018A is located at West 30th Street and discharges in to the Newark Bay. The outfall is an 18" diameter reinforced concrete pipe equipped with inline netting.

CSO – 019A
CSO – 019A is located at Lincoln Parkway and discharges in to the Newark Bay. The outfall is a 36" diameter cast-in-place pipe equipped with inline netting.

CSO – 020A
CSO – 020A is located at West 59th Street and discharges in to the Newark Bay. The outfall is a 36" diameter reinforced concrete pipe equipped with inline netting.

CSO – 021A
CSO – 021A is located at East 50th Street and discharges in to the Upper New York Bay. The outfall is a 48" diameter reinforced concrete pipe equipped with inline netting.

CSO – 022A
CSO – 022A is located at Zabriskie Avenue and discharges in to the Newark Bay. The outfall is a 33" diameter reinforced concrete pipe equipped with three static bar screens.

CSO – 024A
CSO – 024A is located at Humphrey's Avenue and discharges in to the Kill Van Kull. The outfall is a 24" diameter corrugated metal pipe equipped with four static bar screens.

CSO – 026A
CSO – 026A is located at Veteran's Park and discharges in to the Newark Bay. The outfall is a 48" diameter corrugated metal pipe equipped with static bar screens.

CSO – 028A
CSO – 028A is located at Lincoln Parkway and discharges in to the Newark Bay. The outfall is a 36" diameter reinforced concrete pipe equipped with three static bar screens.

CSO – 029A
CSO – 029A is located at West 37th Street and discharges in to the Newark Bay. The outfall is a 42" diameter vitrified clay pipe equipped with end of pipe netting.

CSO – 030A
CSO – 030A is located at West 54th Street and discharges in to the Newark Bay. The outfall is a 24" diameter reinforced concrete pipe equipped with two static bar screens.

CSO – 034A
CSO – 034A is located at Bayview Court and discharges in to the Newark Bay. The outfall is a 12" diameter vitrified clay pipe equipped with a static bar screen.

CSO – 037A
CSO – 037A is located at Trask Avenue and discharges in to the Kill Van Kull. The outfall is a 36" diameter reinforced concrete pipe equipped with a static bar screen.

Borough of East Newark

The Borough of East Newark has one CSO outfall. This single outfall has solids/floatables removal equipment installed upstream of the point of discharge. The outfall discharges in to the Passaic River.

CSO – 001A
CSO – 001A is located at Central Avenue and discharges in to the Passaic River. The outfall is a 30"x45" brick pipe.

Town of Harrison

Harrison Town has six CSO outfalls that are all equipped with solids/floatables removal equipment installed upstream of the point of discharge. All six of the CSO outfalls discharge in to the Passaic River. Harrison previously had seven CSO's but separated the drainage area associated with Outfall 004A and closed the outfall.

CSO – 001A
CSO – 001A is located at Hamilton Street and discharges in to the Passaic River. The outfall is a 24" diameter VTP pipe.

CSO – 002A
CSO – 002A is located at Cleveland Avenue and discharges in to the Passaic River. The outfall is a 20" diameter VTP pipe.

CSO – 003A
CSO – 003A is located at Harrison Avenue and discharges in to the Passaic River. The outfall is a 30"x45" brick pipe.

CSO – 005A
CSO – 005A is located at Middlesex Street and discharges in to the Passaic River. The outfall is a 24" diameter VTP pipe.

CSO – 006A
CSO – 006A is located at Bergen Street and discharges in to the Passaic River. The outfall is a 24" diameter VTP pipe.

CSO – 007A
CSO – 007A is located at Worthington Avenue (Supor Boulevard) and discharges in to the Passaic River. The outfall is a 24" diameter VTP pipe.

City of Newark

The City of Newark has 18 CSO outfalls including the Queen Street outfall that has been reactivated. Ten of the CSO outfalls are equipped with solids/ floatables removal equipment installed upstream of the point of discharge. The CSO outfalls discharge into the Passaic River and the Elizabeth Channel.

CSO – 002A

CSO – 002A is located at Verona Avenue and discharges in to the Passaic River. The outfall is a 59x72" brick pipe.

CSO – 003A

CSO – 003A is located at Delavan Avenue and discharges in to the Passaic River. The outfall is a 60" diameter reinforced concrete pipe.

CSO – 004A

CSO – 004A is located at Herbert Place and discharges in to the Passaic River. The outfall is a 48"x54" brick pipe.

CSO – 005A

CSO – 005A is located at Herbert Place and discharges in to the Passaic River. The outfall is a 51" diameter brick pipe.

CSO – 008A

CSO – 008A is located at 4th Avenue and discharges in to the Passaic River. The outfall is a 48"x48" brick pipe.

CSO – 009A

CSO – 009A is located at Clay Street and discharges in to the Passaic River. The outfall is a 100"x75" brick pipe.

CSO – 010A

CSO – 010A is located at Clay Street and discharges in to the Passaic River. The outfall is a 100"x75" brick pipe.

CSO – 014A

CSO – 014A is located at Saybrook Place and discharges in to the Passaic River. The outfall is a 102"x83" brick pipe.

CSO – 015A

CSO – 015A is located at City Dock and discharges in to the Passaic River. The outfall is a 108"x87" brick pipe.

CSO – 016A

CSO – 016A is located at Jackson Street and discharges in to the Passaic River. The outfall is a 72" diameter brick pipe.

CSO – 017A
CSO – 017A is located at Polk Street and discharges in to the Passaic River. The outfall is a 97" diameter brick pipe.

CSO – 018A
CSO – 018A is located at Freeman Street and discharges in to the Passaic River. The outfall is a 44" diameter reinforced concrete pipe.

CSO – 022A
CSO – 022A is located at Roanoke Avenue and discharges in to the Passaic River. The outfall is a 60" diameter pipe.

CSO – 023A
CSO – 023A is located at Adams Street and discharges in to the Elizabeth Channel.

CSO – 025A
CSO – 025A is located at Peddie Street and discharges in to the Elizabeth Channel. The outfall is a 46"x46" reinforced concrete pipe.

CSO – 026A
CSO – 026A is located at Queen Street and discharges in to the Queen Ditch. The outfall is a 42" diameter pipe.

CSO – 027A
CSO – 027A is located at Waverly and discharges in to the Elizabeth Channel. The outfall is a 96" diameter reinforced concrete pipe.

CSO – 030A
CSO – 030A is located at Avenue A and discharges in to the Elizabeth Channel. The outfall is a 116"x52" pipe.

Town of North Bergen
The North Bergen MUA's Central CSS is part of the PVSC's WRRF collection system. It has nine CSO outfalls that are permitted, owned and operated by the North Bergen MUA. One outfall discharges to Bellmans Creek, six discharge to Cromakill Creek and two discharge to Penhorn Creek which drain to the Hackensack River. During dry weather conditions, all of the wastewater flows from the western and central portions of the North Bergen is ultimately conveyed to the PVSC WRRF in Newark, NJ via the Jersey City MUA pump station and the Hudson County force main. During wet weather periods when the capacity of the collection system is exceeded, combined sewage will be discharged as a CSO from one or more of North Bergen MUA's nine outfalls.

CSO – 003A
CSO – 003A is located at the west end of 91st Street and discharges in to Bellmans Creek. The outfall is equipped with a floating net.

CSO – 005A
CSO – 005A is located at the west end of 69th Street and discharges in to Cromakill Creek. The outfall is equipped with a headwall/pipe.

CSO – 006A
CSO – 006A is located west of 60th Street and Tonnelle Avenue. The outfall discharges in to Cromakill Creek and is equipped with a headwall/pipe.

CSO – 007A
CSO – 007A is located at the intersection of 51st Street and Westside Avenue. The outfall discharges in to Cromakill Creek and is equipped with a fixed net.

CSO – 008A
CSO – 008A is located at the intersection of 43rd Street and Westside Avenue. The outfall discharges in to Cromakill Creek and is equipped with a floating net.

CSO – 009A
CSO – 009A is located at the intersection of Westside Avenue and Paterson Plank Road. The outfall discharges in to Cromakill Creek and is equipped with a floating net.

CSO – 010A
CSO – 010A is located at the intersection of 29th Street and the Penske Facility. The outfall discharges in to Penhorn Creek and is equipped with a headwall/pipe.

CSO – 011A
CSO – 011A is located at the intersection of 11th Street and Dell Avenue. The outfall discharges in to Penhorn Creek and is equipped with a headwall/pipe.

CSO – 014A
CSO – 014A is located at the intersection of Westside Avenue and Paterson Plank Road. The outfall discharges in to Cromakill Creek.

City of Paterson
The City of Paterson has 23 CSO outfalls and one discharge (CSO-028) currently under appeal to be re-added to the permit. Nineteen of the twenty three have solids/floatables removal equipment installed upstream of the point of discharge. All twenty three CSO outfalls discharge in to the Passaic River.

CSO 001A – Curtis Place
The Curtis Place PVSC Regulator is located approximately 100 feet west of the intersection of Curtis Place and Broadway. Outfall 001 is a 48" diameter pipe, approximately 30 feet long, which discharges at the southwest corner of the bridge that leads to the parking lot of the Salvation Army Building.

CSO 003A – West Broadway
The West Broadway PVSC Regulator is located within West Broadway, approximately 40 feet northwest of the intersection of West Broadway and (currently abandoned) River Street. Outfall 003 is an 18" diameter pipe, approximately 40 feet long, which discharges to the Passaic River through the southeastern foundation wall of the County Bridge over the Passaic River that links the north and south sides of West Broadway.

CSO 005A – Bridge Street
The Bridge Street PVSC Regulator is located approximately 50 feet northwest of the intersection of River and Bridge Streets. Outfall 005 is approximately twenty-five (25) feet long, and discharges to the Passaic River beneath the southeast foundation of the bridge that links the north and south sides of Bridge Street over the Passaic River.

CSO 006A – Montgomery Street
The Montgomery Street PVSC Regulator is located in a sidewalk area along the northwest edge of River Street at its intersection with Montgomery Street. There is no discharge pipe at Outfall 006, combined sewer discharge to the Passaic River occurs immediately northwest of the regulator.

CSO 007A – Straight Street
The Straight Street PVSC Regulator is located approximately 30 feet northwest of the intersection of Straight and River Streets. Outfall 007 passes through the southeastern foundation wall of the Straight Street Bridge, and discharges to the Passaic River.

CSO 010A – Warren Street
The Warren Street PVSC Regulator is located on Warren Street approximately 350 feet west of River Street in a truck loading driveway for Halal Meat. Outfall 010 is approximately 50 feet long, and discharges to the Passaic River behind Halal Meat.

CSO 013A – East 11th Street
The East 11th Street PVSC Regulator is located in East 11th Street approximately 450 feet north of 5th Avenue. Outfall 013 discharges to the Passaic River at the north terminus of East 11th Street.

CSO 014A – East 12th Street and 4th Avenue
The East 12th Street and 4th Avenue PVSC Regulator is located at the intersection of East 12th Street and 4th Avenue. Outfall 014 runs north from the regulator and discharges to the Passaic River at the bottom of a steep slope.

CSO 015A – S.U.M. Park
The S.U.M. Park PVSC Regulator is located approximately 200 feet southeast of the southeasterly corner of Hinchcliff Stadium. Outfall 015 is a 36" diameter pipe, which is located along a steep slope. The outfall discharges to the Passaic River approximately 60 feet southeast of the regulator. It should be noted that the S.U.M. PVSC Regulator is the starting point of the PVSC Interceptor.

CSO 016A – Northwest Street
The Northwest Street PVSC Regulator is located at the intersection of Broadway and Presidential Boulevard. Outfall 016 is approximately 20 feet long, and discharges to the Passaic River through the north foundation wall of the County Bridge that links the north and south sides of Broadway over the Passaic River.

CSO 017A – Arch Street
The Arch Street PVSC Regulator is located at the southeast end of Arch Street, approximately 200 feet southeast of Presidential Boulevard. Outfall 017 discharges to the Passaic River underneath the bridge connecting Arch and Bridge Streets.

CSO 021A – Bergen Street
The Bergen Street PVSC Regulator is located at the eastern terminus of Bergen Street. A short section of 32" x 49" box culvert exits the regulator and discharges to the Passaic River immediately east of the regulator.

CSO 022A – Short Street
The Short Street PVSC Regulator is located at the eastern terminus of Short Street. Outfall 022 runs approximately 20 feet to the east and discharges to the Passaic River.

CSO 023A – 2nd Avenue
The 2nd Avenue PVSC Regulator is located along the eastern shoulder of McLean Boulevard (N.J.S.H. 20) at its intersection with 2nd Avenue. Outfall 023 is approximately 35 feet long and discharges to the Passaic River at a point approximately 220 feet east of the intersection of 2nd Avenue and 25th Street.

CSO 024A – 3rd Avenue
The 3rd Avenue PVSC Regulator is located at the intersection of McLean Boulevard (N.J.S.H. 20) and 3rd Avenue. (The regulator lies underneath the southbound travel lanes of Route 20.) Outfall 024 is a 42" diameter pipe, approximately 70 feet long, which discharges to the Passaic River at a point approximately 100 feet east of the intersection of 3rd Avenue and McLean Boulevard.

CSO 025A – 10th Avenue and 33rd Street
The 10th Avenue and 33rd Street PVSC Regulator is located at the intersection of McLean Boulevard (N.J.S.H. 20) and 33rd Street. Outfall 025 runs along the centerline of 33rd Street for approximately 250 feet and discharges to the Passaic River through the southwest foundation wall of County Bridge #8.

CSO 026A – 20th Avenue
The 20th Avenue PVSC Regulator is located along the eastern edge of McLean Boulevard (N.J.S.H. 20) at its intersection with 20th Avenue. Outfall 026 is approximately 600 feet long, and runs to the east along a warehouse complex access driveway, discharging to the Passaic River.

CSO 027A – Market Street
The Market Street PVSC Regulator is located along the western edge of the Market Street exit ramp from McLean Boulevard (N.J.S.H. 20), approximately 240 feet northwest of the intersection of Interstate 80 and McLean Boulevard. Outfall 027 runs beneath Route 20 approximately 400 feet and discharges to the Passaic River through the west foundation wall of the bridge that connects Market Street (Elmwood Park) and McLean Boulevard (Paterson).

CSO 029A – River Road (Loop Road)
Outfall 029 contains six (6) City owned and operated IOCs which discharge to this outfall. The overflow from Overflow Chamber EF-1 discharges to Outfall 029 just north of River Street; the overflow from Overflow Chambers EF-2 through EF-6 discharge to the outfall along Paterson Avenue between the intersections of Grand Street and Van Houten Street.

CSO 030A – 19th Avenue
The 19th Avenue PVSC Regulator is located approximately 500 feet east of the intersection of McLean Boulevard and 19th Avenue. The outfall is a 90" diameter reinforced concrete pipe and discharges in to the Passaic River.

CSO 031A – Route 20 Bypass
The Route 20 Bypass PVSC Regulator is located underneath the entrance ramp to Interstate 80from Route 20. The outfall is a 60"x54" reinforced concrete pipe and discharges in to the Passaic River.

CSO 032A – Hudson Street
The Hudson Street PVSC Regulator is located approximately 30 feet southeast of the intersection of Hudson Street and Presidential Boulevard. Outfall 032 runs approximately 20 feet and discharges to the Passaic River.

The Hudson Street regulator is located on a branch interceptor of the PVSC system, and is used to regulate combined flows from areas upstream of the regulator in which other PVSC Regulators have been plugged (specifically CSO Area 017 - Arch Street, CSO Area 018 - Jefferson Street, CSO Area 019 - Stout Street and CSO Area 020 - North Straight Street).

CSO 033A – River Street
The River Street PVSC Regulator is located approximately 250 feet west of the intersection of Tyler Street and River Street. The outfall is a 48"x42" diameter reinforced concrete arch box and discharges in to the Passaic River.

Town of Kearny
At one time, the Town of Kearny had nine CSO outfalls, but over time has decreased that number to five CSO outfalls. Outfalls at Washington Avenue, Bergen Avenue and Marshall Avenue were separated, and the outfall at Tappan Street was consolidated with the Dukes Street outfall (010A). All five operational CSO outfalls have solids/floatables removal equipment

installed upstream of the point of discharge. The CSO outfalls discharge in to the Passaic River and Frank's Creek.

CSO – 001A
CSO – 001A is located at Stewart Avenue and discharges in to the Passaic River.

CSO – 004A
CSO – 004A is located at Narine Avenue and discharges in to the Passaic River.

CSO – 006A
CSO – 006A is located at Johnston Avenue and discharges in to the Passaic River.

CSO – 007A
CSO – 007A is located at Ivy Street and discharges in to the Lower Passaic River Unnamed Tributary (Frank's Creek).

CSO – 010A
CSO – 010A is located at Dukes Street and discharges in to the Lower Passaic River Unnamed Tributary (Frank's Creek).

Table D-2: CSO Outfalls and Their Receiving Waters

SPDES	Permittee	CSO Number	Regulator Number (Outfall Name)	Receiving Water Body
NJ0109240	Bayonne	001A	B-001A (E. 15th St.)	Kill Van Kull
NJ0109240	Bayonne	002A	B-002A (5th St.)	Kill Van Kull
NJ0109240	Bayonne	003A	B-003A (1st St.)	Kill Van Kull
NJ0109240	Bayonne	004A	B-004A (Lord Ave.)	Kill Van Kull
NJ0109240	Bayonne	006A	B-006A (E. 30th St.)	Upper NY Bay
NJ0109240	Bayonne	007A	B-007A (E. 34th St.)	Upper NY Bay
NJ0109240	Bayonne	008A	B-008A (E. 5th St.)	Kill Van Kull
NJ0109240	Bayonne	009A	B-009A (Broadway)	Kill Van Kull
NJ0109240	Bayonne	010A	B-010A (Ave. C)	Kill Van Kull
NJ0109240	Bayonne	011A	B-011A (W. 3rd St.)	Newark Bay
NJ0109240	Bayonne	012A	B-012A	Newark Bay

SPDES	Permittee	CSO Number	Regulator Number (Outfall Name)	Receiving Water Body
			(W. 5th St.)	
NJ0109240	Bayonne	013A	B-013A (Edwards Ct.)	Newark Bay
NJ0109240	Bayonne	014A	B-014A (W. 16th St.)	Newark Bay
NJ0109240	Bayonne	015A	B-015A (W. 22nd St.)	Newark Bay
NJ0109240	Bayonne	016A	B-016A (W. 24th St.)	Newark Bay
NJ0109240	Bayonne	017A	B-017A (W. 25th St.)	Newark Bay
NJ0109240	Bayonne	018A	B-018A (W. 30th St.)	Newark Bay
NJ0109240	Bayonne	019A	B-019A (Lincoln Pkwy)	Newark Bay
NJ0109240	Bayonne	020A	B-020A (W. 59th St.)	Newark Bay
NJ0109240	Bayonne	021A	B-021A (E. 50th St.)	Upper NY Bay
NJ0109240	Bayonne	022A	B-022A (Zabriskie Ave.)	Newark Bay
NJ0109240	Bayonne	024A	B-024A (Humphrey's Ave.)	Kill Van Kull
NJ0109240	Bayonne	026A	B-026A (Veteran's Park)	Newark Bay
NJ0109240	Bayonne	028A	B-028A (Lincoln Pkwy)	Newark Bay
NJ0109240	Bayonne	029A	B-029A (W. 37th St.)	Newark Bay
NJ0109240	Bayonne	030A	B-030A (W. 54th St.)	Newark Bay
NJ0109240	Bayonne	034A	B-034A (Bayview Ct.)	Newark Bay
NJ0109240	Bayonne	037A	B-037A (Trask Ave.)	Kill Van Kull
NJ0117846	East Newark	001A	E-001A (Central Ave.)	Passaic River
NJ0108871	Harrison Town	001A	H-001A (Hamilton Ave.)	Passaic River
NJ0108871	Harrison Town	002A	H-002A (Cleveland Ave.)	Passaic River

SPDES	Permittee	CSO Number	Regulator Number (Outfall Name)	Receiving Water Body
NJ0108871	Harrison Town	003A	H-003A (Harrison Ave.)	Passaic River
NJ0108871	Harrison Town	005A	H-005A (Middlesex St.)	Passaic River
NJ0108871	Harrison Town	006A	H-006A (Bergen St.)	Passaic River
NJ0108871	Harrison Town	007A	H-007A (Worthington Ave)	Passaic River
NJ0111244	Kearny Town	001A	K-001A (Stewart Ave.)	Passaic River
NJ0111244	Kearny Town	004A	K-004A (Nairne Ave.)	Passaic River
NJ0111244	Kearny Town	006A	K-006A (Johnston Ave.)	Passaic River
NJ0111244	Kearny Town	007A	K-007A (Ivy St.)	Frank's Creek
NJ0111244	Kearny Town	010A	K-010A (Duke St.)	Frank's Creek
NJ0108758	Newark City	002A	N-002A (Verona Ave.)	Passaic River
NJ0108758	Newark City	003A	N-003A (Delavan Ave.)	Passaic River
NJ0108758	Newark City	004A	N-004A/004A (Herbert)	Passaic River
NJ0108758	Newark City	005A	N-005A (Herbert Pl.)	Passaic River
NJ0108758	Newark City	008A	N-008A (Fourth Ave.)	Passaic River
NJ0108758	Newark City	009A	N-009A (Clay St.)	Passaic River
NJ0108758	Newark City	010A	N-010A (Clay St.)	Passaic River
NJ0108758	Newark City	014A	N-014A (Saybrook)	Passaic River
NJ0108758	Newark City	015A	N-015A (City Dock)	Passaic River
NJ0108758	Newark City	016A	N-016A (Jackson St.)	Passaic River
NJ0108758	Newark City	017A	N-017A (Polk St.)	Passaic River
NJ0108758	Newark City	018A	N-018A	Passaic River

SPDES	Permittee	CSO Number	Regulator Number (Outfall Name)	Receiving Water Body
			(Freeman St.)	
NJ0108758	Newark City	022A	N-022A (Roanoke Ave.)	Passaic River
NJ0108758	Newark City	023A	N-023A (Adams St.)	Peripheral Ditch / Elizabeth Channel
NJ0108758	Newark City	025A	N-025A (Peddie St.)	Peripheral Ditch / Elizabeth Channel
NJ0108758	Newark City	026A	N-026A (Queen St.)	Queen Ditch
NJ0108758	Newark City	027A/029A	N-027A/029A (Waverly)	Peripheral Ditch / Elizabeth Channel
NJ0108758	Newark City	030A	N-030A (Ave. A)	Peripheral Ditch / Elizabeth Channel
NJ0108898	North Bergen MUA	003A	NB-003A (W. 91st St.)	Bellmans Creek
NJ0108898	North Bergen MUA	005A	NB-005A (W. 69th St.)	Cromakill Creek
NJ0108898	North Bergen MUA	006A	NB-006A (W. 60th St.)	Cromakill Creek
NJ0108898	North Bergen MUA	007A	NB-007A (51st St.)	Cromakill Creek
NJ0108898	North Bergen MUA	008A	NB-008A (43rd St.)	Cromakill Creek
NJ0108898	North Bergen MUA	009A	NB-009A (Paterson Plank Rd.)	Cromakill Creek
NJ0108898	North Bergen MUA	010A	NB-010A (29th St.)	Cromakill Creek
NJ0108898	North Bergen MUA	011A	NB-011A (11th St.)	Cromakill Creek
NJ0108898	North Bergen MUA	014A	NB-014A (Paterson Plank Rd.)	Cromakill Creek
NJ0108880	Paterson City	001A	P-001A (Curtis Pl.)	Passaic River
NJ0108880	Paterson City	003A	P-003A (W. Broadway)	Passaic River
NJ0108880	Paterson City	005A	P-005A (Bridge St.)	Passaic River
NJ0108880	Paterson City	006A	P-006A (Montgomery St.)	Passaic River
NJ0108880	Paterson City	007A	P-007A (Straight St.)	Passaic River

SPDES	Permittee	CSO Number	Regulator Number (Outfall Name)	Receiving Water Body
NJ0108880	Paterson City	010A	P-010A (Warren St.)	Passaic River
NJ0108880	Paterson City	013A	P-013A (E. Eleventh St.)	Passaic River
NJ0108880	Paterson City	014A	P-014A (Fourth Ave.)	Passaic River
NJ0108880	Paterson City	015A	P-015A (S.U.M. Park)	Passaic River
NJ0108880	Paterson City	016A	P-016A (Northwest St.)	Passaic River
NJ0108880	Paterson City	017A	P-017A (Arch St.)	Passaic River
NJ0108880	Paterson City	021A	P-021A (Bergen St.)	Passaic River
NJ0108880	Paterson City	022A	P-022A (Short St.)	Passaic River
NJ0108880	Paterson City	023A	P-023A (Second Ave.)	Passaic River
NJ0108880	Paterson City	024A	P-024A (Third Ave.)	Passaic River
NJ0108880	Paterson City	025A	P-025A (East 33rd Ave.)	Passaic River
NJ0108880	Paterson City	026A	P-026A (East 20th Ave.)	Passaic River
NJ0108880	Paterson City	027A	P-027A (Market St.)	Passaic River
NJ0108880	Paterson City	029A	P-029A (River St.)	Passaic River
NJ0108880	Paterson City	030A	P-030A (19th Ave.)	Passaic River
NJ0108880	Paterson City	031A	P-031A (Interstate 80)	Passaic River
NJ0108880	Paterson City	032A	P-032A (Hudson St.)	Passaic River
NJ0108880	Paterson City	033A	P-033A (River St.)	Passaic River

D.2.9 Green Infrastructure

Various green infrastructure and source control projects have been implemented across the PVSC service area. Several communities have implemented rain barrel give-away programs or workshops for residents. Rutgers University's Cooperative Extension Water Resource Program

has performed Green Infrastructure Feasibility Studies for almost all of the 48 municipalities within the service area. Several of the projects identified by the Rutgers' Feasibility Studies have already been implemented, including rain gardens, cisterns, and planter boxes. PVSC is designing three right-of-way raingarden demonstration projects and conducting green infrastructure design and construction workshops. In addition, municipal action teams have been formed in most of the combined sewer communities. These municipal action teams are advancing green infrastructure and sustainable practices within their communities. The Green Infrastructure projects will help to intercept runoff from impervious areas such as roads, driveways, parking lots, and roofs and redirect this flow to green infrastructure, thereby reducing the total wet weather flow to the combined sewer system. See **Table I-7** for the percent impervious area in the model area.

D.2.10 Areas Prone to Flooding and Sewer System Backups

Surface and street flooding can be caused by a multitude of conditions, only some of which can be attributed to the condition or capacity of the combined sewer collection system. Local departments of public works often respond to reports of flooding and investigate the likely cause. The format and degree of record keeping vary. Common causes include:

- Blockages within a sewer lateral
- Blockages within a sewer main
- Sewer collapse
- Root intrusion
- Clogged catch basins
- Riverine flooding
- Saturated soils
- Grease
- Internal plumbing issues
- Inadequate stormwater conveyance
- Surface ponding in low lying areas
- Groundwater or interflow entering basements
- Leaves and debris
- Missing or nonfunctioning backflow preventers

Heavy rainfall events can exacerbate these issues and create a perception that the conveyance system is inadequate, when often local maintenance issues or practices are at least in part responsible. The hydraulic models used for this System Characterization study do not have adequate detail or sophistication for investigating local flooding conditions. The simulations of the large trunk and interceptor systems show that flooding in the typical year is limited to a few locations where the peak hydraulic grade line exceeds the manhole rim elevation. However, municipal records and observations of local officials were used to develop and anecdotal assessment of flooding conditions within the service area combined sewered municipalities.

Borough of East Newark

The Borough of East Newark does not have records indicating areas prone to flooding or sewer system backups.

City of Bayonne

The City of Bayonne maintains a detailed record of water and sewer complaints, related investigations and corrective actions implemented. Majority of flooding instances have been found to be caused by blockages at catch basin inlets or clogged sewer. Based on the City's

records, the critical sections of Bayonne that are prone to flooding during heavy rain events are as follows:

- All Underpasses
- 1st Street and Avenue A
- 1st Street and JFK Boulevard
- 1st Street between Humphrey Avenue and Zabriskie Avenue
- 1st Street and Avenue C
- 10th Street and Avenue A
- 13th Street and Avenue C
- 16th Street and Avenue A
- 14th Street and Avenue E
- 22nd Street and Avenue A
- 27th Street and Avenue E
- 22nd Street and Avenue F
- 30th Street and Avenue A
- Avenue A and Lincoln Parkway
- 34th Street and Avenue E
- Hobart Avenue and Cottage Street
- 52nd Street and Avenue E
- 55th Street and Broadway
- 55th Street and Avenue C
- Avenue J and Hook Road
- Avenue J and 22nd Street
- Route 440 and Port Terminal Boulevard

City of Newark

The following locations in the City of Newark have been identified as experiencing frequent sewer system backups:

- Ferry Street between Merchant Street and Adams Street. This area includes many restaurants and grease traps
- Elm Street between Jabez Street and Rome Street. This area includes many restaurants and grease traps
- Niagara Street between Magazine Street and Marne Street. This area includes many restaurants and grease traps
- Barber Street between Magazine Street and Marne Street. This area includes many restaurants and grease traps
- South Munn Avenue between South Orange Avenue and Pine Grove Terrace.
- Fabyan Place between Salvage Place and Buffington Street
- Wainwright Street between St. James Street and Lyons Avenue
- N. 12th Street between Abington Avenue and Bearsly Street
- 15 Avenue between Bruce Street and Springfield Avenue.

City of Paterson

Street flooding occurs throughout the City of Paterson and is most often associated with trash interfering with flow to inlet structures. Additionally, large areas of the City are in the Passaic River Flood Inundation Zone and are subject to frequent river flooding.

The City maintains detailed records of sewer complaints, blockages, and remedial actions. Between 2006 and 2016, a total of 1724 sewer complaints were received and investigated. Complaints originated from homeowners, department of public works staff, police, the City's engineering department, and the public. The majority of complaints were found to be the result of internal plumbing problems. A total of 451 sewer main blockages were reported and resolved during the 10.25 years for which the data was tabulated from Sewer Division Field Reports. 30 chronic trouble areas have been identified from the historical sewer complaints. Of those locations, 13 have had heavy cleaning and internal video inspection completed, of which four have had main repairs completed to mitigate against future backups. A list of all of the blockage locations is shown in **Table D-3**.

Table D-3: Chronic Sewer Blockage Locations

Chronic Trouble Area	Location
1	Lyon Street around Sassafras Street and East 16th Street
2	East 19th Street between 7th Avenue and 8th Avenue
3	East 16th Street between 7th Avenue and Warren Street
4	East 23rd Street between 7th Avenue and 6th Avenue
	7th Avenue between East 22nd Street and East 23rd Street
5	Straight Street between Park Avenue and 16th Avenue
6	10th Avenue between East 26th Street and East 27th Street
7	Getty Avenue between Knickerbocker Avenue Michigan Avenue
8	1st Avenue River Street between East 22nd Street
	Madison Avenue between 1st Avenue and 2nd Avenue
	East 19th Street between 1st Avenue and 2nd Avenue
9	Market Street between East 29th Street East 30th Street
10	Glover Avenue on Nagle Street until dead end
11	East 18th Street between 6th Avenue 7th Avenue
12	East 22nd Street between 8th Avenue 9th Avenue
13	21st Avenue near State Street
	20th Avenue between Gray Street Chestnut Street
14	Jefferson Street between North 10th Street and Burhans Avenue
15	Edmund Avenue between Union Avenue and Hill Street (to dead end)
16	East 25th Street between 10th Avenue and 11th Avenue
17	East 39th Street between 17th Avenue and 19th Avenue
	East 38th Street between 17th Avenue and 19th Avenue

	17th Avenue East between 38th Street and East 39th Street
18	Chestnut Street between 20th Avenue and Essex Street
	21st Avenue to State Street
19	Main Street between Barclay Street and Mary Street
20	Garfield Avenue between Welcome Street and Haledon Avenue
21	East Main Street between Amity Street and Holsman Street
22	George Street between Getty Avenue West and Railway Avenue
23	Preakness Avenue between Walnut Street and Maple Street
24	Rossiter Avenue between Totowa Avenue and Union Avenue
25	East 29th Street between 17th Avenue and 18th Avenue
26	North Main Street between Clinton Street and Arch Street
27	Elberon Avenue between Union Avenue and Crosby Avenue
28	Knickerbocker Avenue between Vernon Avenue and Lakeview Avenue
29	Buffalo Avenue between Hazel Street and Paxton Street
30	Circle Avenue between Temple Street and North 3rd Street

The area near Vreeland Avenue between 18th and 20th Avenues has a history of street flooding during high intensity rainfall dating back to at least the 1930's. A large diameter brick combined trunk sewer extends across the City from the PVSC Market Street Regulating Chamber to near the Clifton border. This trunk was constructed in 1893-1894 and was lined with gunite in the 1990's. A significant number of large diameter branch connections discharge to the trunk. Trunk size ranges from a nominal 36" in upstream segments to 84" at the Market Street Regulating Chamber. The trunk sewer is relieved to a 90" storm sewer at the intersection of Vreeland and 19th Avenues. The trunk sewer was cleaned and inspected in 2012 and found to be in very good condition with moderate deposits of debris. Additional cleanings have been performed on upstream segments and they too were found to be in very good condition.

Street flooding also occurs in the vicinity of Levine and Main Streets where a natural drainage course flows from Clifton across Hazel Street within the NJ Transit right-of-way and is connected to the City combined sewer near that intersection. Flooding may be a result of the maintenance of the inlet structure rather than surcharging of the trunk sewer.

Town of North Bergen

North Bergen experiences regular flooding from Bellman's Creek in the areas of 91st Street and Railroad Avenue. The combined sewer system is known to surcharge along 83rd Street due to back-ups in the main under Westside Avenue. The property on the southeast corner of 86th Street and Tonnelle Avenue has reported issues when downstream blockages causes surcharging that leaks out of the pipe joints and into the parking lot of this property. The area west of Tonnelle Avenue on 86th Street can also experience some back-ups due to the topography of the area. Throughout the Town, complaints are typically found to be the result of blockages in either the lateral or the sewer main. Once these blockages are cleared the issue is usually resolved.

Town of Harrison

Two areas within the Town of Harrison experience accumulations of grease. Harrison Avenue, between 5th Street and Rodgers Blvd., and Rodgers Blvd., between Davis Street and Cross Street, these areas receive more frequent inspection and cleaning. Sewer system induced flooding is not reported as an issue elsewhere within the town.

Town of Kearny

The Town of Kearny experiences regular tidal flooding in the areas east of Schuyler Avenue and west of Belgrove Drive. Records obtained from the Town of Kearny department of public works related to sewer blockages and backups for the years 2013, 2014, and 2015 indicate an average of about 30 backups per year occurring throughout the town. The streets listed in **Table D-4** below are subject to flooding due to their proximity to the Newark Bay or the Passaic River.

Table D-4: Streets Subject to Tidal Flooding

East of Schuyler Avenue		West of Belgrove Drive	
Belleville Tpke	3	Alpine Pl	1
Bergen Ave	4	Belgrove Drive	2
Dukes St	2	Jefferson Ave	1
East Midland Ave	9	Hillcrest Road	1
Harrison Ave	1	Peden Ter	4
Hoyt St	3	South Midland Ave	6
Rizzolo Road	1	Stewart Ave	1
Schuyler Ave	5	Wilkinson Ter	1
Tappan St	1	William St	1
		Webster Ave	3

SECTION E - COLLECTION OF PRECIPITATION AND SEWER FLOW MONITORING DATA

E.1 INTRODUCTION

This section presents information on the collection of precipitation and sewer flow data to meet the requirements of Paragraphs II.A.C.1.a and b of the USEPA's CSO Control Policy.

Rainfall and flow monitoring data were collected from April 2016 to August 2016. After the collected data was reviewed and analyzed, the data was deemed adequate to facilitate the development, calibration and validation of the Hydrologic and Hydraulic (H&H) Model. This section contains a summary of the rainfall and flow monitoring data and discusses the network of rainfall and flow monitoring instrumentation, and describes how the data collected for the rainfall and flow monitoring program was analyzed for use in the H&H Model calibration and validation.

E.2 SEWER FLOW MONITORING PROGRAM

PVSC owns and operates a flow monitoring network across the PVSC Service Area. The monitoring network includes various types of flow meters located throughout PVSC's Service Area, at the WRRF, in each of the Pump Stations, and at the tie-in points where other municipal collection systems tie-into the collection system. There are over 70 permanent flow meters out of which 58 were used for dry weather flow analysis and calibration, which includes 38 existing flow meters in the separate sewer areas (outside the CSO area), 14 existing flow meters at pump stations and one existing flow meter at WRRF were used for the calibration and validation of the H&H Model. In addition, temporary flow meters were installed at 21 new locations to characterize surface runoff from the combined area and CSO discharges. The locations of flow meters installed specifically for the flow monitoring program and the H&H Model calibration and validation can be categorized into the following four categories:

1. Located on the influent pipe to CSO regulators to measure the influent flow to CSO regulator chambers prior to diversion to the interceptor or outfall, the metered flows can be used for combined area runoff calibration.
2. Located on the effluent pipe of CSO regulators to measure the intercepted flows from the regulator entering the interceptor and downstream collection system, the metered flows can be used for regulator calibration.
3. Located on the overflow pipe of CSO regulators to measure the CSO overflows, the metered CSO flows can be used for regulator calibration.
4. Located in the main interceptors to measure level and flows in the major interceptors, the metered flows can be used for interceptor calibration.

Table E-1 lists the locations and categories of the 21 temporary flow meters. Five of the meters were placed on the regulator influent pipe. Two of the meters were placed on the regulator effluent pipe. Thirteen of the meters were placed in the outfall pipe. The final meter was placed on the interceptor toward the downstream end of Paterson.

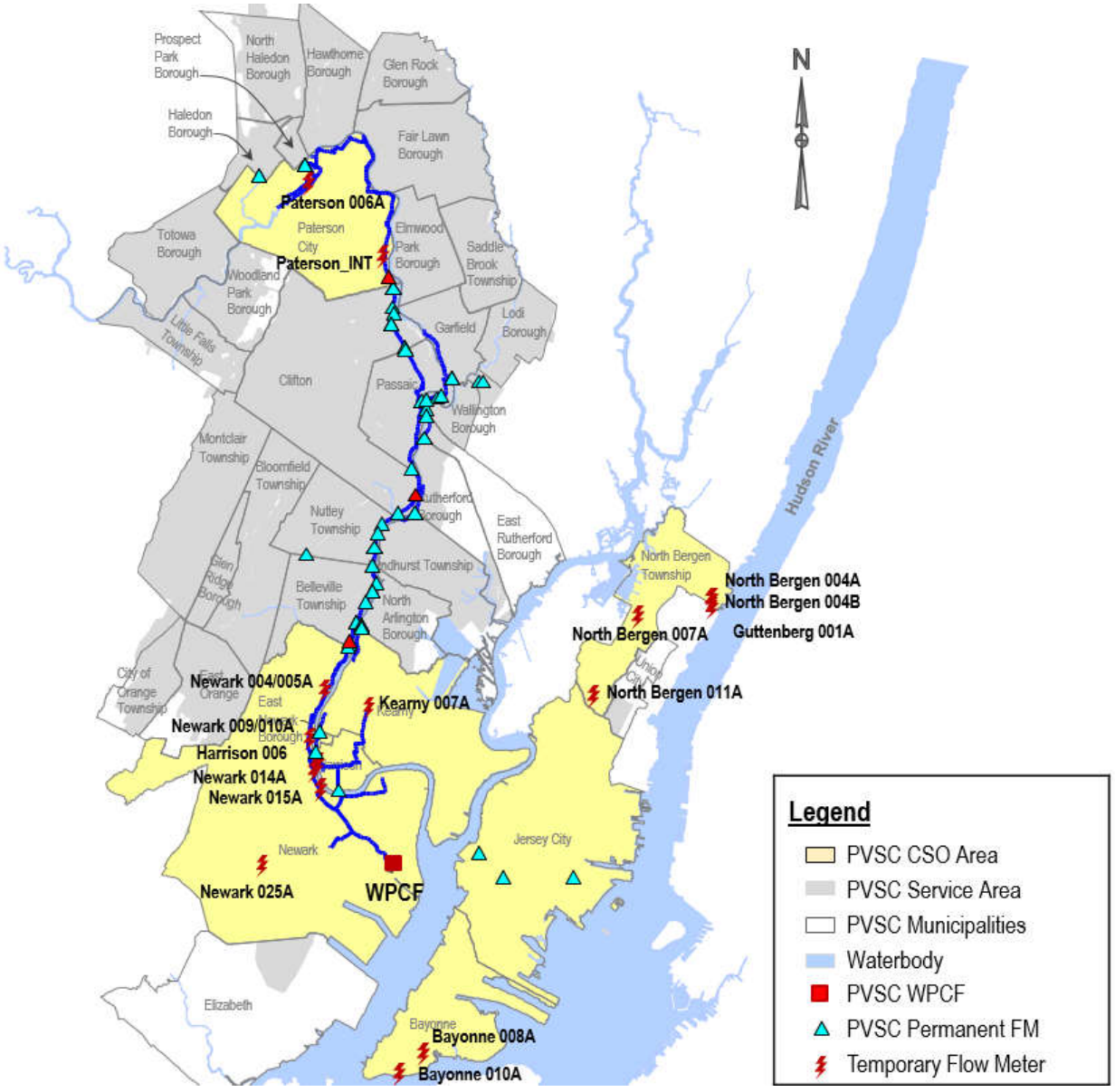


Figure E-1 shows the locations of the flow meters, including both permanent and temporary flow meters, which were used for H&H Model calibration and validation.

Table E-1: Temporary Flow Meter Locations

Meter ID	Municipality	Location	Category
Bayonne 008A OF	Bayonne	East 5th and Ingham Ave	Outfall
Bayonne 010A OF	Bayonne	W 1st and Avenue C	Outfall

Meter ID	Municipality	Location	Category
Guttenberg 001A	Guttenberg	70th and JFK Blvd	Outfall
Harrison 006 Influent	Harrison	Bergen and Dey	Regulator Influent
Kearny 007A	Kearny	King and Ivy Street	Outfall
Newark 004/005A	Newark	Herbert Place under elevated Hwy	Outfall
Newark 009/010 OF North	Newark	Clay Street - inside facility	Outfall
Newark 009/010 OF South	Newark	Clay Street - inside facility	Outfall
Newark 015A	Newark	City Dock	Outfall
Newark 014A	Newark	Saybrook in pull off	Outfall
Newark 025A East	Newark	Peddie - access through parking, near railroad	Regulator Influent
Newark 025A West	Newark	Peddie - access through parking, near railroad	Regulator Influent
Newark 025A Regulated	Newark	Peddie - access through parking, near railroad	Regulator Effluent
North Bergen 004A	North Bergen	73rd and Hudson County 693	Outfall
North Bergen 004B	North Bergen	Near 74th and Hudson County in grassy lot	Outfall
North Bergen 007A	North Bergen	53rd and Tonnelle Ave in Concrete Plant driveway	Outfall
North Bergen 011A	North Bergen	1101 Tonnelle Ave	Outfall
Paterson 006A East	Paterson	Montgomery and River St	Regulator Influent
Paterson 006A West	Paterson	Montgomery and River St	Regulator Influent
Paterson 006A Regulated	Paterson	Montgomery and River St	Regulator Effluent
Paterson_INT	Paterson	McLean Boulevard at Cemetery entrance	Interceptor

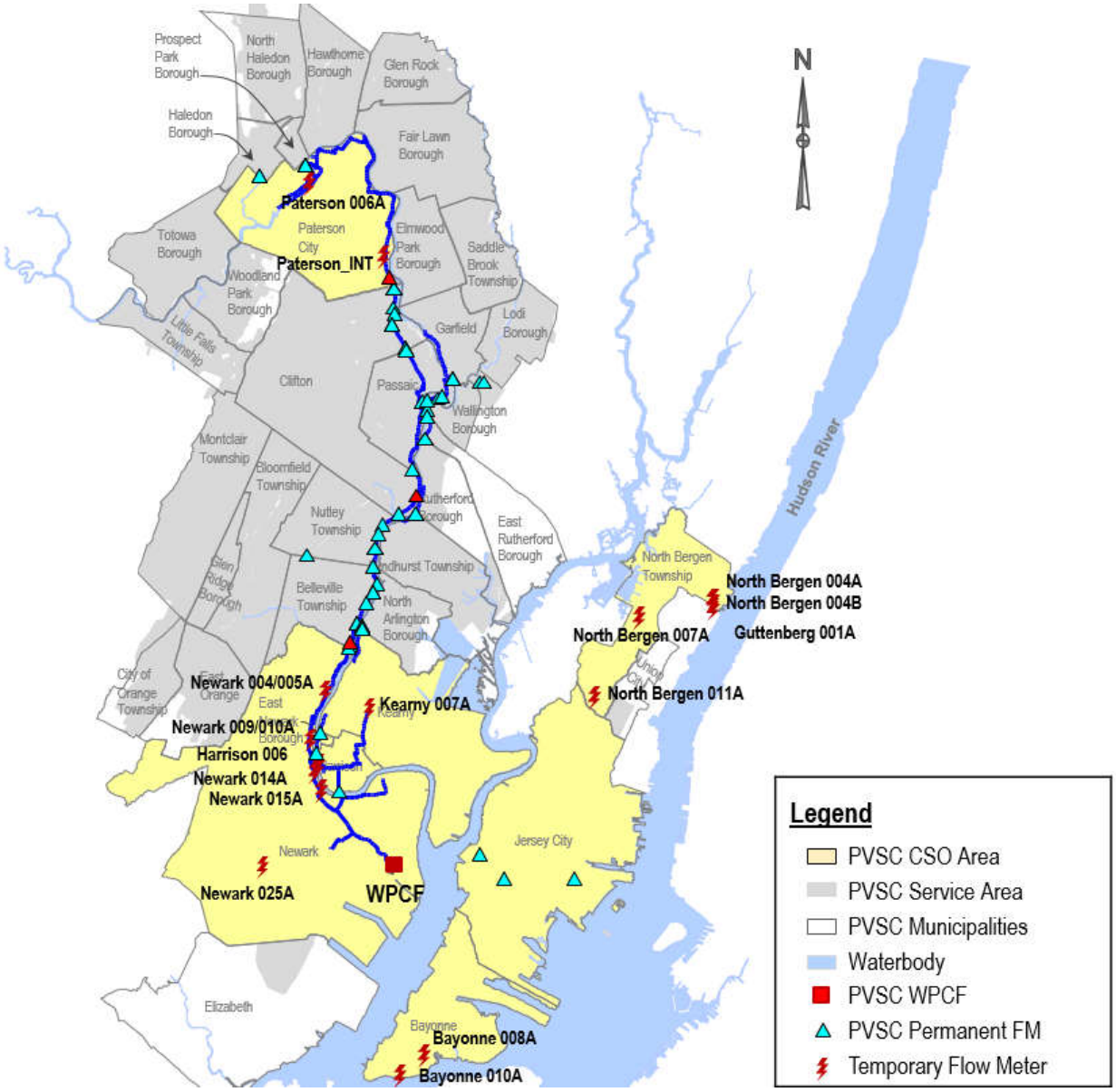


Figure E-1: Flow Meter Location

The availability of metering data from the temporary flow meters are shown in **Figure E-2**, highlighted dots mean no data was collected or the meter was not in service for the periods. Flow data is available for most of the temporary meters for period of 5/20/16 to 8/5/16.

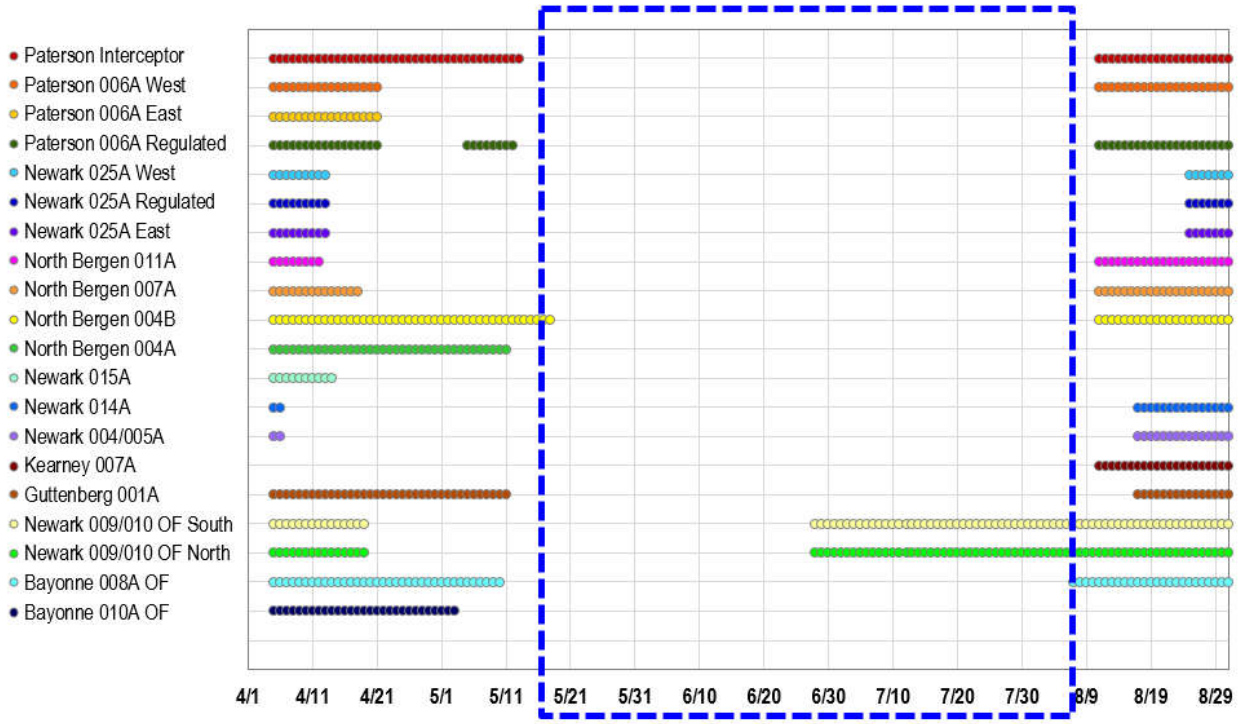


Figure E-2: Missing Data period of Temporary Flow Meter Locations

E.3 DRY WEATHER FLOW (DWF) ANALYSIS

A "dry weather" condition was defined as a period with no precipitation that begins 48 hours after the last wet weather event ends and lasts until the beginning of the next precipitation event (i.e. the rain gauge read a 0.01 inch value). Dry weather flow (DWF) periods based on this definition are illustrated in the hydrograph shown in **Figure E-3.**

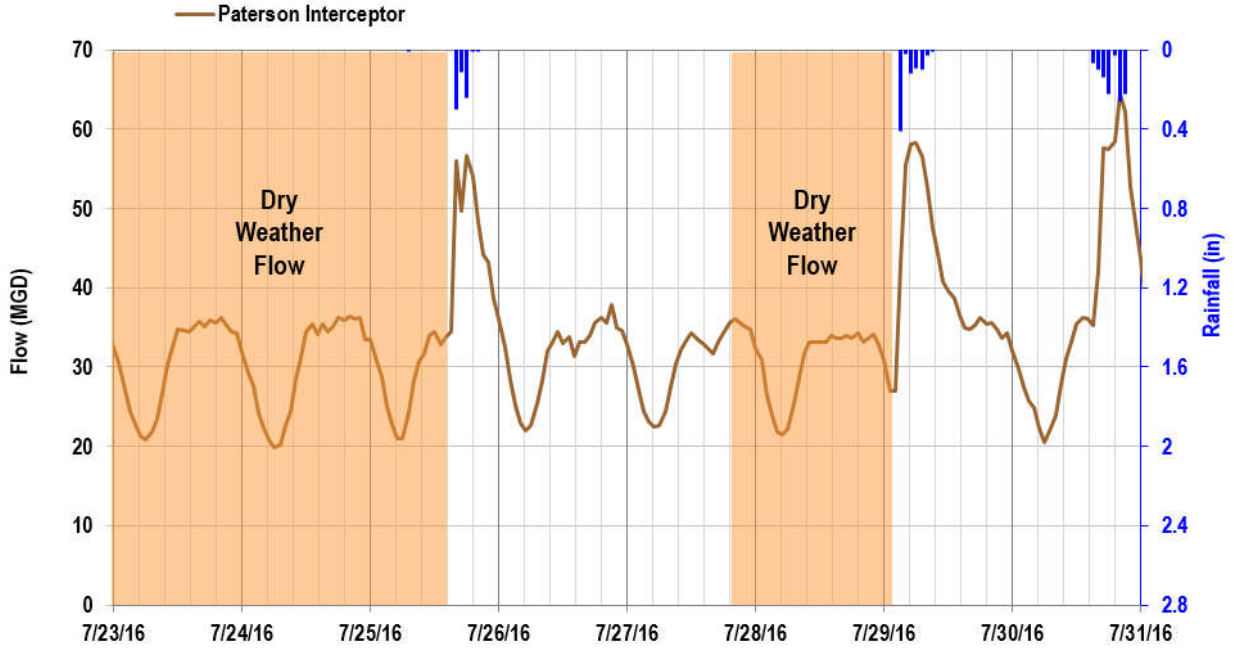


Figure E-3: Hydrograph showing Dry Weather Flow

Average dry weather flow was calculated by averaging the monitored flows from the dry weather periods identified in the rainfall data analysis. The overall and monthly DWFs for all monitoring sites were analyzed.

The DWFs for the monitoring period (April 1, 2016 to August 31, 2016) are also shown in the schematic in **Figure E-4**. Each value displayed next to each flow meter represents the DWF overall average (in MGD) for the monitoring period.

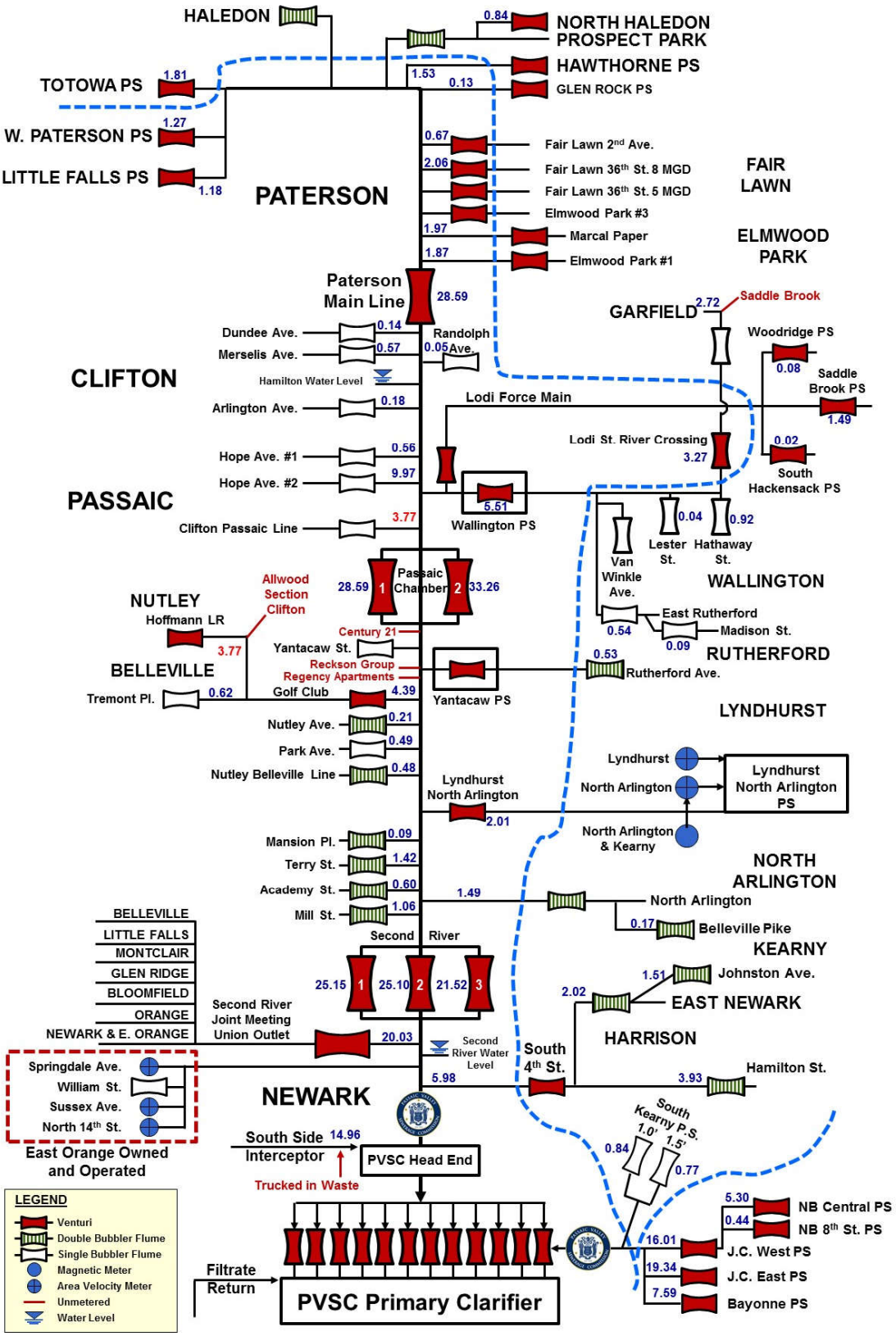


Figure E-4: Dry Weather Flow

The DWFs vary throughout the day, with the highest flows normally occurring around noon and the lowest rates between midnight and early morning. Flow data from the dry weather periods were used to develop a diurnal pattern for each flow meter. Diurnal patterns were analyzed for both weekdays and weekends. In the plot shown on **Figure E-5**, the weekend DWF peak and valley have a 3-hour lag compared to the weekday pattern. The weekday and weekend diurnal patterns, and the overall annual average values discussed above provided the bases of dry weather inputs for the model.

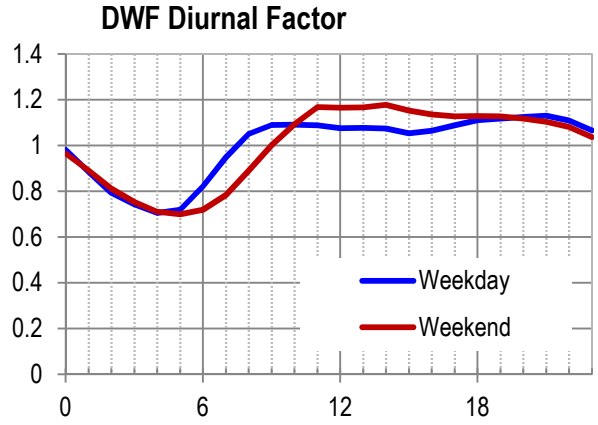


Figure E-5: Weekend and Weekday Dry Weather Flow Diurnal Pattern

E.4 WET WEATHER FLOW ANALYSIS

Wet weather flows are the combination of dry weather flows and additional flows that enter the system during wet weather conditions. The additional flows are from combined area surface runoff and RDII. Inflow normally occurs when rainfall enters the system through direct connections such as roof leaders, yard drains, catch basins, sump pumps, manhole covers and frame seals or cross connections with storm sewers. Inflow is usually recognized graphically by large magnitude, short duration spikes immediately following a rain event. Infiltration occurs during wet weather conditions when water enters a sewer system from the ground through means which include, but not limited to, deteriorated pipes, pipe joints, connections, or manholes. It is significantly influenced by the size and duration of the rainfall event. Infiltration is often recognized graphically by a gradual increase in flow after a wet weather event. The increased flow typically sustains for a short period after rainfall has stopped and then gradually drops off.

The peaking factor represents the ratio of the peak wet weather flow to the average dry weather flow. Usually, an hourly peaking factor is used to represent the wet weather peaking factor. Peaking factors were analyzed for each flow monitoring site. The peaking factors in the separate sewer area can be used to determine the extent of the RDII within a particular basin. **Figure E-6** is an example of the flow monitoring site showing the flow response to precipitations at the monitoring location. Flow volume depicted by the area between the red line (the metered flow hydrograph) and the grey line (the estimated dry weather flow based on metering data) is the wet weather volume corresponded to the rainfall event, and the max flow is the peak flow of the wet weather event. An hourly peaking factor of approximately 3.0 was estimated for the site, which is reasonable for a sanitary sewer collection system. The flow increase shortly after the rainfall

indicates immediate inflow into the collection pipes, and the long tail back to the base flow indicates infiltration occurrence at the site as well.

Wet weather volume and peak flow were analyzed for selected wet weather events for all temporary metering locations and permanent metering locations with quality data. **Table E-2** shows the wet weather volumes and peaks for the four events used in model calibration for all the temporary metering locations. Wet weather event volume and peak for some of the permanent metering locations can be viewed in model calibration plots **Figure I-27** to **Figure I-50**. More plots can be found in **Appendix D** (Model Calibration Result).

Table E-2: Event Wet Weather Volume and Peak for Temporary Metering Locations

Metering Site		Event 1		Event 2		Event 3		Event 4	
		5/30/16 0:00 to 5/30/16 12:00		7/25/16 12:00 to 7/26/16 0:00		7/29/16 0:00 to 7/29/16 12:00		7/30/16 12:00 to 8/1/16 12:00	
	Category	Flow Volume (MG)	Flow Peak (MGD)	Flow Volume (MG)	Flow Peak (MGD)	Flow Volume (MG)	Flow Peak (MGD)	Flow Volume (MG)	Flow Peak (MGD)
PT_INT	Interceptor	20.84	54.5	22.36	64.0	23.22	61.1	82.29	78.1
PT_6A_INF (combination of Paterson 006A East and Paterson 006A West)									
	Regulator Influent	2.52	11.6	4.28	35.0	4.06	23.9	11.23	49.4
PT_6A_Eff	Regulator Effluent	2.78	14.0	3.38	11.4	3.18	18.3	8.65	12.7
NE_25A_E	Regulator Influent	8.25	87.3	4.52	126.7	8.50	87.7	15.29	138.0
NE_25A_W	Regulator Influent	13.90	135.4	16.15	284.9	14.88	118.9	35.06	190.7
NE_25A_Eff	Regulator Effluent	22.03	90.6	13.93	81.4	19.38	72.4	37.02	55.0
HA_06_Inf	Regulator Influent	0.57	5.8	0.60	10.1	0.37	3.9	0.78	6.0
NE_04&05A	Outfall	0.70	13.0	0.96	36.3	0.55	7.6	0.79	14.5
NE_09&10_S	Outfall	12.30	854.0	No Data	No Data	No Data	No Data	No Data	No Data
NE_09&10_N	Outfall	4.04	49.6	No Data	No Data	No Data	No Data	No Data	No Data
NE_14A	Outfall	4.44	50.6	6.26	125.1	4.13	54.7	6.05	69.8
NE_15A	Outfall	0.33	29.1	6.40	137.6	No Data	No Data	0.20	19.3
KE_07A	Outfall	2.19	33.9	2.42	55.9	1.78	24.9	3.43	45.7
BA_08A	Outfall	0.66	10.0	1.21	15.2	0.31	9.0	0.65	11.8
BA_10A	Outfall	0.48	7.8	0.86	9.7	0.19	5.9	0.69	10.3
NB_11A	Outfall	0.30	14.5	0.28	11.8	0.01	0.6	0.08	1.8
NB_07A	Outfall	0.34	8.9	0.20	4.7	0.17	1.9	0.24	3.4

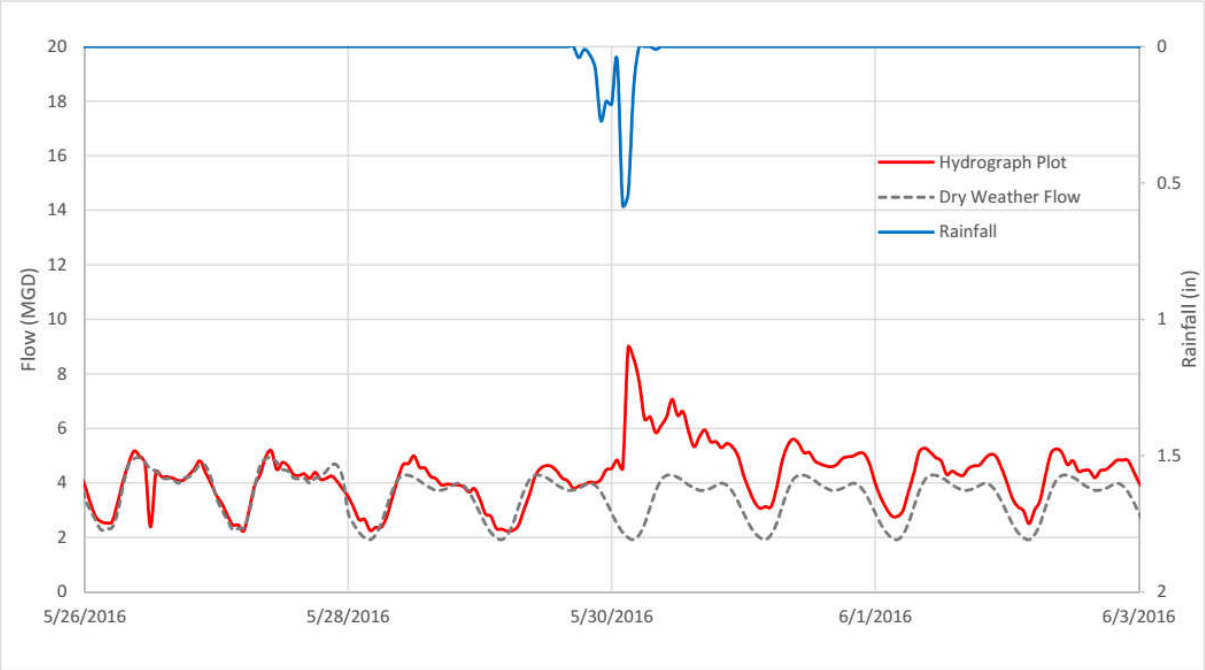


Figure E-6: Flow Monitoring Site Wet Weather Analysis (Example Plot)

E.5 SEWER FLOW MONITORING DATA SUMMARY

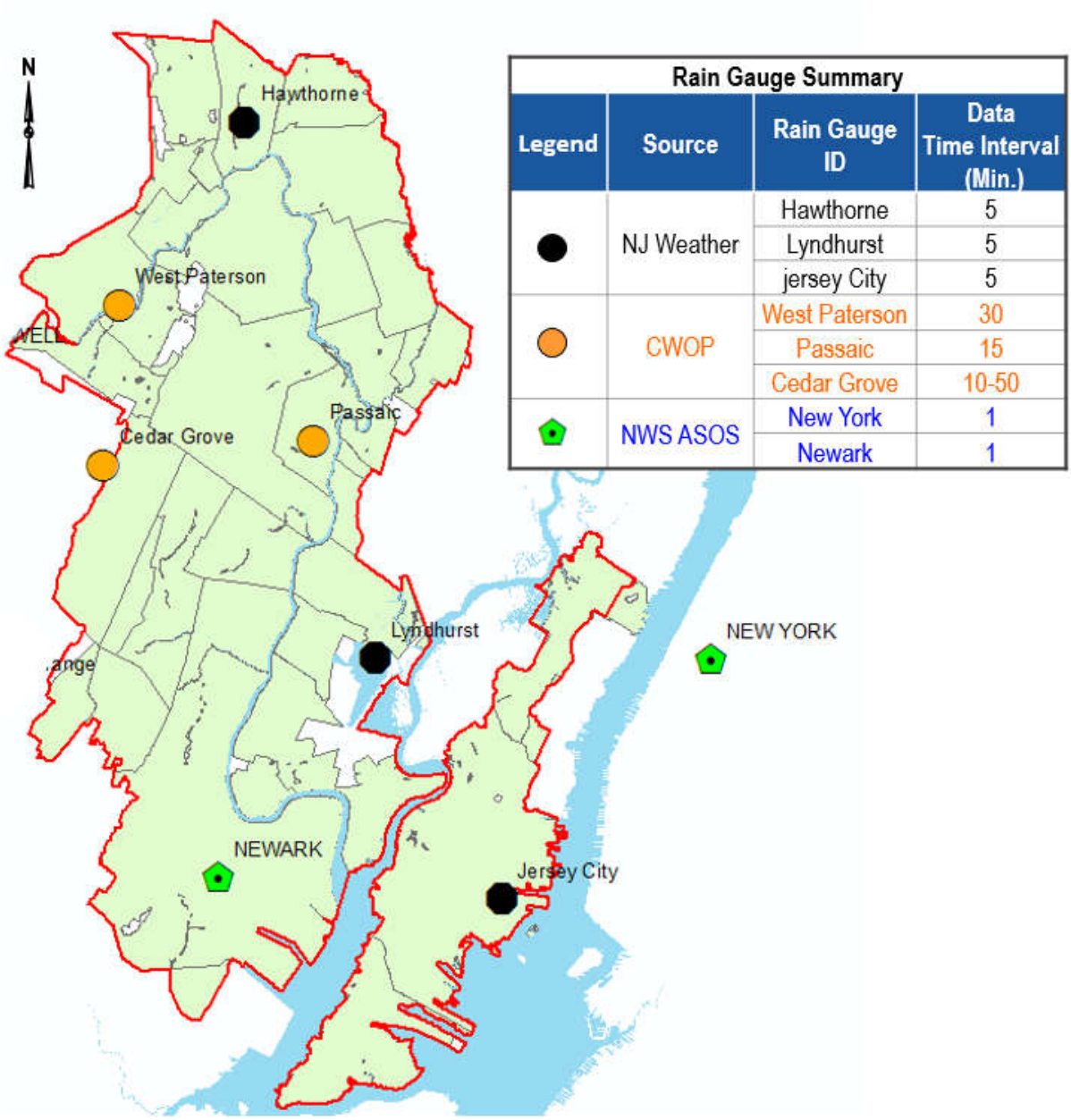
The temporary flow meters measured flow, level and velocity data for each flow monitoring site at 5-minute intervals. Data was converted to 15-minute intervals for further analysis. The PVSC permanent flow metered data was received in 15-minute intervals. Meter data was screened prior to use, abnormal flow spikes (example: second river crossing) were smoothed out as needed by removing erroneous spikes or dips in the metering data and interpolating between the remaining data points. Metering data was analyzed for dry weather flows (DWF) and wet weather flows (WWF) for each monitoring site. Weekday and weekend DWF diurnal patterns were also developed.

The DWF was ultimately used as inputs into the model. Overall average DWFs, average monthly DWFs, and weekday and weekend diurnal patterns were input into the model for each flow meter. The WWF were used to calibrate the model output. Model data was compared side by side with metered data for each wet weather event for each flow meter.

E.6 RAINALL MONITORING LOCATIONS

Precipitation data for the flow monitoring period were obtained from NJ Weather, National Weather Service Automated Surface Observing System (NWS ASOS), and Citizen Weather Observer Program (CWOP). Rain gauge locations are shown in **Figure E-7**. Rain gauge data source, ID, and data time intervals are also included. NWS ASOS rain gauges (Newark and New York) have 1-min rainfall data, NJ Weather rain gauges (Horthorne, Lyndhurst, and Jersey City) have 5-min rainfall data, and CWOP rain gauges have rainfall data in 10-50 minute intervals. All rainfall data was converted to 5-min intervals for consistency. Rainfall distributions for these

eight rain gauges are shown in **Figure E-8**. Significant spatial variance was observed for these rain gauges. Almost half of the rain gauges (Hawthorn, Lyndhurst, Jersey City) are missing data in period of 6/9/16 to 7/24/16. These data gaps needed to be considered when selecting rainfall events for model calibration.



Rain Gauge Summary			
Legend	**Source**	**Rain Gauge ID**	**Data Time Interval (Min.)**
●	NJ Weather	Hawthorne	5
		Lyndhurst	5
		jersey City	5
●	CWOP	West Paterson	30
		Passaic	15
		Cedar Grove	10-50
⬟	NWS ASOS	New York	1
		Newark	1

Figure E-7: Rain Gauge Locations

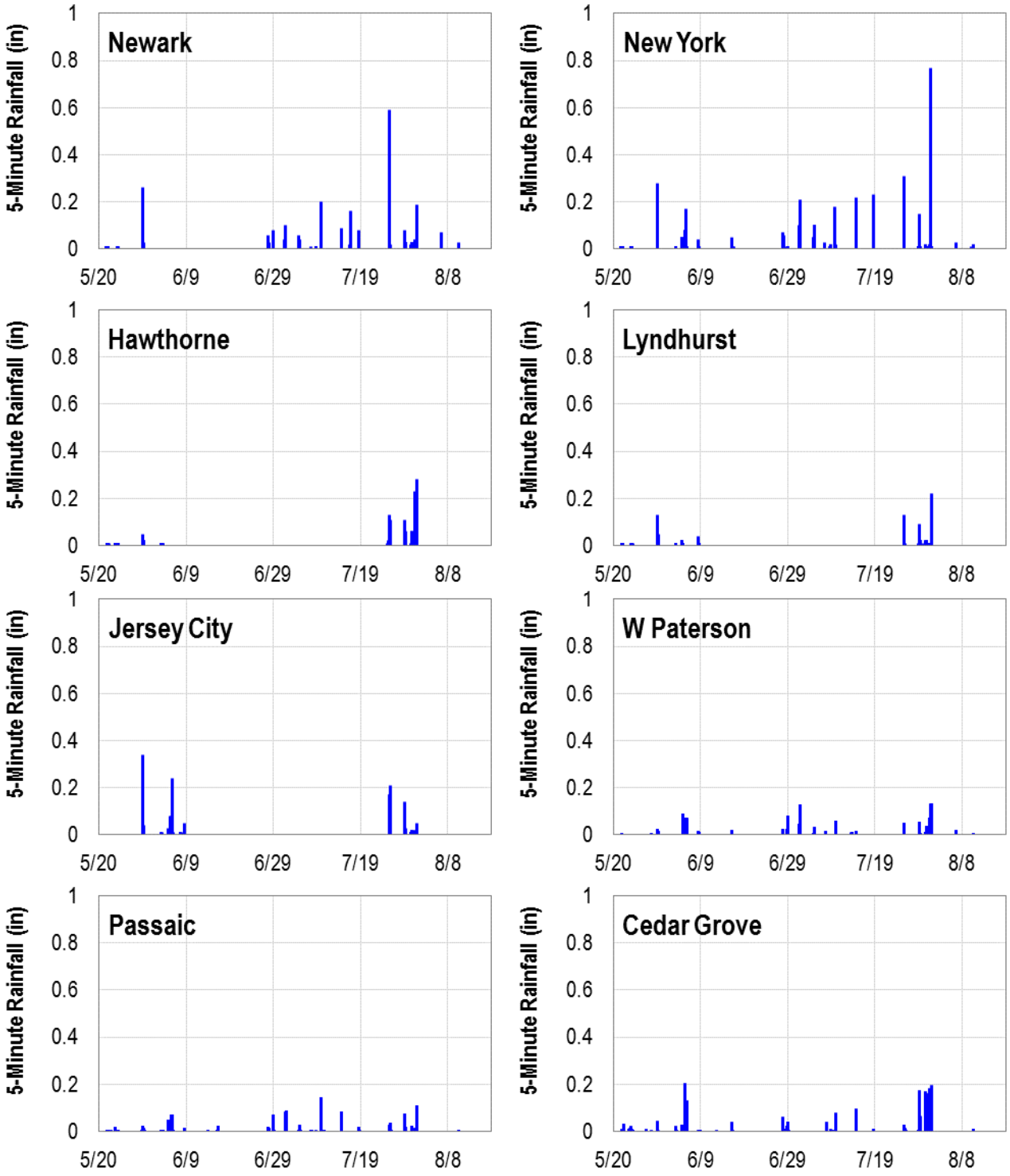


Figure E-8: Rainfall Distribution for All Rain Gauges 5/20/16-8/10/16

E.7 RAINFALL EVENT ANALYSIS

Rainfall events were analyzed based on an inter-event time of 6 hours. Newark Airport rainfall records were used to identify the top 10 rainfall events because this rain gauge covers the largest portion of the combined area in the PVSC sewer service area. Top 10 rainfall events at Newark Airport are listed in **Table E-3**. Rainfall depths at the other rain gauges are also listed in the table for comparison. Only the top 4 events have rainfall data available from all rain gauges.

Table E-3: Top 10 Rainfall Events (Volume Based), 5/20/16-8/10/16

Rainfall Event	Newark (In)	New York (In)	Hawthorne (In)	Lyndhurst (In)	Jersey City (In)	W Paterson (In)	Passaic (In)	Cedar Grove (In)
7/25/16	**1.84**	1.00	0.70	0.74	1.81	0.67	0.34	0.42
5/29/16	**1.60**	1.65	0.63	1.25	1.79	0.46	0.55	0.59
7/30/16	**1.07**	1.29	3.08	1.60	0.60	2.33	1.84	2.79
7/28/16	**0.87**	1.09	1.14	1.17	1.10	0.78	1.10	1.58
7/4/16	0.63	1.15	NA	NA	NA	0.48	0.48	0.00
7/16/16	0.58	0.00	NA	NA	NA	0.00	0.00	0.00
7/9/16	0.49	0.53	NA	NA	NA	0.53	0.66	0.39
6/28/16	0.40	0.04	NA	NA	NA	0.72	0.39	0.69
6/27/16	0.38	0.54	NA	NA	NA	0.26	0.27	0.54
7/18/16	0.23	0.35	NA	NA	NA	0.00	0.07	0.09

Newark Airport rainfall was compared to the NOAA's Precipitation Frequency Table to estimate the return frequency of these events (**Figure E-9**).

- Event 1 on May 29, 2016 is a short and intense event, it is a 1 to 2-year storm in 1 hour and less than 1-year storm beyond 1 hour.
- Event 2 on July 25, 2016 is another short and intense event, it is a 5-year storm in 1 hour and a 2-year storm in 3 hours.
- Event 3 on July 29, 2016 and Event 4 on July 30, 2016 are both less than 1-year storm events.

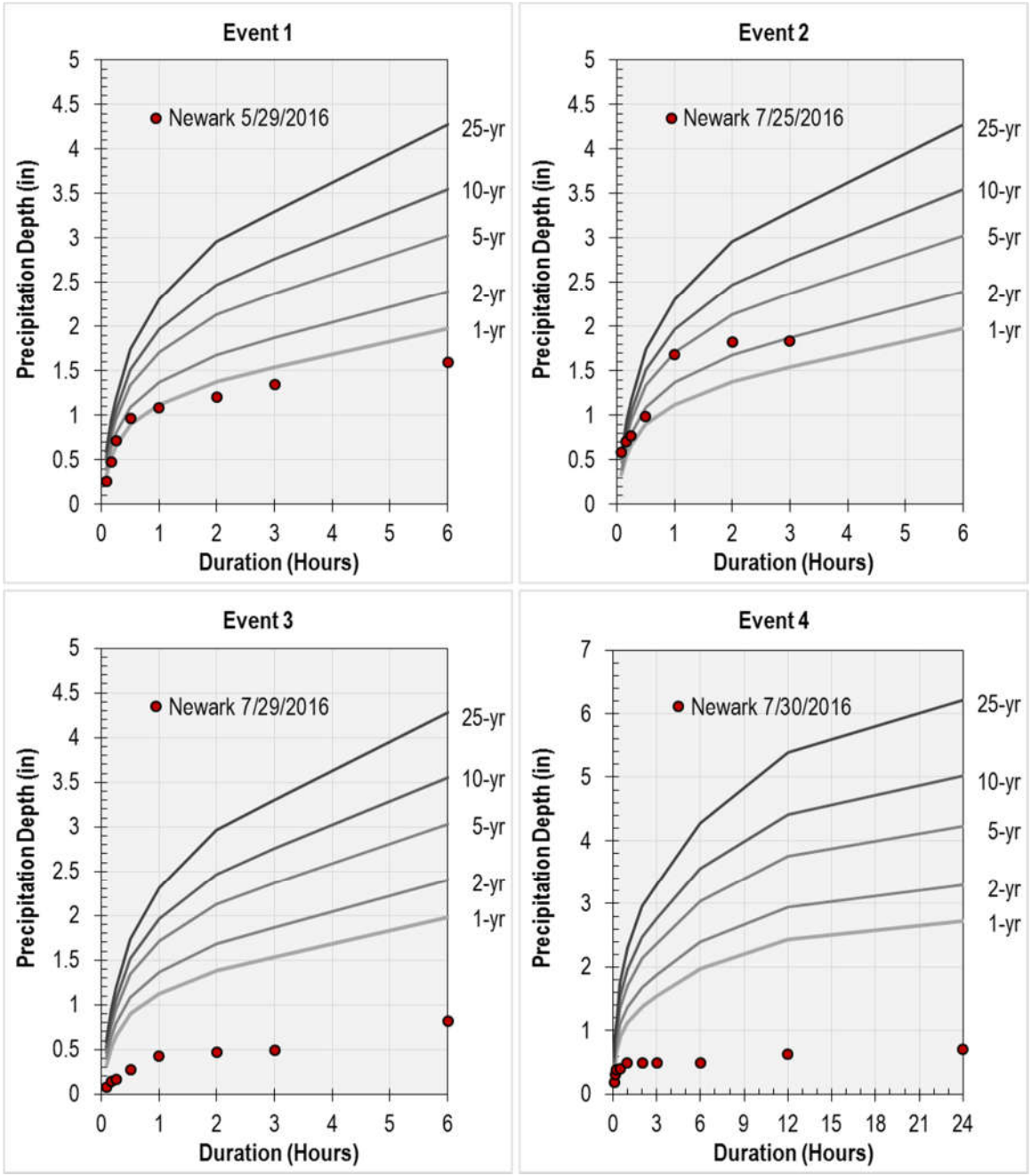


Figure E-9: Depth-Duration-Frequency for Top 4 Rainfall Events

E.8 COLLECTION OF PVSC WATER RESOURCES RECOVERY FACILITY OPERATIONAL DATA

In addition to flow data collected from the flow meters located in the collection system, flow data from the PVSC WRRF influent flow meter was obtained for the same time period. A hydrograph of the 15-minute plant flow is shown in and average daily influent flows are provided in **Table E-4**.

Figure E-10: PVSC WRRF Influent Flow

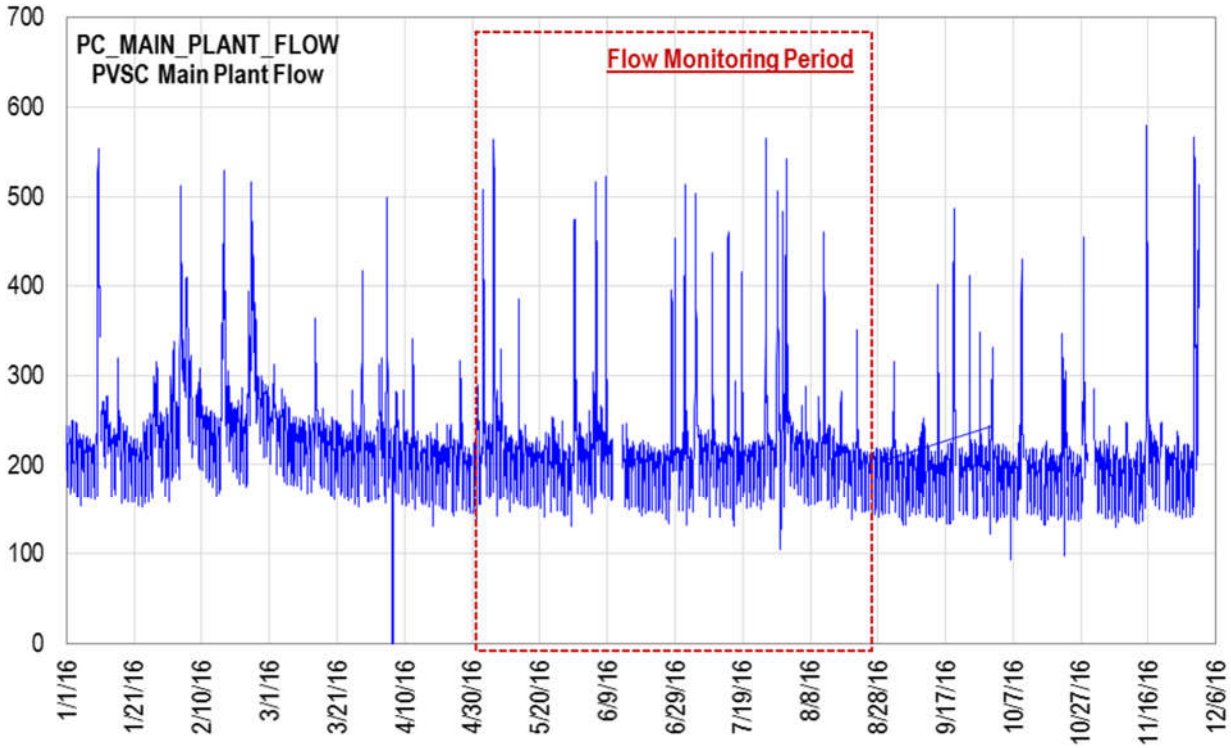


Table E-4: Average Daily WRRF Influent Flow

Date	Avg WRRF Inf (MGD)	Date	Avg. WRRF Inf. (MGD)	Date	Avg. WRRF Inf. (MGD)	Date	Avg. WRRF Inf. (MGD)	Date	Avg. WRRF Inf. (MGD)
4/30/16	201	5/25/16	196	6/18/16	194	7/12/16	198	8/5/16	212
5/1/16	213	5/26/16	195	6/19/16	194	7/13/16	197	8/6/16	211
5/2/16	197	5/27/16	194	6/20/16	196	7/14/16	245	8/7/16	202
5/3/16	315	5/28/16	193	6/21/16	197	7/15/16	207	8/8/16	203
5/4/16	215	5/29/16	186	6/22/16	195	7/16/16	212	8/9/16	192
5/5/16	211	5/30/16	315	6/23/16	194	7/17/16	205	8/10/16	212
5/6/16	306	5/31/16	213	6/24/16	195	7/18/16	230	8/11/16	208
5/7/16	230	6/1/16	208	6/25/16	192	7/19/16	205	8/12/16	255
5/8/16	241	6/2/16	205	6/26/16	190	7/20/16	201	8/13/16	212
5/9/16	216	6/3/16	203	6/27/16	197	7/21/16	200	8/14/16	203
5/10/16	211	6/4/16	213	6/28/16	245	7/22/16	205	8/15/16	201
5/11/16	204	6/5/16	302	6/29/16	240	7/23/16	200	8/16/16	206
5/12/16	203	6/6/16	237	6/30/16	199	7/24/16	198	8/17/16	218
5/13/16	236	6/7/16	217	7/1/16	254	7/25/16	269	8/18/16	204
5/14/16	210	6/8/16	262	7/2/16	235	7/26/16	235	8/19/16	197
5/15/16	205	6/9/16	210	7/3/16	193	7/27/16	208	8/20/16	193
5/16/16	202	6/10/16	204	7/4/16	204	7/28/16	205	8/21/16	213
5/17/16	199	6/11/16	205	7/5/16	308	7/29/16	322	8/22/16	205
5/18/16	201	6/12/16	202	7/6/16	212	7/30/16	250	8/23/16	193
5/19/16	200	6/13/16	195	7/7/16	209	7/31/16	258	8/24/16	192
5/20/16	197	6/14/16	197	7/8/16	206	8/1/16	290	8/25/16	193
5/21/16	199	6/15/16	197	7/9/16	205	8/2/16	222	8/26/16	192
5/22/16	212	6/16/16	204	7/10/16	246	8/3/16	217	8/27/16	190
5/23/16	203	6/17/16	198	7/11/16	200	8/4/16	214	8/28/16	189
5/24/16	211								

E.9 WET WEATHER EVENT SELECTION FOR MODEL CALIBRATION / VALIDATION

Based on the rainfall data availability and flow monitoring data analysis, the top 4 rainfall events shown in **Table E-3** were selected for model calibration and validation. These four events cover variations in terms of rainfall depth, intensity, duration, and antecedent conditions. Detailed rainfall event information for these events, including duration, depth, maximum intensity and average intensity, are summarized for each rainfall gauge in **Table E-5**.

Table E-5: Calibration and Validation Rainfall Events

	Event 1	Event 2	Event 3	Event 4	Event 1	Event 2	Event 3	Event 4
	Newark				New York			
Rainfall Start	5/29/16 23:45	7/25/16 16:05	7/29/16 0:15	7/30/16 14:10	5/30/16 0:10	7/25/16 15:15	7/29/16 0:05	7/30/16 14:30
Rainfall End	5/30/16 5:15	7/25/16 18:50	7/29/16 8:30	7/31/16 22:35	5/30/16 5:30	7/25/16 17:45	7/29/16 8:25	7/31/16 23:50
Duration (Hour)	5.7	3.0	8.5	32.7	5.6	2.7	8.6	33.6
Total Depth	1.60	1.84	0.87	1.07	1.65	1.00	1.09	1.29
Avg. Intensity (in/hr)	0.28	0.61	0.10	0.03	0.30	0.36	0.13	0.04
Max Intensity (in/hr)	1.09	1.68	0.43	0.49	1.09	0.67	0.64	0.83
	Hawthorne				Lyndhurst			
Rainfall Start	5/30/16 0:20	7/25/16 15:45	7/29/16 0:40	7/30/16 15:15	5/30/16 0:55	7/25/16 17:25	7/29/16 1:15	7/30/16 15:35
Rainfall End	5/30/16 8:10	7/25/16 20:40	7/29/16 8:45	7/31/16 22:00	5/30/16 9:55	7/25/16 19:45	7/29/16 9:15	8/1/16 0:35
Duration (Hour)	8.1	5.2	8.3	31.0	9.2	2.6	8.2	33.2
Total Depth	0.63	0.70	1.14	3.08	1.25	0.74	1.17	1.60
Avg. Intensity (in/hr)	0.08	0.14	0.14	0.10	0.14	0.29	0.14	0.05
Max Intensity (in/hr)	0.29	0.32	0.46	1.13	0.65	0.70	0.39	0.70
	Jersey City				W Paterson			
Rainfall Start	5/30/16 1:10	7/25/16 17:10	7/29/16 1:05	7/30/16 15:10	5/30/16 0:30	7/25/16 16:05	7/29/16 3:05	7/30/16 15:35
Rainfall End	5/30/16 6:35	7/25/16 21:50	7/29/16 9:25	8/1/16 0:40	5/30/16 6:25	7/25/16 20:30	7/29/16 9:30	7/31/16 22:00
Duration (Hour)	5.7	4.9	8.6	33.7	6.2	4.7	6.7	30.7
Total Depth	1.79	1.81	1.10	0.60	0.46	0.67	0.78	2.33
Avg. Intensity (in/hr)	0.32	0.37	0.13	0.02	0.07	0.14	0.12	0.08
Max Intensity (in/hr)	1.25	1.67	0.74	0.18	0.21	0.30	0.37	0.81
	Passaic				Cedar Grove			
Rainfall Start	5/29/16 17:35	7/25/16 16:00	7/29/16 1:10	7/30/16 15:30	5/30/16 0:15	7/25/16 17:20	7/28/16 23:20	7/30/16 15:40
Rainfall End	5/30/16 10:30	7/25/16 23:55	7/29/16 8:50	8/1/16 1:00	5/30/16 5:45	7/26/16 2:55	7/29/16 9:25	8/1/16 1:05
Duration (Hour)	17.2	8.2	7.9	33.7	5.7	9.8	10.3	33.7
Total Depth	0.55	0.34	1.10	1.84	0.59	0.42	1.58	2.79
Avg. Intensity (in/hr)	0.03	0.04	0.14	0.05	0.10	0.04	0.15	0.08
Max Intensity (in/hr)	0.19	0.21	0.51	0.68	0.26	0.32	0.72	0.58

E.10 SUMMARY

The rainfall and flow monitoring data analysis was performed to provide adequate data for the development, calibration and validation of the H&H and Water Quality Models. Rainfall data was collected for rain gauges throughout the Model Area. The Newark Airport rain gauge was analyzed to determine wet weather events used for model calibration. The flow meter data was analyzed based on the rainfall patterns and then input into the model as overall annual average DWF, average monthly DWFs, and weekday and weekend diurnal curves for each meter in the

combined area. To calibrate the model, model-generated data was compared to the metered-data hydrographs for each wet weather event for each flow meter.

SECTION F - CHARACTERISTICS OF THE RECEIVING WATERS

Characteristics of the receiving waters include description of the receiving waters designated use, shoreline characteristics, identification of the waters on the impaired waters of NJ and a summary of the sensitive areas within the receiving water. The USEPA CSO Control Policy Guideline requires that highest priority is given to CSO's that discharge to sensitive areas.

F.1 RECEIVING WATERS OVERVIEW

Major receiving waters impacted from PVSC service area combined sewer overflows include the Passaic River, Hackensack River, Newark Bay, Upper New York Bay, Hudson River, Kill Van Kull, Raritan River and Raritan Bay, as well as their tributaries. The NJDEP has categorized these receiving waters into Watershed Management Areas (WMA) 1 through 20 and refers to these designations in the 303(d) list of impaired water.

F.1.1 CSO Receiving Waters

CSO receiving waters are water bodies that either a CSO discharges into, or receive flow from tributaries with CSOs. The receiving waters include the combined sewer service area of the PVSC Sewer District and expands from this service area to include all receiving and adjacent downstream waters that may be potentially affected by CSOs from the various combined sewer service areas of the NJ CSO Group. PVSC CSO Sewer District receiving waters include the Passaic River, Hudson River, Newark Bay, Upper New York Bay, Hackensack River, Kill Van Kull, as well as their tributaries. All of the CSO outfalls and the waterbodies into which they discharge are listed in **Table D-2**.

F.1.2 Summary of Impacted Drainage Basins

The receiving waters and their tributaries belong to drainage basins that are impacted by CSO discharges. Drainage basins, or watersheds, are areas that are separated by drainage divides and within a watershed, all surface water drains to a single outlet such as a river. The impacted watersheds within PVSC Sewer District are listed in **Table F-1**. The watersheds are also shown with the QAPP Part 1 and Part 2 areas from the "System Characterization and Landside Modeling Program Quality Assurance Project Plan (QAPP)," which have been previously approved by NJDEP areas in **Figure F-1**.

Table F-1: Watersheds Affected by CSO Discharges

Watershed Name	Area (sq mi)
Hudson River	5
Passaic River Lower (Saddle to Pompton)	46
Hackensack River (below and including Hirschfeld Brook)	19
Passaic River Lower (Newark Bay to Saddle)	52
Elizabeth River	2
Newark Bay / Kill Van Kull / Upper NY Bay	25

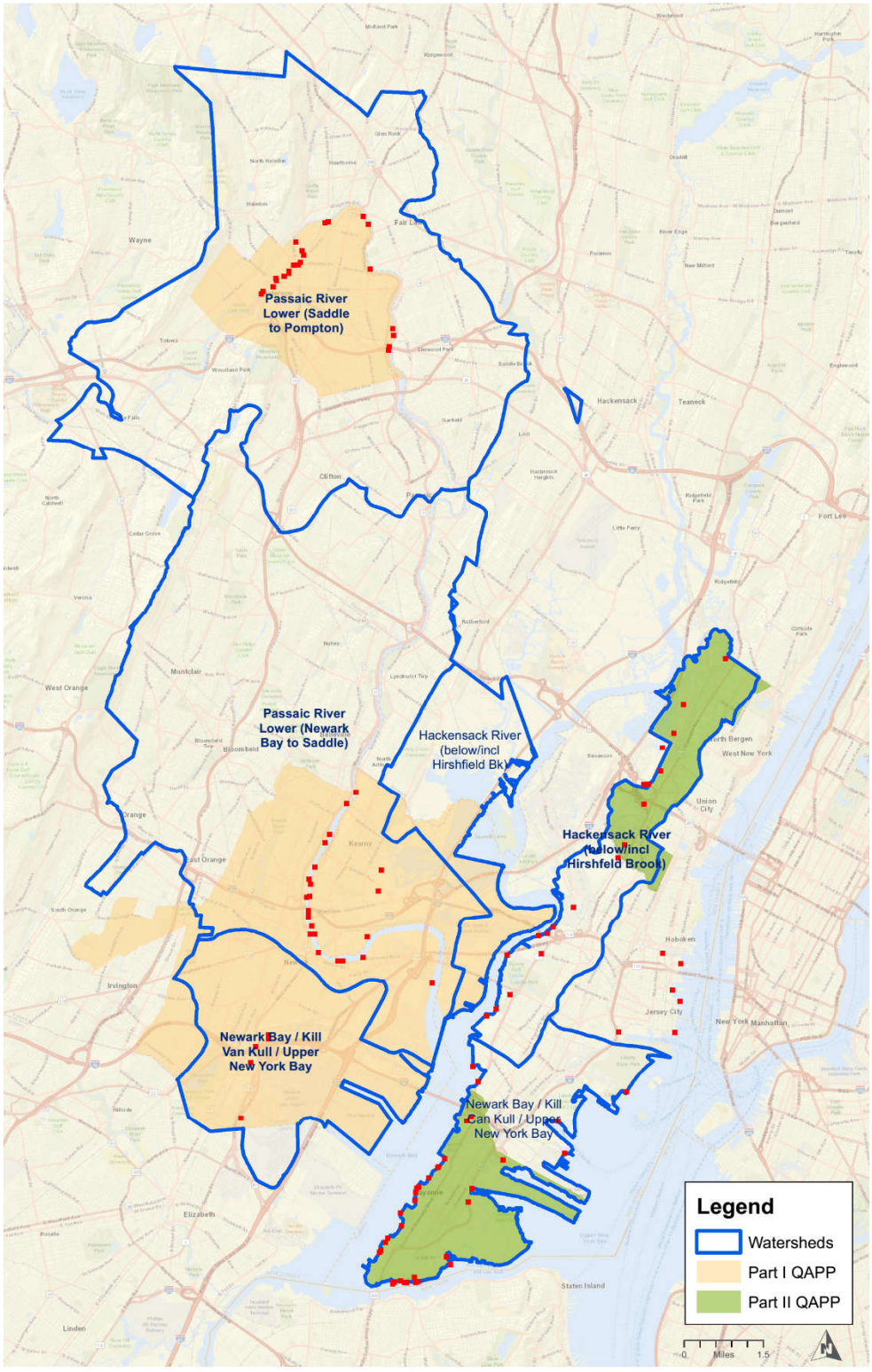


Figure F-1: PVSC Sewer District Watersheds

F.2 POLLUTANTS OF CONCERN IN THE RECEIVING WATERS

F.2.1 Summary of the Identified POCs for Each Receiving Water

Three (3) POCs were determined to apply to each of PVSC Sewer District's four receiving waters. These three POCs are parameters typically associated with CSO discharges. The concentrations of these identified POCs in the receiving waters have been further investigated through the receiving water quality monitoring and modeling, subsequently described in Sections E, G, H and I of this report. The NJDEP determined POCs for each of the receiving waters relative to the PVSC CSO sewer district are listed below:

- Passaic River
  - Fecal Coliform
  - Escherichia coli (E. coli) (fresh water)
  - Enterococcus
- Newark Bay
  - Fecal Coliform
  - E. coli (fresh water tributaries)
  - Enterococcus
- Upper New York Bay
  - Fecal Coliform
  - E. coli(fresh water tributaries)
  - Enterococcus
- Hackensack River
  - Fecal Coliform
  - E. coli (fresh water)
  - Enterococcus

F.3 RECEIVING WATER USE DESIGNATIONS AND APPLICABLE WATER QUALITY STANDARDS

F.3.1 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The New Jersey Integrated Water Quality Monitoring and Assessment Report (303(d) list) is a catalog of the impaired waters throughout the state of New Jersey. More information about the 303(d) list can be found in Section B.2.4

F.3.2 Interstate Environmental Commission (IEC) Water Quality Regulations

The Interstate Environmental Commission (IEC) is an air and water pollution control agency that serves the Interstate Environmental District within the states of New York, New Jersey, and Connecticut. The Commission's goal is to protect the environment and assure compliance with and enforcement of its Water Quality Regulations. For more information about IEC Regulations, see Section B.2.5.

F.3.3 New Jersey Administrative Code

NJAC Section 7:9B Surface Water Quality Standards lists the classifications, designated uses, and water quality criteria for the all New Jersey water bodies. For more information about the NJAC, see Section B.2.6.

F.4 PASSAIC RIVER

F.4.1 Watershed Drainage Basin

The Passaic River basin consists of three areas referred to as the Upper Basin (Highlands), Central Basin and the Lower Basin (Lower Valley) and drains approximately 935 square miles of Northern New Jersey and Southern New York State. The NJDEP has designated the Upper and Mid Passaic River, Whippany and Rockaway as Watershed Management Area 6 (WMA 6) and the Lower Passaic River and Saddle as Watershed Management Area 4 (WMA 4). Passaic River basin is characterized by extensive suburban development of which relies upon ground water sources for water supply. The Passaic River basin lies in portions of Morris, Somerset, Sussex and Essex Counties and includes the Upper and Middle Passaic River, Whippany River and Rockaway River Watersheds. The portion of the Passaic River Basin which overlaps the PVSC service area is mainly in the lower basin and extends from the City of Paterson to the City of Newark. See the Passaic River Watershed map shown below in **Figure F-2.**

Frank's Creek, Second River, Third River, Pompton River, and Saddle River are tributaries of the Passaic River. Generally CSO regulator outfalls located in Paterson, Newark, Harrison, Kearny and East Newark are permitted to discharge to the Passaic River. Several CSOs regulator outfalls located in Kearny are permitted to discharge to Frank's Creek.

F.4.2 Physical Characteristics

The Lower Passaic River begins at the Pompton River confluence and continues downstream eventually reaching the Newark Bay. The Lower Passaic River and its tributaries, including the Saddle River, has a drainage area of about 180 square miles. The Lower Passaic River Watershed lies within portions of Passaic, Essex, Hudson, Morris, and Bergen Counties.

All 129 square miles of the Lower Passaic River Watershed are primarily urban/suburban. The section of the Lower Passaic River within the urban/suburban area has poor water quality conditions due to numerous point sources, significant nonpoint source contributions, and high sediment oxygen demands, (State of New Jersey, 2014). The Lower Passaic River Watershed's water quality conditions are affected by a number of hazardous waste sites and contamination issues that have resulted from a long history of industrialization, (State of New Jersey, 2014).

The primary aquatic habitats of the lower Passaic River are intertidal mudflats and subtidal bottom (Ianuzzi, 2004). The intertidal mudflats and their associated shallow-water subtidal areas are primary habitats for estuarine organisms, providing the only available foraging habitat for fish, blue crab, and waterbirds.



Figure F-2: Map of the Passaic River Basin Retrieved from https://passaicriver.org/passaic-river-basin/

F.4.3 Hydrodynamics

The Passaic River stretches approximately 80 miles from Mendham, NJ to Newark Bay. The Passaic River Basin drains approximately 935 square miles, 85% of which are located in New Jersey and the rest in New York. The project study area includes the last nine miles of the Upper Passaic River from just upstream of Paterson, NJ to the Dundee Dam in Garfield, NJ, as well as the Lower Passaic River. The Upper Passaic River includes water withdrawals by the North Jersey District Water Commission and the Passaic Valley Water Commission. The Upper Passaic River also includes the Great Falls in Paterson, NJ. The Lower Passaic River is the 17-mile tidal stretch of the Passaic River from the Dundee Dam to its confluence with Newark Bay. Most of the freshwater originates from upstream of the Dundee Dam with an annual average discharge rate of about 1,200 cfs (TSI, 2003). There are, however, three major tributaries to the Lower Passaic River that bring additional fresh water river downstream of the Dundee Dam. These are:

- Saddle River (99 cfs)
- Third River (about 21 cfs)
- Second River (18 cfs)

Four other tributaries, McDonald Brook, Frank Creek, Lawyer's Creek, and Plum Creek have also been identified historically as contributing freshwater inflow to the Lower Passaic River. However, these tributaries are now urbanized tributaries, and now receive freshwater inflows via CSO and / or Stormwater Outfalls (SWO) inputs. The combined flow of the three major tributaries (Saddle River, Third River, and Second River) is estimated to represent less than 10% of the total flow at the mouth of the estuarine section of the combined Lower Passaic River/Hackensack River system.

CSOs, as well as SWOs, also contribute to the inflow of freshwater in the Passaic River. No WRRF outfalls are located in the Lower Passaic River. However, the Northwest Bergen County Utilities Authority discharges Ho-Ho-Kus Brook, which flows to the Saddle River.

The waters of the Lower Passaic River are also influenced by semidiurnal tides reaching a mean tidal range of about 5 ft. Density stratification is prevalent in the Lower Passaic River causing a distinct reversal of residual currents between top and bottom layers of the water column. Historical salinity data indicates that salt can travel upstream about 10 miles from the mouth of Passaic River during conditions of low river inflows. The salt front can be pushed out of the Lower Passaic River under moderately high river flows, i.e., 100 m^3/sec or 3,500 cfs (Chant, personal communication). Field studies conducted by TSI in 1995-6 and Rutgers University in 2004 indicate that intra-tidal variations in surface and bottom salinities near the mouth of the Lower Passaic River can reach as high as 10 ppt (parts per thousand).

F.4.4 Shoreline Characteristics

The Lower Passaic River (downstream of the Dundee Dam) has a mix of bulkheaded industrial and natural shorelines. Extensive parkland line the River in Bergen County. Natural vegetation also lines the freshwater sections along Dundee Lake and sections in Paterson and further

upstream. Vegetated wetland comprises approximately one acre of the lower six miles of shoreline of the Lower Passaic River.

The natural shoreline of the lower six miles of the Lower Passaic River has been industrialized and is mostly lined with buildings and parking lots. Approximately 52 percent of the lower six miles of the Passaic River has been bulkheaded; another 30 percent of the shoreline is riprap, (New Jersey, 2014). Weedy vegetation lines the shoreline in a few remaining riparian areas. In mudflats reeds grow in abundance. Trees and scrub-shrubs grow in higher elevations. Ruderal plants such as tree of heaven and goldenrod are found throughout the area (Ianuzzi, 2004).

F.4.5 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The Lower Passaic River is listed on the 303 (d) list as being impaired for the following pollutants:

- Arsenic
- Benzo(a)pyrene (PAHs)
- Cause Unknown
- Chlordane in Fish Tissue
- DDT and its metabolites in Fish Tissue
- Dieldrin
- Dioxin (including 2, 3, 7, 8-TCDD)
- Escherichia coli
- Heptachlor epoxide
- Mercury in Fish Tissue
- Oxygen, Dissolved
- PCBs in Fish Tissue
- pH
- Phosphorus (Total)
- Total Suspended Solids (TSS)

F.4.6 Designated Uses and Water Quality Criteria from NJ Code

NJAC Section 7:9B Surface Water Quality Standards lists the Passaic River as FW2-NT in the Paterson reach, FW2-NT/SE2 in the Little Falls reach, and SE3 in the Newark reach at the Second River. The classification FW2-NT refers to a fresh water non trout water body. SE2 and SE3 both refer to saline estuarine water bodies. Classifications along with designated uses, indicator bacteria and their criteria are shown in **Table F-2** below.

Table F-2: NJ Administrative Code Regarding the Passaic River

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 mL)
FW2	Primary Contact	E. coli	126 GM, 235 SSM
SE2	Secondary Contact	Fecal Coliform	770 GM
SE3	Secondary Contact	Fecal Coliform	1500 GM

F.4.7 Classification and Water Quality Regulations from the IEC

The IEC classifies the mouth of the Passaic River as Class B-1. For more information regarding the IEC standards for Class B-1 water bodies, see Section B.2.4.

F.5 NEWARK BAY

F.5.1 Watershed Drainage Basin

Newark Bay is a tidal bay and is located at the confluence of the Passaic and Hackensack Rivers at the northern end of the bay. Newark Bay is connected to the Kill Van Kull and Arthur Kill at the southern end adjacent to Staten Island. The Kill Van Kull is a tidal strait which connects the Newark Bay to the Raritan Bay and lies between Staten Island and the City of Bayonne. The Arthur Kill links the Newark Bay with the Lower New York Bay. Other tributaries of Newark Bay include the Elizabeth River, the Arthur Kill, and the Peripheral Ditch, Queen Ditch and Great Ditch. The Upper New York Bay is also a tidal bay and is located between New York City and Jersey City. The Hudson River flows into the northern end of the Upper Bay. Newark Bay, Upper New York Bay, Kill Van Kull and Arthur Kill are all considered part of the NJDEP Arthur Kill Watershed Management Area 7.

City of Bayonne CSO regulator outfalls are permitted by NJDEP to discharge to the Newark Bay, Kill Van Kull and the Upper New York Bay. A few CSO outfalls located in the City of Newark are permitted to overflow to the Peripheral Ditch and Queen Ditch. See **Figure F-3** below for location of the CSO Outfalls in the Newark Bay area.

F.5.2 Physical Characteristics

The Newark Bay is approximately 6 miles long extending in the north south direction and varies in width from one-half mile to 1.2 miles. Newark bay shipping channels range in depth from 35 to 50 feet at Mean Low Low Water tide (MLLW). The bay area aside from the channel range in depth from 0 at the shoreline to approximately 11 to 15 feet at MLLW. The Kill Van Kull is a narrow straight channel that is approximately 3 miles long extending in the east west direction and 1000 feet wide. The shipping channel depth through the Kill Van Kull is approximately 50 feet at MLLW. The Arthur Kill is a 10 mile channel extending in the north south direction and runs along the west side of Staten Island. The Arthur Kill shipping channel depth ranges from 30 to 50 feet at MLLW.

F.5.3 Hydrodynamics

The Passaic River along with the Hackensack River and Newark Bay is one of the most complex estuarine systems in the United States. The system is connected to two tidal straits, named the Kill van Kull and the Arthur Kill. These straits connect Newark Bay and the Passaic and

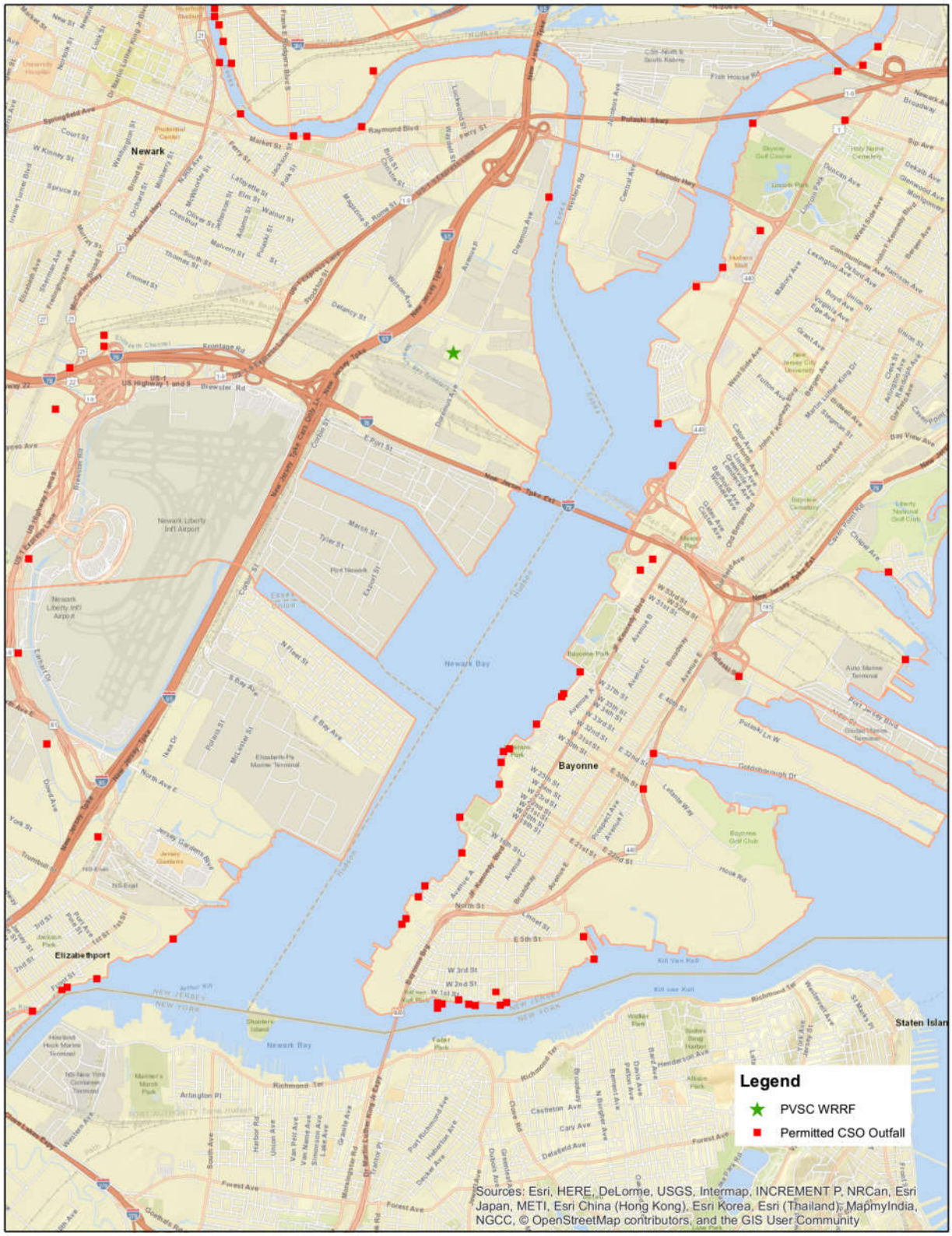


Figure F-3: The Newark Bay

Hackensack Rivers with the Upper New York Bay and Raritan Bay, through which tides, originating in the Atlantic Ocean, enter the system. The bathymetry of the Passaic-Hackensack-Newark Bay system is characterized by deep shipping channels along the center of both the Arthur Kill and the Kill van Kull, as well as the west side of Newark Bay through the center of both the Lower Passaic and Hackensack Rivers, with shallower side banks. The USACE maintains the navigability of the channels in order to support New York-New Jersey Port operations. The shipping channels, maintained by the USACE to facilitate the movement of container ships in and out of Newark Bay, added additional complexity to the dynamics of the system. The shipping channels in Newark Bay and the Kills are relatively deep (35 - 50 ft). The near-shore depths vary significantly. The shipping channels play an important role in transporting saline water from the ocean into the system.

The hydrodynamics of the Passaic-Hackensack-Newark Bay system is predominantly controlled by three forcing mechanisms, freshwater flows, tides, and winds. Two major sources of freshwater inflows, the Passaic and Hackensack Rivers, contribute to the salinity gradients in the system. By far, the largest freshwater contribution is from the Passaic River. The long-term (1983-2003) daily average flow measured at Little Falls is about 29 m^3/sec (1,000 cfs) and the maximum flow during this 21-year period was approximately 500 m^3/sec (18,000 cfs) in April 1984. In contrast the average flow in the Hackensack River is only 1.6 m^3/s (56 cfs) and a maximum flow of approximately 158 m^3/s (5,500 cfs) was measured in September 1999 during Hurricane Floyd. The salinity dynamics in the system are mostly controlled by the freshwater flows from the Passaic and Hackensack Rivers and the saltier ocean waters that enter the system through the Kill van Kull and the Arthur Kill. During most low to moderate flow periods, the salinity front stays within upper Newark Bay and the Lower Passaic and Hackensack Rivers. Salinity is, in general, higher during the time of low freshwater flow and is also more uniform both vertically and horizontally throughout the system than during the time of high freshwater flow. Freshwater flows emanating from the Passaic River stay along the western edge of Newark Bay, creating cross channel salinity gradients (Pence, 2004). The deep shipping channels in the system act as conveyances of denser and saltier ocean water to upper Newark Bay and to the Lower Passaic and Hackensack Rivers.

Tidal influence has significant importance within the Passaic-Hackensack-Newark Bay estuarine system. A harmonic analysis of tidal elevation data measured at Bergen Point, which is at the entrance to Newark Bay, suggests that the semi-diurnal constituents (M2 and S2) dominate the system. A spectral analysis of the tidal elevations also indicated that maximum variance occurred at an interval of approximately 12.4 hours, suggesting a dominant semi-diurnal tidal signal. The resultant tidal harmonic constituents are provided in **Table F-3**. The table indicates that the study area has predominant semi-diurnal tides.

Table F-3: Characteristics of Principal Tidal Constituents in Newark Bay

Constituents	Period (Hrs)	Amplitude (m)	Phase (deg)
O_1	25.82	0.05	107.1
K_1	23.93	0.10	108.6
M_2	12.42	0.73	233.7
S_2	12.00	0.14	263.8
N_2	12.66	0.16	220.4

Tidal currents in Newark Bay and in the Passaic and Hackensack Rivers are found to be moderate, with maximum amplitudes of 0.5 m/sec. Most of the time, the surface and bottom tidal currents are of equal magnitude and are in phase in Newark Bay. However, during high-flow periods the surface currents, directed towards the ocean (ebb currents), become much stronger than the bottom currents, indicating the presence of strong vertical shear (Pence, 2004). During high freshwater flow, classical two-layer estuarine circulation is observed during flood tides, with surface currents flowing seaward and bottom currents flowing upstream. The net flow along the side banks is downstream, with an increased magnitude under higher freshwater flow conditions.

Strong and persistent wind events in Newark Bay can have a strong effect on the circulation in the estuary, and in some extreme cases can disrupt the normal pattern of estuarine circulation. Modeling analysis (Pence, 2004, Pecchioli et al., 2006) suggests that strong winds from the west will flush water and water borne constituents from Newark Bay out through the Kill van Kull, with weaker flow in through the Arthur Kill. Model computations indicate that this flow pattern changes direction when strong winds blow from the east, i.e., flow enters the Kill van Kull from the upper portion of New York/New Jersey Harbor and then enters Newark Bay (Pecchioli et al., 2006).

F.5.4 Shoreline Characteristics

The Newark Bay shoreline has been industrially developed with approximately two-thirds of the shoreline consisting of riprap and bulkhead.

- Bulkhead - 40%
- Mixed Intertidal - 10%
- Riprap - 30%
- Vegetation - 20%

Most of the western shoreline of Newark Bay is bulkheaded and lies in industrial areas. In 1958, the Port Authority dredged the Elizabeth Channel and created the Elizabeth Marine Terminal on the northwest side of Newark Bay. Most of the eastern shoreline is riprap or bulkheaded and lies in residential and recreational areas. At the south end of Newark Bay, near Staten Island, is Shooters Island, which is a 43-acre bird sanctuary with riprap shoreline. The south side of

Newark Bay, on the north side of Staten Island, is wetlands. There is a small remaining plant community located in the upland and wetland area as a reflection of these disturbed bulkheaded conditions. Some of the area along the shoreline is used for fishing.

F.5.5 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The Newark Bay is listed on the 303 (d) list as being impaired for the following pollutants:

- Benzo(a)pyrene (PAHs)
- Cause Unknown
- Chlordane in Fish Tissue
- DDT and its metabolites in Fish Tissue
- Dieldrin
- Dioxin (including 2, 3, 7, 8-TCDD)
- Heptachlor epoxide
- Hexachlorobenzene
- Mercury in Fish Tissue
- PCB in Fish Tissue
- Phosphorus (Total)

F.5.6 Designated Uses and Water Quality Criteria from NJ Administrative Code

NJAC 7:9B Surface Water Quality Standards lists the portion of the Newark Bay north of an east-west line connecting Elizabethport with Bergen Pt., Bayonne up to the mouths of the Hackensack and Passaic Rivers as SE3. SE3 refers to a saline estuarine water body. Classifications along with designated uses, indicator bacteria and their criteria are shown in **Table F-4** below.

Table F-4: NJAC Regarding the Newark Bay

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 mL)
SE3	Secondary Contact	Fecal Coliform	1500 GM

F.5.7 Designated Zone and Water Quality Regulations from the IEC

The IEC classifies the Newark Bay as Class B-2. For more information regarding the IEC standards for Class B-1 and B-2 water bodies, see Section B.2.4.

F.6 UPPER NEW YORK BAY

F.6.1 Watershed Drainage Basin

The Upper New York Bay is a tidal bay and is located between New York City and Jersey City at the confluence of the Hudson and East Rivers.

CSOs regulators located in Guttenberg and northern part of Bayonne are permitted by NJDEP to discharge to the Hudson River and the Upper New York Bay area. See **Figure F-4** below for location of the CSO Outfalls in the Upper New York Bay Area.

F.6.2 Physical Characteristics

The Upper New York Bay is approximately 7 miles long extending in the north south direction and varies in width from 1 mile to 5 miles. The Upper New York Bay is connected to the Lower New York Bay by the Narrows. The Upper New York Bay has a maximum shipping channel depth of 50 feet. The Upper New York Bay includes Ellis Island, Liberty Island and Governors Island.

F.6.3 Hydrodynamics

Upper New York Bay is bordered by the New York City boroughs of Manhattan, Brooklyn and Staten Island and the New Jersey municipalities of Jersey City and Bayonne. The hydrodynamics within the bay are complicated due to its interconnectedness with several waterbodies. It receives freshwater from the Hudson River to the north, and is connected with the East River, Kill Van Kull, and the New York Bight (Atlantic Ocean). The channel of the Hudson as it passes through the bay is called the Anchorage Channel and is approximately 50 feet deep in the midpoint of the bay. The drainage area for the Hudson River is approximately 14,000 square miles, with 8,090 square miles in the non-tidally affected area above the Troy Dam near Green Island, NY. USGS gage 01358000 at Green Island, NY measures an average flow of approximately 14,500 cfs, with a maximum estimated flow of 215,000 cfs occurring on March 19, 1936. Additional freshwater is added from the drainage area below the dam.

The combination of freshwater flow from the Hudson River, saltwater flow from the Atlantic Ocean, and tidal exchange can create a two layer flow with freshwater at the surface leaving the bay to the south, and saltwater flow at the bottom entering the bay through the deep channel. The salt front (100 milligrams per liter of chloride) ranges from below Hastings-on-Hudson to New Hamburg during most years, but can move as far north as Poughkeepsie during periods of drought.

F.6.4 Shoreline Characteristics

The Upper New York Bay shoreline has been bulkheaded for industrial development including shipping and ferry terminals, residential use and park and recreational use. Several islands are located in the Upper New York Bay including Governors Island, Liberty Island, Ellis Island, and Robbins Reef. A small portion of the shoreline in is riprap and natural shoreline.

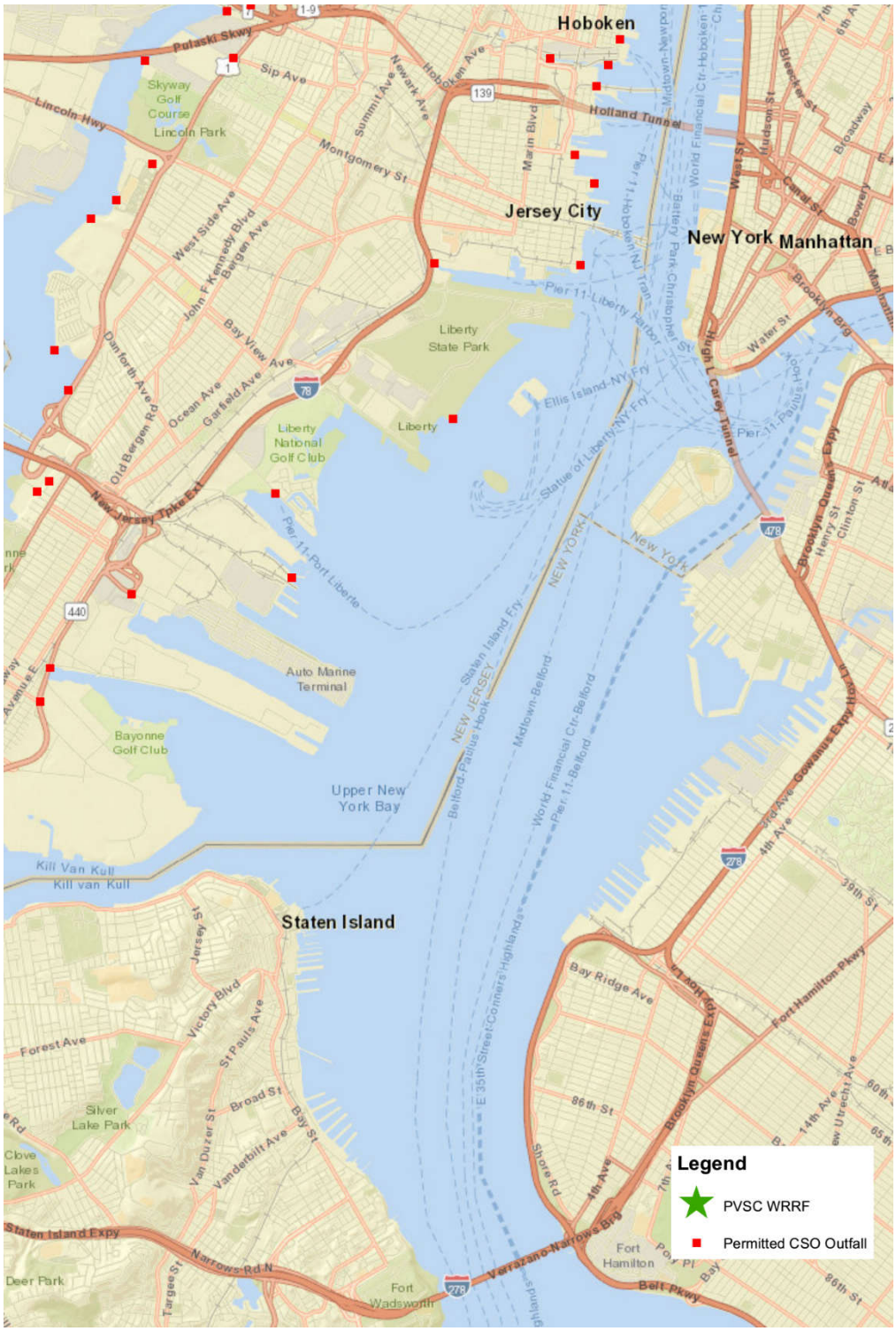


Figure F-4: The Upper New York Bay

F.6.5 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The Upper New York Bay is listed on the 303 (d) list as being impaired for the following pollutants:

- Benzo(a)pyrene (PAHs)
- Cause Unknown
- Chlordane in Fish Tissue
- DDT and its metabolites in Fish Tissue
- Dieldrin
- Dioxin (including 2, 3, 7, 8-TCDD)
- Heptachlor epoxide
- Hexachlorobenzene
- Mercury in Fish Tissue
- PCB in Fish Tissue
- Phosphorus (Total)

F.6.6 Designated Uses and Water Quality Criteria from NJ Administrative Code

The Upper New York Bay is included in the NJAC as the Hudson River and saline portions of New Jersey tributaries from the confluence with the Harlem River, New York to a north-south line connecting Constable Hook (Bayonne) to St. George (Staten Island, New York) as SE2. SE2 refers to a saline estuarine water body. Classifications along with designated uses, indicator bacteria and their criteria are shown in **Table F-5** below.

Table F-5: NJAC Regarding the Newark Bay

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 mL)
SE2	Secondary Contact	Fecal Coliform	770 GM

F.6.7 Designated Zone and Water Quality Regulations from the IEC

The IEC classifies the Upper New York Bay (Hudson River) as Class B-1 and the Newark Bay as Class B-2. For more information regarding the IEC standards for Class B-1 and B-2 water bodies, see Section B.2.4.

F.7 HACKENSACK RIVER

F.7.1 Watershed Drainage Basin

The Hackensack River is considered part of the NJDEP Watershed Management Area 5 (WMA 5) which has a drainage area of over 165 square miles. There are three watersheds in WMA 5 including the Hackensack River, Hudson River and the Pascack Brook. The majority of the lower Hackensack River is tidal marsh known as the Hackensack Meadowlands. Tributaries of the Hackensack River include Cromakill Creek, Bellman's Creek, and Penhorn Creek.

CSOs regulators located in North Bergen Township are permitted by NJDEP to discharge to the Cromakill Creek and Bellman's Creek. See **Figure F-5** below for location of the CSO Outfalls in the Hackensack River Area.

F.7.2 Physical Characteristics

The Hackensack River watershed contains tidal marshes known as the Hackensack Meadowlands District. Seven hundred plant and animal species live in the Meadowlands, including several rare and endangered species. The Hackensack River watershed is the most populated out of all the CSO receiving watersheds outlined in this report. Although half of the land is still not developed, more than one third has been developed into dense residential areas. The remaining developed land is used for commercial/industrial activity.

Point sources of pollution such as hazardous waste and Superfund sites are known to contaminate the surface waters in the Hackensack River watershed. Due to contamination, it is prohibited to consume or sell striped bass and blue crabs.

Nonpoint sources of pollution mainly affect water quality. Examples of nonpoint sources in the area include extensive urban/suburban development and landfills. Runoff from construction sites, impervious surfaces, landfill leachate and CSOs impact the Hackensack River along. The Hackensack River has experienced flooding, habitat destruction and fish community degradation, along with reduction of dissolved oxygen, excessive nutrients and accelerated eutrophication. These characteristics are attributed to the physical characteristics of the Hackensack River watershed and pollution from nonpoint sources.

F.7.3 Hydrodynamics

The Hackensack River begins in Rockland County, NY and has a length of approximately 50 miles and a drainage area of approximately 197 square miles. The Oradell Reservoir, completed in 1923, essentially divides the Hackensack into upper and lower regions. United Water currently diverts flow from the Oradell Reservoir for water supply to 750,000 residents of Bergen and Hudson Counties. The diversion of flow essentially cuts off the flow to the Hackensack River during dry-weather, which has altered the natural conditions of the river. The area of interest for this project begins at the Oradell Reservoir Dam and flows approximately 22 miles to the confluence of Newark Bay. The average flow in the Hackensack River is approximately 1.6 m^3/sec (56 cfs) and a maximum flow of approximately 158 m^3/sec (5,500 cfs) was measured in September 1999 during Hurricane Floyd. At Little Ferry the river is joined by Overpeck Creek. There is some indication, based on an analysis of salinity, that an additional 2.8 to 4.2 m^3/sec (100 to 150 cfs) additional freshwater flow joins the Hackensack River via groundwater along this length of the river. The Bergen County Municipal Utilities Authority's Little Ferry Water Pollution Control Facility adds approximately 4.2 m^3/s (80 MGD) of flow to the river during normal operations and contributes up to 13.1 m^3/s (250 MGD) during wet-weather.

In the Hackensack River, salt can penetrate about 15 miles from the river mouth due to relatively low freshwater inflows over the Oradell Dam. The lower section of the Hackensack River consists of vast area of tidal wetlands, known as the Meadowlands. USEPA's National Wetland Inventory identifies about 1,500 acres of the wetland area that are submerged under average tidal



Figure F-5: The Hackensack River

condition. Hydrodynamics in the Passaic River system are complicated by the presence of these large intertidal marshes on the Hackensack River. This is due to the fact that these marshes can provide significant water storage over a tidal cycle and during and after storm events, thereby altering the movement of water up the Hackensack River and to a lesser degree, the Passaic River.

F.7.4 Shoreline Characteristics

The Hackensack River is bordered by tidal wetlands, parking lots, and industrial and residential buildings. Historical wetland loss due to industrialization, land development has transformed the Hackensack Meadowlands District into a brackish tidal estuary. The Hackensack River experiences tidal fluctuations and seasonal wet weather events that flood the adjacent wetlands and tributaries.

F.7.5 NJ Integrated Water Quality Monitoring and Assessment Report (303(d) list)

The Hackensack River is listed on the 303 (d) list as being impaired for the following pollutants:

- Arsenic
- Benzo(a)pyrene (PAHs)
- Chlordane in Fish Tissue
- DDT and its metabolites in Fish Tissue
- Dieldrin
- Dioxin (including 2, 3, 7, 8-TCDD)
- Enterococcus
- Heptachlor epoxide
- Mercury in Fish Tissue
- Oxygen, Dissolved
- PCB in Fish Tissue
- pH
- Phosphorus (Total)
- Turbidity

F.7.6 Designated Uses and Water Quality Criteria from NJ Administrative Code

NJAC Section 7:9B Surface Water Quality Standards lists the Hackensack River as SE1 in the Overpeck Creek reach, SE2 in the Little Ferry reach, and SE3 in the Kearny Point reach. The classification SE1, SE2 and SE3 all refer to saline estuarine water bodies. Classifications along with designated uses, indicator bacteria and their criteria are shown in **Table F-6** below.

Table F-6: NJAC Regarding the Passaic River

Classification	Designated Use(s)	Indicator Bacteria	Criteria (per 100 mL)
SE1*	Shellfishing; Primary Contact	Enterococci	35 GM, 104 SSM
SE2	Secondary Contact	Fecal Coliform	770 GM
SE3	Secondary Contact	Fecal Coliform	1500 GM

* Shellfishing area must also comply with the National Shellfish Sanitation Program standards for total and/or fecal coliform.

F.7.7 Designated Zone and Water Quality Regulations from the IEC

The IEC classifies the mouth of the Hackensack River as Class B-1. For more information regarding the IEC standards for Class B-1 water bodies, see Section B.2.4.

F.8 IDENTIFICATION OF SENSITIVE AREAS

F.8.1 Regulatory Requirements

Requirements of the USEPA's CSO Control Policy and Sensitive Areas Definition

The USEPA's CSO Control Policy (Federal Register 59 [April 19, 1994]: 18688-18698) "expects a permittee's long-term CSO control plan to give the highest priority to controlling overflows to sensitive areas" (Section II.C.3).

The CSO Control Policy states the six (6) criteria for defining an area as a "Sensitive Area" include:

1. Designated Outstanding National Resource Waters
2. National Marine Sanctuaries
3. Waters with threatened or endangered species and their habitat
4. Waters with primary contact recreation
5. Public drinking water intakes or their designated protected areas
6. Shellfish beds

The CSO Control Policy states that if Sensitive Areas are present and impacted, the LTCP should include provisions to:

- Prohibit new or significantly increased overflows
- Eliminate or relocate overflows wherever physically possible and economically achievable
- Treat overflows where necessary
- Where elimination or treatment is not achievable, reassess impacts each permit cycle

NJDES Permit Requirements

Sensitive Areas should be considered prior to the evaluation of CSO control alternatives. This allows a CSO community to identify and estimate costs for controls that could eliminate or relocate CSOs from Sensitive Areas where pollutant loadings pose a high environmental or public health risk and where control efforts should be focused. The cost of these controls can

then be considered, along with the community's financial capability, to evaluate cost-effective controls for all of the receiving waters.
The NJPDES permits indicate that the permittee's LTCP shall give the highest priority to controlling overflows to sensitive areas. The NJPDES Permit further states that "Sensitive areas include designated Outstanding National Resource Waters, National Marine Sanctuaries, waters with threatened or endangered species and their habitat, waters used for primary contact recreation (including but not limited to bathing beaches), public drinking water intakes or their designated protection areas, and shellfish beds."

The NJPDES Permits indicate that if Sensitive Areas are present and impacted, the following requirements will apply:

- Prohibit new or significantly increased CSOs.
- Eliminate or relocate CSOs that discharge to sensitive areas wherever physically possible and economically achievable, except where elimination or relocation would provide less environmental protection than additional treatment.
- Where elimination or relocation is not physically possible and economically achievable, or would provide less environmental protection than additional treatment, the permittee shall provide the level of treatment for remaining CSOs deemed necessary to meet WQS for full protection of existing and designated uses.

F.8.2 Summary of Sensitive Areas

A comprehensive review of online databases, direct observations and correspondence with regulatory agencies and local environmental organizations was conducted to identify potential Sensitive Areas within the combined sewer system portion of the collection system and in the associated receiving waters.

Outstanding National Resource Waters (ONRW) are maintained and protected by Tier 3 of the USEPA's Anti-degradation Policy. Only waters of "exceptional ecological significance" qualify as ONRWs, as determined by States and Tribes. No Outstanding National Resource Waters were located within the project boundaries.

The Office of National Marine Sanctuaries (ONMS) is the trustee of all national marine sanctuaries which currently recognizes fourteen (14) national marine sanctuaries, none of which are located within PVSC's Study Area.

The resources from the US Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), New Jersey Heritage Program (NJHP), and New Jersey DEP Division of Fish and Wildlife (NJDFW) were utilized to identify several Endangered or Threatened species which potentially could live in the project area. All species listed by United States Fish and Wildlife Service are included in NJDEP's lists. NOAA maps show potential areas that may have endangered or threatened species during parts of the year. However, both NJHP and NJDEP's correspondence indicate there are no critical habitats for these species found in the waters of the Study Area. Since CSOs impact receiving water bodies, Endangered or Threatened species that have been identified but do not require the receiving water bodies to live,

propagate, and eat in an area cannot be considered to be in their critical habitat. It is unclear if the identified areas are critical for the species' conservation when other areas are providing similar if not additional needs. Atlantic and Shortnose sturgeon may share their critical habitat in CSO discharge areas, but poor water quality is not inhibiting Atlantic sturgeon recovery, and Shortnose sturgeon have surpassed the recovery criteria in the adult population for the past few decades. The current water quality and habitat protections are viewed as adequate to maintain a healthy sturgeon population. The impact of human enteric pathogens on sturgeon should not have any negative effects on sturgeon at any life stage of the fish both now and in the future, and only commercial bycatch and prior environmental degradation is viewed as a stressor threatening sturgeon recovery.

There are thirteen locations where endangered or threatened species have been identified near permitted CSOs, but no certainty of a critical habitat existing at these locations. Primary contact was not observed or expected in the Passaic River throughout Paterson and is therefore not considered a Sensitive Area. Beaches on the Southeastern boundary of the City of Perth Amboy are not currently designated by the city for recreational bathing use, and signs are installed at this location in order to advise the public against swimming or entering the water. While monitoring this area is a priority, it is not considered a Sensitive Area.

There are no Sensitive Areas as a result of active drinking water intakes within the study area.

There are no commercial shellfish harvesters that operate within the service area. For details of the Sensitive Area Study see the Identification of Sensitive Areas Report dated June 2018 submitted to the NJDEP on behalf of the participating permittees by the PVSC.

SECTION G - COLLECTION OF WATER QUALITY DATA

G.1 BACKGROUND

The NJDEP, PVSC and the leadership of the CSO permittees have agreed that a cooperative or regional approach to the development of a single CSO LTCP is desirable. PVSC has agreed to develop a sewer system characterization work plan on their behalf from its QAPPs for its hydraulically connected CSO Permittees. Several coordination meetings have been held with representatives of the CSO permittees tributary to PVSC's conveyance and treatment facilities as well as other participating CSO permittees. PVSC has agreed to lead the Combined Sewer System Characterization and Landside Modeling Tasks, as well as the Baseline Compliance Monitoring Program, on behalf of the participating permittees.

In accordance with consultation with NJDEP, multiple Sewer System Characterization Work plans QAPPs were developed to cover different aspects of the LTCP work activities for the eight combined sewer municipalities. The QAPPs for the Baseline Compliance Monitoring Program (BCMP) and Receiving Water Quality Modeling were submitted separately from the Sewer System Characterization Work Plan QAPP. The BCMP was developed to serve all of the North Jersey CSO permittees. This System Characterization Report has been developed to include PVSC and seven of the CS municipalities per agreement with each municipality. Jersey City MUA will submit their own System Characterization Report.

The Sewer System Characterization Work Plan was developed to quantify and qualify wastewater and pathogen concentration variations at key CSO and stormwater drainage basins. The Sewer System Sampling Program is outlined in Section G.3 and results are provided in Section G.4 below.

The Baseline Compliance Monitoring Program (BCMP) is modeled in part on the program performed by the New Jersey Harbor Dischargers Group. NJHDG is a similarly allied collaborative undertaking that includes nine (9) sewerage agencies representing eleven (11) wastewater treatment plants in northeastern New Jersey that discharge into the New Jersey portion of the NY/NJ Harbor Estuary. The purpose of NJHDG's long-term water quality monitoring program is to develop ambient water quality data for the Hackensack River, Passaic River, Rahway River, Elizabeth River, Raritan River, Raritan Bay, Newark Bay, and the New Jersey portions of the Hudson River, Upper New York Harbor, and the Arthur Kill, allowing long-term evaluation of water quality in these areas by providing baseline and annual information on water quality in these waterbodies as it relates to current water quality standards. This evaluation identifies changes in water quality over time under varying seasonal conditions, providing a basis for documenting pollution sources and water quality improvements resulting from the implementation of pollution control programs. The Receiving Water Quality Monitoring Program focuses on the CSO receiving waters and is outlined in Section G.6 and a summary of the results are provided in Section G.7 below. The complete Water Quality BCMP results and analysis are provided under a separate report, Baseline Compliance Monitoring Program Report.

G.2 REGULATORY REQUIREMENTS

G.2.1 NJPDES Permit Requirements

PVSC holds NJPDES Permit No. NJ0021016. For more information regarding NJPDES Permit Regulations, see Section B.2.1.

G.2.2 USEPA's CSO Control Policy and Guidance Documents

USEPA's CSO Control Policy (Policy) provides guidance to municipal permittees with CSOs, to the state agencies and to state and interstate water quality standards authorities. The Policy establishes a framework for the coordination, planning, selection and implementation of CSO controls required for permittee compliance with the Clean Water Act. For more information regarding the USEPA's CSO Control Policy, see Section B.2.2.

Requirements for the Monitoring and Modeling Plan are established in the USEPA's "CSO Guidance for Monitoring and Modeling". For more information on other USEPA CSO Guidelines, see Section B.2.3.

G.2.3 Interstate Environmental Commission Requirements

The Interstate Environmental Commission (IEC) is an air and water pollution control agency that serves the Interstate Environmental District within the states of New York, New Jersey, and Connecticut. The Commission's goal is to protect the environment and assure compliance with and enforcement of its Water Quality Regulations. For more information on IEC, see Section B.2.4.

G.3 OVERVIEW OF SEWER SYSTEM QUALITY MONITORING PROGRAM

G.3.1 Historic CSO Discharge Monitoring

The following historical report provided background information on the combined sewer systems tributary to each regulator as well as the analysis of historical overflow volumes and pollutants contained in the CSO discharges.

CSO Monitoring Report (December 1998): This effort was intended to quantify and qualify dry weather and wet weather wastewater flow and pollutant concentration variations at key CSO drainage basins so that this information can be used to calibrate and verify hydrologic and hydraulic models of the combined sewer systems for the combined communities within the PVSC service area tributary to PVSC's Interceptor Sewer and Newark's Southside Interceptor.

G.3.2 Sewer System Quality Monitoring Objectives

The purpose of the monitoring program was to quantify and qualify dry weather and wet weather wastewater flow and pathogen concentration variations at key CSO and stormwater drainage basins to calibrate and verify hydrologic and hydraulic models (InfoWorks) of the CSSs within the PVSC service region. This data was used to update the mathematical tool (sewer system model) that will be used to assess storage and maximum hydraulic conveyance capacity in the PVSC interceptor system, pathogen concentrations and loading distributions during storm events and among CSO discharge points, calculate pathogen loads from CSOs and stormwater to the

receiving water, and for the development and evaluation of long term control alternatives and/or modifications to the water quality standards (WQS) during wet weather events.

G.3.3 Sewer System Quality Sampling Locations

The original Quality Assurance Project Plan (QAPP) targeted 18 CSO and 8 stormwater locations, distributed throughout the PVSC region by municipality and land use. See **Figure G-1** for an overview of the sampling locations. The goal of the sampling protocol was to obtain three wet-weather events of sufficient depth, intensity, and duration for valid model calibration at each targeted location. This was the case for all eight stormwater locations; however, only one of the 18 CSO locations was successfully sampled three times, and four of the targeted CSO locations were not sampled at all due to access or other logistical issues. The use of this data is described in Section G.4.

CSO locations were sampled prior to overflow, then at the following intervals: 0.5 hour, 1 hour, 2 hours, 4 hours, and 8 hours. During the execution of the sampling, the last of these samples was often truncated because the event stopped, so crews routinely collected the last sample any time after 6 hours from start of the event or overflow. Stormwater locations were sampled four times per event, generally on an hourly basis but adjustments were made as events progressed to capture as much of a precipitation event as possible.

G.3.4 Analytical Parameters

Water quality sampling at each location included grab samples and analysis for fecal coliform and enterococcus. Grab samples for analysis of E. coli were also collected at monitoring sites where the outfall discharges to a fresh water receiving waterbody. Laboratory Methods utilized are shown in **Table G-1**.

Table G-1: Lab Methods

Parameter	Laboratory Method	Preservation	Holding Time	Reporting Limit
Fecal Coliform	EPA Micro Manual p. 124 (1978), Single Step Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 CFU/100 mL
Enterococcus	EPA 1600 (Dec 2009), Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 PE/100 mL
E. coli	EPA 1603 (Dec 2009), Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 CFU/100 mL

CFU: colony forming units; PE: presumptive enterococci.

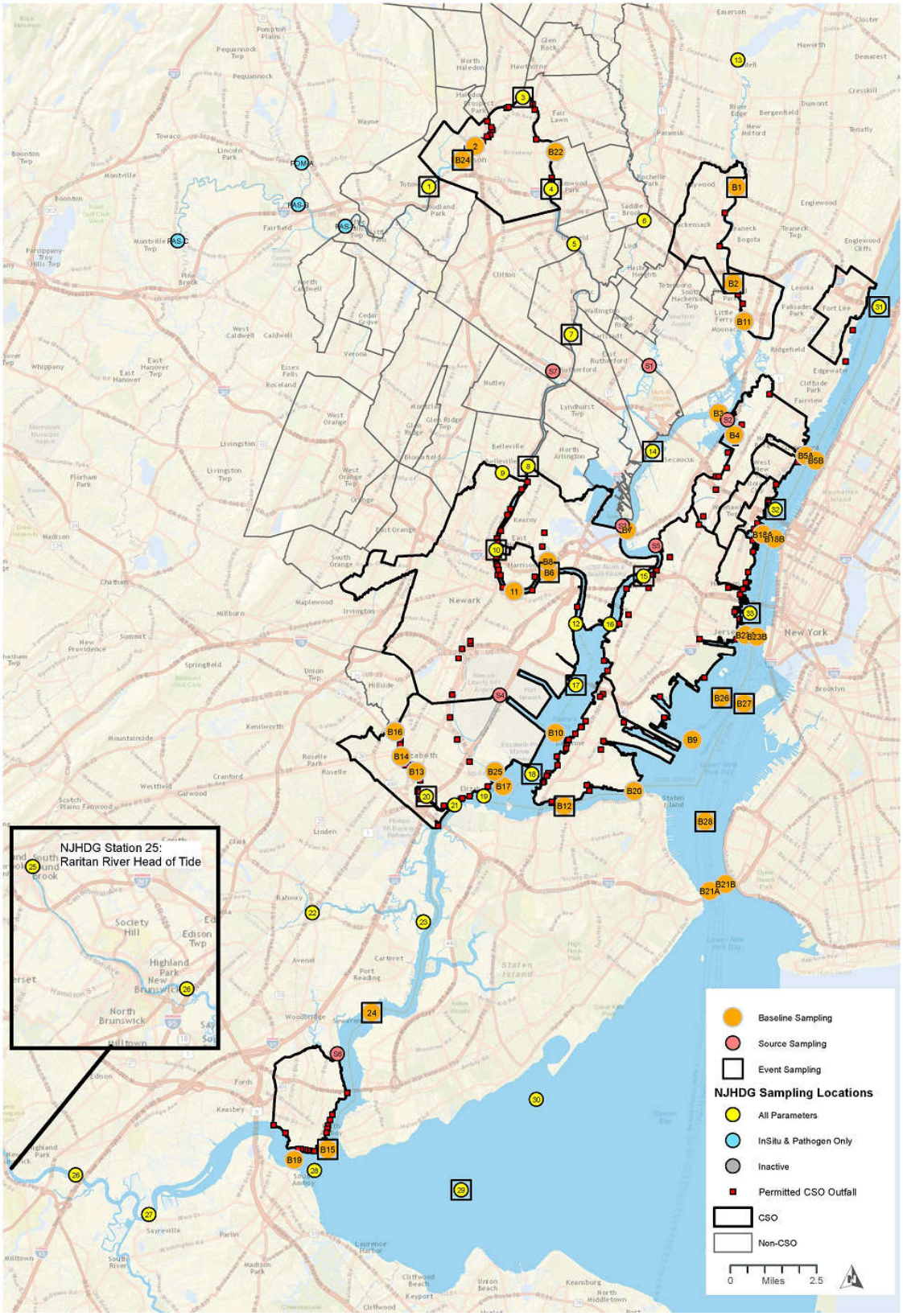


Figure G-1: Overview of Sampling Station Locations

G.3.5 Sampling Schedule and Dates

Water quality sampling was performed. A summary of the CSO sampling dates with corresponding locations and sample identification numbers are shown in **Table G-2** and **Table G-3** below.

Table G-2: CSO Sampling Dates

Date	Locations	CSO Sample Identification
8/21/2016	1	PAT-06A
11/29/2016	5	HAR-06A, HAR-07A, KEA-07A, NWK-25A, NWK-45A
4/4/2017	4	HAR-06A, HAR-07A, KEA-07A, NWK-91A
4/6/2017	4	NWK-14A, NWK-45A, PAT-06A, PAT-27A
6/19/2017	4	BAY-08A, BAY-10A, PAT-25A, PAT-27A
7/23/2017	2	BAY-08A, BAY-10A
10/24/2017	4	NWK-14A, NWK-25A, NWK-45A, NWK-91A
Total	**13**	**Unique CSO Locations**
Total	**27**	**CSO Location-Events**

Table G-3: Stormwater Sampling Dates

Date	Locations	Stormwater Sample Identification
7/29/2016	2	OAK-LR4, PAT-LR1
9/19/2016	2	NWK-CI2, PAT-LR1
9/30/2016	2	NWK-CI2, OAK-LR4
10/21/2016	1	NWK-HR1
11/15/2016	4	NWK-CI2, NWK-HR1, OAK-LR4, PAT-LR1
12/6/2016	1	NWK-HR1
1/17/2017	2	NWK-HR2, NWK-LR2
5/5/2017	4	HAW-LR3, NWK-HR2, NWK-LR2, PAT-CI1
5/22/2017	2	NWK-HR2, NWK-LR2
5/25/2017	2	HAW-LR3, PAT-CI1
7/7/2017	2	HAW-LR3, PAT-CI1
Total	**8**	**Unique Stormwater Locations**
Total	**24**	**Stormwater Location-Events**

G.3.6 System Characterization and Landside Modeling QAPP Goals

The project goals and objectives for the System Characterization and Modeling Program presented herein included:

- Supplement and update, as appropriate, the site specific dry and wet weather data to be used to recalibrate and verify the InfoWorks collections system model of those collections systems tributary to the PVSC WRRF.
- Define the CSSs' hydraulic response to rainfall.

- Supplement the existing dry weather water quality and quantity data to be used in the representation of each CSO drainage basin.
- Determine the CSO flows and pathogen concentrations/loadings being discharged to the receiving streams as a result of varied rainfall events.
- Supplement the stormwater quality data for various land use applications.

G.4 SEWER SYSTEM QUALITY RESULTS

Graphs of data collected by HDR during April 2016 through March 2017 are presented in **APPENDIX A**. Stormwater data were collected in areas that were meant to represent low-density residential, high-density residential and industrial/commercial land-use areas. An analysis of the data indicated that the measured stormwater concentrations had more variability within land-use types than between land-use types making it difficult to make differentiations between the land-use areas. **Figure G-2** presents the data by land-use type. Therefore, the stormwater data were combined to represent stormwater in general. **Table G-4** presents the maximum likelihood estimation (MLE) of the stormwater pathogen data. An MLE can be used estimate a mean of a log-normally distributed dataset. The MLE fecal coliform concentration is similar to the low-level fecal coliform concentration assigned to stormwater in New York City's (NYC) LTCPs, which was 50,000 cfu/100mL. The MLE fecal coliform concentration based on the sampling program is also similar to the mean of all of the fecal coliform data in the International Stormwater BMP Database, which is 62,557 cfu/100mL. As E. coli bacteria are a subset of fecal coliform bacteria, the E. coli MLE concentration of 38,253 cfu/100mL is a reasonable value as it is lower than the MLE concentration of the fecal coliform concentrations collected as part of the sampling program. The enterococci concentrations are high when compared to the fecal coliform concentrations. In the NYC LTCP program, it was typical to measure fecal coliform concentrations higher than the enterococci concentrations, and the high-level area enterococci concentration used for stormwater was 35,000 cfu/100mL. However, a review of the enterococci data collected as part of this sampling program does not indicate that any outlier measurements were the cause of a higher MLE for enterococci, and in general enterococci concentrations were measured at higher levels than fecal coliform in the stormwater. Without evidence that the data are flawed, the concentrations shown in Table G-4 will form the starting point for estimating the stormwater concentrations in the modeling analysis. These stormwater concentrations are also part of the CSO concentration calculations as part of the approach for calculating loads.

Table G-4: MLE of Stormwater Pathogen Data

	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	E. coli (cfu/100mL)
MLE	41,103	110,016	38,253

The CSO data will be used to verify the CSO concentrations calculated by using a combination of sewer system model output and estimated sanitary and stormwater pathogen concentrations. This "Mass Balance Approach" will be used to estimate pathogen loading from CSOs in the receiving water model.

As described in Section G.3.3, fewer CSO overflow events were sampled than planned. However, these data were not collected to develop the pathogen loads for the CSOs, or to calibrate the model. There are too many CSOs for a sampling program to effectively characterize the pathogen loading from each outfall. The CSO sampling was conducted to help verify that the Mass Balance Approach is an adequate way to estimate the CSO concentrations at each outfall. The number of CSO events that were captured were enough to indicate that the pathogen loading approach is reasonable despite not capturing as many events at as many CSOs as planned. Additional discussion will be provided in a modeling report as described in the Pathogen Water Quality Modeling QAPP.

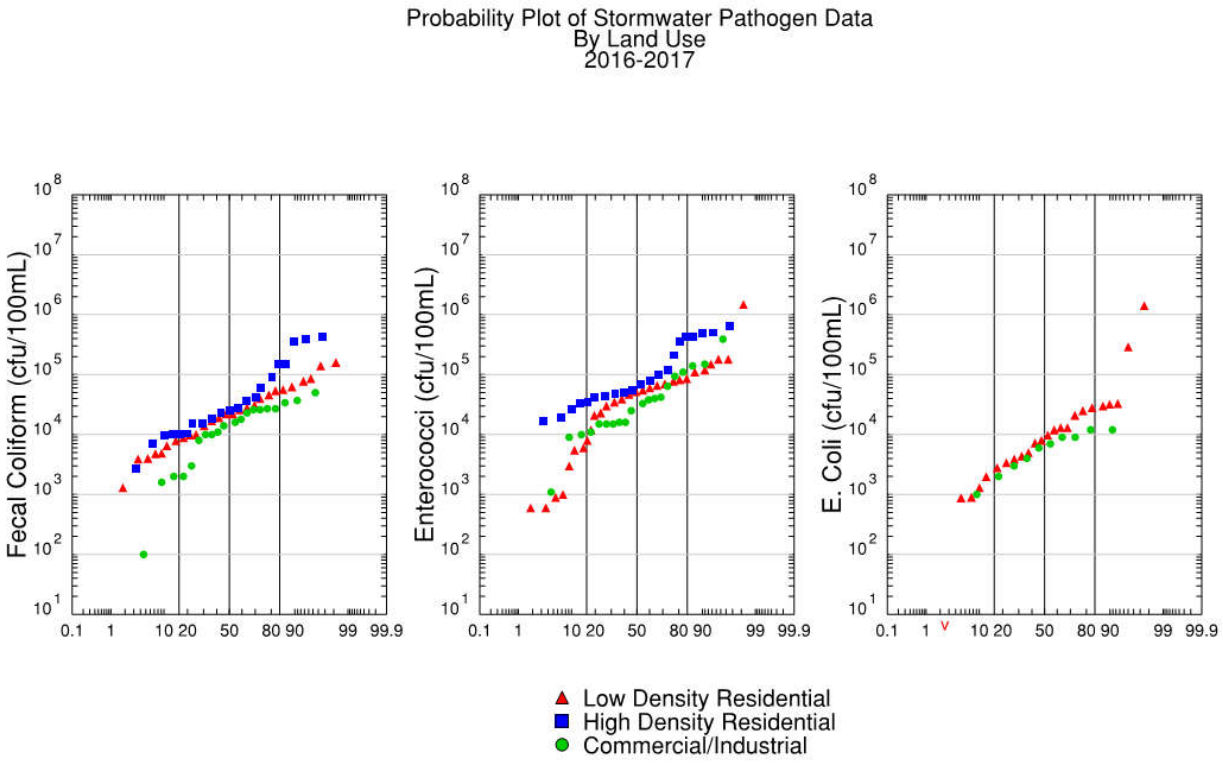


Figure G-2: Probability Distributions of Stormwater Pathogens by Land-use Type

G.4.1 Plant Influent Sampling and Results

Fecal coliform, enterococci, and E. coli concentrations were measured in PVSC plant influent for the period of July 11, 2016 through February 8, 2018. These concentrations will be used to assign the concentrations for the sanitary fraction of the CSO flow as part of the Mass Balance Approach that will be used to calculate CSO pathogen concentrations for use in the receiving water quality model. **Table G-5** provides a summary of the concentrations collected. Fecal coliform had the highest concentrations, followed by E. coli, and then enterococci. Fecal coliform and E. coli showed a seasonal pattern with higher concentrations in the warmer months and lower concentrations in the cooler months. A seasonal trend was not evident in the enterococci concentration data. The sanitary data used as part of the Mass Balance Approach for

assigning CSO concentrations will be assessed to determine if annual or seasonal concentrations do a better job of reproducing the CSO concentrations measured as part of the field sampling program.

Table G-5: Pathogen Concentration Summary

Statistic	Fecal Coliform (cfu/100mL)	Enterococci (cfu/100mL)	E. coli (cfu/100mL)
Average	3,722,595	682,661	2,616,057
MLE	3,804,207	700,260	2,716,496
Geometric Mean	2,771,484	597,075	2,127,581
Minimum	160,000	4,000*	100,000
Maximum	47,000,000	6,200,000	7,200,00

* A value of < 2 cfu/100mL was recorded but not considered valid

G.5 OVERVIEW OF HISTORICAL RECEIVING WATER QUALITY MONITORING

G.5.1 Historic Water Quality Sampling

The New Jersey Harbor Dischargers Group (NJHDG) is an allied collaborative undertaking that includes nine (9) sewerage agencies representing 11 wastewater treatment plants in northeastern New Jersey that discharge into the New Jersey portion of the NY/NJ Harbor Estuary. PVSC, BCUA, JMEUC, MCUA, NBMUA, NHSA are overlapping members of NJHDG and the NJ CSO Group. These agencies collaborate, jointly fund, and perform various water quality studies in the region.

In 2003, the NJHDG initiated a Long-Term Ambient Water Quality Monitoring Program for the NJ portion of the NY/NJ Harbor Estuary. PVSC had previously initiated a long-term ambient water quality monitoring program of the Passaic River, Hackensack River, and Newark Bay in 2000, and has taken the lead for the NJHDG monitoring program. The NJHDG monitoring program is modeled after the successful New York City Department of Environmental Protection (NYCDEP) Harbor Survey. The main objective of the NJHDG program is to develop a comprehensive database on the existing water quality of the NY/NJ Harbor by routinely and extensively monitoring the waters of the Hackensack River, Passaic River, Rahway River, Elizabeth River, Raritan River, Raritan Bay, Newark Bay, and the New Jersey portions of the Hudson River, Upper New York Harbor, and the Arthur Kill. The data collected allows long-term evaluation of water quality in these areas by providing baseline and annual information on water quality in these waterbodies as it relates to current water quality standards. This evaluation identifies changes in water quality over time under varying seasonal conditions, providing a basis for documenting pollution sources and water quality improvements resulting from the implementation of pollution control programs.

Thirty-four locations throughout the region are monitored for 18 conventional chemical water quality parameters including: temperature, pH, dissolved oxygen (DO), salinity, Secchi depth, total suspended solids (TSS), 5-day carbonaceous biochemical oxygen demand (CBOD-5), total

Kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), ammonia-nitrogen (NH_3-N), total phosphorus (TP), orthophosphate (OP), dissolved organic carbon (DOC), chlorophyll-a (Chlor-a), fecal coliform bacteria and Enterococcus bacteria. **Figure G-1** presents the monitoring station locations. Monitoring is performed at each station biweekly during May and June, weekly from July through September and monthly from October through April. All resources for the monitoring program, including sampling personnel and laboratory analyses, are provided by the NJHDG member agencies.

The NJHDG program has effectively served to eliminate the data gap for NJ waters of the NY/NJ Harbor Estuary system by monitoring waterbodies that are not currently monitored by the New Jersey Department of Environmental Protection (NJDEP) Surface Water Quality

Monitoring Network, United States Geological Survey (USGS) Surface Water Quality Gages, or the United States Environmental Protection Agency (USEPA) New York Bight Water Quality Monitoring Program.

This program formed the basis of the LTCP sampling program as described in Section G.4.

G.6 OVERVIEW OF THE RECEIVING WATER QUALITY MONITORING PROGRAM

G.6.1 Receiving Water Quality Monitoring Objectives and Baseline Compliance Monitoring

The Baseline Compliance Monitoring Program has the following objectives:

- Fulfilling the CSO Permit requirement under paragraph D.3.c and under paragraph G.9 for ambient monitoring.
- Generating sufficient data for establishing existing ambient water quality conditions for pathogens to foster appropriate regulatory decisions based on current water quality measurements.
- Generating sufficient relevant data under wet and dry conditions to be used to update, calibrate and validate a pathogen water quality model of the receiving water bodies.
- Supporting the goals of the other components of the LTCP (System Characterization and Receiving Water Quality Modeling).

The Baseline Compliance Monitoring Program includes three parallel data collection efforts to achieve these objectives:

1. Baseline Sampling, which may supplement data from the ongoing NJHDG annual program;
2. Source Sampling, which will target the major influent streams within the study area to establish non-CSO loadings, and will coincide with the NJHDG and Baseline Sampling; and
3. Event Sampling, which is timed to coincide with rainfall to capture three discrete wet-weather events over the course of the year on each segment of the NY-NJ Harbor complex impacted by CSOs.

G.6.2 Receiving Water Quality Sampling Locations

Sampling stations were located to supplement the existing NJHDG monitoring program to provide additional spatial coverage and ensure that each permittee had at least one monitoring station in its local waterbody. A total of 35 additional baseline monitoring stations were added to the existing 34 NJHDG stations. Twenty-five of those 69 stations were chosen for event sampling. An additional seven source sampling stations were added to identify other sources of bacteria to the system. All of the monitoring stations are presented in **Figure G-1**. Shallow stations were sampled at mid-depth and deeper stations were sampled at near surface and mid-depth.

G.6.3 Analytical Parameters

The focus of the LTCP is pathogens. Accordingly, the sampling program was created to measure pathogens and the factors that can affect their concentrations.

Field Testing

The following parameters were directly measured in the field:

- Dissolved Oxygen (DO)
- Temperature
- pH
- Salinity
- Secchi depth (where applicable)
- Turbidity

Methods, reporting limits, method detection limits and holding times are presented in **Table G-6**.

Table G-6: Field Methods

Parameter	Method	Reporting Limit (RL)	Method Detection Limit (MDL)	Holding Time
Temperature (°Celsius)	SM 2550 B	0.1 °C	0 °C	Analyze Immediately
Salinity (parts per thousand)	SM 2520 B	0.1 ppt	0 ppt	Analyze Immediately
Dissolved Oxygen (milligrams per liter)	SM 4500-O C SM 4500-O G	0.1 mg/L	0 mg/L	Analyze Immediately
pH	SM 4500-H B EPA 150.2	0.1	0	Analyze Immediately
Light Penetration (feet)	Secchi Depth	0.1 ft	0.1 ft	Analyze Immediately
Turbidity (Nephelometric Turbidity Units)	SM 2130 B	0 NTU	0 NTU	Analyze Immediately

Laboratory Testing

The following parameters were analyzed at Eurofins QC, Inc.:

- Fecal Coliform (all locations)
- Enterococcus (all locations)
- E. coli (freshwater locations only; Elizabeth River & Upper Passaic River)

Methods, reporting limits, preservation and holding times are presented in **Table G-7**.

Table G-7: Lab Methods

Parameter	Laboratory Method	Preservation	Holding Time	Reporting Limit
Fecal Coliform	EPA Micro Manual p. 124 (1978), Single Step Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 CFU/100 mL
Enterococcus	EPA 1600 (Dec 2009), Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 PE/100 mL
E. coli	EPA 1603 (Dec 2009), Membrane Filtration	Cool ≤ 4°C	6 hrs	1, 2, 4, 10 CFU/100 mL

CFU: colony forming units; PE: presumptive enterococci.

G.6.4 Sampling Schedule and Dates

The Baseline Sampling is modeled after the approved routine sampling program of the NJHDG. However, the proposed Baseline Sampling targeted additional locations to supplement NJHDG data and enhance overall spatial coverage. The Baseline sampling occurred over a period of 12-months from April 2016 through March 2017. The sampling frequency matched the NJHDG program, varying with time of year as follows:

- Spring (May-Jun): Biweekly (4 dates)
- Summer (Jul-Sep): Weekly (12 dates)
- Winter (Oct-Apr): Monthly (7 dates)

The Baseline Sampling and the NJHDG program provided a seasonally-based characterization of existing water quality. All sampling dates for the Baseline Sampling were predetermined at the initiation of the program. For the purposes of the Baseline Compliance Monitoring Program, a sampling date was considered to be wet weather if 0.2 inches of rain or more fell within 24 hours prior to sample collection. Source Sampling coincided with Baseline Sampling.

G.6.5 QAPP Overview

The Baseline Compliance Monitoring Program QAPP was finalized on February 19, 2016. The QAPP included four standard sections: Project Management, Data Generation and Acquisition, Assessment and Oversight, and Data Validation and Usability as outlined in Guidance for Quality Assurance Project Plans, EPA QA/G-5 (EPA 2002). The plan outlined the necessary steps to achieve a successful monitoring program.

Table G-8 presents the quality targets outlined in the QAPP.

Table G-8: Data Quality Criteria and Performance Measurement for Field Collection

Data Quality Indicator	Performance Criterion	Assessment Activity
Completeness	Valid data from 90% of collected samples	Percentage of valid measurements
Precision	RPD[1] < 30% for duplicates	1 field duplicate/crew-day
Representativeness	Blanks ≤MDL[2]	1 field blank/crew-day 1 equipment blank/crew-day

[1]Relative Percent Difference on a log basis; non-representative when (a) both the original and duplicate results are not detected or are less than 5x the reporting limit or (b) either result is estimated, rejected, or suspected of contamination. [2]Method Detection Limit, calculated where applicable.

The sampling program achieved its targeted performance criteria. The data collected in this program should provide an adequate characterization of the variable water quality of receiving waters in the project area.

G.7 RECEIVING WATER QUALITY RESULTS

The field work completed consisted of Baseline Sampling, Source Sampling and Event Sampling as outlined in Section G.4. Field work for these three elements was completed on April 28, 2017; the last of the laboratory results were provided June 10, 2017. A total of 23 baseline and source sampling events were completed. The goal of the event sampling was to capture three significant wet weather events (precipitation >0.5 inches in 24 hours) at each targeted station, which was completed across four sampling events (one set of samples was collected across two precipitation events). All samples collected were analyzed for fecal coliform and enterococcus; freshwater samples were also analyzed for E. coli.

The data collected under the Baseline Compliance Monitoring Program appears to be sufficient for the intended goal of calibrating the water quality model to be used for PVSC and NJCSO communities' LTCPs.

The BCMP was not designed to provide an adequate data volume for assessing attainment of water quality standards, which would have required five samples per month at each sampling location to compute monthly geometric means. However, a review of the data collected can indicate the likelihood of attainment in a particular area:

- The lower regions of the Passaic and Hackensack Rivers appear likely to violate water quality criteria, but attainment appears to improve closer to Newark Bay.
- The larger waterbodies (Newark Bay, Hudson River, Arthur Kill, Kill Van Kull) appear to meet existing water quality criteria. Newark Bay and the Kills are primarily SE3 waterbodies, and Raritan Bay is subject to more stringent shellfishing water quality standards.

- Several smaller riverine waterbodies appear unlikely to meet attainment. This includes the Rahway River, Saddle River, Second River, and Elizabeth River. The Raritan River may also have attainment issues.
- Many rivers without CSOs have high bacteria loads. Data collected at source sampling locations indicate non-attainment of waters entering the Passaic and Hackensack Rivers, contributing pollutant loads into the study area from areas that do not have CSOs.

The companion document Baseline Compliance Monitoring Program Data Summary provides a more comprehensive summary of the water quality results.

SECTION H - TYPICAL HYDROLOGIC PERIOD

H.1 INTRODUCTION

H.1.1 Typical Year for CSO LTCP Development

Precipitation generates urban storm water and combined sewer overflows (CSOs). These will contribute bacteria and pollutants to the New York-New Jersey Harbor and its surrounding major tributaries. The effect of these contributors on the receiving streams mainly depends on the magnitude and duration of rainfall events and on the prevailing ambient river conditions controlling dilution and transport of the pollutants. This variability and complexity poses a significant challenge for assessing the performance of wet weather and CSO control alternatives.

In accordance with the Combined Sewer Overflows - CSO Control Policy from the U.S. Environmental Protection Agency, Office of Water, Washington, DC, EPA 830-B-94-001, April 1994 and the NJDEP Master General Permit issued January 1995, the CSO control alternatives should be assessed on a "system-wide, annual average basis". This is accomplished by continuous simulation using a typical hydrologic period for the combined sewer system (CSS) and receiving water quality modeling applications. The CSO Policy supports continuous simulation modeling, i.e., using long-term precipitation records rather than records for individual storms. Long-term continuous precipitation records enable simulations to be based on a sequence of storms so that the additive effect of storms occurring close together can be examined. They also enable storms with a range of characteristics to be included.

The typical year is intended to contain the closest to average year for the years with available data. Average year conditions are defined as the arithmetic average of the predictions for the selected period.

H.1.2 Annual Precipitation Trend 1948-2015

Average U.S. precipitation has increased since 1900, but there are regional differences, with some areas having larger increases, and others, decreases. Local climate change should be considered when selecting appropriate data records for the typical period analysis.

Daily precipitation data from Newark Liberty International Airport were obtained from the National Oceanic and Atmospheric Administration (NOAA) from 1948 through 2015 to evaluate precipitation trend.

Figure H-1 shows annual precipitation depth from 1948 to 2015. An average straight trend line using sum of least squares is also shown in the figure for characterizing long-term precipitation pattern. During 1948 through 2015, annual precipitation depth ranges from 26.9 to 69.91 inches, with the driest year in 1963 and the wettest year in 2011. The figure splits to show the trend line change from 1948 to 1970 contrasted to 1970 to 2015. From 1948 to 1970 shows a declining pattern with an approximate change of 0.337 inch per year. From 1970 to 2015 shows an inclining pattern with an approximate change of 0.032 inch per year. The latter trend line is more relevant to present day. Therefore it is determined that the typical period for the LTCP to

be selected based on statistical analysis of precipitation records in recent 46 years (i.e., 1970-2015).

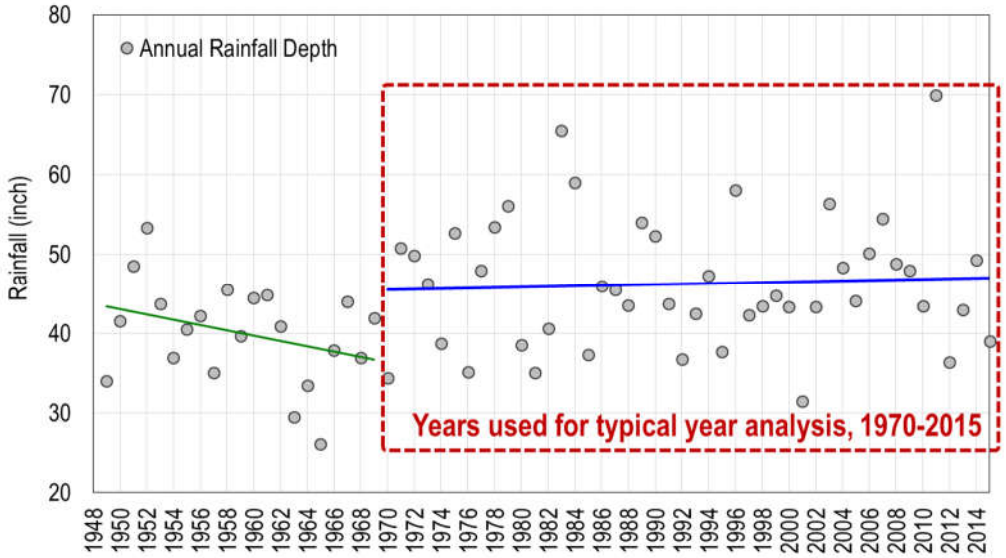


Figure H-1: Historical Annual Precipitation at Newark Liberty International Airport

H.1.3 Methodology of Typical Year Selection

The typical hydrologic year is selected to provide representative and unbiased approximations of expected conditions in terms of both averages and historical variability. Representativeness is assessed using objective criteria for each of the ambient factors. As indicated in the previous section, the selection of the typical hydrologic period is based on the historical records in the past 46 years from 1970 through 2015. The following datasets are used for the analysis of the typical hydrologic period:

- Hourly precipitation data for the National Climate Data Center gauge at Newark Liberty International Airport for 1970 - 2015 is used for analyzing individual rainfall event and event characteristics.
- Daily precipitation data for the National Climate Data Center gauge at Newark Liberty International Airport for 1970 - 2015 is used for analyzing annual and seasonal precipitation amounts.

Criteria used in this typical year analysis were developed based on requirements listed in the presumption approach and the demonstration approach, and potential operational and maintenance considerations for CSO control facilities (EPA's CSO Control Policy, 1994).

Key criteria parameters used in the evaluation are listed in **Table H-1**. Each parameter is given a weighting factor to describe the individual importance on the averageness of the analyzed time period.

Table H-1: Typical Hydrologic Year Ranking Parameters

Criteria Parameter	Weighing Factor	Description / Importance
Annual rainfall depth	30%	Impacting annual overflow volume and storage volume
# of events with rainfall depth ≥ 0.2 in	10%	Rainfall depth to trigger overflow in existing system
# of events with rainfall depth ≥ 0.1 in	5%	Rainfall depth to trigger surface runoff
5th largest storm volume	5%	Determining max storage capacity or WRRF capacity
Rainfall volume for 85% captured	5%	Determining max storage capacity or WRRF capacity
# of back-to-back rainfall events	10%	Determining antecedent conditions and potential storage facility operation
Maximum peak intensities of the 5th largest storm and less	5%	Determining the sizing of conveyance pipes, diversions, regulators, pumps, etc.
# of storms with return frequency ≥ 1-year	5%	Extremely large storms to be avoided
Average Rainfall Duration	15%	Determining storage capacity
Average Rainfall Intensity	10%	Determining storage capacity including pipes, regulators, diversions, etc.

H.2 TYPICAL YEAR SELECTION

H.2.1 Annual Rainfall Statistics

The 46-year hourly precipitation data (1970 - 2015) from the Newark Liberty International Airport was analyzed to evaluate all individual rainfall events in the period. An inter-event time (IET) of 6 hours (i.e. minimum dry time of six hours between rainfall events) was used to differentiate between individual rainfall events. All rainfall events for the data period were analyzed for duration, inter-event time, total rainfall amount, as well as maximum rainfall intensities.

A total of 4,812 rainfall events were counted for the period of 1970 – 2015 (3022 events with a total depth ≥ 0.1 inch). Events with a total precipitation depth equal to or greater than 0.1 inch are used for further analysis. **Table H-2** summarizes rainfall events on an annual basis for annual rainfall depth, number of events above 0.2 inch, number of events above 0.1 inch, the 5th largest storm volume, rainfall volume for 85% captured, number of back-to-back rainfall events, maximum peak intensity of 5th largest and smaller events, number of events with return frequency of one-year and above, average rainfall duration, and average rainfall intensity. The average of the 46 years is shown at the end of the table for each criteria parameter.

Table H-2: Annual Rainfall Statistics 1970-2015

Year	Annual Rainfall (in)	# of Events >=0.2" Rainfall Depth	# of Events >=0.1" Rainfall Depth	5th Largest Storm (in)	Rainfall Volume for 85% Captured (in)	# of back-to-back events	Maximum Peak Intensity of 5th Largest & Smaller	# of Storms with Return Freq > 1-yr	Average Rainfall Duration (hr)	Average Rainfall Intensity (in/hr)
1970	34.39	50	64	1.07	0.77	17	0.98	0	9.36	0.080
1971	50.77	49	64	1.67	3.02	14	0.99	3	10.33	0.092
1972	49.86	57	82	1.78	1.35	14	0.62	4	11.00	0.060
1973	46.29	50	61	2.15	1.27	7	0.72	2	11.77	0.082
1974	38.76	54	74	1.2	0.93	11	0.88	1	9.16	0.076
1975	52.65	59	78	1.72	1.57	18	1.01	4	11.19	0.078
1976	35.19	50	66	1.3	0.94	11	0.91	2	9.14	0.082
1977	47.97	49	73	2.04	2.05	9	1.00	1	10.47	0.071
1978	53.41	51	72	2.42	1.54	13	1.28	5	11.85	0.073
1979	56.1	59	76	2.17	1.55	17	0.87	3	11.45	0.075
1980	38.51	37	48	1.85	1.32	4	0.71	2	11.15	0.079
1981	35.04	47	63	1.45	0.94	12	0.92	1	9.03	0.068
1982	40.58	44	55	1.54	1.15	8	0.75	1	11.20	0.068
1983	65.5	58	65	2.49	1.39	9	0.93	4	13.22	0.090
1984	59.01	51	71	1.98	1.63	9	0.94	7	10.90	0.087
1985	37.29	40	58	1.42	1.21	12	0.84	2	11.29	0.069
1986	45.95	52	67	1.77	1.43	13	0.76	2	11.03	0.072
1987	45.53	54	64	1.61	1.07	12	0.97	0	11.39	0.079
1988	43.51	55	59	1.66	1.12	10	0.80	2	10.81	0.078
1989	53.99	61	79	1.95	1.23	15	0.69	2	10.14	0.093
1990	52.3	62	79	1.88	1.08	11	1.04	2	9.78	0.096
1991	43.76	54	64	1.95	1.33	5	0.88	2	11.03	0.084
1992	36.74	46	65	1.31	1.22	9	0.80	2	11.09	0.058
1993	42.51	50	60	1.65	1.07	10	0.80	1	12.60	0.074
1994	47.32	57	72	1.76	1.16	12	0.96	0	11.18	0.077
1995	37.67	43	58	1.35	1.05	7	0.60	1	10.05	0.073
1996	58.07	63	76	2	1.30	10	1.09	3	10.09	0.086
1997	42.35	45	60	1.35	1.21	7	0.71	2	10.75	0.066
1998	43.47	43	56	1.89	1.42	10	1.23	2	11.59	0.089
1999	44.75	52	60	1.43	1.82	11	0.65	3	11.92	0.076
2000	43.35	49	63	1.43	1.02	10	0.50	2	10.24	0.081
2001	31.44	40	55	1.41	0.95	8	0.69	0	10.40	0.058
2002	43.37	49	54	1.67	1.14	5	1.03	1	12.24	0.107
2003	56.33	64	76	1.89	1.16	18	0.86	2	11.41	0.081

Year	Annual Rainfall (in)	# of Events >=0.2" Rainfall Depth	# of Events >=0.1" Rainfall Depth	5th Largest Storm (in)	Rainfall Volume for 85% Captured (in)	# of back-to-back events	Maximum Peak Intensity of 5th Largest & Smaller	# of Storms with Return Freq > 1-yr	Average Rainfall Duration (hr)	Average Rainfall Intensity (in/hr)
2004	48.37	54	73	1.63	1.18	12	0.99	3	10.33	0.084
2005	44.14	44	57	1.4	2.16	3	0.80	2	12.75	0.061
2006	50.16	52	65	2.01	1.44	12	1.17	3	11.26	0.078
2007	54.49	52	67	2.36	1.88	4	1.46	6	9.72	0.095
2008	48.83	49	69	1.84	1.34	11	0.77	3	10.04	0.094
2009	47.93	54	74	1.87	1.13	13	0.80	1	10.91	0.074
2010	43.47	44	52	1.6	1.51	10	0.93	2	12.08	0.103
2011	69.91	59	76	2.4	2.76	17	0.89	4	10.22	0.106
2012	36.35	51	68	1.47	0.94	11	1.01	1	8.81	0.095
2013	42.94	49	61	1.43	1.06	9	1.10	1	10.41	0.083
2014	49.33	60	69	1.56	1.24	10	1.26	2	10.99	0.083
2015	38.98	42	54	1.46	0.95	5	0.99	1	11.43	0.089
Average (1970-2015)	**46.3**	**51.2**	**65.7**	**1.72**	**1.35**	**10.54**	**0.90**	**2.2**	**10.9**	**0.081**

H.2.2 Ranking Analysis

With the weighting factors listed in **Table H-1**, a deviation score was developed for each individual period. The steps to perform the ranking analysis is discussed in detail in the *Typical Hydrologic Year Report* prepared for Passaic Valley Sewerage Commission (PVSC). The 1-year periods were then ranked based on the deviation score. The lower deviation score (**Figure H-2** Y-axis), the higher the rank for the hydrologic period (i.e., the closer it is to the average condition). **Figure H-2** shows the ranking results of the 46 hydrologic years,

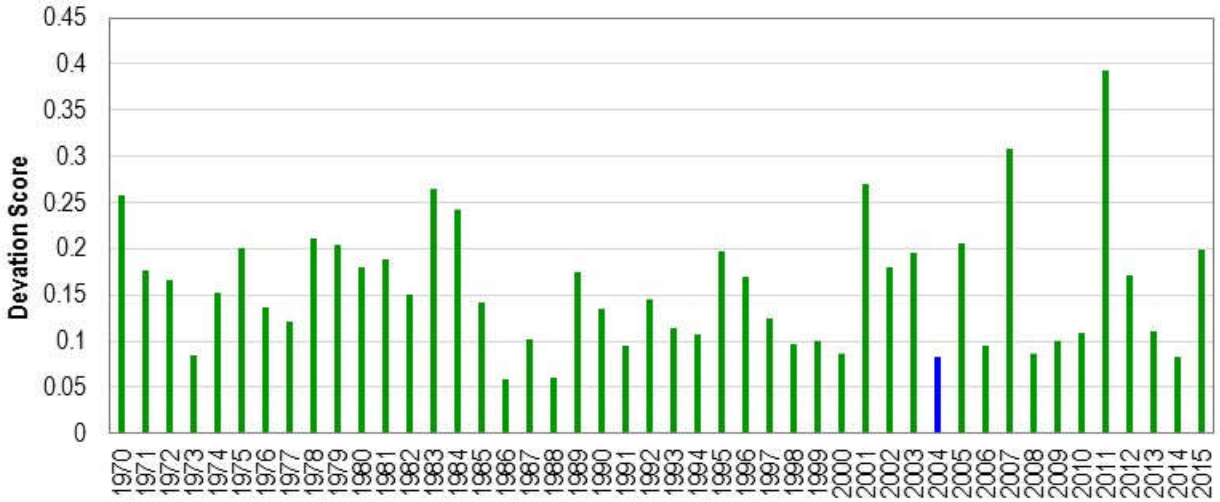


Figure H-2: Ranking Score of 1970-2015

H.2.3 Top Ranked Hydrologic Years

Table H-3 summarizes top 20 ranked years based on the ranking analysis. It was decided that a more recent period be used for the PVSC CSO LTCP study to reflect recent climate conditions. It was also determined that the typical year should be selected from years with an annual precipitation depth greater than the average value (highlighted with green background in **Table H-3**) to be more conservative. Therefore, the following five years are the top years to be considered for typical year selection:

- 1: 2004
- 2: 2014
- 3: 1973
- 4: 2008
- 5: 2006

Table H-3: Top 20 Ranked Years

Preliminary Rank	Year	Deviation Score	Annual Rainfall (in)	# of Events >=0.2" Rainfall Depth	# of Events >=0.1" Rainfall Depth	5th Largest Storm (in)	Rainfall Volume for 85% Captured (in)	# of back-to-back events	Maximum Peak Intensity of 5th Largest & Smaller	# of Storms with Return Freq > 1-yr	Average Rainfall Duration (hr)	Average Rainfall Intensity (in/hr)
	Weighing Factor		30%	10%	5%	5%	5%	10%	5%	5%	15%	10%
	Average 1970-2015		46.3	51.2	66	1.7	1.35	10.54	0.90	2.2	10.85	0.081
1	1986	0.058	46.0	52	67	1.77	1.43	13	0.76	2	11.03	0.072
2	1988	0.060	43.5	55	59	1.66	1.12	10	0.80	2	10.81	0.078
3	2004	0.082	48.4	54	73	1.63	1.18	12	0.99	3	10.33	0.084
4	2014	0.082	49.3	60	69	1.56	1.24	10	1.26	2	10.99	0.083
5	1973	0.084	46.3	50	61	2.15	1.27	7	0.72	2	11.77	0.082
6	2008	0.086	48.8	49	69	1.84	1.34	11	0.77	3	10.04	0.094
7	2000	0.086	43.4	49	63	1.43	1.02	10	0.50	2	10.24	0.081
8	2006	0.095	50.2	52	65	2.01	1.44	12	1.17	3	11.26	0.078
9	1991	0.096	43.8	54	64	1.95	1.33	5	0.88	2	11.03	0.084
10	1998	0.097	43.5	43	56	1.89	1.42	10	1.23	2	11.59	0.089
11	1999	0.099	44.8	52	60	1.43	1.82	11	0.65	3	11.92	0.076
12	2009	0.099	47.9	54	74	1.87	1.13	13	0.80	1	10.91	0.074
13	1987	0.101	45.5	54	64	1.61	1.07	12	0.97	0	11.39	0.079
14	1994	0.107	47.3	57	72	1.76	1.16	12	0.96	0	11.18	0.077
15	2010	0.108	43.5	44	52	1.60	1.51	10	0.93	2	12.08	0.103
16	2013	0.110	42.9	49	61	1.43	1.06	9	1.10	1	10.41	0.083
17	1993	0.114	42.5	50	60	1.65	1.07	10	0.80	1	12.60	0.074
18	1977	0.120	48.0	49	73	2.04	2.05	9	1.00	1	10.47	0.071
19	1997	0.125	42.4	45	60	1.35	1.21	7	0.71	2	10.75	0.066
20	1990	0.135	52.3	62	79	1.88	1.08	11	1.04	2	9.78	0.096

Rainfall return frequency was analyzed to understand the distribution of the large rainfall events with return frequencies above one year. **Table H-4** summarizes quantity of large rainfall events with return frequencies for the above-mentioned top ranked hydrologic periods.

Table H-4: Top 5 Ranked Years – Quantity of Rainfall Events

Final Rank	Year	Quantity of Rainfall Events with Return Frequency Above				
		1-yr	2-yr	5-yr	10-yr	50-yr
1	2004	2	1			
2	2014	1			1	0
3	1973	2				
4	2008	1	1	1		
5	2006	1		1		1

H.2.4 Selected Hydrologic Period

The year 2004 will be used as the typical hydrologic year for the CSO LTCP. The year 2004 was ranked first in the criteria described above and contains a wide range of storms and antecedent conditions. Year 2004 also has close to an average CSO volume and event number based on the hydrologic and hydraulic model results.

A summary of the parameters and the percent difference is shown below in **Table H-5**.

Table H-5: Summary of the Recommended Typical Year - 2004

Parameters	2004
Annual Precipitation*	48.37 in (4.5% greater than average 46.27)
Number of Events >=0.2" Rainfall Depth	54 (5% greater than average 51.2)
Number of Events >=0.1" Rainfall Depth	73 (11% greater than average 66)
5th Largest Storm Volume	1.63 in (5% less than average 1.70)
Rainfall Volume for 85% Capture	1.18 in (12% less than average 1.35)
Back-to-Back Storm Events	12 (14% greater than average 10.5)
Max Peak Intensity of 5th Largest Storm & Smaller	0.99 in/hr (9.5% greater than average 0.90)
Extreme Storm	1 Year Storm (2) 2 Year Storm (1)
Average Rainfall Duration	10.3 hr (4.8% less than average 10.8)
Average Rainfall Intensity	0.084 in/hr (3.8% greater than average 0.081)

Note:

* Includes snowfall

Characteristics of the top 20 rainfall events (by rainfall depth) in the hydrologic year are shown in **Table H-6**.

Table H-6: Top 20 Rainfall Events by Depth in 2004

2004	Event Start	Duration (hr)	Precipitation Depth (in)	Max Rainfall Intensity (in/hr)	Average Rainfall Intensity (in/hr)	Return Frequency
1	9/28/2004 1:00	28	**3.68**	0.53	0.13	2-yr – 24hr
2	9/8/2004 4:00	25	**2.21**	0.63	0.09	1-yr – 6hr
3	7/12/2004 9:00	27	**1.99**	0.32	0.07	
4	4/12/2004 17:00	30	**1.67**	0.25	0.06	
5	4/25/2004 14:00	35	**1.67**	0.25	0.05	
6	7/23/2004 10:00	24	**1.66**	0.33	0.07	
7	2/6/2004 5:00	33	**1.63**	0.33	0.05	
8	7/18/2004 16:00	14	**1.60**	0.64	0.11	
9	11/28/2004 2:00	12	**1.50**	0.85	0.13	
10	7/27/2004 15:00	18	**1.45**	0.41	0.08	
11	9/17/2004 22:00	12	**1.44**	1.33	0.12	1-yr – 2hr 2-yr – 1hr
12	6/25/2004 17:00	5	**1.39**	0.40	0.28	
13	11/12/2004 7:00	23	**1.08**	0.10	0.05	
14	5/12/2004 16:00	2	**1.08**	0.99	0.54	
15	11/4/2004 14:00	16	**1.03**	0.20	0.06	
16	7/5/2004 3:00	12	**1.00**	0.69	0.08	
17	12/1/2004 4:00	10	**1.00**	0.18	0.10	
18	8/16/2004 0:00	21	**0.94**	0.60	0.04	
19	8/21/2004 14:00	3	**0.84**	0.81	0.28	
20	12/6/2004 12:00	39	**0.83**	0.20	0.02	

SECTION I - HYDROLOGIC AND HYDRAULIC MODELING

I.1 PREVIOUS H&H MODELS

An integrated PVSC collection system Hydrologic and Hydraulic (H&H) model is needed for the purpose of evaluating CSO control alternatives and developing a holistic CSO Long Term Control Plan (LTCP) for all the combined municipalities in the PVSC sewer service area.

Prior to this project/study, several H&H models were already developed using different modeling software platforms to simulate collection systems in several CSO communities. These models are henceforth referred to as "pre-LTCP" models. Detailed modeling information including communities, permittee, WRRF, and modeling software for these pre-LTCP models are summarized in **Table I-1**. The service area locations served by each individual models are shown in **Figure I-1**.

Table I-1: PVSC Service Area Previous H&H Models Summary

Model	Community	WWTP	Permittee	Software	County
PVSC Interceptor Model	City of Paterson	PVSC	Paterson City	InfoWorks CS	Passaic
	City of Newark	PVSC	Newark City		Essex
	Town of Kearny	PVSC	Town of Kearny		Hudson
	Borough of East Newark	PVSC	East Newark Borough		Hudson
	Town of Harrison	PVSC	Harrison Town		Hudson
Bayonne Model	City of Bayonne	PVSC	City of Bayonne	InfoWorks CS	Hudson
North Bergen Model (PVSC) (2 models)	Township of North Bergen	PVSC	North Bergen MUA	PC-SWMM	Hudson
Jersey City	City of Jersey City	PVSC	Jersey City MUA	XP-SWMM	Hudson
North Bergen (Woodcliff)*	Township of North Bergen	NBMUA Woodcliff	North Bergen MUA	PC-SWMM	Hudson
Guttenberg*	Town of Guttenberg	NBMUA Woodcliff	Town of Guttenberg	SWMM	Hudson

* North Bergen (Woodcliff) and Guttenberg areas are discussed under a separate System Characterization Report for NBMUA Woodcliff and Guttenberg.

Four of the pre-LTCP H&H models in **Table I-1** were used for developing the integrated PVSC LTCP model, including one PVSC Interceptor model, one Bayonne model and two North Bergen models. Brief descriptions of these four models are included in the following subsections. The Jersey City model was not detailed in this report because it was determined that Jersey City would manage its own model and submit a separate System Characterization Report.

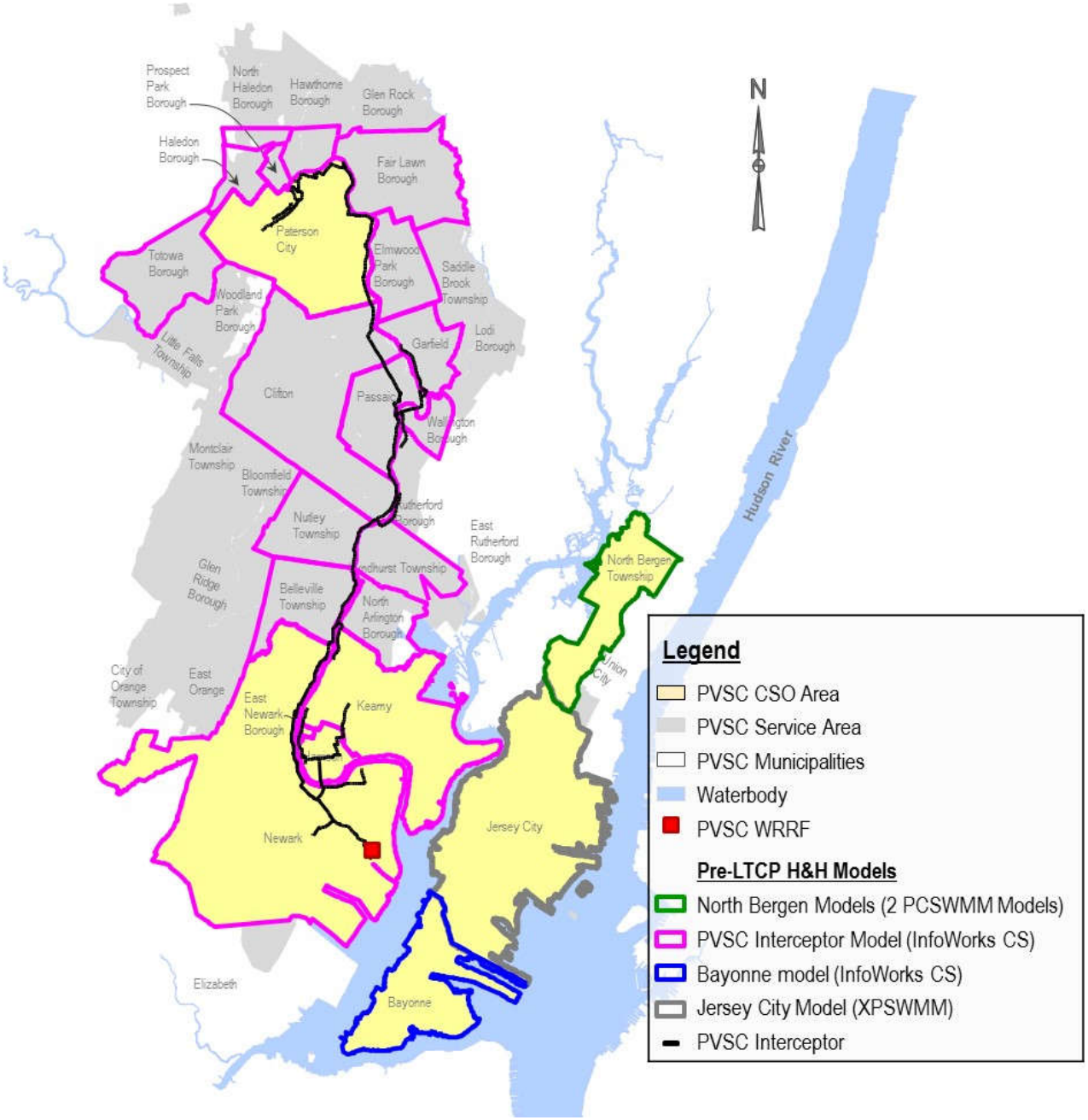


Figure I-1: Service Area Simulated in the Pre-LTCP Models

I.1.1 PVSC Interceptor Model

The PVSC Interceptor Model is the largest of the four pre-LTCP models used during model integration. **Figure I-2** shows its model network in InfoWorks CS. The model was lastly updated and calibrated by HDR in June 2016. It provides the backbone for the new integrated model. It simulates PVSC's service area west of the Newark Bay, including five of the eight combined sewer municipalities and seventeen separately sewered municipalities that are adjacent to and directly connected to the main interceptor. The five combined municipalities are the City of Paterson, the Borough of East Newark, the Town of Kearny, the Town of Harrison, and the City of Newark. The separately sewered municipalities include Totowa, Haledon, North Haledon, Prospect Park, Hawthorne, Fair Lawn, Elmwood Park, Clifton, Garfield, Passaic, Wallington, Nutley, East Rutherford, Rutherford, Lyndhurst, North Arlington, and Belleville (municipalities are listed based on their geographical location from north to south). The corresponding service area simulated in the model are shown as the subcatchments in **Figure I-2** and the pink-highlighted areas in **Figure I-1**.

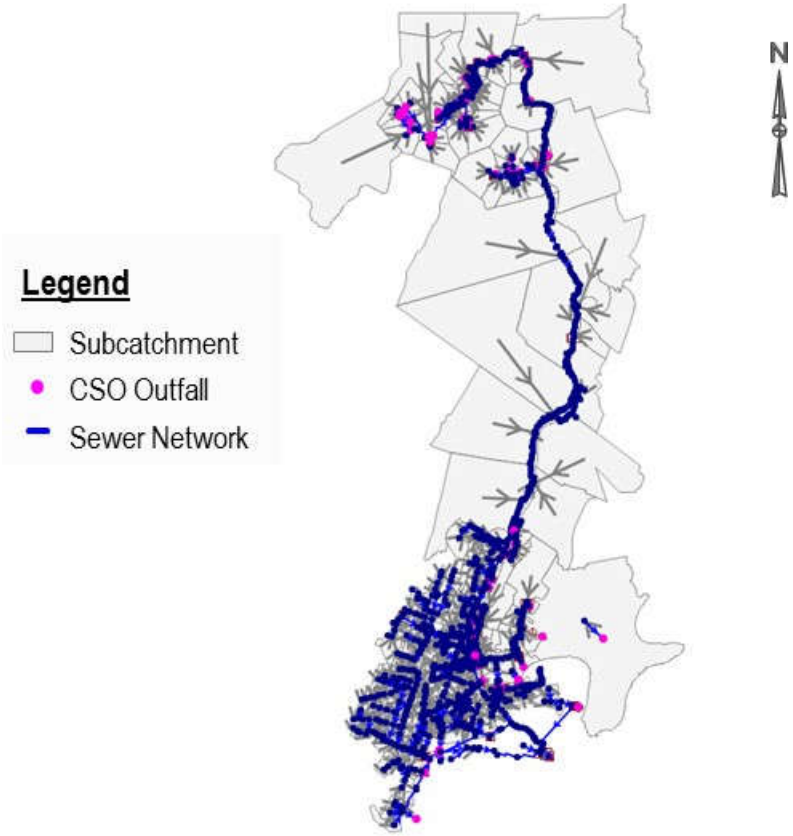


Figure I-2: Received PVSC Interceptor Model

Major features of the pre-LTCP PVSC Interceptor Model are listed below. More detailed modeling information can be found in the technical memorandum "PVSC Model Recalibration" by HDR, June 2017.

- The model was calibrated/validated to eighteen temporary meters (fourteen in the main

interceptor and four in branch interceptors) using flow metering data from May 8th to October 5th 2015. Flow data at the three PVSC Venturi meters (Paterson, Passaic, and Second River), force mains, South Side Interceptor (SSI), and total treatment plant flow were also used in the calibration/validation. Historically, the model was modified and updated along different time periods, and was calibrated to 1999-2001 period and 2005-2006 period, during these two time periods monitored data was collected.

- The model did not include the Hudson County Force Main. Flow from the Hudson County Force Main was included as hourly inflow time series in the model to allow the model to simulate the total flows to the WRRF.

- The operation of the plant main gates and regulated regulator gates in Newark were simulated with real time control (RTC) rules based on the actual operation logs.

- The rainfall derived inflow and infiltration (RDII) for the separately sewered municipalities were simulated using the rational method (Q=CIA), where flow is a function of the drainage area, rainfall intensity and a runoff coefficient.

- The model was created based on PVSC datum (the PVSC datum is 100 feet below Mean Sea Level (MSL) at Sandy Hook).

I.1.2 Bayonne Model

The pre-LTCP Bayonne Model was created in InfoWorks CS. The model was lastly updated by HDR/Mott MacDonald. **Figure I-3** shows its model network in InfoWorks CS. The model simulates the collection system in the City of Bayonne. The corresponding service area simulated in the model is shown as the subcatchments in **Figure I-3** and the blue-highlighted area in **Figure I-1**.

Major features of the pre-LTCP Bayonne Model are listed below.

- The model simulates the entire sewer service area in the City of Bayonne. Because the City does not have its own wastewater treatment facility, sewer flows collected from the City are pumped to the Bayonne Force Main and further conveyed to the Hudson County Force Main to the PVSC WRRF for treatment. The received Bayonne model does not include the Hudson County Force Main and downstream treatment, the model ends at the Bayonne Force Main.

- The operation of eleven regulated regulator gates in Bayonne are simulated with real time control (RTC) rules based on the correlations between the gate opening and water depth.

- No boundary conditions were applied for CSO outfalls.

- The Bayonne Model was created based on MSL at Sandy Hook (the PVSC datum is 100 feet below MSL at Sandy Hook).

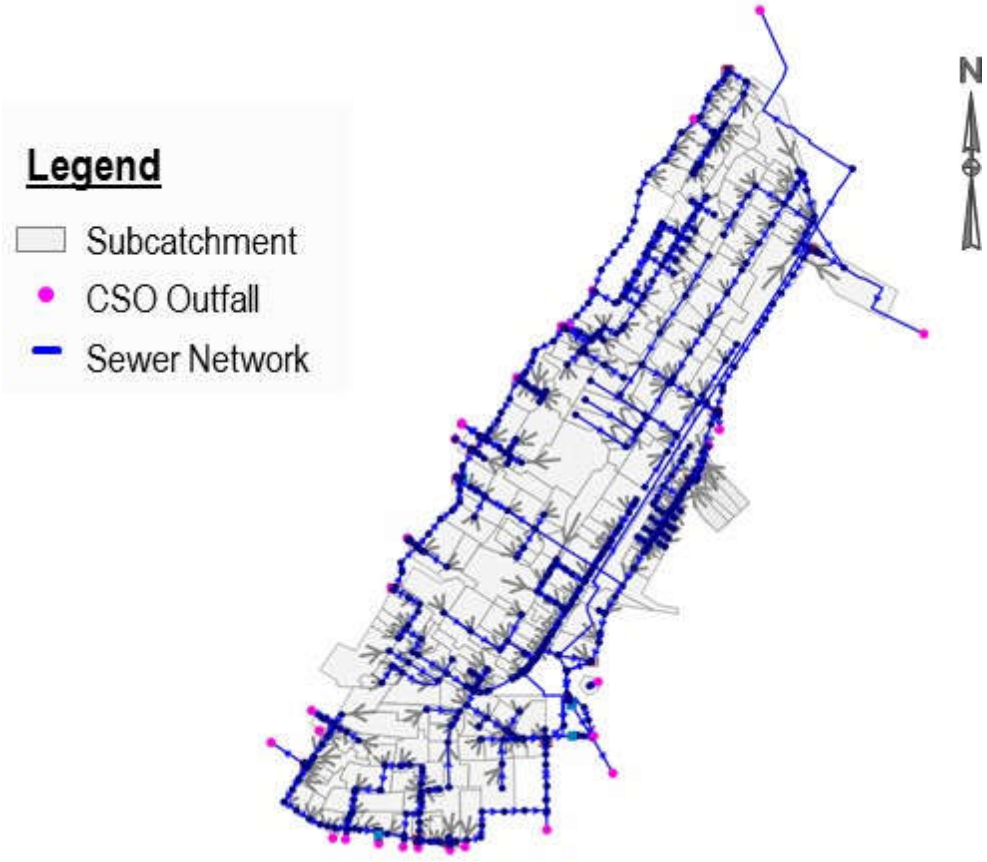


Figure I-3: Received Bayonne Model

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I.1.3 North Bergen Models

The two pre-LTCP North Bergen models were lastly updated by Kleinfelder. Both were originally created in PCSWMM; however, the models were converted to EPA SWMM5 for the convenience of model integration in InfoWorks ICM. **Figure I-4** shows the model networks in EPASWMM. The subcatchments in the EPASWMM model are not GIS based, the corresponding service area simulated by these two models are shown in the green-highlighted areas in **Figure I-1**.

Major features of the two North Bergen models are listed below. More detailed modeling information can be found in the Report "*Adaptation of SWMM to Simulate the Combined Sewer Overflows of the North Bergen MUA*" by Najarian Associates, January 2007.

- The two models represent the Northerly Interceptor System and Southerly Interceptor Sewer System, respectively.

- Both models are needed to represent the area of North Bergen served by PVSC WRRF.

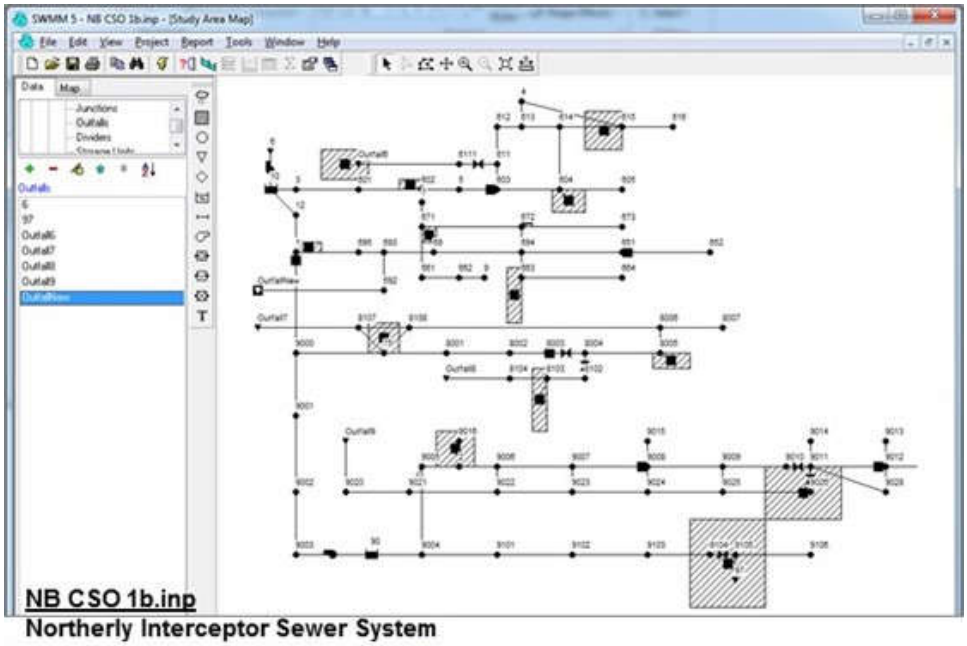
- Both models are non-GIS based skeleton-type SWMM models.

- The models were calibrated to five flow metered locations within the watershed on the Northerly Interceptor for October-December of 2002, and five metered locations within the watershed on the Southerly Interceptor for February-April of 2003.

- There is no real time control rule set up for the regulator gates, suggesting the gates were not regulated during wet weather conditions. All regulator gates were assumed to be frozen in the open position and all gates were set at a level that just allowed the dry weather flow to pass without obstacles.

- All CSO outfalls were assumed to be free outfalls and thus no boundary conditions were applied.

- The North Bergen models were created based on the MSL at Sandy Hook (the PVSC datum is 100 feet below the MSL at Sandy Hook).



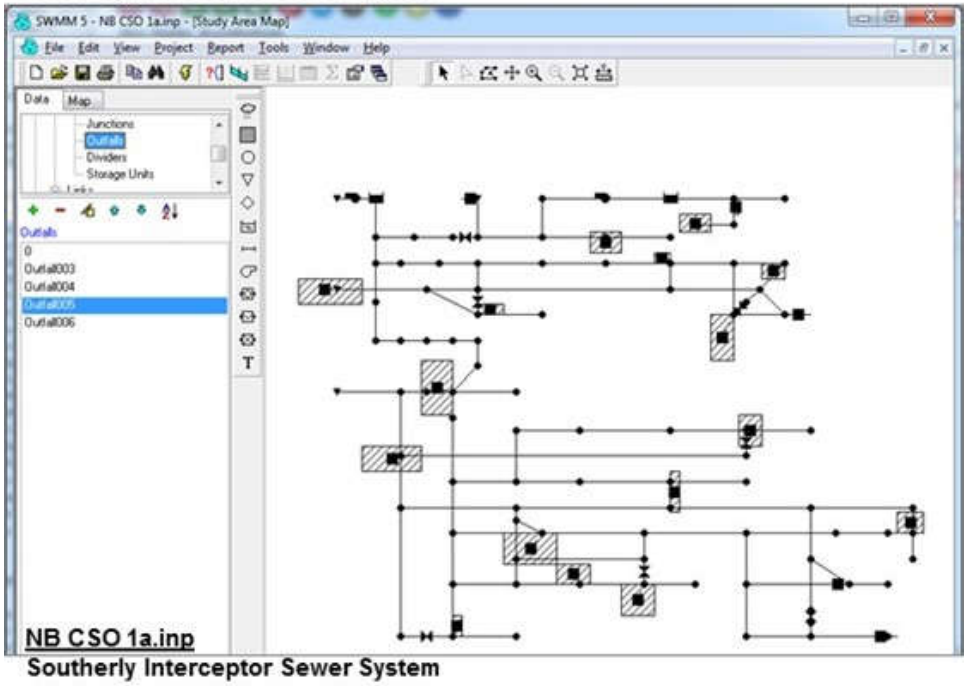


Figure I-4: Received North Bergen Model

I.2 PVSC DISTRICT LTCP H&H MODEL INTEGRATION & DEVELOPMENT

The LTCP PVSC District H&H model was developed by integrating these four pre-LTCP models (the PVSC Interceptor model, the Bayonne model and the two North Bergen models) into one complex PVSC model in InfoWorks ICM v9.0. The model was then expanded to include all 40 municipalities with separate sewer service area that contribute flows to the PVSC WRRF.

The calibrated Jersey City model (XPSWMM) provided by the Jersey City MUA was also converted to InfoWorks and integrated into the PVSC model to complete the connections of North Bergen model and Bayonne model to the Hudson County Force Main and PVSC WRRF.

I.2.1 Integration of PVSC Interceptor Model

The original PVSC Interceptor Model (InfoWorks CS) was integrated to the to the PVSC LTCP model (InfoWorks ICM) through a straight forward procedure of transferring data from CS to ICM. Most of the model network features remain the same during the transferring except the following major changes.

Paterson Re-delineation

In the Pre-LTCP PVSC Interceptor model, the subcatchment boundaries in the City of Paterson were delineated based on Theissen polygons. To better represent the actual drainage characteristics and sewer connectivity in the area, the subcatchments were re-delineated based on GIS information of contours, sanitary sewer, storm sewer, etc. **Figure I-5** shows the City of Paterson delineation before (orange polygon in **Figure I-5 (a)**) and after (blue polygon in **Figure I-5 (b)**) model integration. Subcatchments including red sewer lines are the separate areas.

Paterson Internal Regulator

There are 24 internal regulators in the City of Paterson to relieve extreme wet weather flows to storm sewers connecting to CSO outfall points. Typically the internal regulator conveys dry weather flow and a portion of wet weather flow to the PVSC Interceptor through a downstream CSO regulator. During larger storm events overflow would occur when the water surface level in the internal regulator is above its overflow weir crest. The extreme wet weather flows are conveyed to a storm sewer connecting to a CSO outfall. The description of individual internal regulators is detailed in **Table I-2**. **Table I-3** summarizes internal regulators in the area and their corresponding downstream CSO regulators and overflow CSO outfalls.

Figure I-6 (a) shows the model network around the internal regulators (highlighted with the dashed red lines) in the Pre-LTCP PVSC Interceptor Model. The conveyance of flows from the internal regulator overflow weir to CSO outfall were not included. Instead, artificial outfalls were created and connected to the overflow weirs. In the integrated PVSC LTCP Model, the artificial outfalls were removed, and the model network of manholes and sewers were extended from the internal regulator overflow weirs to CSO outfalls based on sewer GIS data and actual sewer connectivity shown in **Table I-2** and **Table I-3**. **Figure I-6 (b**) shows the updated model network in the integrated model.

Table I-2: Paterson Internal Regulator Description

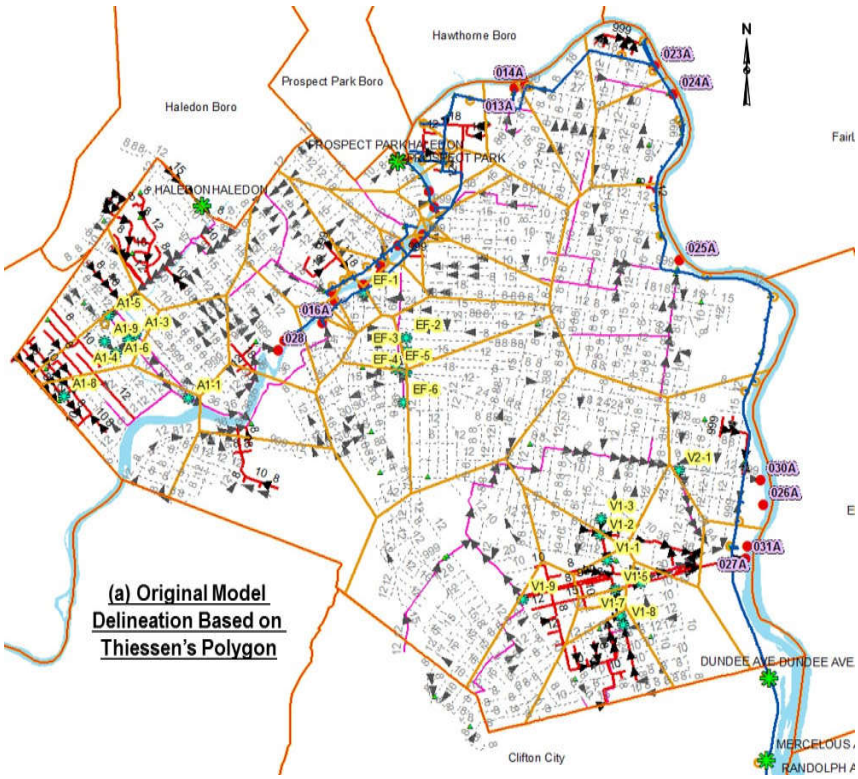
Outfall # or Internal Regulator #	Location	Description
Outfall 028	**S.U.M. Park 2**	**120 " RCP**
A1-1	Westside Park	Side overflow weir with 36" RCP pipes in and out. Normal flow (including dry weather flow and a small portion of wet weather flow) discharges to 36" pipe flowing south cross the Passaic River, and then to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 36" pipe to a 69" storm sewer connecting to CSO-028A.
A1-2	Union. & Sherwood Ave.	Side overflow Weir - Plugged
A1-3	Sherwood Avenue	Side overflow weir with 30" RCP pipes in and out. Normal flow discharges to 30" pipe passing to the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 24" pipe to a 90" storm sewer connecting to CSO-028A.
A1-4	Linwood. & Crosby Ave.	Side overflow weir at the bench with 18" VCP pipes in and 12 "out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through an 18" pipe to a 30" storm sewer connecting to CSO-028A.
A1-5	Linwood. & Chamberlain Ave.	Side overflow weir at the bench with 12" & 24" VCP pipes in and 18" out. Normal flow discharges to 18" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 12" pipe to a 30" storm sewer connecting to CSO-028A.
A1-6	Richmond & Crosby Avenue	Side overflow weir at the bench with 12" ACP pipes in and out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 12" pipe to 90" storm sewer connecting to CSO-028A.
A1-7	Crosby. & Emerson Ave.	Side overflow weir at the bench with 12" VCP pipes in and out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through a 12" pipe to 60" storm sewer connecting to CSO-028A.
A1-8	Crosby. & Maitland Ave.	Side overflow weir at the bench with 10" & 12" VCP pipes in and 12" out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through an 18" pipe to 60" storm sewer connecting to CSO-028A.
A1-9	Richmond Avenue between Crosby and Chamberlain	Side overflow weir at the bench with 10" & 12" VCP pipes in and 12" out. Normal flow discharges to 12" pipe passing thru the A1-1 Regulator and connecting to the PVSC interceptor at CSO-001A. Wet weather overflow is through an 18" pipe to 60" storm sewer connecting to CSO-028A.
Outfall 029A	**Loop Road**	Twin 108" RCP, each pipe fitted with dual upturned flow diffusers at the outfall point
EF-2	Van Houten Street	An incoming 18" VCP pipe is regulated by a 7.5"H x 9.75"W gate and a side overflow weir. Normal flow discharges to a 15" VCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 36" RCP storm sewer connecting to CSO-029A.
EF-3	Ellison Street	An incoming 36" VCP pipe is regulated by a 7.5"H x 15.75"W gate and a side overflow weir. Normal flow discharges to an 18" VCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 48" RCP storm sewer connecting to CSO-029A.

Outfall # or Internal Regulator #	Location	Description
EF-4	Market Street	An incoming 48" RCP is regulated by a 12"H x 12"W gate and a side overflow weir. Normal flow discharges to an 18" VCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 48" RCP storm sewer connecting to CSO-029A.
EF-5	Market Street	An incoming 18" VCP is regulated by a 5"H x 9.25"W gate and a side overflow weir. Normal flow discharges to a 12" VCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 30" RCP storm sewer connecting to CSO-029A.
EF-6	Railroad Ave and Grand Street	An incoming flow is in a 77"H x 121"W concrete box culvert and is regulated by a 16"H x 27.5"W gate and a side overflow weir. Normal flow discharges to a 36" RCP connecting to the PVSC interceptor at CSO-006A. Wet weather overflow is through a 120" RCP storm sewer connecting to CSO-029A
Outfall 030	**Nineteenth Avenue**	**90 " RCP**
V2-1	19th Avenue Regulator	An incoming 70.5"H x 85"W brick pipe is regulated by two (2) 19.25' long side overflow weirs with mechanical solids/floatables screening. Normal flow discharges to a 70.5"H x 85"W brick pipe connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 90" RCP storm sewer connecting to CSO-030A.
Outfall 031	**Route 20 Bypass**	**120 " RCP**
V1-1	23rd & Trenton Avenue	An incoming 15" VCP pipe is regulated by a 2.5' long side overflow weir. Normal flow discharges to a 15" VCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 42" RCP storm sewer connecting to CSO-031A.
V1-2	22nd & Trenton Avenue	An incoming 15" VCP pipe is regulated by a 5' long side overflow weir. Normal flow discharges to a 15" VCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 42" RCP storm sewer connecting to CSO-031A.
V1-3	Trenton Avenue between 22nd & 21st	Two incoming 8" VCP pipes are regulated by a side overflow weir. Normal flow discharges to a 12" pipe connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 10" VCP to a 30" RCP storm sewer connecting to CSO-031A.
V1-4	Maryland Avenue	Three incoming pipe (10" VCP, 12" VCP, and 30" RCP) are regulated by a 10' long side overflow weir. Normal flow discharges to a 30" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 102" RCP storm sewer connecting to CSO-031A.
V1-5	Trenton & Maryland Avenue	Two incoming pipe (24" RCP) are regulated by a 9' long side overflow weir. Normal flow discharges to a 30" pipe connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 102" RCP storm sewer connecting to CSO-031A.
V1-6	Trenton & Florida Avenue	An incoming 24" RCP pipe is regulated by 9' long side overflow weir. Normal flow discharges to a 24" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through an 84" RCP storm sewer connecting to CSO-031A.
V1-7	Trenton & Illinois Avenue	An incoming 24" RCP pipe is regulated by 11' long side overflow weir. Normal flow discharges to a 24" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through an 84" RCP storm sewer connecting to CSO-031A.

Outfall # or Internal Regulator #	Location	Description
V1-8	Trenton & Michigan Avenue	An incoming 24" RCP pipe is regulated by an 18' long side overflow weir with mechanical solids/floatables screening. Normal flow discharges to a 24" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 60" RCP storm sewer connecting to CSO-031A.
V1-9	Alabama & E. Railway Avenue	An incoming 30"x42" Brick pipe is regulated by a 16' long side overflow weir with mechanical solids/floatables screening. Normal flow discharges to a 36" RCP connecting to the PVSC interceptor at CSO-027A. Wet weather overflow is through a 54" RCP storm sewer connecting to CSO-031A.
Outfall 033A	**Tyler Street /Washington Street**	**Outfall is direct to Passaic River at CSO-033A**
EF-1	River Street	An incoming 48" RCP is regulated by a 7.5"H x 12.375"W gate with a side overflow weir. Normal flow discharges to a 15" VCP connecting to the PVSC interceptor at PVSC MH243. Wet weather overflow is through a 48" RCP storm sewer connecting to CSO-033A.

Table I-3: Paterson Internal Regulator Downstream Flow Conveyance

Regulator #	Normal Flow	Overflow
A1-1 to A1-9 (8)	P_001A Regulator	P_028A
EF-2 to EF-6 (5)	P_006A Regulator	P_029A
V2-1	P_027A Regulator	P_030A
V1-1 to V1-9 (9)	P_027A Regulator	P_031A
EF-1	PVSC Interceptor MH 243	P_033A


Hawthorne Boro
Prospect Park Boro
Haledon Boro
Clifton City
N
014A
013A
023A
024A
025A
016A
028
EF-1
EF-2
EF-3
EF-4
EF-5
EF-6
A1-1
A1-2
A1-3
A1-4
A1-5
A1-6
A1-8
A1-9
V1-1
V1-2
V1-3
V1-5
V1-7
V1-8
V1-9
V2-1
030A
026A
031A
027A
DUNDEE AVE
(a) Original Model Delineation Based on Thiessen's Polygon

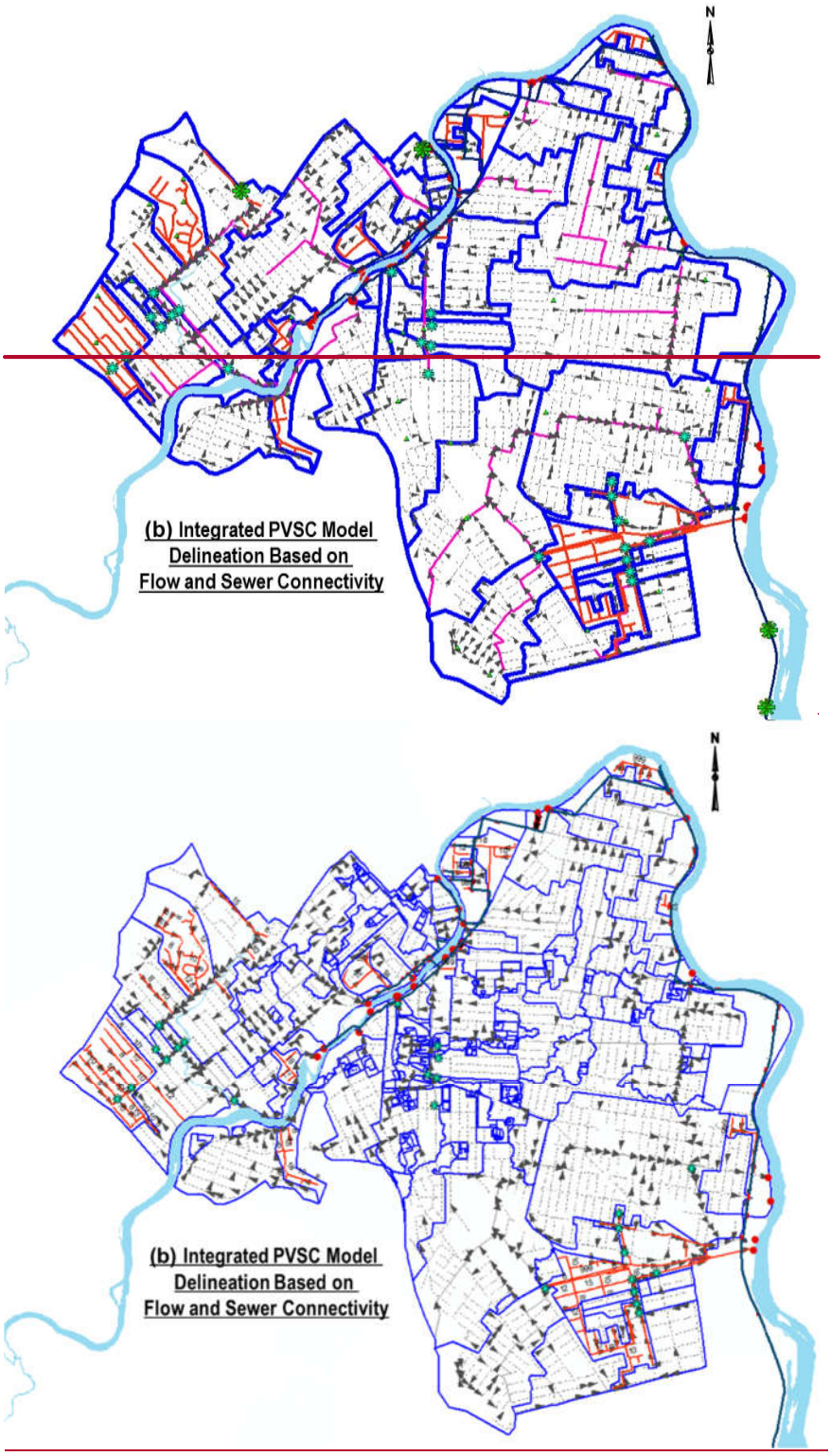
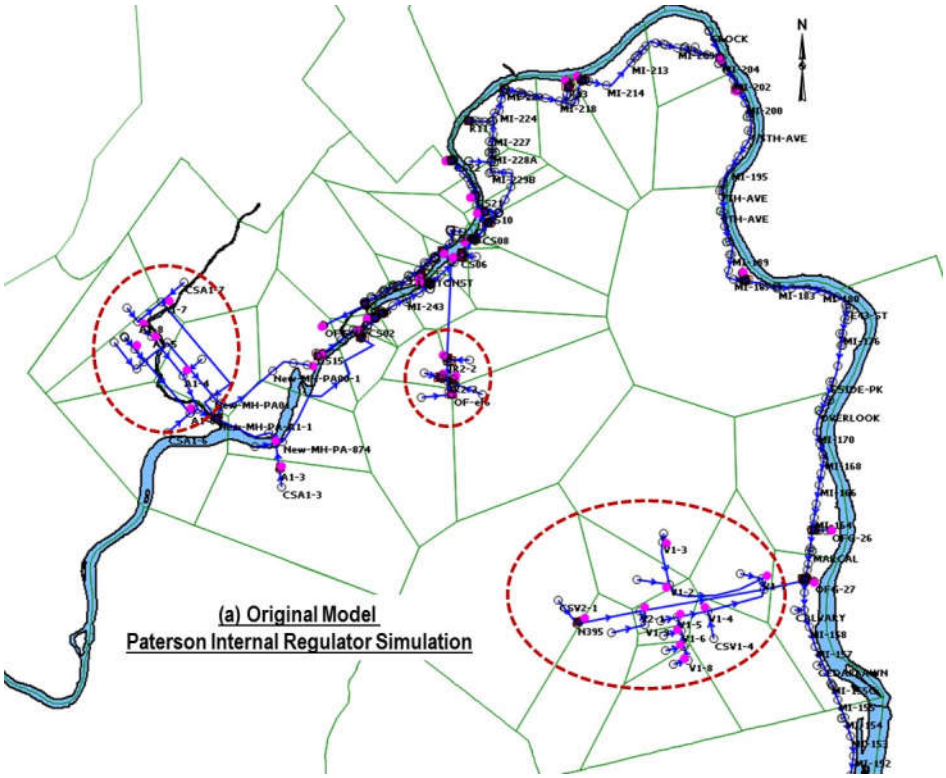


Figure I-5: Subcatchment Re-delineation of Paterson City


N
(a) Original Model
Paterson Internal Regulator Simulation

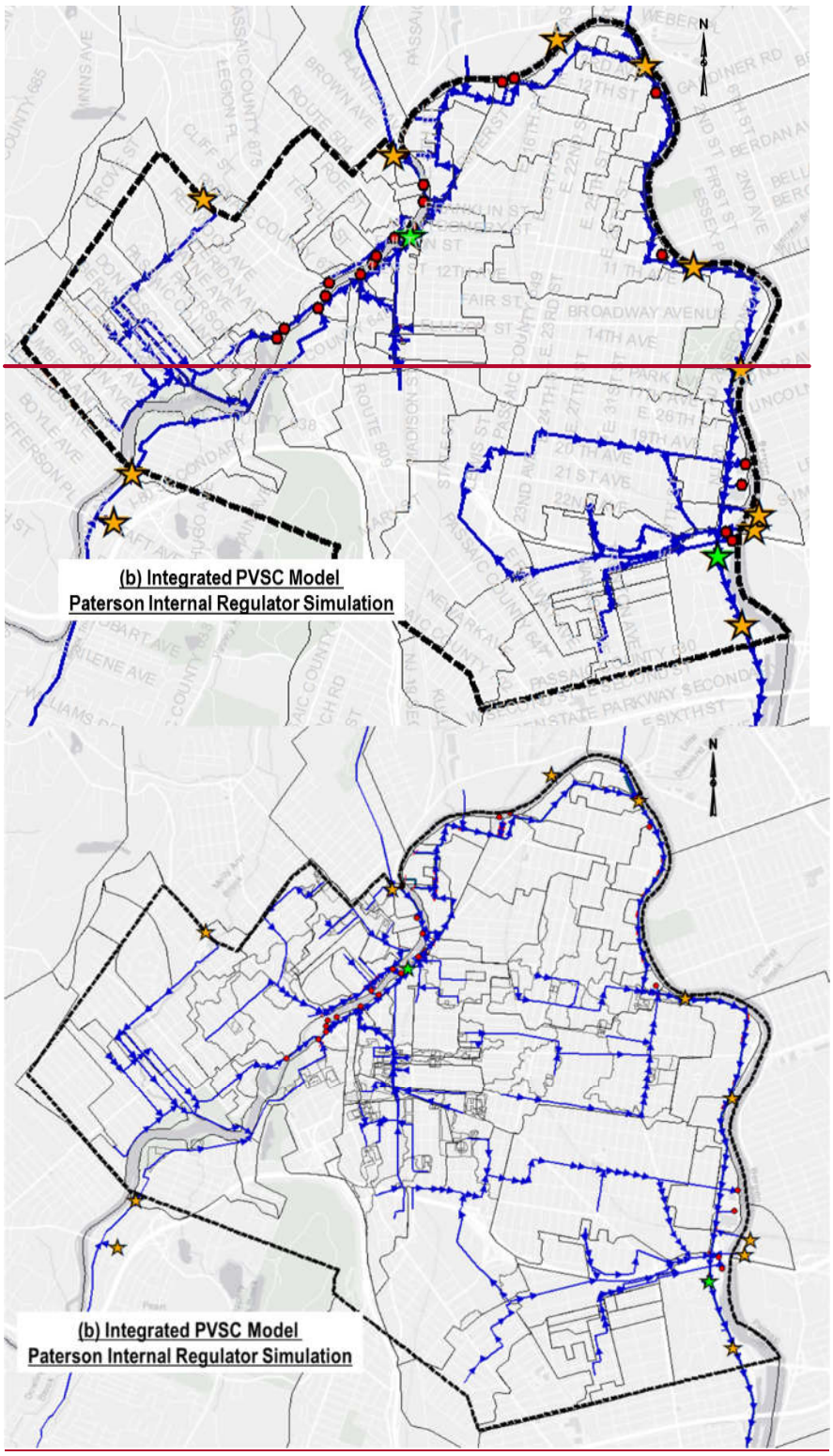


Figure I-6: Paterson City Internal Regulator Simulation

Model Network of the CSO Municipalities in the Integrated PVSC Model

There are five CSO municipalities included in the pre-LTCP PVSC Interceptor Model: Paterson, Newark, East Newark, Kearny, and Harrison. The model network of these five municipalities in the integrated model are shown in **Figure I-7** through **Figure I-11**. Quantities of subcatchments, nodes and links are also shown on the map. Permanent meters and temporary meters indicated on the map are the meters used for model calibration.

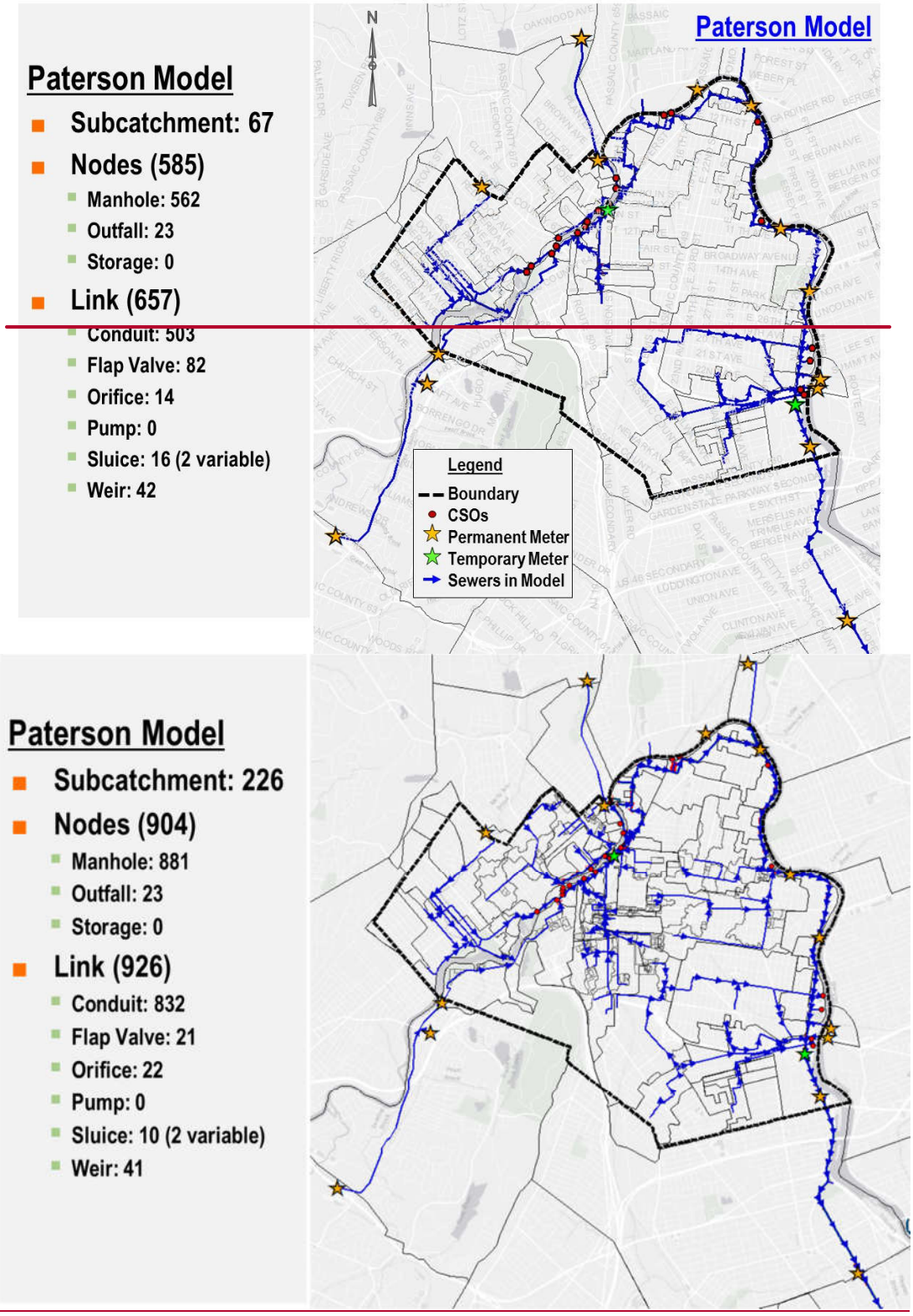


Figure I-7: Snapshot of Model Network in Paterson

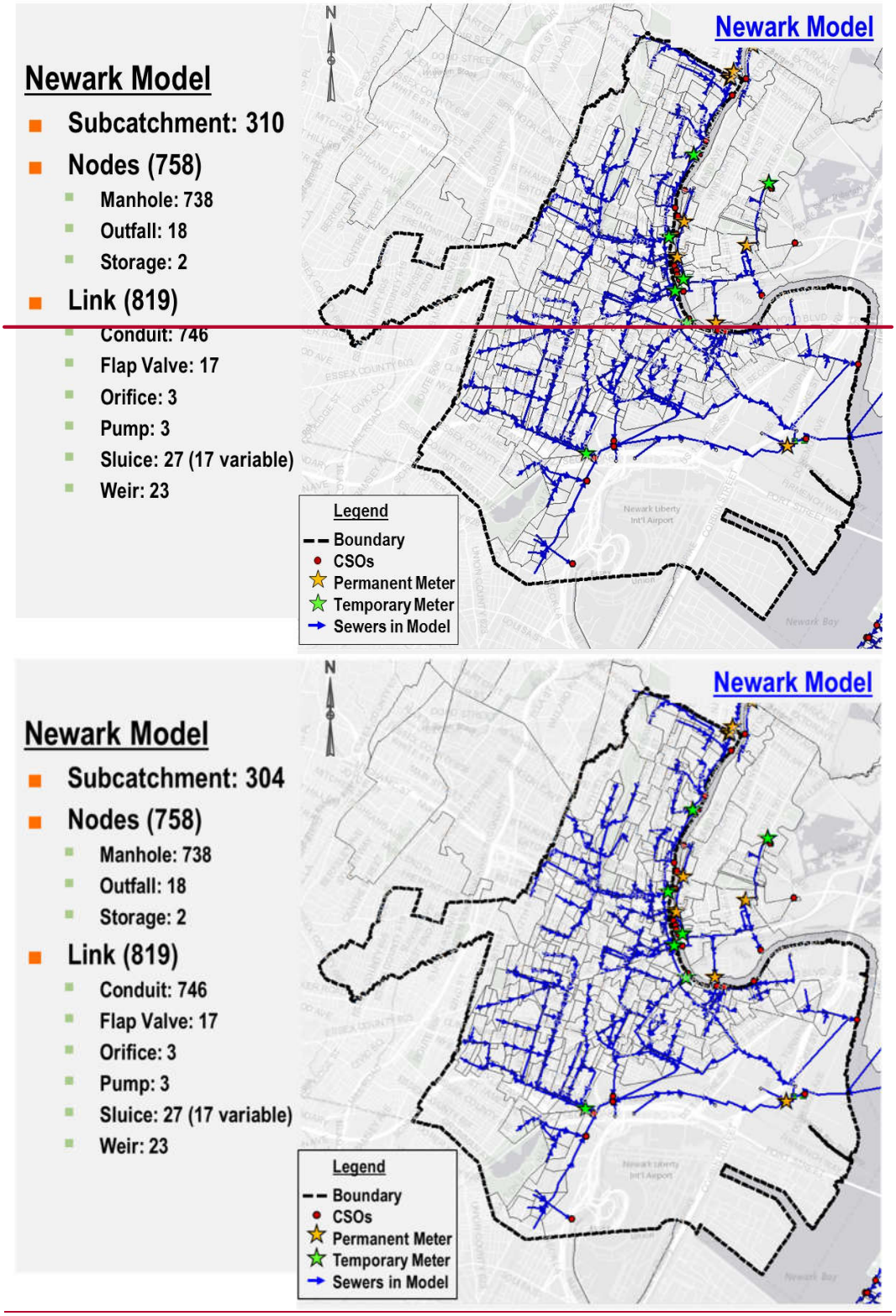


Figure I-8: Snapshot of Model Network in Newark

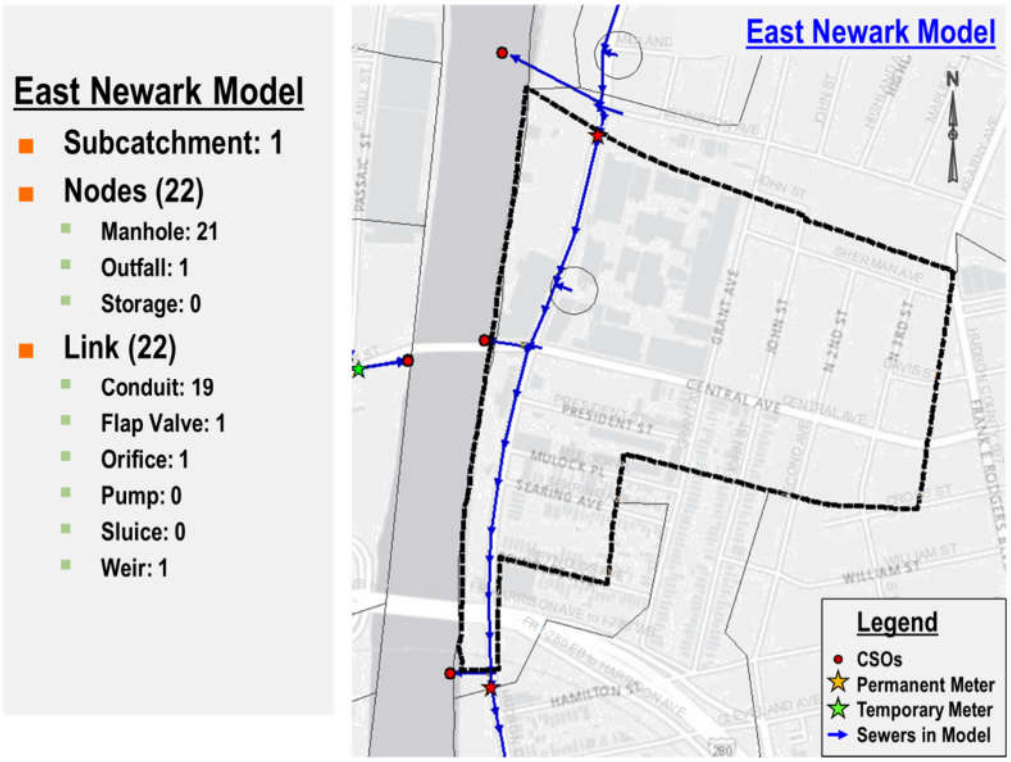


Figure I-9: Snapshot of Model Network in East Newark

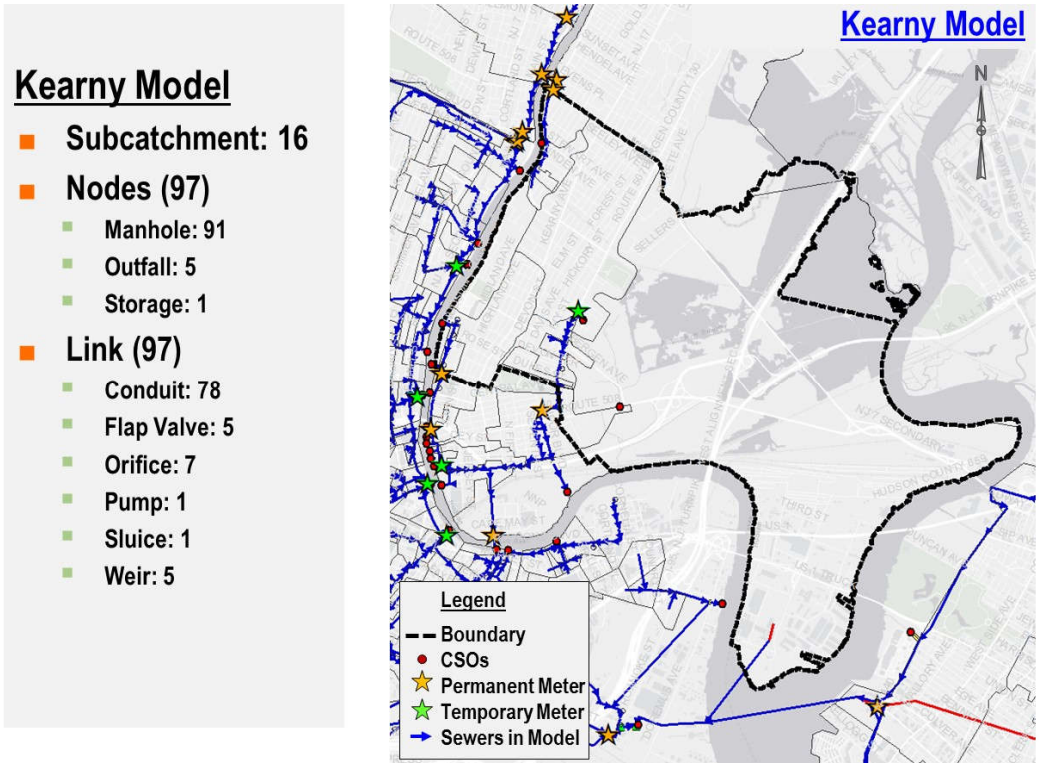


Figure I-10: Snapshot of Model Network in Kearny

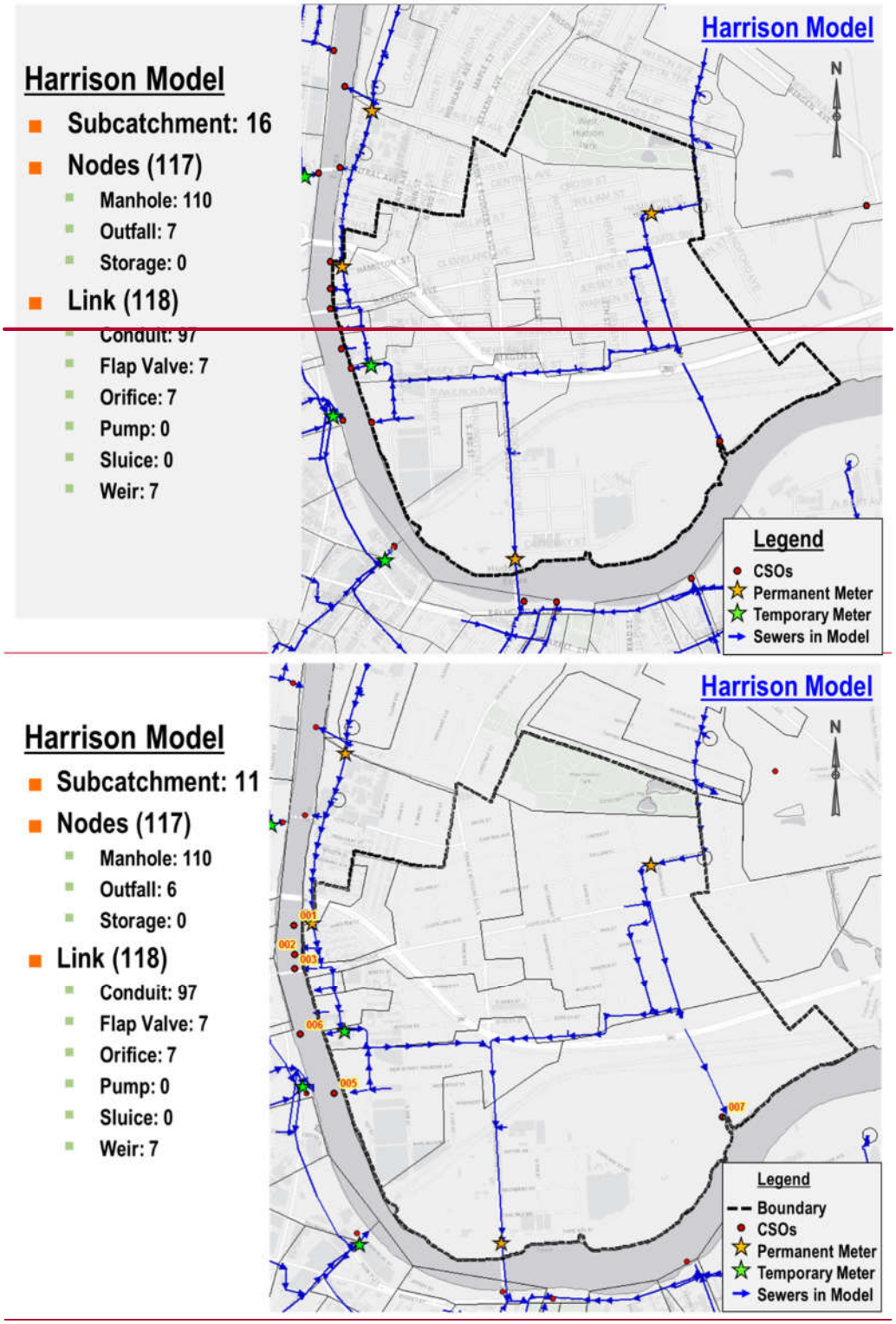


Figure I-11: Snapshot of Model Network in Harrison

I.2.2 Integration of Bayonne Model

The pre-LTCP Bayonne Model (InfoWorks CS) was integrated ~~to~~ into the PVSC LTCP model (InfoWorks ICM) through a straight forward procedure of transferring data from CS to ICM. All of the model network features remain the same during the transferring except the following minor changes.

- Updated IDs of subcatchments, nodes and links to start with "BA-"
- All Real Time Controls (RTCs) were appended to the integrated model.

  The eleven RTCs are used to control regulator gate openings based on the water levels. **Table I-4** shows the level-opening ~~table~~ settings prior to and post model integration. The "output" column in the table ~~is corresponded~~ corresponds to the regulator gate opening with a default unit of "meters". The values used in the "output" column ~~in~~ from the ~~original~~ pre-LTCP Bayonne model ~~are~~ correspond~~ed~~ to ~~the~~ units of "feet", which ~~should~~ had to be converted to "meters". This is completed for all the eleven RTC tables in the integrated model.
- Updated datum from the MSL to PVSC datum
- Extended the 36" Bayonne force main from the municipality boundary to the Jersey City West Pump Station to connect to the Hudson County Force Main.

The model network for the City of Bayonne in the integrated model is shown in **Figure** I-12. Quantities of subcatchments, nodes and links are also shown on the map. Permanent meters and temporary meters indicated on the map are the meters used for model calibration.

Table I-4: Bayonne RTC Table Update

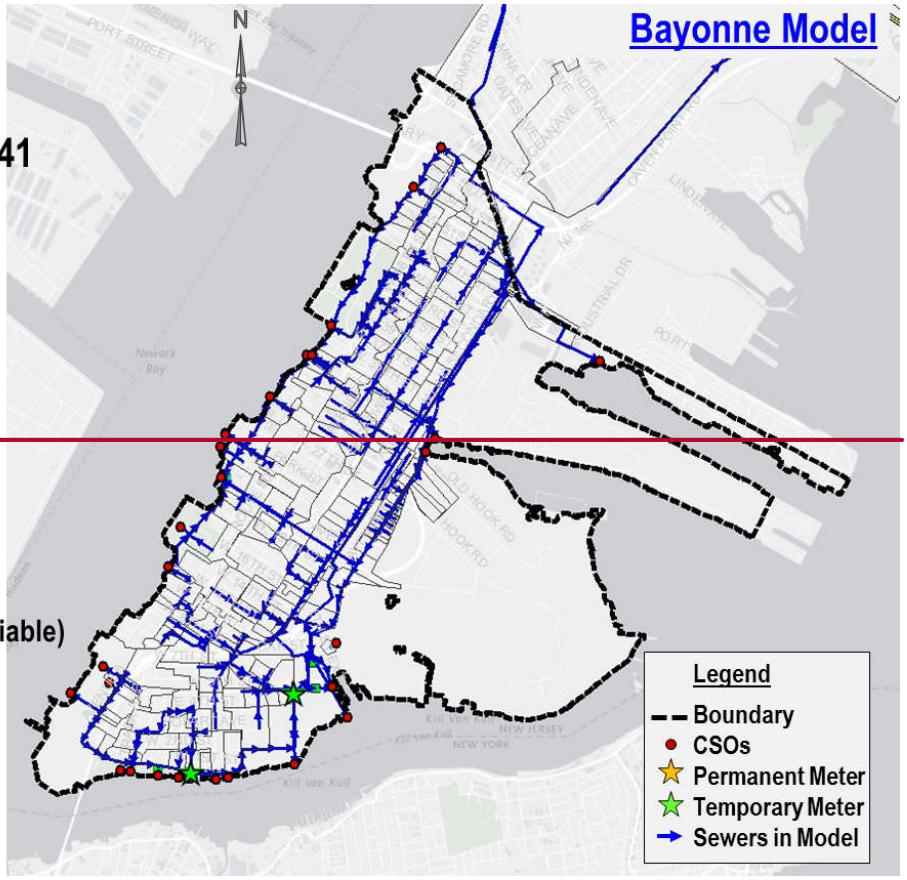
	Original Bayonne Model		Integrated PVSC Model	
	Input (ft)	Output[1]	Input (ft)	Output[2]
B1A-R011.S	0	0.625	0	0.190
	0.751	0.313	0.751	0.095
	1.499	0	1.499	0.000
BA-R014.S	0	1	0	0.305
	1.749	0.5	1.749	0.152
	3.501	0	3.501	0.000
BA-R018.S	0	1.33	0	0.405
	1.749	0.665	1.749	0.203
	3.501	0.665	3.501	0.203
BA-R003.S	0	1	0	0.305
	2.251	0.5	2.251	0.152
	4.501	0.5	4.501	0.152
BA-R006.S	0	1	0	0.305
	1.499	0.5	1.499	0.152
	2.999	0.5	2.999	0.152
BA-R008.S	0	0.625	0	0.190
	1.25	0.313	1.25	0.095
	2.5	0.313	2.5	0.095
BA-R009.S	0	1	0	0.305
	1.001	0.5	1.001	0.152
	2.001	0.5	2.001	0.152
BA-R010.S	0	0.417	0	0.127
	0.499	0.209	0.499	0.064
	1.001	0.209	1.001	0.064
BA-R012.S	0	1.083	0	0.330
	1.001	0.542	1.001	0.165
	2.001	0	2.001	0.000
BA-R015.S	0	0.417	0	0.127
	1.749	0.209	1.749	0.064
	3.501	0	3.501	0.000
BA-R017.S	0	1	0	0.305
	1.375	0.5	1.375	0.152
	2.749	0	2.749	0.000

Note:
1. The data is corresponded to unit of feet, however the model considers the data in unit of meter because the default unit in InfoWorks ICM is meter.
2. The data is corrected to match unit of meter.

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Bayonne Model

- Subcatchment: 41
- Nodes (685)
  - Manhole: 651
  - Outfall: 29
  - Storage: 5
- Link (712)
  - Conduit: 648
  - Flap Valve: 27
  - Orifice: 0
  - Pump: 5
  - Sluice: 20 (11 variable)
  - Weir: 12



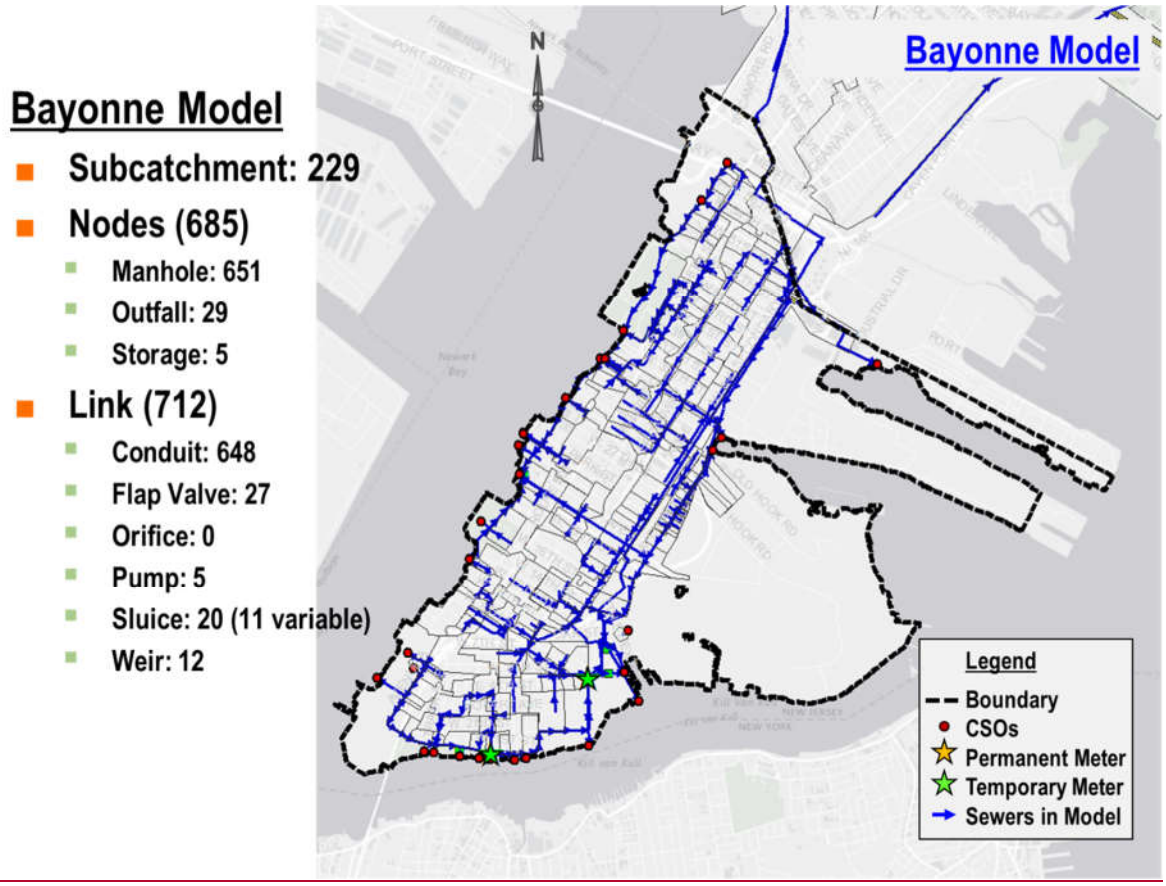


Figure I-12: Snapshot of Model Network in Bayonne

I.2.3 Integration of North Bergen Models

The two pre-LTCP North Bergen models (**Figure I-4**, EPASWMM, one for north side and the other for the south side) were imported to the InfoWorks ICM to obtain the input information for subcatchments, nodes and links. The pre-LTCP models were not GIS based so additional efforts were required to prepare a spatially based model network for North Bergen.

North Bergen Subcatchments

A paper copy of the North Bergen subcatchment delineation was obtained from the modeling document "Adaptation of SWMM to Simulate the Combined Sewer Overflows of the North Bergen MUA" (January 2007, by Najarian Associates). The paper copy was used to prepare a digitized polygon shape file in GIS to represent subcatchments (**Figure I-13**). The subcatchment ID was assigned to the polygons according to the acreage information in the model document (**Figure I-14**). The subcatchment shape file was then incorporated into the integrated model through "Data Import Centre".

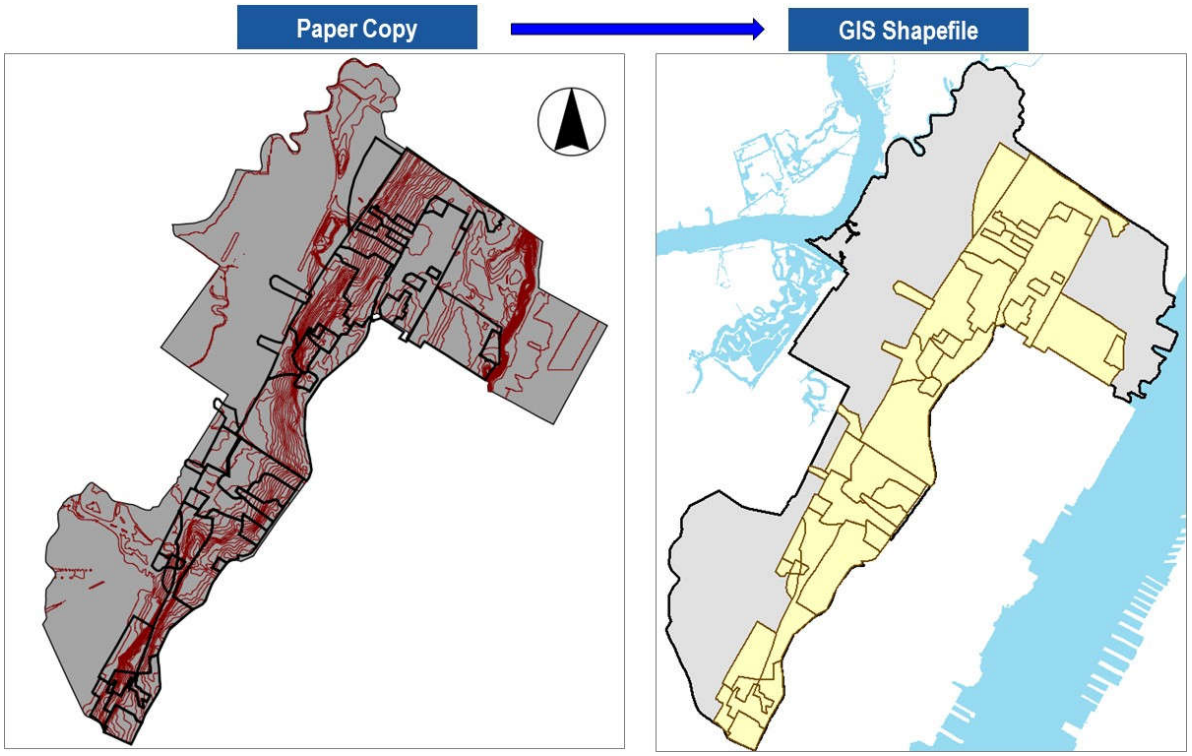


Figure I-13: Digitizing Model Subcatchment Based on Paper Copy

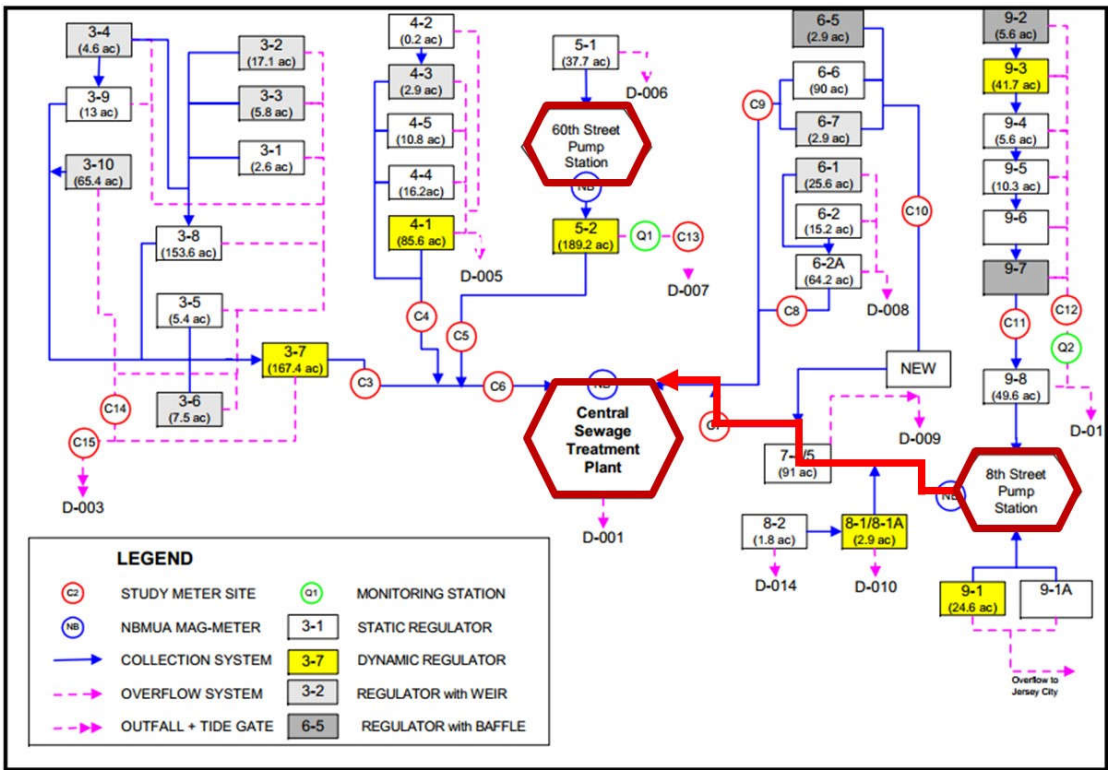


Figure I-14: Model Schematics from Previous Modeling Document

North Bergen Sewer Network

The North Bergen manholes and sewers to be included in the integrated model were selected based on sewer connectivity shown in GIS shape files (
Figure I-15) and schematic sewers shown in the EPASWMM model (**Figure I-4**). The selected manholes and sewers were then incorporated into the integrated model through "Data Import Centre".

Detail sewer data (invert, dimension, etc.) and manhole data (invert, rim elevation, etc.) were not available from the sewer GIS file, therefore the invert and pipe size information from the received EPASWMM model were used for the integrated model.

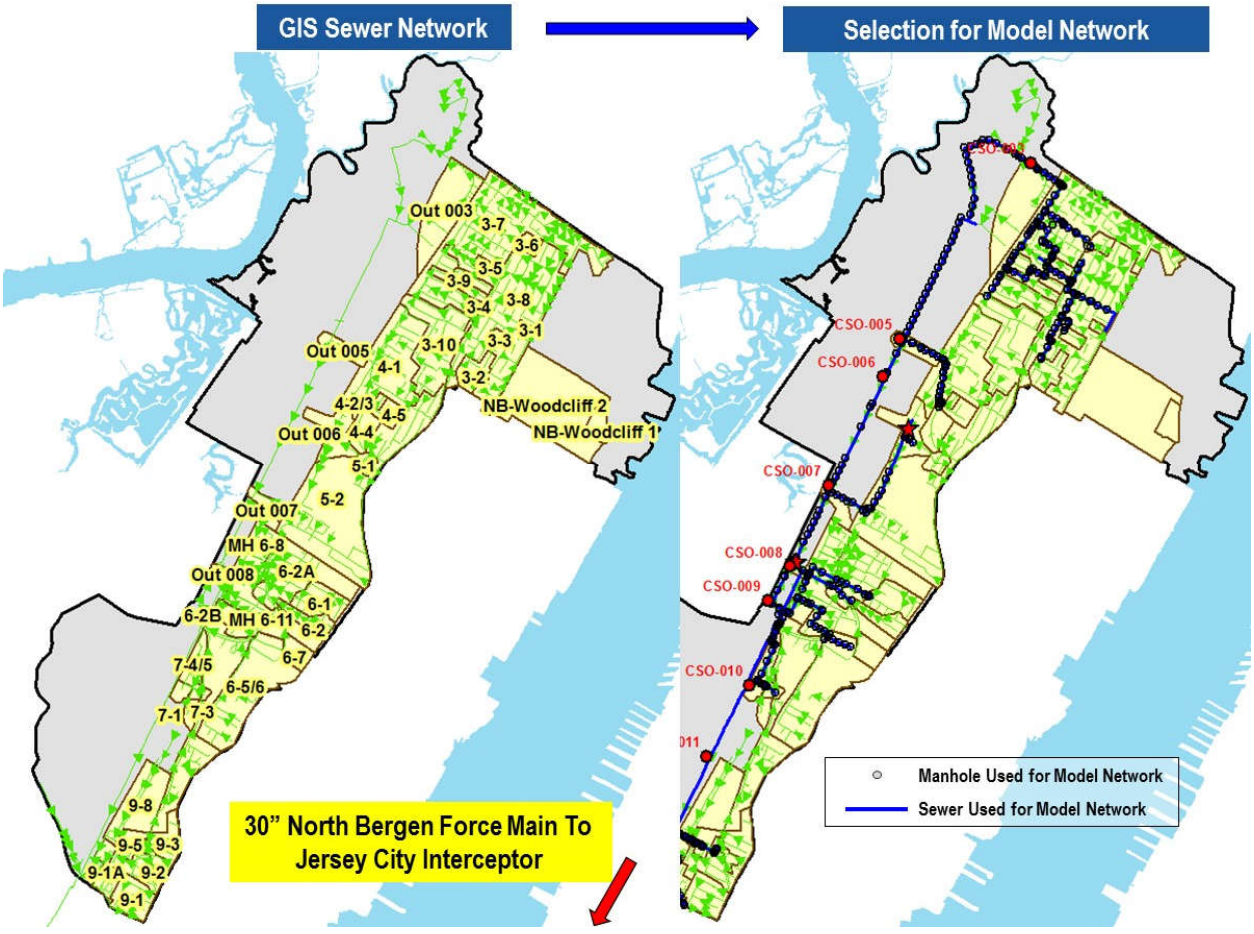


Figure I-15: Selected Manhole and Sewers for Model Network

North Bergen Sewer Connectivity Update

In the pre-LTCP model, the 8th Street Pump Station pumps flow to the downstream sewer system. The joined pumped flow and local flow were conveyed to the Central Sewage Treatment Plant by gravity (**Figure I-14**). In 2010, the Central Sewage Treatment Plant was decommissioned and the Central Pump Station was built to convey flows from North Bergen to

Jersey City through a 30-in force main. With the decommission of the Central Sewage Treatment Plant, the 8th Street Pump Station no longer pumps flow to the downstream gravity sewer mains but instead it pumps flow to the 30-in force main. Flows from North Bergen are conveyed through the Jersey City's gravity sewer mains to the Jersey City West Pumping Station (JCWP). The JCWP pumps flows through the Hudson County Forcemain to the primary clarifier at the PVSC treatment plant.

The updated flow schematics shown in **Figure I-16** is incorporated into the integrated model.

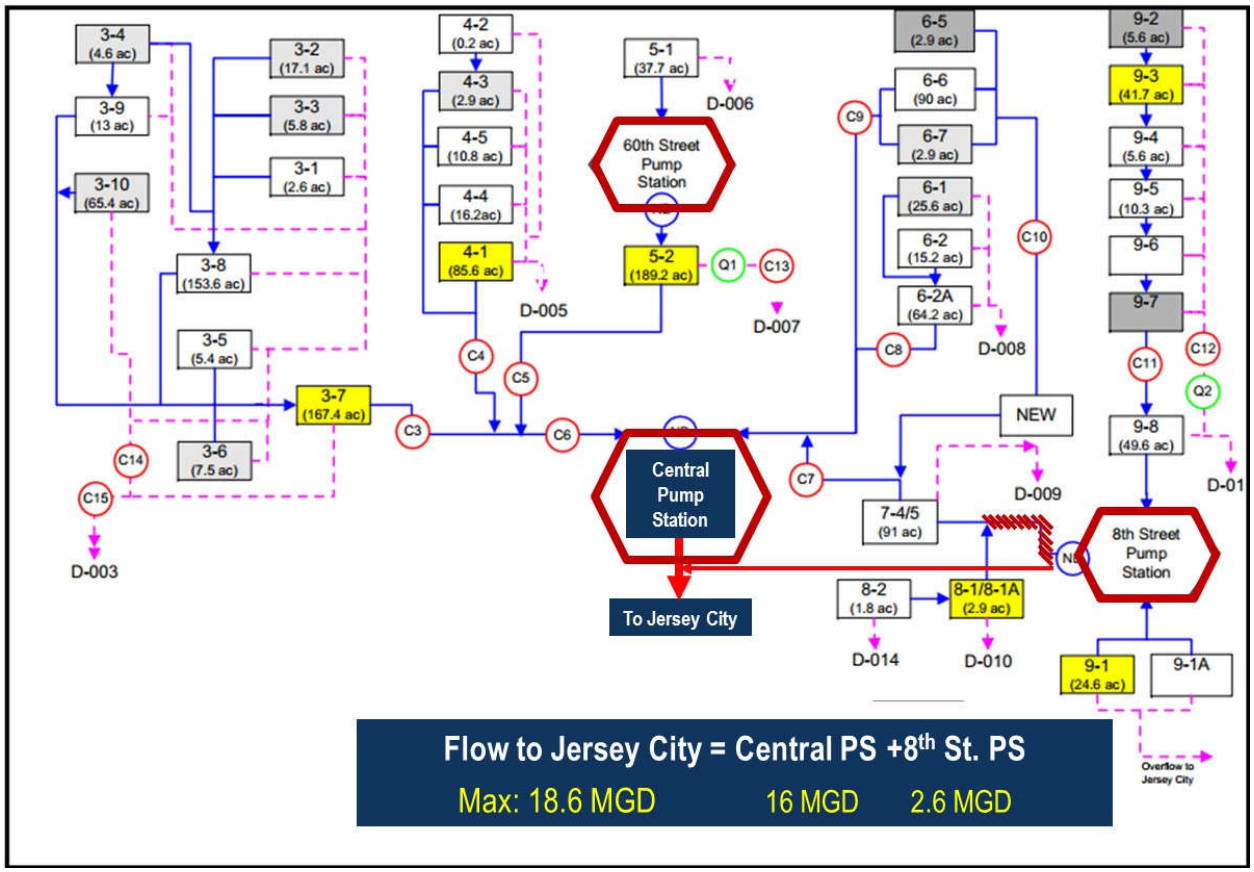


Figure I-16: Updated North Bergen Model Schematics

North Bergen in the Integrated Model

In a summary, the integration of the North Bergen includes the following major steps:

- Updated IDs of subcatchments, nodes and links to start with "NB1A-" or "NB1B-"
- Model inputs are mostly derived from the received EPASWMM model
- Subcatchment and model network were updated to GIS-based
- Updated sewer network connectivity due to the decommission of the Central Sewer Treatment Plant
- Converted dry weather inputs to subcatchment inflows

- Added North Bergen Central Pump Station
- Updated pump curves based on received information for the 8th Street PS, 60th Street PS, and the North Bergen Central PS
- Updated datum from the MSL to PVSC datum
- Added the 30" North Bergen force main between the Central Pump Station and Jersey City Sewer System

The model network for North Bergen in the integrated model is shown in **Figure I-17** (not including the area draining to the Woodcliff Treatment Plant). Quantities of subcatchments, nodes and links are also shown on the map. Permanent meters and temporary meters indicated on the map are the meters used for model calibration.

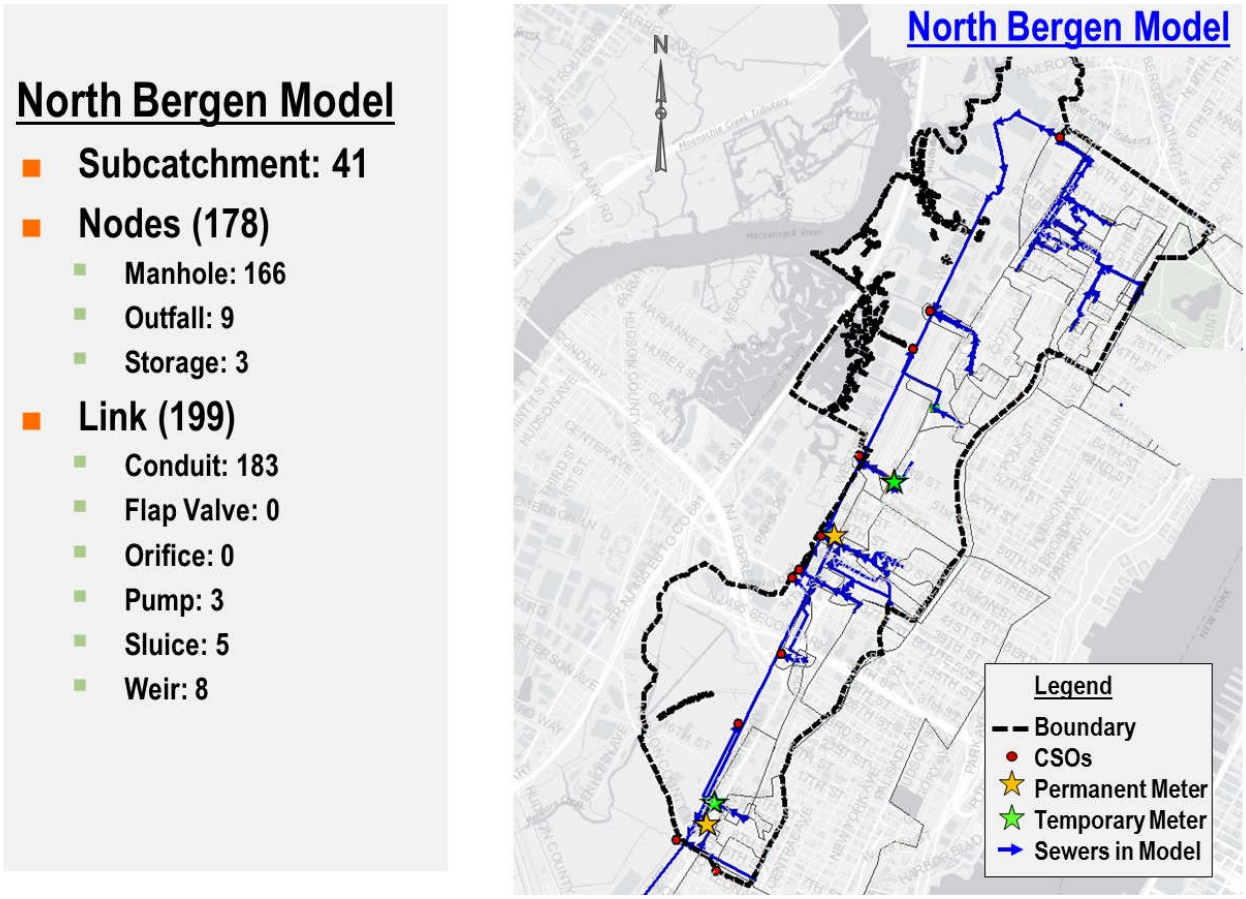


Figure I-17: Snapshot of Model Network in North Bergen

I.2.5 Integration of Jersey City Model

The integration of Jersey City Model is not detailed in this report because Jersey City MUA is submitting a separate System Characterization Report. The calibrated Jersey City model (XPSWMM) received from the Jersey City MUA was converted to ICM and integrated into the PVSC LTCP model. This allows for the connections of the North Bergen and Bayonne collection systems to the Hudson County Force Main and PVSC WRRF.

The model network of Jersey City in the integrated model is shown in **Figure I-18**. Quantities of subcatchments, nodes and links are also shown on the map. Two permanent meters (Jersey City West Pump Station and Jersey City East Pump Station) shown on the map are the meters used for flow verification. Calibration/validation of Jersey City model is not part of the efforts of this study. Therefore, the characteristics of Jersey City model remain unchanged in the integrated PVSC model.

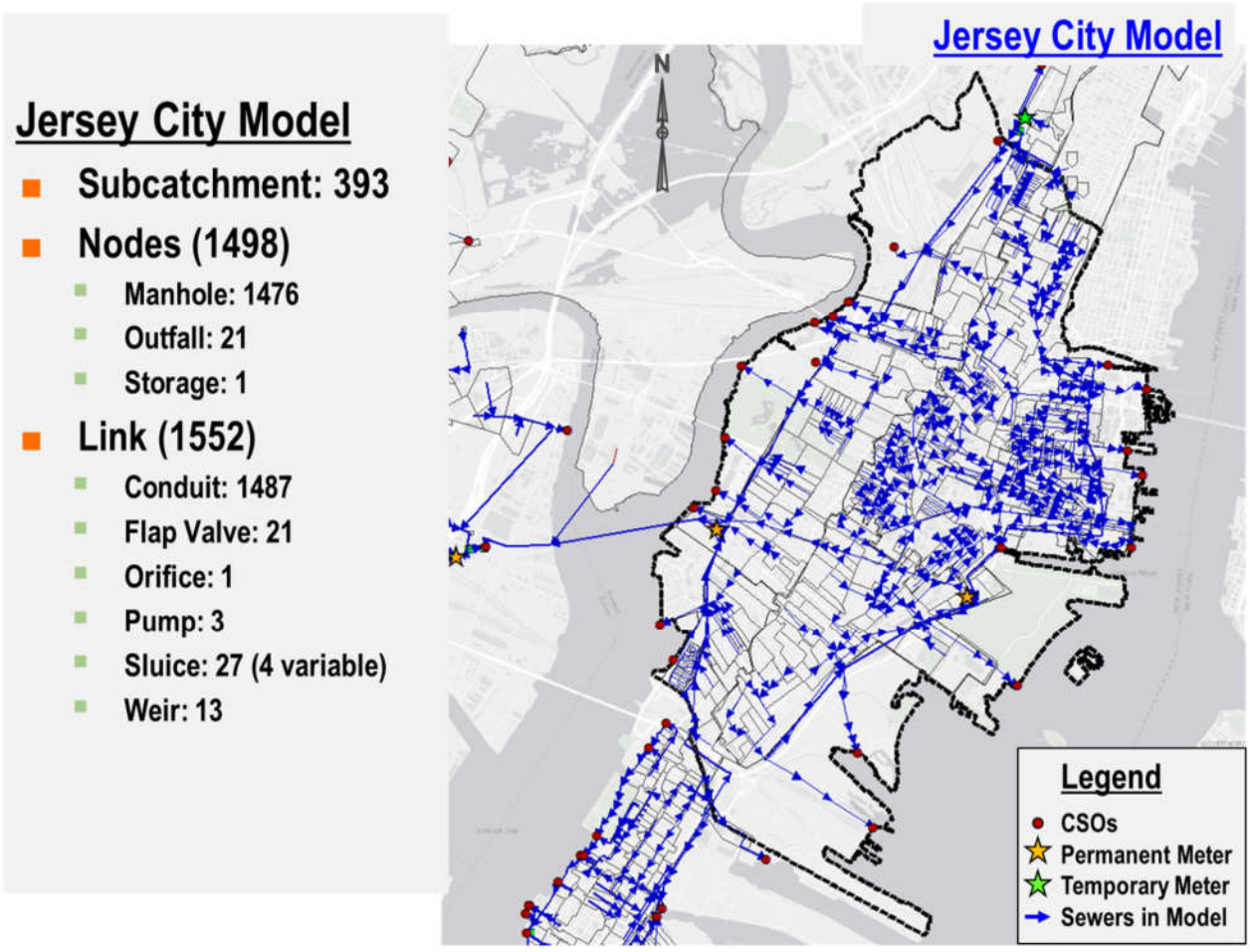


Figure I-18: Snapshot of Model Network in Jersey City

I.2.6 Model Expansion to Whole Service Area

The above mentioned model integration incorporated all the communities with combined sewer systems into the same model, including

- Paterson (Passaic County)
- Newark (Essex County)
- East Newark (Hudson County)
- Kearny (Hudson County)
- Harrison (Hudson County)
- North Bergen (Hudson County), and
- Bayonne (Hudson County)
- Jersey City (Hudson County)

The model integration also brought a portion of the PVSC separate sewered communities in the system from the PVSC Interceptor Model (**Figure I-1**), including

- Totowa, Haledon, North Haledon, Prospect Park, Hawthorne, Clifton and Passaic from the Passaic County,
- Fair Lawn, Elmwood Park, Garfield, Wallington, Rutherford, East Rutherford, Lyndhurst, and North Arlington from the Bergen County, and
- Nutley and Belleville from the Essex County.

The integrated model was then expanded to include all PVSC served separate sewer communities. The newly added separate sewer communities are shown in **Figure I-19**, including

- Franklin Lakes, Woodland Park, Little Falls, North Caldwell, and Cedar Grove from the Passaic County,
- Ridgewood, Glen Rock, Saddle Brook, Lodi, South Hackensack, Hackensack, Wood-Ridge, and Hasbrouck Height from the Bergen County,
- Montclair, Glen Ridge, Bloomfield, City of Orange, East Orange, West Orange, South Orange, and Hillside from the Essex County, and
- Elizabeth City from Union County.

Communities simulated in the final PVSC model are shown in the schematic **Figure I-20**.

I.2.7 Model Evaluation Group (MEG) Review

A Model Evaluation Group (MEG) comprised of recognized experts in hydrologic, hydraulic, hydrodynamic, and water quality monitoring and modeling was formed to provide technical review and guidance. The MEG was comprised of the following individuals:

- Dr. Alan Blumberg, Stevens Institute of Technology;
- Dr. Steve Chapra, Tufts University; and
- Dr. Wayne Huber, Oregon State University, emeritus.

The MEG's stated mission was as follows:

> *"The Model Evaluation Group (MEG) will review all significant technical aspects of the PVSC Long Term Control Plan model development. Model development will consist of three distinct components: Landside, Hydrodynamic, and Water Quality. The goal is to ensure that these model components are technically viable for use by the engineering team in the assessment of engineering alternatives and with withstand regulatory and public scrutiny.*
>
> *The MEG will provide guidance, where appropriate, to improve or enhance the approaches and methodologies that lead to model development. The MEG will judge, individually and jointly, the technical acceptability of the major model components. If a component is deemed unacceptable, the MEG will outline steps to improve the technical acceptability of the model components."*

Workshop meetings with the MEG, PVSC and their consultants, and the New Jersey Department of Environmental Protection were held to discuss the development and use of each of the models, as well as to receive feedback and input regarding the monitoring and modeling work. These meetings were held on the following dates:

- February 5, 2016;
- March 17, 2017; and
- September 15, 2017.
- December 5, 2018.

The MEG provided various comments related to the updating, calibration, and validation of the hydrologic and hydraulic model. The below **Table I-5** is a summary of key related comments and how the model was configured to address or respond to these comments. A copy of the MEG's comments for all the MEG meetings and a MEG memorandum providing PVSC Characterization Report Comments with responses are ~~is~~ included in Appendix B.

Table I-5: Summary of MEG Comments and Responses

MEG Session	MEG Comments	Responses
Session 1 Feb 5, 2016	It might be useful to sample sediment in the interceptor if it has sedimentation issues.	We will not sample sediment quality in sewers, but will measure sediment depths at flow metering sites
	Interceptor geometry is critical for hydraulic grade line determination.	The existing local models and the PVSC interceptor model represent geometry adequately in all major pipes. The integrated PVSC model has incorporated good representation of the geometry of all pipes.
	Infiltration/inflow (I/I) was discussed, but monitoring of sanitary sewers was not adequately described. Will I/I just	PVSC already monitors incoming flows from each of its communities. The modeling can thus discretely represent sanitary flow and I/I. Bacteria concentrations have been separately assigned to

MEG Session	MEG Comments	Responses
	get merged with downstream sanitary sewage for estimating bacteria concentrations?	each flow component and tracked through the collection system model.
	Was it stated that there is not a significant groundwater infiltration contribution to the sewer system, or just that it will not be dynamically modeled? How leaky are the regional sewers?	Base flow in regional streams typically varies from 1.5 cfs per square mile (cfsm) in spring to less than 0.5 cfsm in fall; regional sewers can be expected to exhibit similar variation in groundwater driven infiltration flows. For areas where such seasonality has not already been incorporated into the collection system models, monthly infiltration factors have been developed to represent this flow variation based on long-term flow data already collected by PVSC. We have compiled long-term flow data for the wastewater treatment plant and key permanent monitoring locations to establish seasonal infiltration factors.
Session 2 Mar 17, 2017	Whether New York City utilized a similar method for selecting their typical year?	The New York City analysis utilized the same methodology that was previously used to select the JFK 1988 typical year.
	Suggested that an official approval of the typical year report would be useful	The official approval of the typical year report was obtained from NJDEP on May 31, 2018.
	Whether Paterson Outfall 028 is included in the model as a CSO? NJDEP recently confirmed that it is a CSO.	Paterson Outfall 028 was added to the integrated model as an active outfall.
	Whether in-pipe sedimentation is being considered?	Sedimentation is not included in the baseline model. See response to Session 1 comment.
Session 3 Sep 15, 2017	How are rain gauges assigned to a subcatchment?	Rain gauges are assigned to a subcatchment based on Thissen Polygons.
	Standard time or Daylight Saving Time should be applied consistently to rainfall and flow monitoring data	Daylight Saving Time was used for both rainfall and flow metering data.
Session 4 Dec 5, 2018	Flow monitoring noise should be smoothed out for model calibration	The flow monitoring data was adjusted based upon this MEG suggestion, and the calibration results were updated
	Statistics, such as root mean square error, should be included on the monitored vs modeled volume and peak flow scatter plots	The scatter plots were updated to include statistics of monitored vs modeled fit
	Calibration scatter plots should be developed for all locations for each event, and then a single scatter plot for all locations with all events	These plots were created and included in the revised System Characterization Report

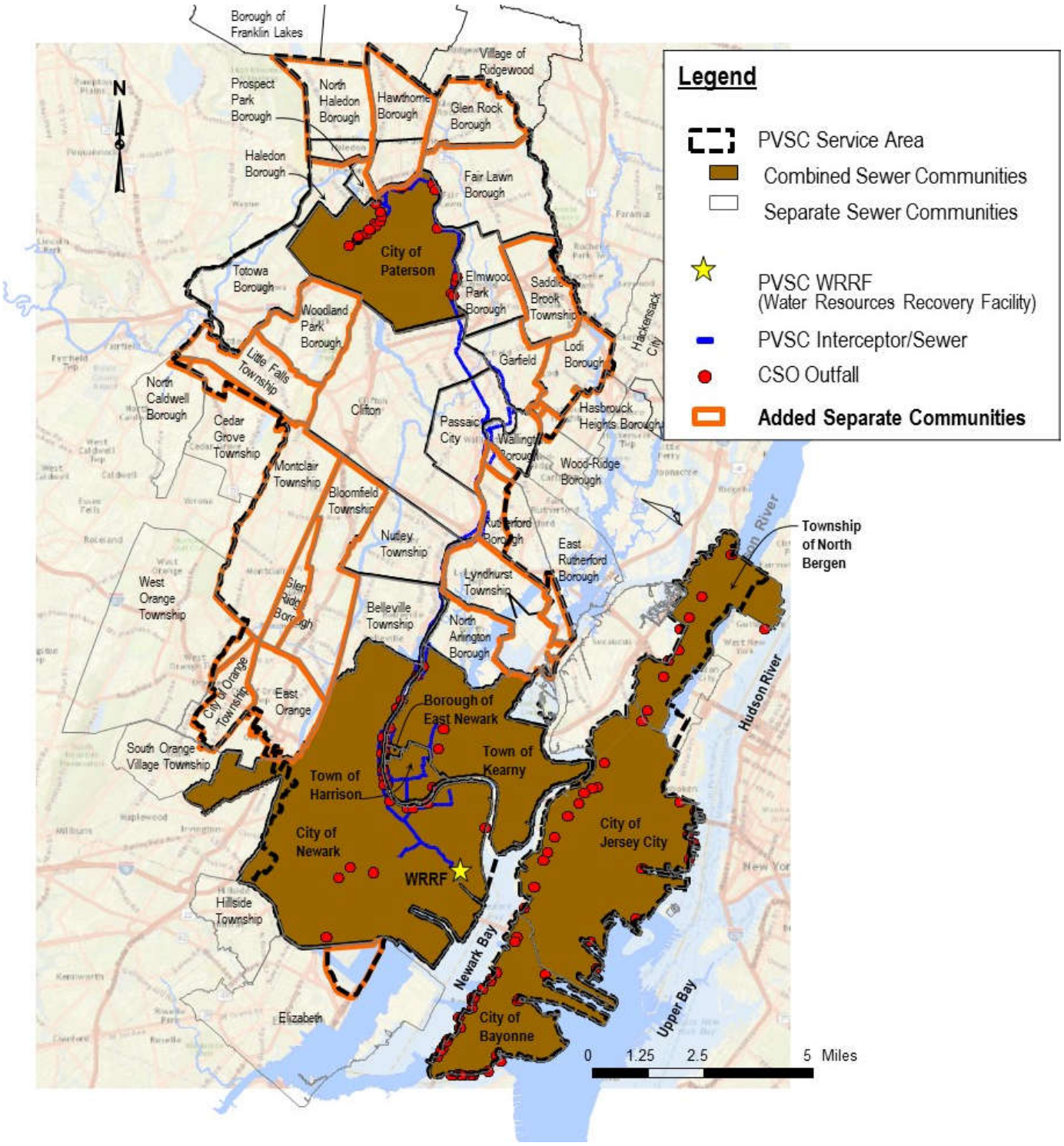


Figure I-19: Separate Communities Added during Model Expansion

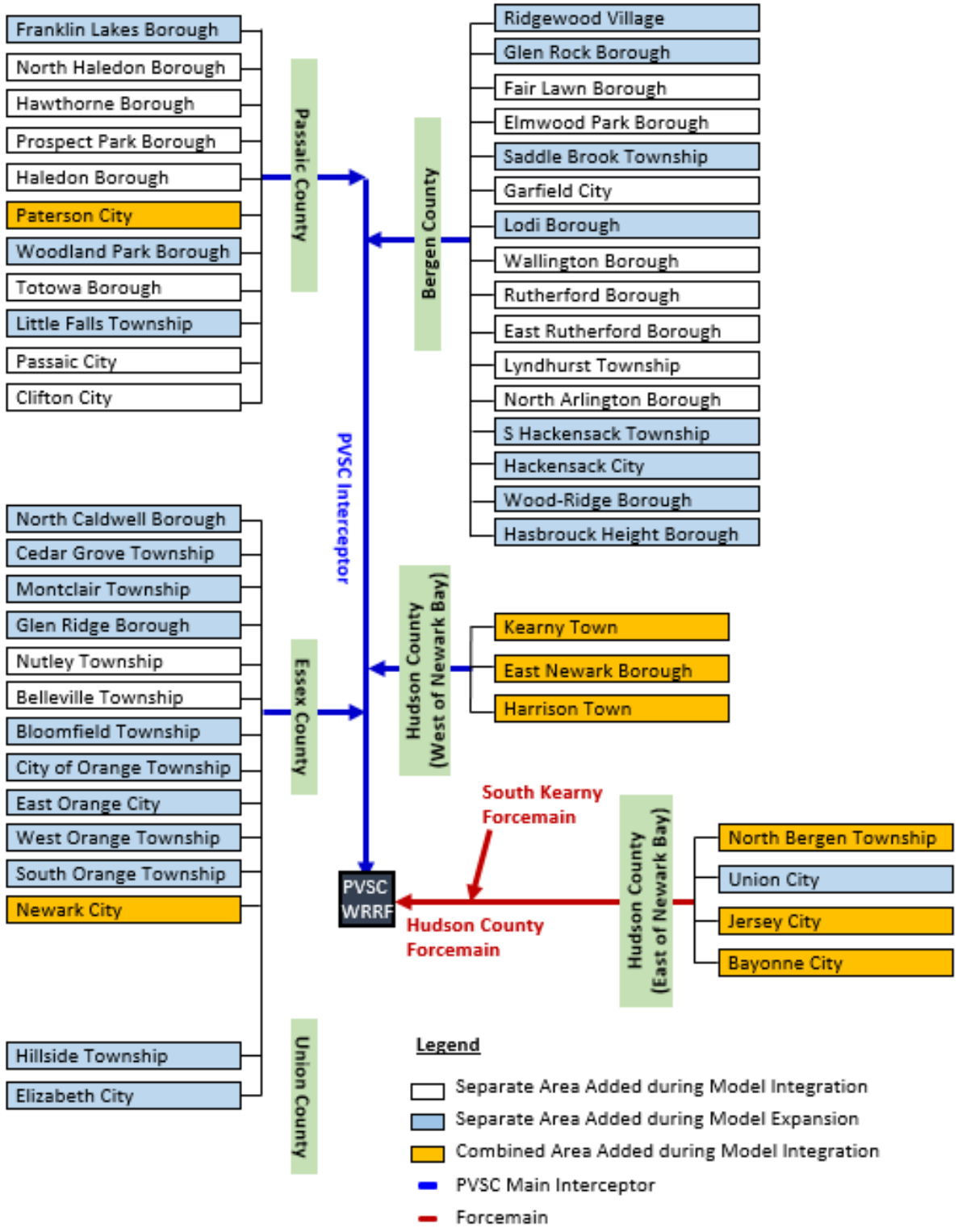


Figure I-20: Municipalities in the Final PVSC Model

I.3 H&H MODEL COMPONENT AND INPUTS

I.3.1 Rainfall

Rainfall data assigned to a subcatchment within the model represent the average precipitation that falls on the area within a defined time interval. Rainfall data was entered in the model as rainfall intensity occurring within a time interval. The rainfall time interval can be as short as a minute or as long as an hour. Generally, the model results satisfactorily match observed flow monitor data when the rainfall input time interval is at a maximum of 15 minutes. Rainfall data recorded at 5-minute frequency were entered into the model for both model calibration and typical year simulation.

Model Calibration Rainfall: Rainfall records from eight (8) rainfall stations in the vicinity of the PVSC service area were used during model calibration to account for spatial rainfall pattern in the large area. **Figure I-21** shows locations of each rainfall stations on the map and summarizes data source and available time interval in the table. 5-min rainfall data was developed for model input based on the available time interval. Rainfall station was assigned to individual model subcatchment based on Thiessen Polygons.

Typical Year Simulation Rainfall: Typical hydrologic period was analyzed based on rainfall records from the Newark station and Year 2004 was selected as the typical year (**Section H.2)**. 5-min rainfall data was developed based on the Newark NWS ASOS 1-min precipitation records for model input. This precipitation was applied to all subcatchments in the model for the typical year simulation.

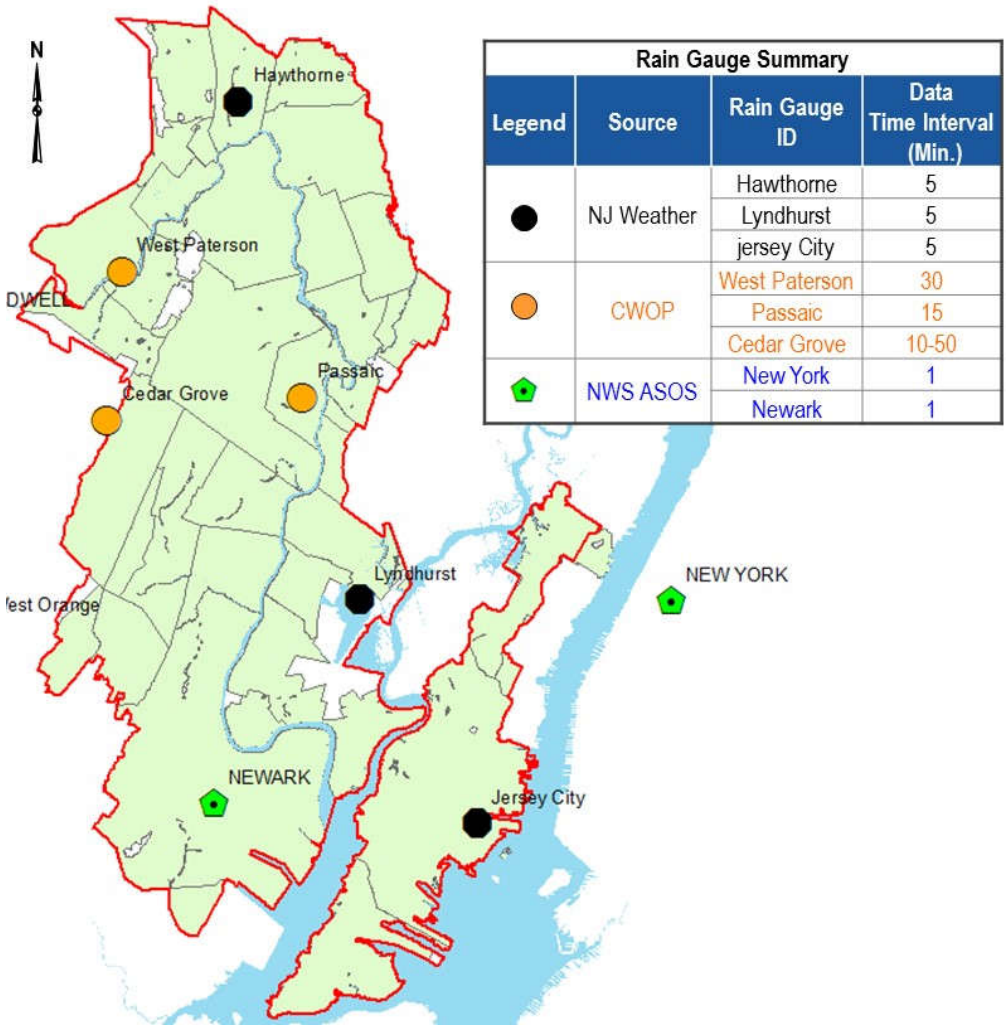


Figure I-21: Rainfall Stations Used in Model Calibration

I.3.2 Subcatchment

The model's surficial hydrology maintains the EPA SWMM runoff method used in the prior PVSC interceptor model and the Bayonne, North Bergen, and Guttenberg models that were incorporated into the comprehensive PVSC model. The SWMM methodology separately computes runoff from impervious and pervious surfaces based on a simplification of Manning's equation for shallow flow. Manning's equation computes discharge as:

$$Q = \frac{1.49}{n} A_w R_h^{2/3} S^{1/2}$$

where:
Q = discharge (ft^3/s)
n = Manning's roughness coefficient
A_w = wetted area (ft^2)
R_h = hydraulic radius (ft)
S = slope

The SWMM runoff method represents flow from a subcatchment as having $A_w = dW$, where d the depth of sheet flow and W is the representative width of sheet flow across the subcatchment orthogonal to the principal flow path. The hydraulic radius (wetted area divided by wetted perimeter) of this flow is dW/[W+2d]. As W is much larger than d (e.g. the width of runoff from a subcatchment is measured in feet, while sheet flow depth is typically a fraction of an inch), the hydraulic radius effectively equals d (e.g. for a sheet flow depth of 0.01 ft and width of 50 ft, $R_h = 0.01 \times 50 / [50 + 0.02] \approx 0.01$). Manning's equation can then be rewritten as:

$$Q = \frac{1.49}{n}(dW)d^{2/3}S^{1/2} \text{ or } Q = \frac{1.49}{n}Wd^{5/3}S^{1/2}$$

Instantaneous discharge from a subcatchment to its inlet is thus calculated from the depth of water over the subcatchment's "reservoir", Manning's "n", representative width, and subcatchment slope. This is known as the SWMM non-linear reservoir runoff model. W is the SWMM width parameter, identified in InfoWorks as the "dimension" parameter. It is usually calibrated during model development to control hydrograph shape: a large width increases instantaneous runoff and yields a sharp, rapidly-responsive hydrograph, whereas a small width yields a flatter hydrograph with a smaller peak and longer response. Manning's "n" and subcatchment slope are usually held constant during calibration, as adjusting these values has the same effect as adjusting W (the differing exponents mean that the response may be inverted or less pronounced, but the overall effect on the hydrograph is the same). The model is applied separately for impervious and pervious surfaces, and considers that initial abstraction (e.g. puddles) is applicable across most of a subcatchment, except on roofs and other steep surfaces.

Subcatchment Area

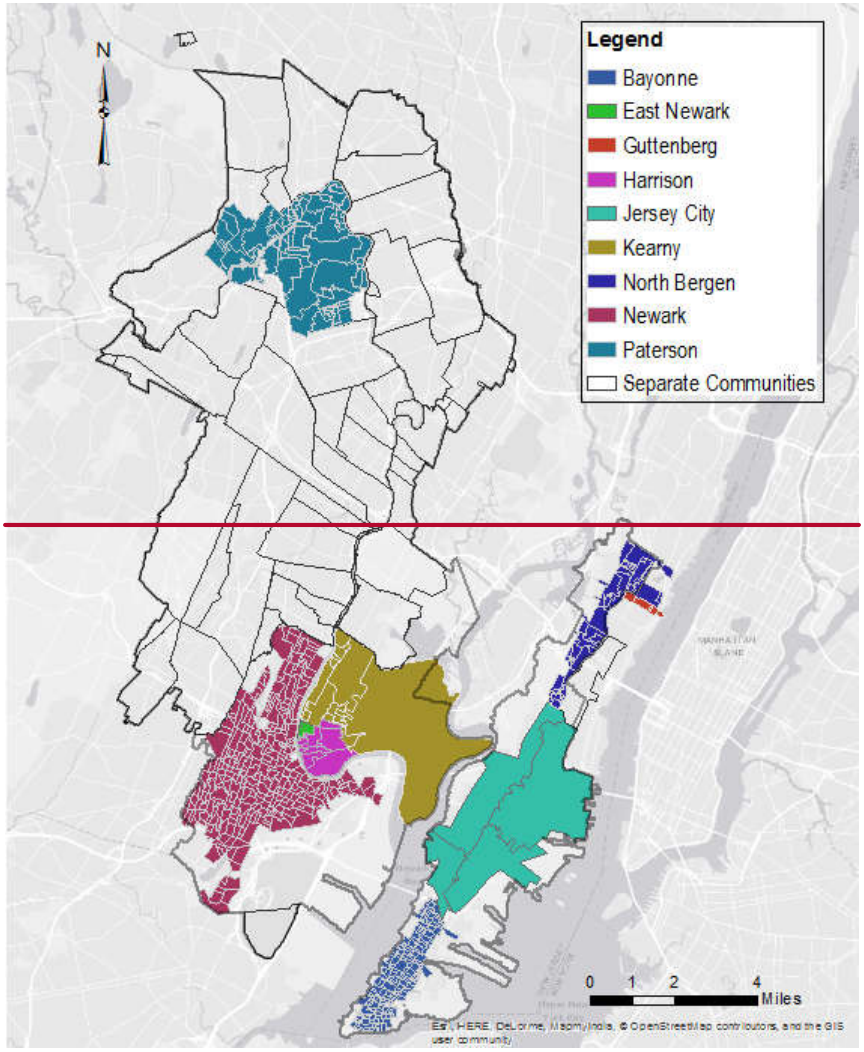
Figure I-22 shows the model's ~~732~~ 1274 subcatchments, ~~51~~ 51 of which represent sanitary flows from contracted, lessee, and non-contracted contributing communities. **Table I-6** summarizes the number and size of subcatchments in each combined sewer community. Modeled contributing

areas are generally smaller than total community area; some areas drain directly to receiving waters. Others, such as Newark Airport and the surrounding industrial area, are served by separate drain systems. As the model was assembled from various component models, the level of detail varies considerably among communities. Bayonne, which was previously represented in an independent model, has the most detail, with an average subcatchment size of 8 acres. ~~Jersey City, which is only coarsely represented in this model, as it is currently being separately considered in another study, has the least detail, with just four subcatchments.~~ The other combined communities have average subcatchment sizes ranging from ~~31~~ 10 acres in Jersey City~~East Newark~~ to 199~~250~~ acres in Kearny. Detailed characteristics of all combined subcatchments for the baseline model, including surface area, basin width, percent impervious, effective impervious, slope, Manning's Roughness, etc., are included in **Appendix C**.

Table I-6: Subcatchment Summary

Municipality	Total Contributing Area (acres) [1]	Contributing area (acres)		Subcatchments	Average Acres per subcatchment
		Combined	Separate		
Bayonne	1,~~742~~750	~~1706~~1714	36	229	8
East Newark	62	62	0	~~2~~1	~~31~~62
~~Guttenberg~~	~~124~~	~~111~~	~~13~~	~~5~~	~~25~~
Harrison	~~777~~778	~~423~~427	~~354~~352	~~10~~11	~~78~~71
Jersey City	~~53,365~~958	3,958~~5,365~~	0	~~4~~393	~~1,341~~10
Kearny	~~4,006~~3,185	1,243	1,942~~2,763~~	16	~~250~~199
Newark	10,~~036~~050	7,~~153~~167	2,883	304	33
North Bergen	1,414~~591~~	1,414~~552~~	~~39~~0	414	3~~4~~6
Paterson	5,139~~95~~	4,595	~~544~~600	~~67~~226	~~77~~23
40 Sanitary communities	55,214	0	55,214	51	1,083
Total	~~84,112~~81,589	20~~2~~,579~~210~~	61,010~~902~~	1272~~732~~	~~115~~64

Note:
1. The total acreage in the table above includes only the subcatchment areas in the model that contribute flow to the PVSC WRRF. The acreage does not include rivers, creeks or unsewered areas within a municipality.


N
Legend
Bayonne
East Newark
Guttenberg
Harrison
Jersey City
Kearny
North Bergen
Newark
Paterson
Separate Communities
0 1 2 4
Miles

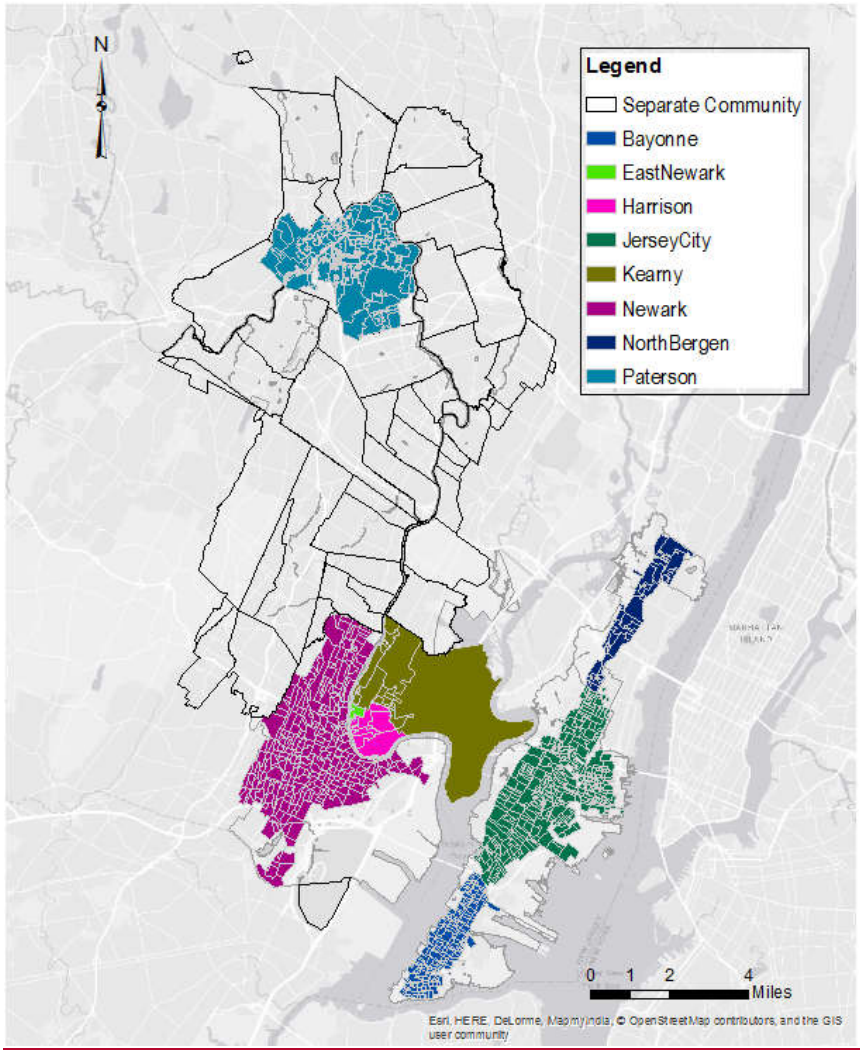


Figure I-22: The PVSC Service District

Subcatchment Percent Imperviousness

Effective imperviousness is the fraction of a subcatchment from which all rainfall runs off after initial abstraction for puddles and other minor depressions. It is calibrated in the combined sewer communities except Bayonne through adjustment of the "Runoff routed internally (%)" parameter. The Runoff routed internally parameter identifies the fraction of a catchment's total impervious surface (i.e. surfaces with negligible infiltration capacity) that drains onto adjacent pervious ground, such as roof leaders that drain to lawns. In Bayonne, no distinction was made between effective and total imperviousness in the model input data. **Table I-7** presents total and effective impervious area and percentages for each combined sewer community. Total imperviousness for all the combined sewer subcatchments computed from the *2011 National Land Cover Database (NLCD; Homer, C.G., et al., 2015)* is approximately 70 percent, while effective imperviousness was calibrated as 41 percent. The disparity between these values suggests that the contributing area for the collection system is smaller than the modeled areas; while **Table I-7** shows that modeled areas are already smaller than the community extent, the

true contributing areas appear to be smaller still. While the difference between total and effective impervious area suggests that modeled areas may be overestimated, the table indicates the comparative extent of effective impervious area among the communities: Newark account for 35 ~~and Jersey City together account for 65~~ percent of the impervious area across the combined service area, Paterson accounts for 21 percent, North Bergen, Jersey City, and Bayonne ~~and Paterson~~ account for ~~21~~ 36 percent, and the other communities (East Newark, Kearny, and Harrison) account for ~~14~~ 8 percent.

Table I-7: Impervious and Effective Impervious Area

Community	Modeled Area (ac)	Total Impervious Area (ac)	Effective Impervious Area (ac)	Total Imperviousness (%)	Effective Imperviousness (%)
Bayonne[1]	1,714	1,376	1,005	80	59
East Newark	62	52	31	84	50
~~Guttenberg~~	~~111~~	~~95~~	~~48~~	~~86~~	~~43~~
Harrison	427	342	145	80	34
Jersey City[2]	~~6,337~~3,958	~~4,570~~2,683	2,683~~3,304~~	~~68~~72	~~68~~52
Kearny	1,243	782	~~390~~452	63	~~31~~36
Newark	7,167	4,942	2,839	69	40
North Bergen	1,~~555~~414	~~1,093~~994	~~641~~498	70	~~41~~35
Paterson	4,595	~~2,994~~3,001	~~1,006~~806	65	~~22~~18
Total	~~23,210~~20,579	~~16,246~~14,173	~~9,409~~8,461	~~70~~69	41

1. Imperviousness and effective imperviousness not distinguished in model for Bayonne. Total impervious area reported from NLCD; effective imperviousness is as specified in model.
2. Imperviousness and effective imperviousness not distinguished in model for Jersey City. Information in the table is based on received model from Jersey City ~~is modeled coarsely in PVSC model. Jersey City has its own detailed model that was not used for this project~~.

Subcatchment Width

Subcatchment width is a principal calibration parameter, as hydrograph timing has many controlling factors such as catch basin density and conveyance characteristics of pipes omitted from the hydraulic model. For this study, widths in areas that had not been recently calibrated were initially specified based on a regression relationship for existing widths in the model, with width (feet) calculated as $300\ A^{0.6}$, where A is area in acres. For example, the median subcatchment area across all the combined sewer communities is 15 acres. The estimated width for a 15-acre subcatchment is 1500 feet, or 100 ft/ac. This can also be considered as an overland flow length of 430 feet, although the SWMM method does not explicitly account for overland flow. While unit width depends on various factors, higher values are generally associated with faster runoff and lower values with attenuated runoff. As shown in **Table I-8**, Bayonne has the highest unit width, ~~and Guttenberg and~~ North Bergen have the lowest unit widths.

Table I-8: Subcatchment Unit Width

Community	Unit Width (ft/ac)
Bayonne	~~123~~99
East Newark	~~68~~57
~~Guttenberg~~	~~9~~
Harrison	~~64~~52
Jersey City	~~21~~50
Kearny	~~31~~20
Newark	~~90~~62
North Bergen	~~9~~7
Paterson	~~67~~37
Total	~~42~~51

Subcatchment Slope

Subcatchment slope was transferred from the component models into the systemwide model with only minor adjustments (except for the Jersey City values, which were directly estimated for this study). Average values by community are shown in **Table I-9**. Slope on its own is not of key importance, since, as discussed above, it is composited with width and Manning's "n" for computing runoff rates, and the width parameter was adjusted through calibration.

Table I-9: Average Slope %

Community	Slope (%)
Bayonne	1.0
East Newark	3.4
~~Guttenberg~~	~~0.5~~
Harrison	~~2.3~~2.7
Jersey City	~~0.5~~1.3
Kearny	3.5
Newark	2.1
North Bergen	~~4.2~~4.1
Paterson	~~2.2~~1.7
Total	~~1.8~~2.1

Depression Storage

Except in Bayonne, impervious area was partitioned so that 75 percent of each subcatchment has an initial abstraction depth of 0.05 inches, and 25 percent of the area has no initial abstraction (representative of pitched roofs). In Bayonne, all impervious area is subject to 0.05 inches initial abstraction. Pervious areas across the entire model were specified with initial abstraction of 0.1 inches. During continuous simulation, available initial abstraction depth is restored based on evaporation.

Manning's "n" Roughness Coefficient

Overland flow travels slower or faster depending on the roughness of the surface in the subcatchment. The higher the roughness coefficient, the greater the friction and the slower the flow travels. Again, this is a model parameter that cannot be practically measured. A typical range of Manning's "n" suggested by the SWMM is 0.011-0.024 for impervious area and 0.05-0.80 for pervious area. The initial values were set to 0.02 for impervious surfaces and 0.05 for pervious surfaces. Roughness is an empirical value and may be treated as a calibration parameter if necessary.

Soil Infiltration

Pervious areas were uniformly modeled using the Horton infiltration equation with an initial infiltration rate of 5 inches per hour, and a limiting rate of 2 inches per hour. This typical infiltration rate was estimated from review of soils data for the area. Much of the area is identified in the national soils database as "urban land", for which no hydraulic properties are identified. The predominant named soil types are Boonton, Riverhead, Greenbelt, Whippany, and Parsippany, each of which has a saturated conductivity between 1 and 4 inches per hour. As few storms have sustained rainfall exceeding 2 inches per hour, runoff from pervious area is simulated for only a few hours a year. Most runoff in the combined service area comes from impervious surfaces. It is thus not possible to distinguish the impact of pervious area runoff from the available flow metering data. This is typical for CSO studies in areas with well-drained soils, such as those predominant in the PVSC combined service area.

I.3.3 Trunk sewer and Main Interceptor

Most of the gravity sewer mains and PVSC Interceptor in the final PVSC model were imported from the previous models during model integration. Sewer size, shape, invert, and Manning's "n" value were inherited from the previous models as well. A small amount of new sewer lines were added as needed during model expansion or refinement. Input for the new sewer lines were prepared based on available sewer GIS information or with appropriate assumptions (for example: assuming constant slope for neighboring sewers).

Manning's roughness coefficient is related to the pipe material. Manning's "n" values in the model are in the range of 0.009 to 0.049. Approximately 72% of the sewers have Maning's "n" of 0.015 in the model, 14% sewers have Manning's "n" of 0.010, and 10% with Manning's "n" around 0.013. The Manning's "n" may be changed during calibration to account for minor loss or additional sediment depositions in the pipe

I.3.4 Manhole

Most of the manholes in the final PVSC model were imported from the previous models during model integration. Manhole invert and rim were inherited from the previous models as well. A small number of new manholes were added as needed during model expansion or refinement. Input for the new sewer lines were prepared based on available sewer GIS information or with appropriate assumptions (for example: assuming constant slope for neighboring sewers, manhole rim at the ground contour, etc.).

I.3.5 CSO Outfall

All the permitted/active CSO outfalls were included in the model. More than half of the CSO outfalls have flap gates to prevent water backup from receiving water body. Outfall information in the final PVSC model were mostly imported from the previous models during model integration.

I.3.6 Regulator

CSO regulators and outfalls serve as combined sewer reliefs necessitated by stormwater entering the sewer system and exceeding the hydraulic capacity of the sewers and/or treatment plant. Wet weather flows in excess of the collection system's capacity are discharged to the receiving water body. There are 50 regulators included in the PVSC model. Regulator gate and weir dimensions and elevations were mostly inherited from the previous model during model integration. Regulator drawings received from PVSC were carefully reviewed to validate the settings in the model (**Table I-10**).

Table I-10: PVSC Regulators

Regulator #	Overflow Weir				Regulating Sluice Gate / Orifice						Real Time Control
	Drawing		PVSC Model		Drawing			PVSC Model			
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height	
P_015A (S.U.M. Park)	152.9	2.5	152.9	2.5	151.87	1.25		151.87	1.25		
P-001A (Curtis Pl.)	146.9	3.83	146.9	3.83	143.94	3	1	143.94	2.25		
P-003A (West Broadway)	139.5	4	139.5	4	137.4	1.25		137.4	1.25		
P-005A (Bridge St.)	133.4	5	136.71	5	131.7	0.833	1.667	131.7	1.25		
P-006A (Montgomery St.)	134.2	8.0	135.25	8	129.53	2		129.53	2		
P-007A (Straight St.)	133.8	6	133.8	5	130.1	1.83	3	130.1	1.25		
P-010A (Keen St.)	135.4	4	135.4	4	133.44	1.67	0.83	133.44	1.25		
P-010A (Warren St.)	133.85	4	135.21	3							
P-016A (Northwest) modified	138.8	8	140.94	8.5	136.25	2.5		136.25	2.5		
P-017A (Arch St.)	135.7	4.5	135.69	3.67	132.6	1		132.6	1		
P-032A (Hudson St.)	135.2	4	135.2	4							
P-022A (Short St.)	132.6	4.5	132.6	4.5	130.63	2		130.63	2		
P-021A (Bergen St.)	132.7	4.5	132.7	4.5	130.75	1		130.75	1		
P-013A (E. Eleventh St.)	133.4	4.83	133.4	4.83	131.7	1.67	0.83	131.7	1.25		
P-014A (Fourth Ave.)	140.9	4.5	140.9	3	137.76	1.67	0.83	137.76	1.25		
P-023A (Second Ave.)	129.8	4.5	130.56	5	127.4	Not available		127.4	1.25		
P-024A (Third Ave.)	130.3	4.5	130.3	5	128.2	1.67	0.83	128.2	1.25		
P-025A (East 33rd Ave.)	128.9	8.58	129.87	8.58	127.07	3	1	127.07	2		
P-026A (East 20th Ave.)	129.2	5.5	128.92	5.5	126.95	1.67	0.83	126.95	1.66	0.83	
P-027A (Market St.)	131.1	7.11	131.1	4.0	129.6	3.5	1.167	129.6	3.5	2.0	Yes
					129.6	3.5	1.167	129.6	3.5	0.0	

Regulator #	Overflow Weir				Regulating Sluice Gate / Orifice						Real Time Control
	Drawing		PVSC Model		Drawing			PVSC Model			
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height	
N-002A (Verona Ave.) modified	110.43	41	103	6	102.65	2.5	2.5	99.33	2	2	Yes
N-004A/005A (Herbert) modified	114.34	41	105.55	6.667	107.06	2	2	103.6	1.5	1.5	Yes
N-008A (Fourth Ave.)	103.5	6	103.5	6	100.7	1.5	1.5	100.7	1.5	1.5	Yes
N-009A (Clay St.)	103.24	4	103.24	4	102.4	1.66	0.83	102.4	1.66	0.83	Yes
N-010A (Clay St.)	105.12	8.42	105.12	8.42	101.24	6	3	101.24	6	3	Yes
	105.12	8.42	105.12	8.42	101.24	6	3	101.24	6	3	
	105.12	8.42	105.12	8.42							
N-014A (Rector) modified	102.56	5.5	103.66	5.5	99.97	1.5	1.5	101.07	1.5	1.5	Yes
N-014A (Saybrook) modified	102.33	7	103.43	7	99.02	2	2	100.12	2	2	Yes
N-015A (City Dock) modified	98.67	14	98.67	14	95.67	3.5	2.5	95.67	3.5	2.5	Yes
N-016A (Jackson St.)	97.62	7	97.62	4.5	96	1.5	1.5	96	1.33	1.33	Yes
N-017A (Polk St.)	97.8	8	97.8	7	95.2	1.5	1.5	95.35	1.33	1.33	Yes
N-018A (Freeman St.)	100.26	4	100.26	4	99	2	2	99	2	2	Yes
N-022A (Roanoke Ave.)	98.93	6	98.93	6							
N-027A/029A (Waverly)	102	4.5	102	4.5	96.4	4	2.33	96.4	4	2.33	
N-025A (Peddie St.)	98.6+	6	98.6	8	93	4	2.33	93	4	2.33	
	98.6+	8	98.6	8							
	105.85	5	98.6	8							
	105.85	5	98.6	8							
N-030A (Ave. A)	102.32	10	102.32	10	99.04	4	3	99.04	4	3	
N-023A (Adams St.)	98.54	7	98.54	7							
K-001A (Stewart Ave.)	120.85	4.5	120.27	1.5	119.07	1		119	1		
K-004A (Nairne Ave.)	107.9	1.5	108	1.5	106.9	1		107	1		
K-006A (Johnston Ave.)	99.9	5	100.9	10	98.7	1.5		98.2	1.5		
	100.1	5									
K-007A (Ivy St.)	103	9	103	9	100.2	3	1	100.2	3	1	
K-010A (Duke St.)	102.5	4	102.5	4.5	98.84	1	1	100.45	1		
E-001A (Central Ave.)	101.6	4	101.6	4	99.2	1.25		99.2	1.25		
H-001A (Hamilton Ave.)	101.2	4	101.2	4	99.8	1.25		99.8	1		
H-002A (Cleveland Ave.)	102.2	4	102.2	4	101	1		101.2	1		

Regulator #	Overflow Weir				Regulating Sluice Gate / Orifice						Real Time Control
	Drawing		PVSC Model		Drawing			PVSC Model			
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height	
H-003A (Harrison Ave.)	103.9	4	103.9	4	101.4	1.25		101.4	1.25		
H-005A (Middlesex St.)	100.8	3.5	100.8	3.5	99.1	1		99.1	1		
H-006A (Bergen St.)	99.9	4	99.9	4	97.9	1		97.9	1		
H-007A (Worthington Ave)	102.4	4.5	102.4	4.5	101.2	1		101.2	1		

Note:

1. Dimension in feet.
2. Red font color was applied when the dimensions were different between the Drawings and the PVSC Model. The PVSC Model inputs were maintained.
3. Refer to **Section I.3.10** for detailed real time control information for the regulators with "yes" in the last column.

I.3.7 Pump Station and Force Main

The Hudson County Force Main was added in the model based on record drawings. It conveys flows from the municipalities located east of Newark Bay (including North Bergen, Union City, Jersey City and Bayonne) to the PVSC wastewater treatment plant.

In addition to the pump stations inherited from the previous model, South Kearny Pump Station and force main were added to the model to convey flows from the Kearny Meadowlands District and South Kearny District. Both districts are served with separate sewers. The service area of the pump station is shown in **Figure I-23.** Maximum capacity of the pump station is 17.5 MGD, with dry weather flows around 1.6 MGD.

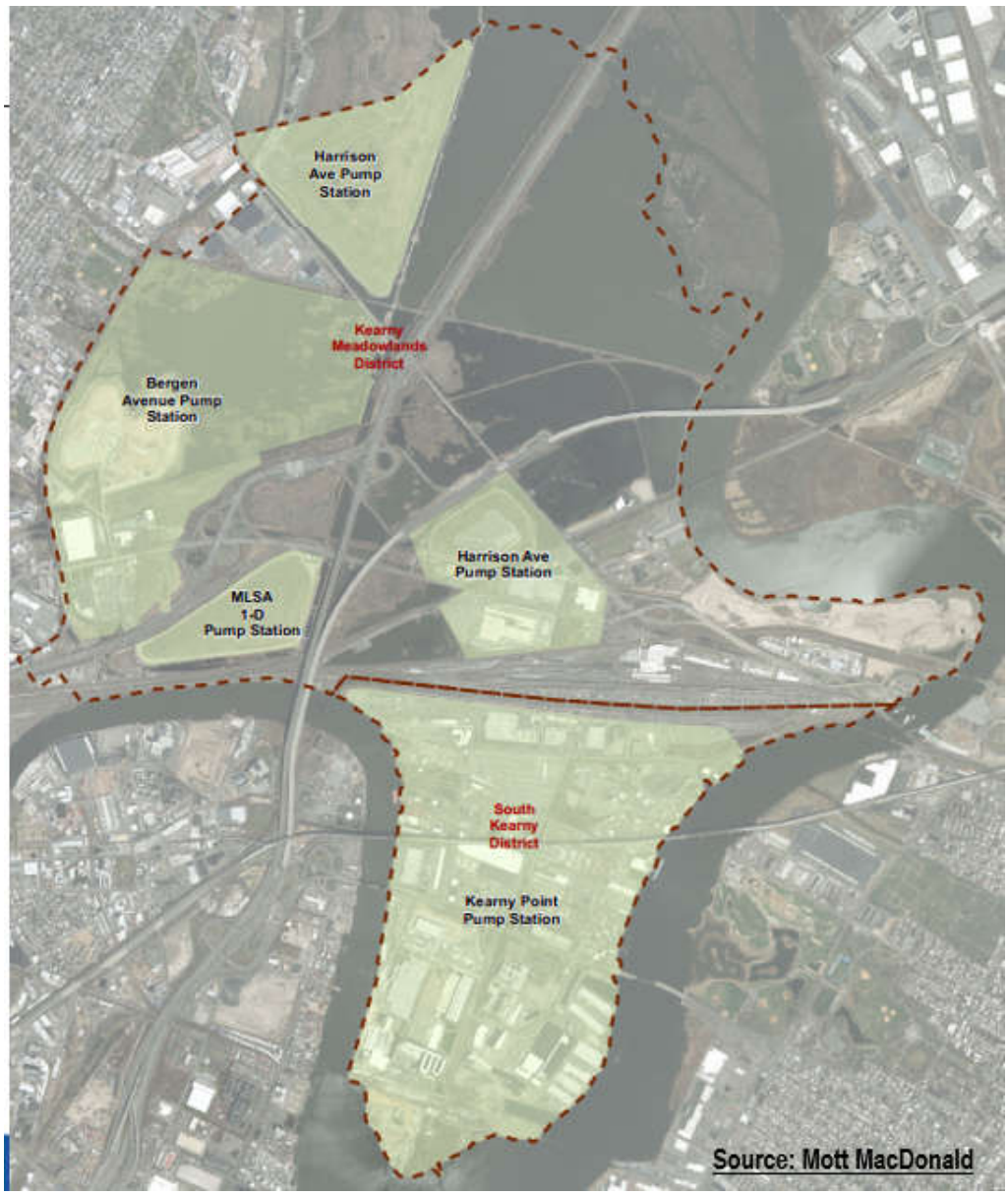


Figure I-23: South Kearny Pump Station Service Area

I.3.8 Rainfall Derived Infiltration and Inflow (RDII)

The model uses the RTK unit hydrograph (UH) to estimate RDII into the separate area sewer systems. As shown in **Figure I-24**, a RTK UH set contains up to three hydrographs (Muleta & Boulos, 2008): one for a short-term response (UH1), one for an intermediate-term response (UH2), and one for a long-term response (UH3). UH1 represents the most rapidly responding inflow component and has a short T value, UH2 includes both inflow and infiltration and has a longer T value, and UH3 includes infiltration that may continue long after the storm event has ended and has the longest T value. The unit hydrograph is defined by the following three parameters:

- R: the fraction of rainfall volume that enters the sewer system and equals to the volume under the hydrograph,
- T: the time from the onset of rainfall event to the peak of the unit hydrograph in hours, and
- K: the ratio of time to recession of the unit hydrograph to the time to peak.

The same set of RDII parameters were applied in the same metershed because of the availability of the flow hydrograph for model calibration. The initial values of RTK were estimated based on previous modeling document. The RTK values are calibration parameters to be refined during model calibration.

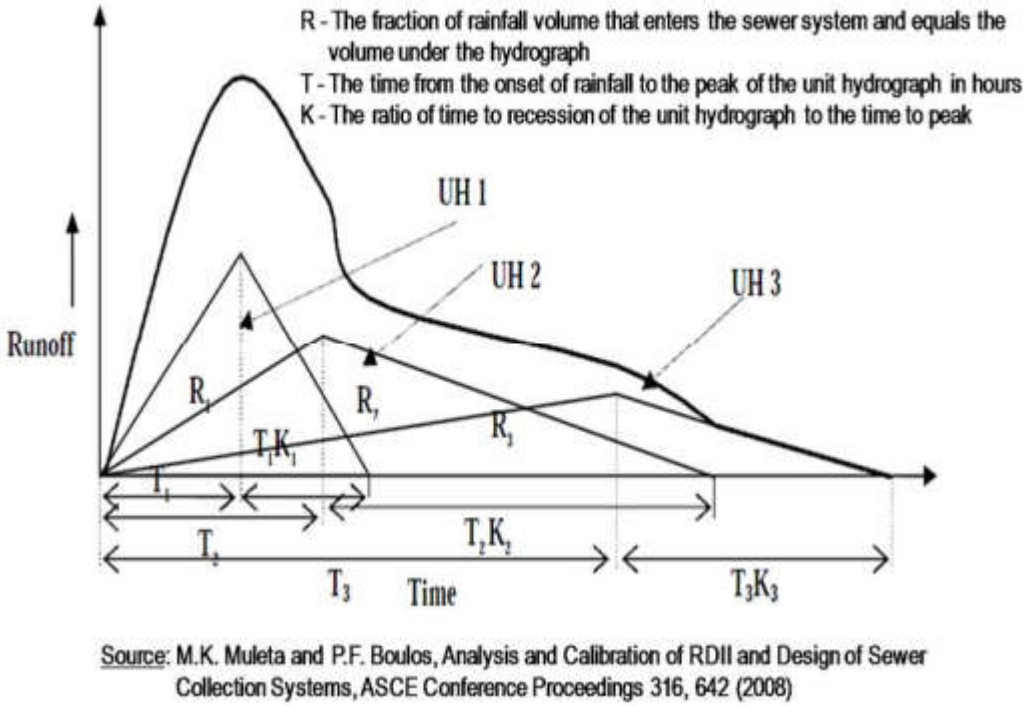


Figure I-24: RTK Unit Hydrograph

I.3.9 Dry Weather Flow

Dry Weather flow shown in **Figure E-4** was assigned to subcatchments in proportion to the service area in the same metershed. Same weekday and weekend dry weather flow diurnal patterns (example **Figure E-5**) developed from flow metering data were assigned to the subcatchments in the same metershed. Concentration of Pollutant PL1 was assumed to be 100 for all dry weather input, this allows users to differentiate wet weather flow quantity from the dry weather flow quantity.

I.3.10 Real Time Control (RTC)

RTC for Gate Operation of Regulators along PVSC Interceptor

Real time controls for gate operation of regulators along PVSC interceptor were developed based on the PVSC Primary Clarifier Auto Fill System Operating Procedure (SOP, October 27, 2016). The SOP includes sequenced procedures to be performed during wet weather conditions. These procedures were incorporated into the PVSC model through real time controls. Schematics in **Figure I-25** illustrate the following wet weather operating procedures in the model:

(a) When the WRRF flow (including flows from the Hudson County Force Main) is less than 350 MGD, all regulator gates are kept open

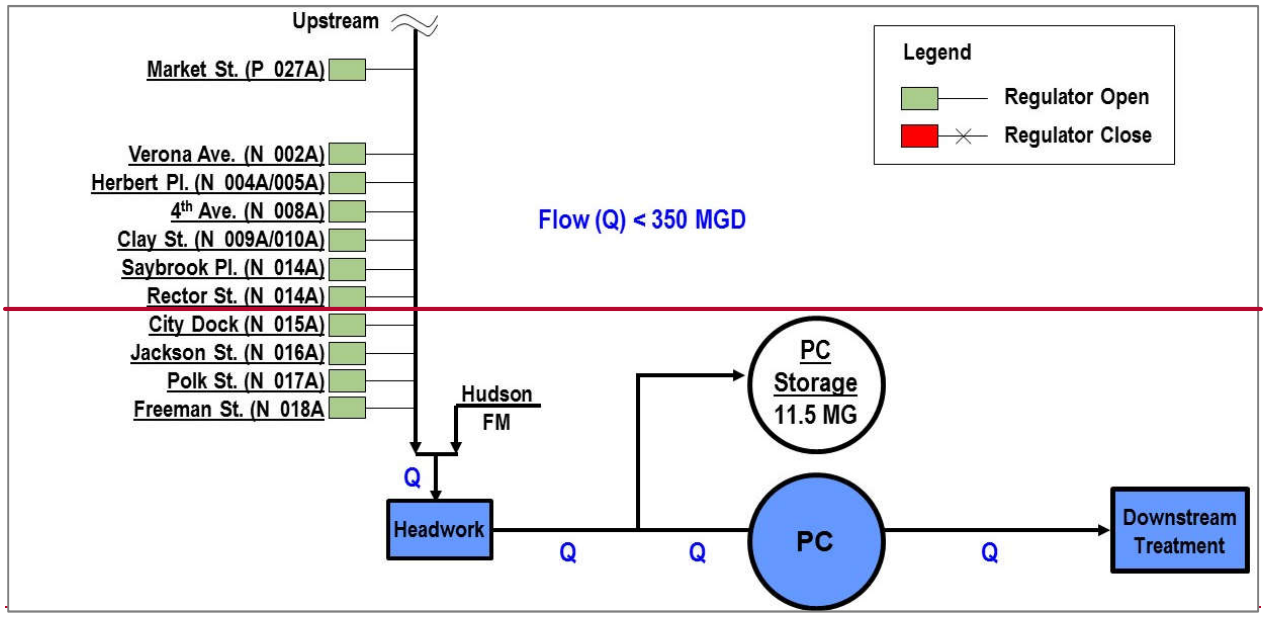
(b) When the WRRF flow increases above 350 MGD, close regulator gates on Verona Ave. (N_002A), Herbert Pl. (N_004A/005A), 4th Ave. (N_008A), Saybrook Pl. (N_014A), City Dock (N_015A), Jackson St. (N_016A), Polk St. (N_017A), and Freeman St. (N_018A).

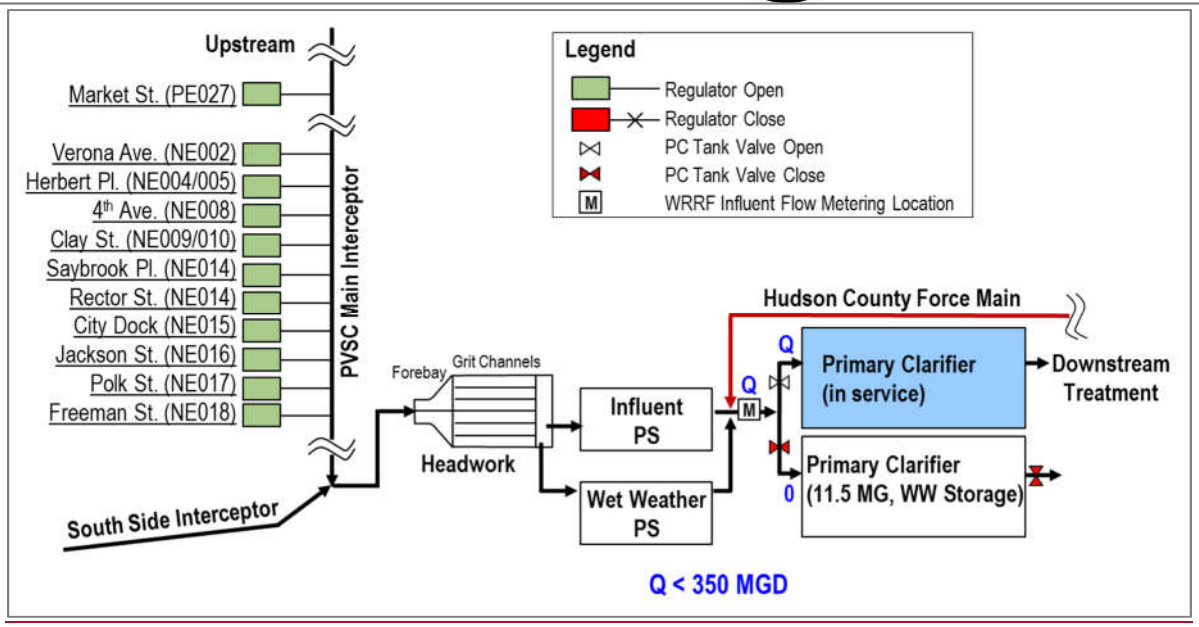
During 10/7/2015 to 7/7/2016 (model calibration events were in this period), these regulator gate were put in use at plant flow 400 MGD.

(c) When the WRRF flow further increases to above 400 MGD, start primary clarifier (PC) filling at flow rate 50 MGD

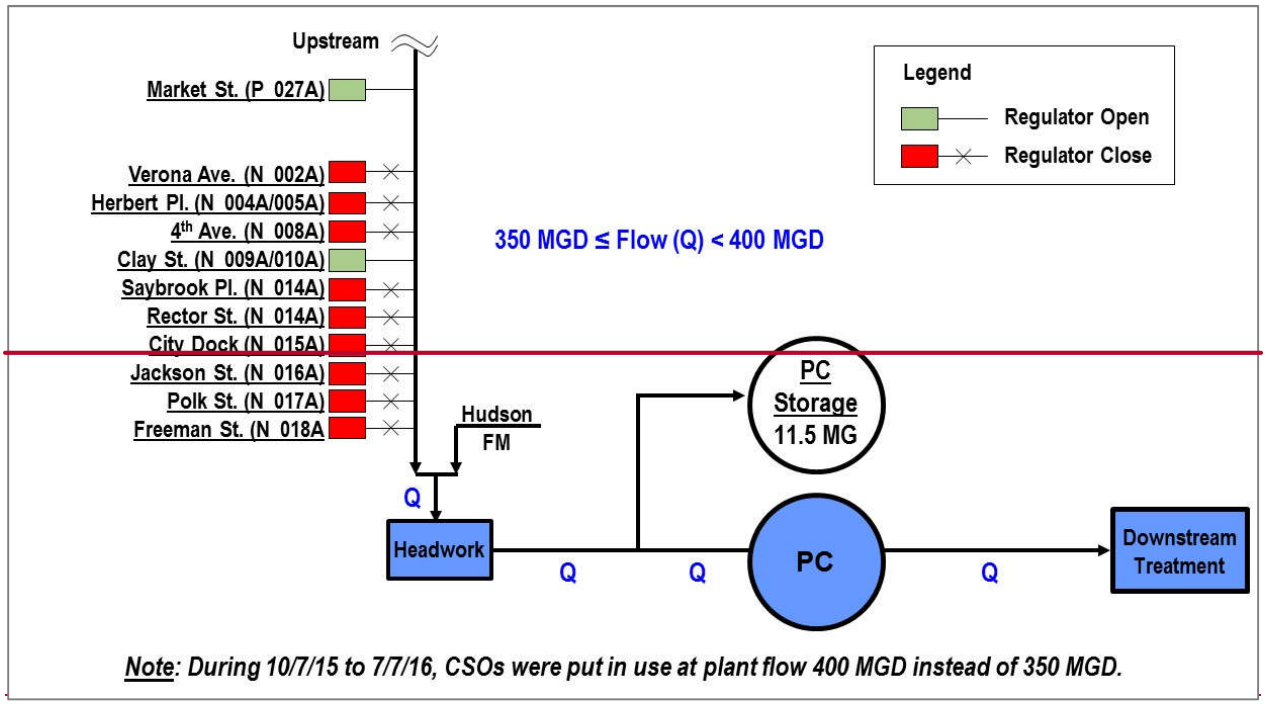
(d) When the PC storage is full, stop PC filling and close regulator gate at Clay St.

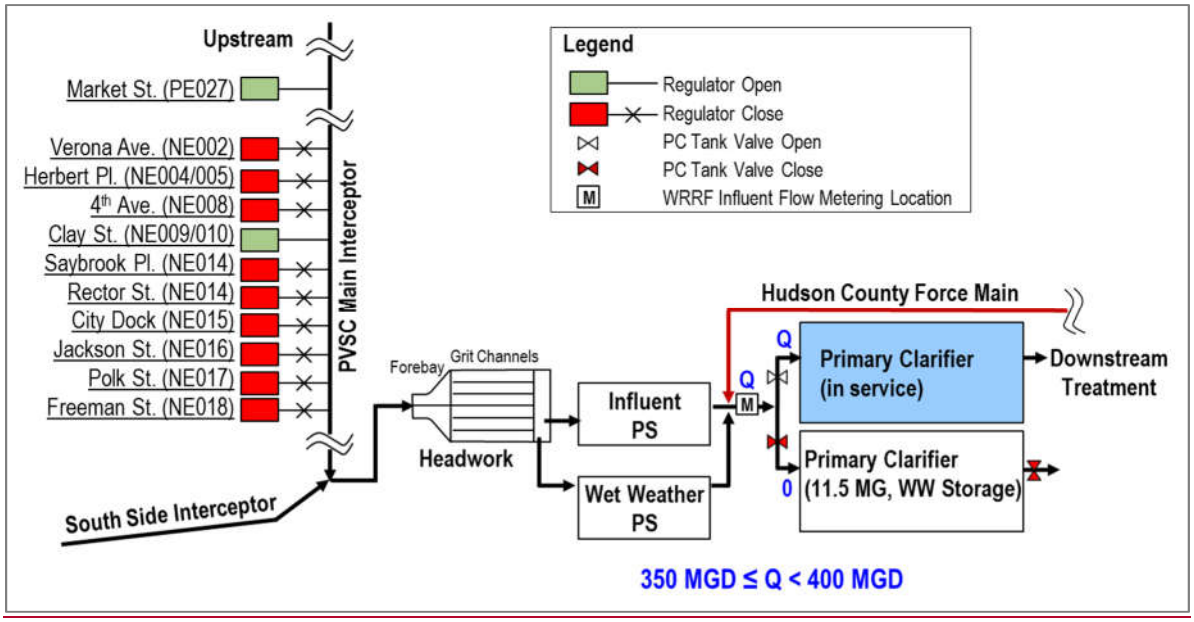
(e) When the WRRF flow recede to 350 MGD post storm event, open all regulator gates and start dewatering PC storage



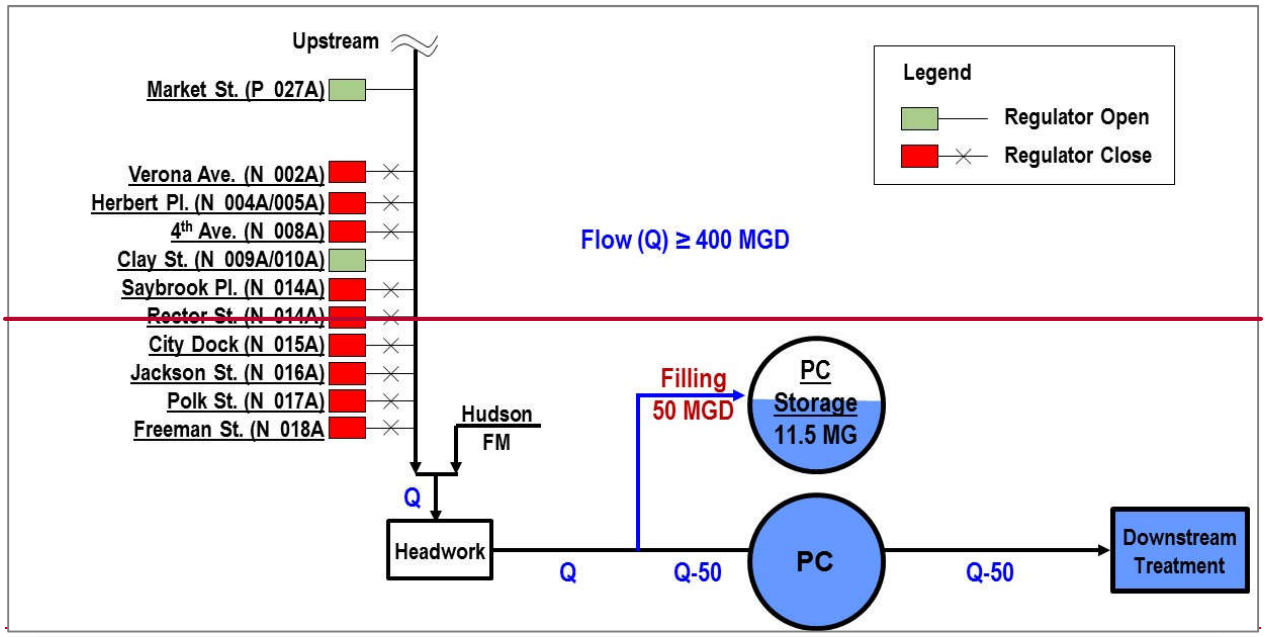


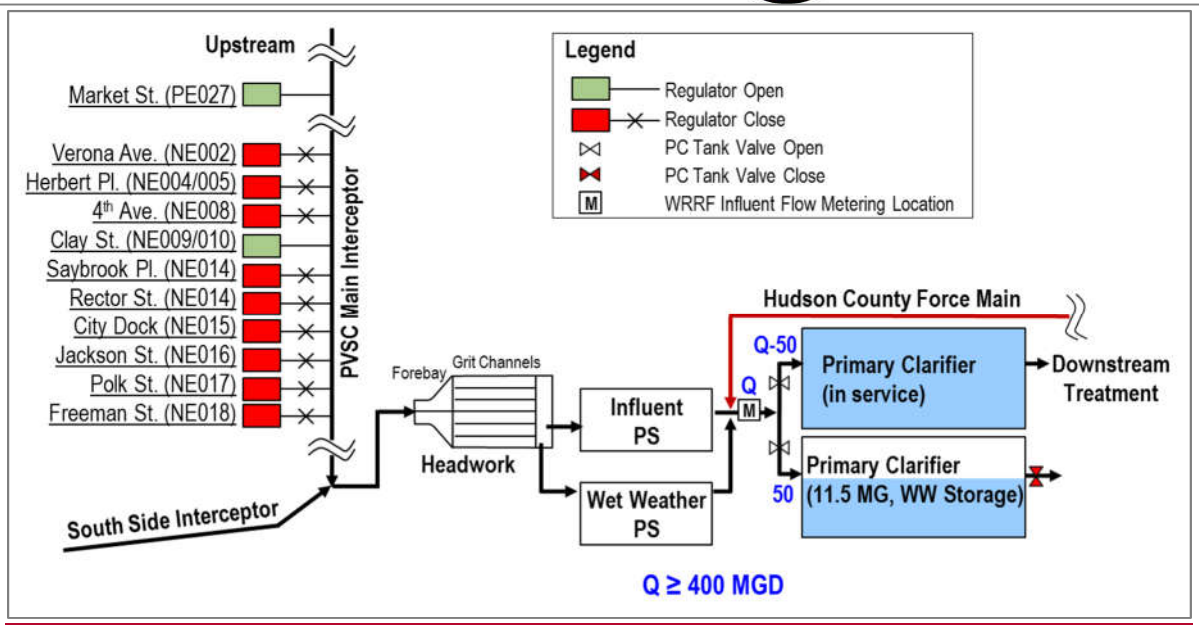
(a) Keep regulator gate open when WRRF flow is less than ~~400~~ 350 MGD



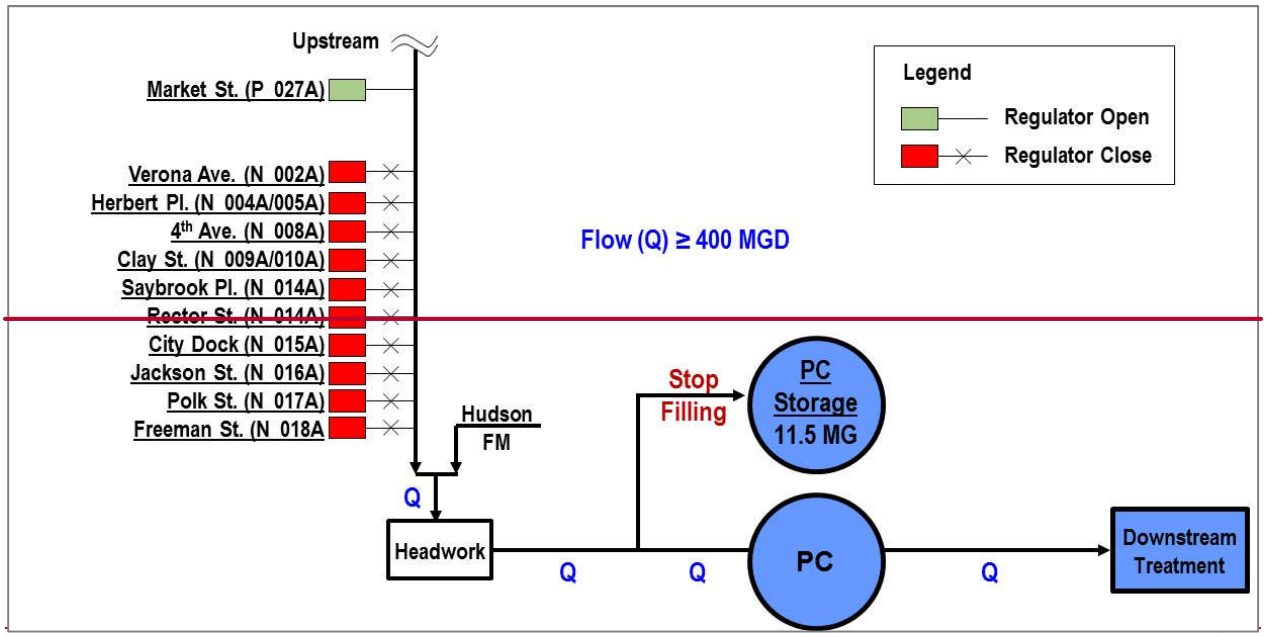


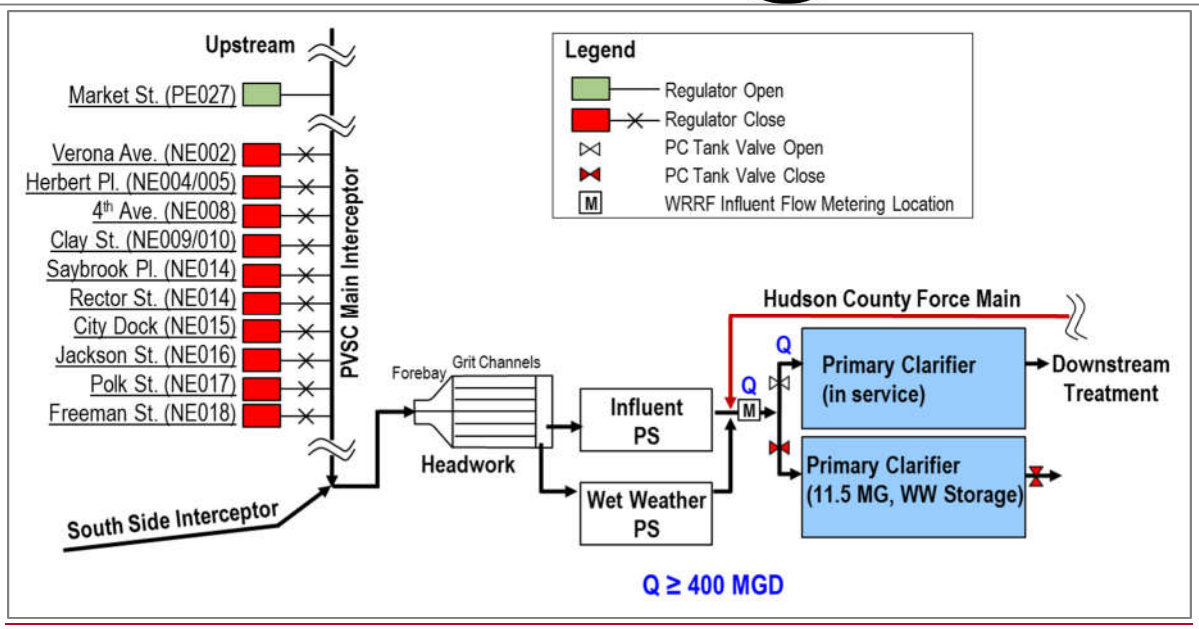
(b) Close regulator gates (except Clay Street) when WRRF flow is greater than 350 MGD



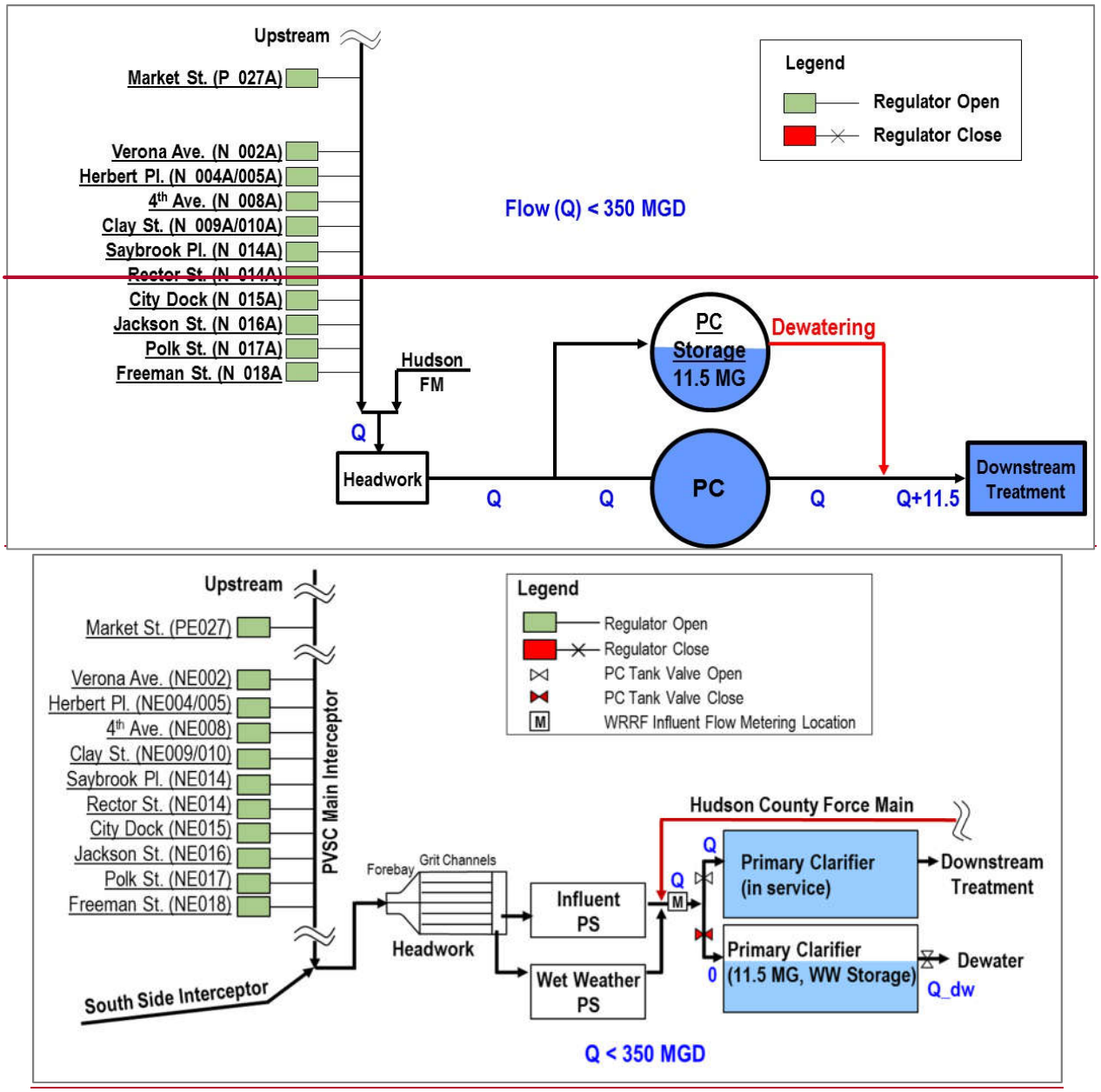


(c) Start filling PC Storage when flow is greater than 400 MGD





(d) Close Clay Street regulator gate when the PC Storage is full



(e) Open regulator gate and dewater PS Storage when WRRF flow recedes to 350 MGD

Figure I-25: PVSC Wet Weather Operating Procedure

RTC for Gate Operation of Regulators in City of Bayonne

All real time controls for City Bayonne regulators are inherited from its original model, with update of unit conversion detailed in **Table I-4.**

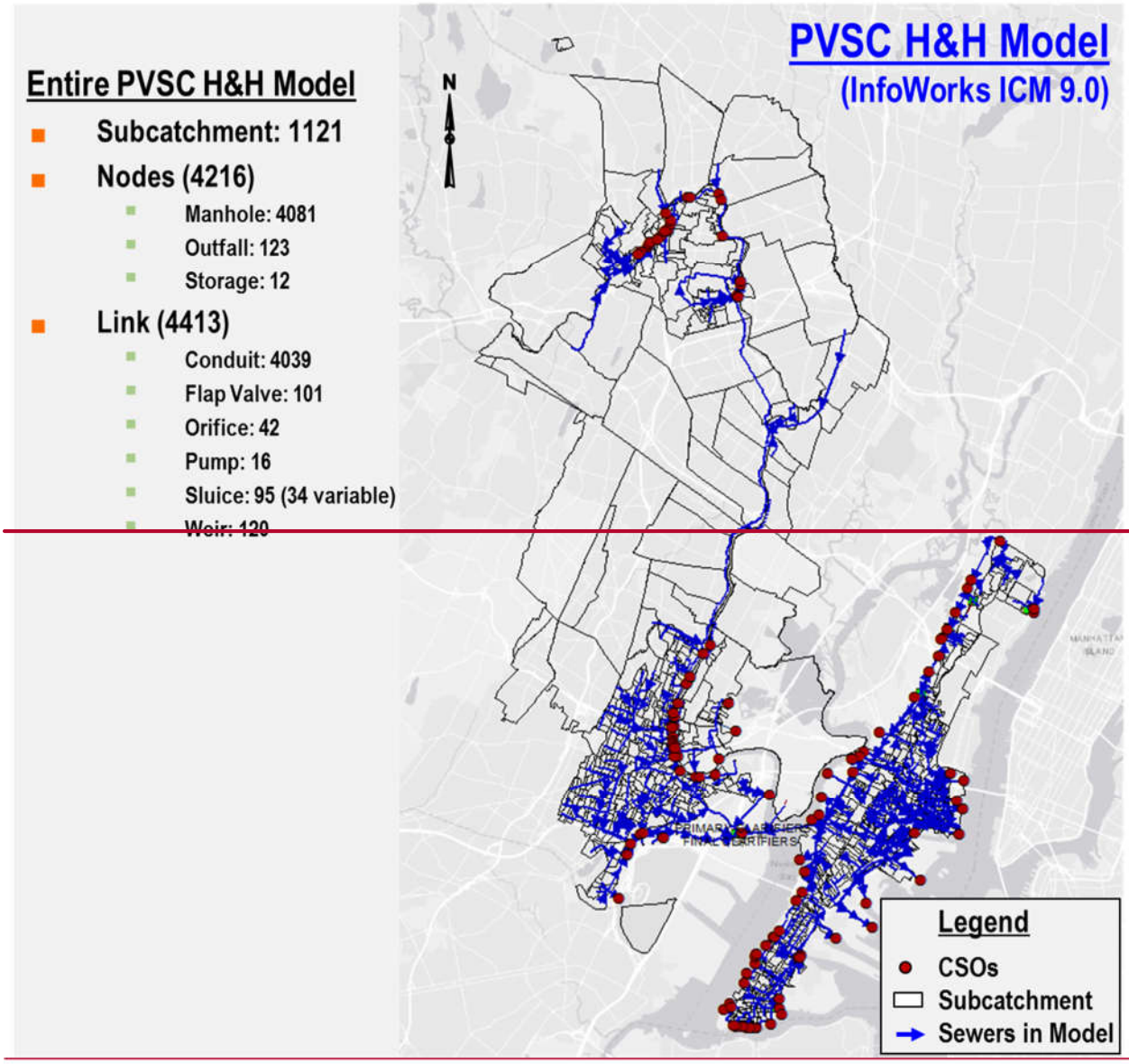
I.4 MODEL CONSTRUCTION SUMMARY

The PVSC CSO LTCP model was developed from the integration of four existing CSO community models in InfoWorks ICM 9.0 based on PVSC datum. The model was then further expanded to include all separate sewer service areas. The model has the following features:

- 1121 subcatchments, including all 48 served communities (both combined and separate)
- 4216 nodes, including 4081 manholes, 123 CSO outfalls, and 12 storage for pump station wet well and primary clarifier serving as a storage facility. Real time control rules were set up for filling the primary clarifiers served as storage facility based on the wet weather Standard Operating Procedure (SOP) of PVSC WRRF.
- 4413 links, including 4039 conduits, 42 orifice, 120 weirs, 101 flap valves, 95 sluice gates, and 16 pumps. 34 of the 95 gates are with variable gate openings to be regulated during wet weather conditions. Real time control rules were set up for the variable gate based on wet weather SOP.
- Hudson County Force Main was extended to the PVSC WRRF based on drawings to convey flows from the Hudson County to the WRRF. Force main from Bayonne was extended to the tie-in point to the Hudson County Force Main. Force Main from North Bergen was extended to the Jersey City sewer system.
- South Kearny pump station and force main are also added and tied into the Hudson County Force Main. The force main receive flows from Kearny Meadowlands District and South Kearny District, both areas are with separate sewer.
- Dry weather flow based on 2016 flow monitoring data.
- Wet weather flow simulated as runoff from the combined areas and RDII from the separate areas.
- Real time control based on the current PVSC WRRF wet weather SOP.

Model network of the integrated PVSC model is shown in **Figure I-26**. Quantities of subcatchments, nodes and links are also shown on the map. Two permanent meters (Jersey City West Pump Station and Jersey City East Pump Station) shown on the map are the meters used for flow verification. Calibration/validation of Jersey City model is not part of the efforts of this study because Jersey City is in charge of its model and the received model has been calibrated. Therefore the characteristics of Jersey City model remains unchanged in the integrated PVSC model.

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PVSC H&H Model
(InfoWorks ICM 9.0)
Entire PVSC H&H Model
Subcatchment: 1121
Nodes (4216)
Manhole: 4081
Outfall: 123
Storage: 12
Link (4413)
Conduit: 4039
Flap Valve: 101
Orifice: 42
Pump: 16
Sluice: 95 (34 variable)
Weir: 120
N
Legend
CSOs
Subcatchment
Sewers in Model

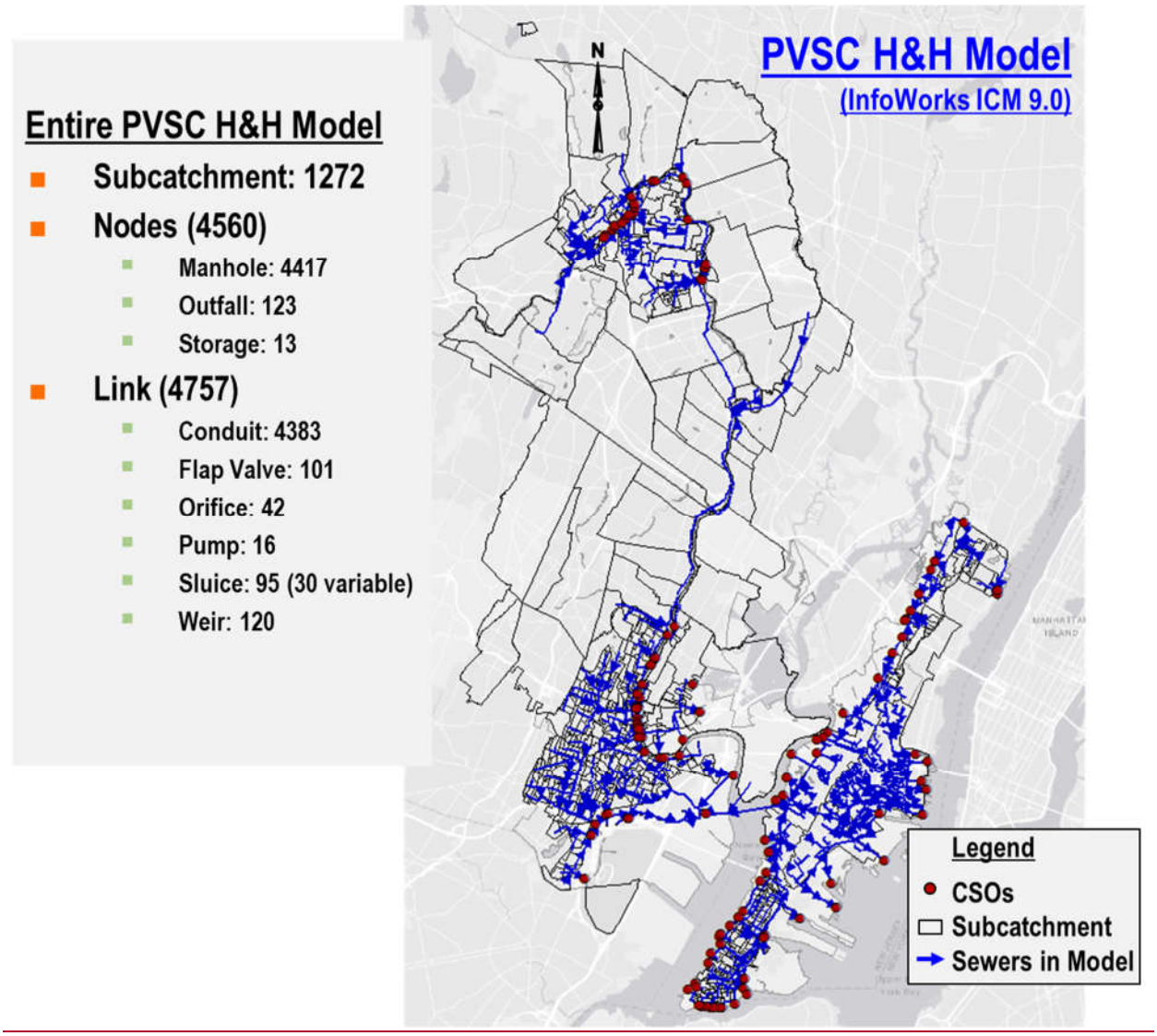


Figure I-26: Snapshot of Entire PVSC H&H Model Network

I.5 H&H MODEL CALIBRATION/VALIDATION

Model credibility is developed through model calibration and validation. Model calibration involves application of the model to known external inputs (e.g., rainfall), evaluation of the model's ability to replicate monitored conditions (e.g., flow and volume), and adjustment of key model parameters as needed until an acceptable level of agreement is reached between simulated and monitored conditions. Model validation generally involves verifying model performance with additional independent storm events. Further model adjustments are often made during model validation process to improve model accuracy. Due to the limited availability of monitoring data, it is common practice for H&H models to undergo and single calibration/validation process. In this approach, model parameters are adjusted to improve model

accuracy across all of the events, and then each event is evaluated independently to verify model performance cross a range of conditions. The four storm events identified in Section E.9 were used for the PVSC model calibration/validation.

The collection system H&H Model was calibrated in conjunction with the flow monitoring. The H & H Model was calibrated by running the model with rainfall data collected from selected storms and then comparing the calculated results to the actual flow monitoring data collected. The model parameters were adjusted and the process repeated until the calculated results approximated the actual flow monitor measurements. Goals for the model calibration included:

- To match visually the shape of the curve between model and flow monitor.
- To match model runoff volumes (volume under curve) to actual runoff volumes.
- To match model runoff peak flow rates to actual runoff peak flow rates.

I.5.1 Dry Weather Flow Calibration/Validation

Dry weather flow (DWF) analysis was based on the rainfall and flow monitoring results. DWF distribution in the collection system was based on land use data. Weekday, weekend and monthly diurnal factors from the DWF analysis were applied for each flow meter service area. Upstream meters in the system were calibrated first, then flows through the system to the pumps stations and to the WRRF were balanced. **Figure E-4** shows the arrangement of the meters in the system and meter identification.

The DWF calibration goals are included below based on the "Code of Practice for the Hydraulic Modeling of Sewer Systems" by the Wastewater Planning Users Group (WPUG):

- The simulated hydrograph should match the general observed hydrograph shape,
- The simulated time of peaks and troughs will be within 1 hour of the observed,
- The simulated peak flow will be within 10% of the observed flow, and
- The simulated flow volume over 24 hours will be within 10% of observed flow.

After the dry weather calibration was considered to be satisfactory, the model was calibrated for wet weather periods as described below.

I.5.2 Wet Weather Calibration/Validation

Wet weather flow (WWF) includes surface runoff from the combined area and RDII from the combined and separate sewered areas. Surface runoff parameters for the combined area and RDII parameters for the separate area were adjusted to calibrate the system response to the wet weather conditions.

The WWF calibration goals are also based on the "Code of Practice for the Hydraulic Modeling of Sewer Systems" by WPUG:
:

- The simulated hydrograph should match the general observed hydrograph shape,
- The simulated time of peaks and troughs will be similar,

- The simulated peak flow for significant peaks will be within the range of -15% to +25%,
- The simulated flow volume will be within the range of -10% to +20%,

Storm events were analyzed based on precipitation data from the Newark Liberty International Airport. Four storm events selected for calibration/validation of the collection system model met all the desired storm characteristics as describe in **Section E** of this Report. The July 25, 2016 storm was a 1.81-inch storm with a duration of approximately 3 hours and a maximum intensity of 1.68 in/hr. The May 29, 2016 storm was a 1.60-inch storm with a duration of 5.75 hours and a maximum intensity of 1.09 inches/hour. The July 25, 2016 storm was a 1.84 inch storm with a duration of 3 hours and a maximum intensity of 1.68 in/hr. The July 29, 2016 storm was a 0.87 inch storm with a duration of 8.5 hours and a maximum intensity of 0.43 in/hr. The July 30, 2016 rain event was a 1.07-inch storm with a duration of 32.75 hours and a maximum intensity of 0.49 in/hr. Detailed storm characterizations can be found in **Table E-5** for all eight rain gauges. Precipitation data collected by the eight rain gauges throughout the PVSC service area were applied to modeling subcatchments based on Thiessen Polygons for model calibration. Examples of model calibration/validation results are shown in the following figures for the observed and simulated flow, the one-to-one plots for modeled versus observed volumes, and the one-to-one plots for modeled versus observed peak flows. A well calibrated model will result in plotted values that are close to a one-to-one relationship. Deviations from this one-to-one relationship can be result from a variety of factors including error inherent with monitoring data, special variations in rainfall, and model limitations. When a modeled versus observed point is well outside of the calibration goal range, a note is provided to explain the likely cause of the discrepancy. Examples of model calibration results are shown in **Figure I-27** to **Figure I-52** for flow meters in different locations of the collection systems. **Appendix D** shows calibration plots for all meters.

- **Figure I-27** to **Figure I-34** for flow meters in along the PVSC Interceptor;
- **Figure I-35** to **Figure I-42** for flow meters in the separate sewer area,
- **Figure I-43** to **Figure I-50** for flow meters in the combined sewer area, and
- **Figure I-51** to **Figure I-54** for flow meters in the CSO overflow lines.

Obtaining accurate flow monitoring in an outfall pipe is often challenging. Most of the time the meter is recording no flow but when the overflow begins the flow rate can increase rapidly. This can result in instabilities in the recorded flows and difficulties in matching modeled and monitored timing for individual overflow meters. Another way to consider how the outfall meters are performing overall is to consider the total predicted vs. monitored overflow volumes for each event across all of the overflow meter locations. **Figure I-55** shows that the model underpredicts the total overflow volume for Event 4, but shows a very good fit for the remaining 3 events. Overall the predicted overflow volume at these metered locations is consistent with the monitored data.

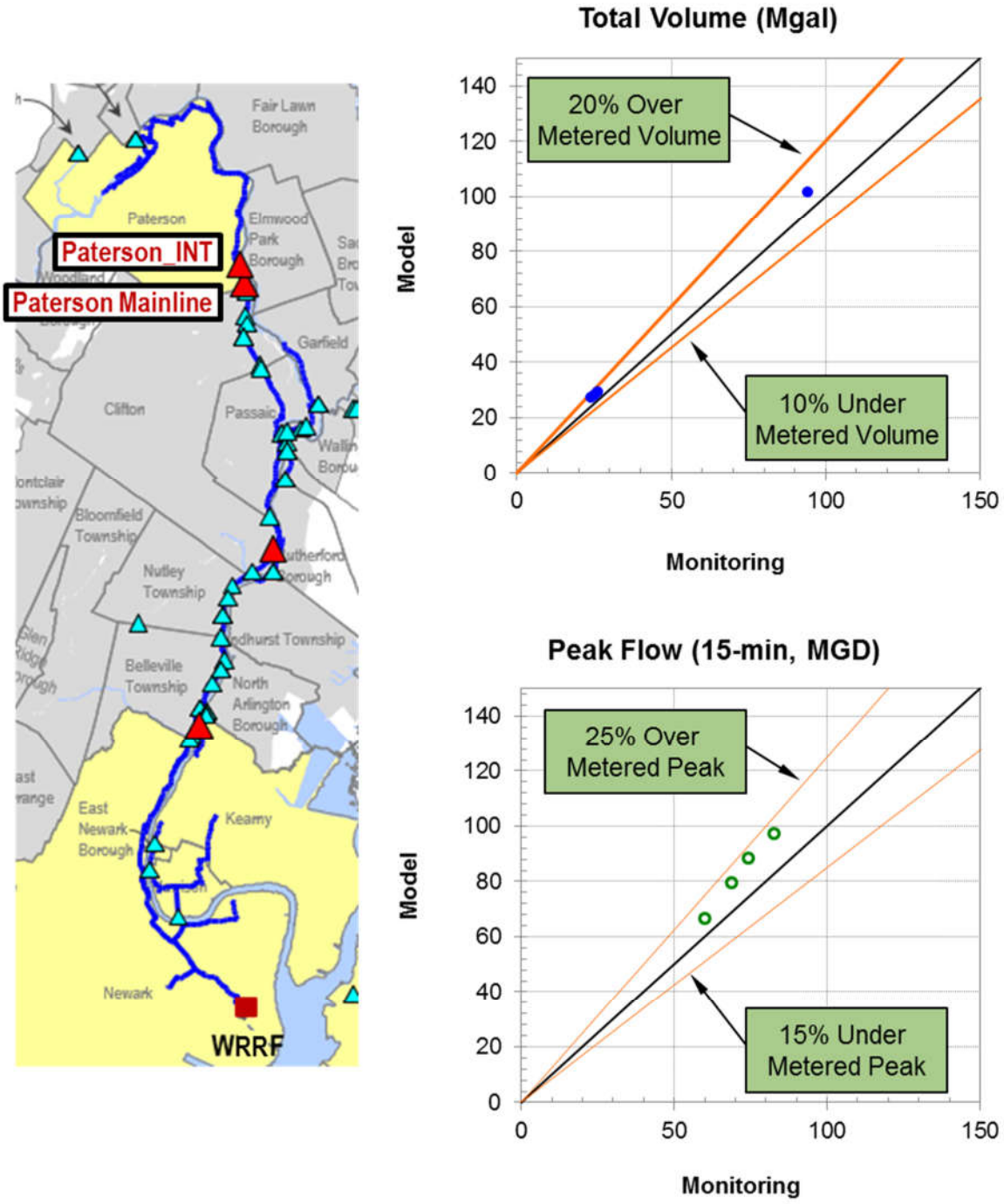


Figure I-27: Calibration Plot for Interceptor_Paterson Main Line_I

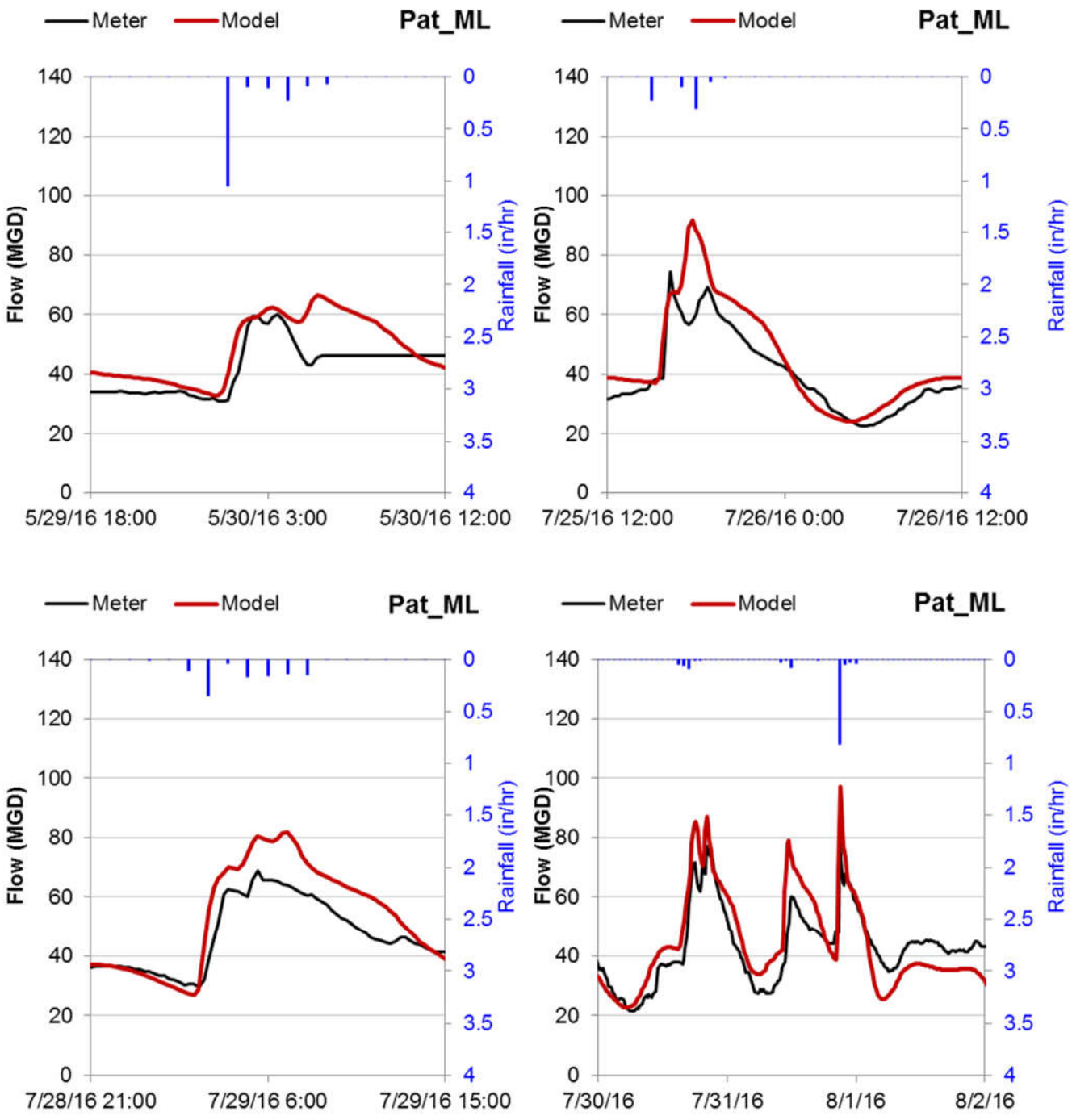


Figure I-28: Calibration Plot for Interceptor_Paterson Main Line_II

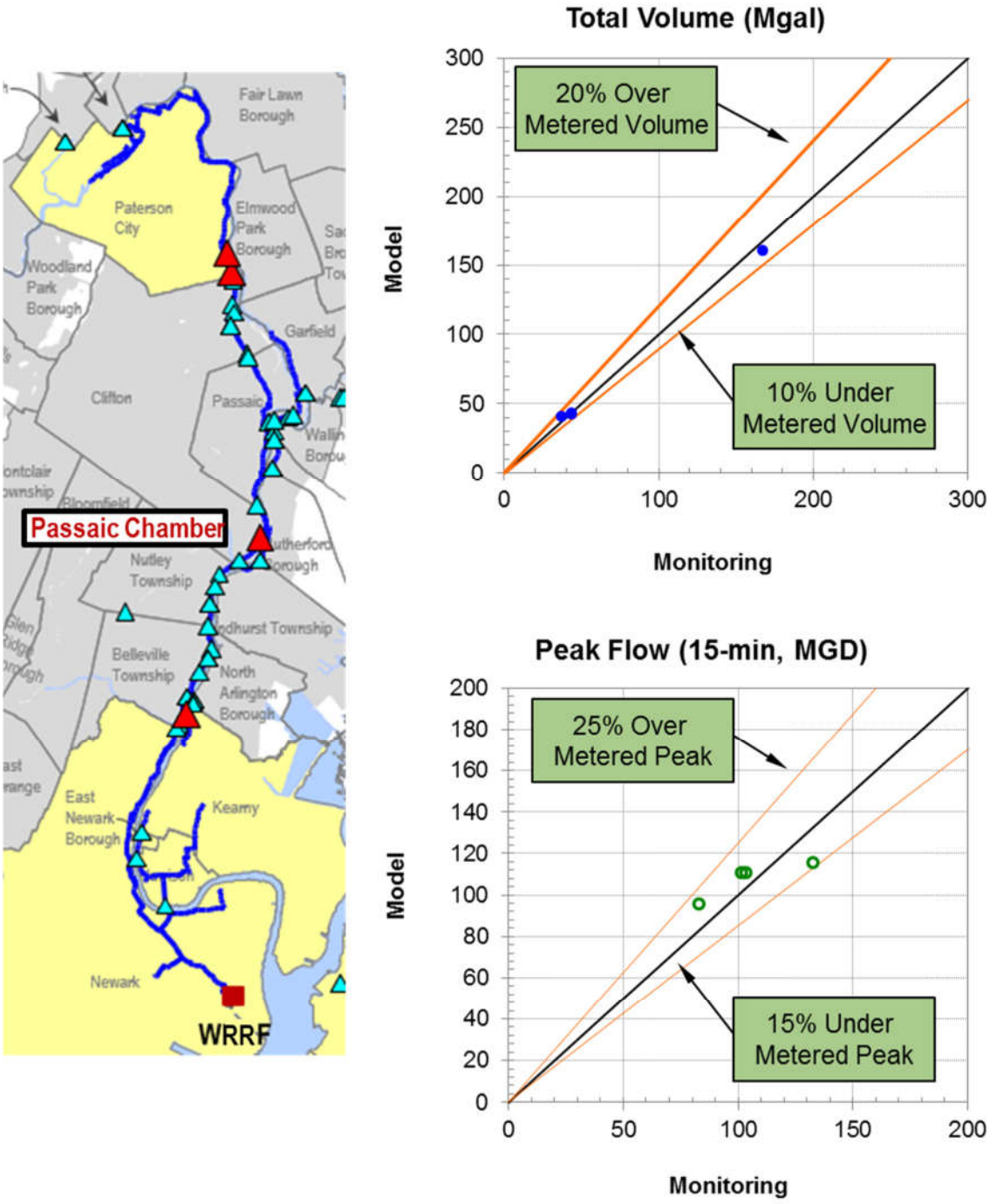


Figure I-29: Calibration Plot for Interceptor_Passaic Chamber_I

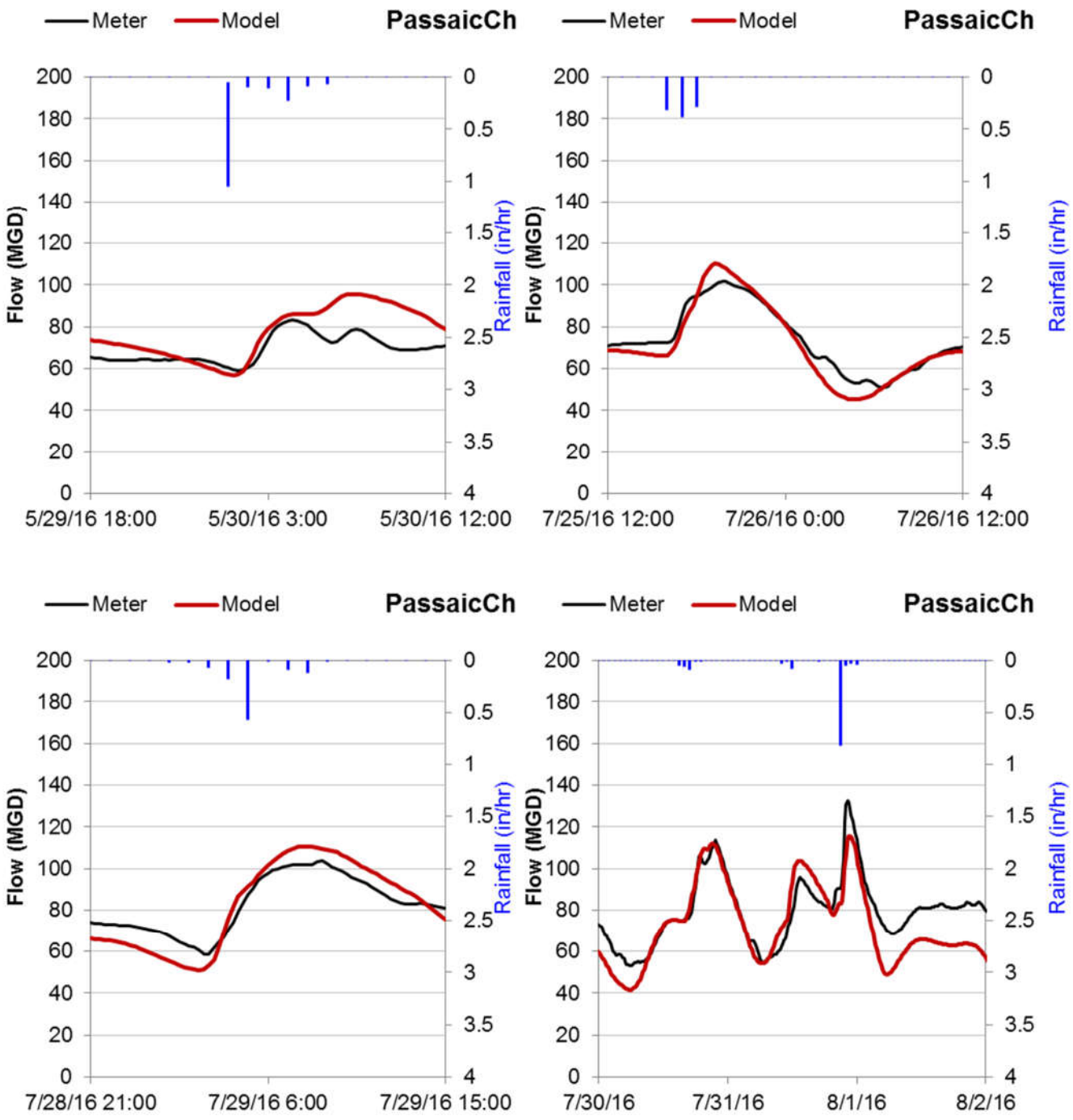


Figure I-30: Calibration Plot for Interceptor_Passaic Chamber_II

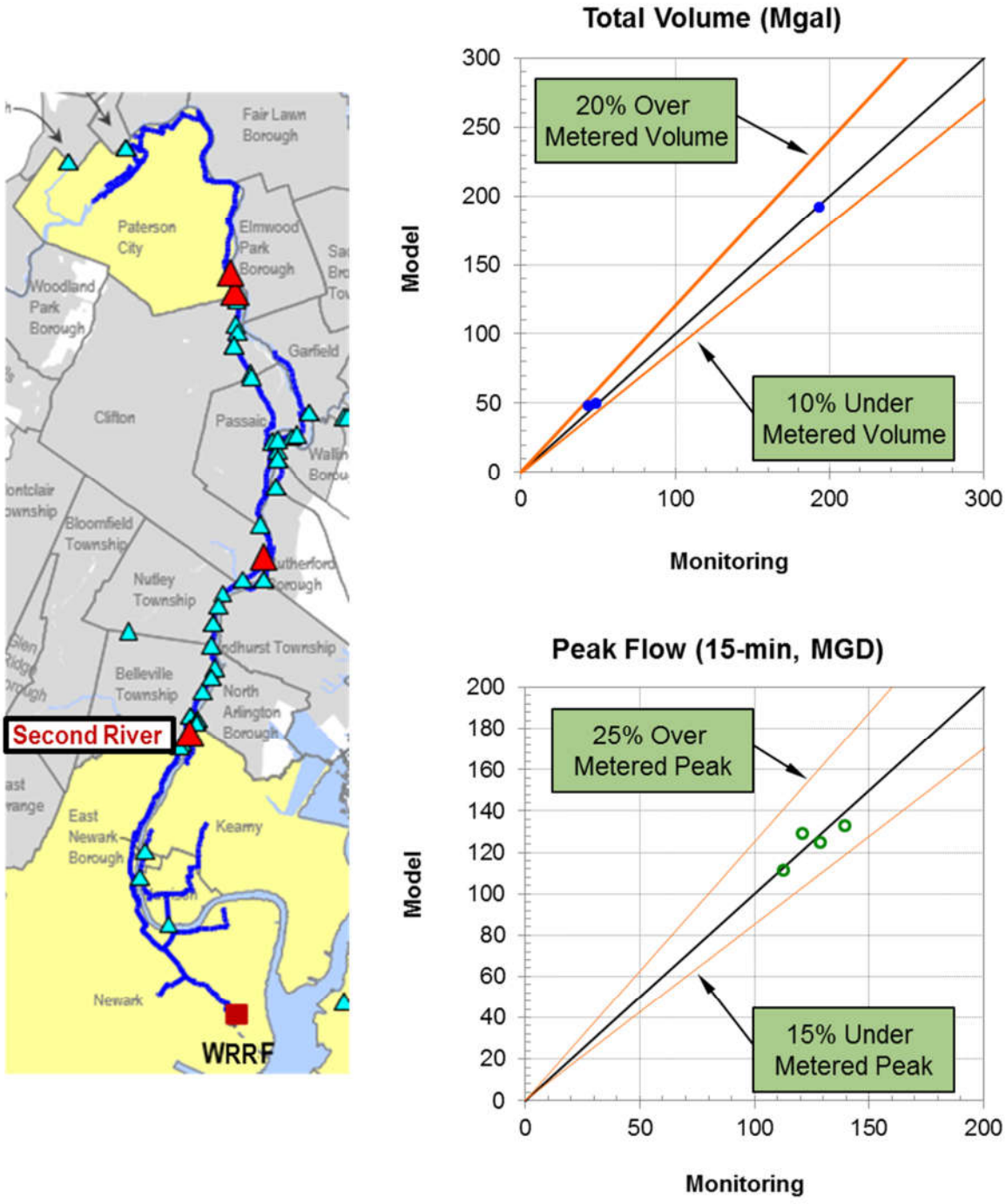


Figure I-31: Calibration Plot for Interceptor_Second River Crossing_I

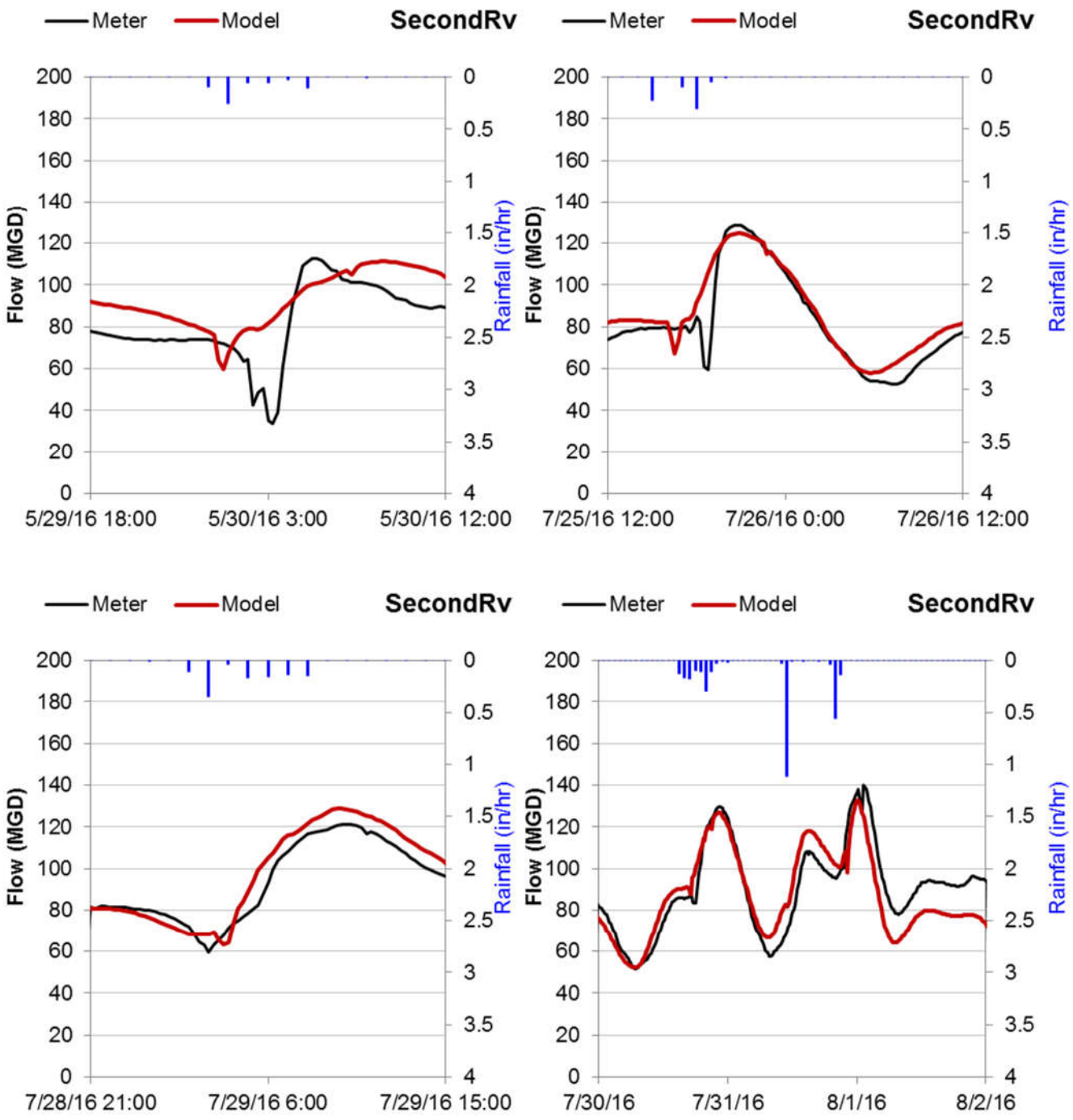


Figure I-32: Calibration Plot for Interceptor_Second River Crossing_II

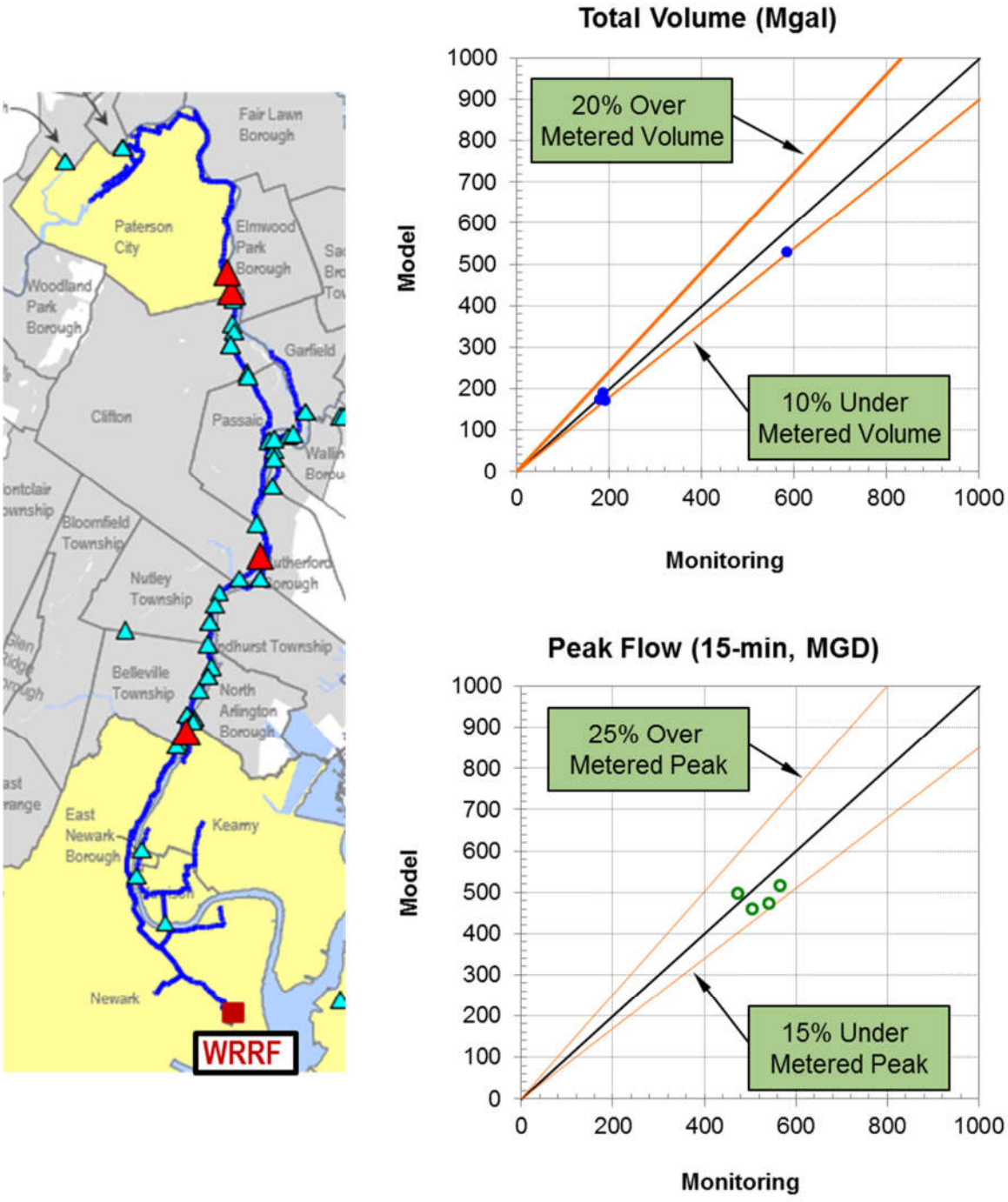


Figure I-33: Calibration Plot for PVSC WRRF_I

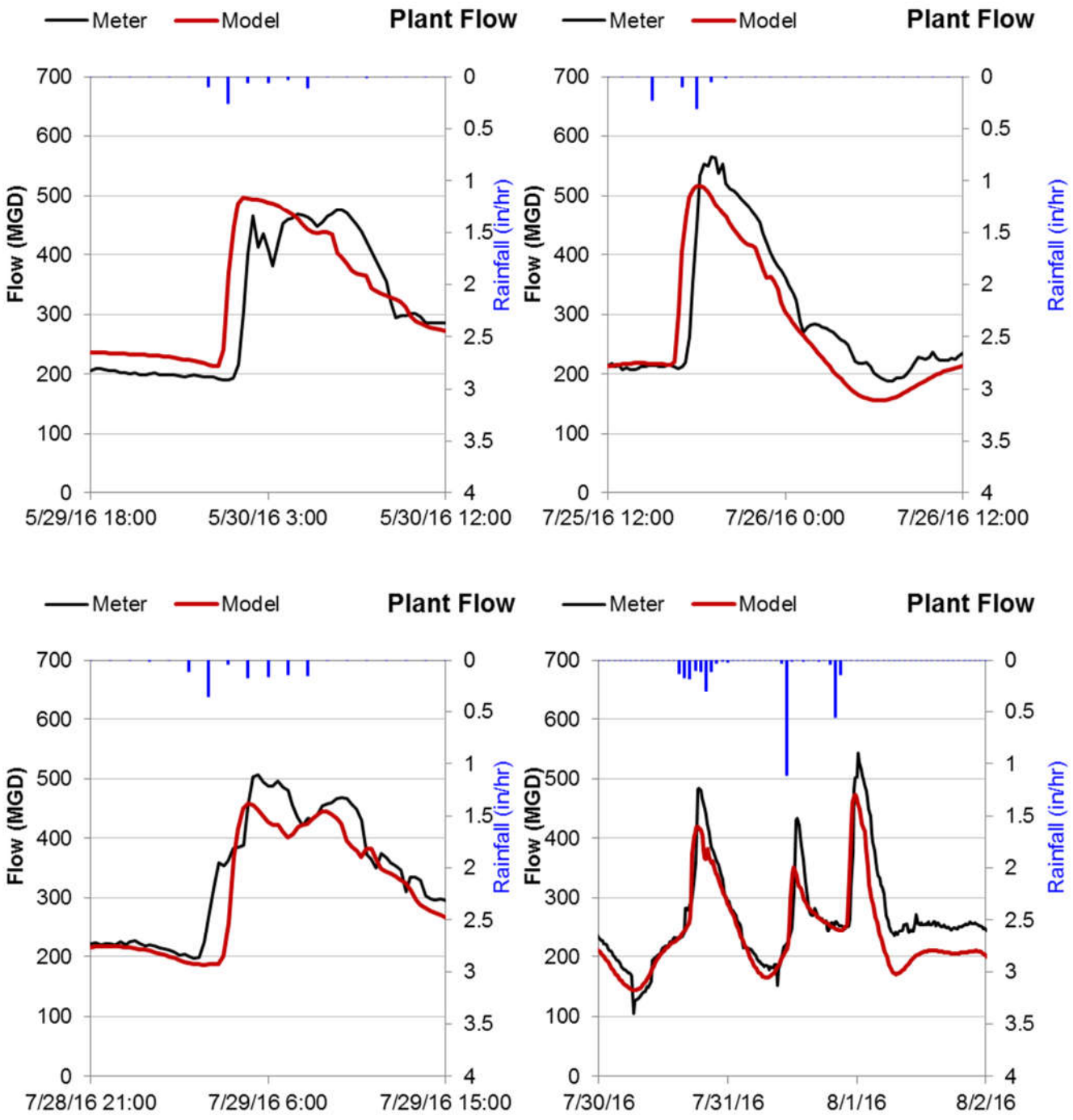


Figure I-34: Calibration Plot for PVSC WRRF_II

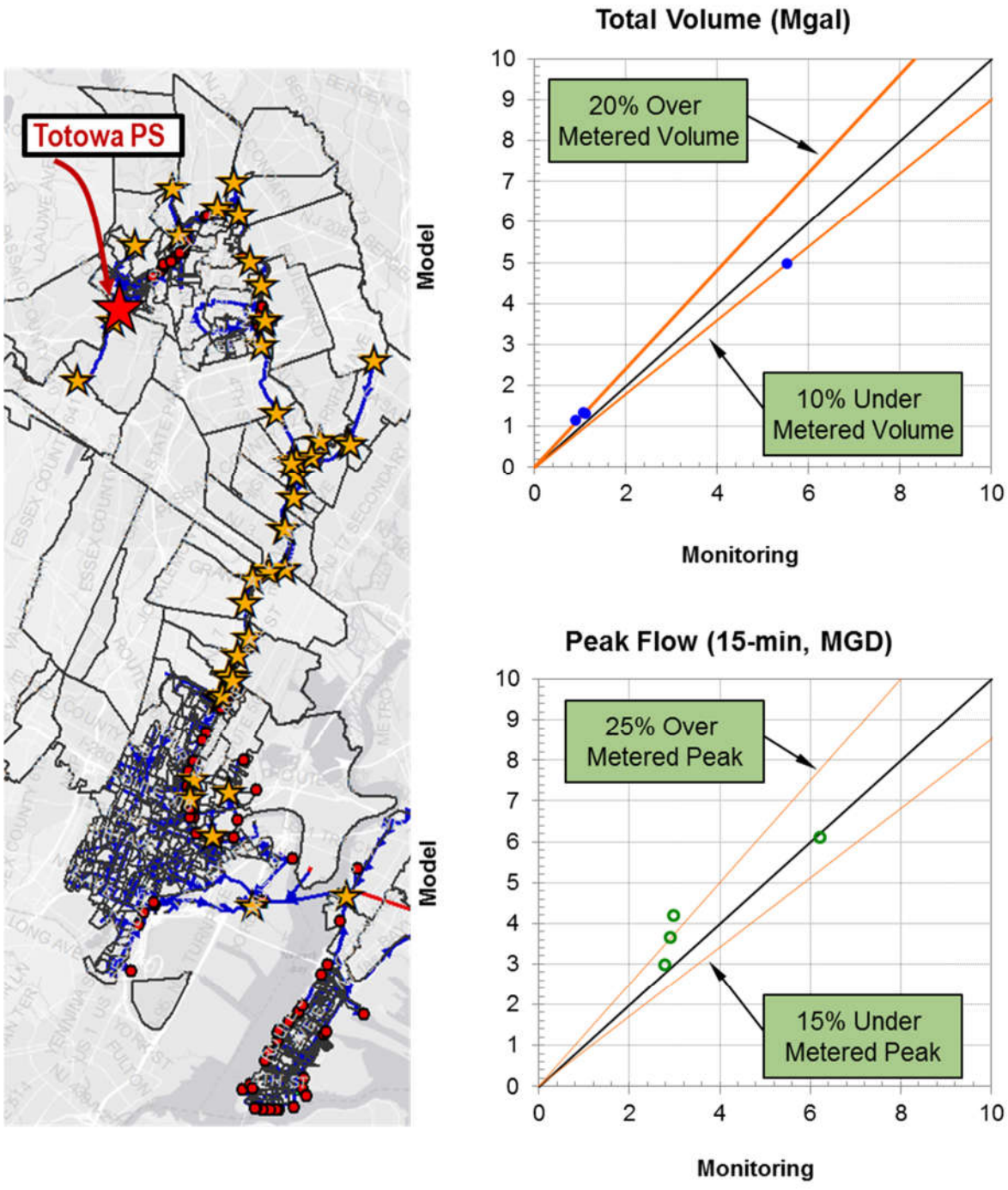


Figure I-35: Calibration Plot for Separate Area_Totowa PS_I

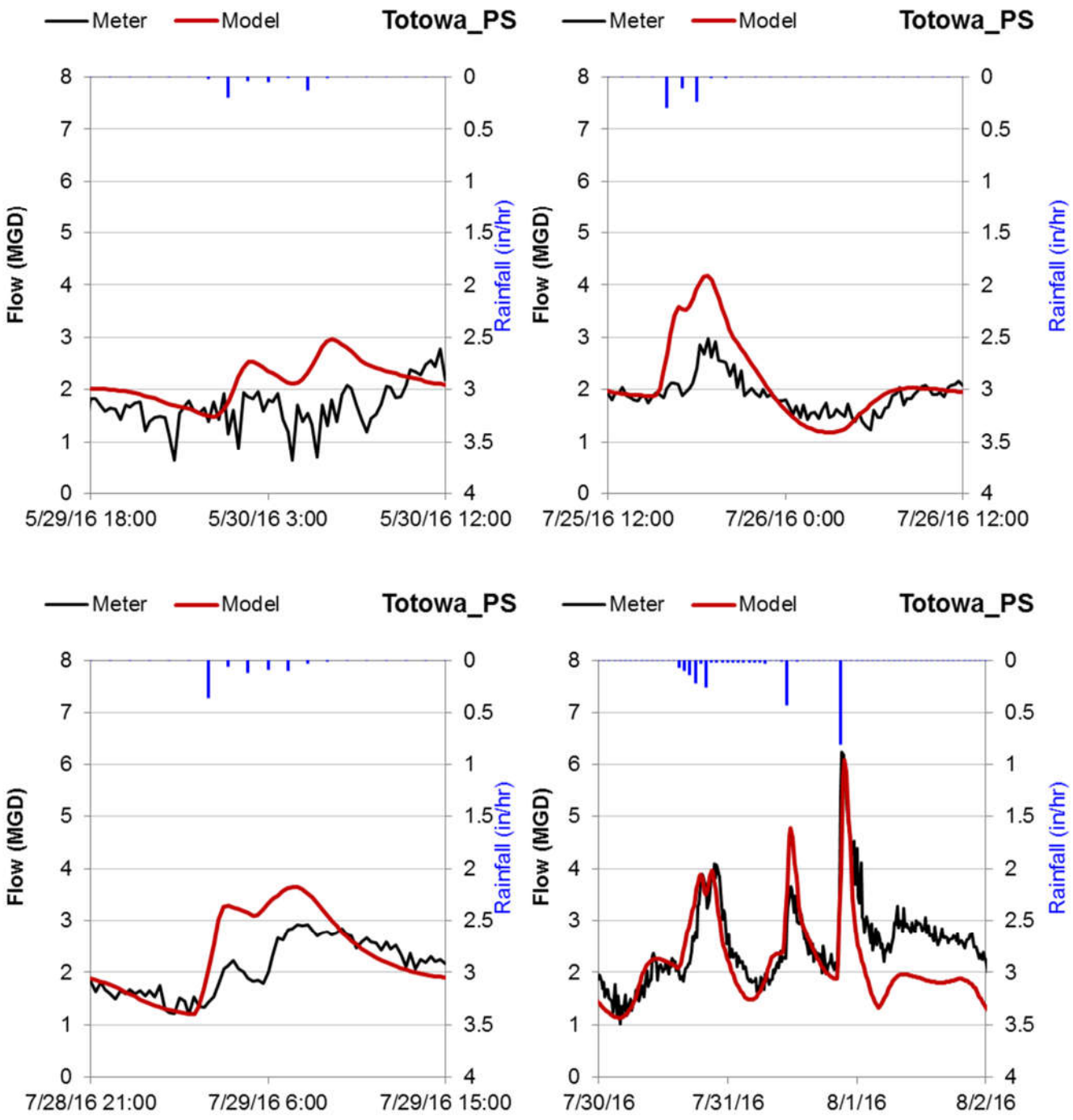


Figure I-36: Calibration Plot for Separate Area_Totowa PS_II

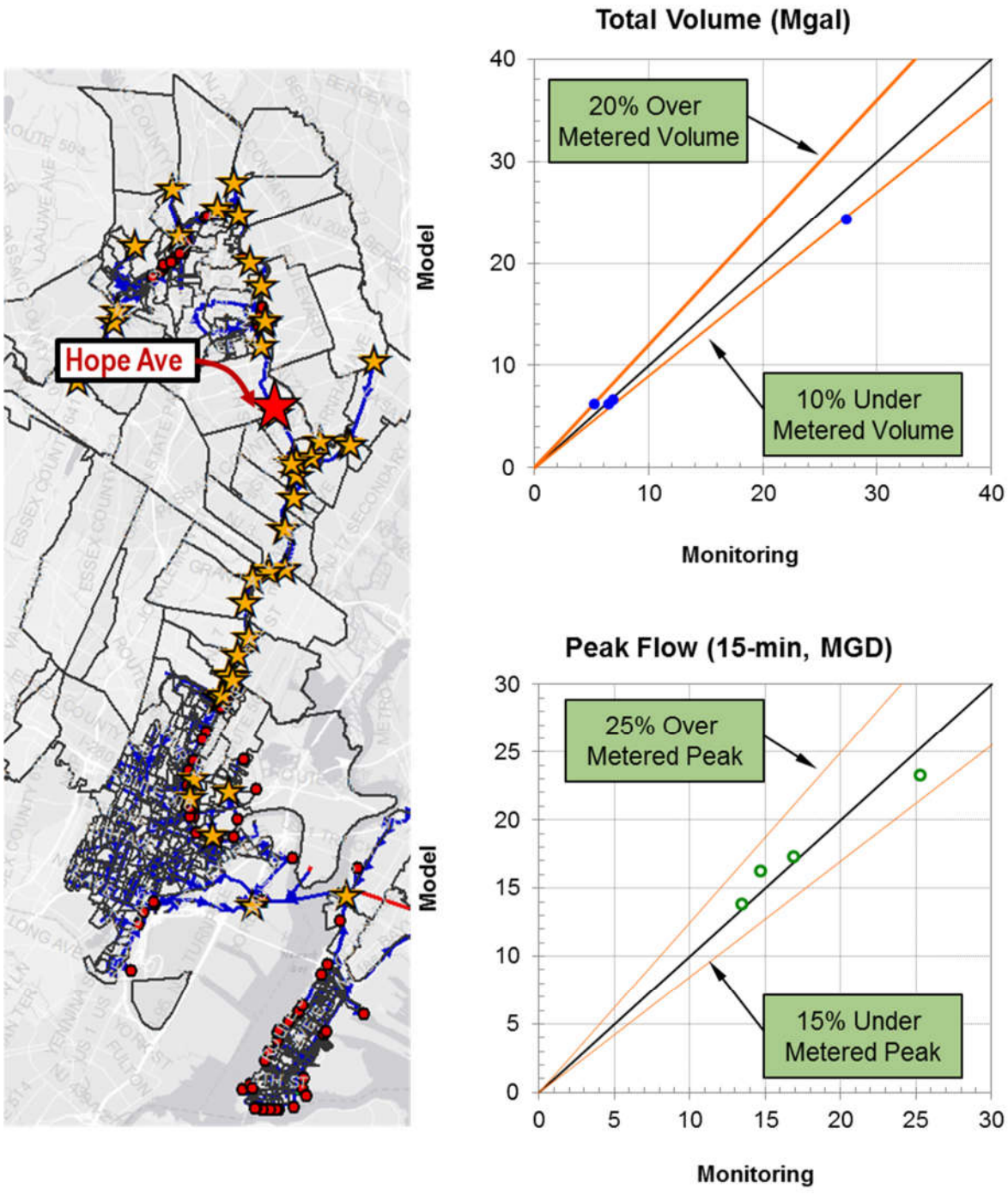


Figure I-37: Calibration Plot for Separate Area_Hope Ave_I

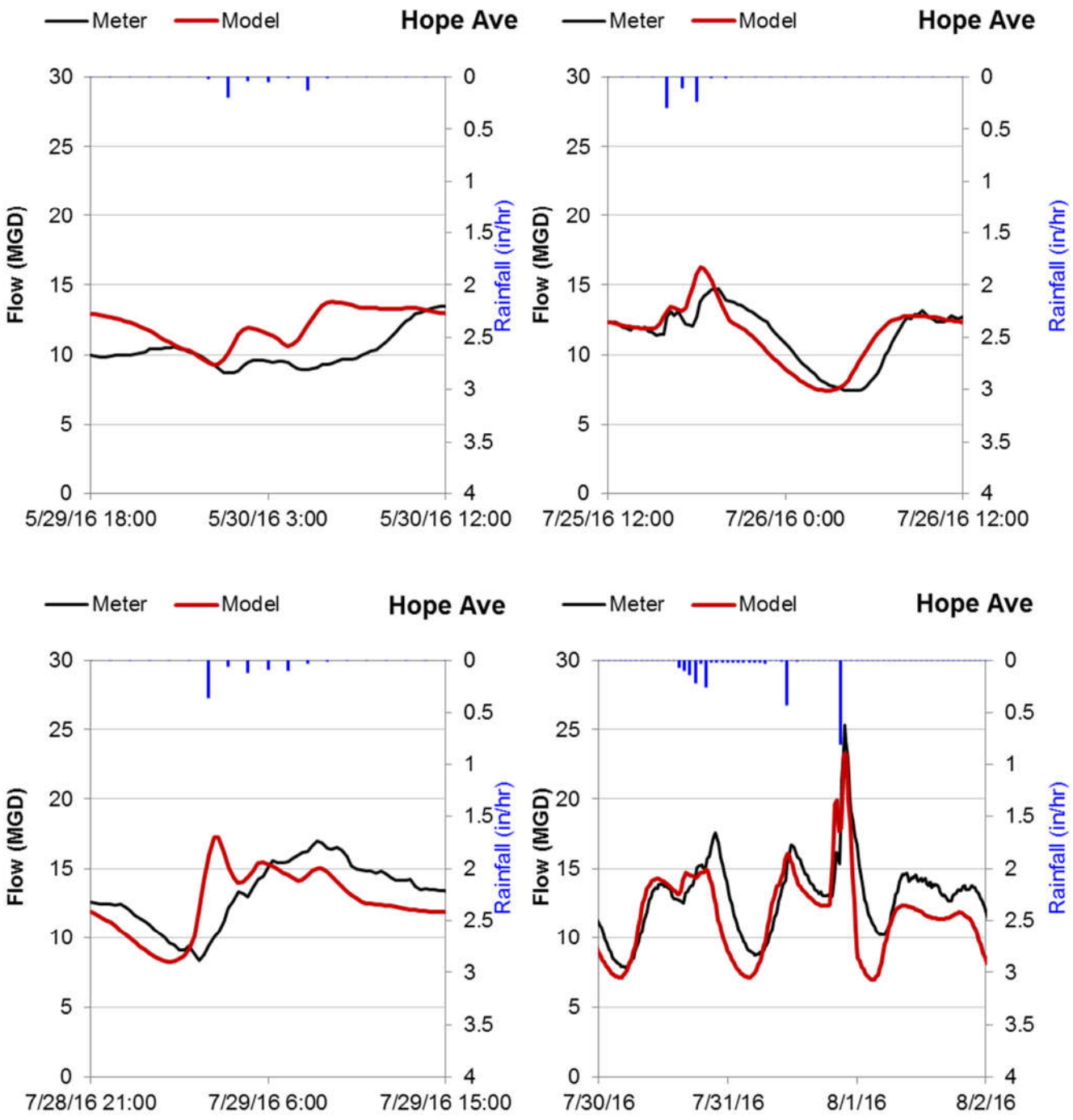


Figure I-38: Calibration Plot for Separate Area_Hope Ave_II

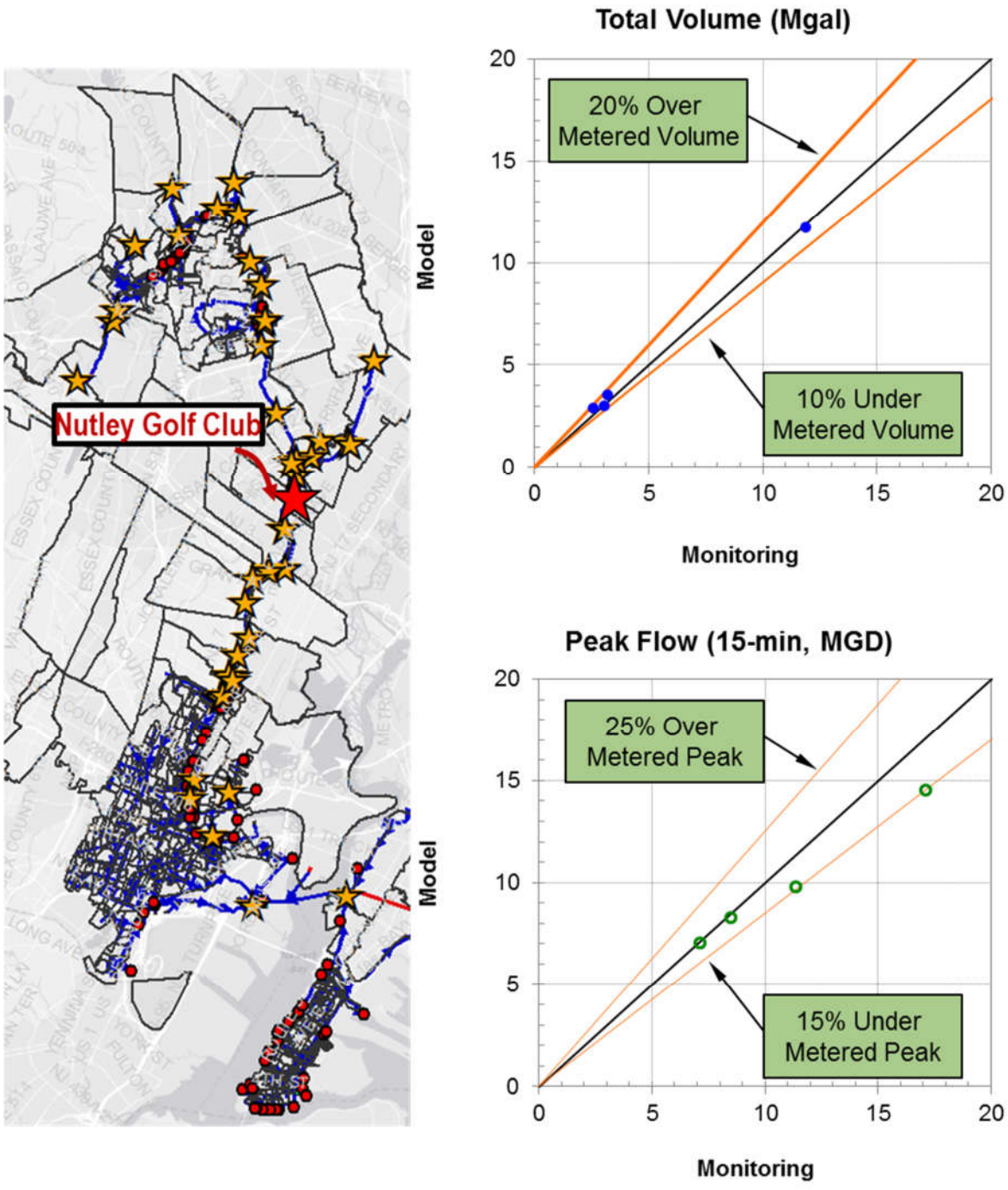


Figure I-39: Calibration Plot for Separate Area_Nutley Golf Club_I

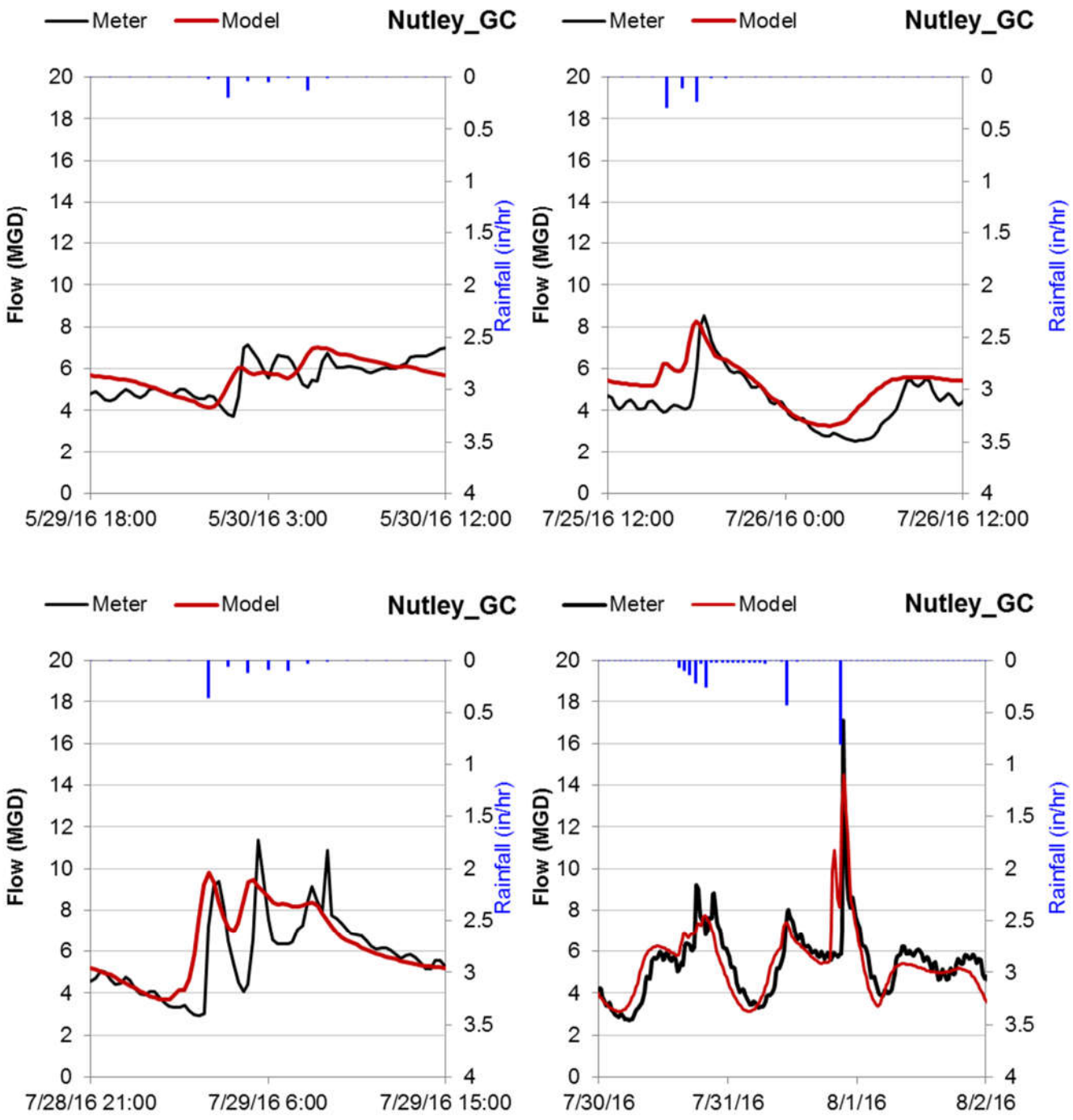


Figure I-40: Calibration Plot for Separate Area_Nutley Golf Club_II

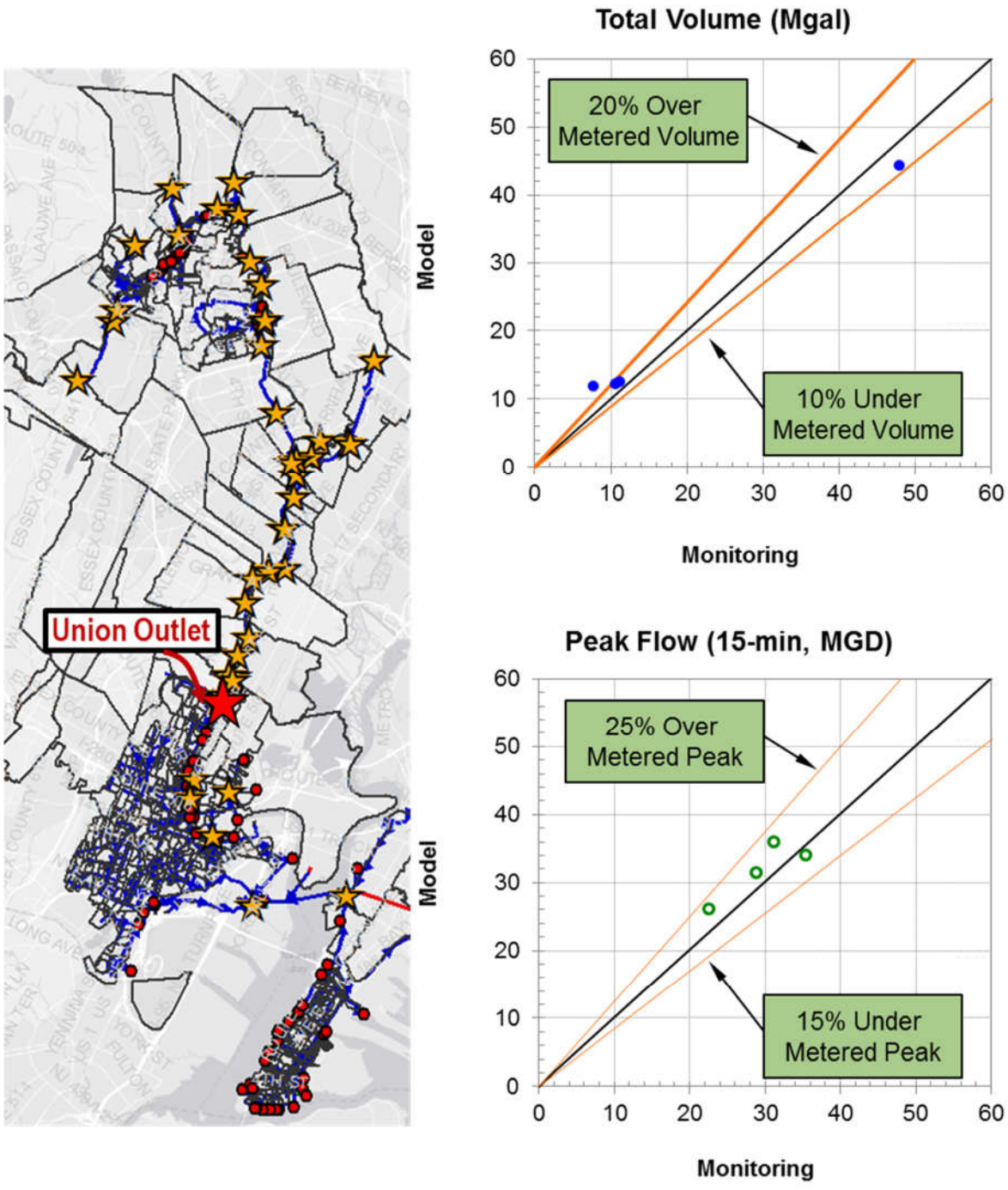


Figure I-41: Calibration Plot for Separate Area_Union Outlet_I

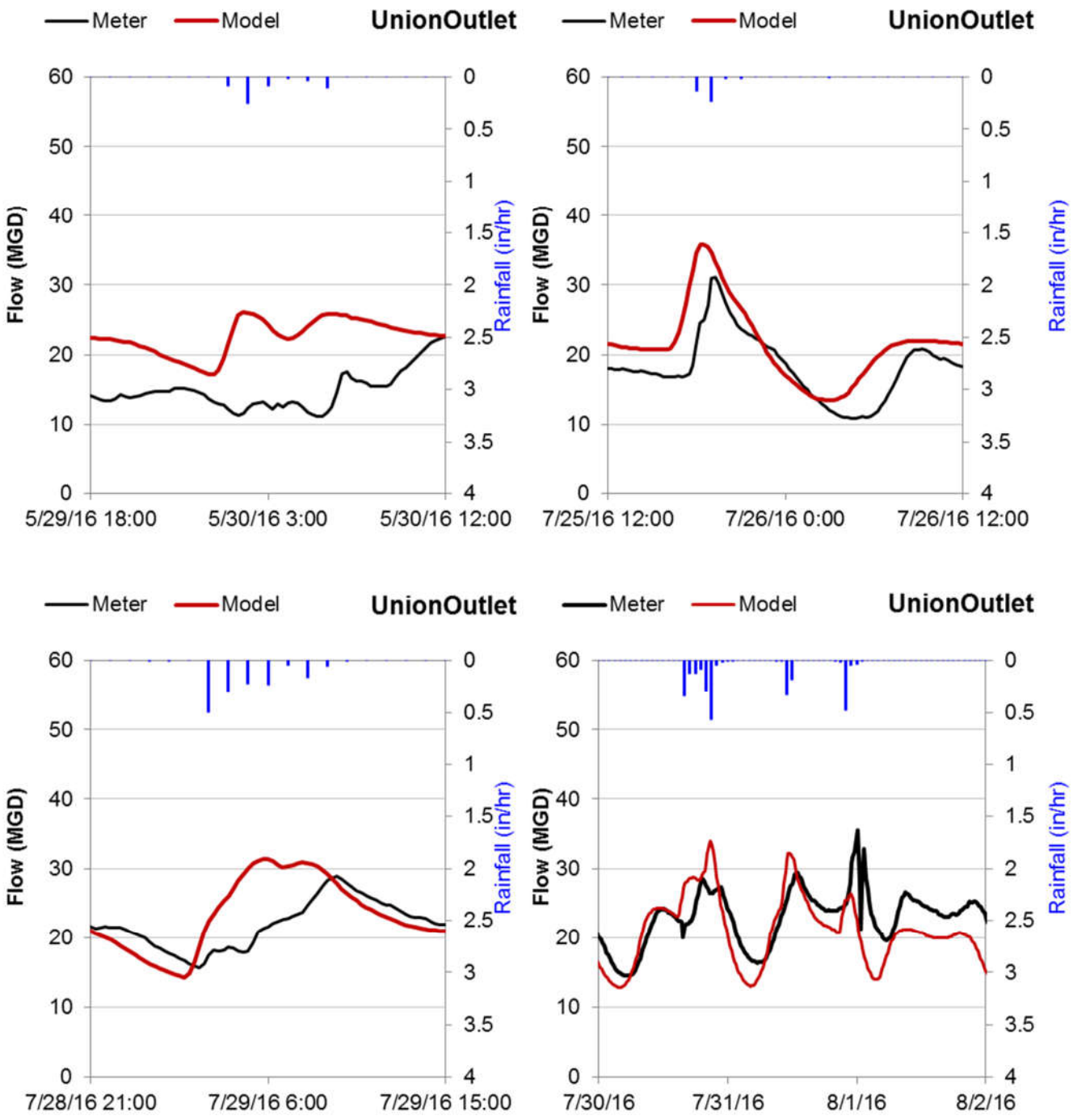


Figure I-42: Calibration Plot for Separate Area_Union Outlet_II

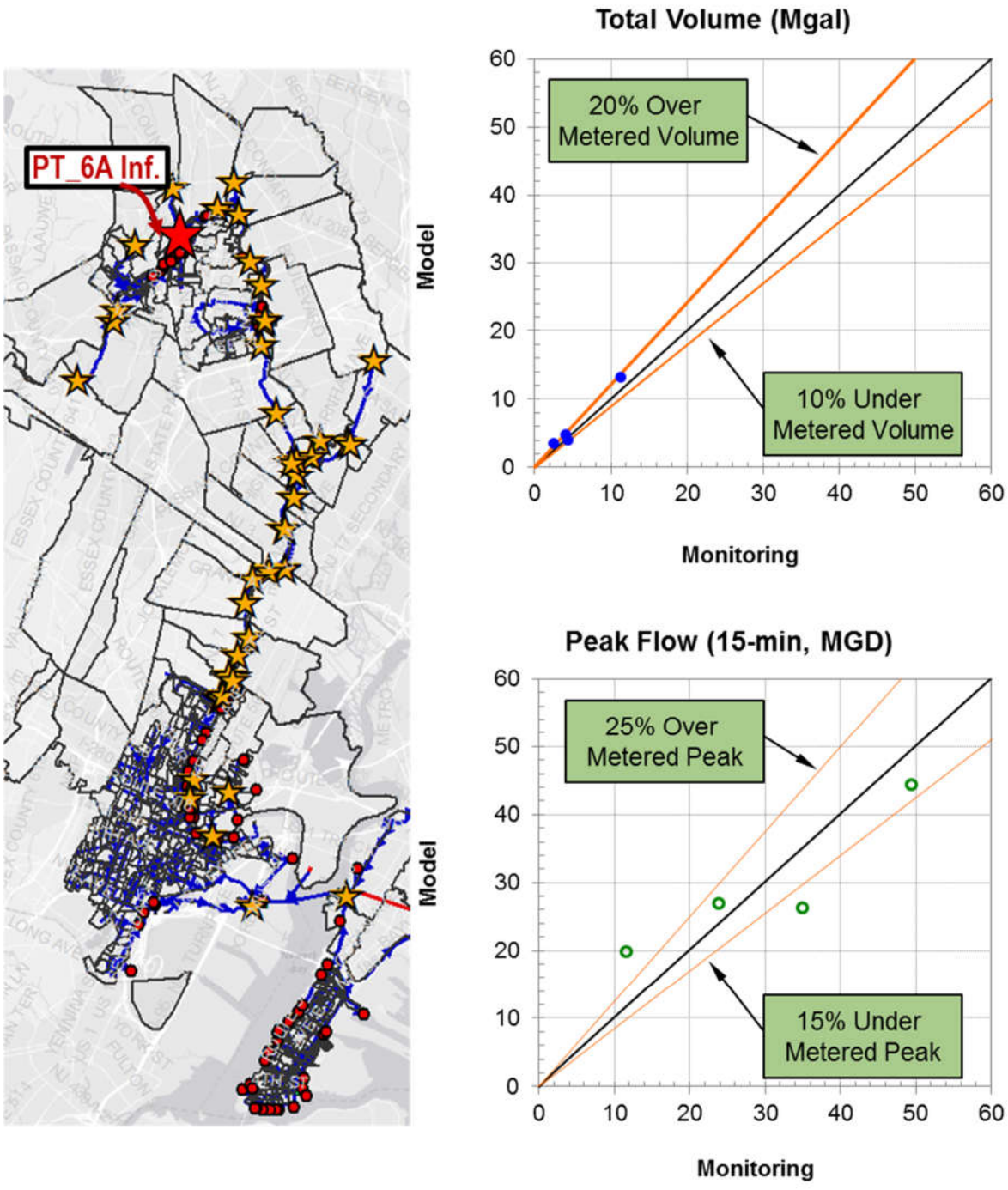


Figure I-43: Calibration Plot for Combined Area_Paterson 6A Influent_I

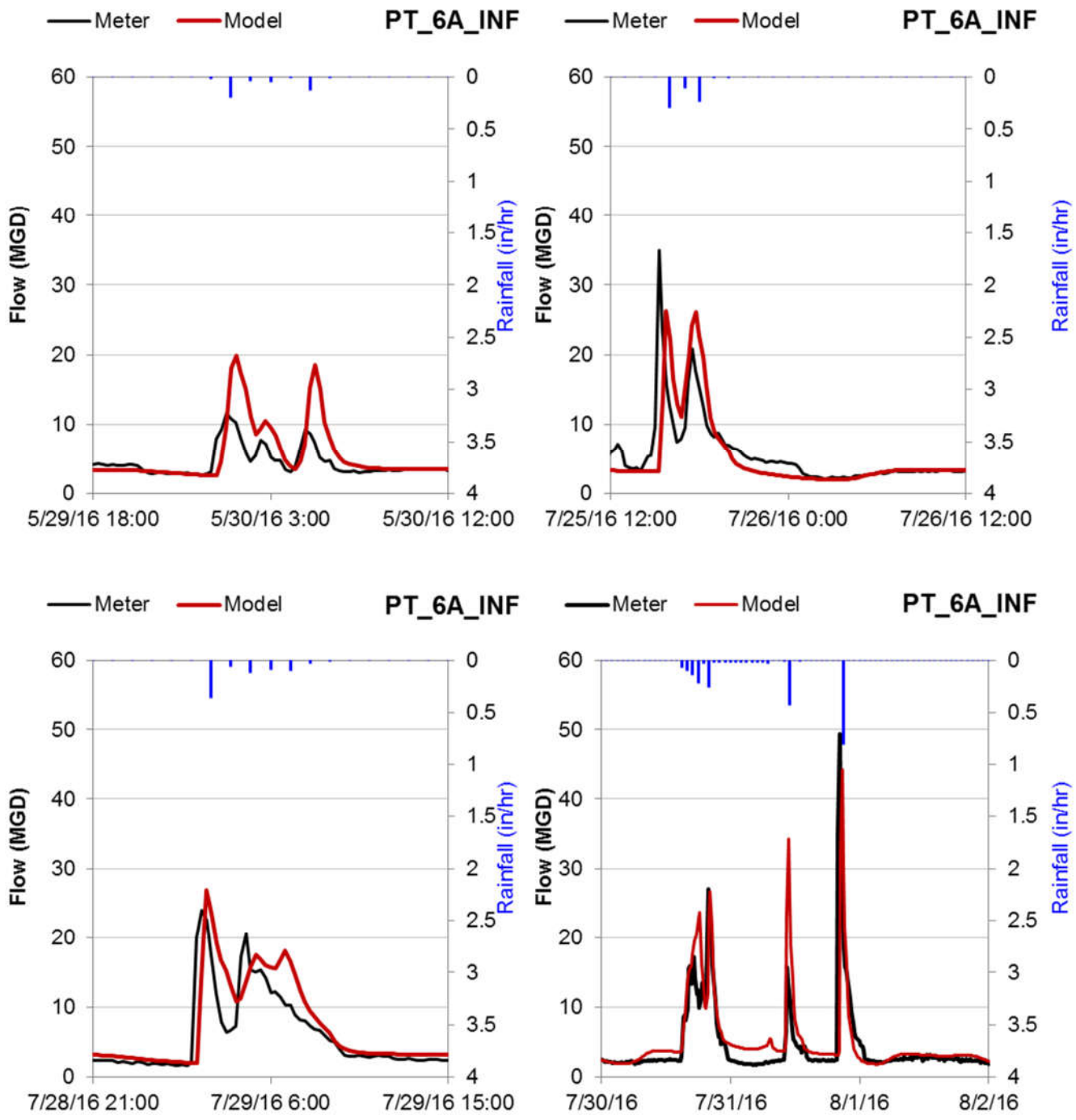


Figure I-44: Calibration Plot for Combined Area_Paterson 6A Influent_II

Note: The simulated volume and peak flow for the May 29, 2016 event exceeded the monitored values beyond the targeted calibration ranges. Adjusting the model parameters to provide a better fit for this event would have resulted in under simulation of the larger events.

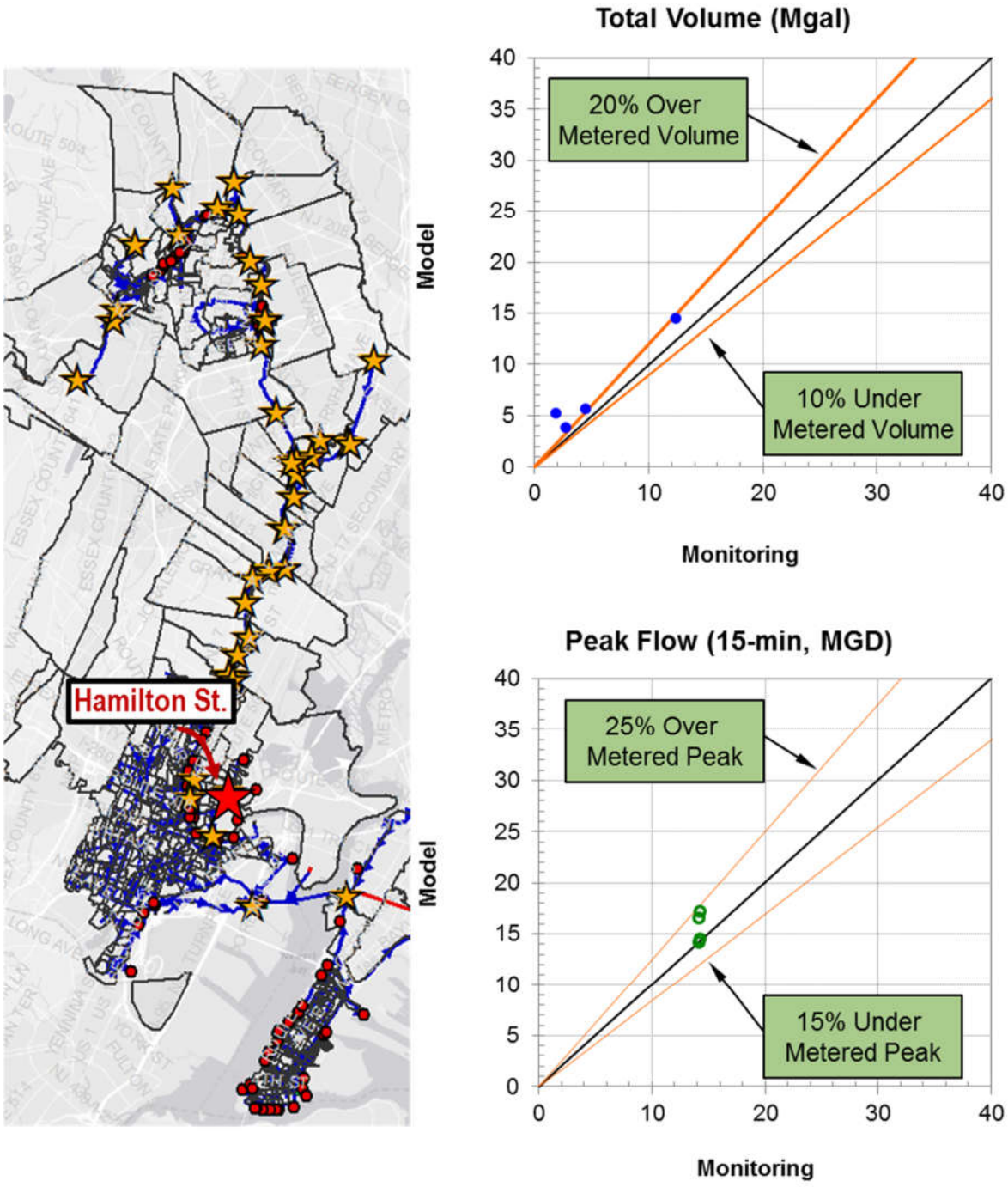


Figure I-45: Calibration Plot for Combined Area_ Hamilton St._I

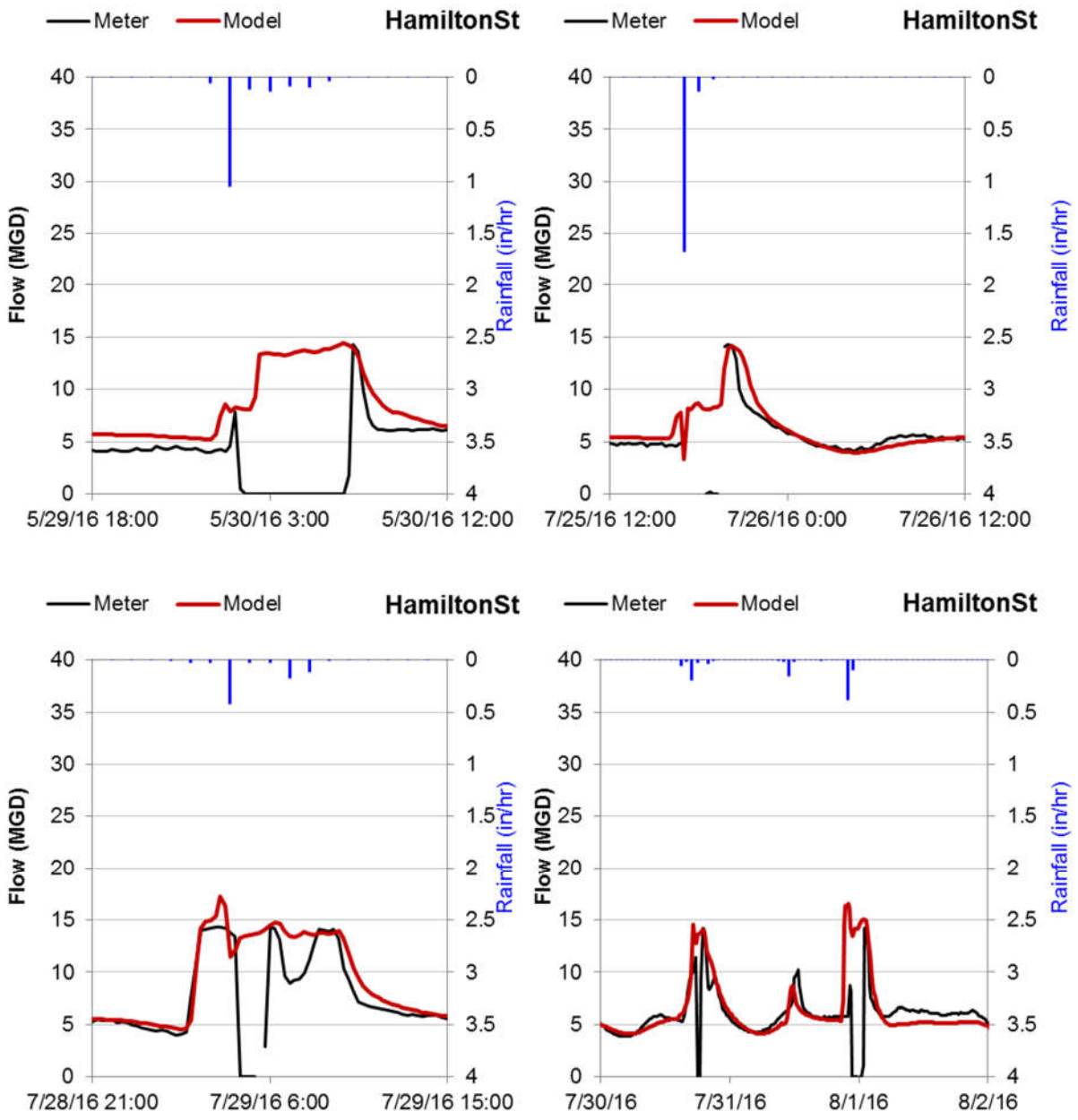


Figure I-46: Calibration Plot for Combined Area_ Hamilton St._II

Note:

1. Monitored data was not available for an extended portion of the May 29th, 2016 event. Therefore, this event was not considered during model calibration.
2. The monitored data for the July 29th, 2016 and July 30th, 2016 events also has some missing or periods of zero flow. The calibration effort for this site focused on matching peak flows and the hydrograph pattern.

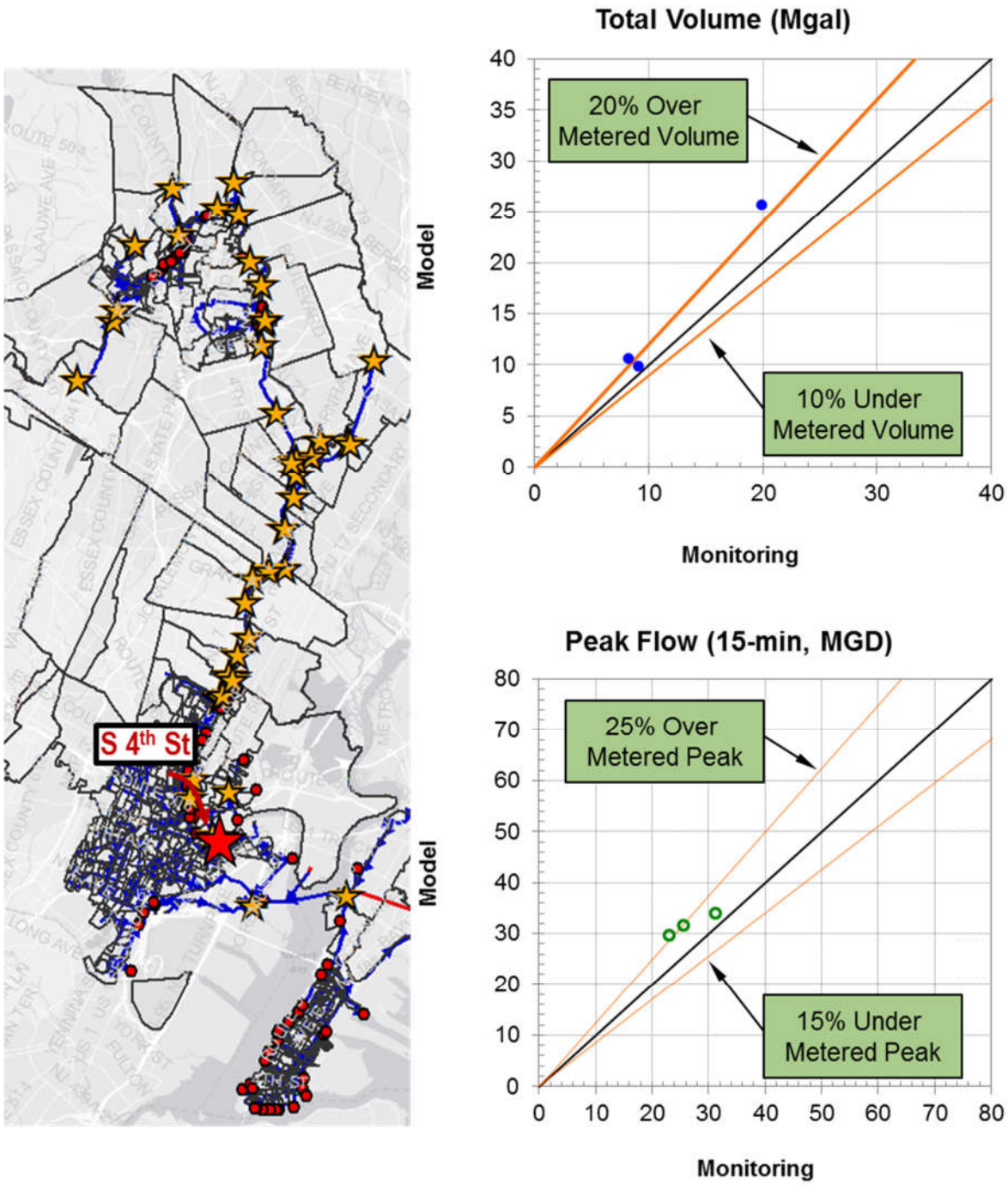


Figure I-47: Calibration Plot for Combined Area_ South 4th St._I

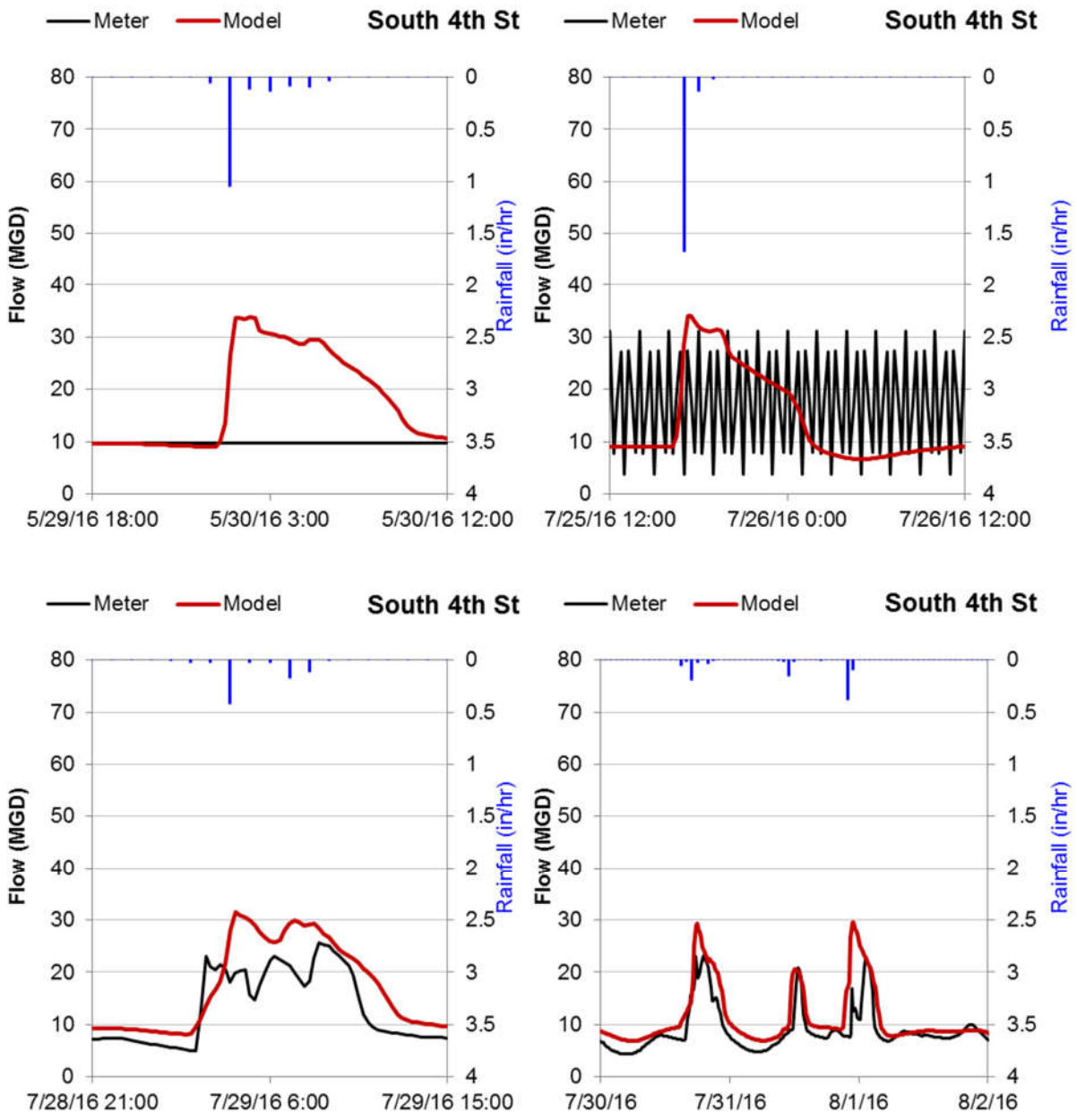


Figure I-48: Calibration Plot for Combined Area_ South 4th St._II

Note:

1. Accurate monitoring data was not available for the May 29th, 2016 event. Therefore, this event was not considered during model calibration and is not shown on the one-to-one plots.
2. Monitored data for Event July 25, 2016 has significant fluctuations and was therefore not considered during model calibration.

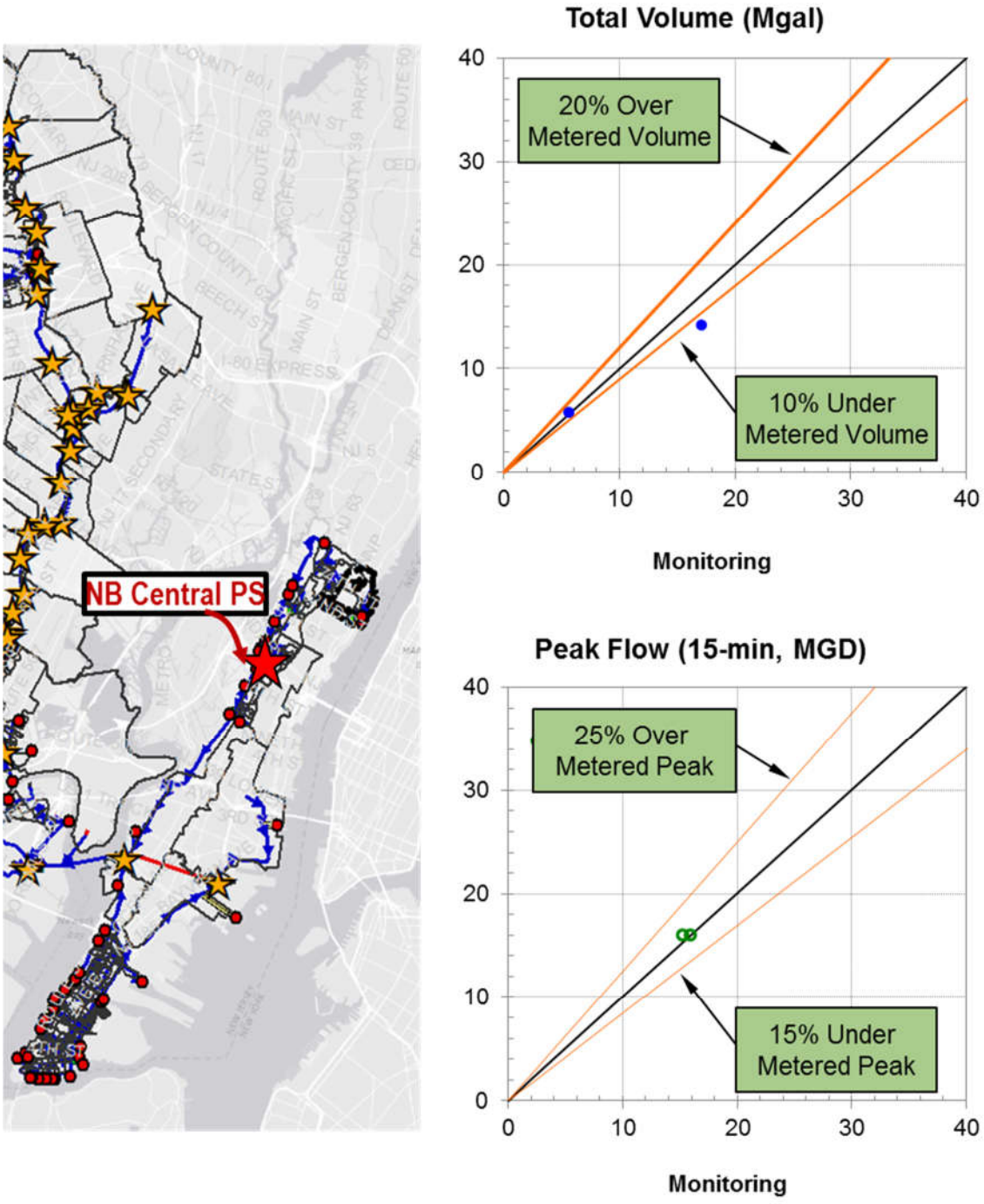


Figure I-49: Calibration Plot for Combined Area_ NB Central Pump Station I

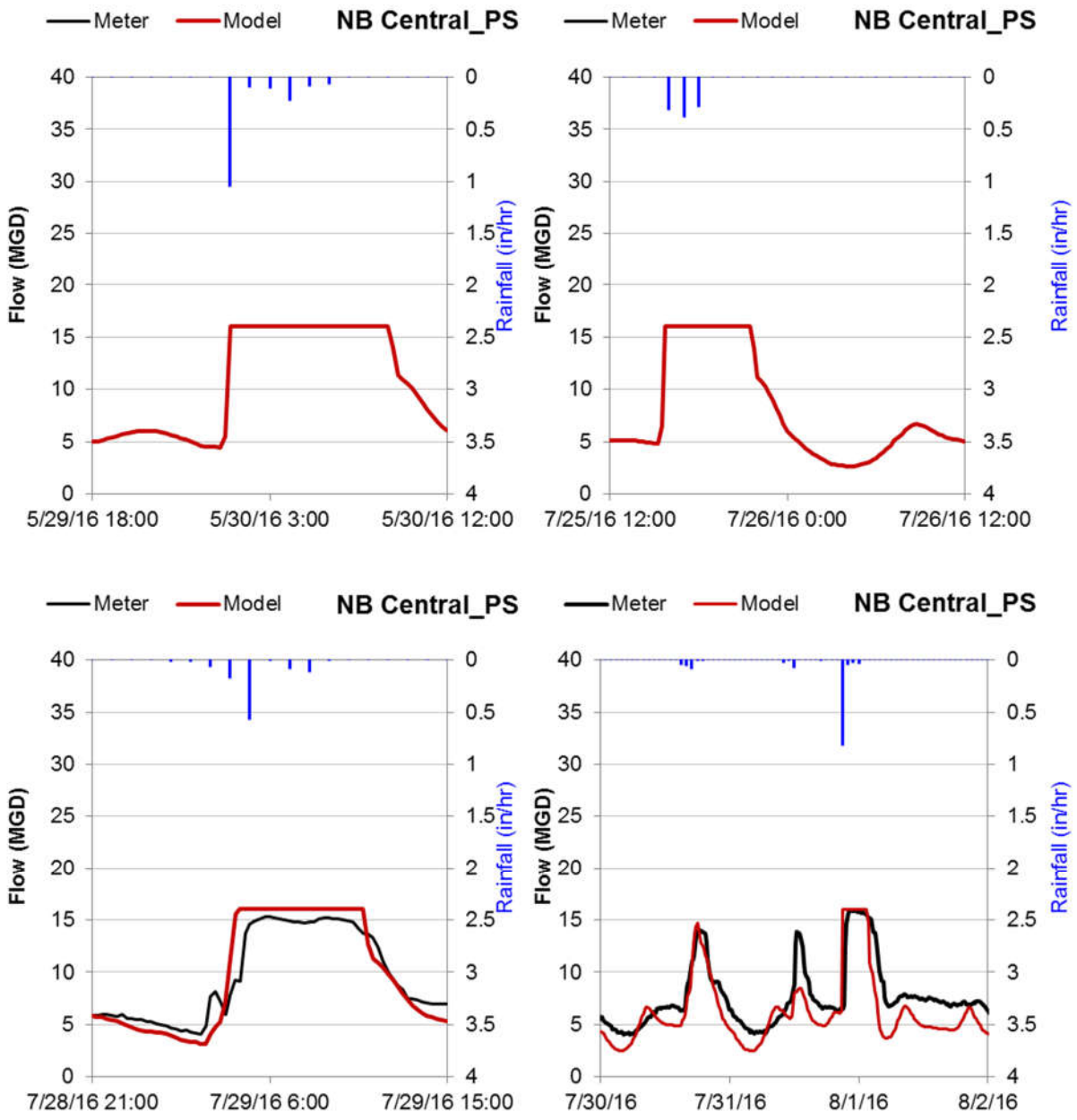


Figure I-50: Calibration Plot for Combined Area_ NB Central Pump Station_II

Note:

1. Monitored data was not available for the May 29th, 2016 and July 25, 2016 events. Therefore, these events were not considered during model calibration and are not shown on the one-to-one plots.

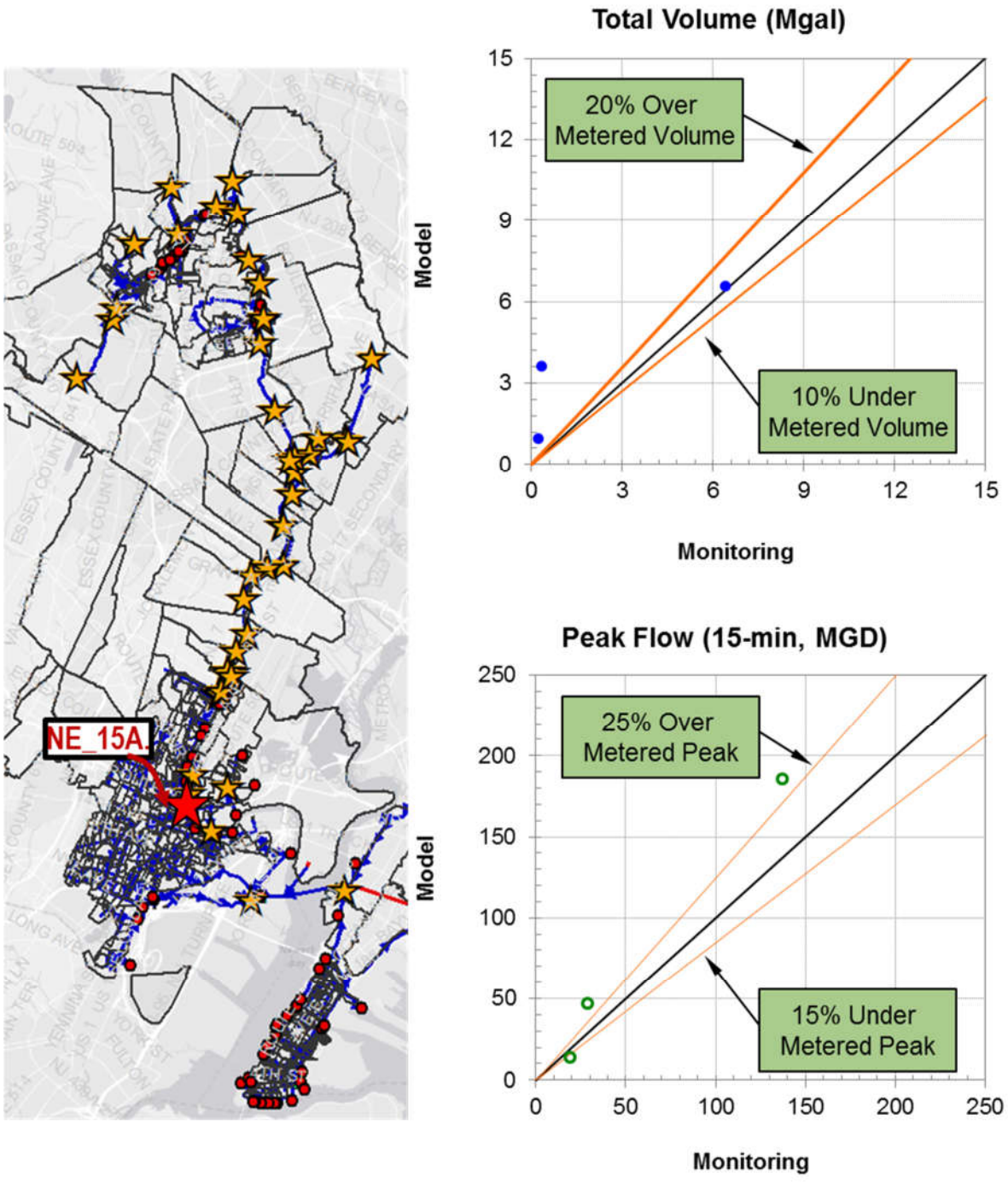


Figure I-51: Calibration Plot for CSO Overflow_ NE_15A_I

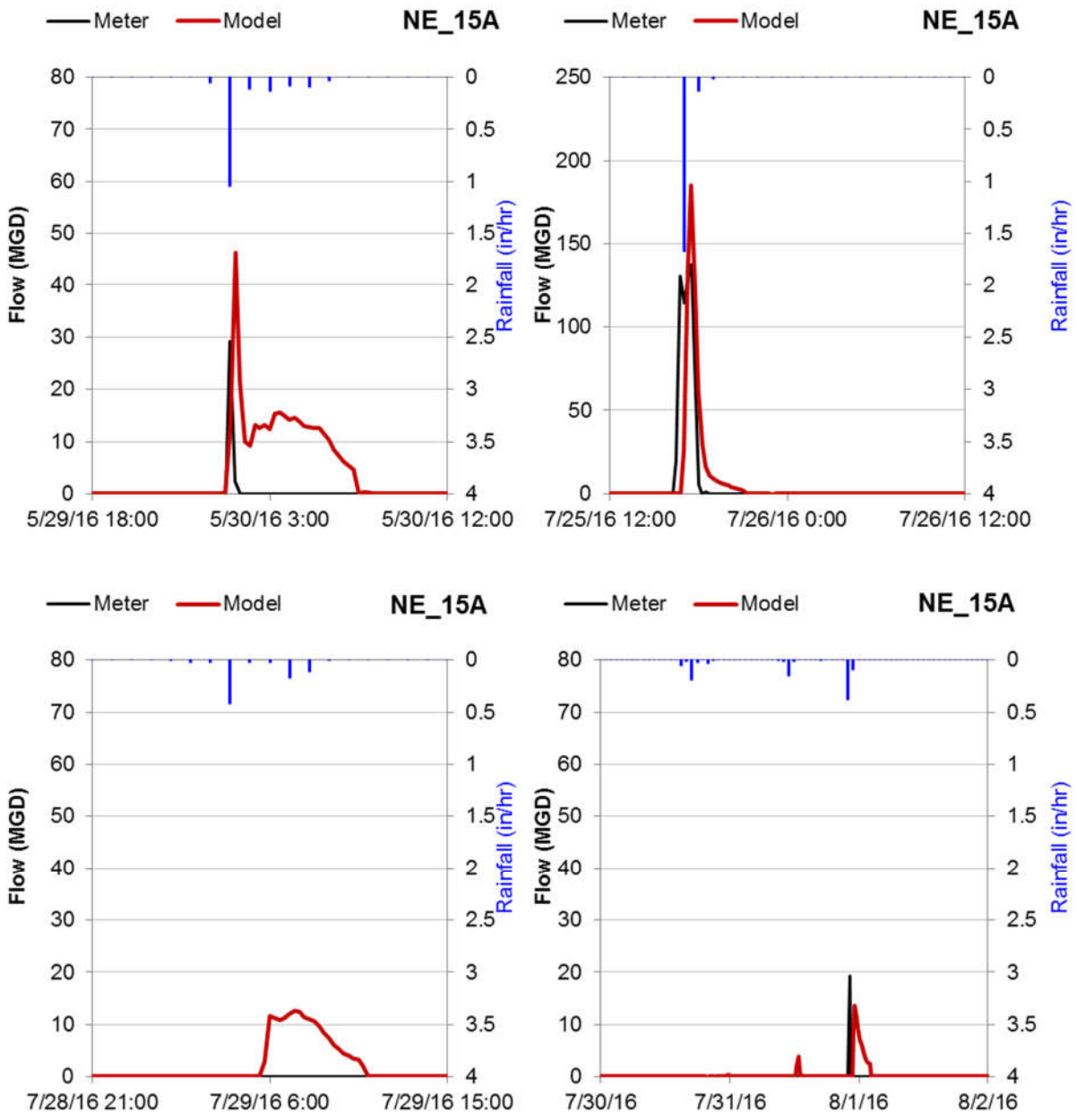


Figure I-52: Calibration Plot for CSO Overflow_ NE_15A_II

Note:

1. Calibration efforts were focused on the July 25, 2016 event because it had the most reasonable wet weather response to rainfall pattern and as the largest event has the most significant impact on overflows. The model is producing overflows during smaller precipitation increments which are not reflected in the monitoring data.

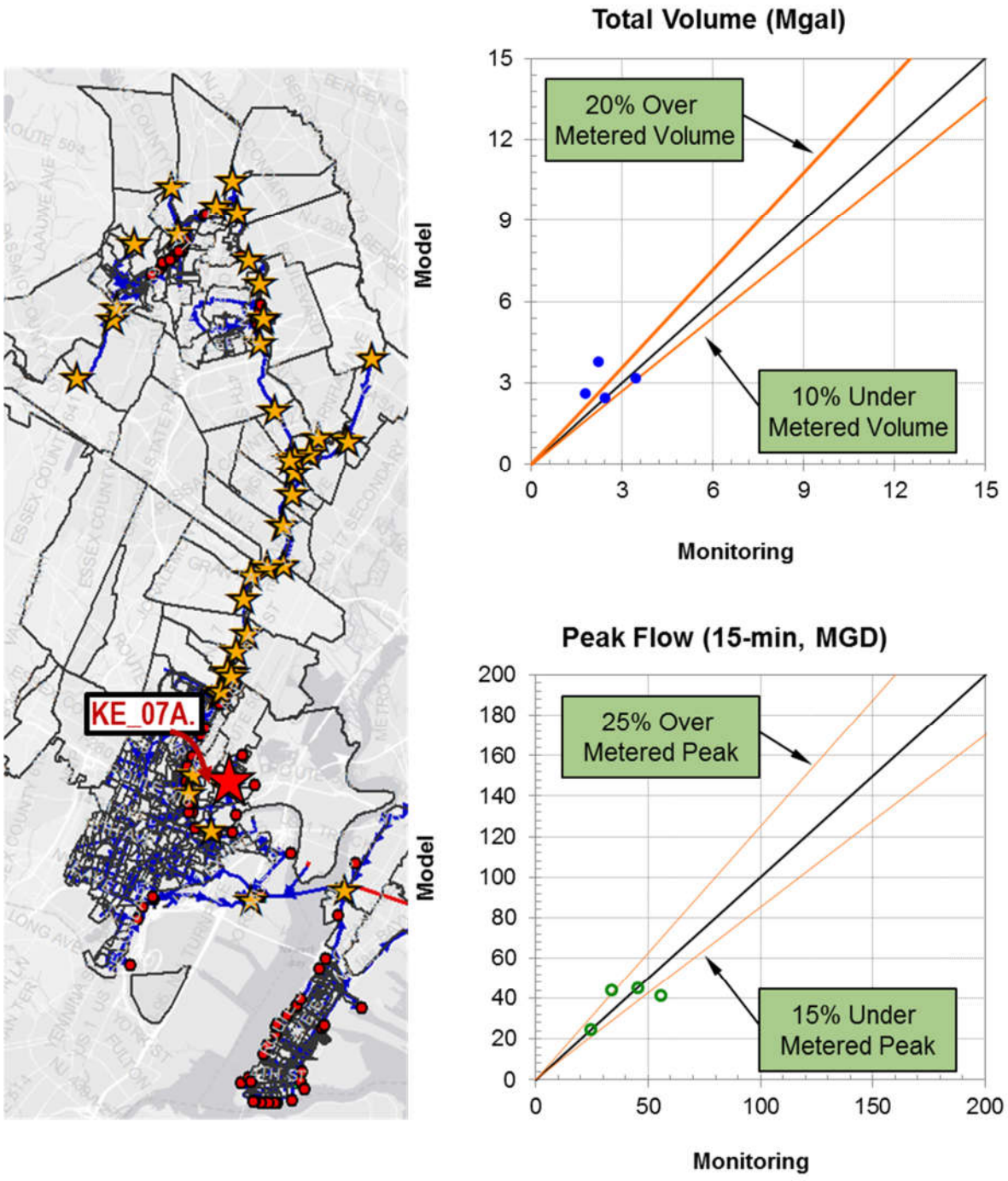


Figure I-53: Calibration Plot for CSO Overflow_ KE_07A_I

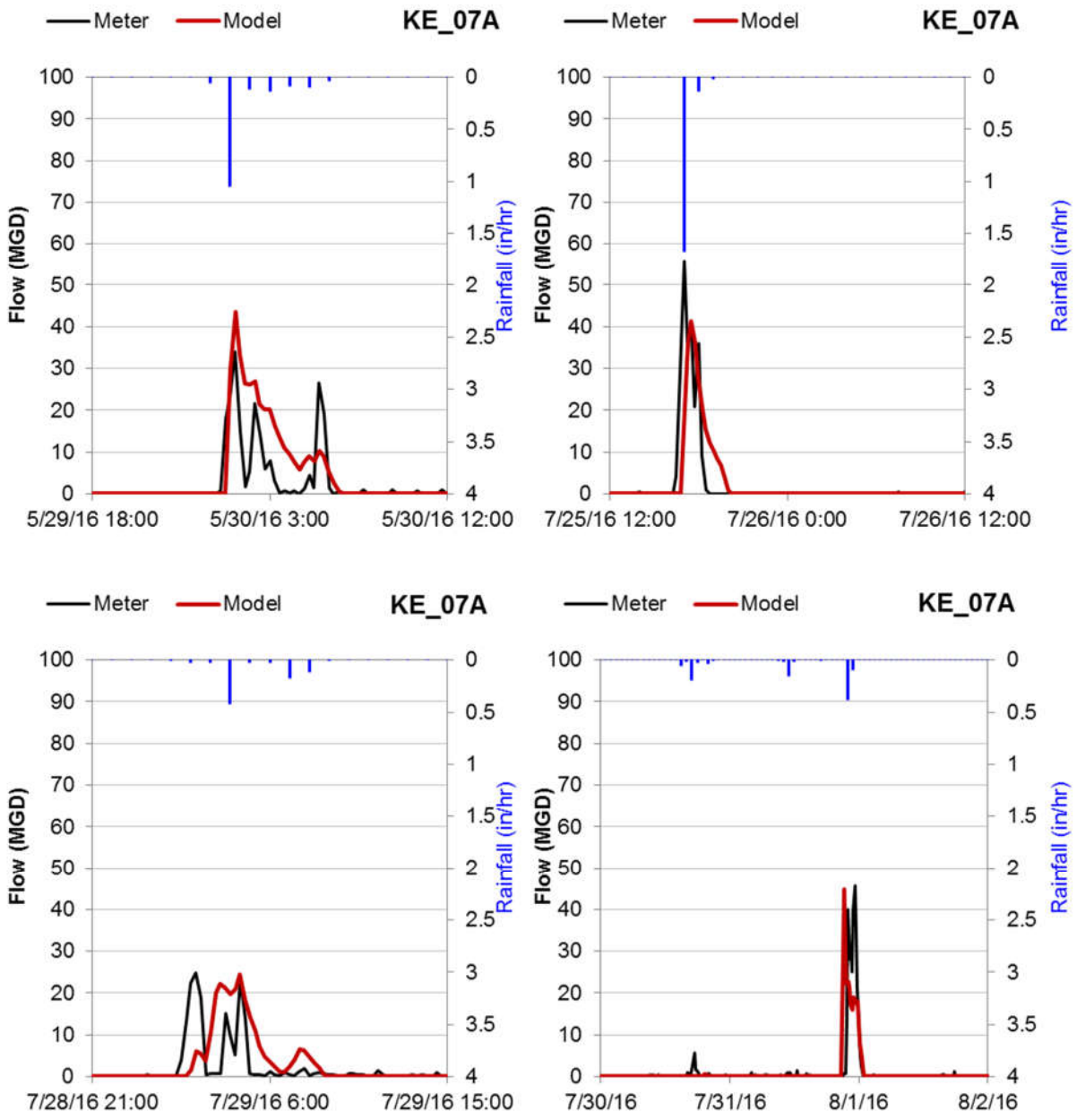


Figure I-54: Calibration Plot for CSO Overflow_ KE_07A_II

Note:

1. The calibration was performed to have a balanced calibration on both overflow volume and peak (both on conservative side).

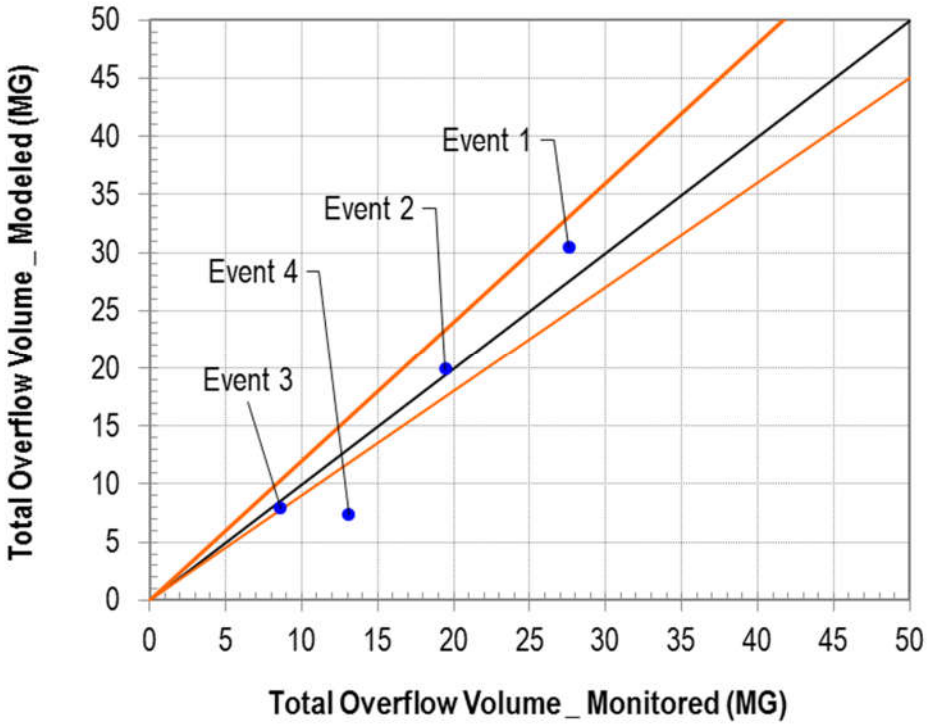


Figure I-55: System-Wide Overflow Volume Calibration

I.5.3 Model Calibration/Validation Result Statistics

The coefficient of determination, R^2, is used to evaluate the goodness-of-fit of modeled peak flow and event volume vs. the observed values. The calculation of R^2 is based on the most general definition detailed below.

- Assuming the observed data (event peak or event volume) is represented by a data set with n values marked $x_1, \ldots, x_n$, each associated with a modeled value $y_1, \ldots, y_n$.
- Define the *residuals* as $e_i = x_i - y_i$
- Define the mean of the observed data

$$x_0 = \frac{1}{n}\sum_{i=1}^{n} x_i$$

- The total sum of squares (proportional to the variance of the data) is:

$$SS_{tot} = \sum_{i=1}^{n} (x_i \quad x_0)^2$$

- The sum of squares of residuals (i.e. residual sum of squares) is

$$SS_{res} = \sum_{i=1}^{n} (x_i \quad y_i)^2 = \sum_{i=1}^{n} {e_i}^2$$

- The definition of R^2 is

$$R^2 = 1 \quad \frac{SS_{res}}{SS_{tot}}$$

The R^2 defined above is also known as the Nash-Sutcliffe Efficiency (NSE). It is an appropriate statistical measure of the goodness-of-fit for model calibration/validation. It has been widely applied in hydrologic models (Moriasi et al., 2007) and thus can be used to assess the event predictions of the hydrologic component of the model. Although interpretation of NSE values may be subjective, model calibration is generally considered satisfactory for values greater than 0.5, with values greater than 0.75 being considered very good (Moriasi et al., 2007).

Figure I-56 shows modeled vs. observed event peak of all calibrated flow meters for individual events. The R^2 values was calculated for individual event and shown on the figure, they are 0.945, 0.885, 0.947, and 0.879 for Event 1, Event 2, Event 3, and Event 4 respectively.

Figure I-57 shows modeled vs. observed event volume of all calibrated flow meters for individual events. The R^2 values are 0.996, 0.994, 0.992, and 0.995 for Event 1, Event 2, Event 3, and Event 4 respectively.

Figure I-58 shows modeled vs. observed event volume (and peak) of all calibrated flow meters for all four events. The overall R^2 values are 0.909 for event peak and 0.994 for event volume. This is consistent with individual event R^2.

The R^2 of the event volume is closer to 1 than the R^2 of the event peak for both individual event statistics and entire event statistics, indicating that the model has a more satisfied prediction of the wet weather event volume than the event peak flow. All the R^2 values are greater than 0.85, which means the calibrated model can predict wet weather flows in a great agreement with the metered data for the PVSC sewer collection system.

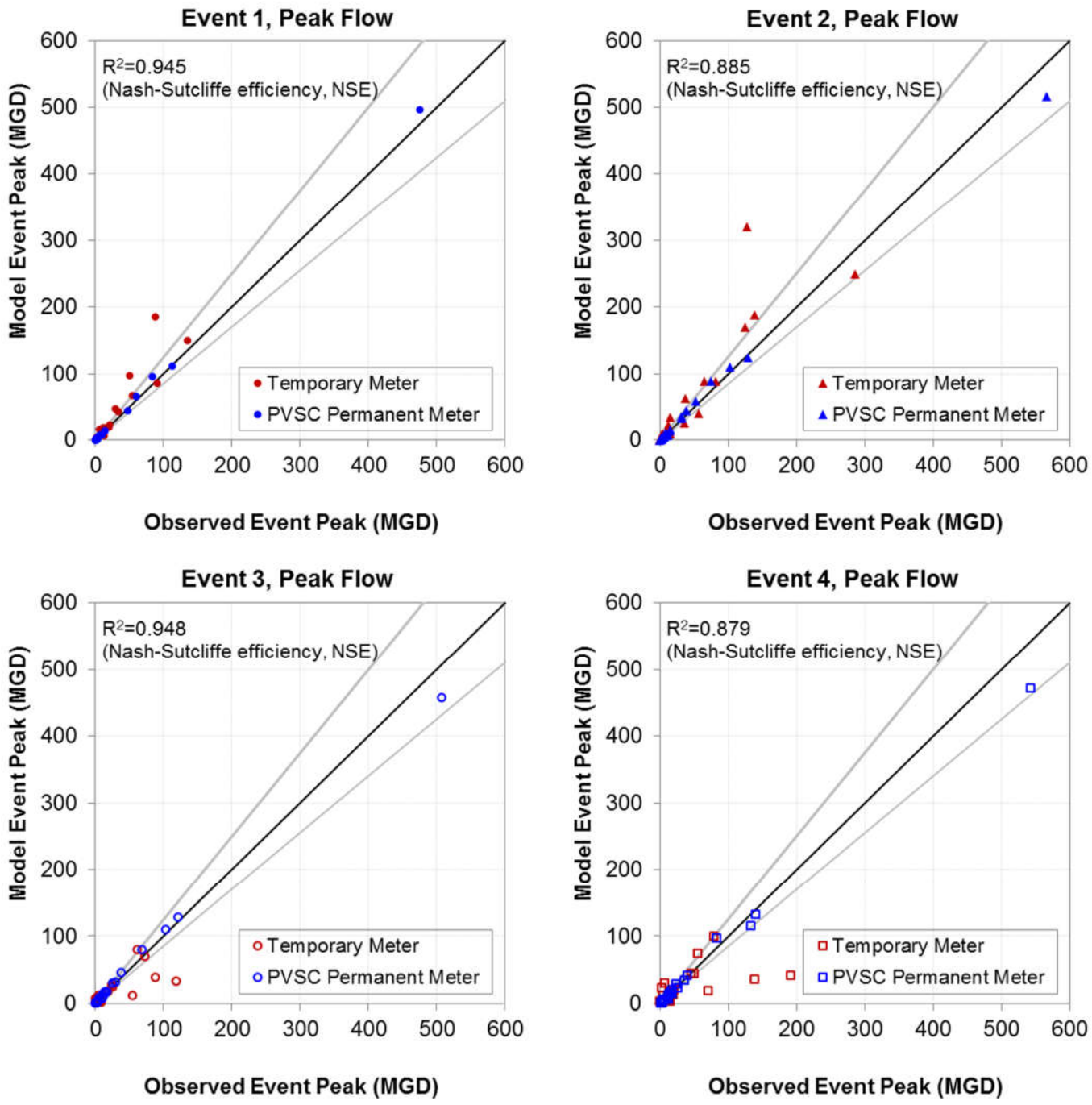


Figure I-56: Modeled vs. Observed Flow Peak for Individual Events

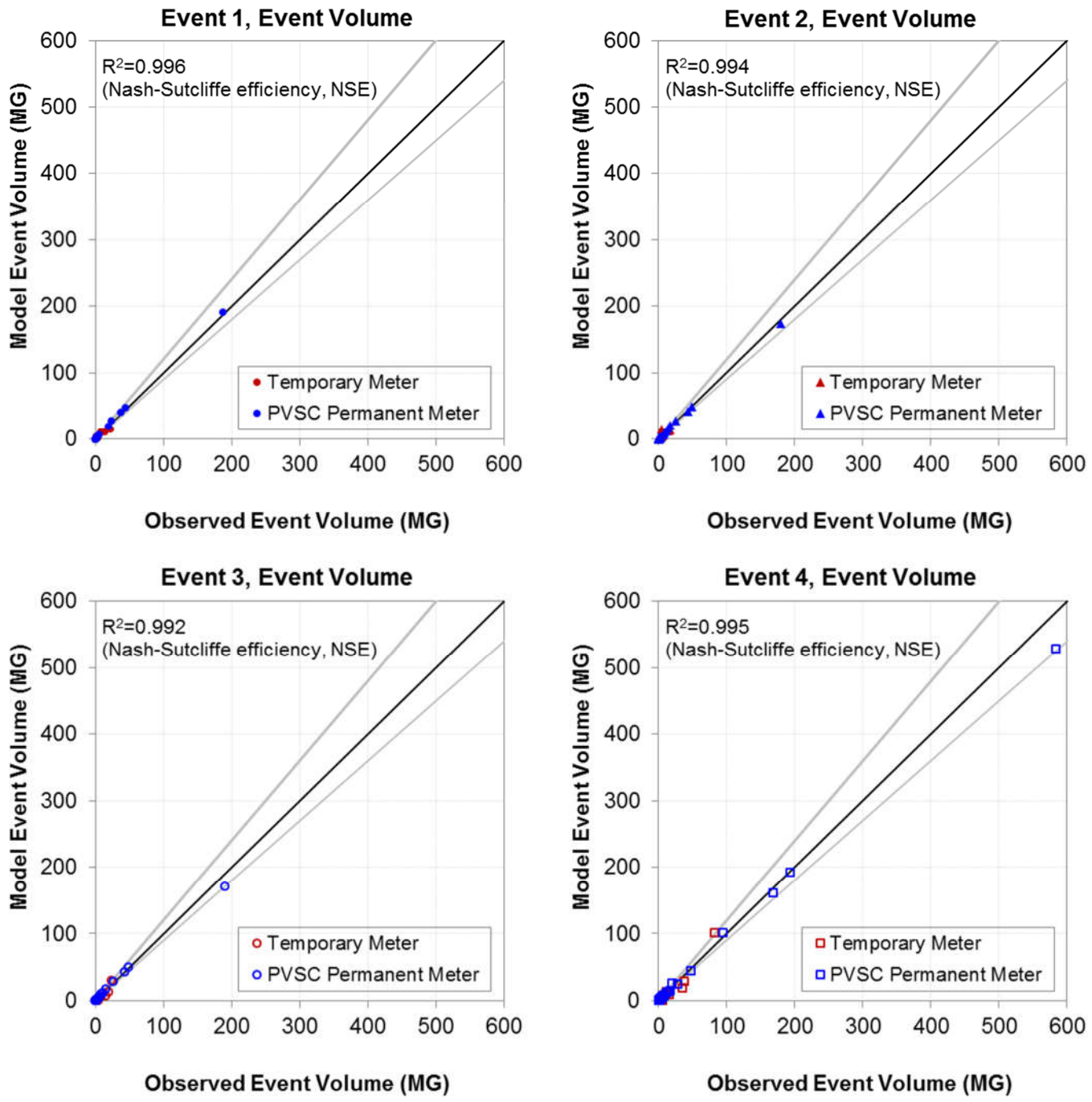


Figure I-57: Modeled vs. Observed Flow Volume for Individual Events

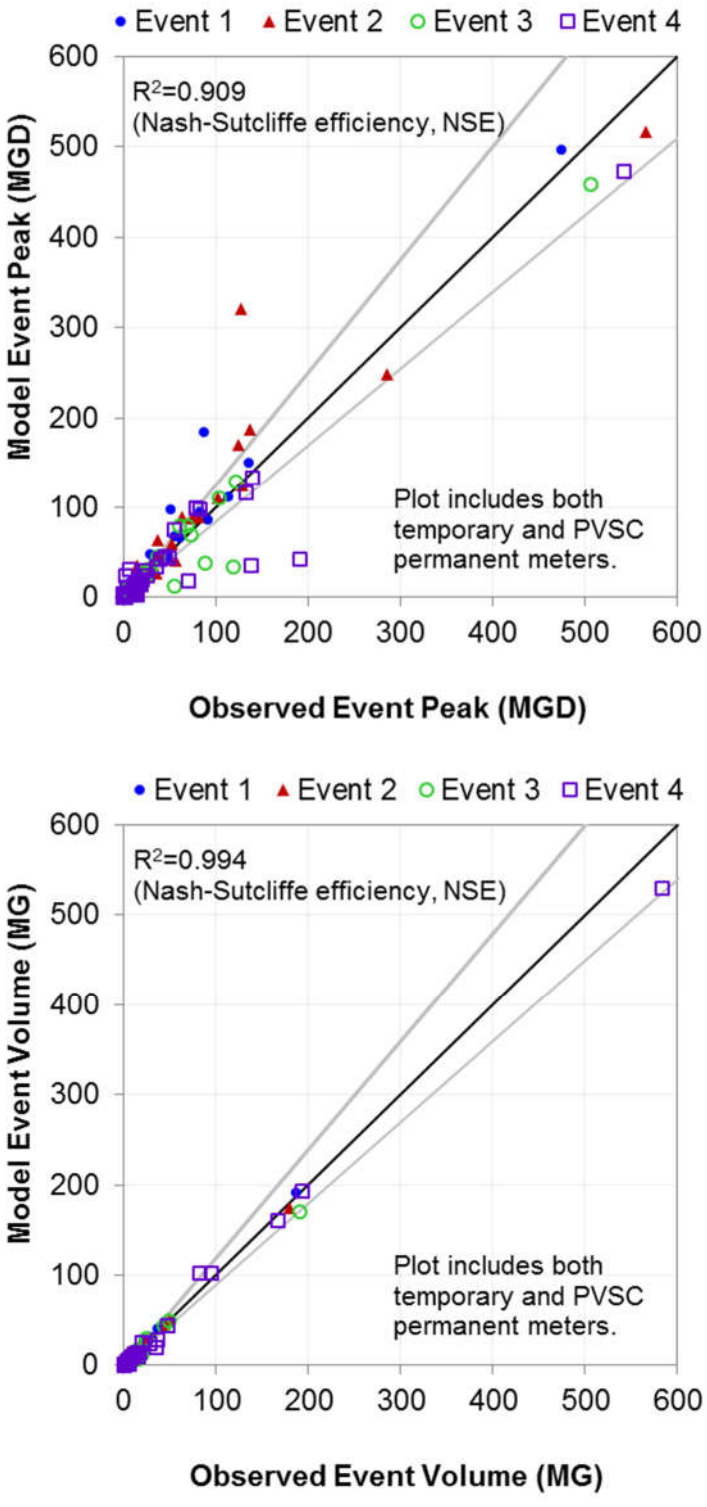


Figure I-58: Modeled vs. Observed Flow Peak and Volume for All Four Events

I.6 H&H MODEL RESULTS

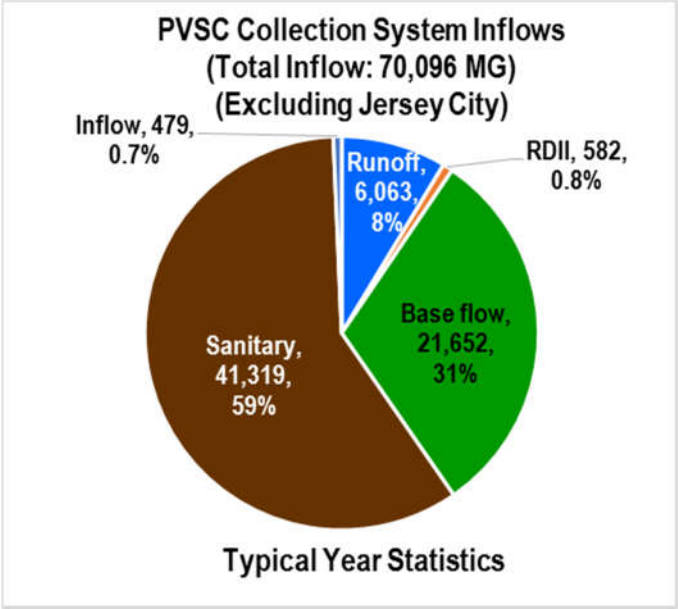
The calibrated model was run using 2004 rainfall and tides to evaluate collection system performance under existing conditions.

Five-minute precipitation data was developed from 1-minute NOAA ASOS (Automated Surface Observing System, National Centers for Environmental Information) for Newark. Minor gaps in the 5-minute data were filled using corresponding hourly and daily data for the airport. The same precipitation data was applied uniformly system wide.

Model results were extracted for all CSO overflow points and for WRRF and other community effluent flows at 5-minute intervals. The data were converted to 15-minute intervals for overflow event statistics analysis. A 24-hour inter-event-time was used for overflow event definition.

The following figures present a partitioning of the simulated volumes in the typical year. ~~Jersey City flows and runoff have been included in the typical year statics.~~

- **Figure I-59** ~~**Figure I-62**~~ presents the total collection system inflows. Approximately ~~12~~9% of the total influent volume is attributed to rainfall runoff and RDII, with the remainder coming from sanitary and baseflow.
- **Figure I-60** ~~**Figure I-63**~~ presents the runoff and losses in the combined sewer areas. Approximately ~~32~~27% of the precipitation volume over the combined sewered portions of the model reaches the collection system as runoff. The remainder is lost to hydrologic process such as evaporation and infiltration.~~.~~
- **Figure I-61** ~~**Figure I-64**~~ presents the total outflow from the model. Approximately 9~~5~~6% of the flow reaches the plant, with ~~5~~4% discharging through CSOs.
-



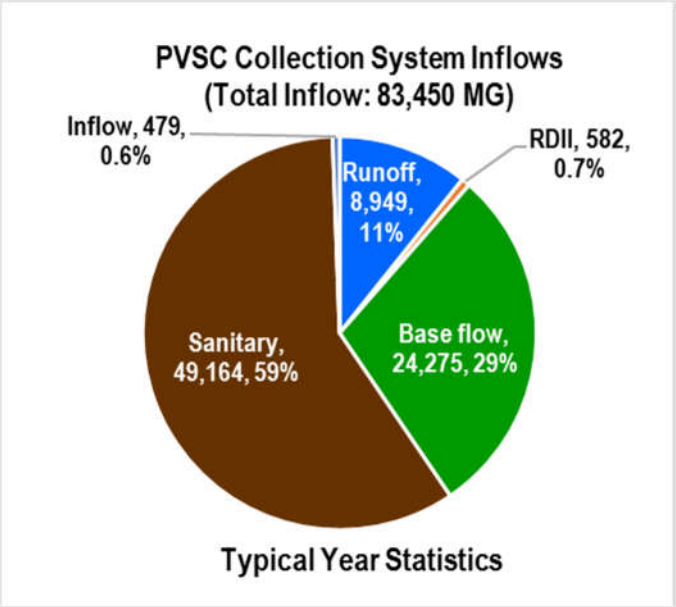
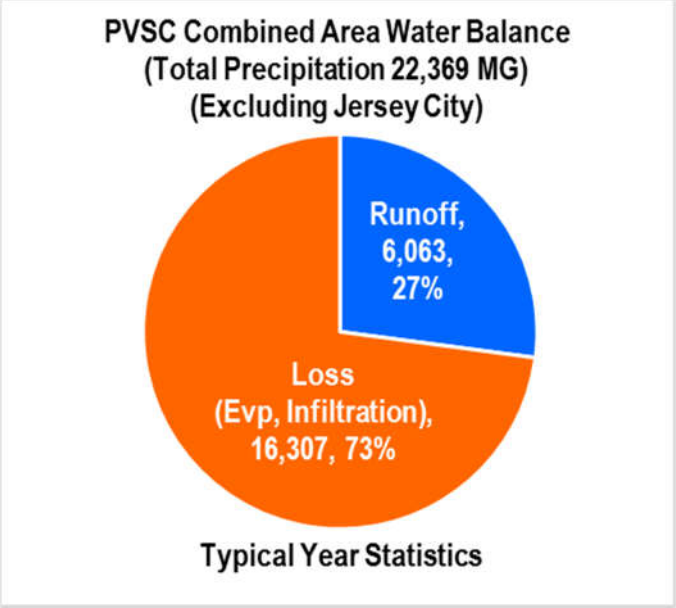


Figure I-59: Typical Year Collection System Inflows



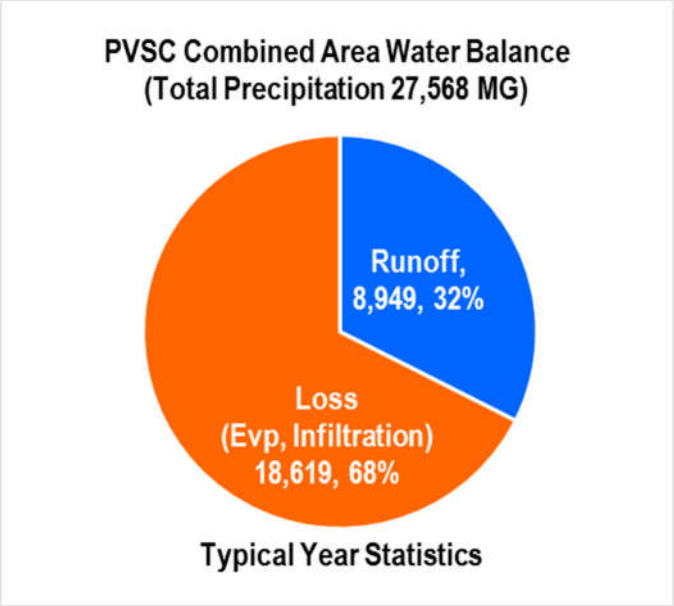
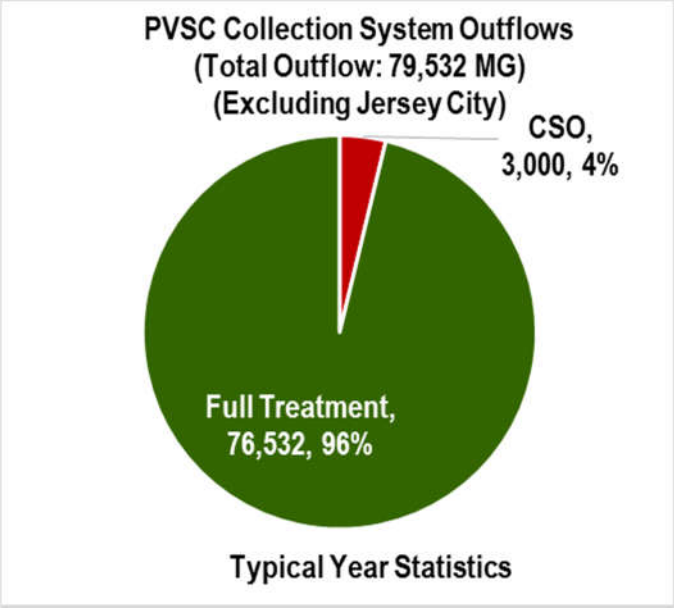


Figure I-60: Typical Year Runoff and Losses



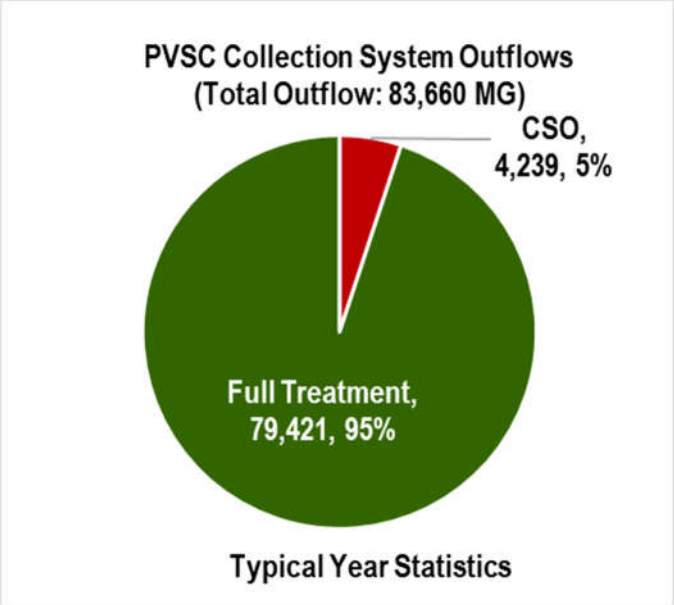
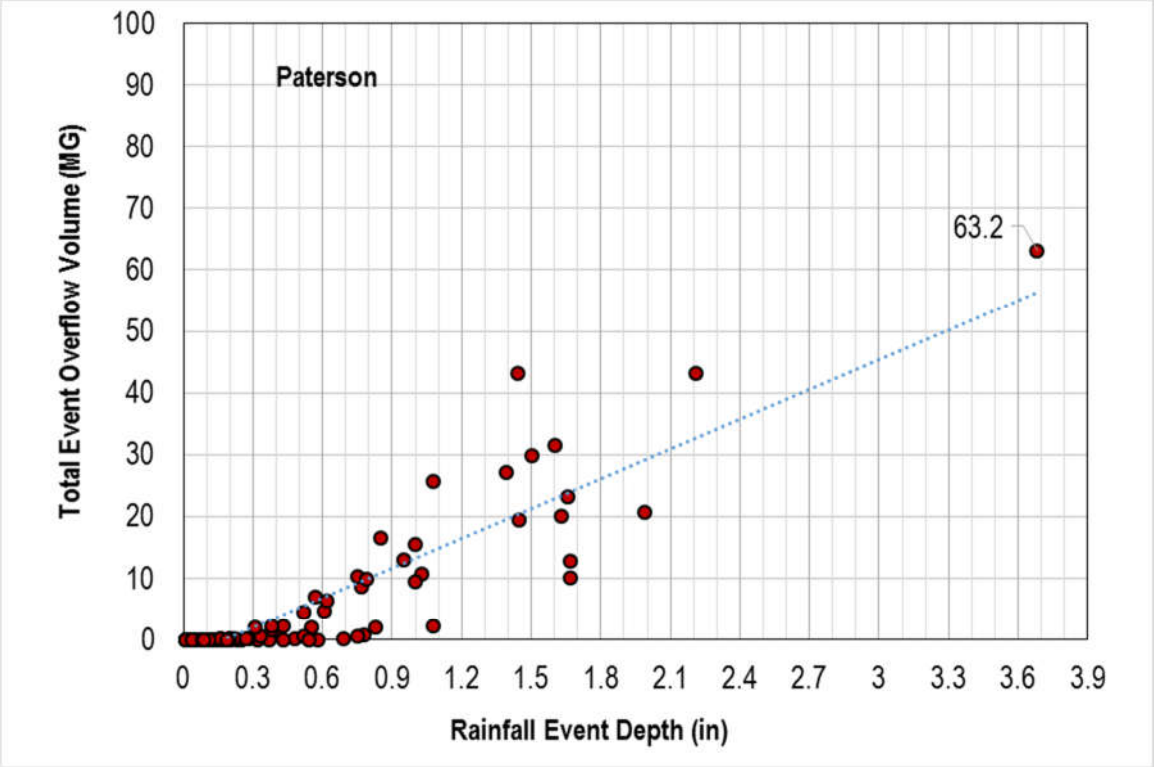


Figure I-61: Typical Year Total Outflows

I.6.1 Characterization of System Performance

There are 97 rainfall events in the typical year (IET 12 hours), including events with a total rainfall depth less than 0.1 inch. Overflows at each CSO outfall were analyzed for event overflow volume for each rainfall event. Community overflow volume was then estimated by summing CSO event volumes from all CSOs located within the same community. For example, Paterson's total overflow volume is 63 million gallons (from all 23 CSO outfalls in Paterson) for the 3.68-in storm event on Sep 28, 2004. The effects of the same size storm event on different communities are different, this is reasonable because each community has different regulator configurations, system storage capacities, and wet weather operation rules. However, most of the PVSC combined communities start to experience CSO overflow occurrences in a rainfall depth range of 0.2 to 0.3 inches.

- Correlations between community CSO volume and rainfall depth are shown in **Figure I-62** for Paterson and Newark. A rainfall depth of 0.2 inch will trigger overflows in Paterson and Newark.
- Correlations between community CSO volume and rainfall depth are shown in **Figure I-63** for Kearny and Harrison. A rainfall depth of 0.15 inch will trigger overflows in Kearny and a rainfall depth of 0.2 inch will trigger overflows in Harrison.
- Correlations between community CSO volume and rainfall depth are shown in **Figure I-64** for East Newark. A rainfall depth of 0.3 inch will trigger overflows in East Newark.
- Correlations between community CSO volume and rainfall depth are shown in **Figure I-65** for Bayonne and North Bergen. A rainfall depth of 0.15 inch will trigger overflows in Bayonne and a rainfall depth of 0.2 inch will trigger overflows in North Bergen.



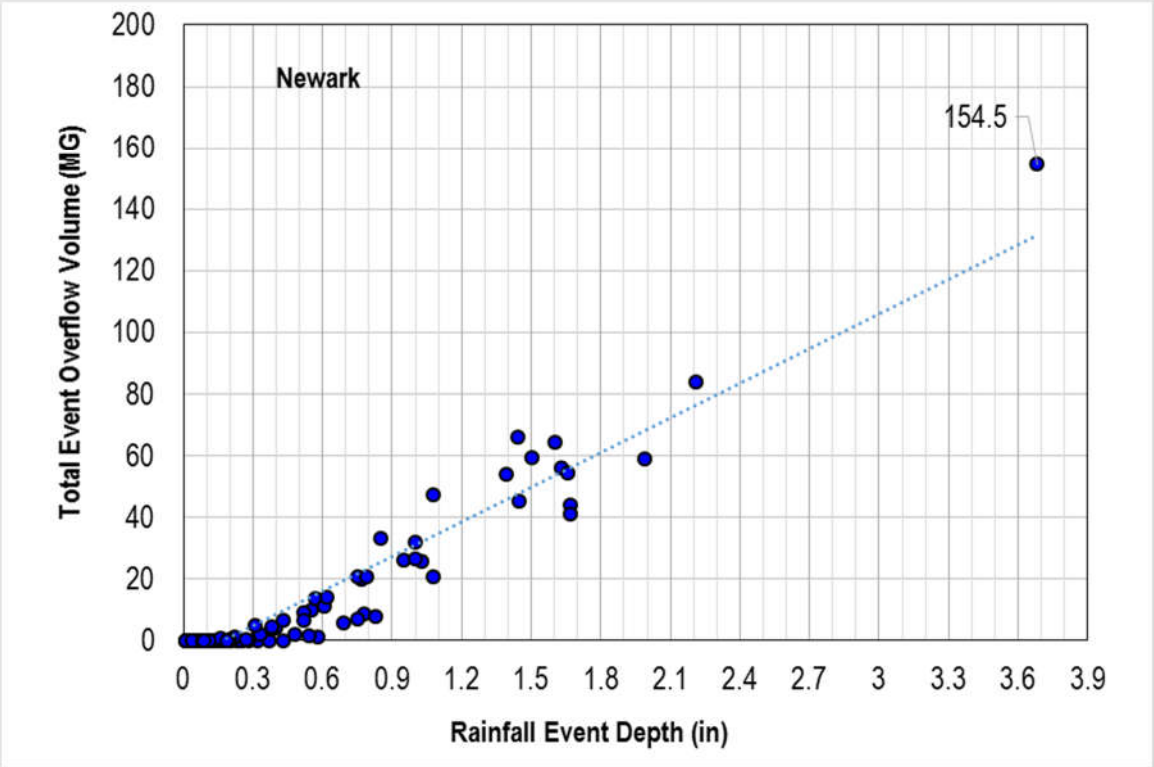
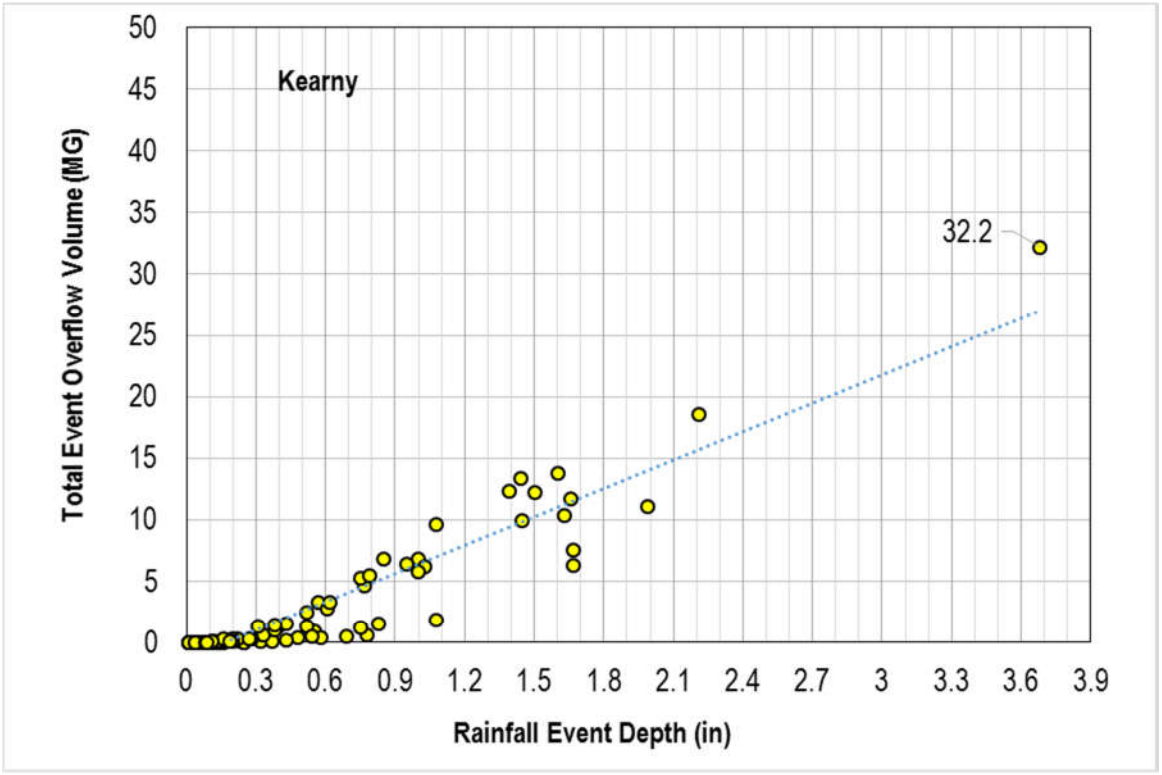


Figure I-62: Correlation between Rainfall Depth and CSO Volume (Patterson, Newark)



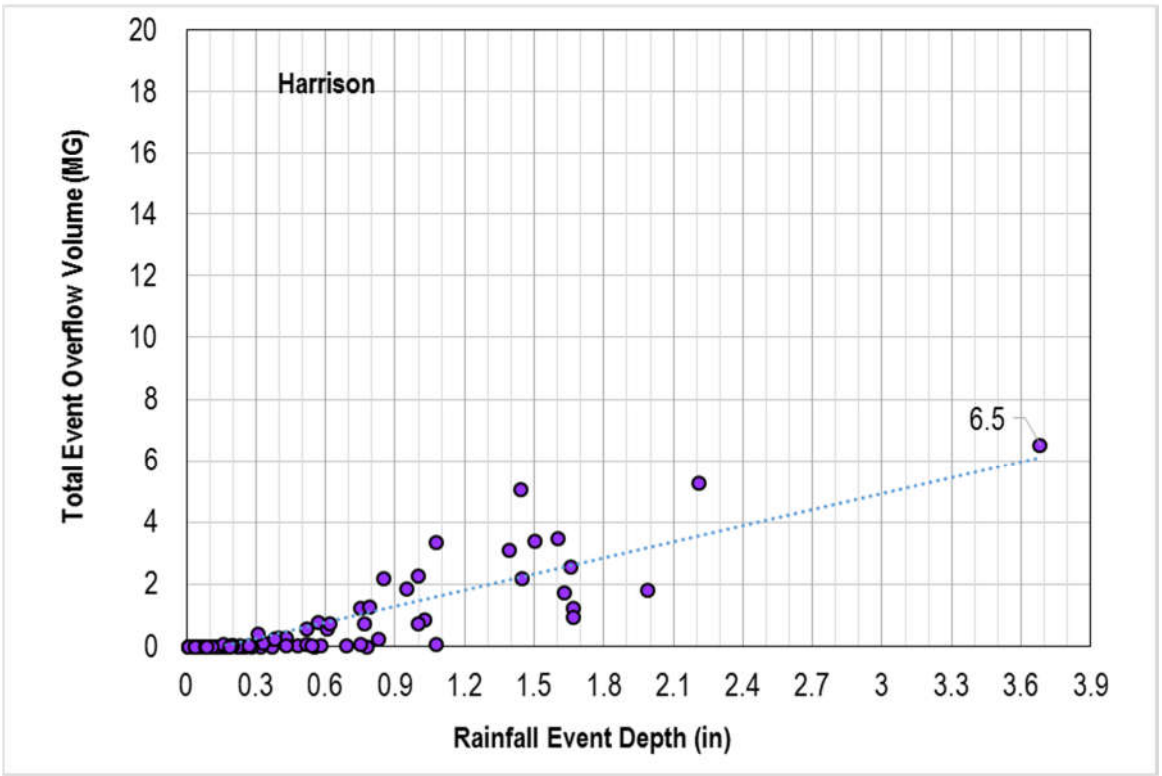


Figure I-63: Correlation between Rainfall Depth and CSO Volume (Kearny, Harrison)

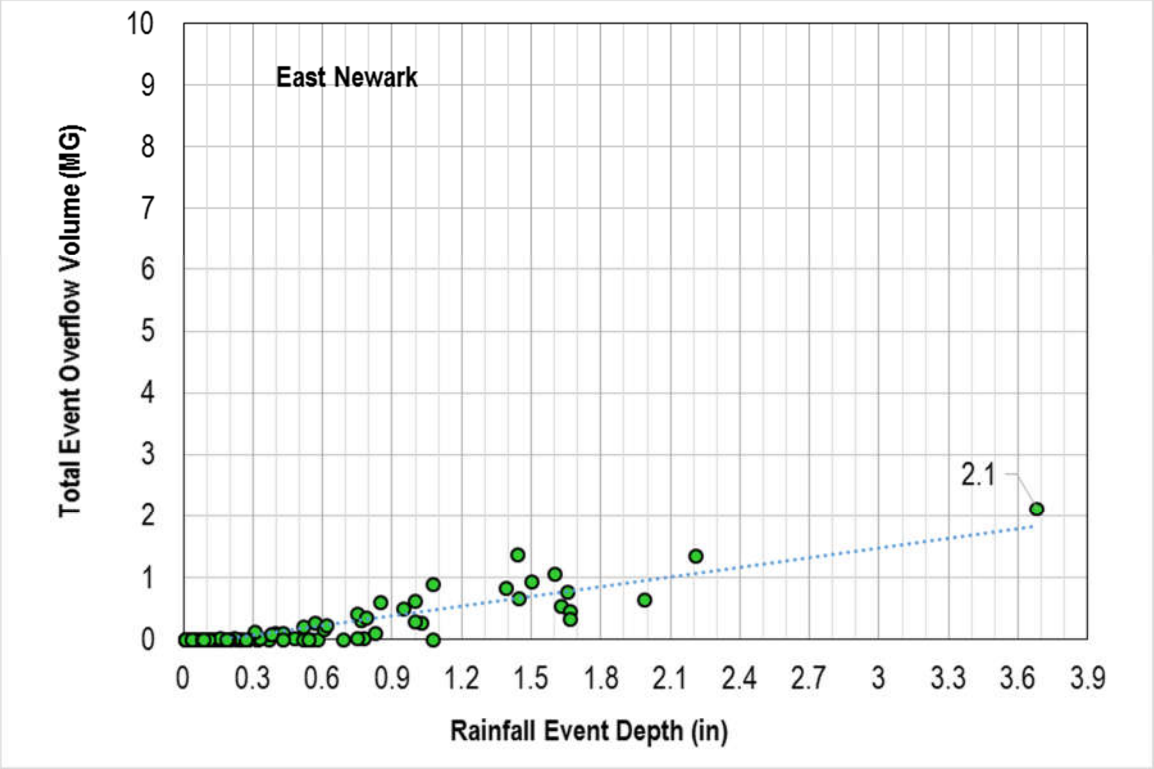
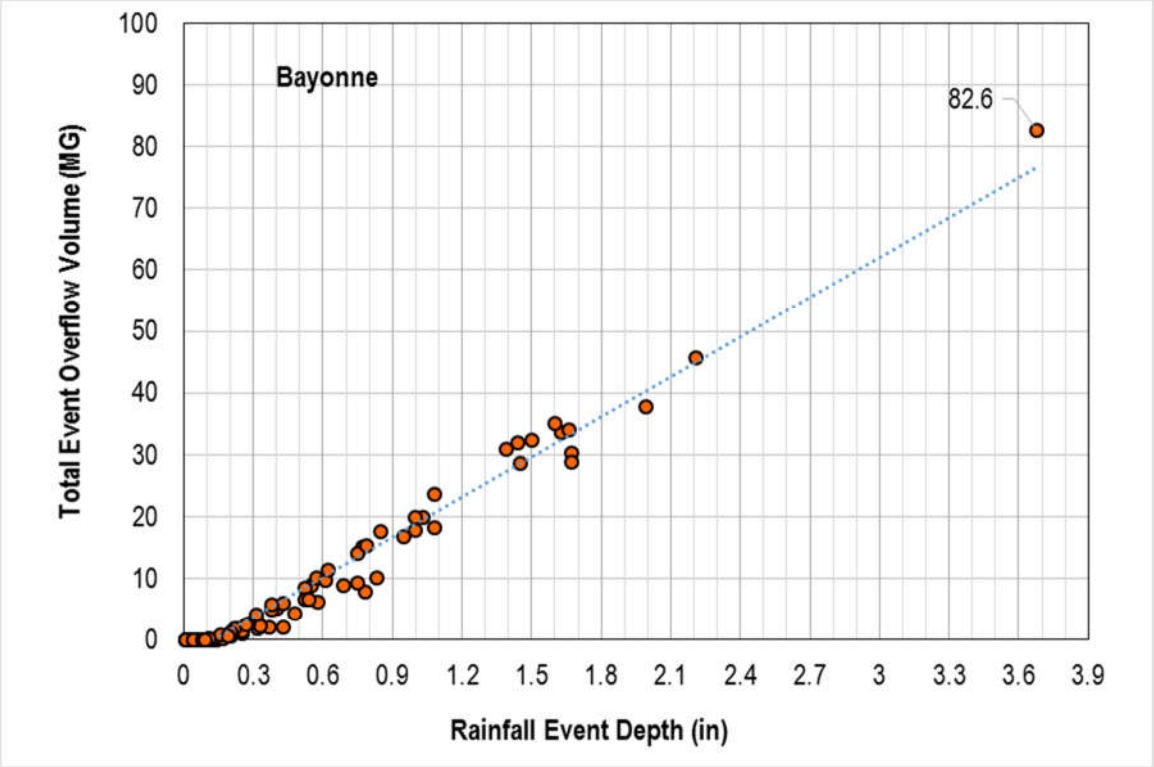


Figure I-64: Correlation between Rainfall Depth and CSO Volume (East Newark)



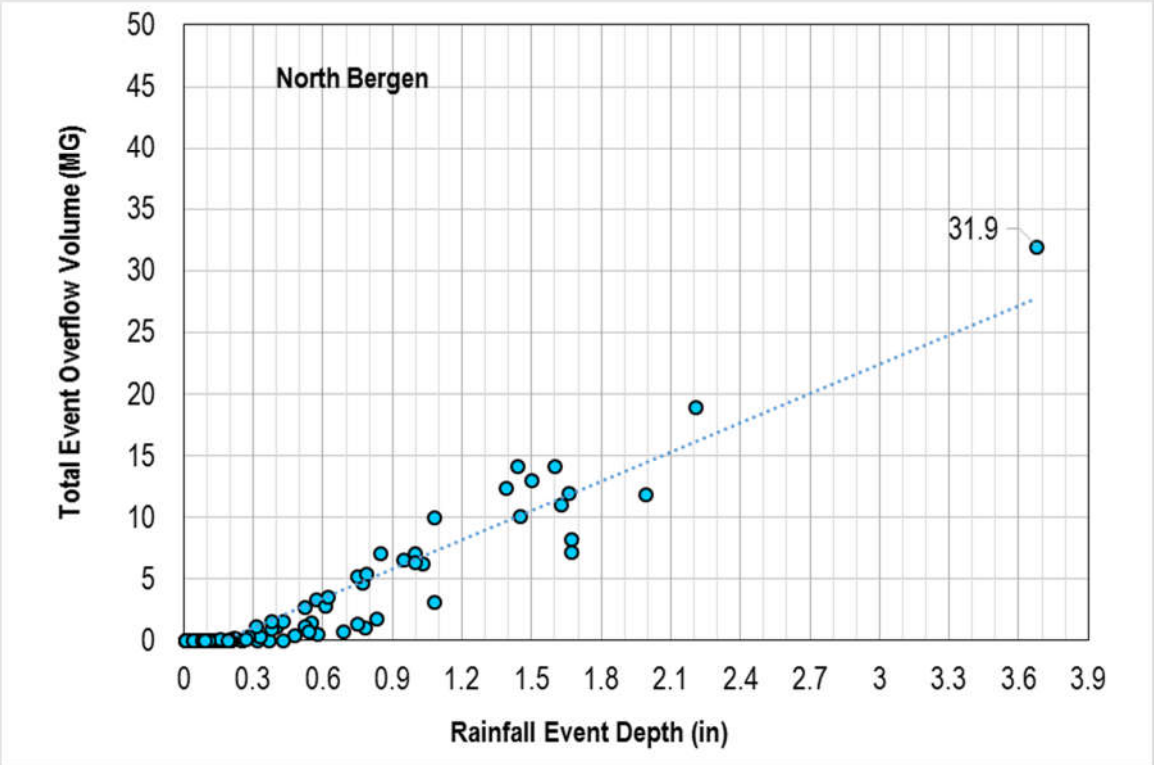


Figure I-65: Correlation between Rainfall Depth and CSO Volume (North Bergen, Bayonne)

I.6.2 Overflow Statistics

Typical year CSO volume, frequency and duration is summarized in **Table I-11** for CSO outfalls in Paterson, East Newark, Harrison, Kearny, Newark, North Bergen, and Bayonne. Jersey City was not included in the table. Inter-event time of 24 hours was used to identify overflow events, i.e., multiple periods of overflow from one or more outfalls are considered one overflow event if the time between periods of overflow is no more than 24 hours without a discharge from any outfall. Overflow duration in the table is the total overflow hours at the corresponding CSO outfall in the typical year.

The PVSC system (excluding Jersey City) overflows ~~59~~ 60 times in the typical year of 2004, with a total overflow volume of ~~3078~~ 3000 MG and overflow duration of ~~532~~ 414 hours. Newark has the highest annual overflow volume (1,288~~181~~ MG), followed by Bayonne (~~791~~ 712 MG), Paterson (~~54183~~4 MG), North Bergen (~~251~~ 255 MG), Kearny (~~247~~ 251 MG), Harrison (~~57~~ 59 MG), and East Newark (17 MG).

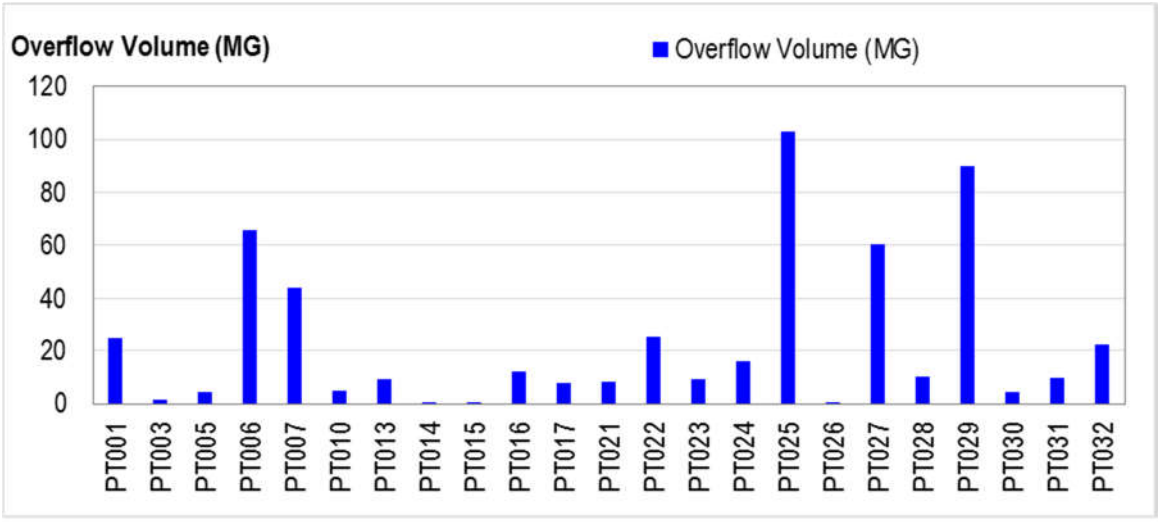
The following figures are provided for visual comparisons of CSO outfalls.

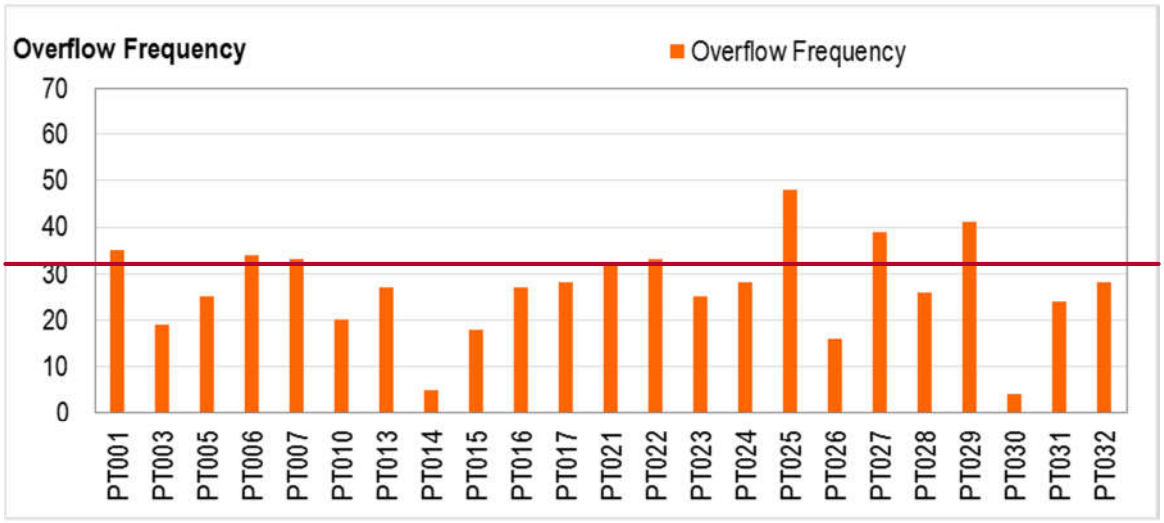
- **Figure I-66** shows overflow volume, frequency and duration for CSOs in Paterson.
- **Figure I-67** shows overflow volume, frequency and duration for CSOs in East Newark, Harrison, Kearny, and Newark. And
- **Figure I-68** shows overflow volume, frequency and duration for CSOs in North Bergen and Bayonne.

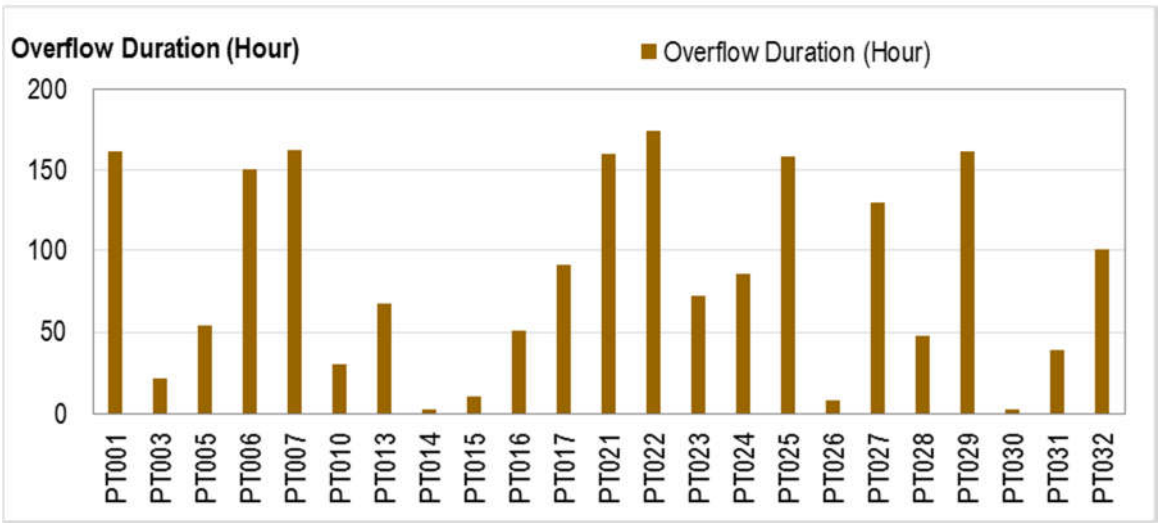
Table I-11: Typical Year CSO Overflow Volume, Frequency, and Duration

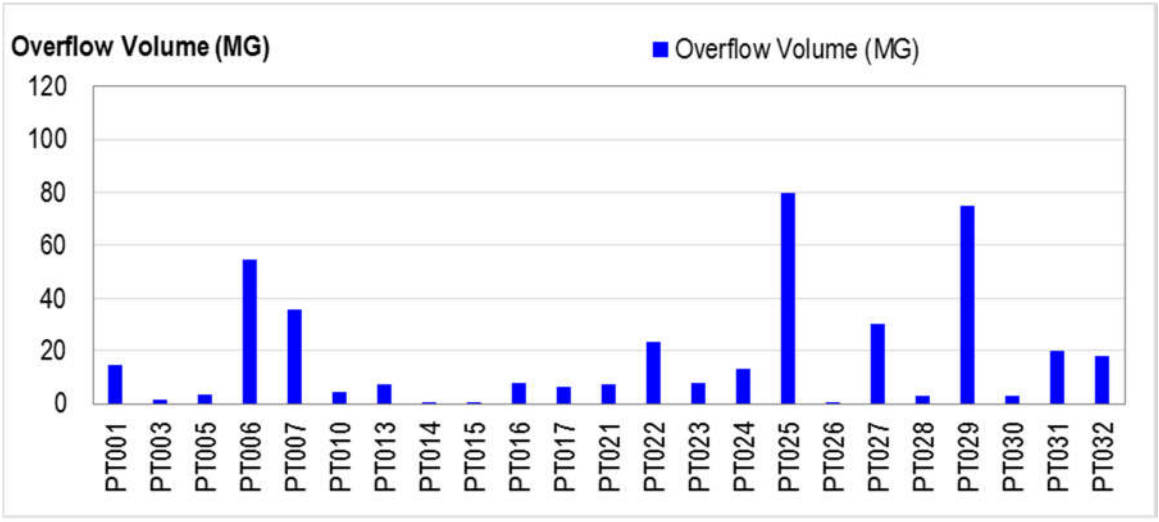
CSO ID	Overflow			CSO ID	Overflow			CSO ID	Overflow		
	Volume (MG)	# per Year	Duration (Hour)		Volume (MG)	# per Year	Duration (Hour)		Volume (MG)	# per Year	Duration (Hour)
PT001	14.5	2835	116162	EN001	17.016.8	3434	10199	NB003	143.4141.4	4342	260254
PT003	1.41.5	1519	1721					NB005	24.424.1	4747	230227
PT005	3.44.2	2225	4354	HR001	1.61.4	2727	4439	NB006	0.020.02	11	11
PT006	54.866.0	3134	135151	HR002	3.02.9	2929	5350	NB007	13.212.9	3030	140137
PT007	35.744.1	3133	147162	HR003	13.813.7	2929	6261	NB008	20.920.5	3029	116113
PT010	4.24.9	1520	1830	HR004	0.40.4	1413	108	NB009	25.425.0	3535	163159
PT013	7.19.3	2727	5468	HR005	19.518.9	3232	136133	NB010	1.21.0	2323	3737
PT014	0.20.1	55	23	HR006	7.46.8	2828	5549	NB011	19.419.2	3434	132132
PT015	0.30.5	1118	511	HR007	13.513.3	4242	133133	NB014	6.46.3	2727	9492
PT016	7.812.0	2527	4251								
PT017	6.17.6	2728	8392	KE001	3.93.9	2929	5454	BA001	362.2373.9	5659	388532
PT021	7.38.1	3032	150160	KE004	12.312.3	4949	177177	BA002	8.08.7	99	1314
PT022	23.425.2	3133	164174	KE006	120.6119.3	5453	251247	BA003	6.010.9	2731	71108
PT023	7.89.3	2225	6773	KE007	88.186.0	3232	170165	BA004	0.00.0	23	11
PT024	13.115.9	2728	7885	KE010	26.326.0	4747	146144	BA006	11.716.0	2833	94138
PT025	79.7103.2	4248	153159					BA007	53.472.1	2932	97125
PT026	0.40.7	1216	69	NE002	95.591.4	4242	299266	BA008	2.510.1	1630	1388
PT027	30.260.2	2939	119130	NE003	00	00	00	BA009	2.74.2	2629	3658
PT028	2.910.0	1626	1948	NE004	1.51.4	2322	3229	BA010	10.117.4	3749	107179
PT029	75.189.9	3241	139161	NE005	23.721.1	3939	281246	BA011	5.05.9	2930	5771
PT030	3.04.5	34	23	NE008	97.693.1	4645	356323	BA012	11.514.0	4149	108142
PT031	19.69.5	2724	8539	NE009	187.2162.4	3636	234207	BA013	0.60.8	2429	2735
PT032	18.022.3	2728	93101	NE010	187.2162.4	3636	234207	BA014	13.312.7	3737	129127
	0.4	10	8.5	NE014	191.0179.7	4645	414384	BA015	45.446.6	4447	212231
	0.4	12	13.3	NE015	81.574.3	4039	278244	BA016	5.86.5	4343	119130
	1.8	11	11.0	NE016	56.854.2	4444	272248	BA017	52.054.2	5254	330350
				NE017	112.4107.1	4544	304277	BA018	13.714.6	4650	200232
				NE018	79.175.4	4746	357320	BA019	35.638.8	3031	103112
				NE022	46.245.7	6059	262262	BA020	9.710.1	2929	6065
				NE023	18.316.8	3030	111108	BA021	52.462.9	4447	170212
				NE025	63.858.2	1716	3730	BA022	00	00	00
				NE026	21.516.6	1917	3525	BA024	0.10.1	33	22
				NE027	13.611.3	1717	4538	BA026	1.31.3	99	44
				NE030	10.810.3	1919	2221	BA028	00	00	00
								BA029	6.86.8	2323	4141
								BA030	1.51.5	1616	1010
								BA034	0.20.1	77	64
								BA037	1.11.0	98	98

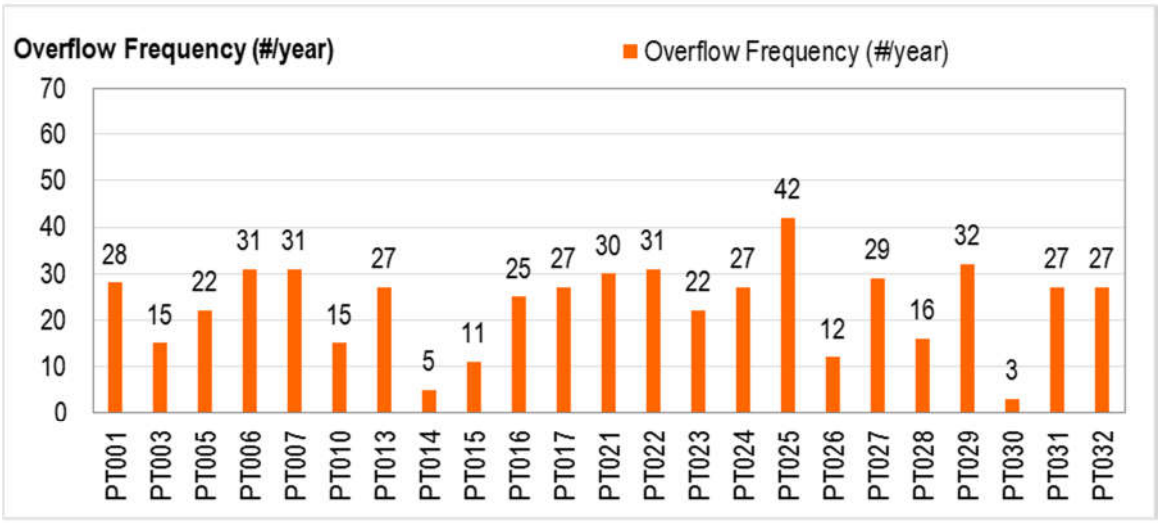
Note: Overflow statistics were not included in the table for Jersey City.

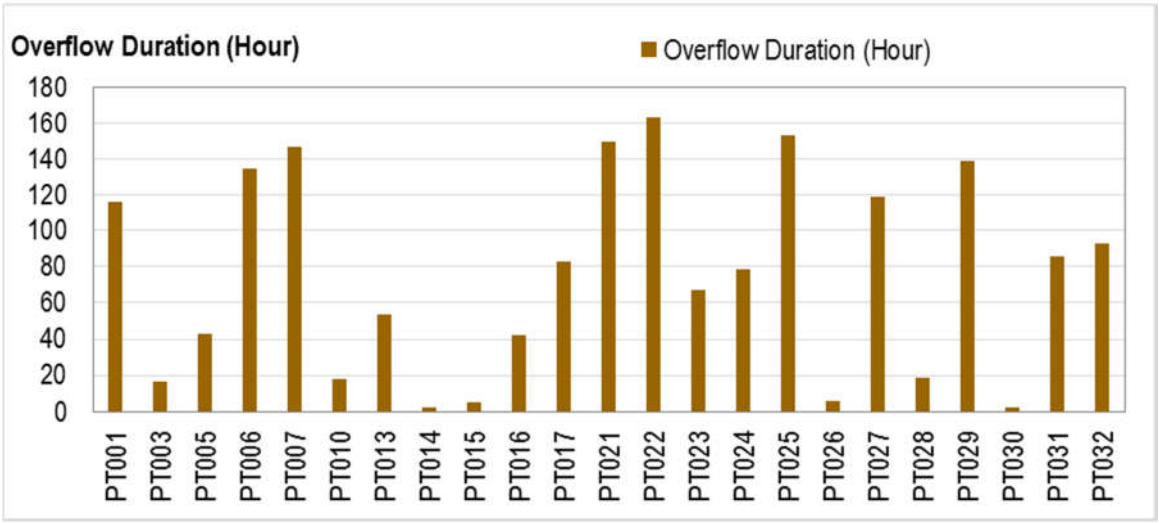

Overflow Volume (MG)
Overflow Volume (MG)
120
100
80
60
40
20
0
PT001
PT003
PT005
PT006
PT007
PT010
PT013
PT014
PT015
PT016
PT017
PT021
PT022
PT023
PT024
PT025
PT026
PT027
PT028
PT029
PT030
PT031
PT032


Overflow Frequency
Overflow Frequency
70
60
50
40
30
20
10
0
PT001
PT003
PT005
PT006
PT007
PT010
PT013
PT014
PT015
PT016
PT017
PT021
PT022
PT023
PT024
PT025
PT026
PT027
PT028
PT029
PT030
PT031
PT032


Overflow Duration (Hour)
Overflow Duration (Hour)
200
150
100
50
0
PT001
PT003
PT005
PT006
PT007
PT010
PT013
PT014
PT015
PT016
PT017
PT021
PT022
PT023
PT024
PT025
PT026
PT027
PT028
PT029
PT030
PT031
PT032


Overflow Volume (MG)
Overflow Volume (MG)
120
100
80
60
40
20
0
PT001
PT003
PT005
PT006
PT007
PT010
PT013
PT014
PT015
PT016
PT017
PT021
PT022
PT023
PT024
PT025
PT026
PT027
PT028
PT029
PT030
PT031
PT032


Overflow Frequency (#/year)
Overflow Frequency (#/year)
70
60
50
40
30
20
10
0
28
15
22
31
31
15
27
5
11
25
27
30
31
22
27
42
12
29
16
32
3
27
27
PT001
PT003
PT005
PT006
PT007
PT010
PT013
PT014
PT015
PT016
PT017
PT021
PT022
PT023
PT024
PT025
PT026
PT027
PT028
PT029
PT030
PT031
PT032


Overflow Duration (Hour)
Overflow Duration (Hour)
180
160
140
120
100
80
60
40
20
0
PT001
PT003
PT005
PT006
PT007
PT010
PT013
PT014
PT015
PT016
PT017
PT021
PT022
PT023
PT024
PT025
PT026
PT027
PT028
PT029
PT030
PT031
PT032

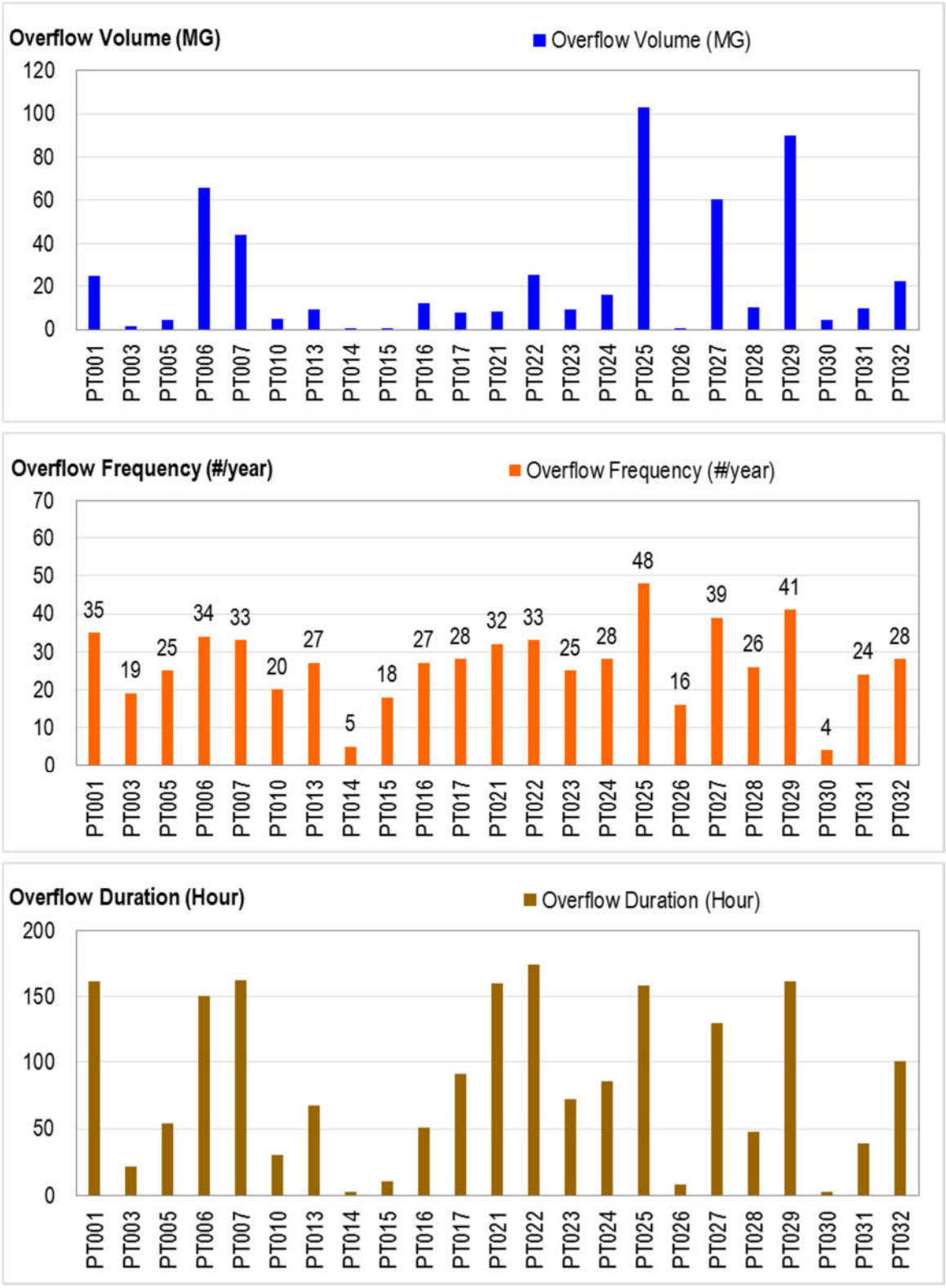
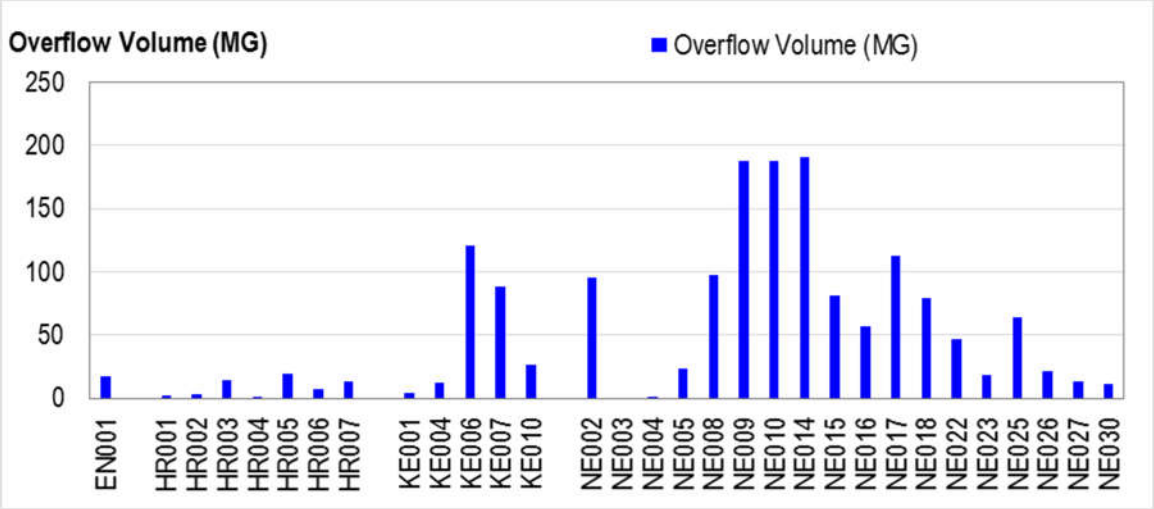
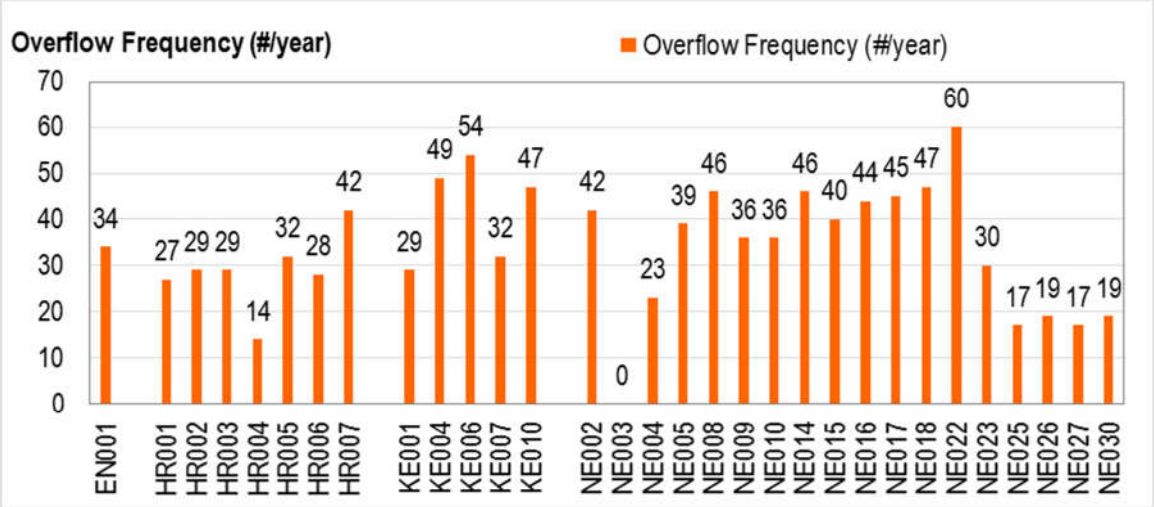
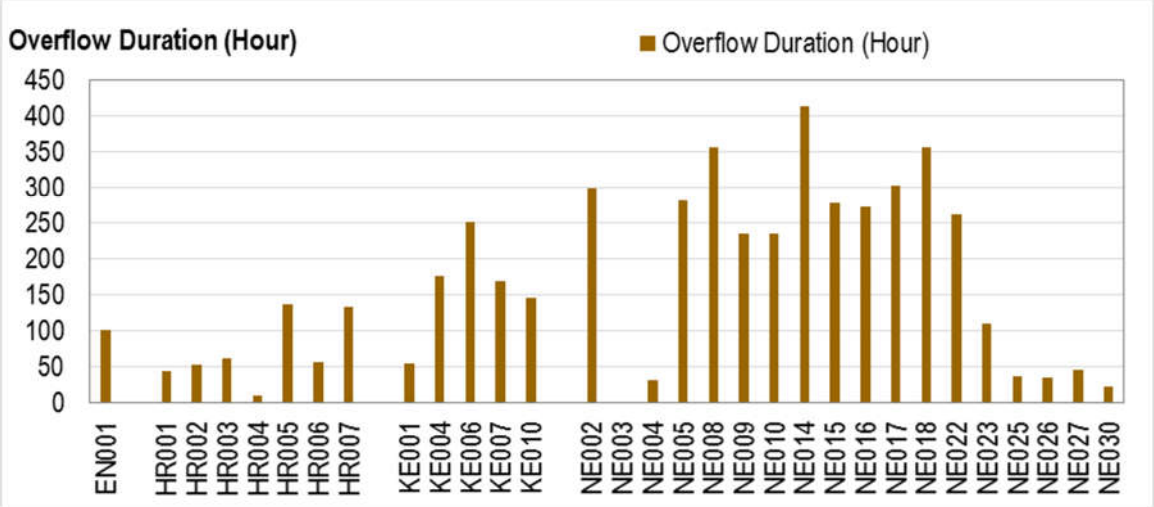
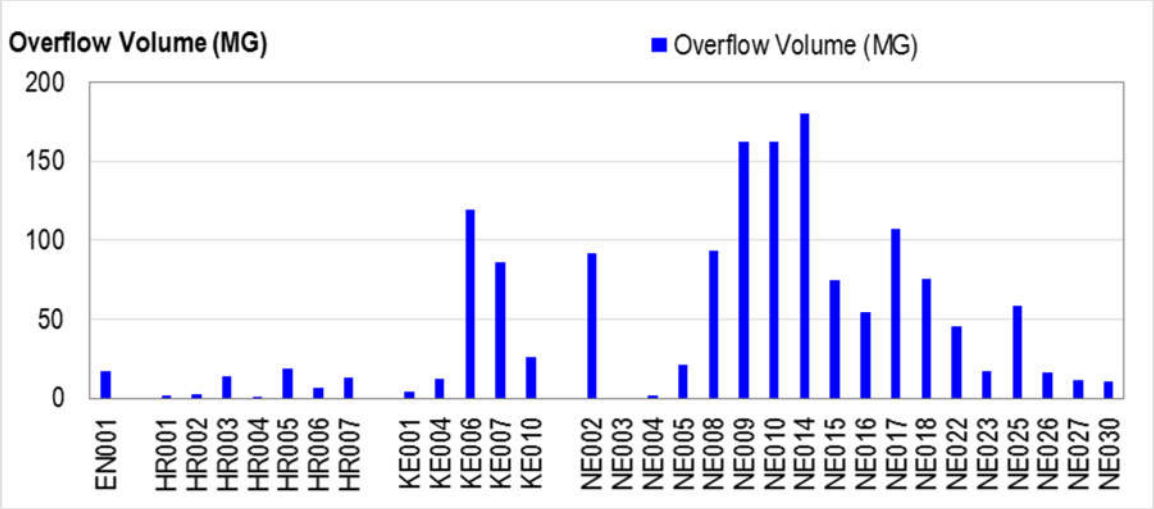


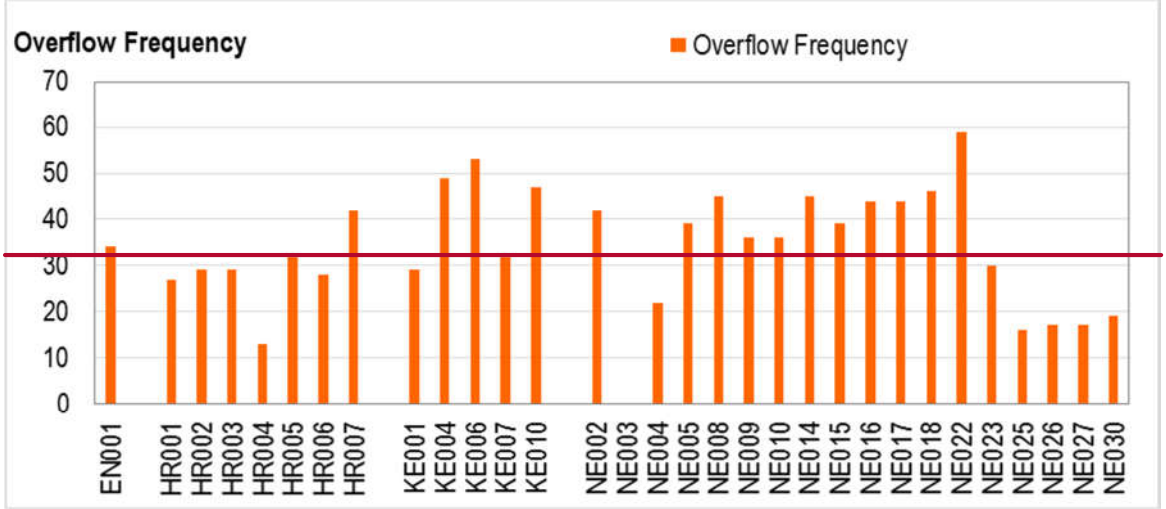
Figure I-66: Typical Year CSO Overflow Volume and Frequency Paterson

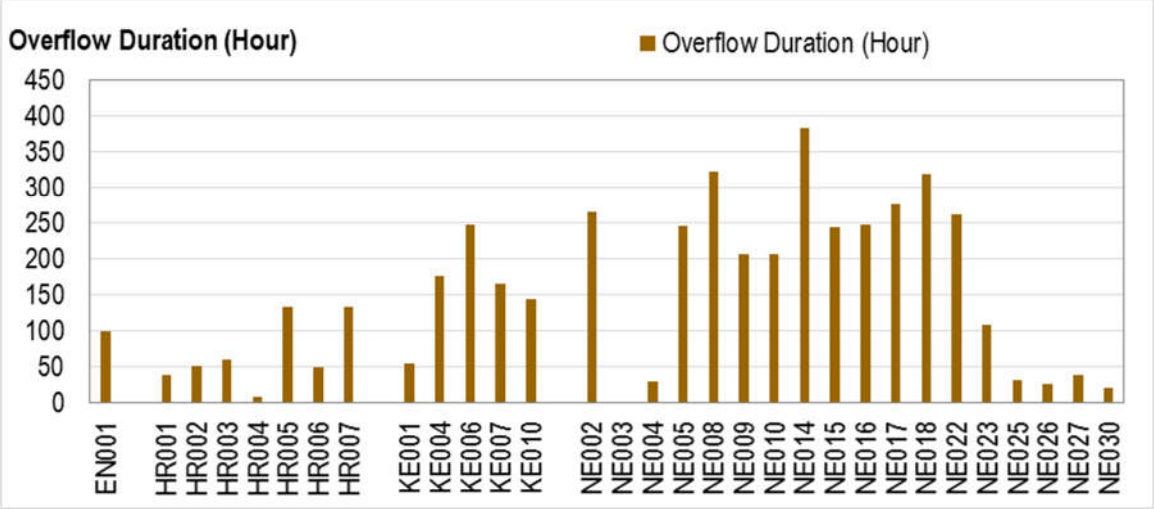

Overflow Volume (MG)
Overflow Volume (MG)
250
200
150
100
50
0
EN001
HR001
HR002
HR003
HR004
HR005
HR006
HR007
KE001
KE004
KE006
KE007
KE010
NE002
NE003
NE004
NE005
NE008
NE009
NE010
NE014
NE015
NE016
NE017
NE018
NE022
NE023
NE025
NE026
NE027
NE030


Overflow Frequency (#/year)
Overflow Frequency (#/year)
70
60
50
40
30
20
10
0
34
27
29
29
14
32
28
42
29
49
54
32
47
42
0
23
39
46
36
36
46
40
44
45
47
60
30
17
19
17
19
EN001
HR001
HR002
HR003
HR004
HR005
HR006
HR007
KE001
KE004
KE006
KE007
KE010
NE002
NE003
NE004
NE005
NE008
NE009
NE010
NE014
NE015
NE016
NE017
NE018
NE022
NE023
NE025
NE026
NE027
NE030


Overflow Duration (Hour)
Overflow Duration (Hour)
450
400
350
300
250
200
150
100
50
0
EN001
HR001
HR002
HR003
HR004
HR005
HR006
HR007
KE001
KE004
KE006
KE007
KE010
NE002
NE003
NE004
NE005
NE008
NE009
NE010
NE014
NE015
NE016
NE017
NE018
NE022
NE023
NE025
NE026
NE027
NE030


Overflow Volume (MG)
Overflow Volume (MG)
200
150
100
50
0
EN001
HR001
HR002
HR003
HR004
HR005
HR006
HR007
KE001
KE004
KE006
KE007
KE010
NE002
NE003
NE004
NE005
NE008
NE009
NE010
NE014
NE015
NE016
NE017
NE018
NE022
NE023
NE025
NE026
NE027
NE030


Overflow Frequency
Overflow Frequency
70
60
50
40
30
20
10
0
EN001
HR001
HR002
HR003
HR004
HR005
HR006
HR007
KE001
KE004
KE006
KE007
KE010
NE002
NE003
NE004
NE005
NE008
NE009
NE010
NE014
NE015
NE016
NE017
NE018
NE022
NE023
NE025
NE026
NE027
NE030


Overflow Duration (Hour)
Overflow Duration (Hour)
450
400
350
300
250
200
150
100
50
0
EN001
HR001
HR002
HR003
HR004
HR005
HR006
HR007
KE001
KE004
KE006
KE007
KE010
NE002
NE003
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NE027
NE030

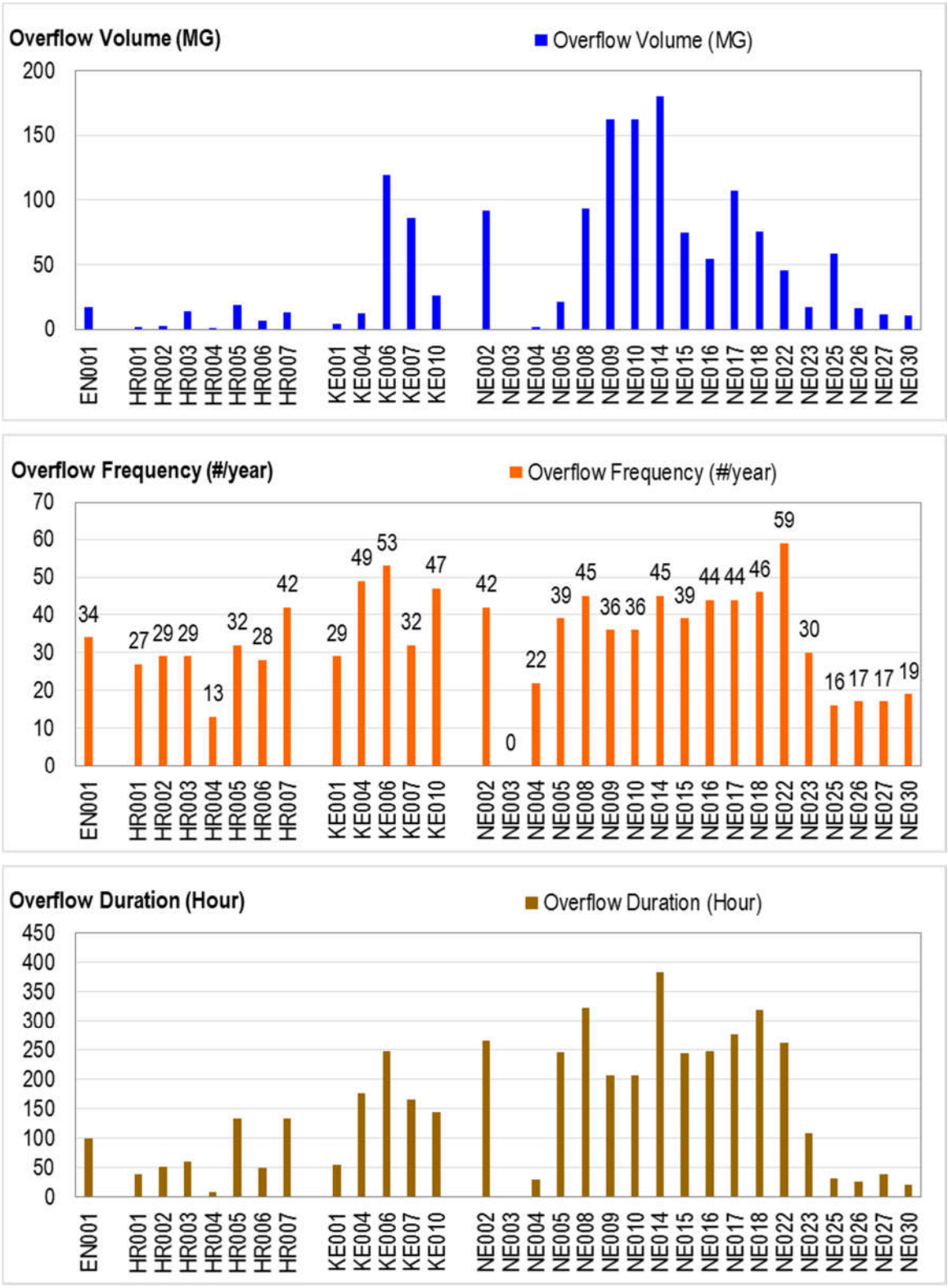
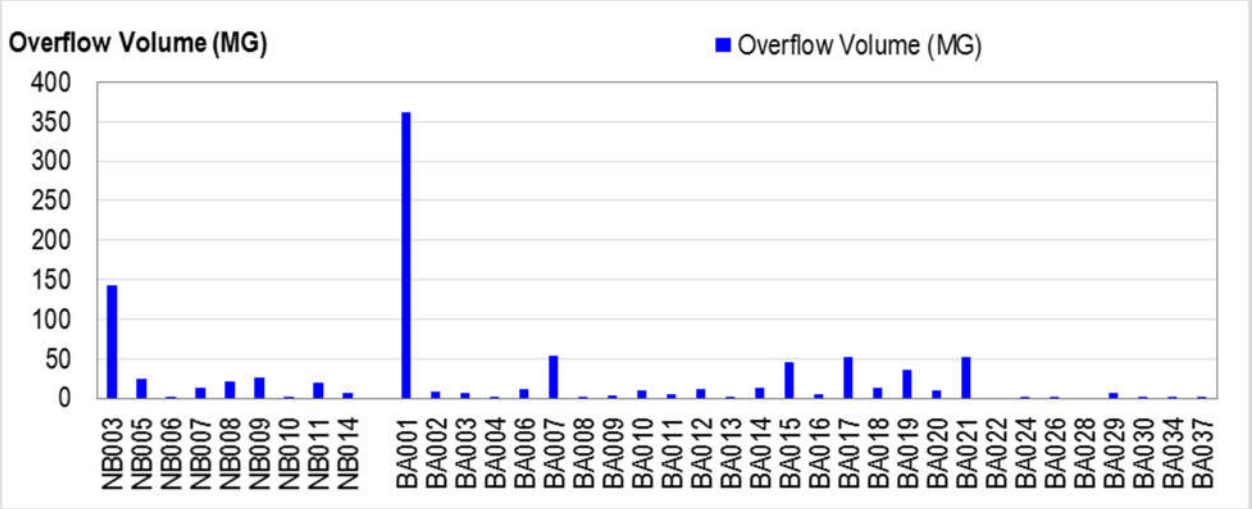
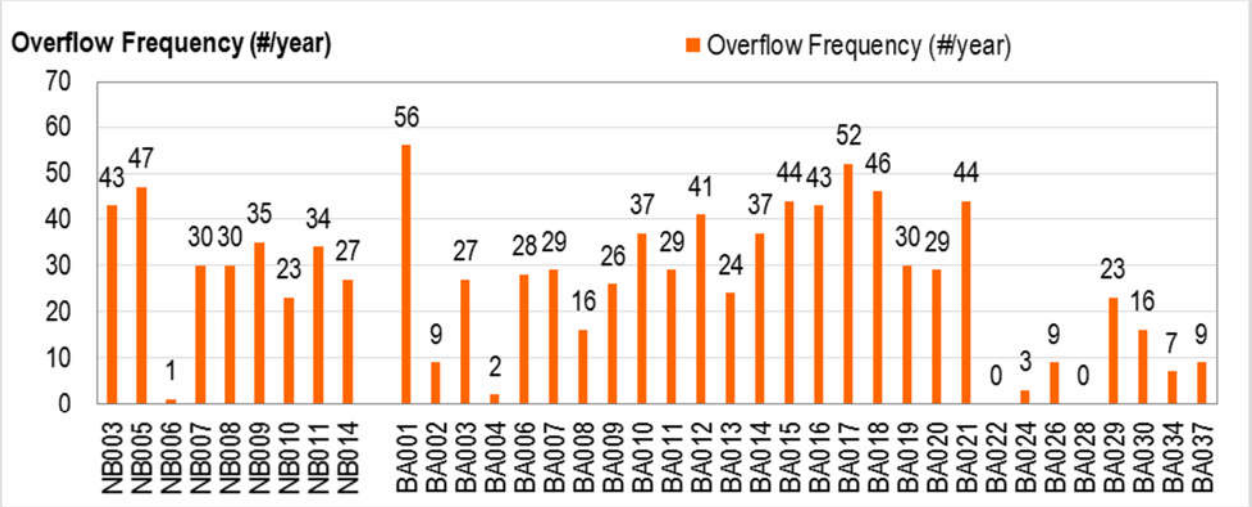
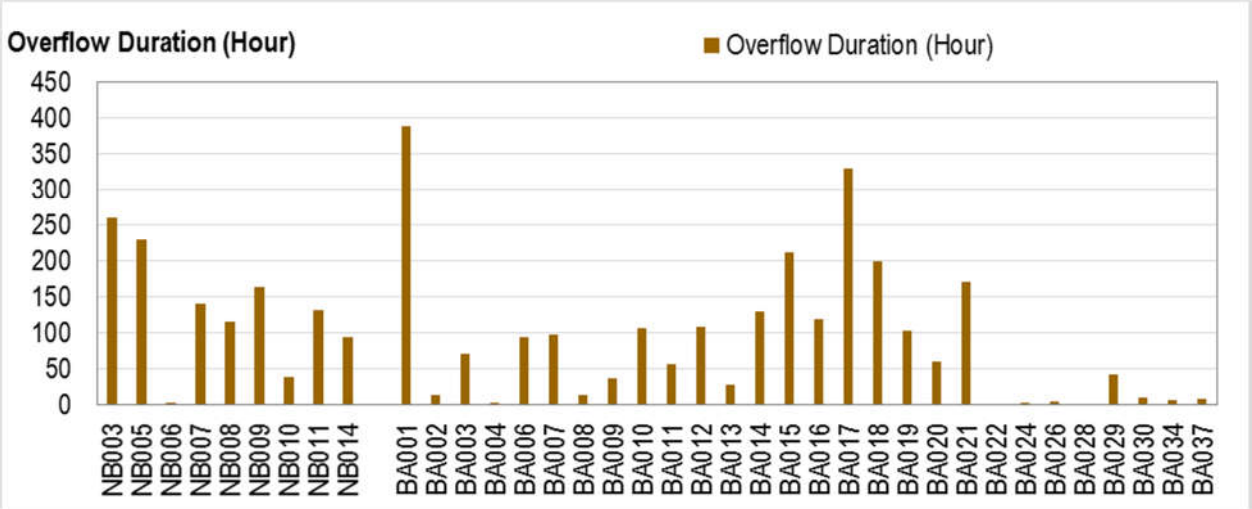
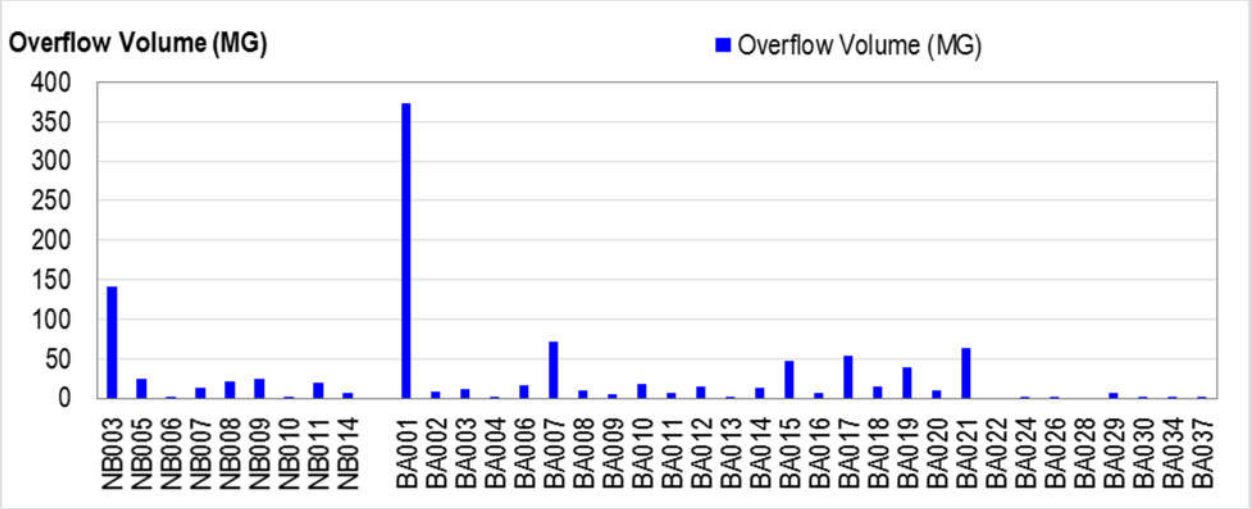


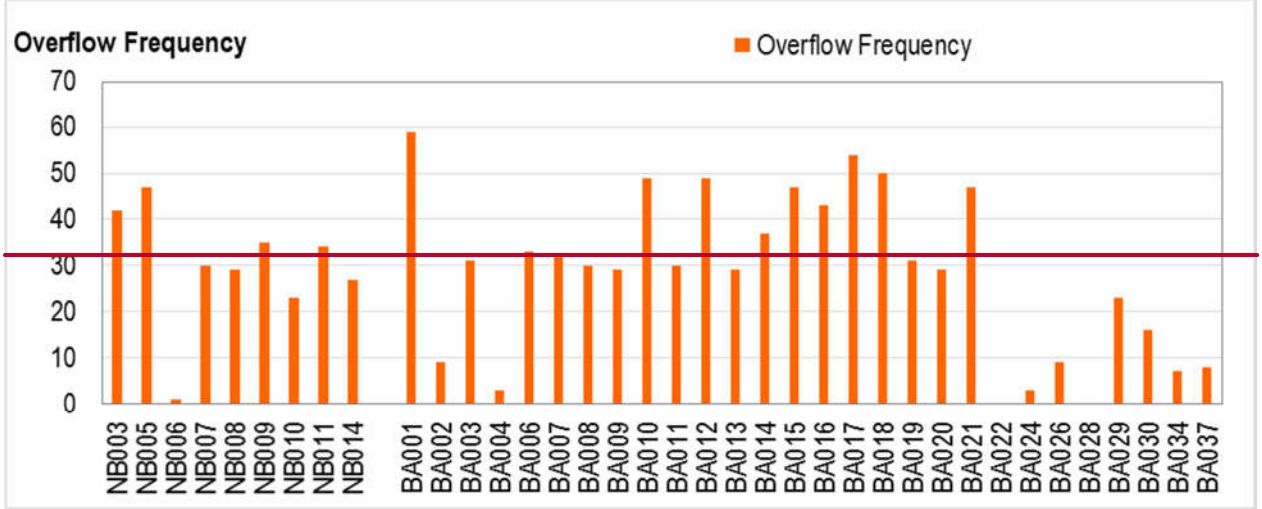
Figure I-67: Typical Year CSO Overflow Volume and Frequency East Newark, Harrison, Kearny and Newark

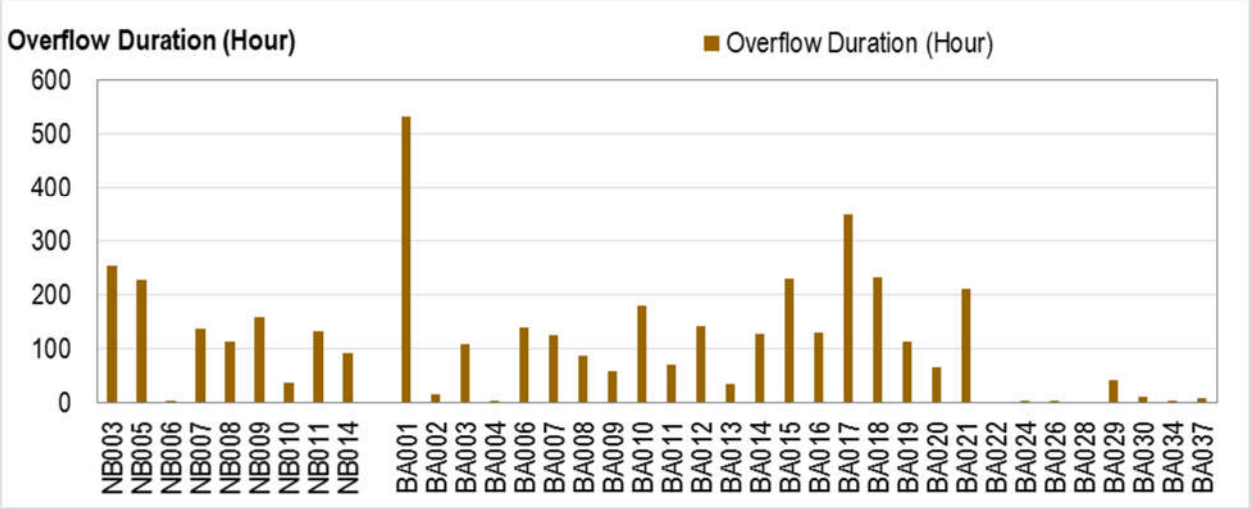

Overflow Volume (MG)
Overflow Volume (MG)
400
350
300
250
200
150
100
50
0
NB003 NB005 NB006 NB007 NB008 NB009 NB010 NB011 NB014
BA001 BA002 BA003 BA004 BA006 BA007 BA008 BA009 BA010 BA011 BA012 BA013 BA014 BA015 BA016 BA017 BA018 BA019 BA020 BA021 BA022 BA024 BA026 BA028 BA029 BA030 BA034 BA037


Overflow Frequency (#/year)
Overflow Frequency (#/year)
70
60
50
40
30
20
10
0
43 47 1 30 30 35 23 34 27
56 9 27 2 28 29 16 26 37 29 41 24 37 44 43 52 46 30 29 44 0 3 9 0 23 16 7 9
NB003 NB005 NB006 NB007 NB008 NB009 NB010 NB011 NB014
BA001 BA002 BA003 BA004 BA006 BA007 BA008 BA009 BA010 BA011 BA012 BA013 BA014 BA015 BA016 BA017 BA018 BA019 BA020 BA021 BA022 BA024 BA026 BA028 BA029 BA030 BA034 BA037


Overflow Duration (Hour)
Overflow Duration (Hour)
450
400
350
300
250
200
150
100
50
0
NB003 NB005 NB006 NB007 NB008 NB009 NB010 NB011 NB014
BA001 BA002 BA003 BA004 BA006 BA007 BA008 BA009 BA010 BA011 BA012 BA013 BA014 BA015 BA016 BA017 BA018 BA019 BA020 BA021 BA022 BA024 BA026 BA028 BA029 BA030 BA034 BA037


Overflow Volume (MG)
Overflow Volume (MG)
400
350
300
250
200
150
100
50
0
NB003 NB005 NB006 NB007 NB008 NB009 NB010 NB011 NB014 BA001 BA002 BA003 BA004 BA006 BA007 BA008 BA009 BA010 BA011 BA012 BA013 BA014 BA015 BA016 BA017 BA018 BA019 BA020 BA021 BA022 BA024 BA026 BA028 BA029 BA030 BA034 BA037


Overflow Frequency
Overflow Frequency
70
60
50
40
30
20
10
0
NB003 NB005 NB006 NB007 NB008 NB009 NB010 NB011 NB014 BA001 BA002 BA003 BA004 BA006 BA007 BA008 BA009 BA010 BA011 BA012 BA013 BA014 BA015 BA016 BA017 BA018 BA019 BA020 BA021 BA022 BA024 BA026 BA028 BA029 BA030 BA034 BA037


Overflow Duration (Hour)
Overflow Duration (Hour)
600
500
400
300
200
100
0
NB003 NB005 NB006 NB007 NB008 NB009 NB010 NB011 NB014 BA001 BA002 BA003 BA004 BA006 BA007 BA008 BA009 BA010 BA011 BA012 BA013 BA014 BA015 BA016 BA017 BA018 BA019 BA020 BA021 BA022 BA024 BA026 BA028 BA029 BA030 BA034 BA037

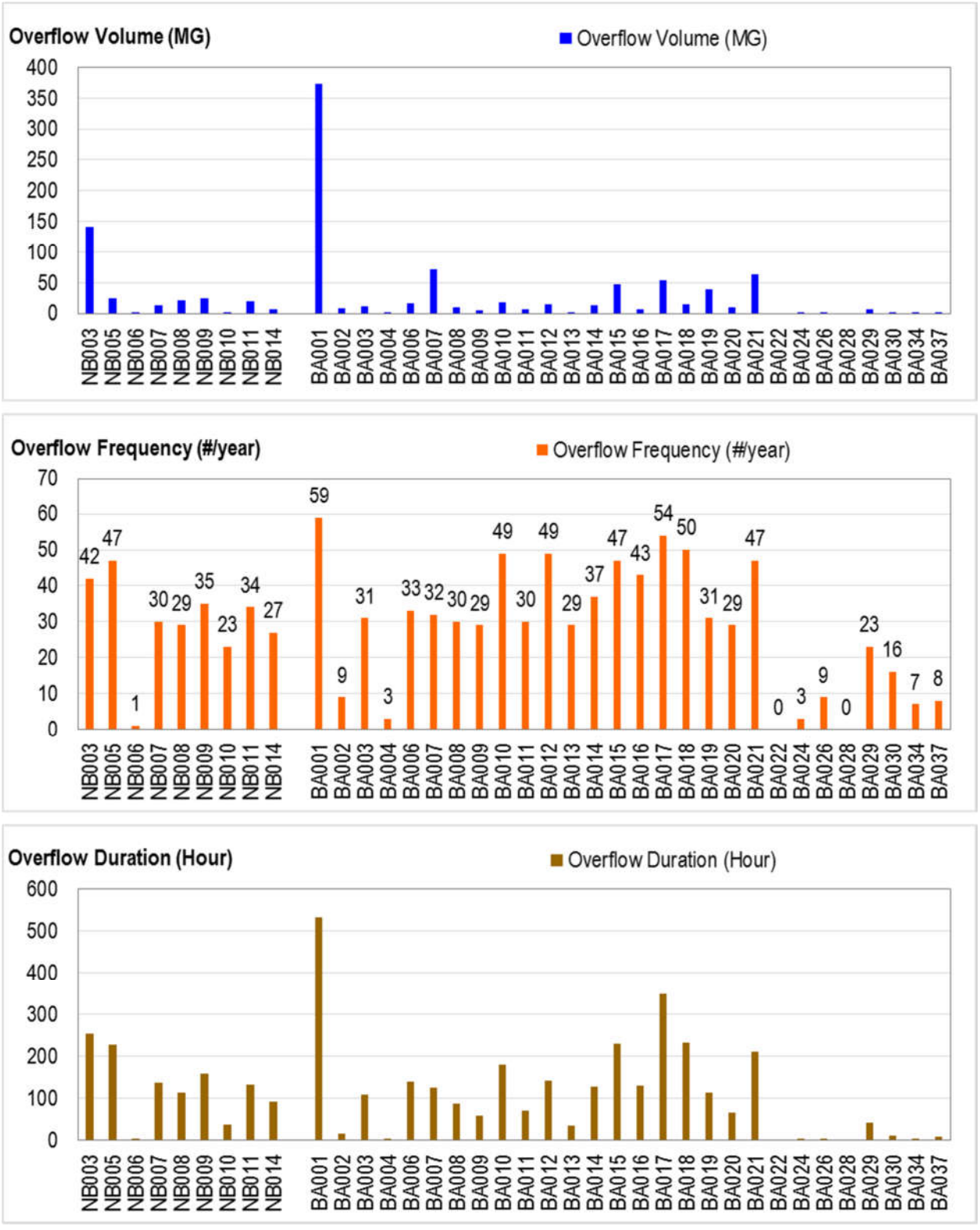


Figure I-68: Typical Year CSO Overflow Volume and Frequency North Bergen and Bayonne

I.6.3 Percent Capture

Wet weather percent capture was calculated for the PVSC Interceptor communities, North Bergen, and Bayonne. The wet weather volume was estimated based on durations from the time when the accumulated precipitation depth is over 0.1 inch to 12 hours after the storm event.

Table I-12: Typical Year % Capture

	PVSC Interceptor Communities	North Bergen	Bayonne
Total WWF Volume (MG)	12,52968	78064	1,48601
Total CSO Volume (MG)	2,0337	2541	77391
% Capture	83.8%	67.42%	52.143.6%
Additional Capture Volume (MG) for 85% Capture	1542	1376	490581

SECTION J - REFERENCES

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SECTION K - ABBREVIATIONS

CSO: Combined Sewer Overflow
CSS: Combined Sewer System
CWA: Clean Water Act
DWF: Dry Weather Flow
EPA: United States Environmental Protection Agency
ESI: Environmental Sensitivity Index
GIS: Geographic Information System
H&H: Hydrologic and Hydraulic
LTCP: Long Term Control Plan
MGD: million gallons per day
NJPDES New Jersey Pollutant Discharge Elimination System
PCBs: polychlorinated biphenyls
QAPP: Quality Assurance Project Plan
SSS: Separate Sewer System
USEPA: United States Environmental Protection Agency
WRRF: Water Resources Recovery Facility

APPENDIX A

Combined Sewer Overflow and Stormwater Sampling Results

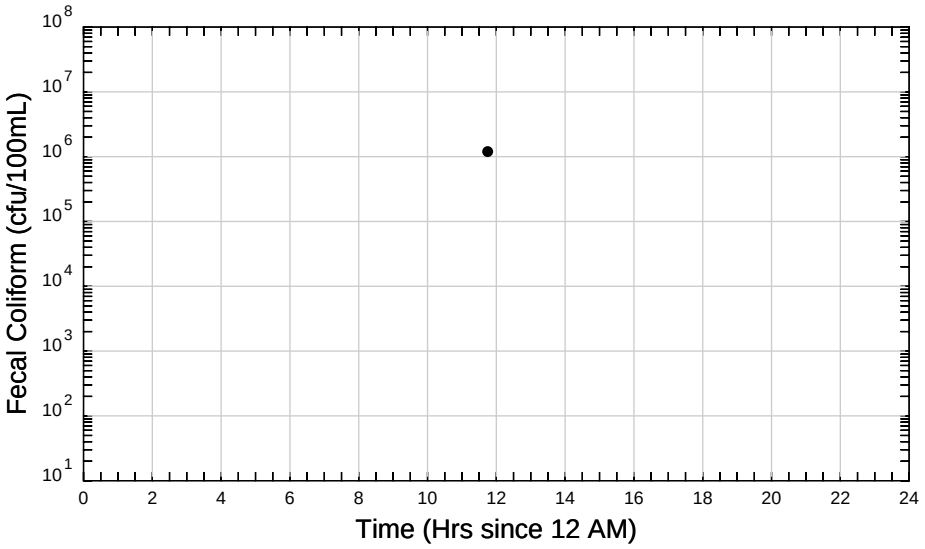
APPENDIX A

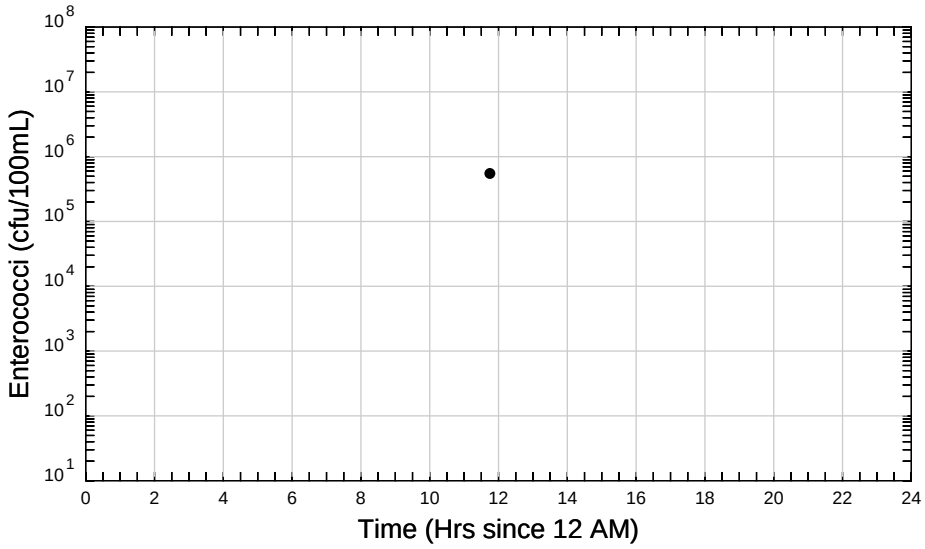
Sampling Schedule and Dates

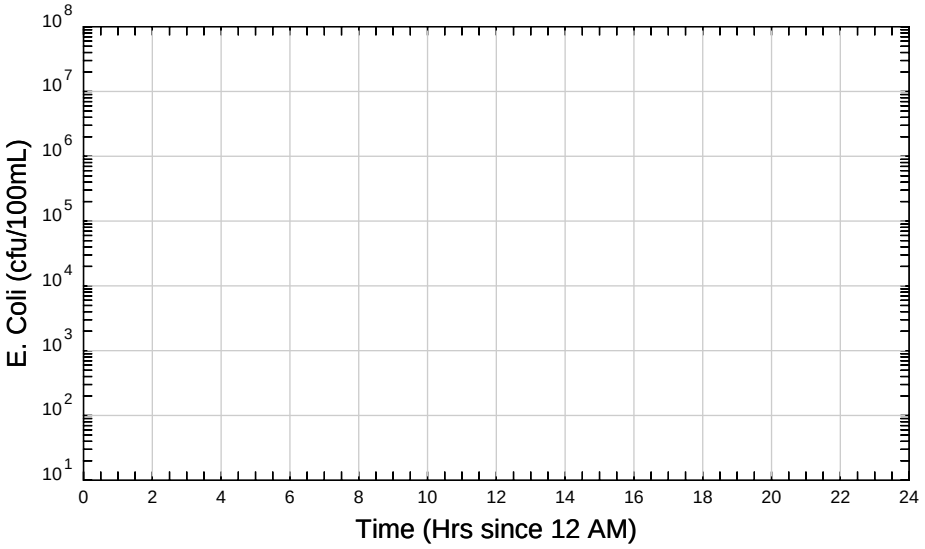
A summary of the sampling dates with corresponding locations and sample station identification numbers are shown in the table below. The Sampling Identification is noted at the top of each page in Appendix A.

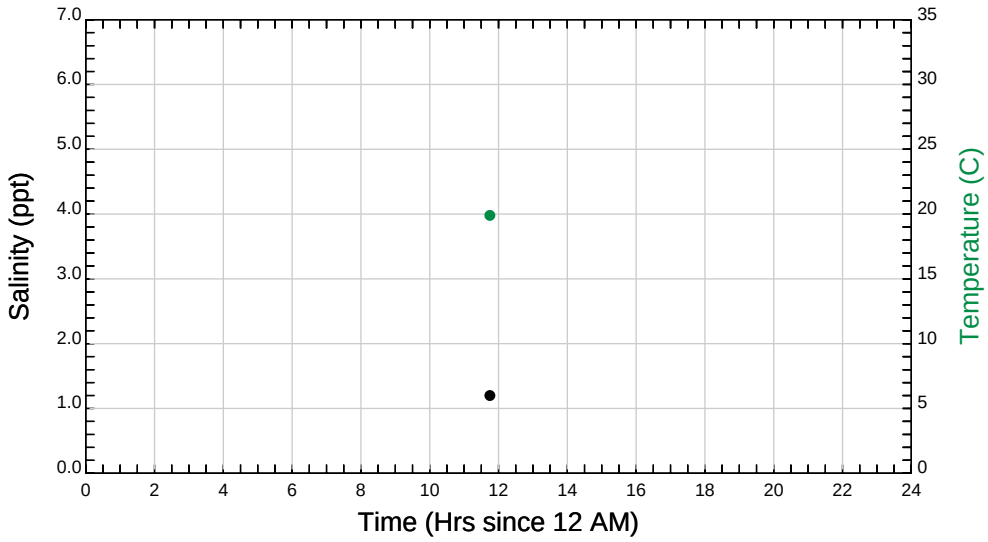
CSO Sampling		
Date	**Locations**	**CSO Sample Identification**
8/21/2016	1	PAT-06A
11/29/2016	5	HAR-06A, HAR-07A, KEA-07A, NWK-25A, NWK-45A
4/4/2017	4	HAR-06A, HAR-07A, KEA-07A, NWK-91A
4/6/2017	4	NWK-14A, NWK-45A, PAT-06A, PAT-27A
6/19/2017	4	BAY-08A, BAY-10A, PAT-25A, PAT-27A
7/23/2017	2	BAY-08A, BAY-10A
10/24/2017	4	NWK-14A, NWK-25A, NWK-45A, NWK-91A
Total	**13**	**Unique CSO Locations**
Total	**27**	**CSO Location-Events**

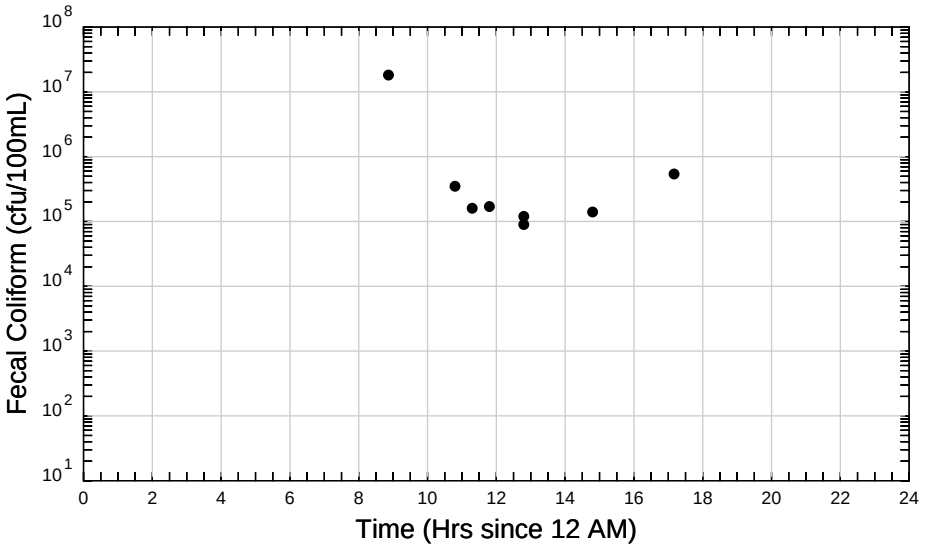
Stormwater Sampling		
Date	**Locations**	**Stormwater Sample Identification**
7/29/2016	2	OAK-LR4, PAT-LR1
9/19/2016	2	NWK-CI2, PAT-LR1
9/30/2016	2	NWK-CI2, OAK-LR4
10/21/2016	1	NWK-HR1
11/15/2016	4	NWK-CI2, NWK-HR1, OAK-LR4, PAT-LR1
12/6/2016	1	NWK-HR1
1/17/2017	2	NWK-HR2, NWK-LR2
5/5/2017	4	HAW-LR3, NWK-HR2, NWK-LR2, PAT-CI1
5/22/2017	2	NWK-HR2, NWK-LR2
5/25/2017	2	HAW-LR3, PAT-CI1
7/7/2017	2	HAW-LR3, PAT-CI1
Total	**8**	**Unique Stormwater Locations**
Total	**24**	**Stormwater Location-Events**

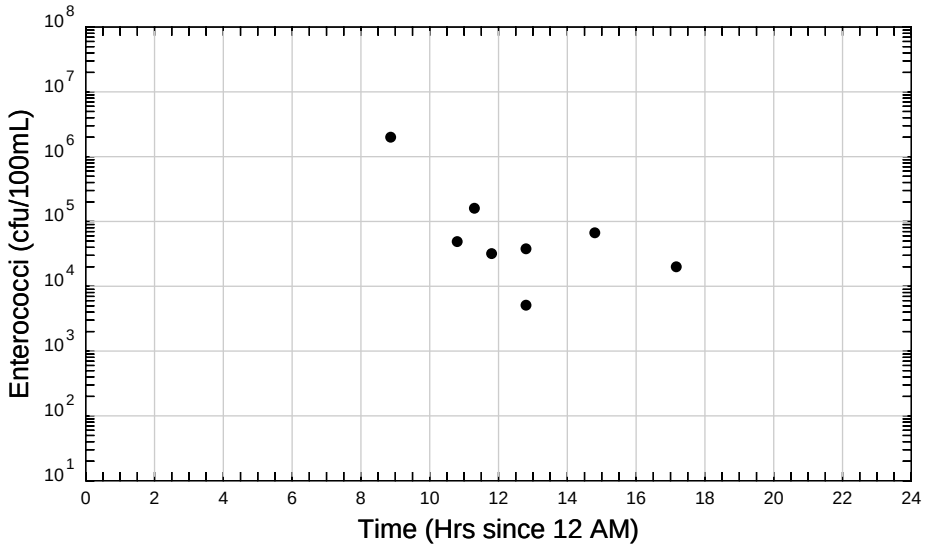

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

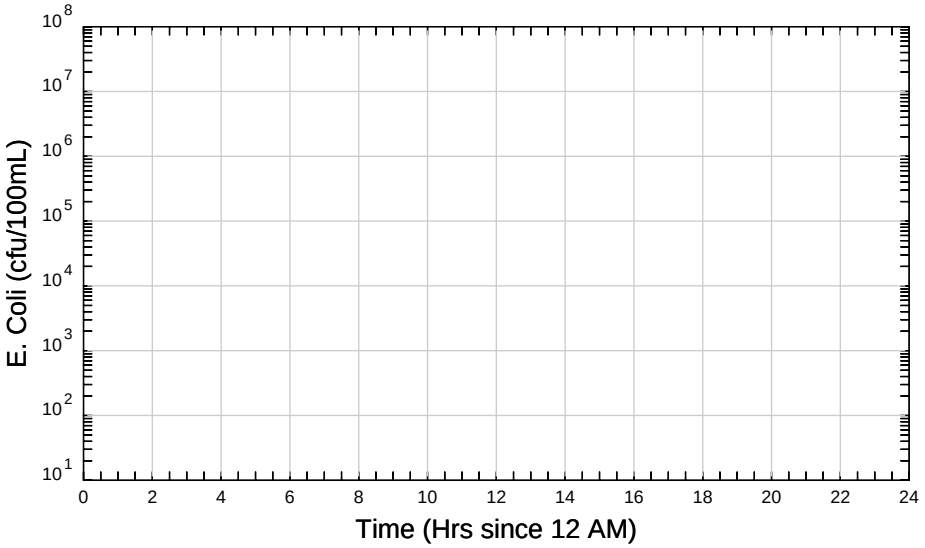

Enterococci (cfu/100mL)
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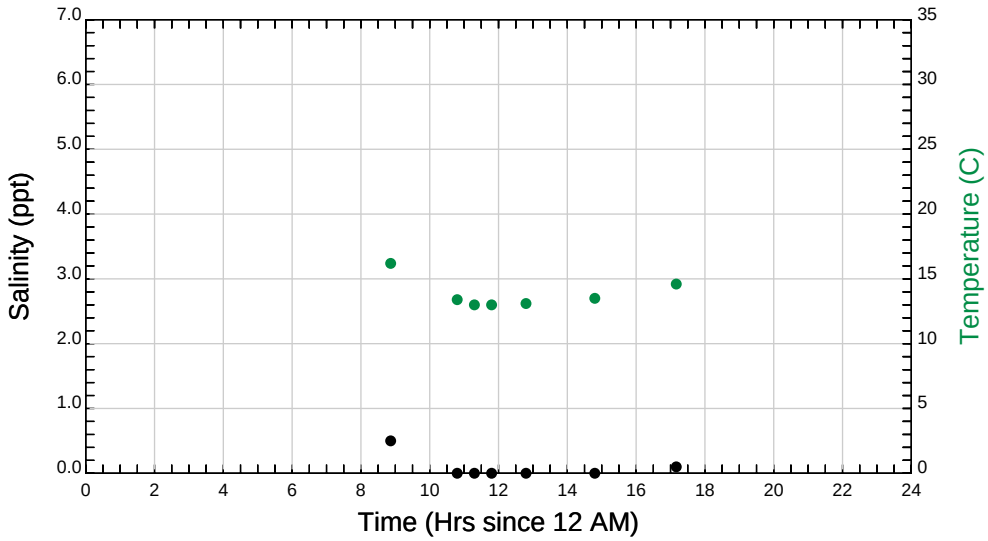

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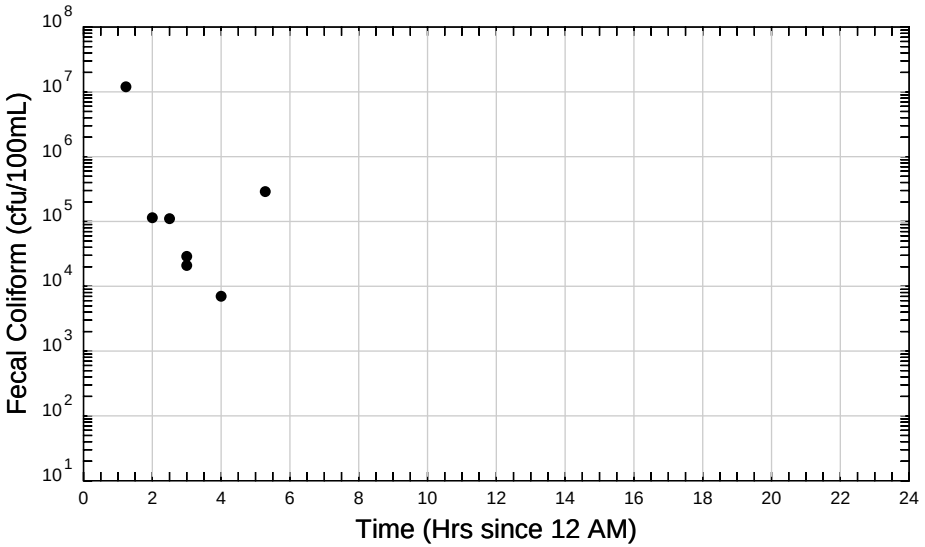

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

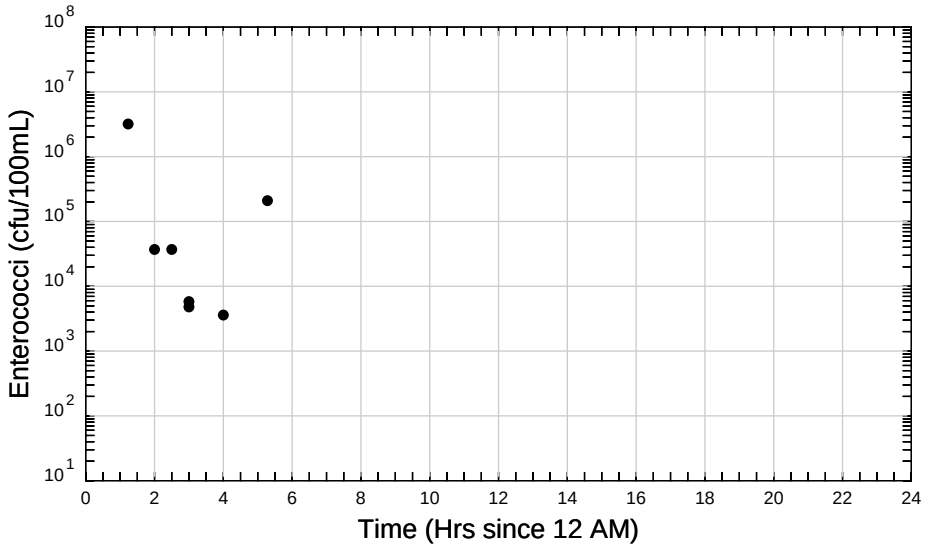

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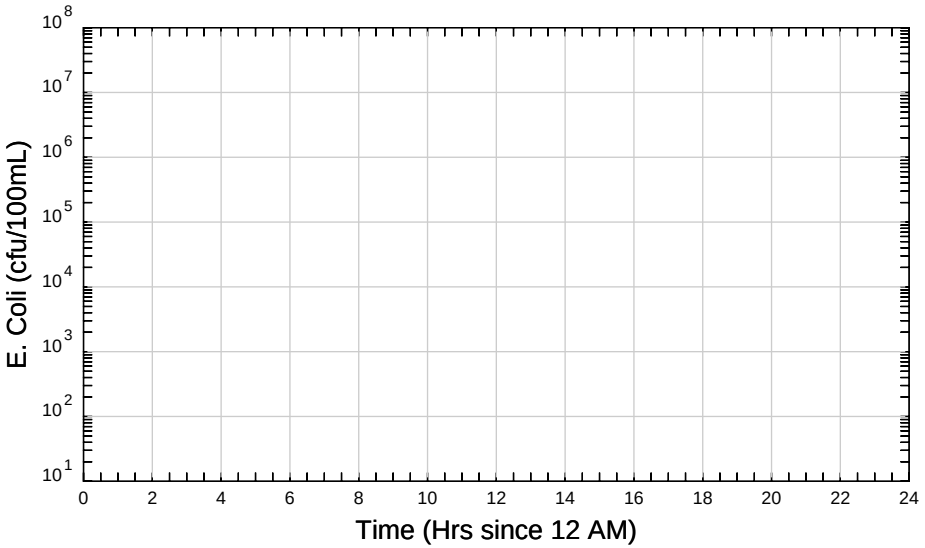

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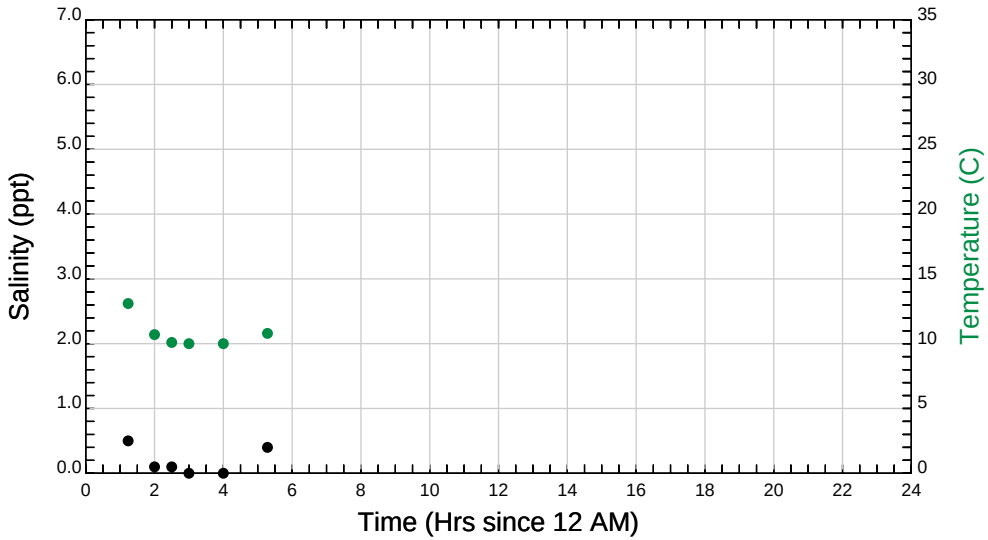

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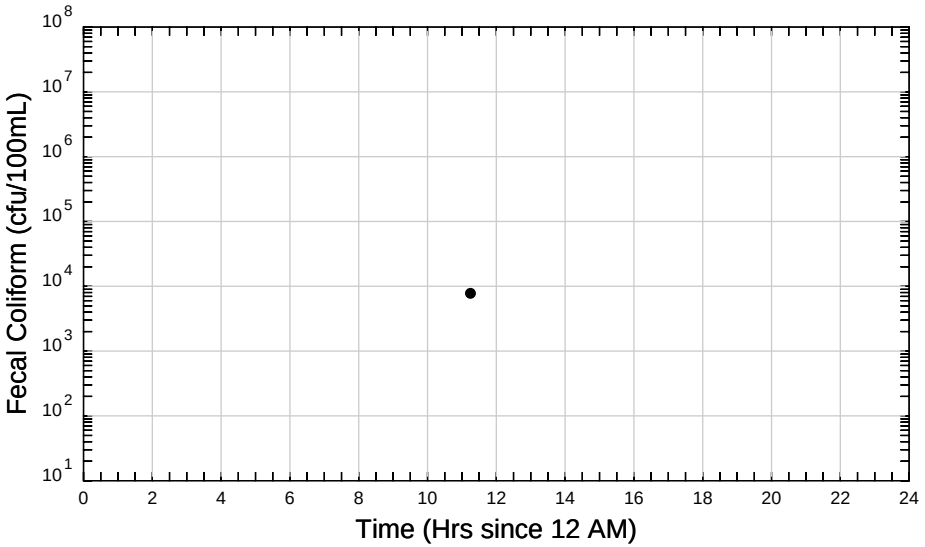

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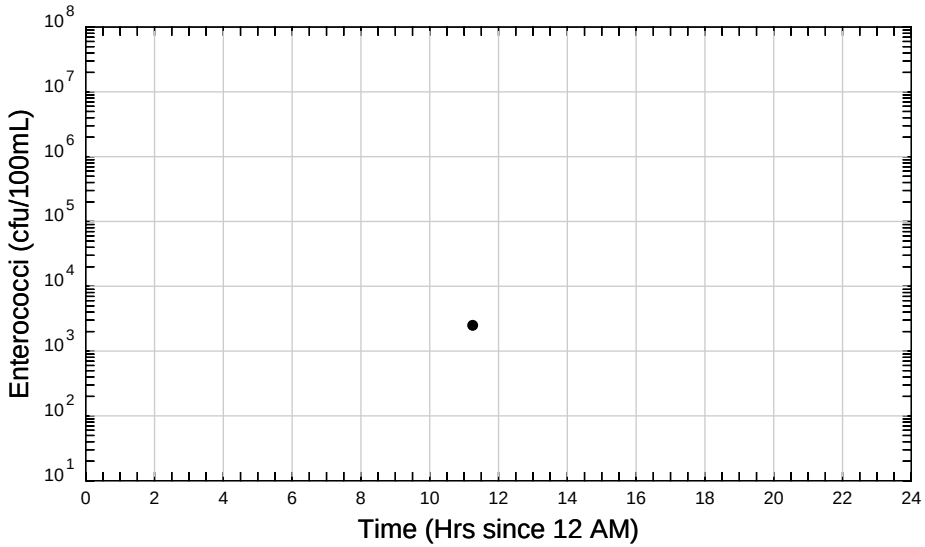

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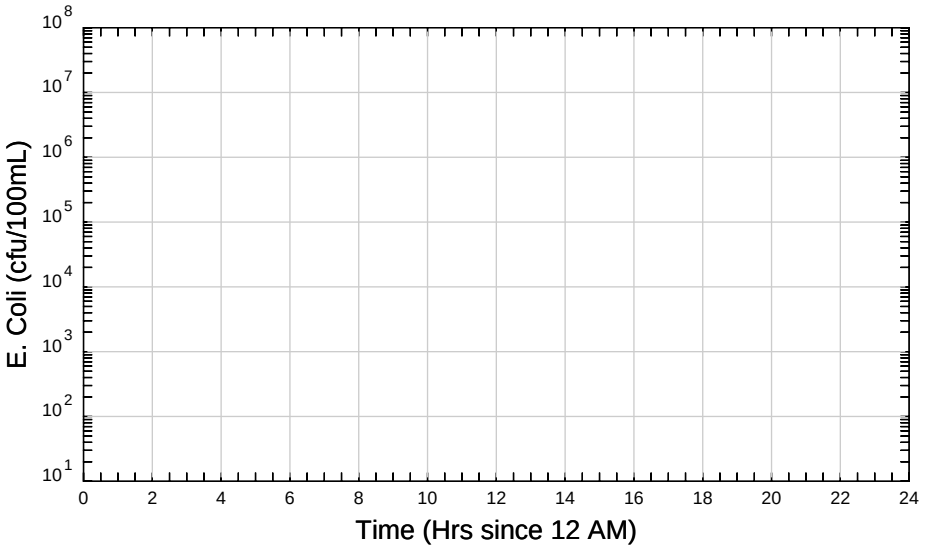

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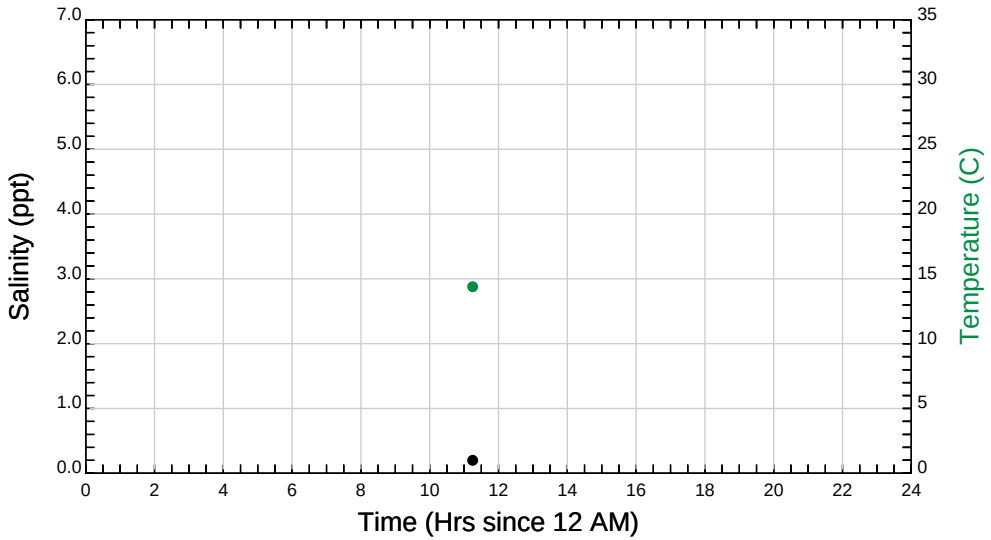

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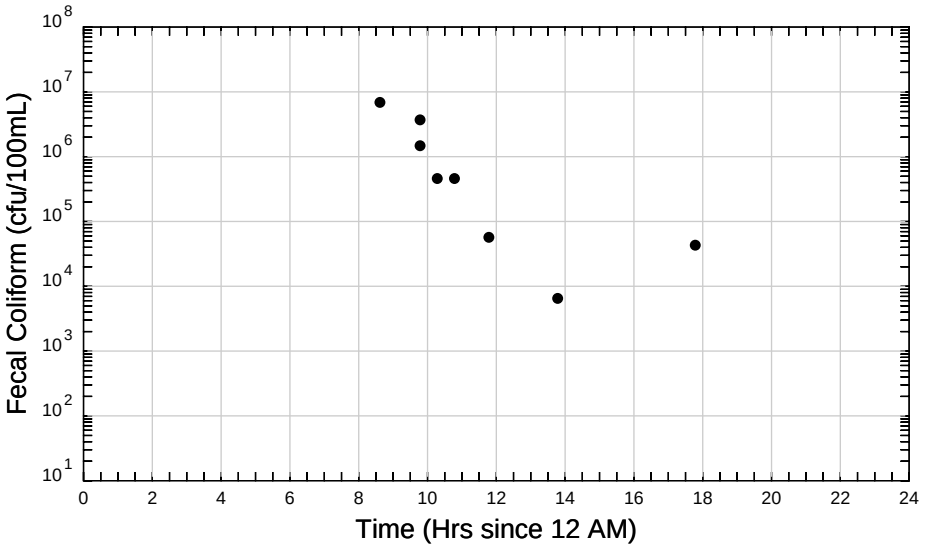

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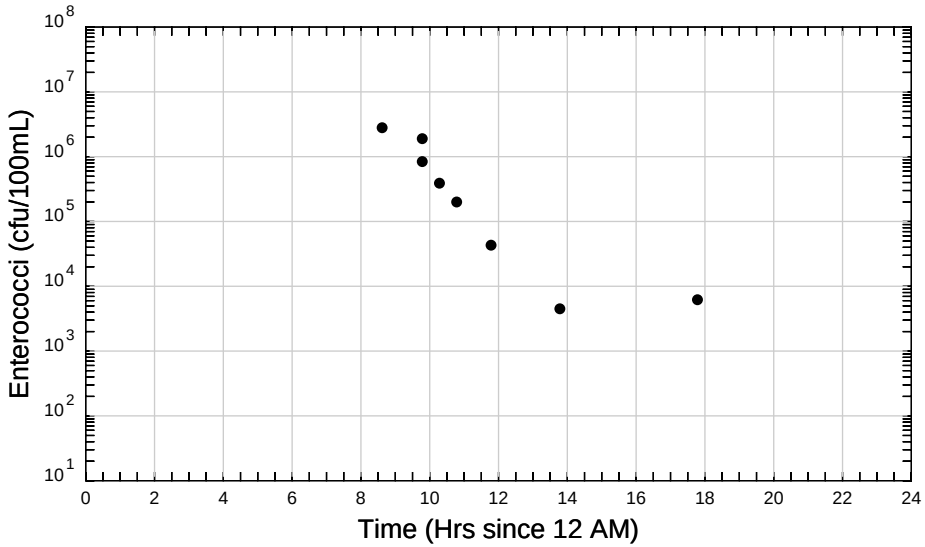

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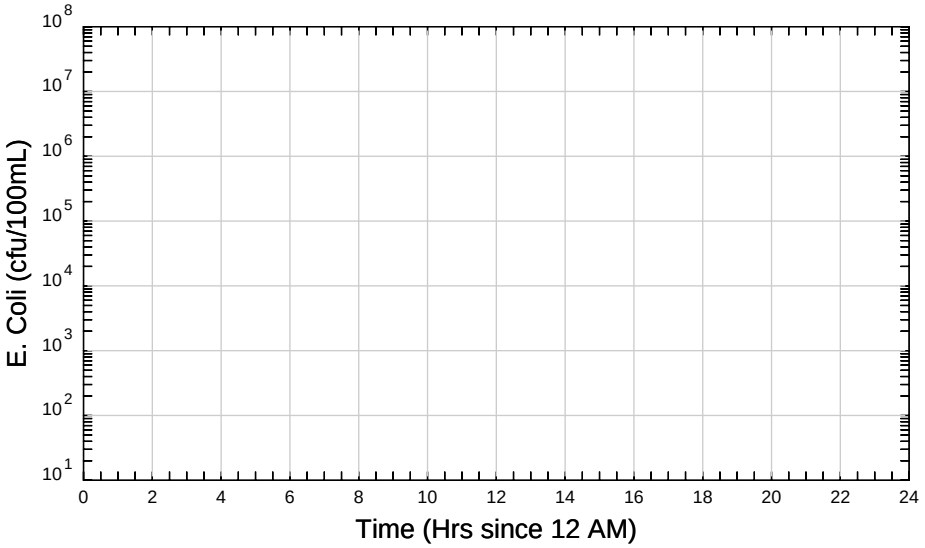

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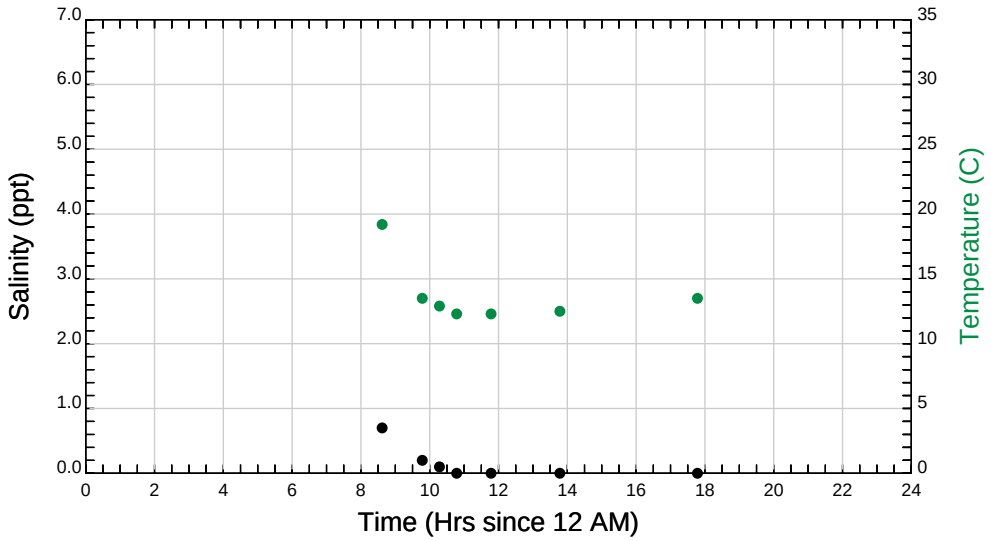

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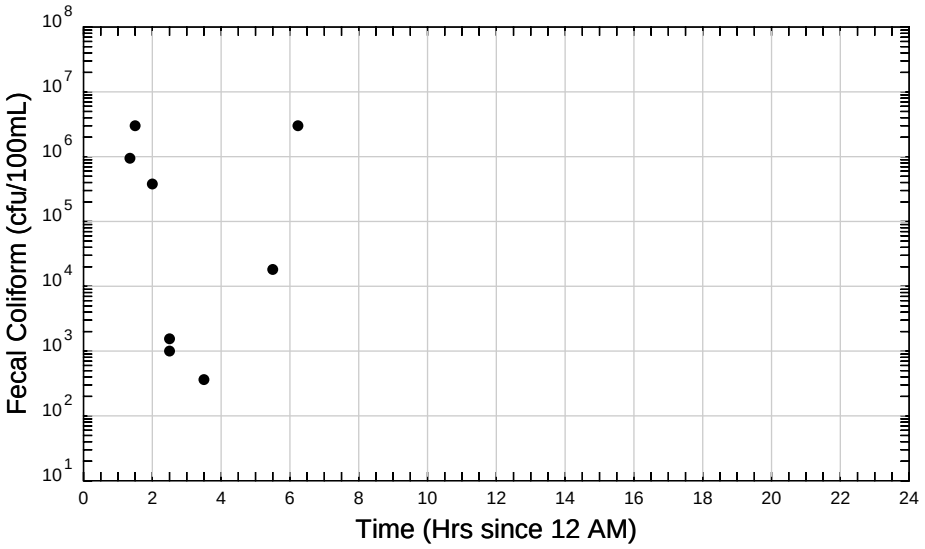

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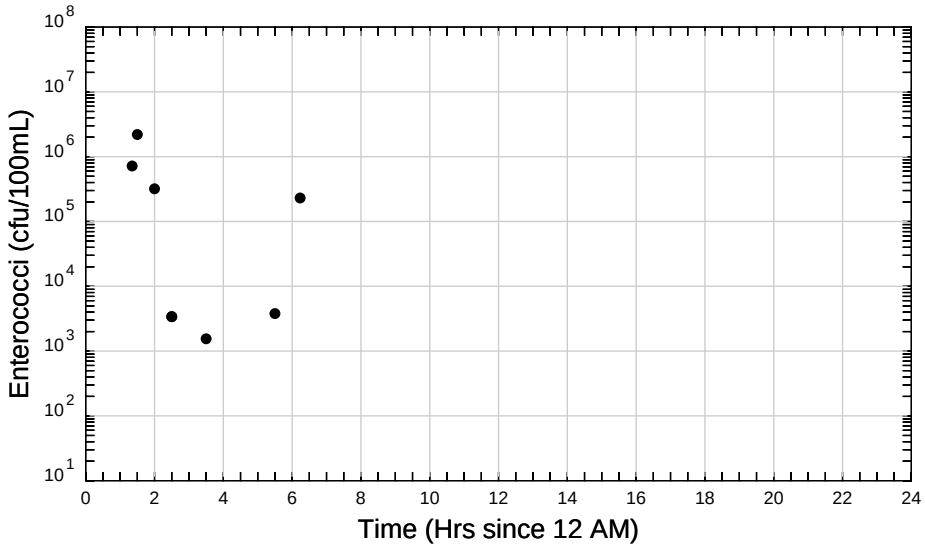

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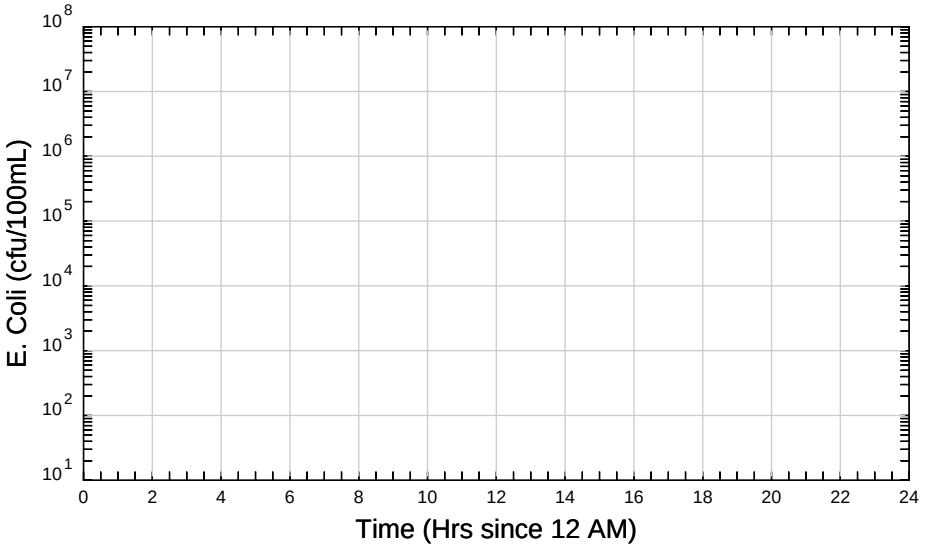

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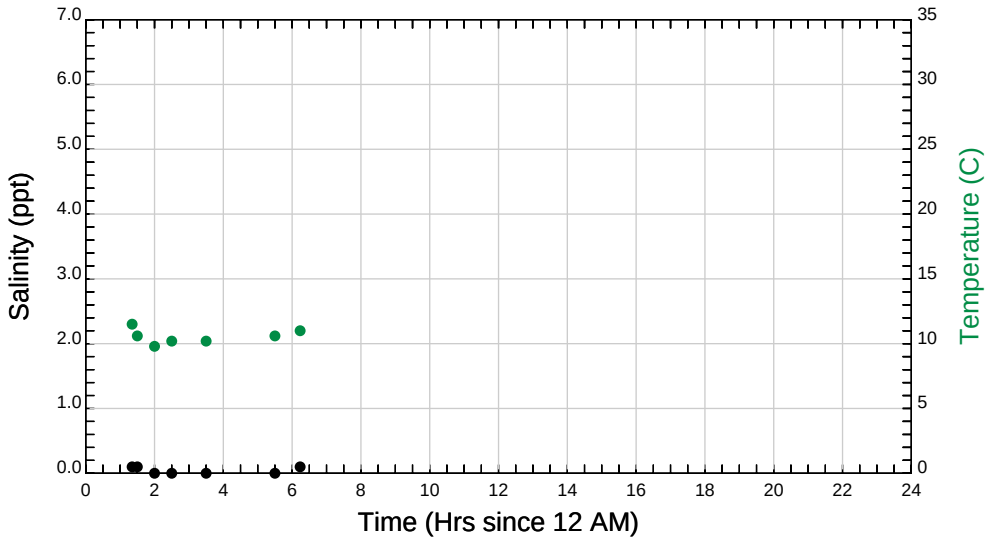

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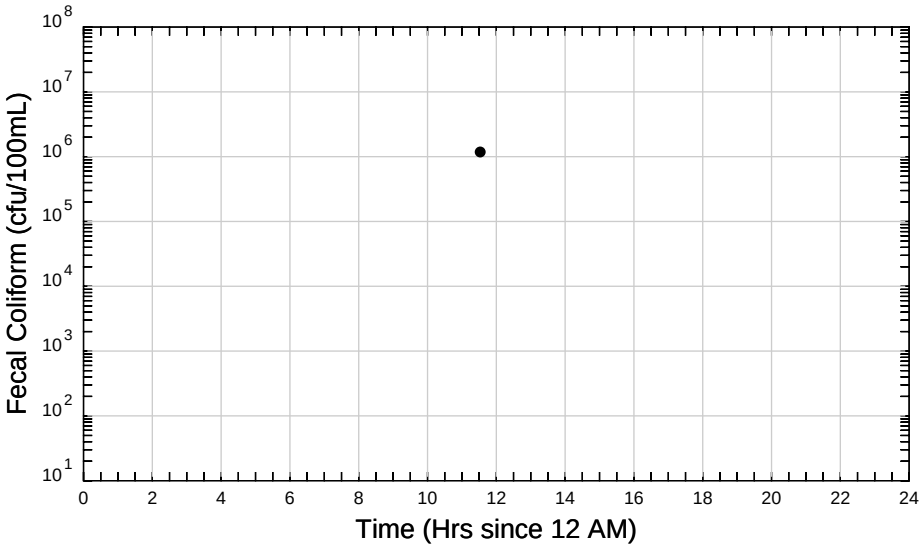

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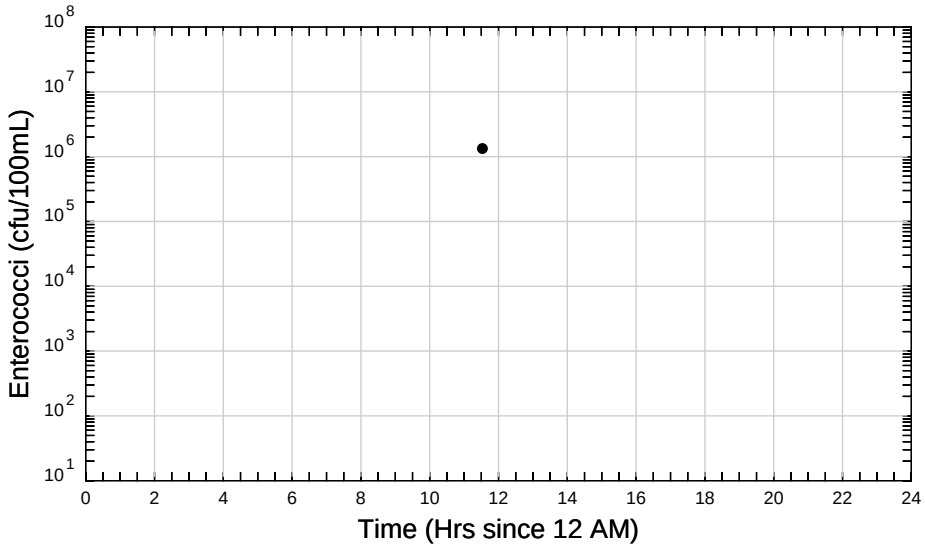

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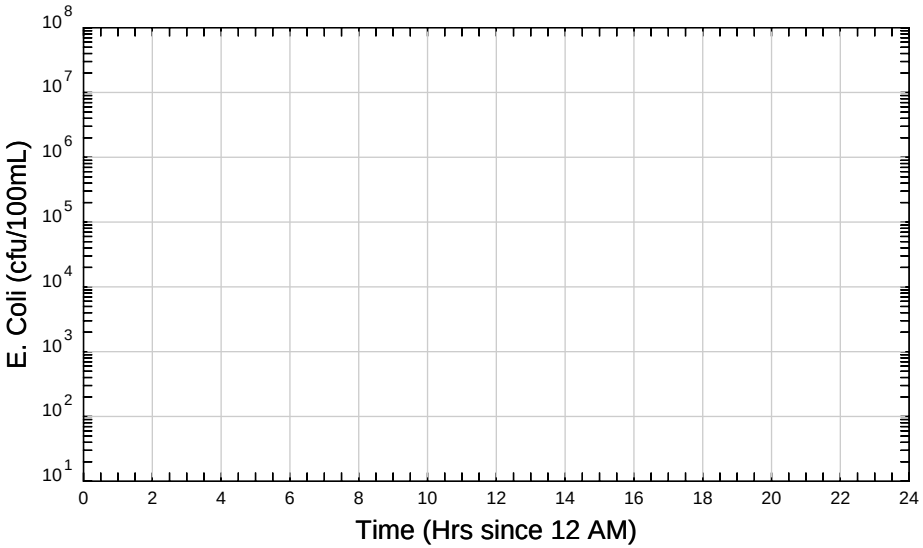

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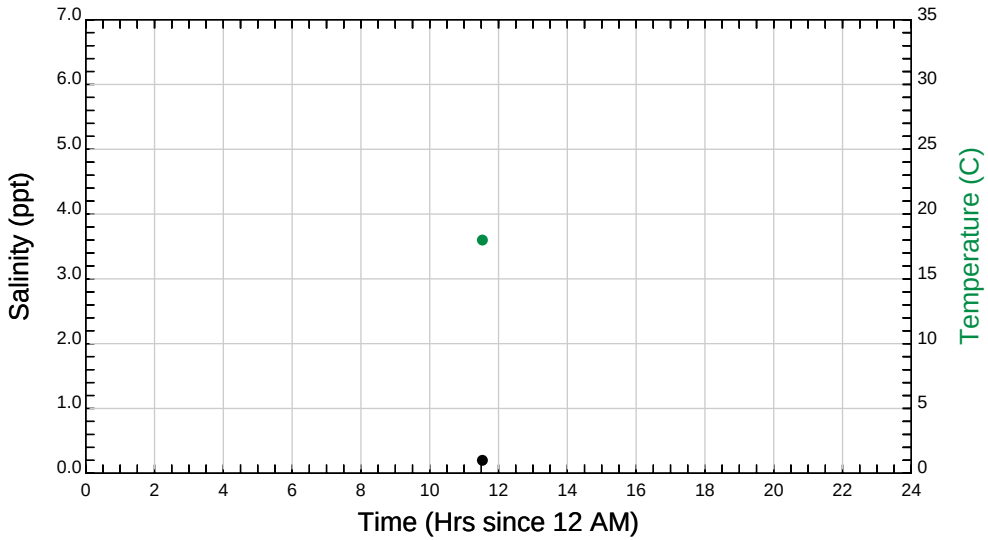

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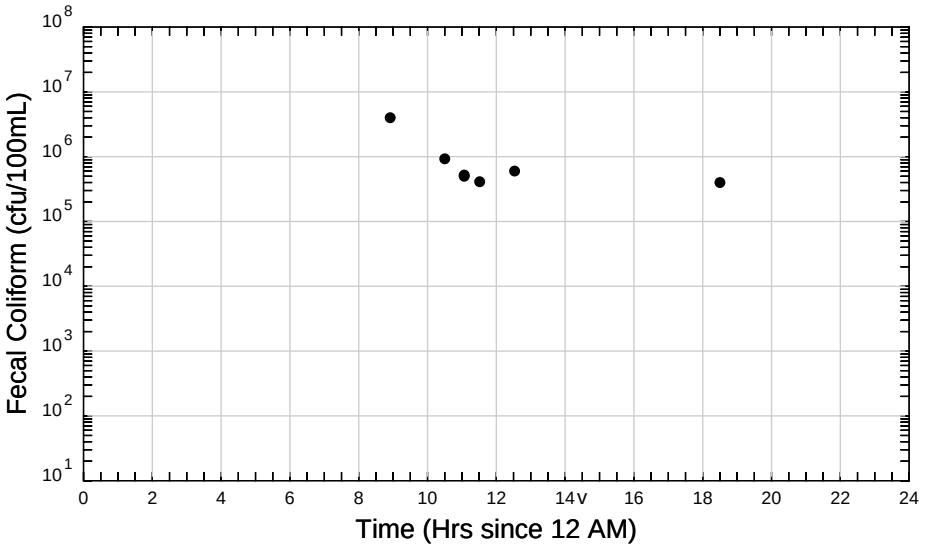

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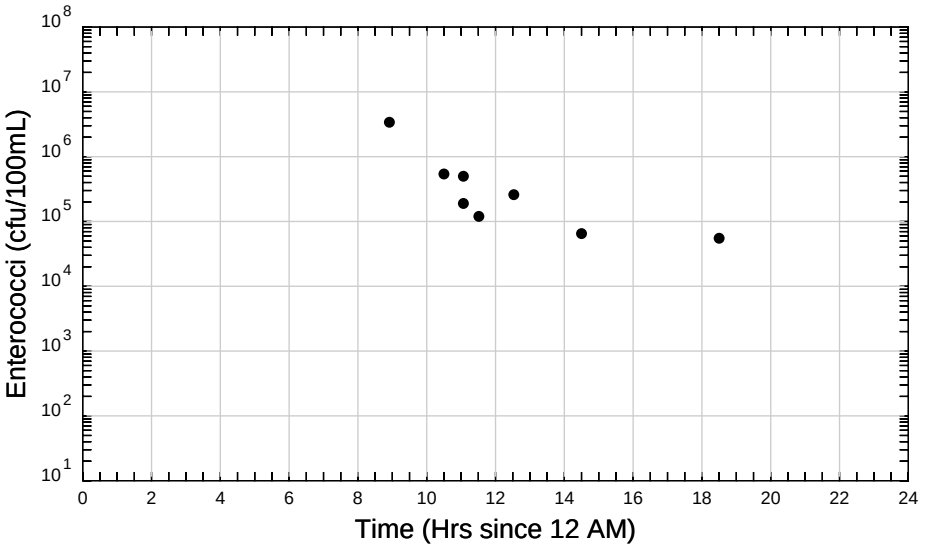

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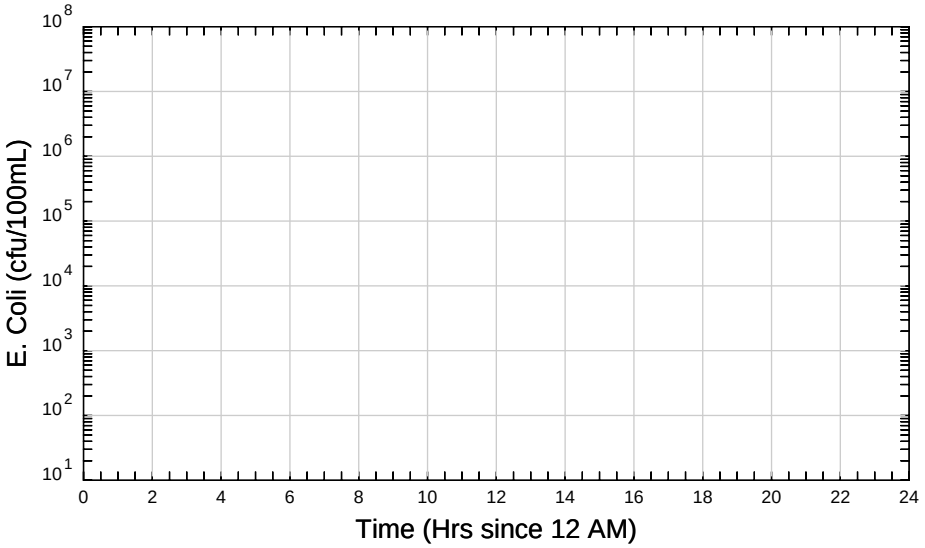

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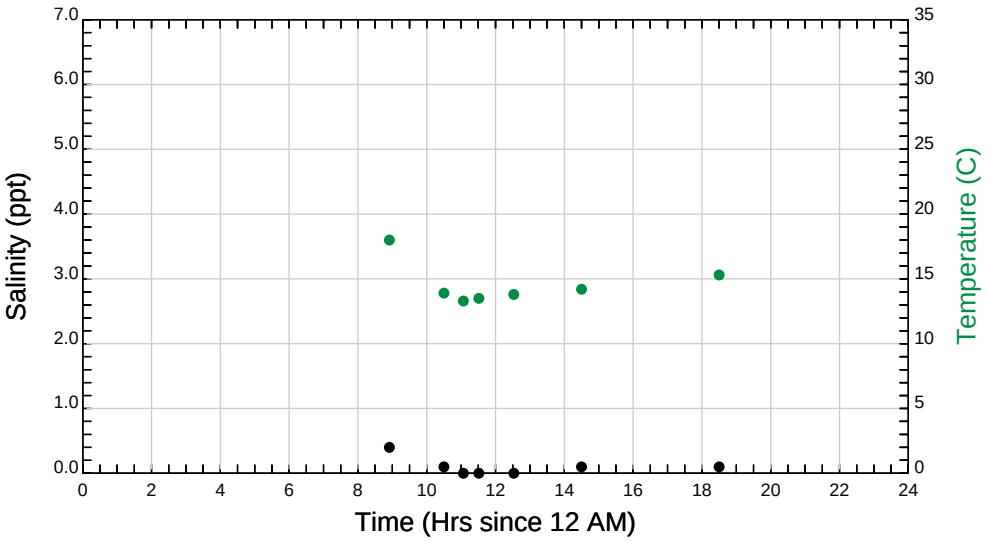

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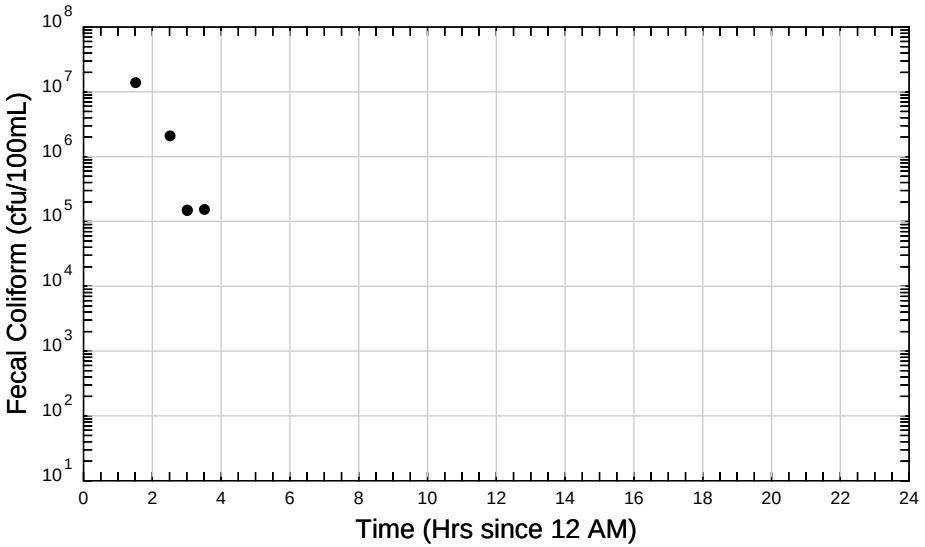

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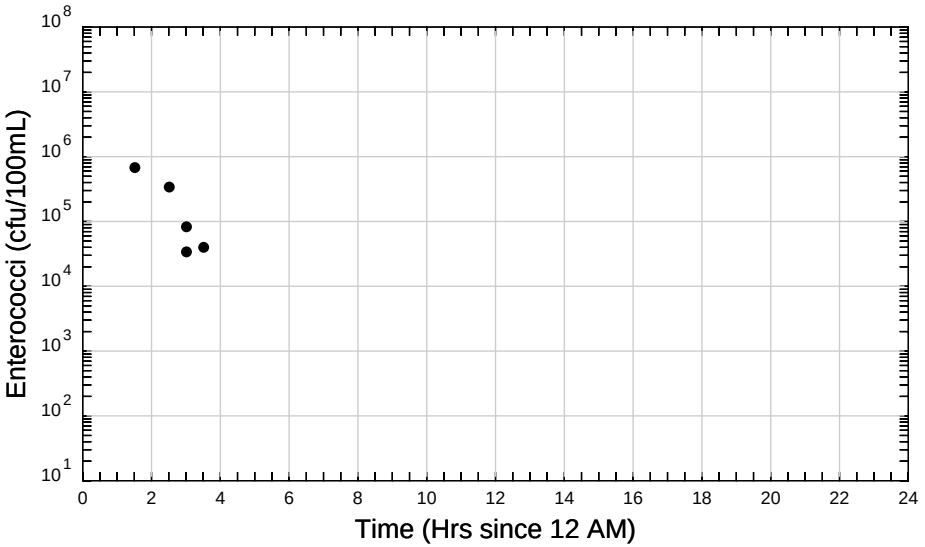

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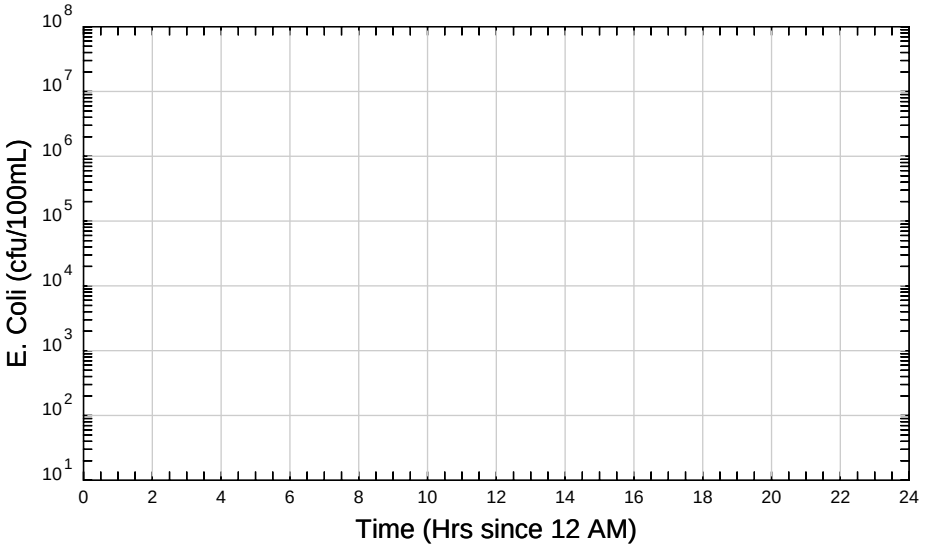

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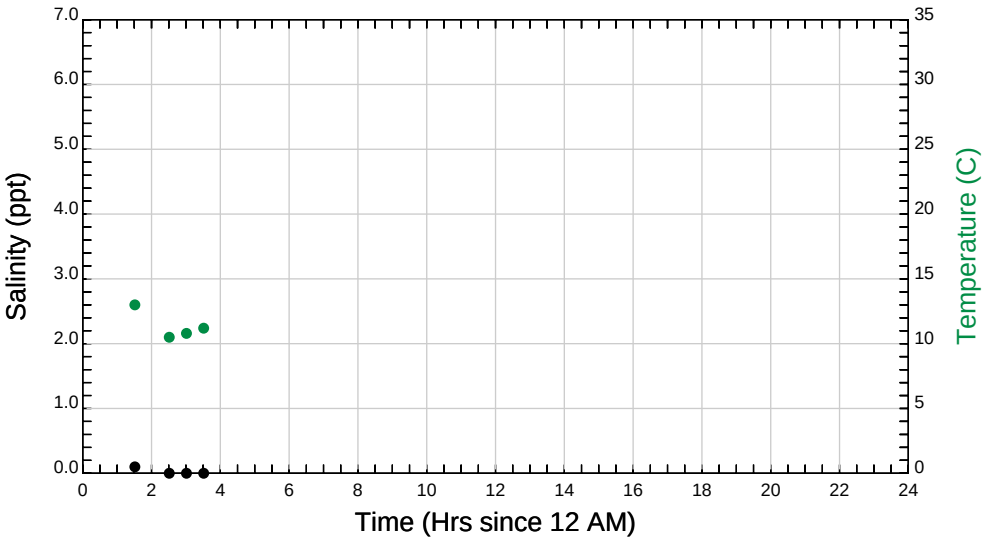

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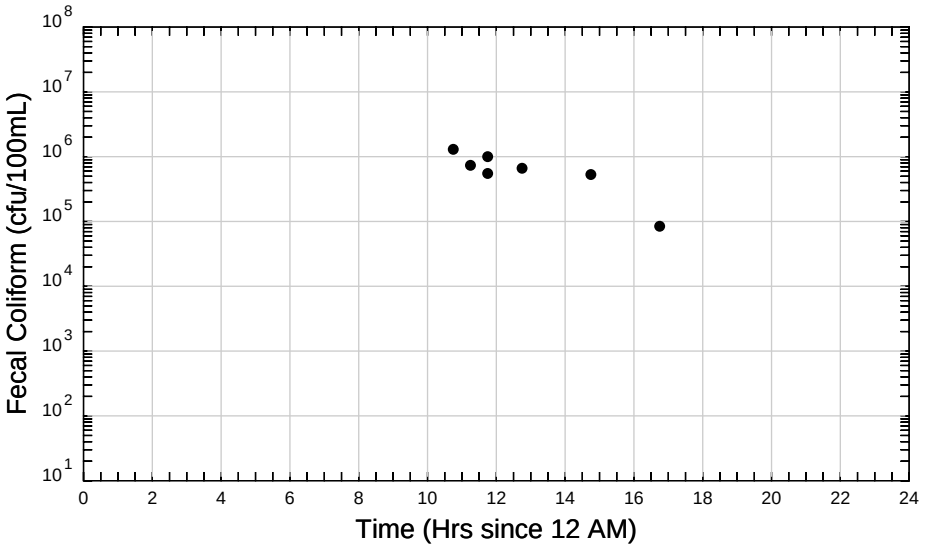

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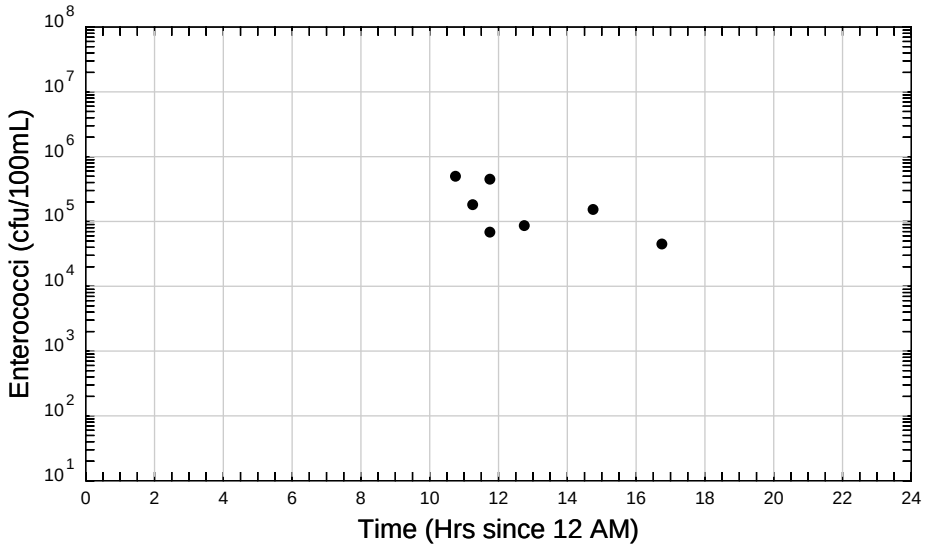

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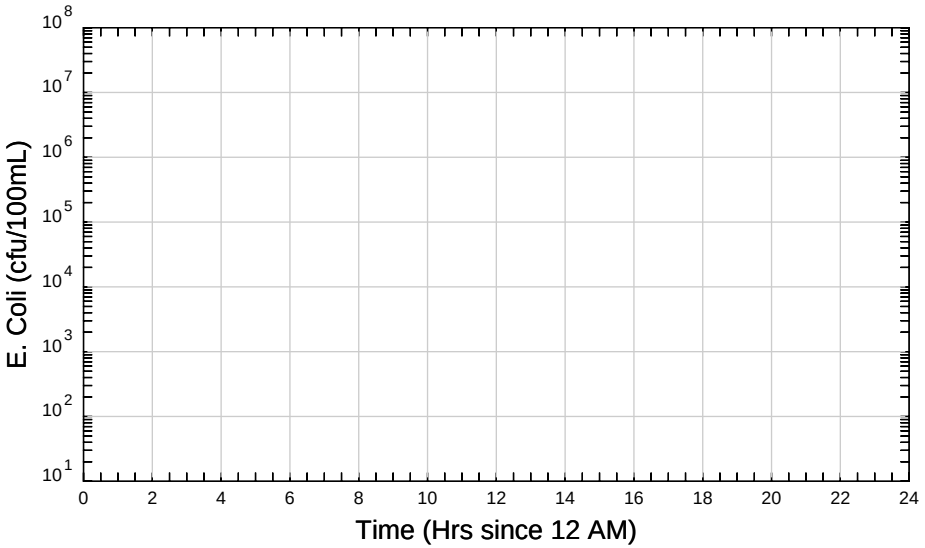

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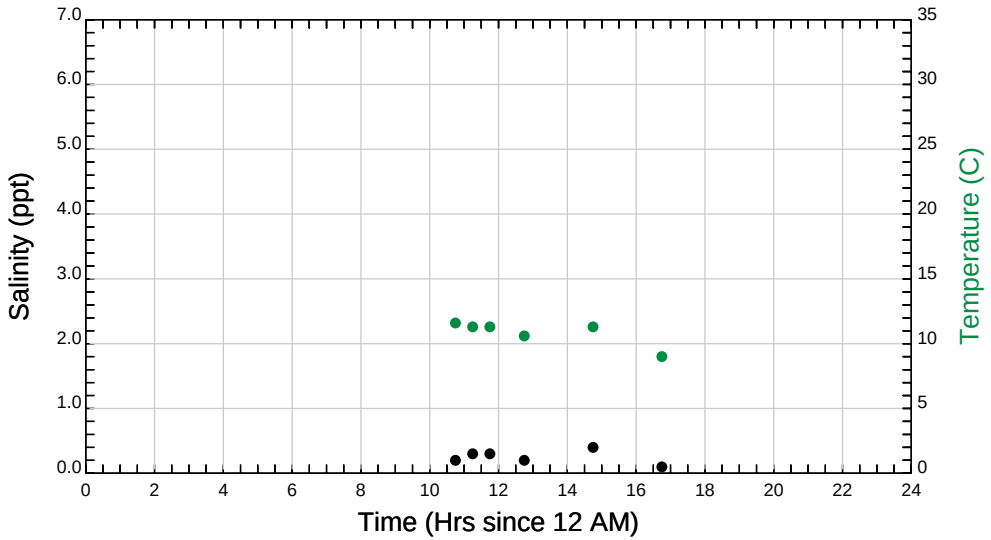

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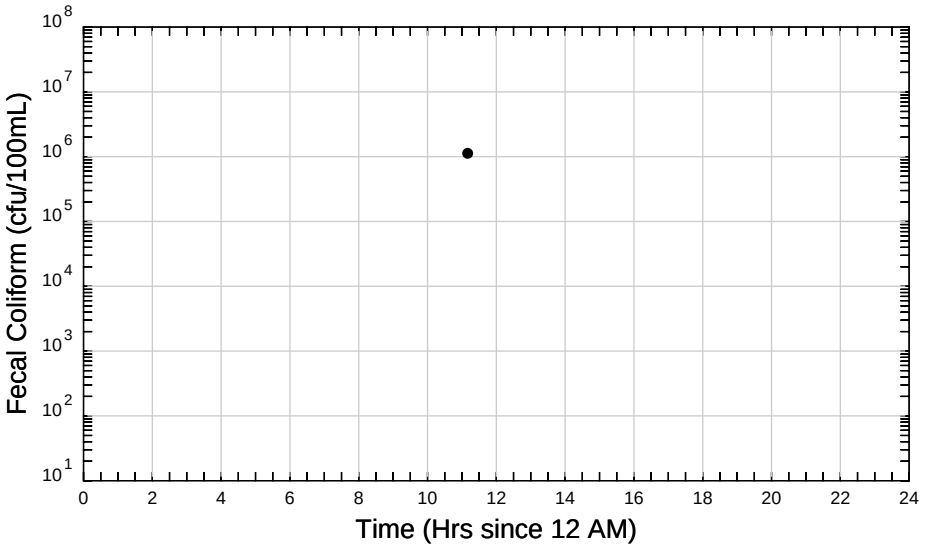

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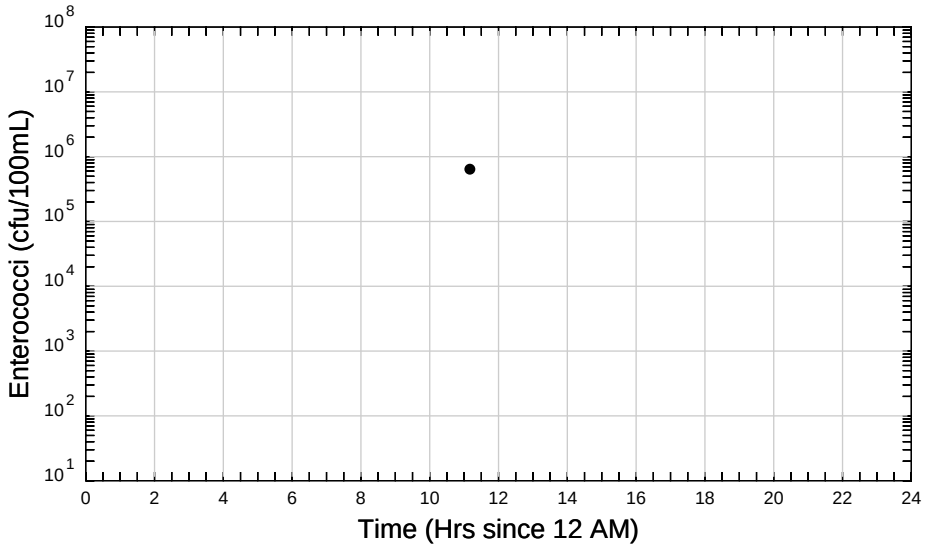

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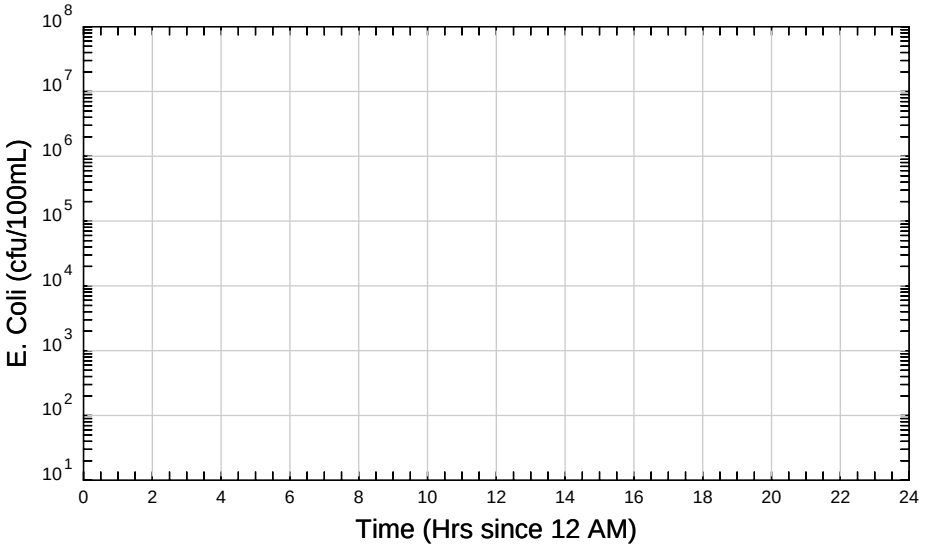

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

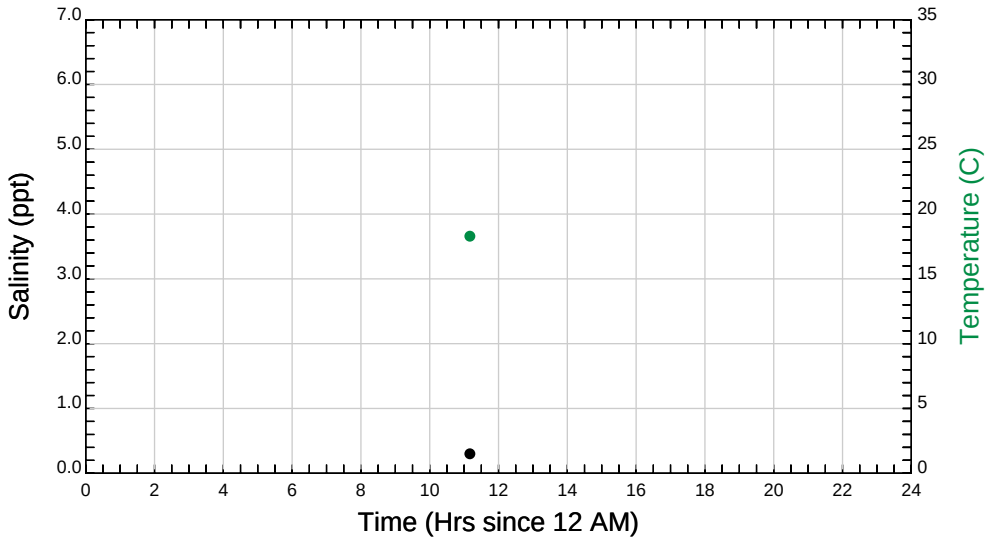

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

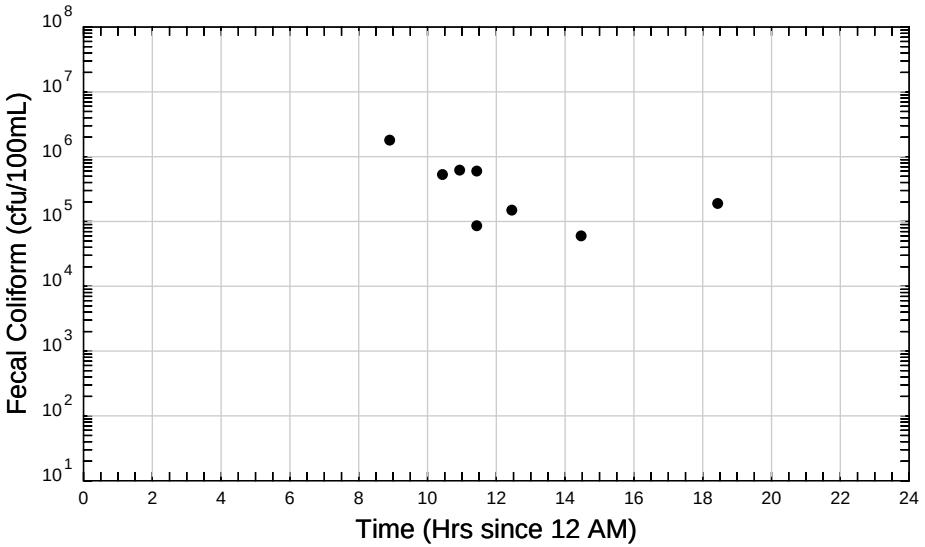

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

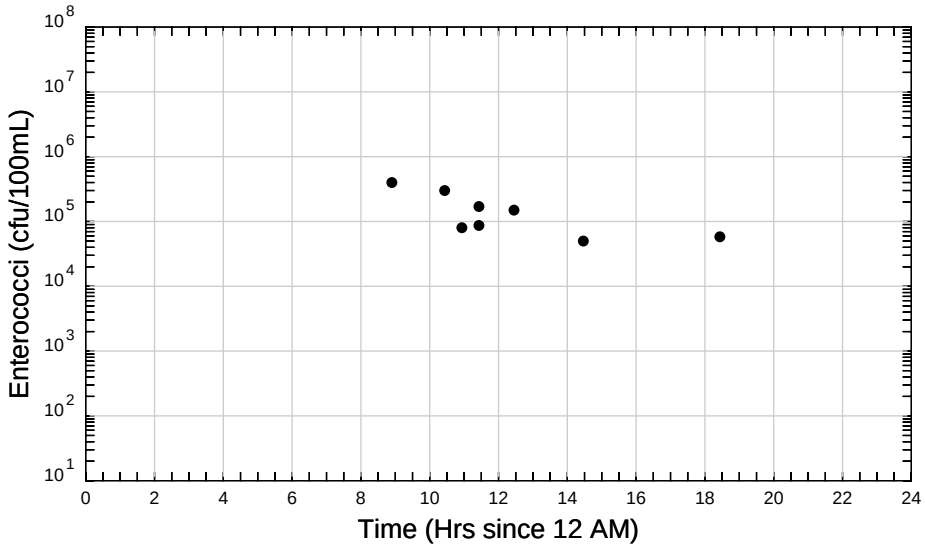

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

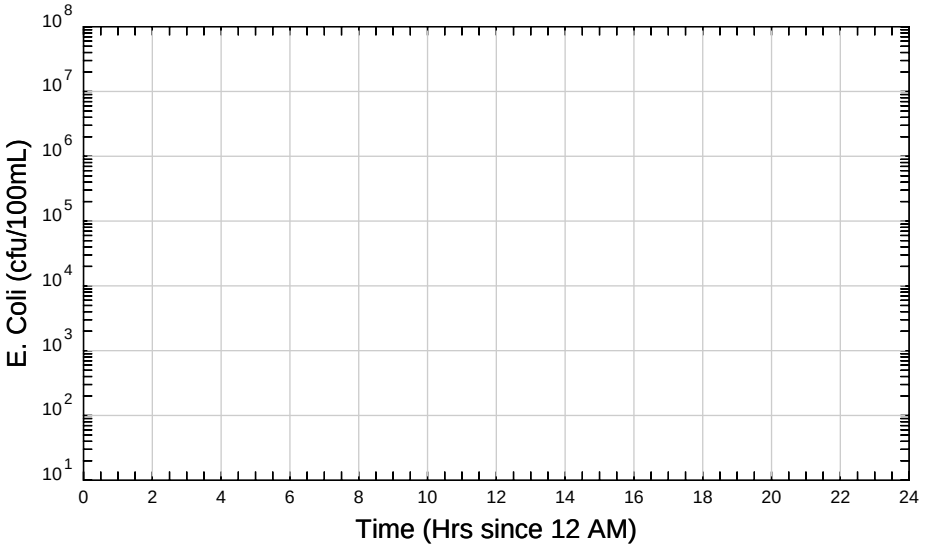

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

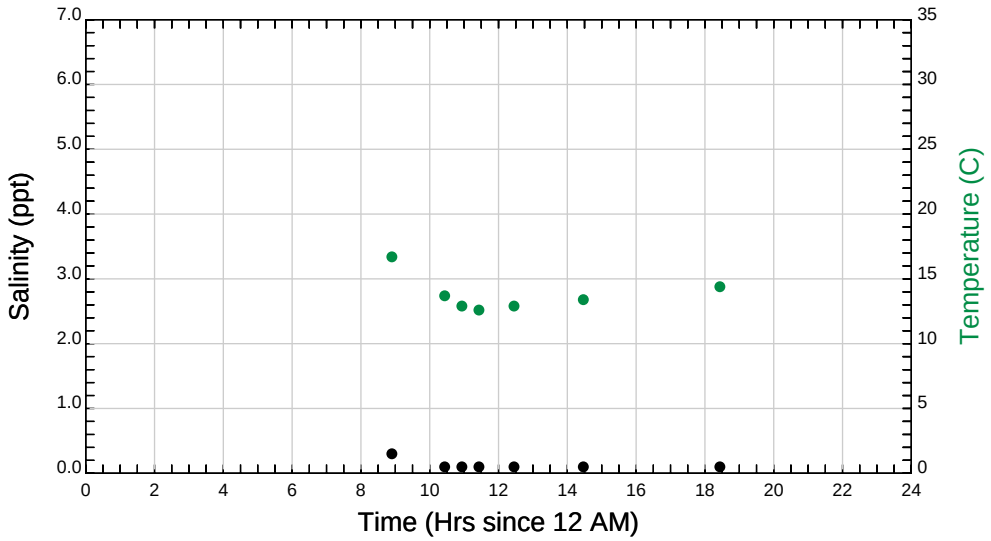

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

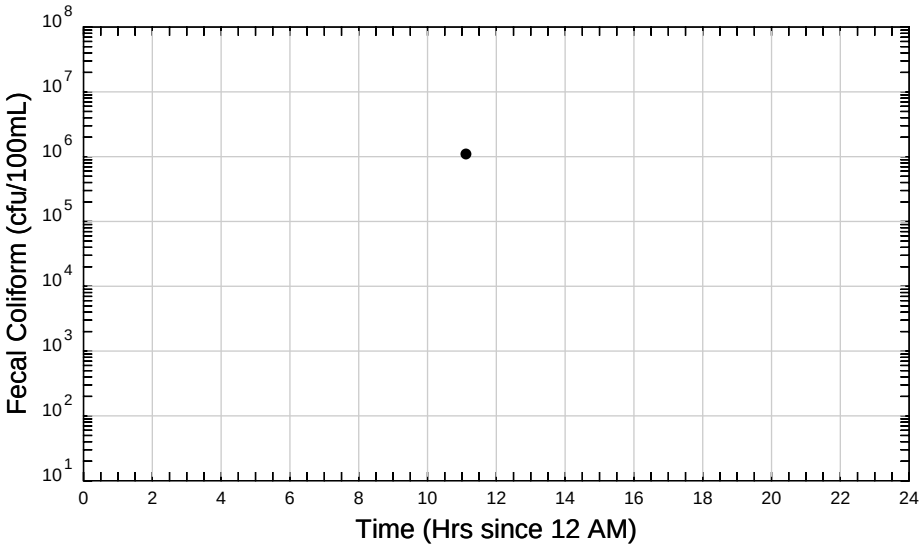

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

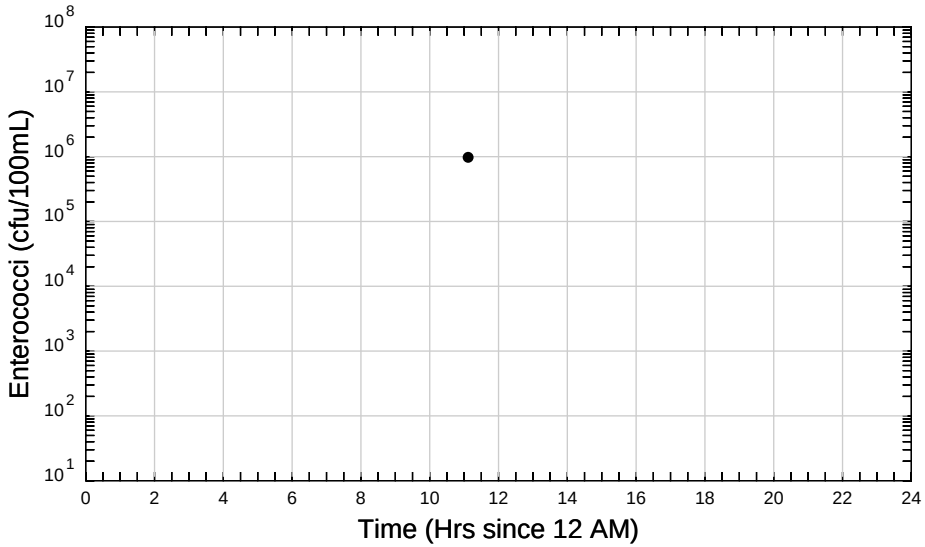

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

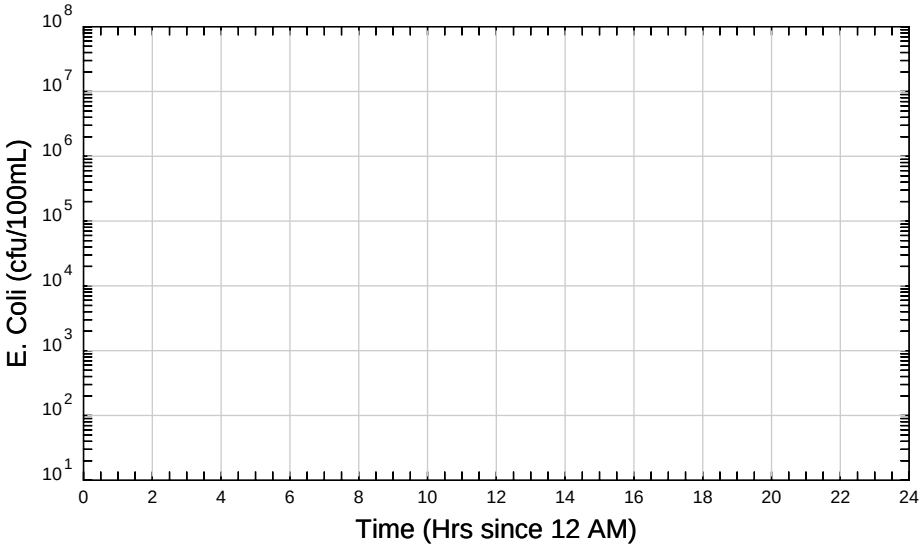

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

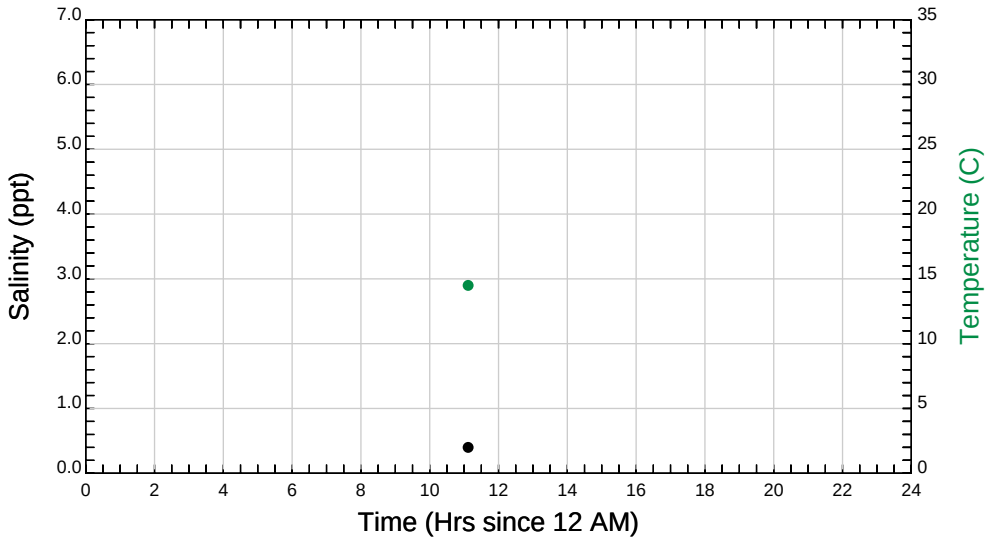

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

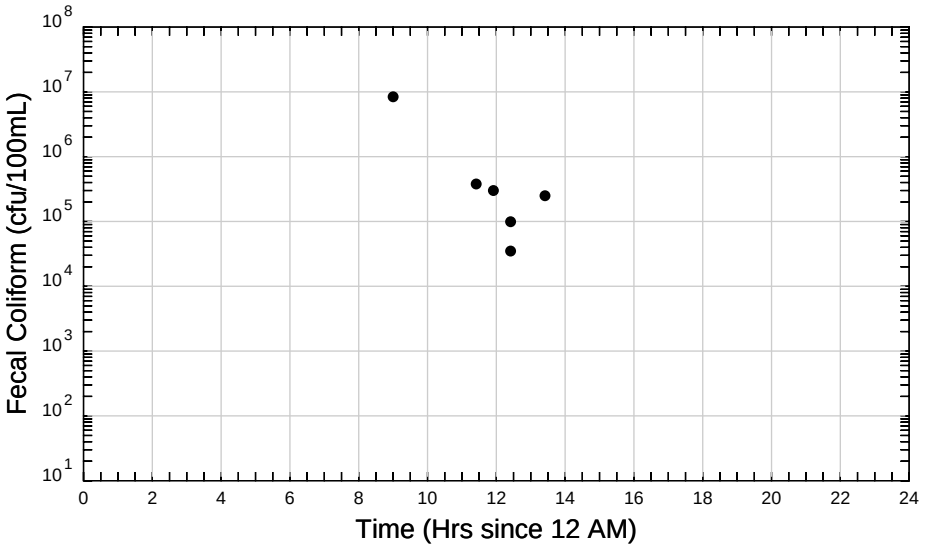

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

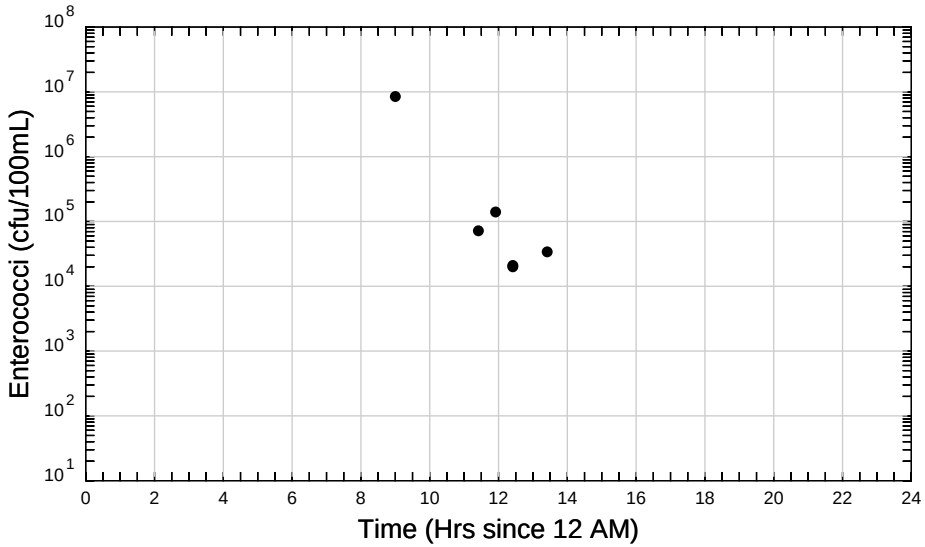

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

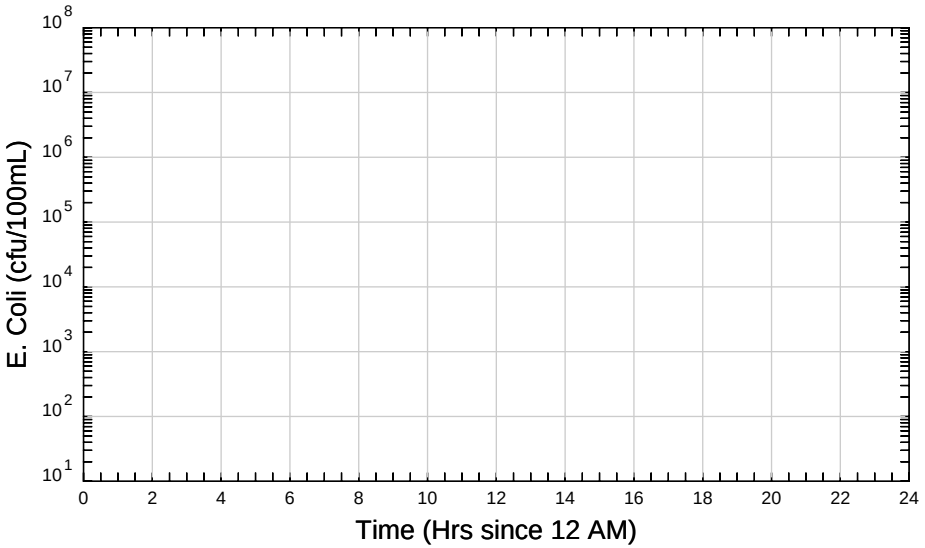

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

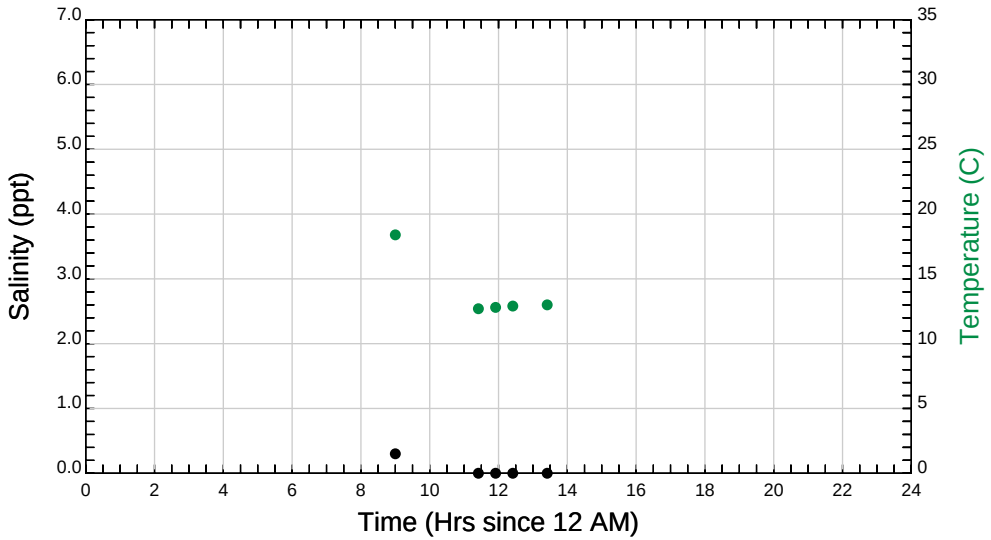

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

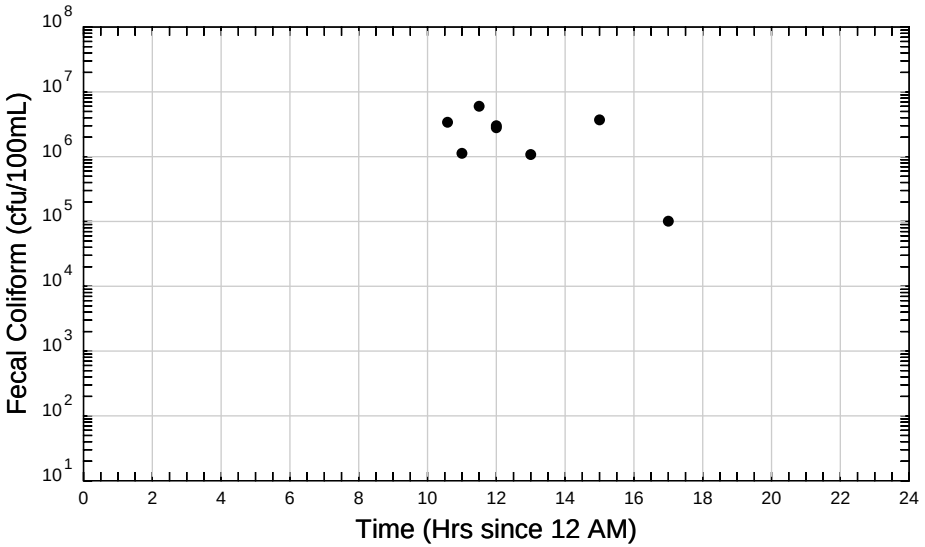

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

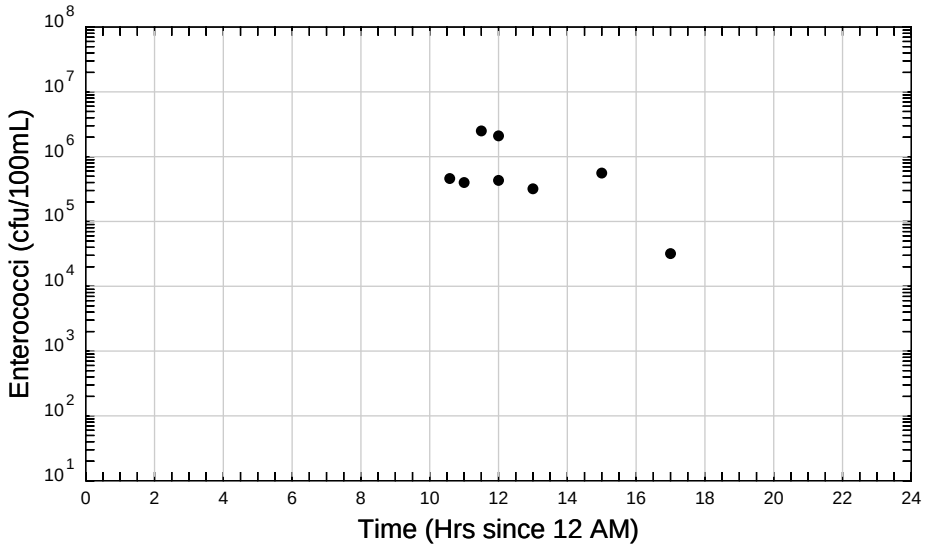

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

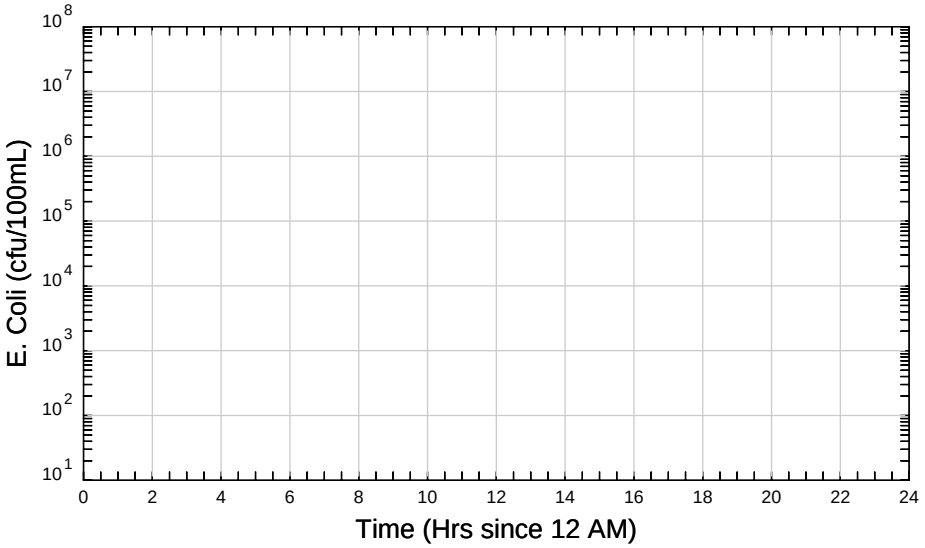

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

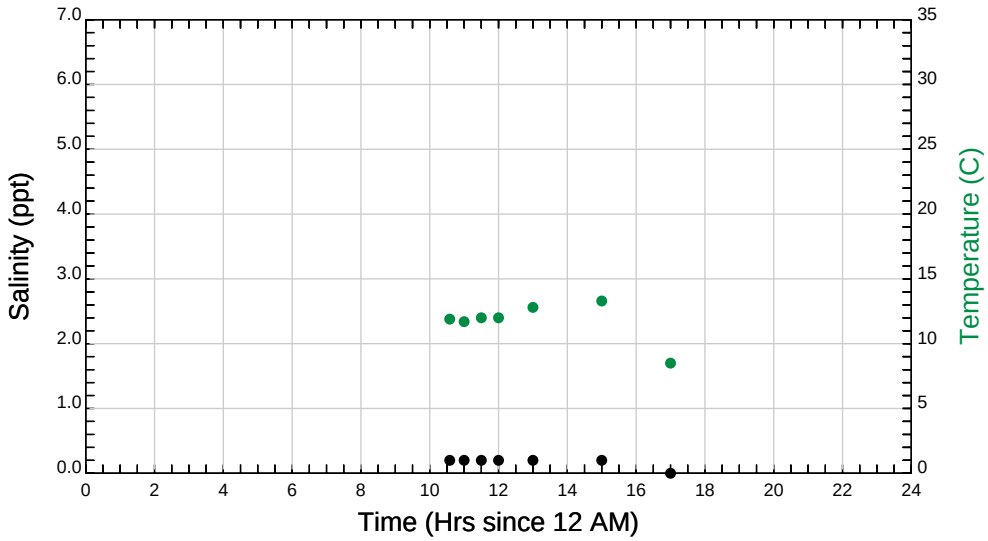

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

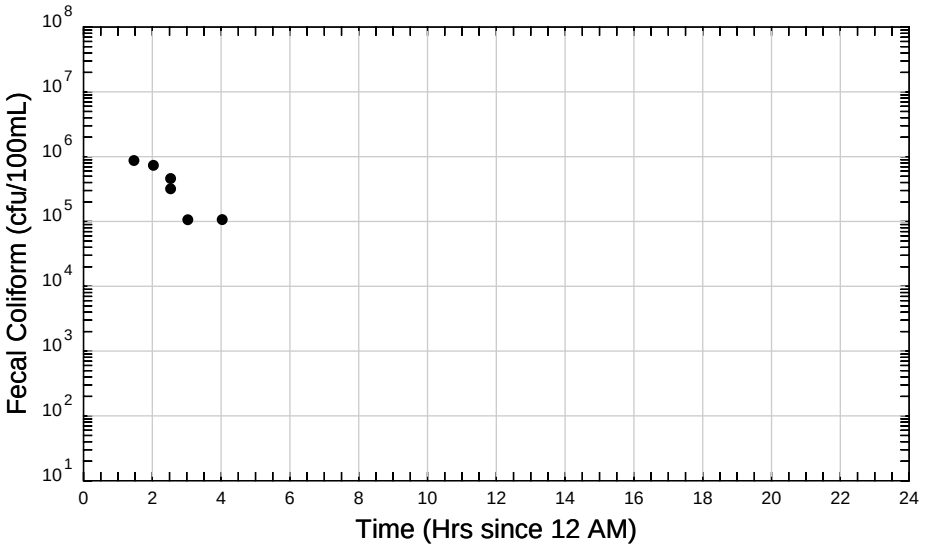

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

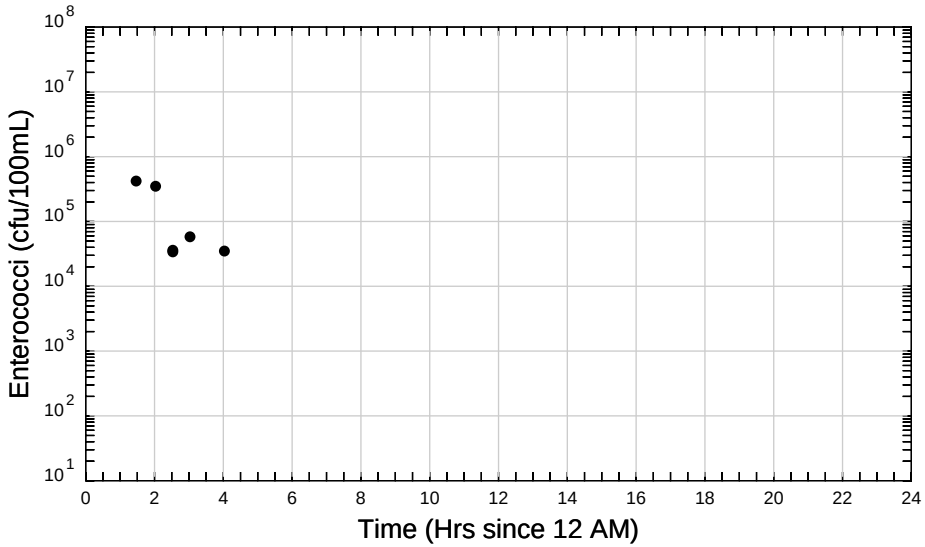

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

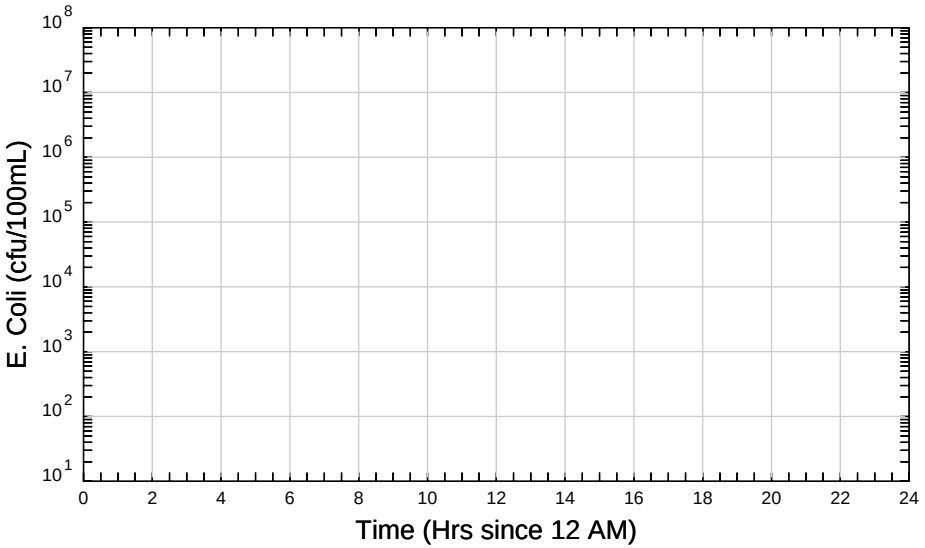

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Time (Hrs since 12 AM)

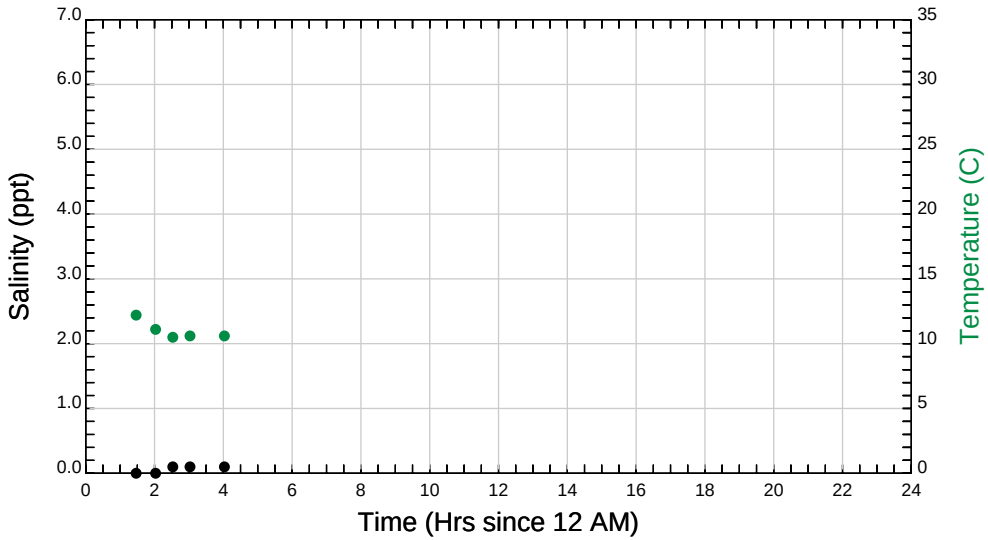

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

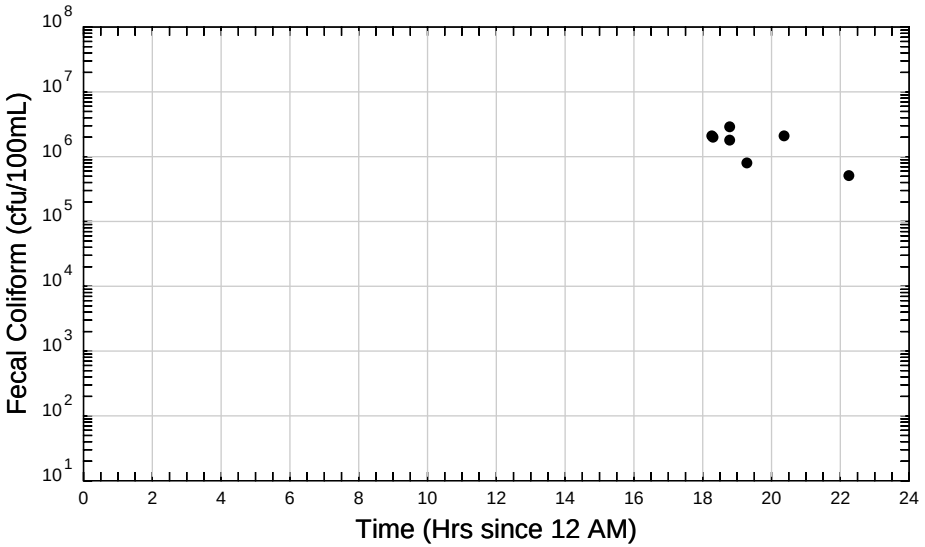

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

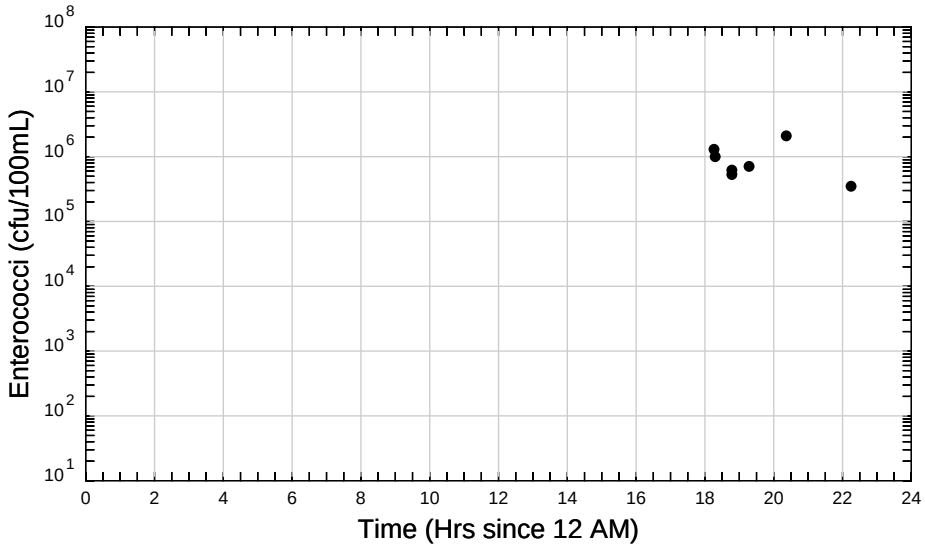

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

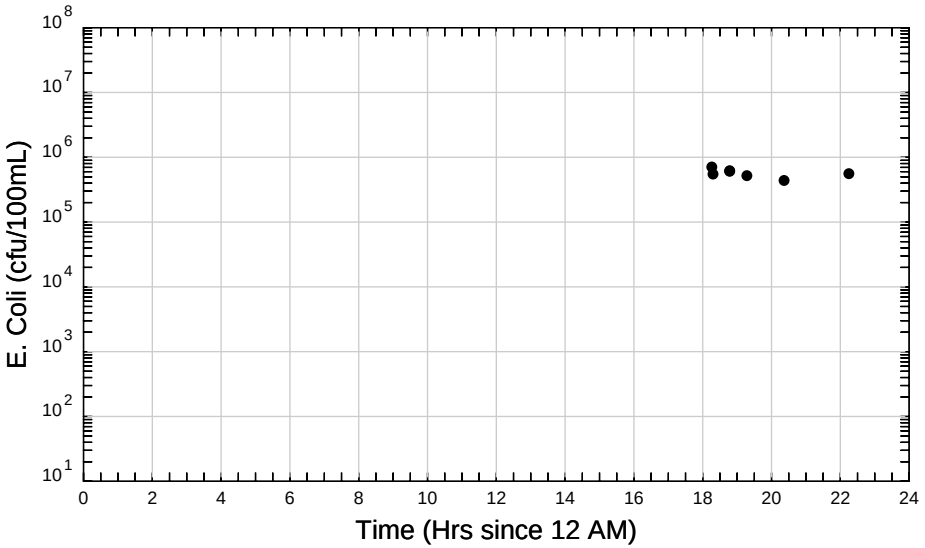

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Time (Hrs since 12 AM)

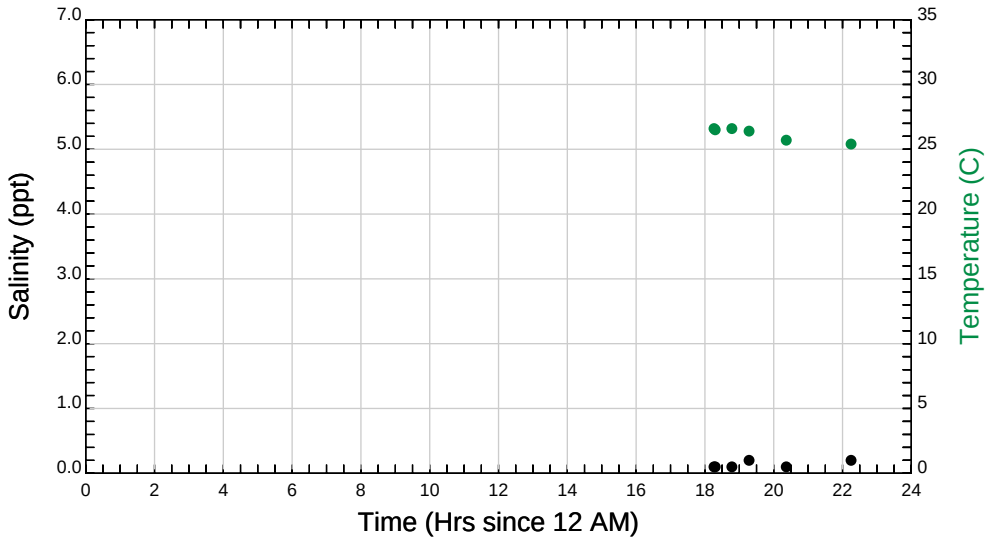

E. Coli (cfu/100mL)
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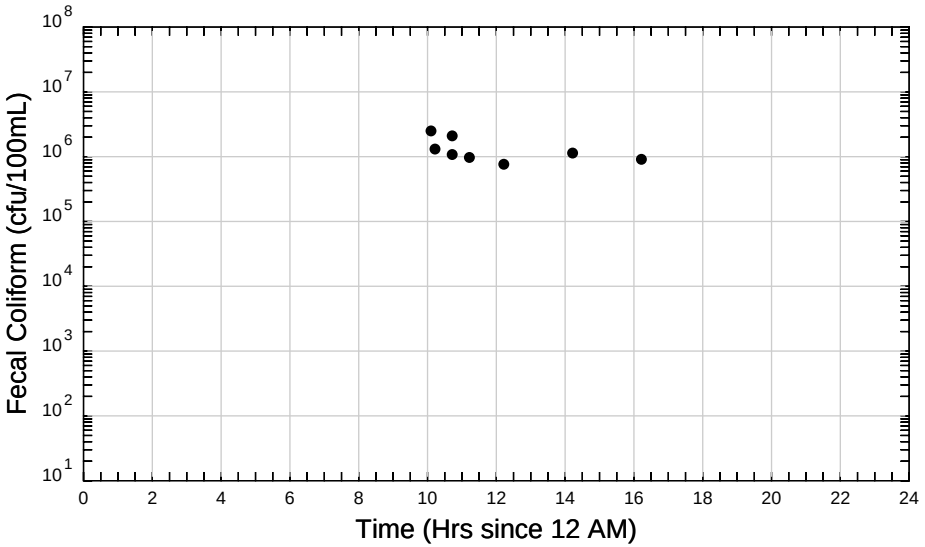

Salinity (ppt)
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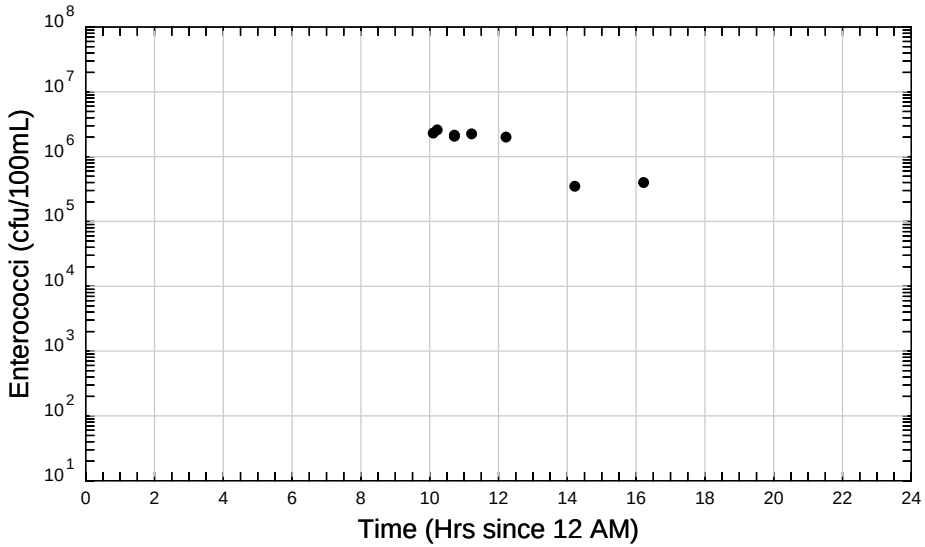

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Time (Hrs since 12 AM)

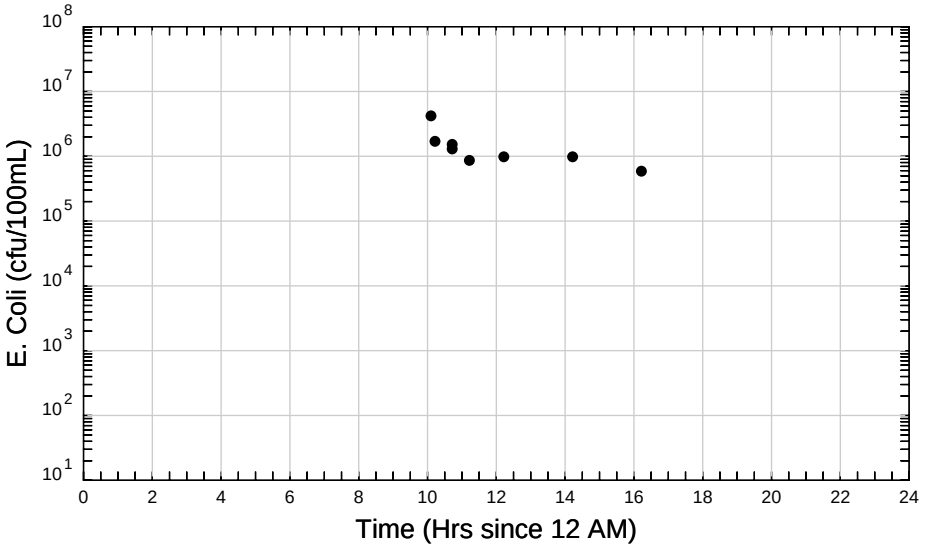

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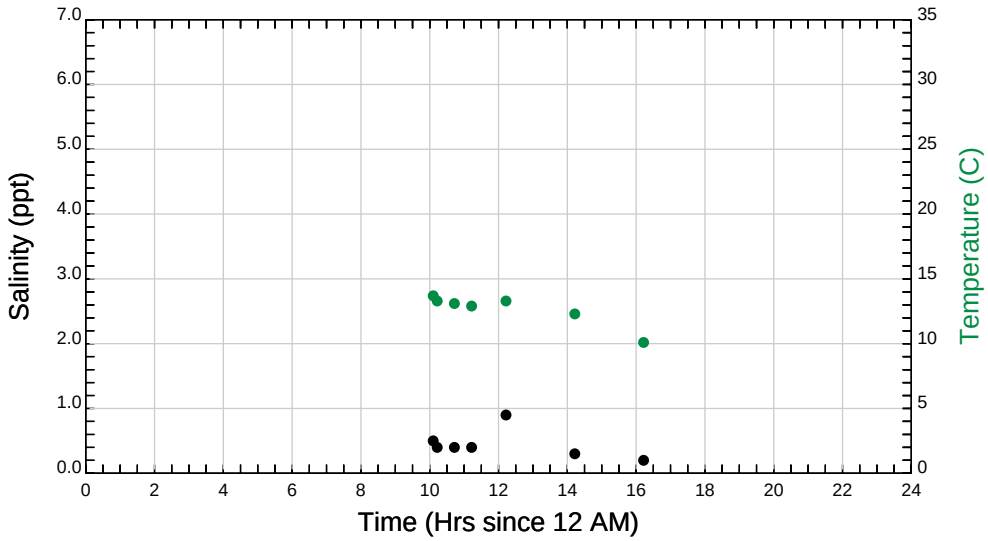

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Time (Hrs since 12 AM)

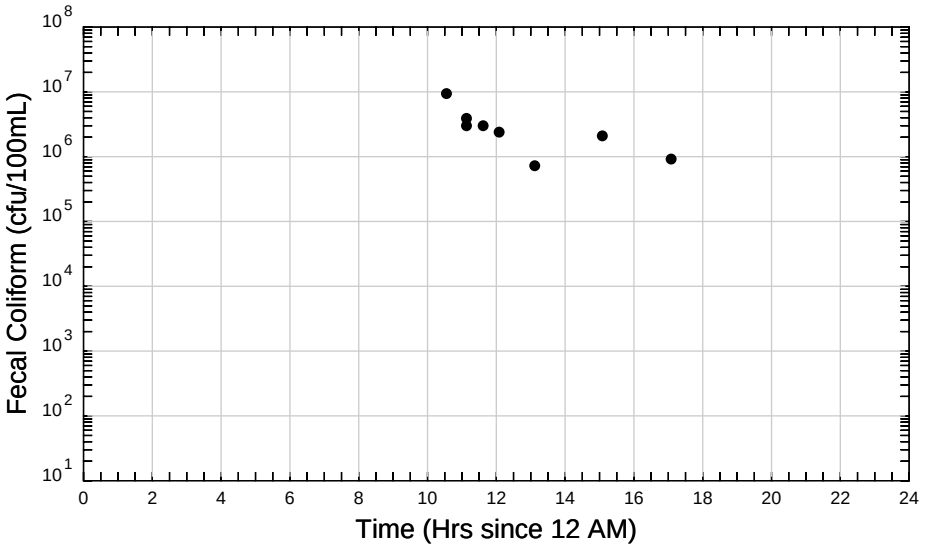

Salinity (ppt)
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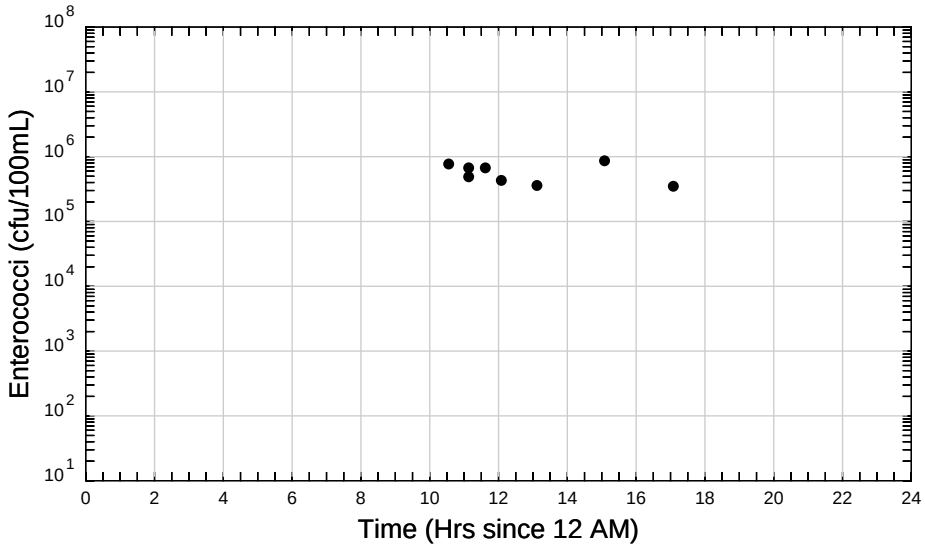

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

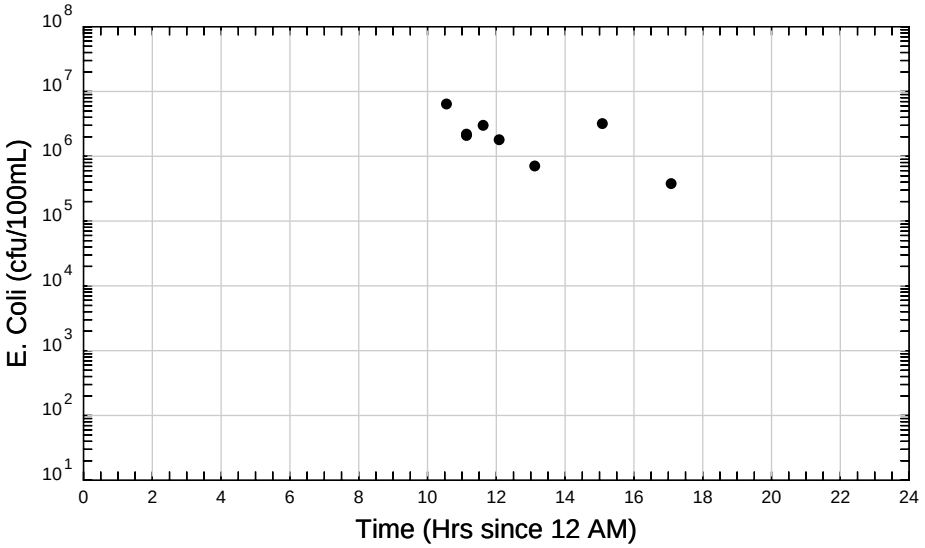

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

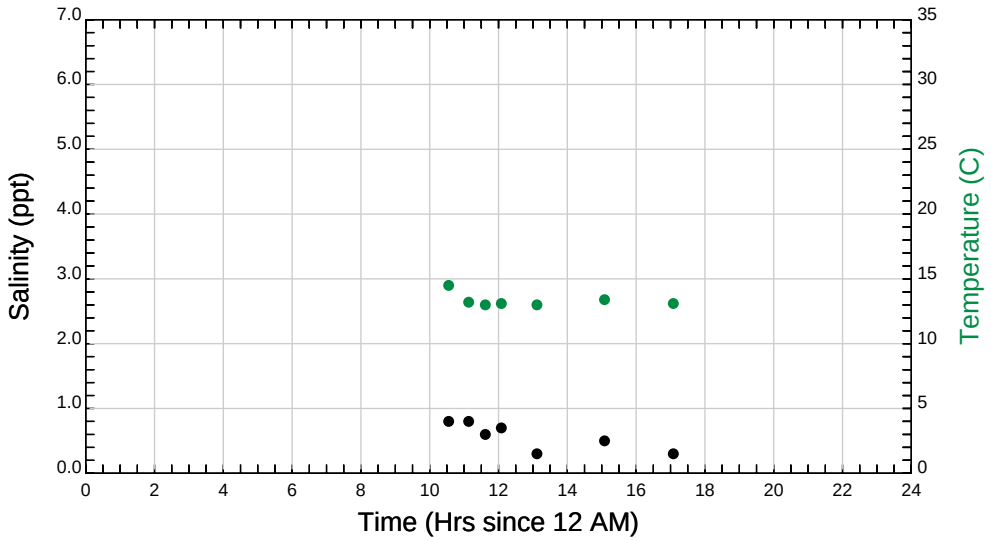

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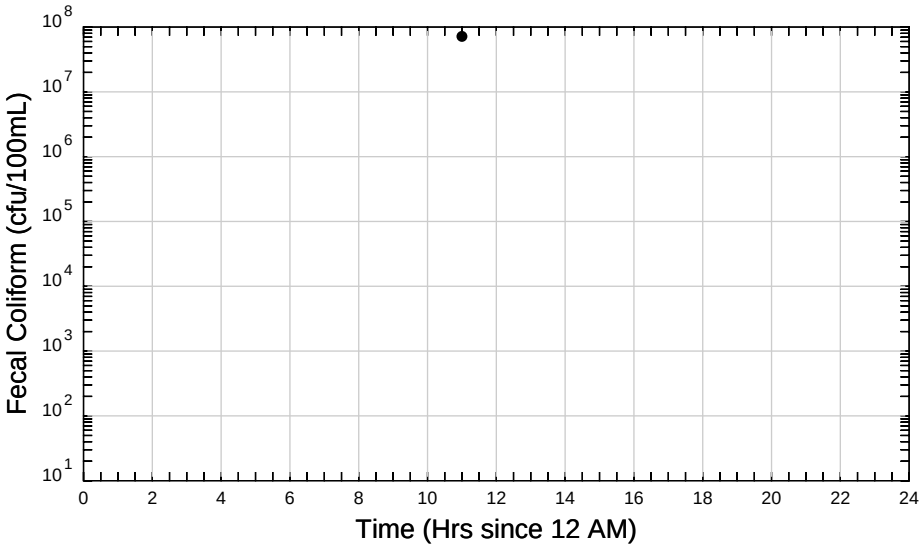

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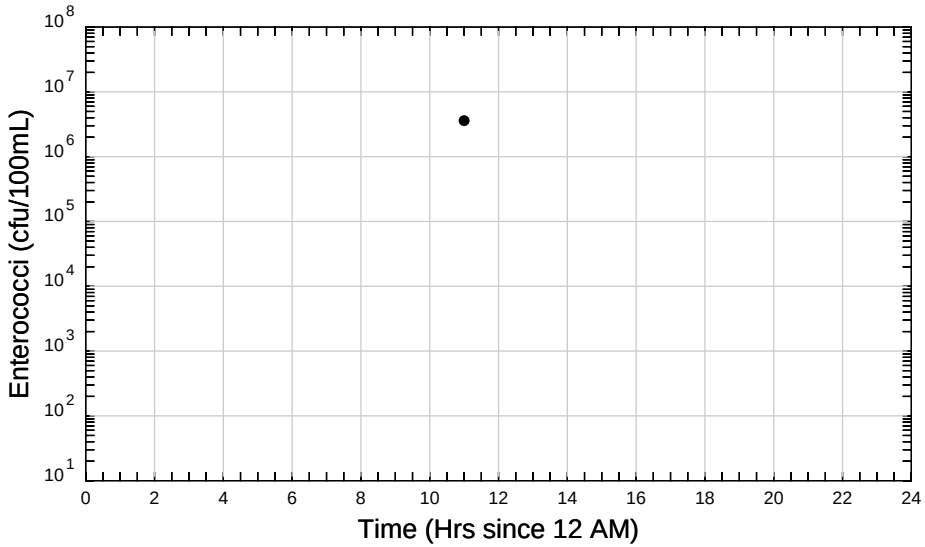

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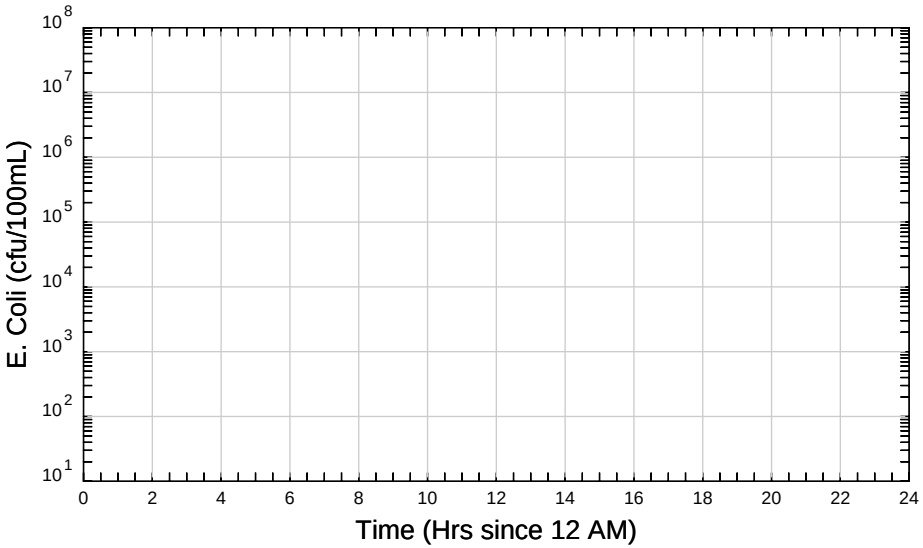

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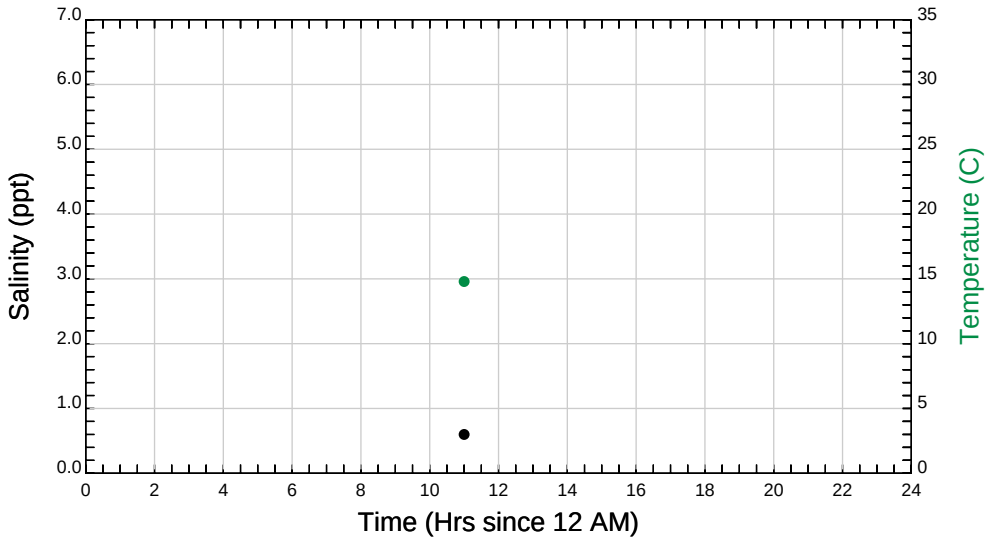

E. Coli (cfu/100mL)
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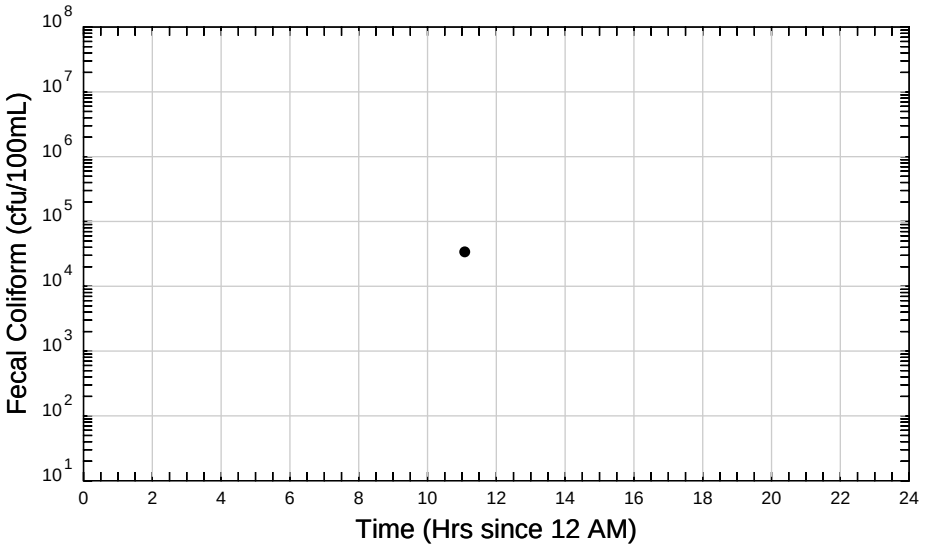

Salinity (ppt)
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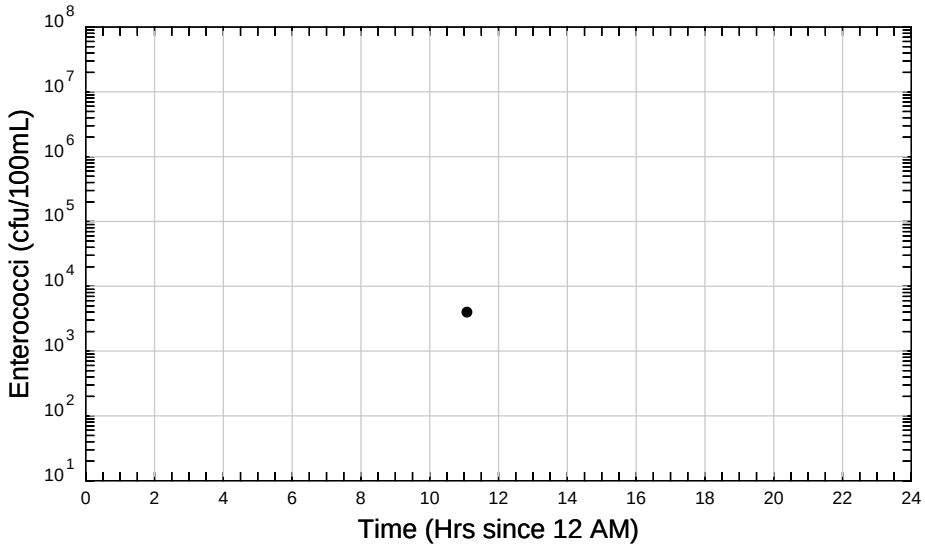

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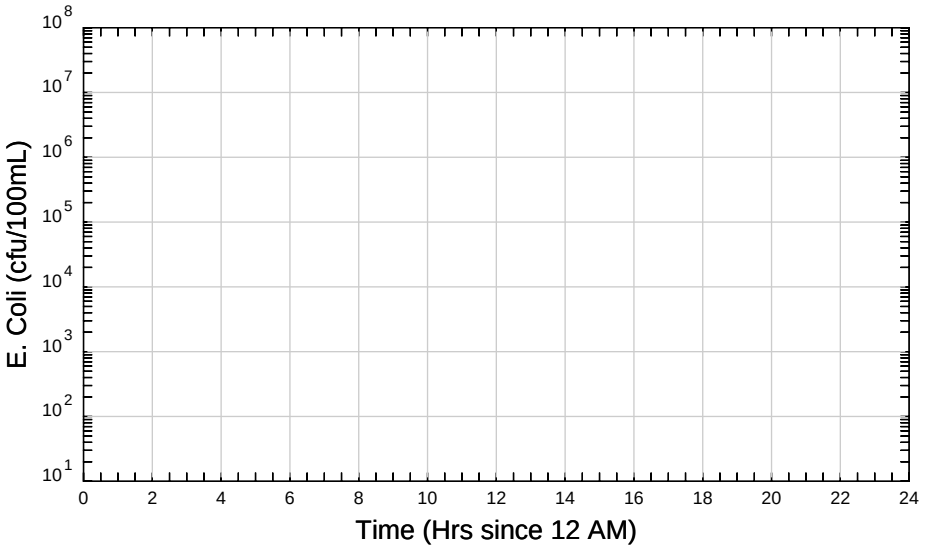

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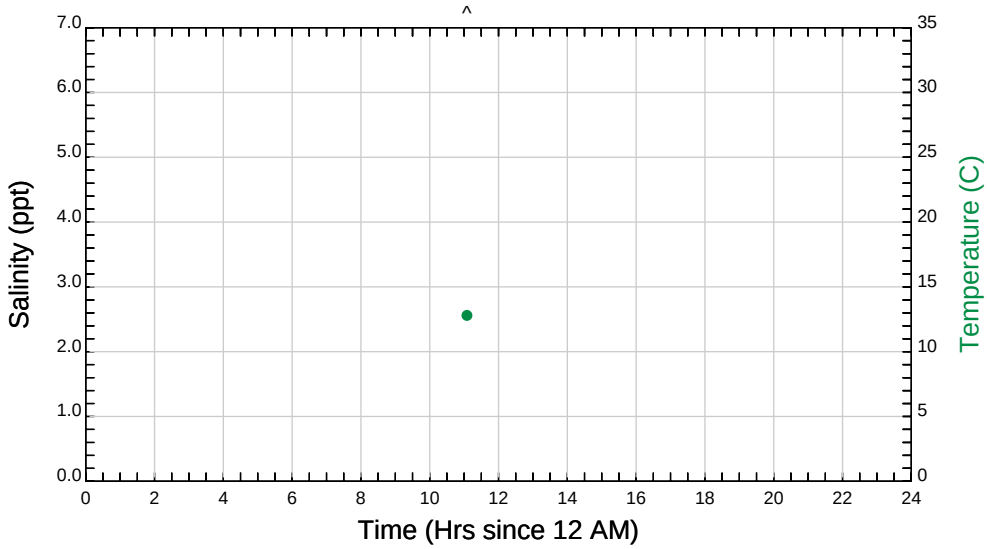

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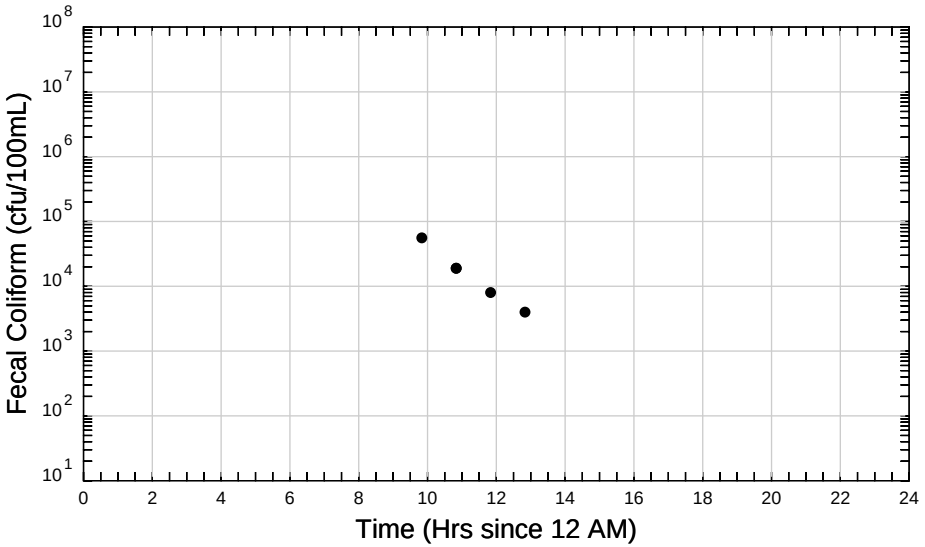

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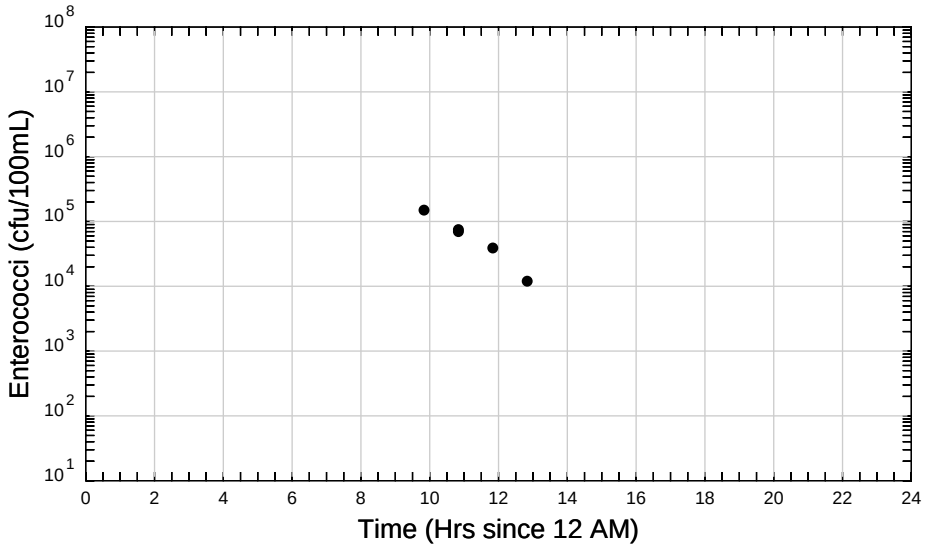

Fecal Coliform (cfu/100mL)
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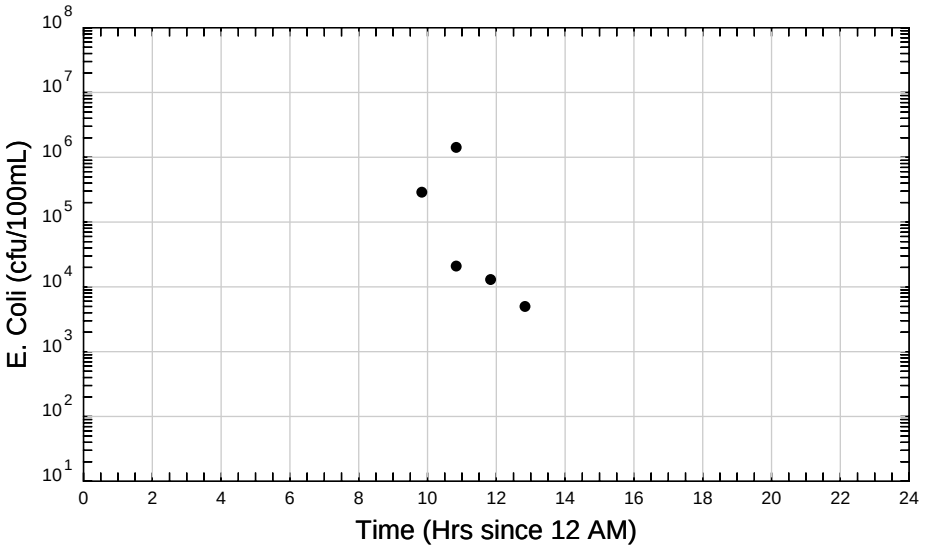

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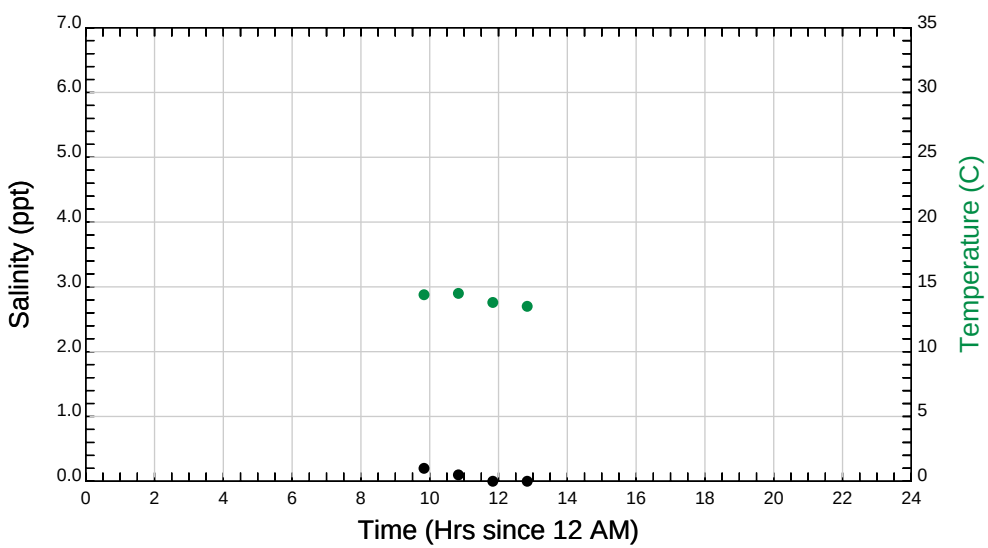

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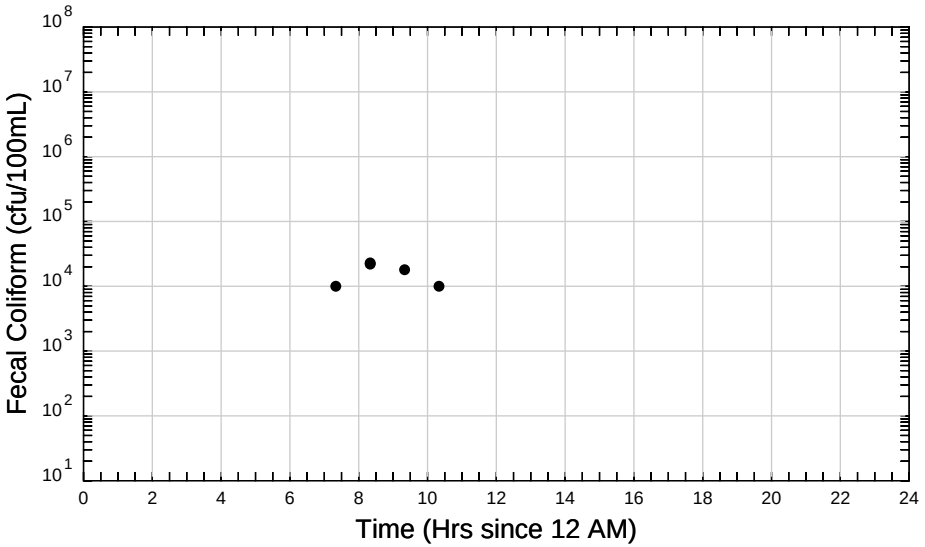

Salinity (ppt)
Temperature (C)
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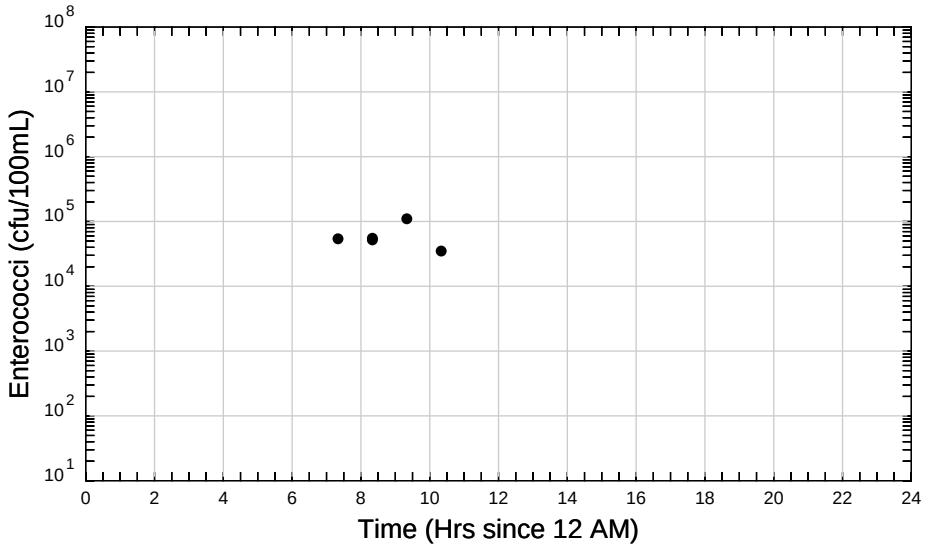

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Time (Hrs since 12 AM)

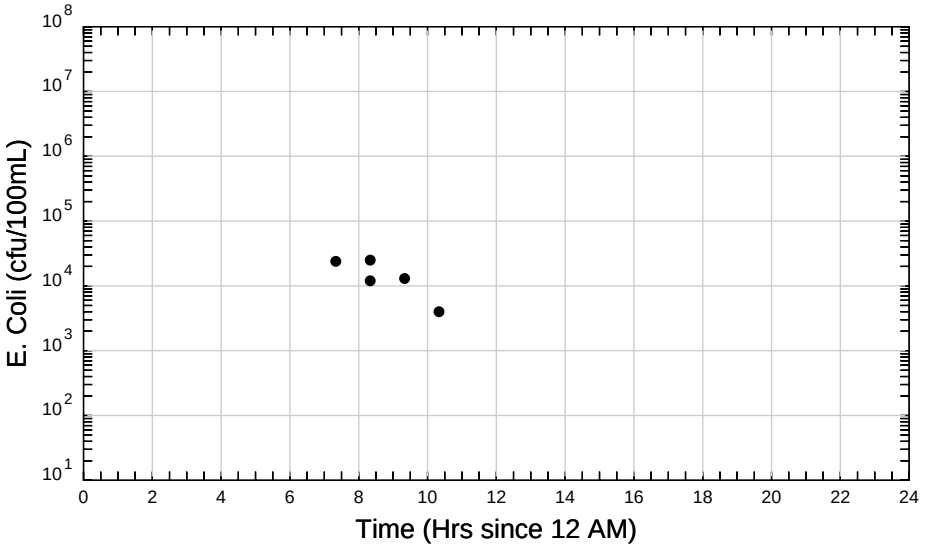

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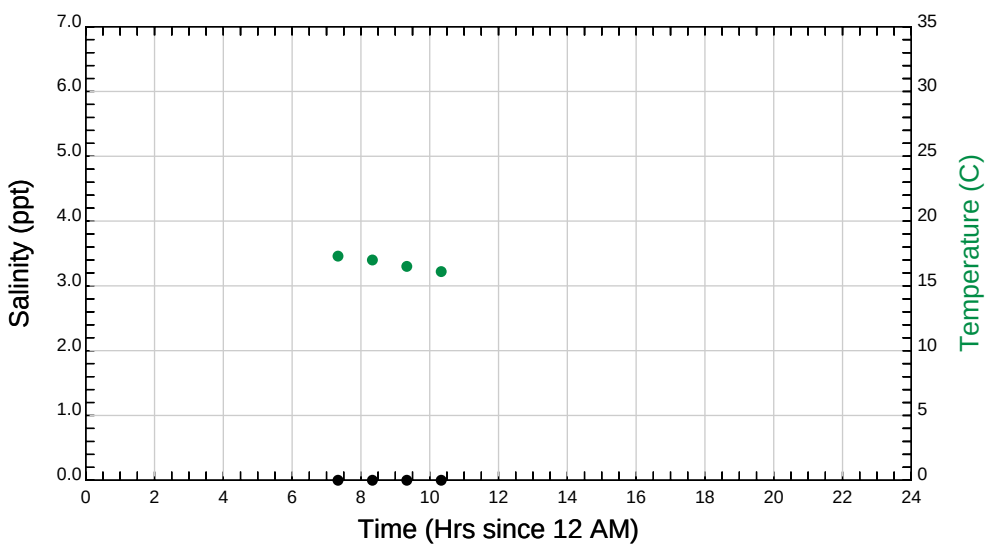

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Time (Hrs since 12 AM)

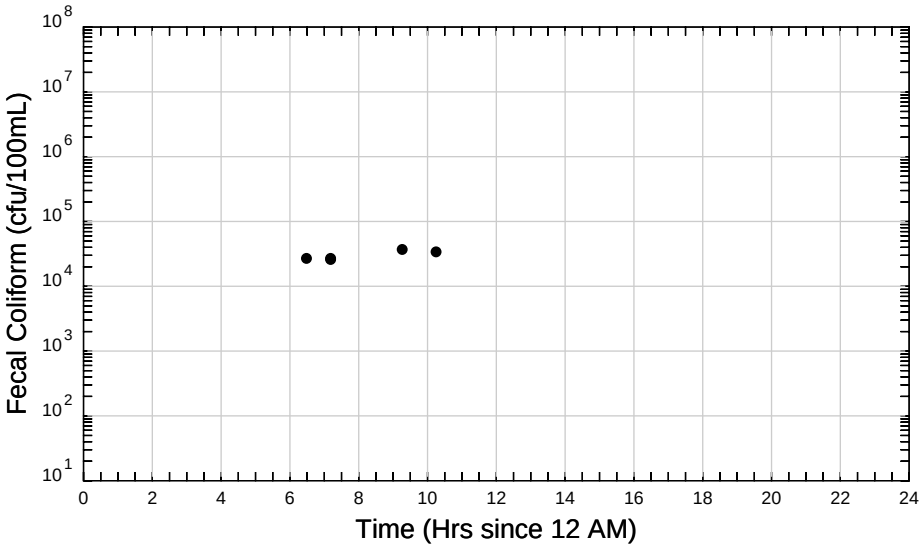

Salinity (ppt)
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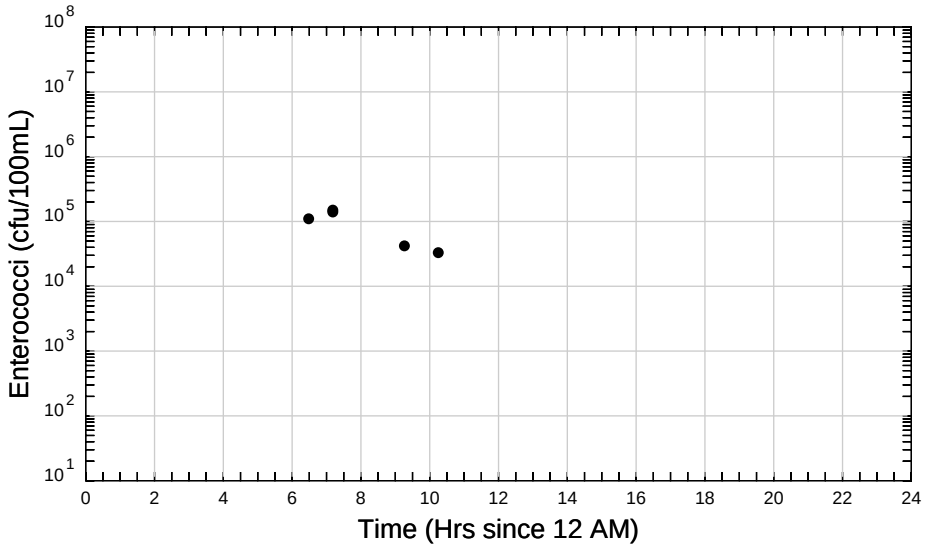

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

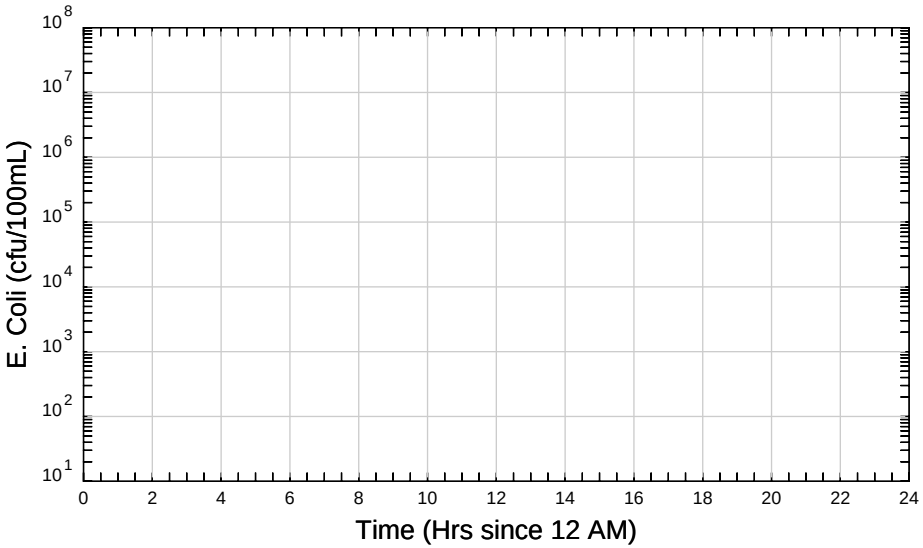

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

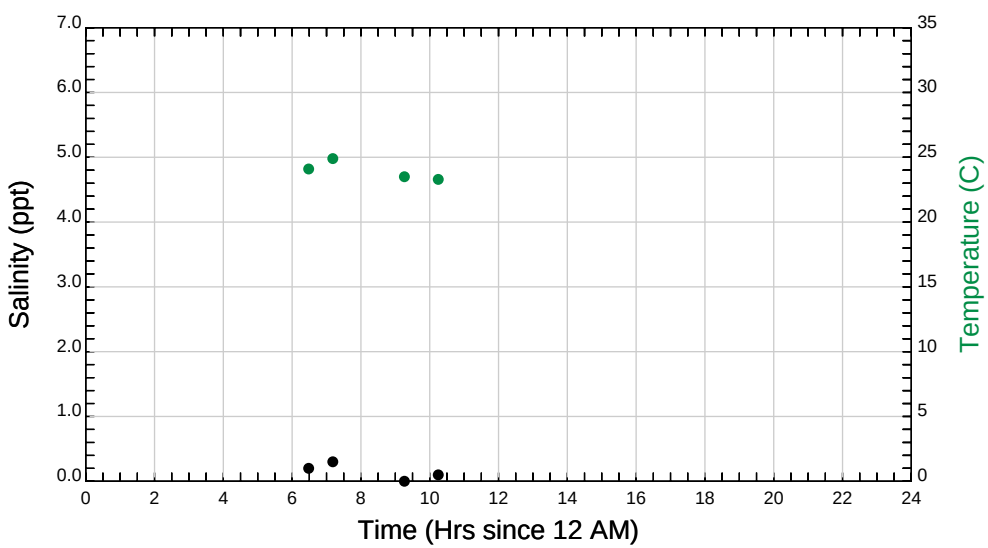

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

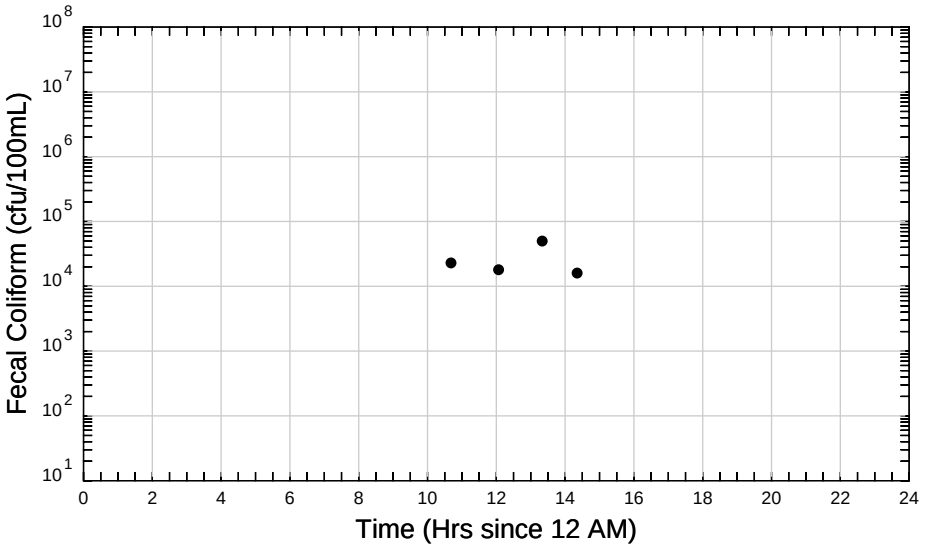

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

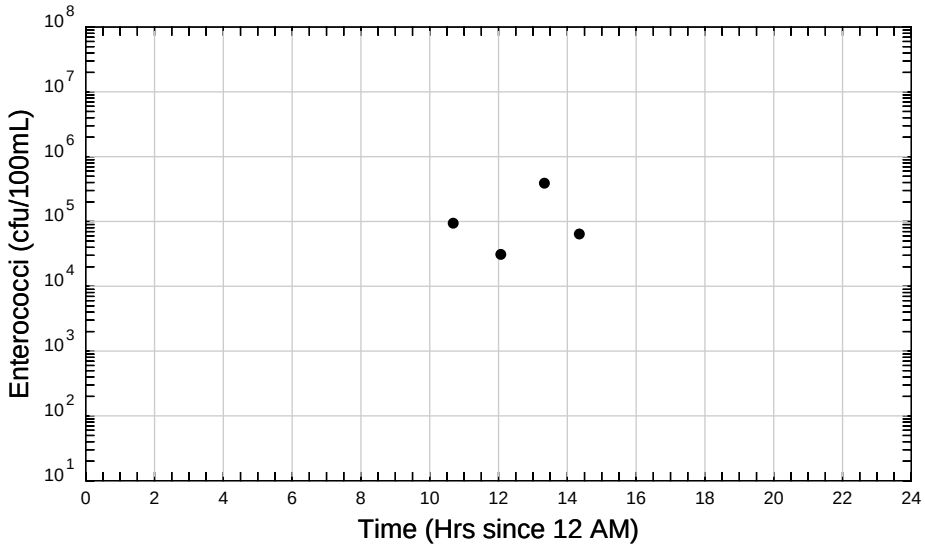

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

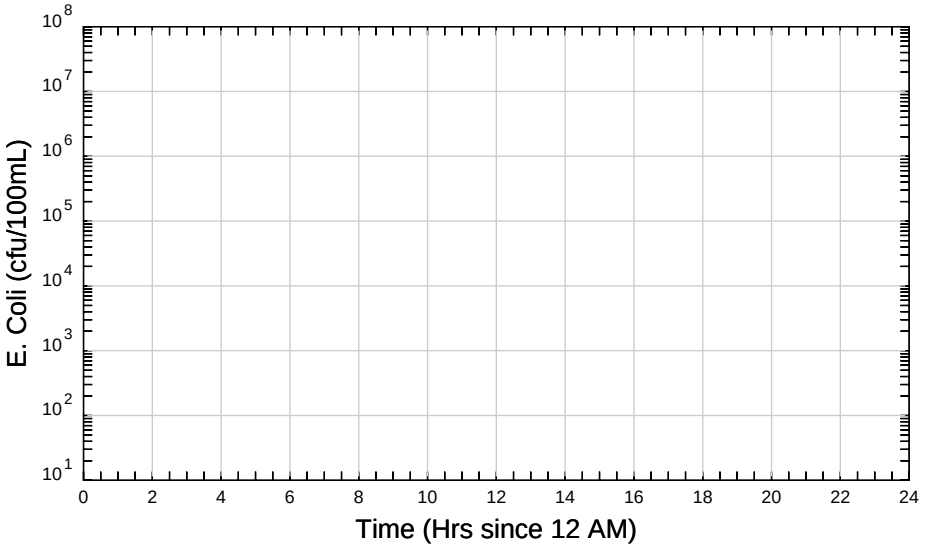

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

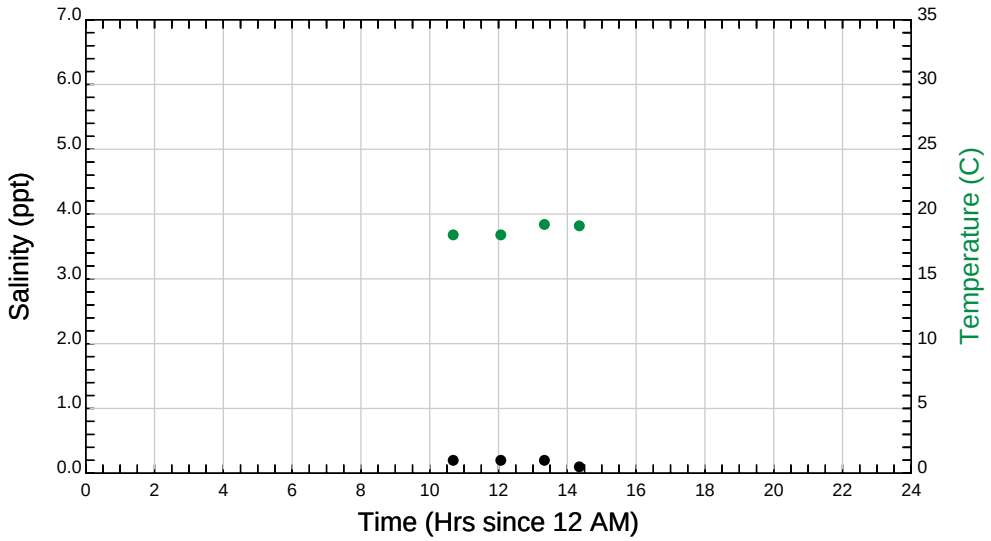

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

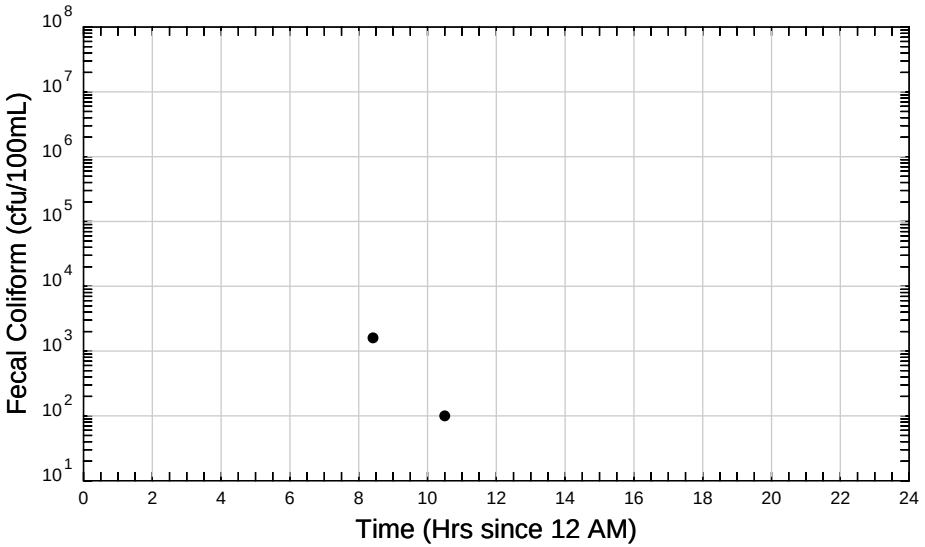

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

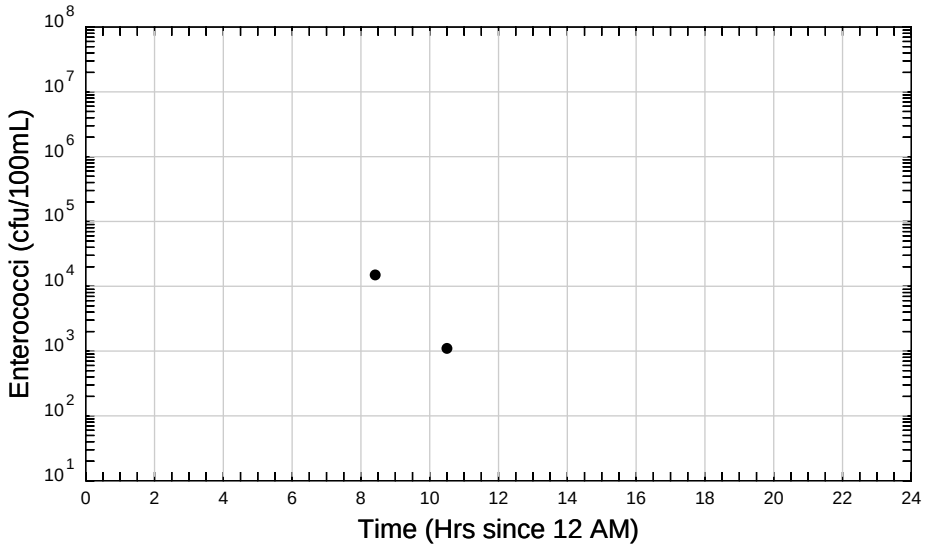

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

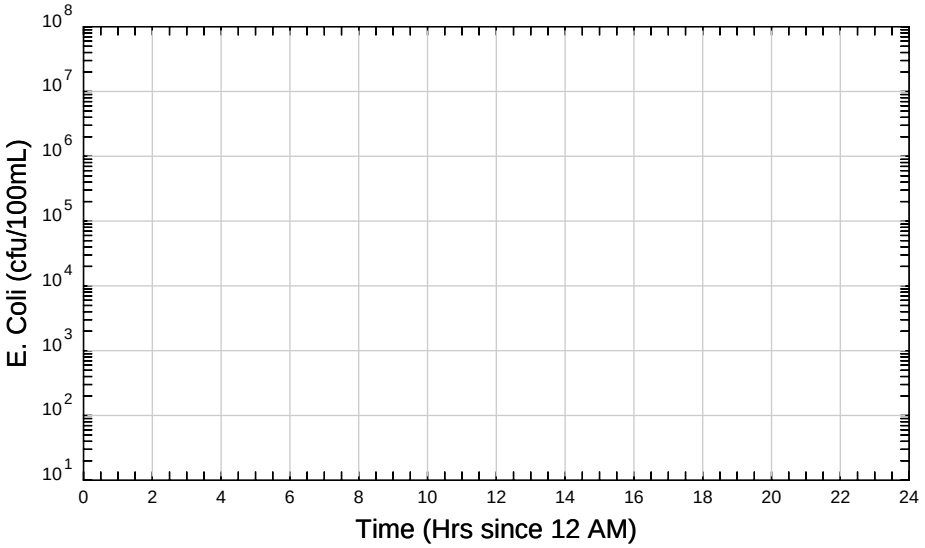

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

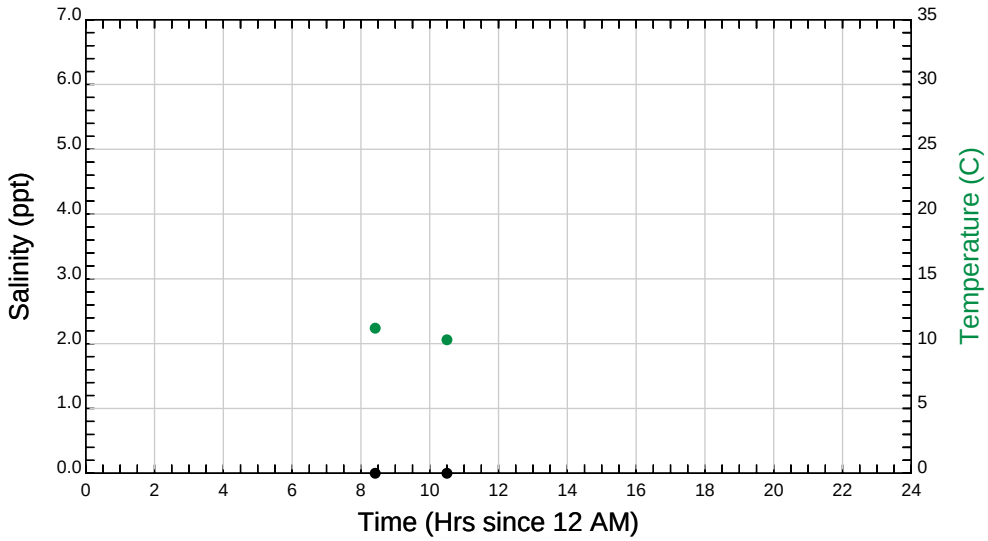

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

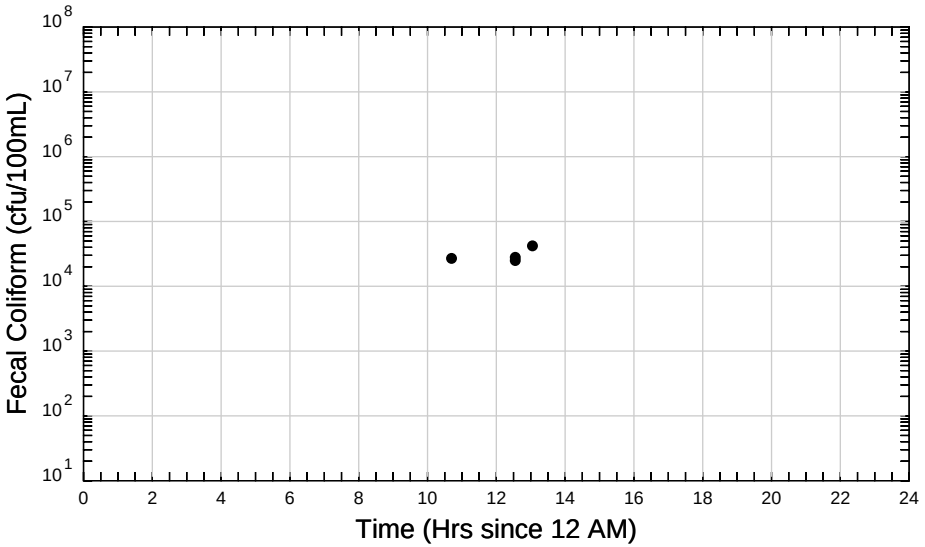

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

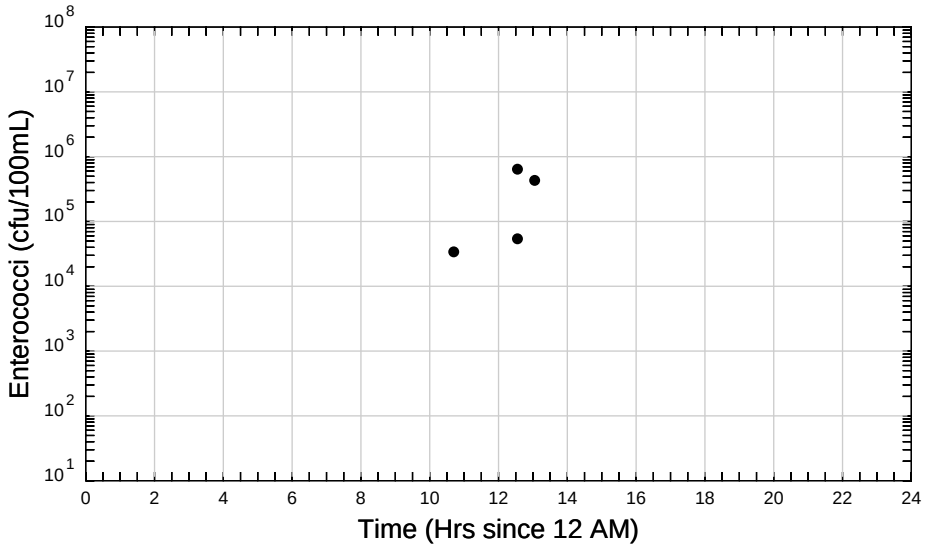

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

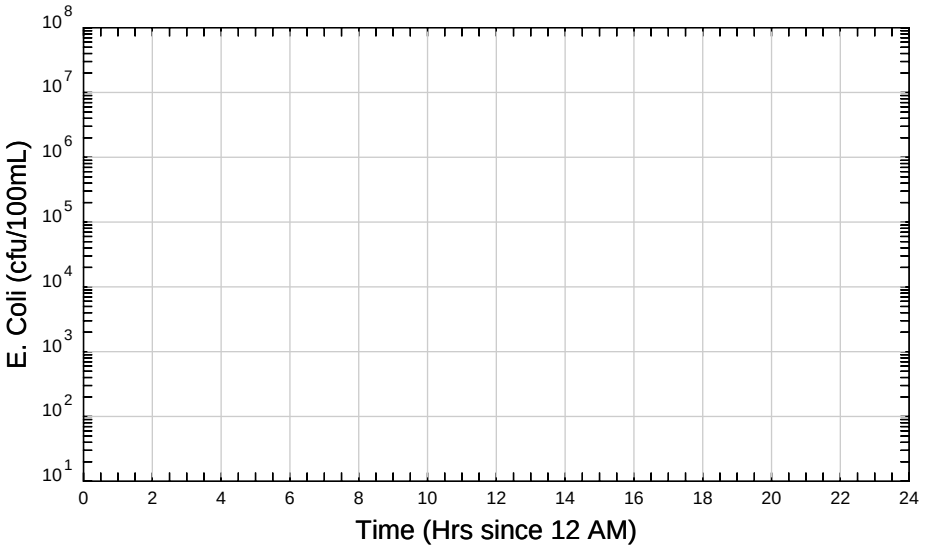

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

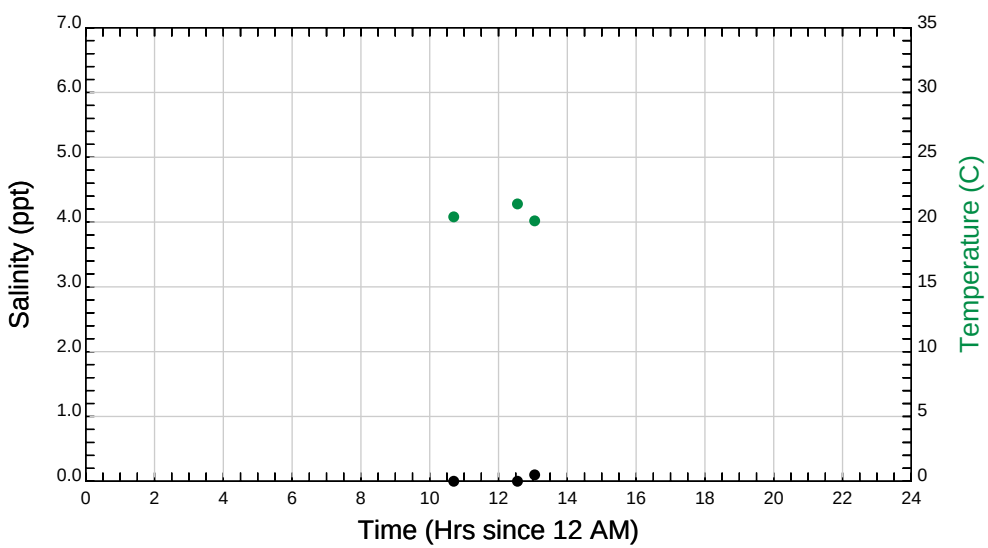

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

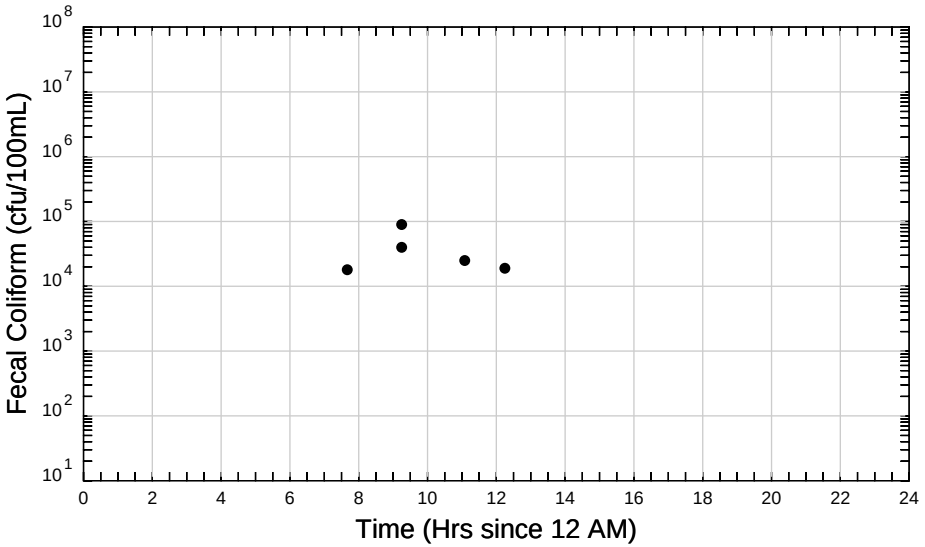

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

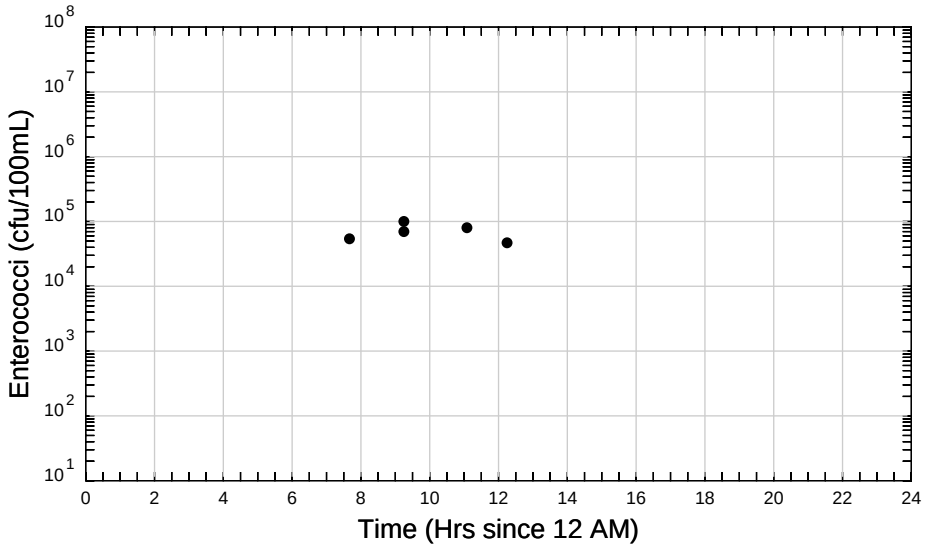

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

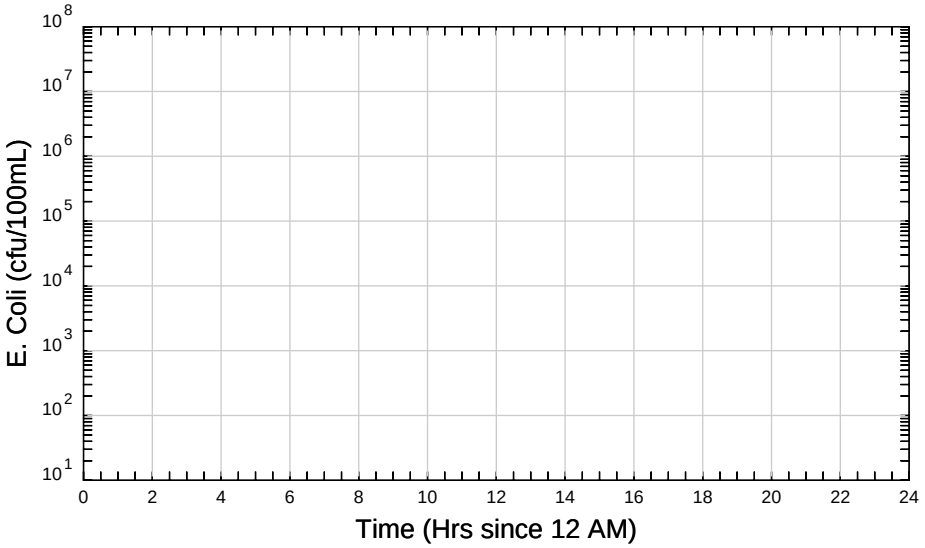

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

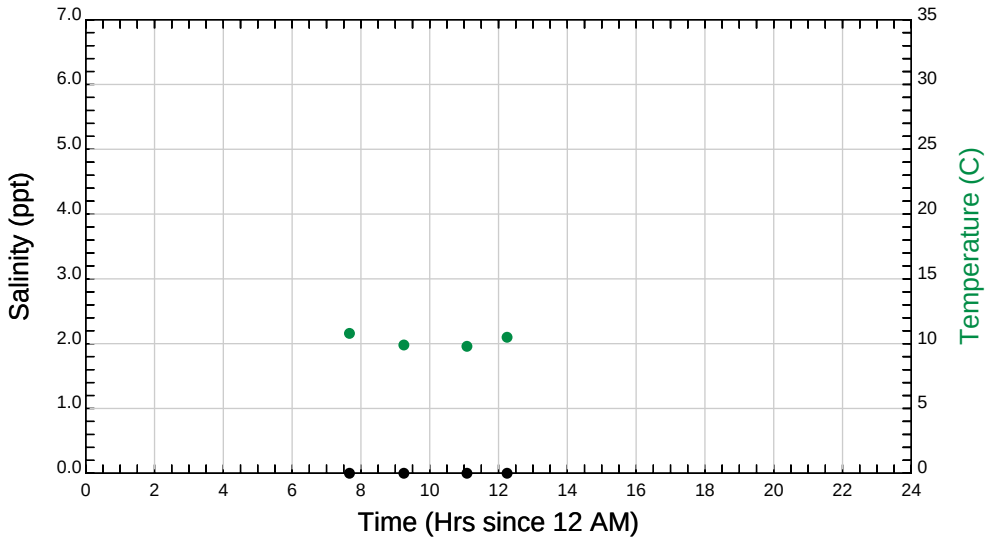

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

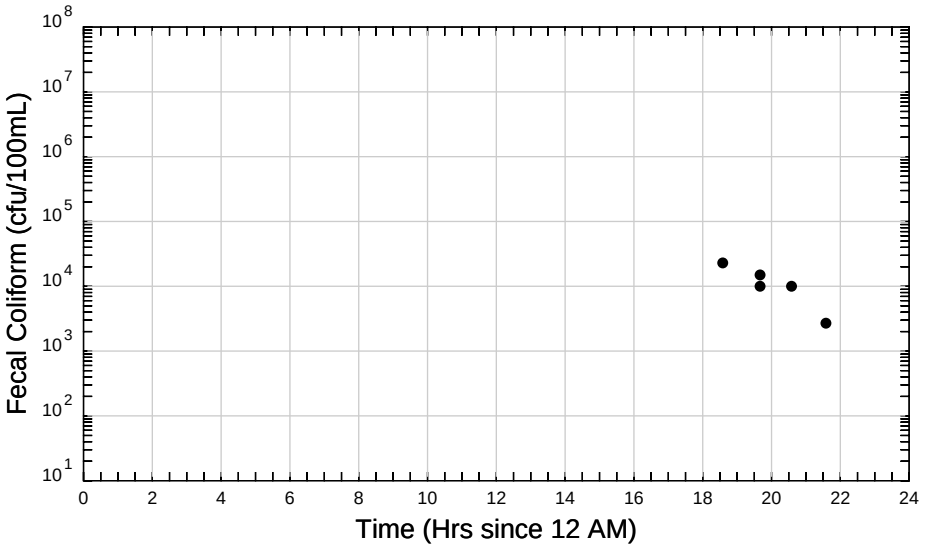

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

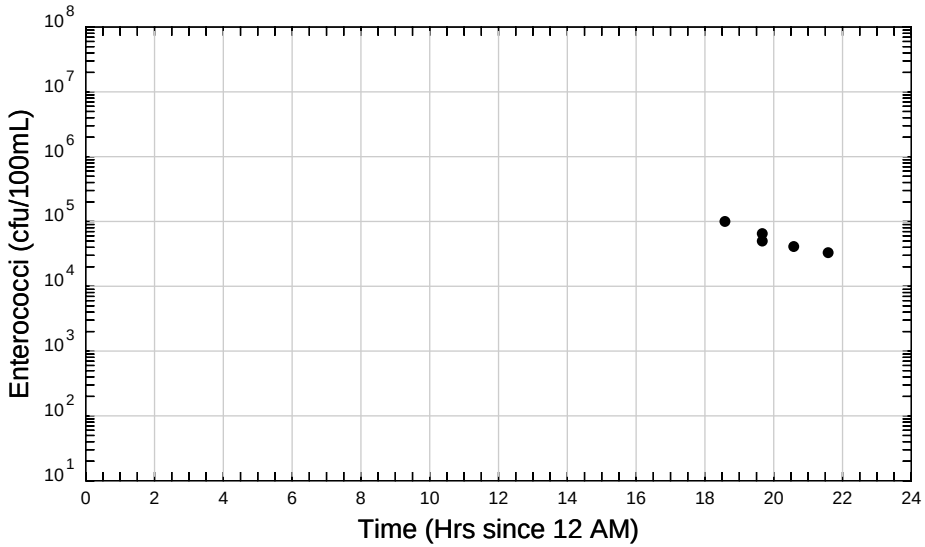

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

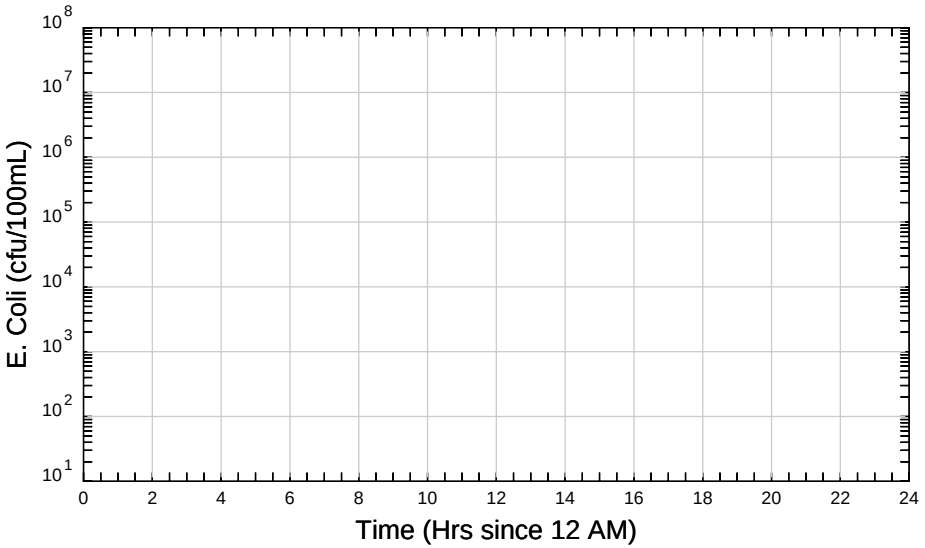

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

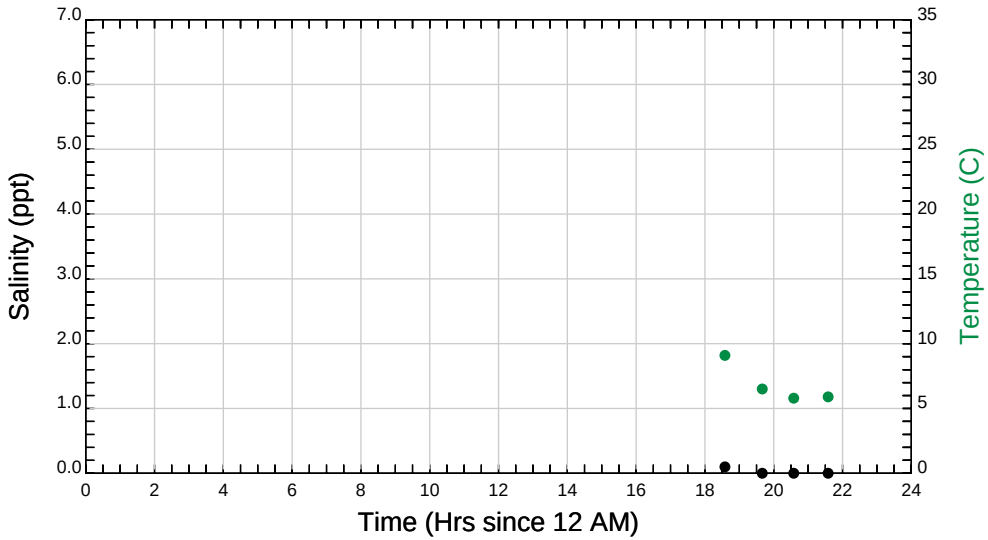

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

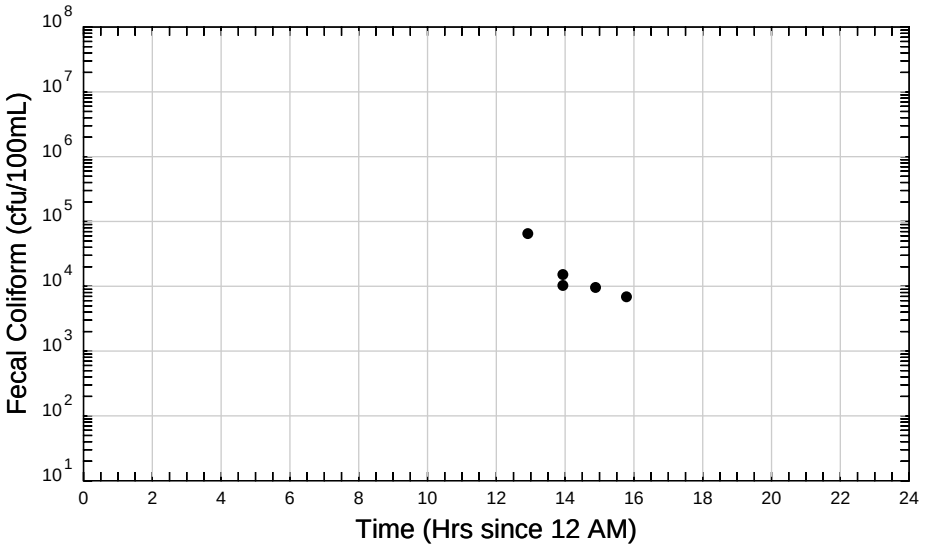

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

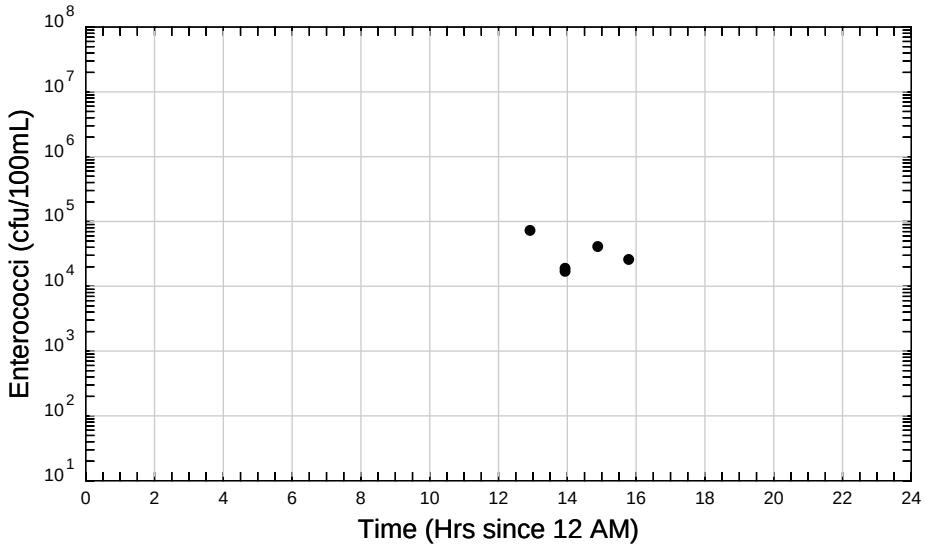

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

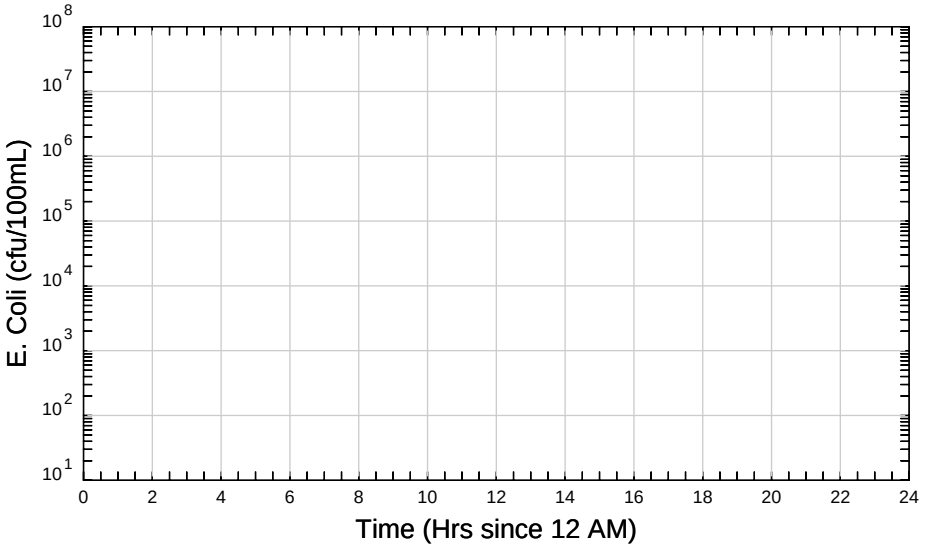

Enterococci (cfu/100mL)
Time (Hrs since 12 AM)

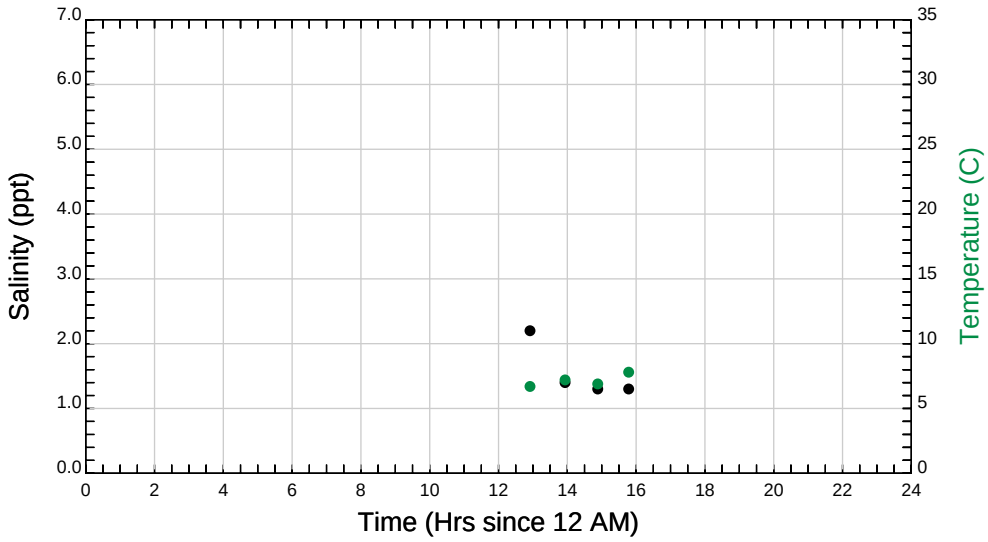

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

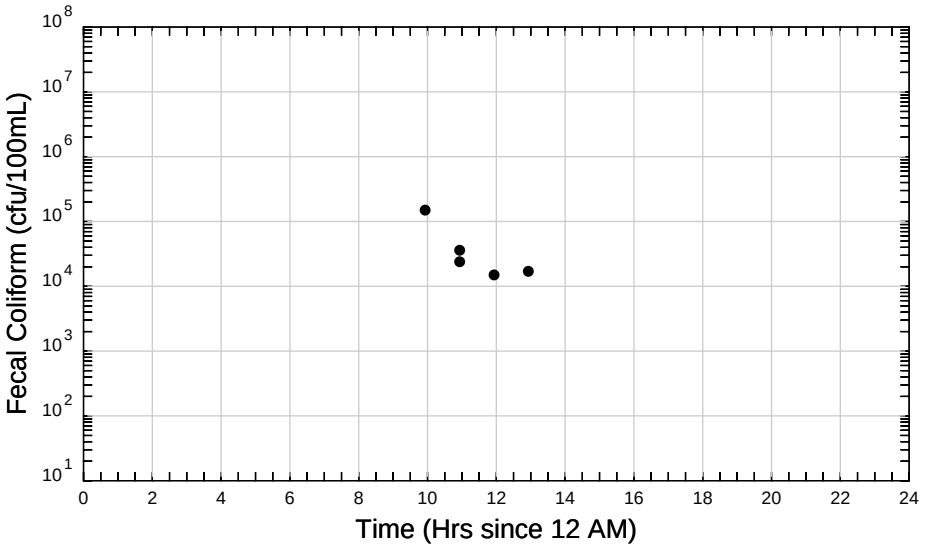

Salinity (ppt)
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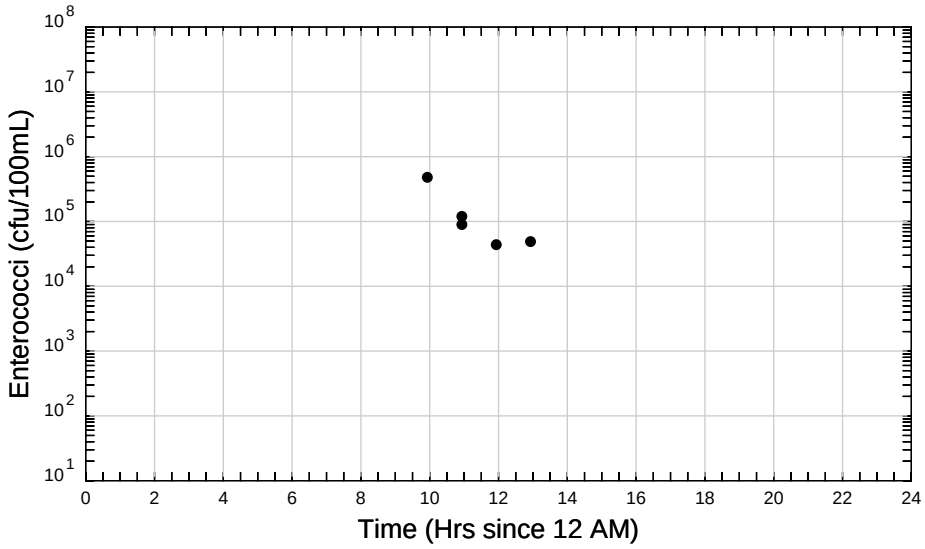

Fecal Coliform (cfu/100mL)
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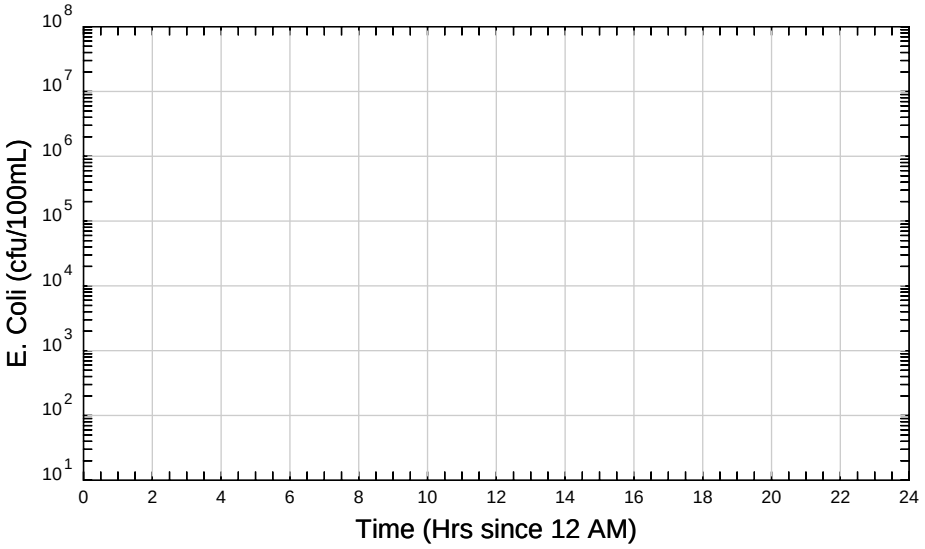

Enterococci (cfu/100mL)
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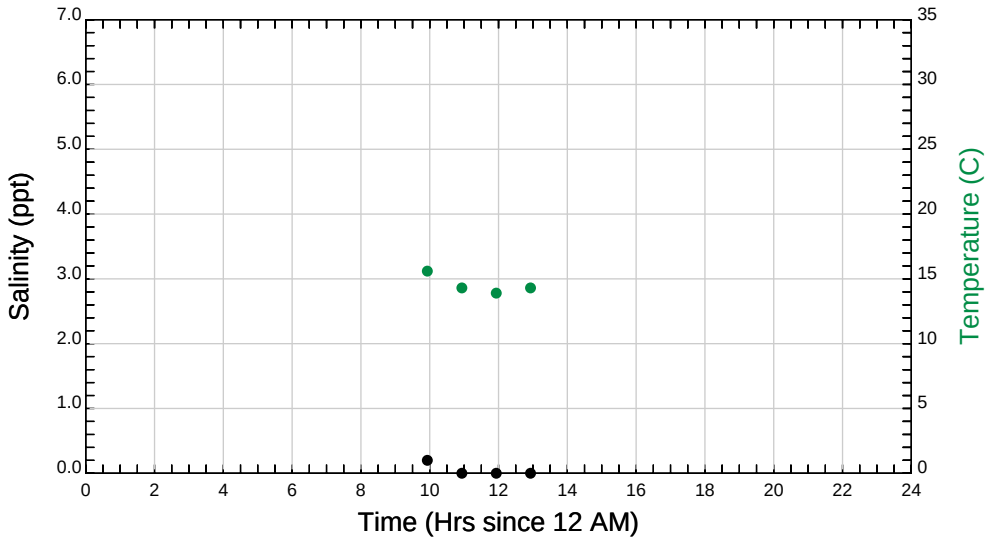

E. Coli (cfu/100mL)
Time (Hrs since 12 AM)

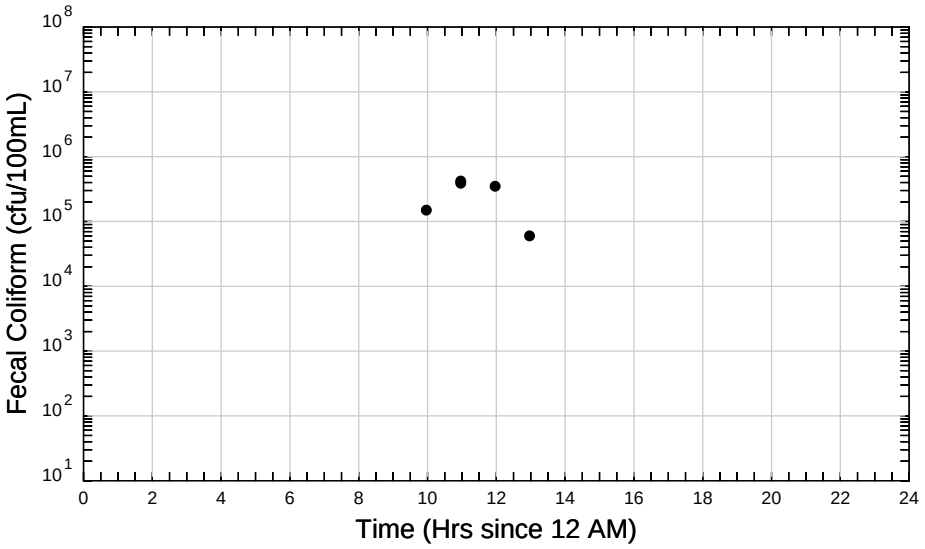

Salinity (ppt)
Temperature (C)
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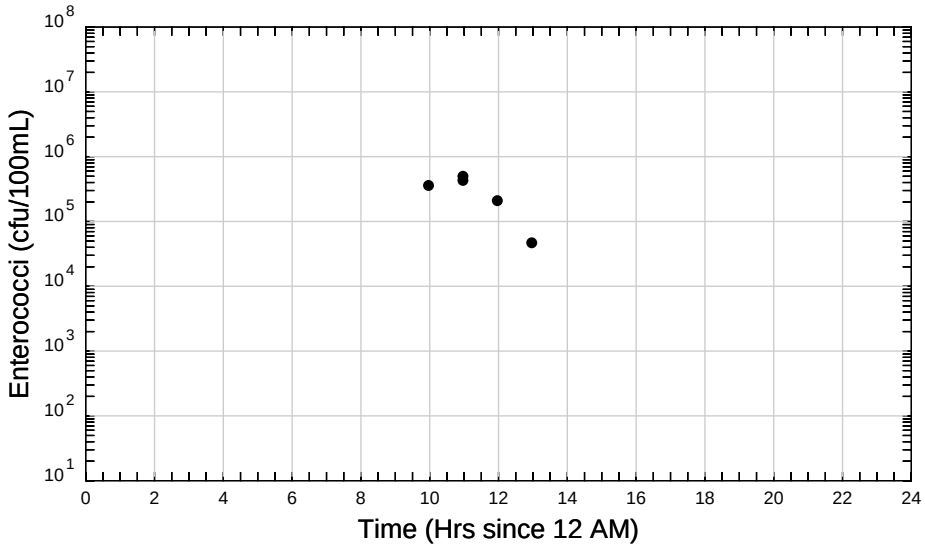

Fecal Coliform (cfu/100mL)
Time (Hrs since 12 AM)

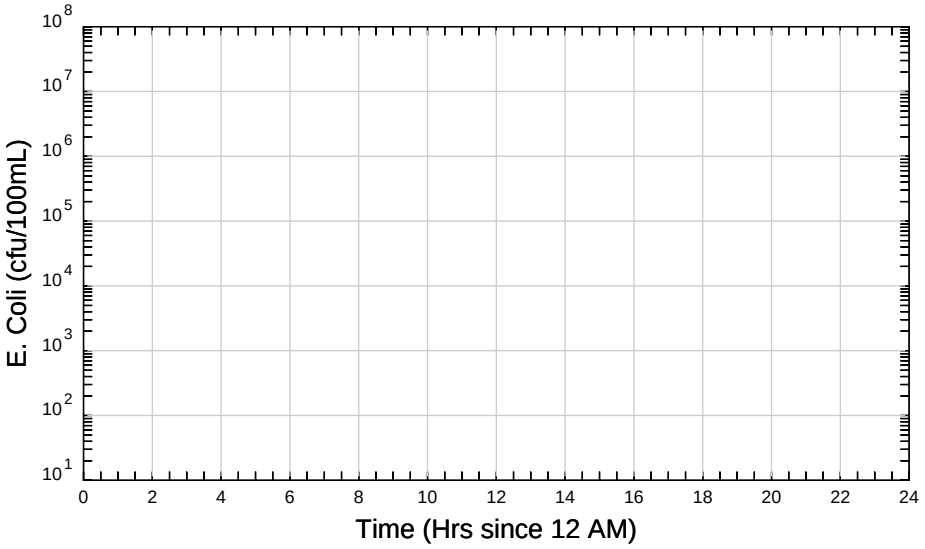

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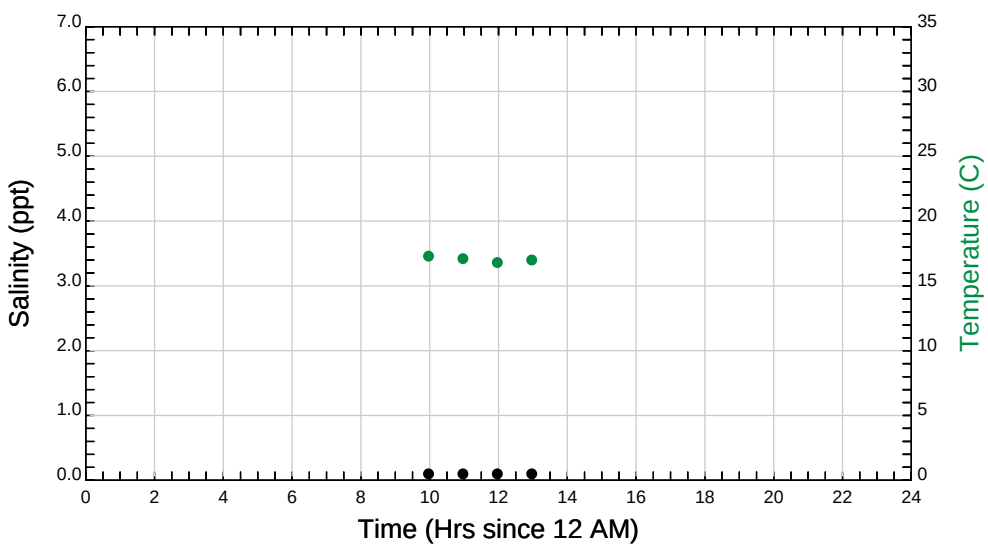

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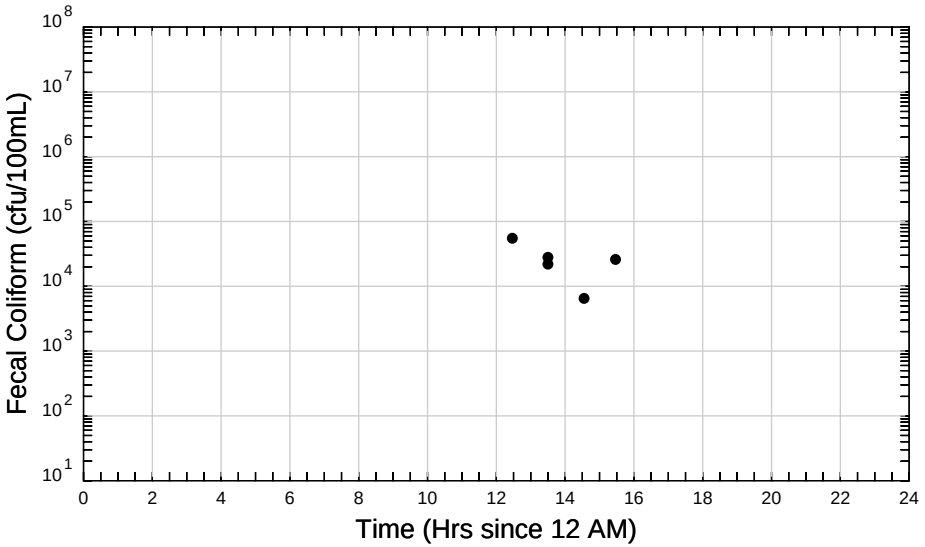

Salinity (ppt)
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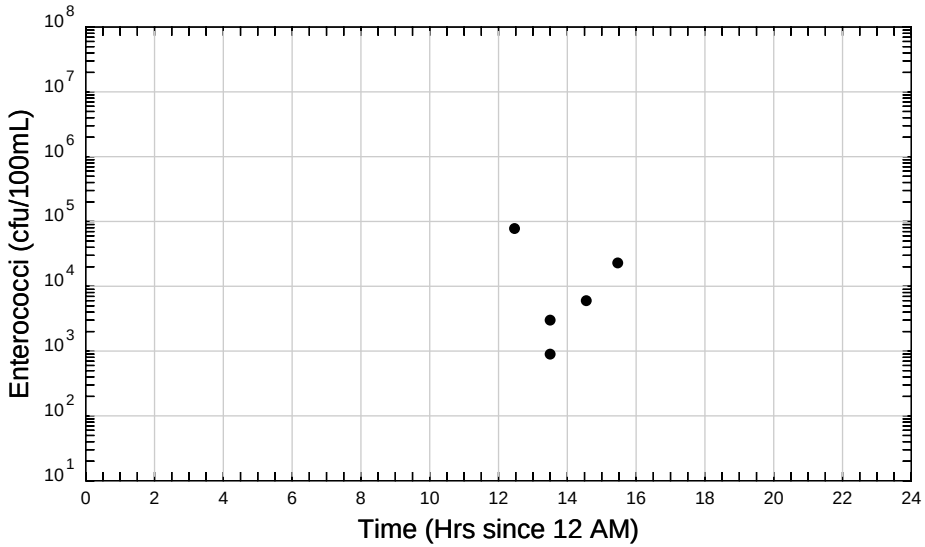

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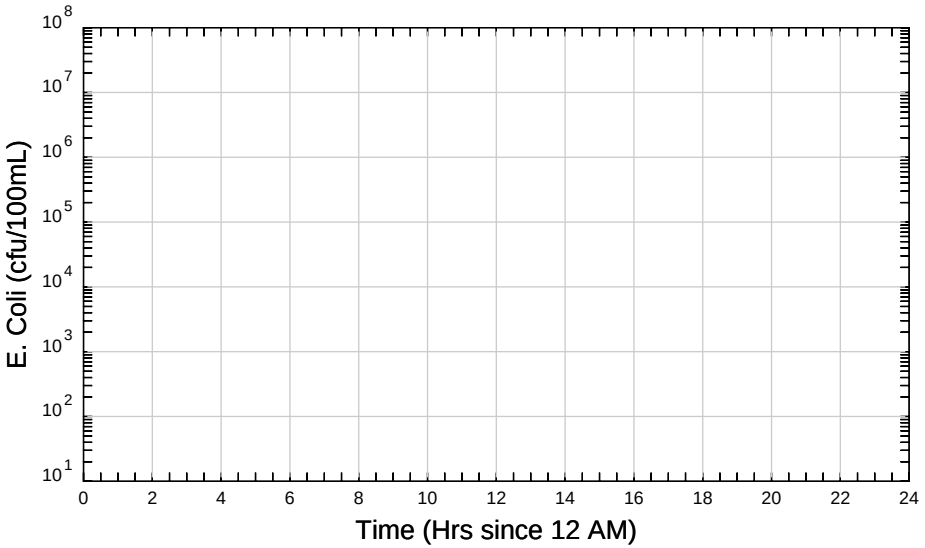

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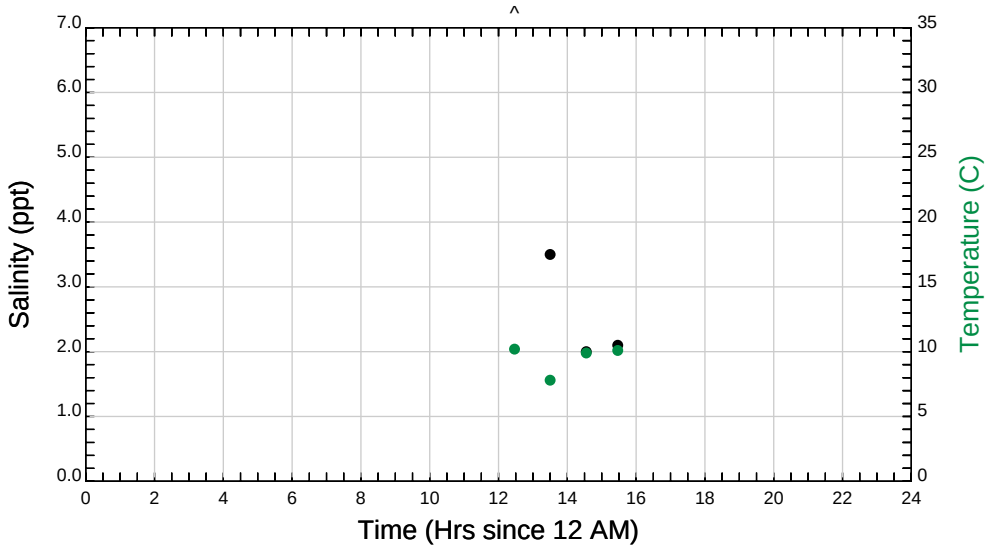

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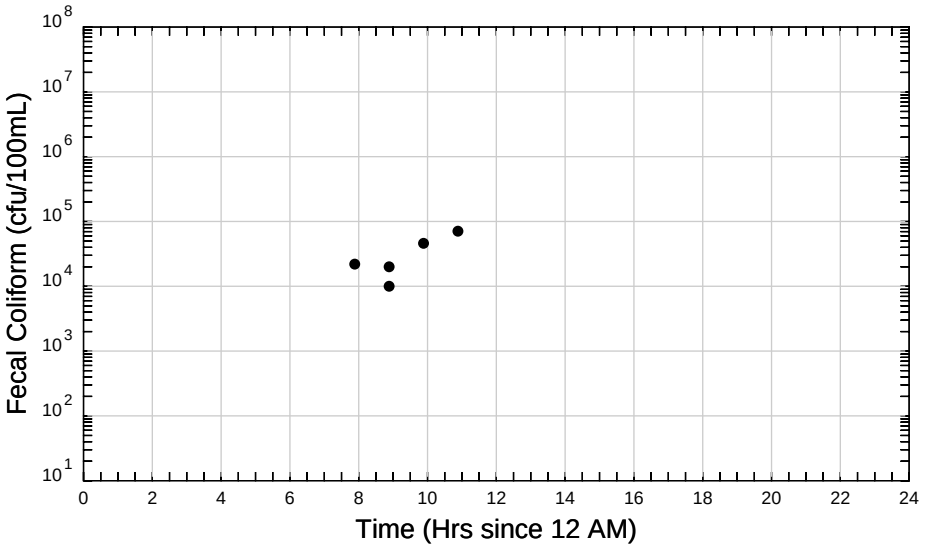

Salinity (ppt)
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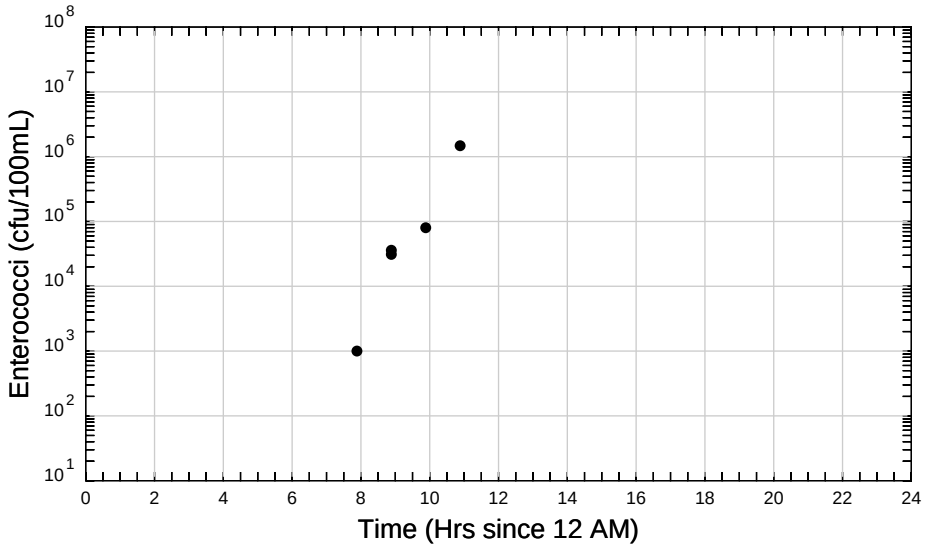

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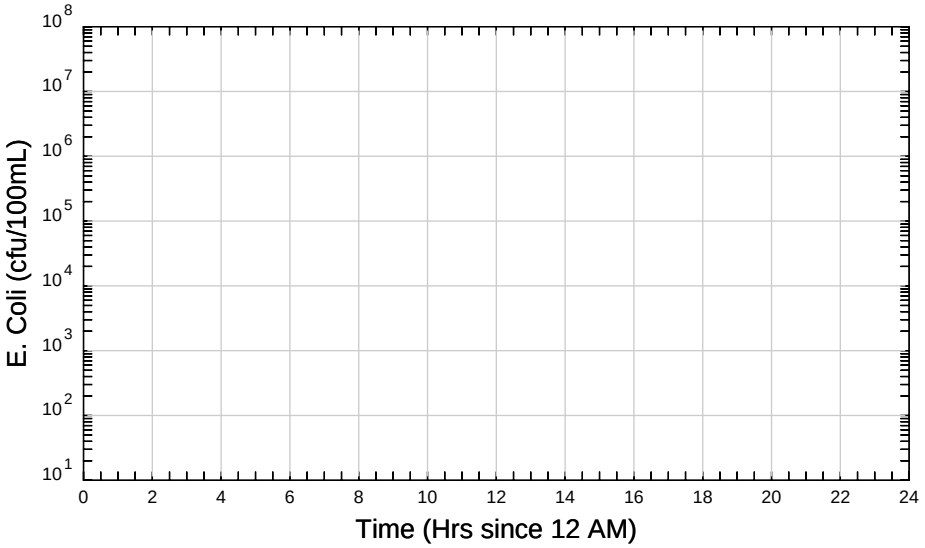

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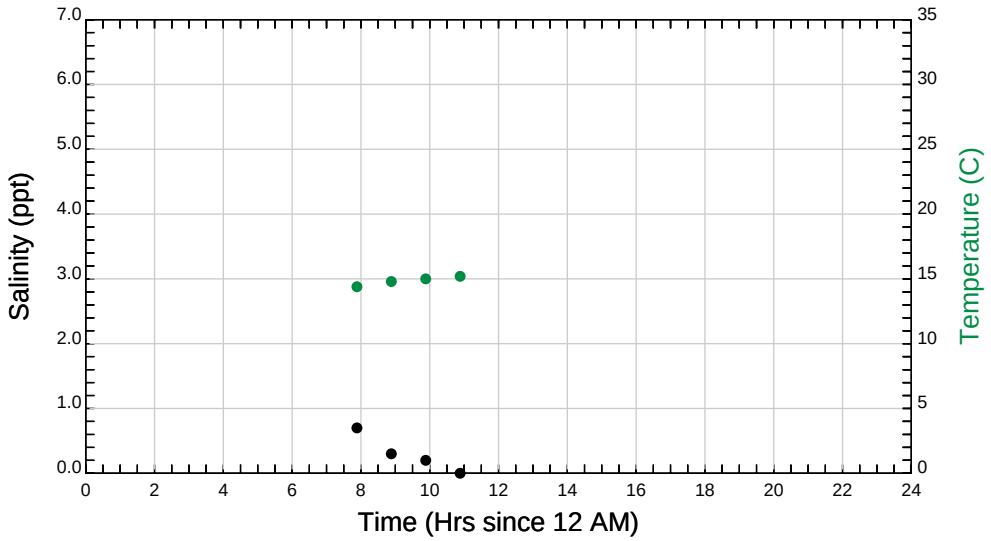

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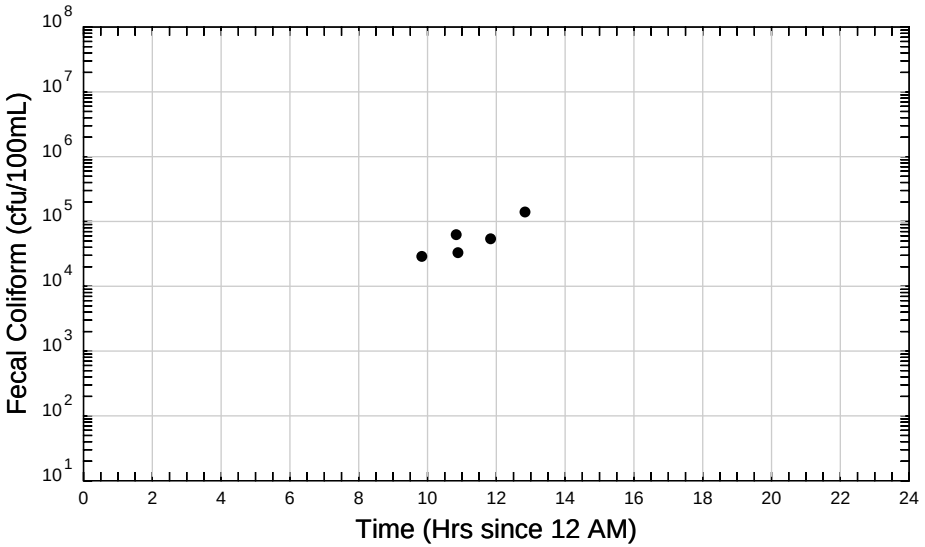

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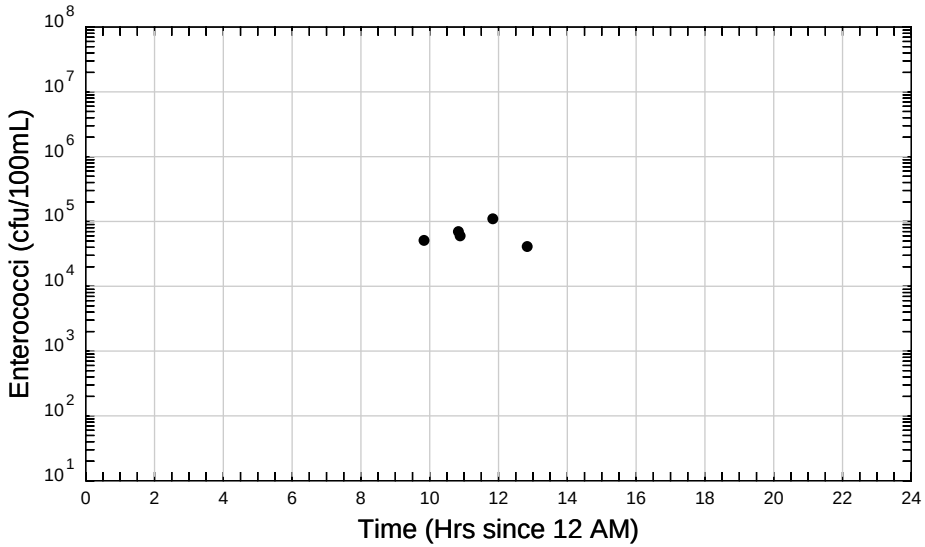

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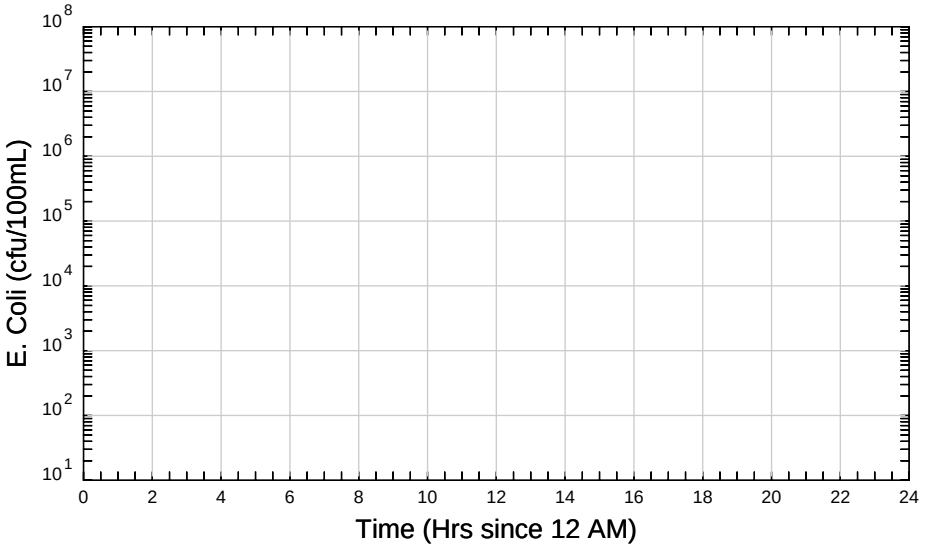

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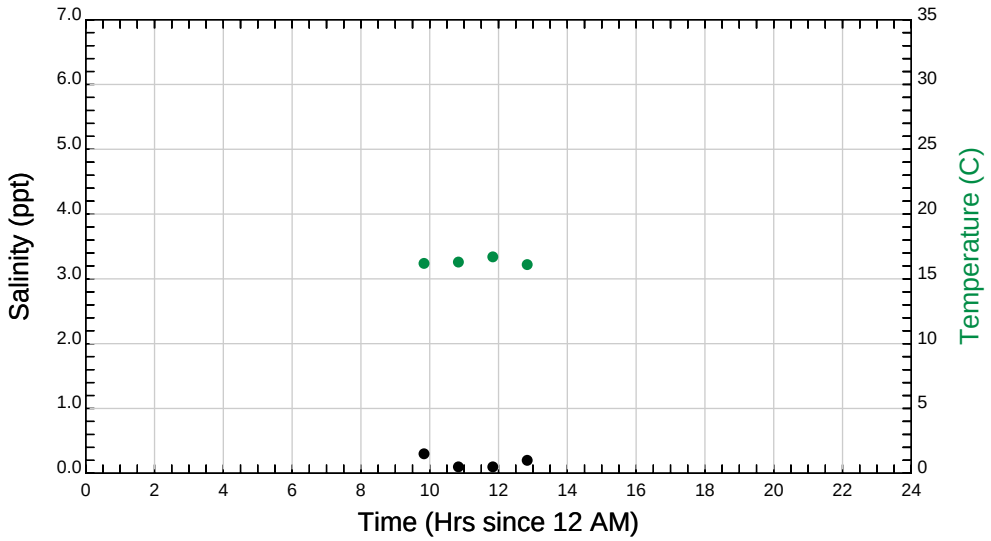

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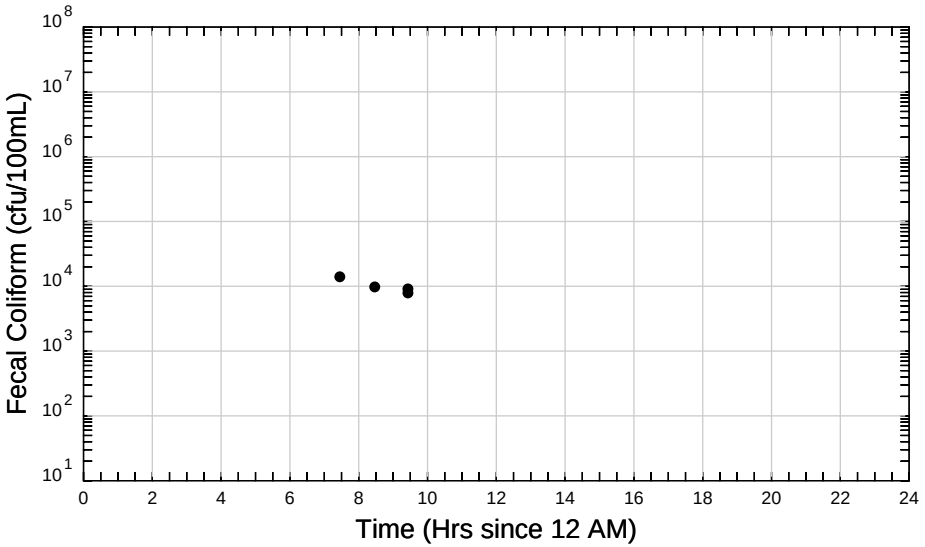

Salinity (ppt)
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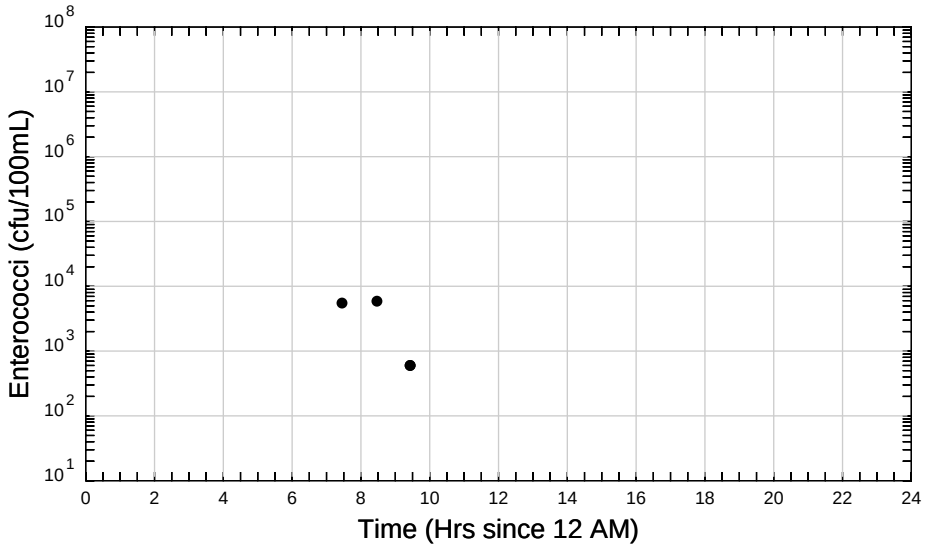

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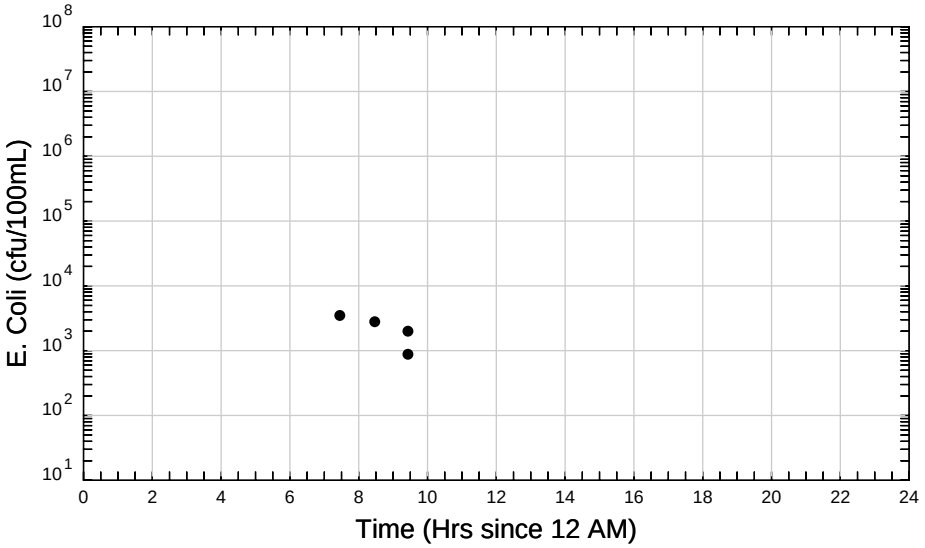

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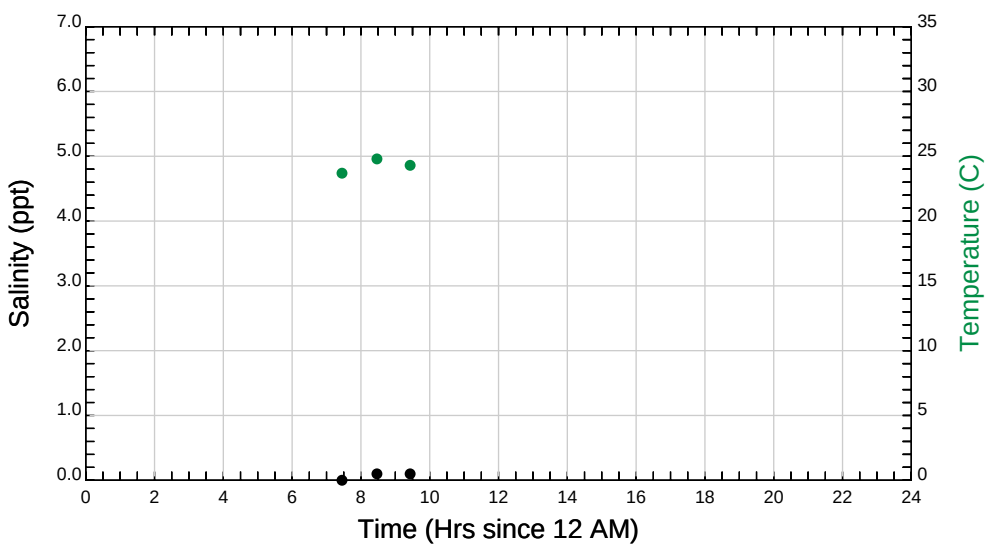

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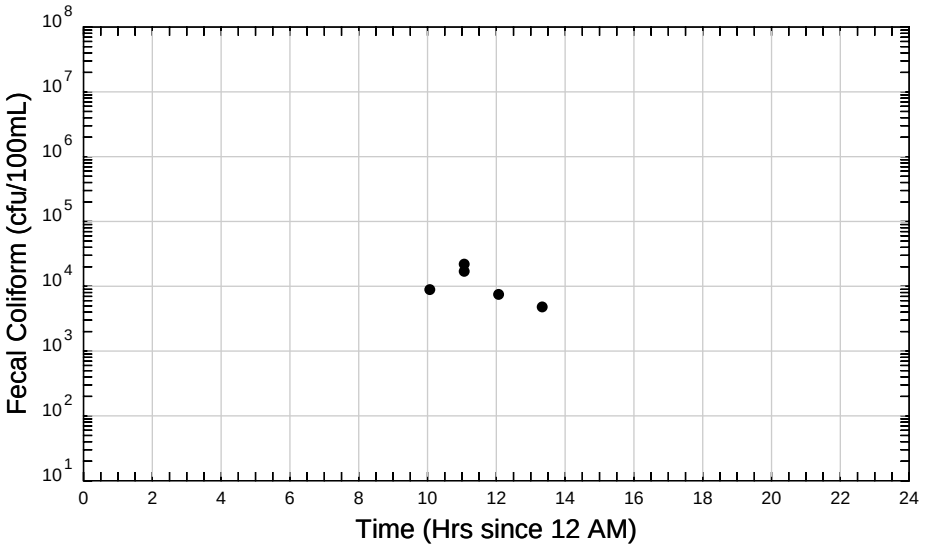

Salinity (ppt)
Temperature (C)
Time (Hrs since 12 AM)

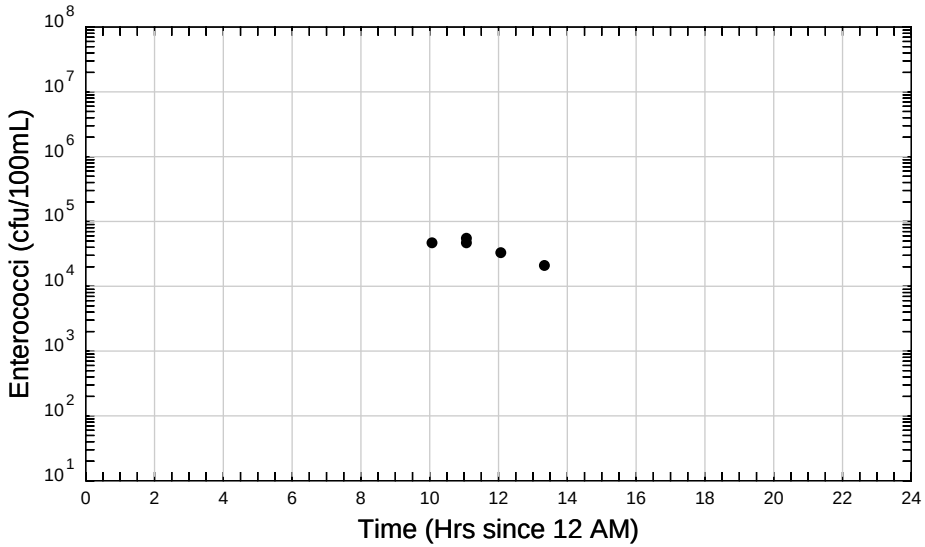

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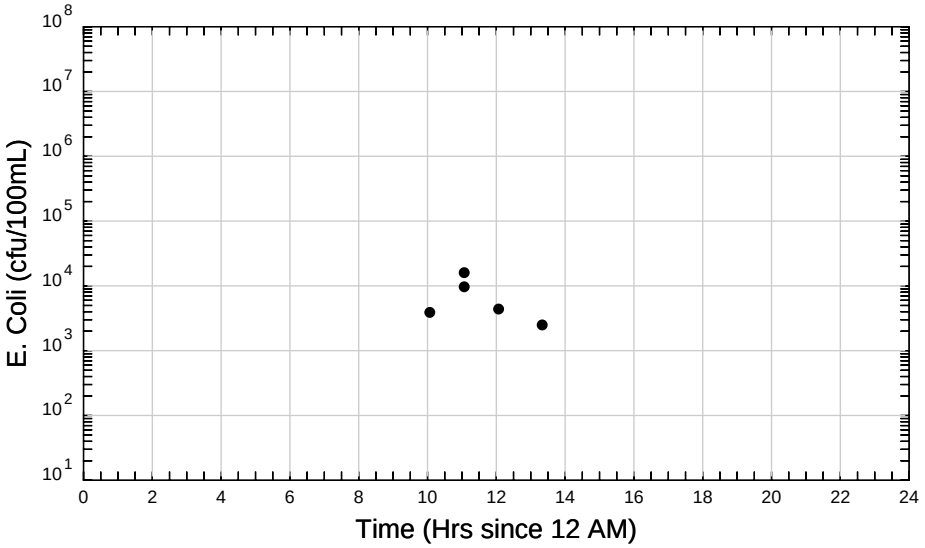

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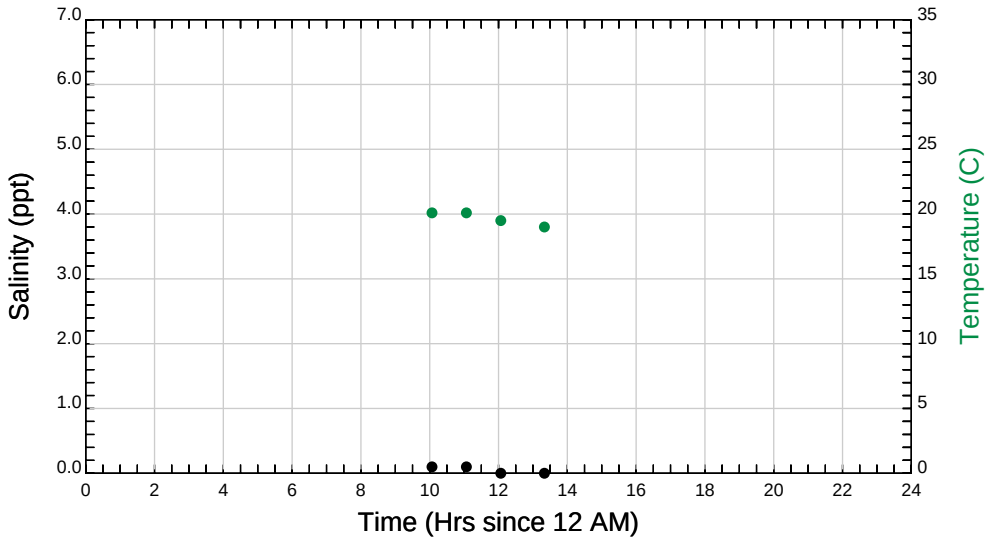

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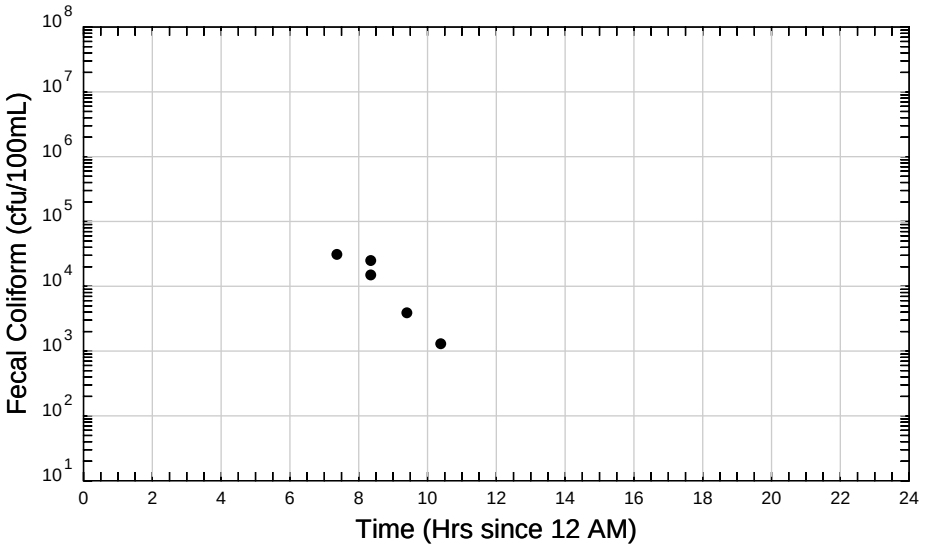

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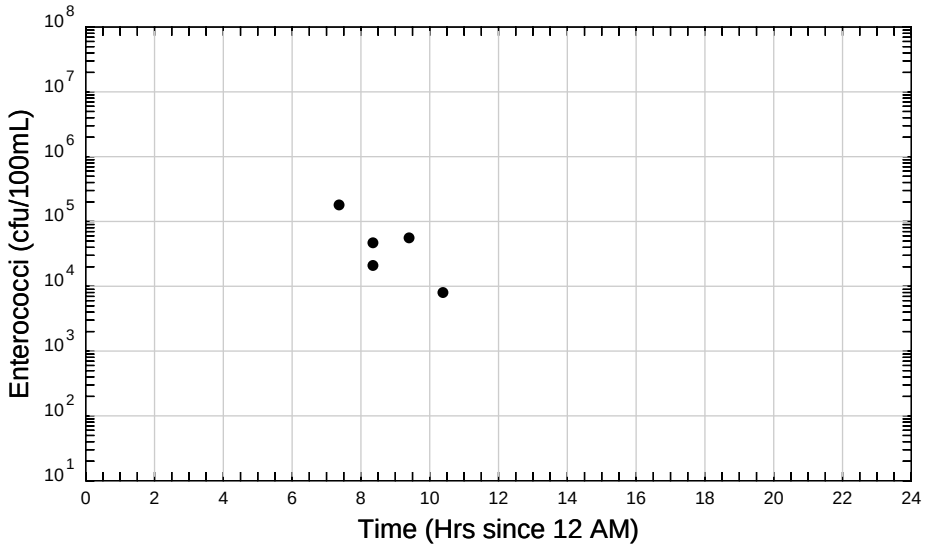

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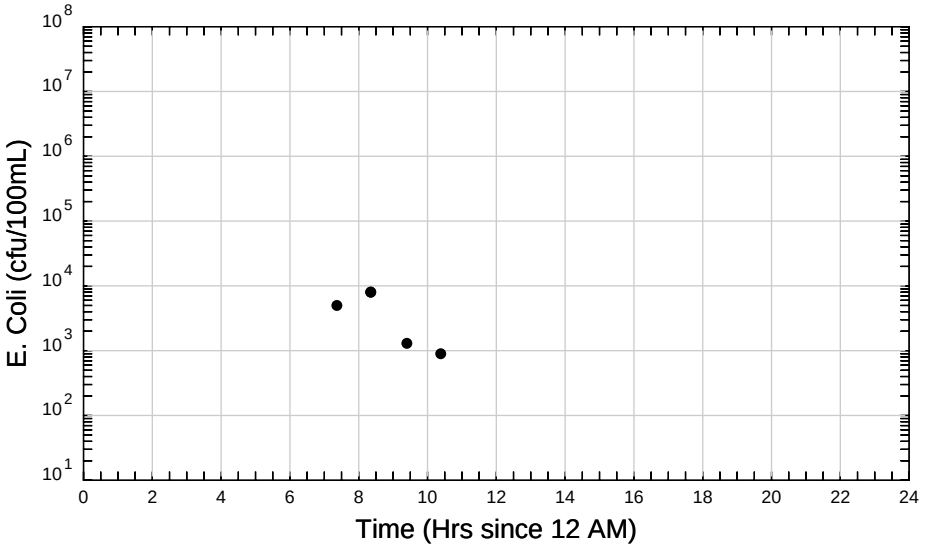

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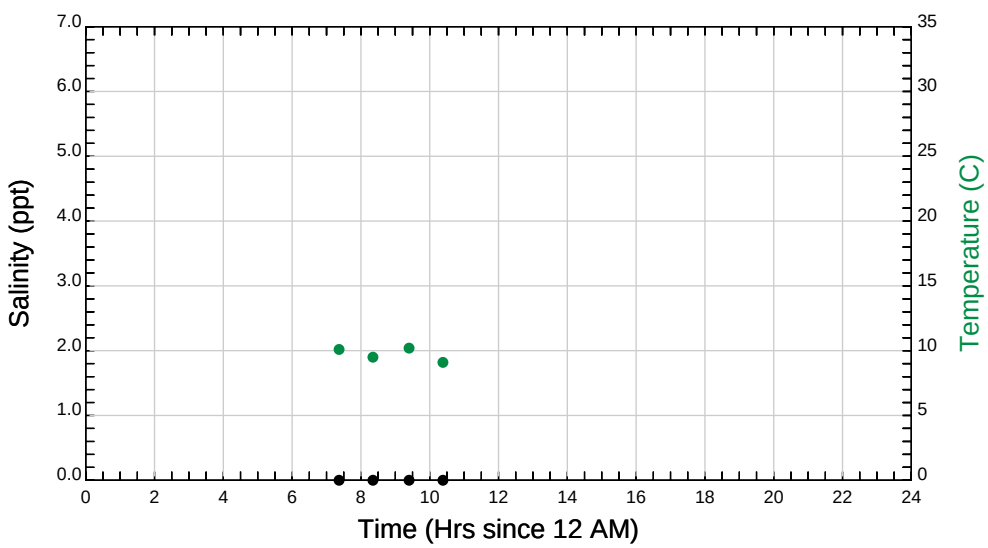

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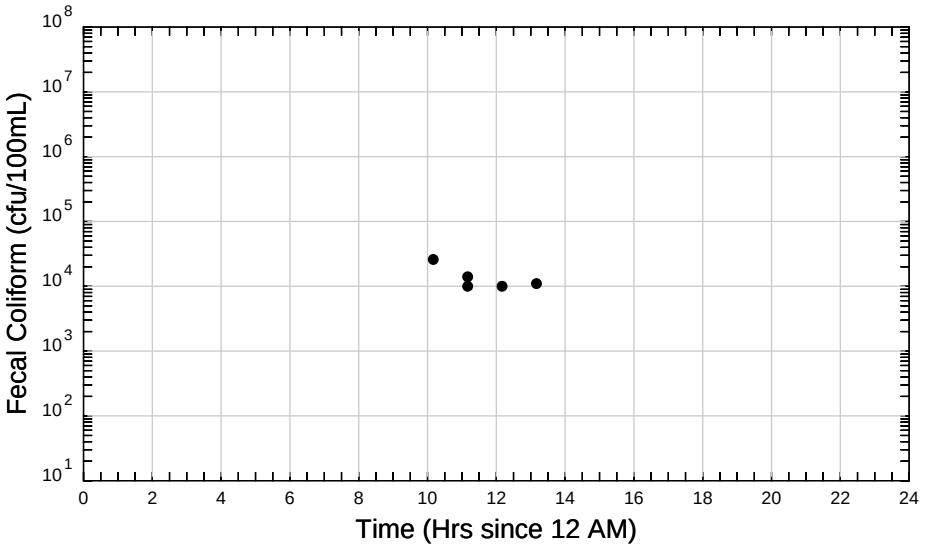

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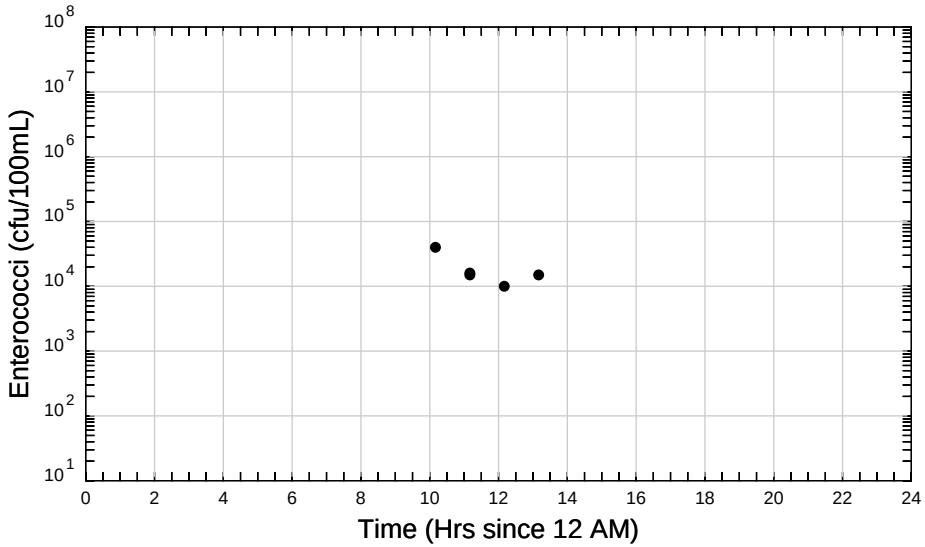

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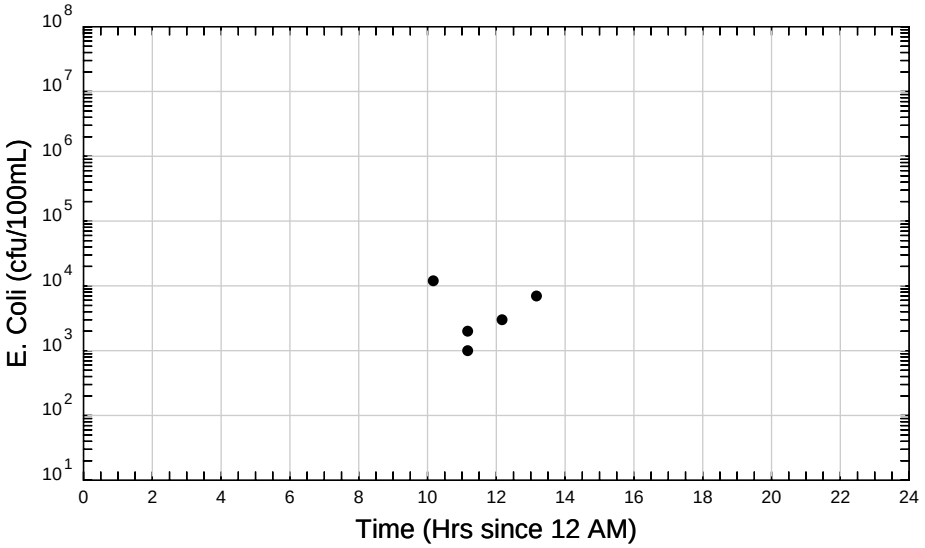

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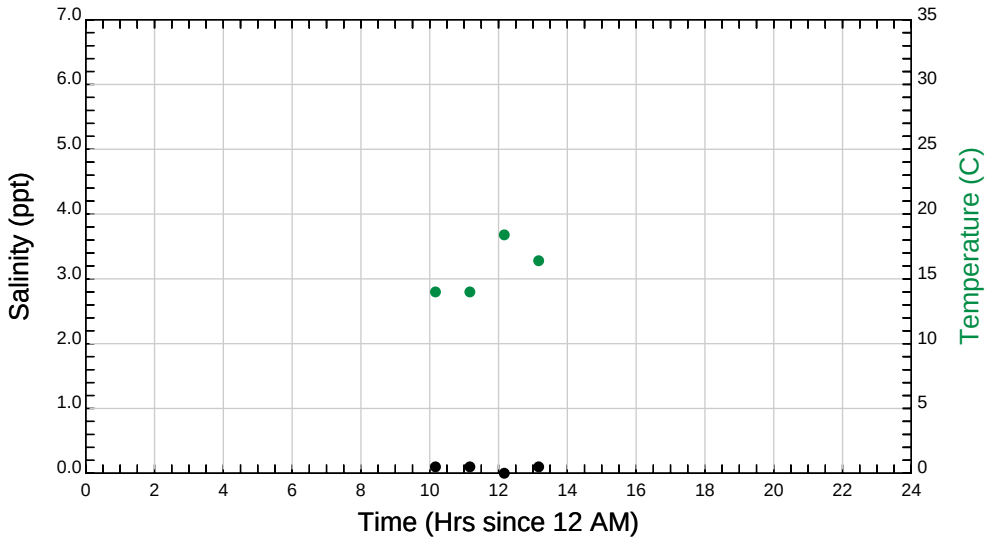

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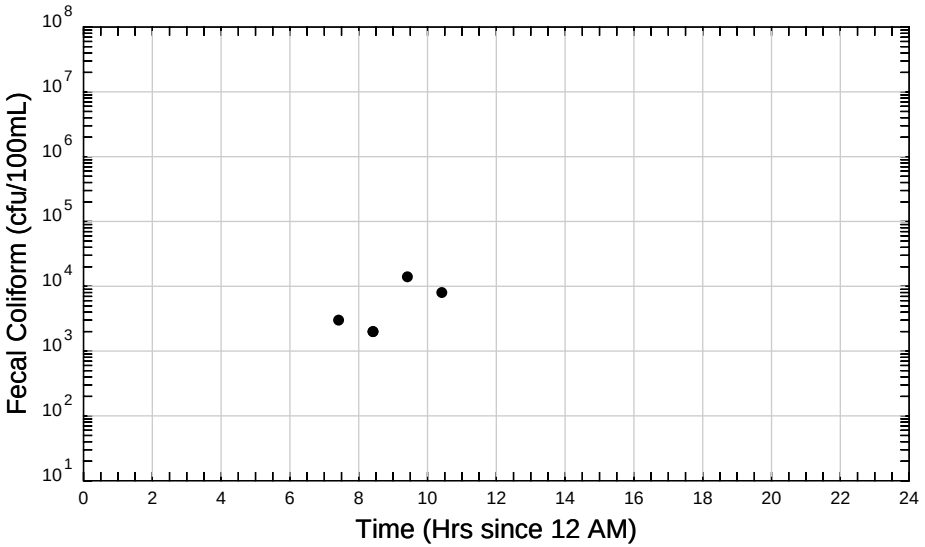

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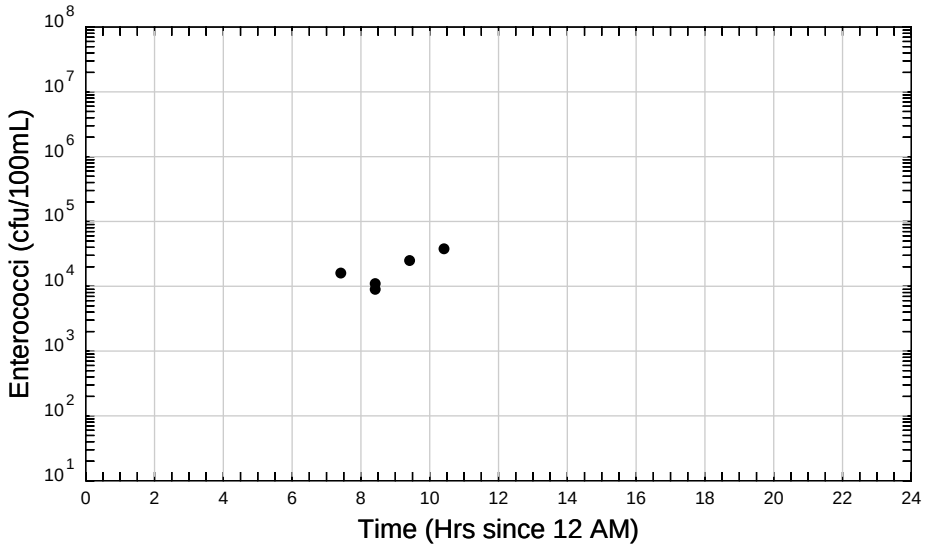

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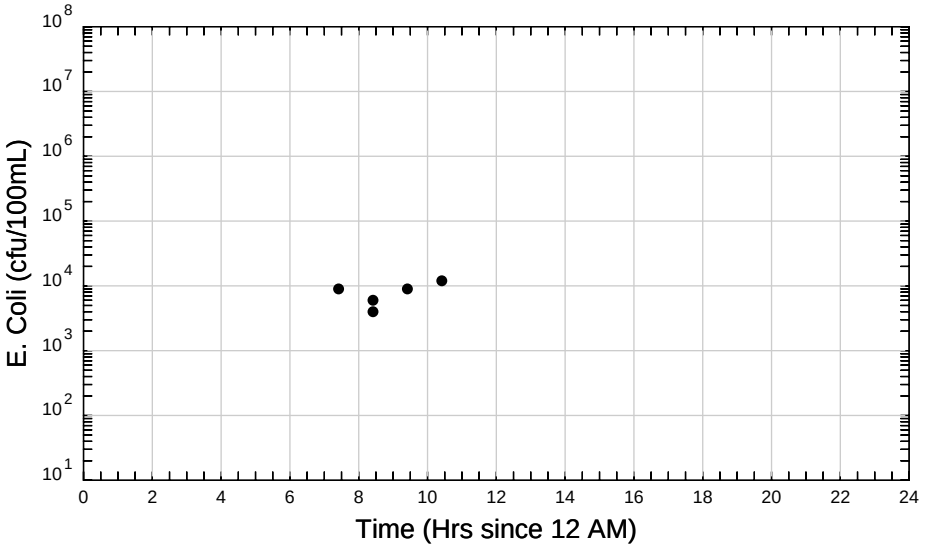

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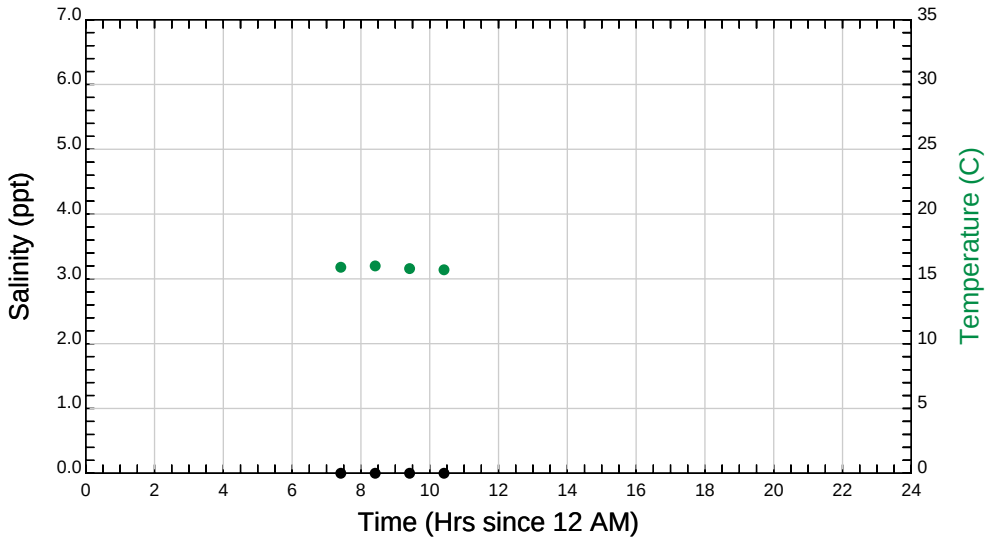

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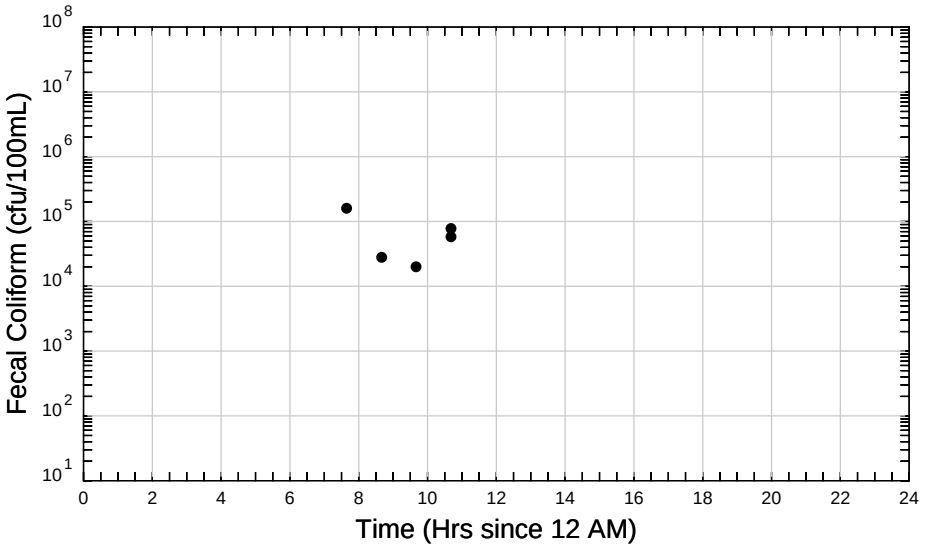

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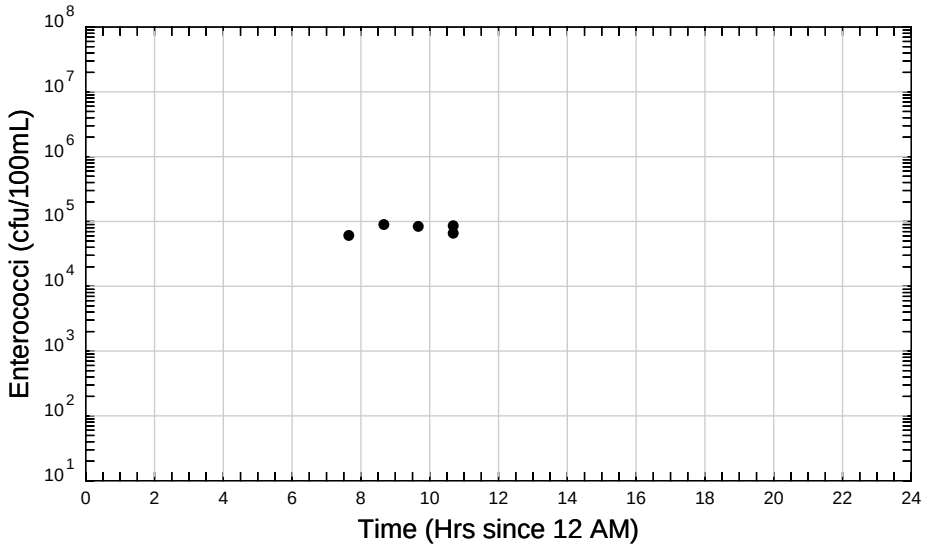

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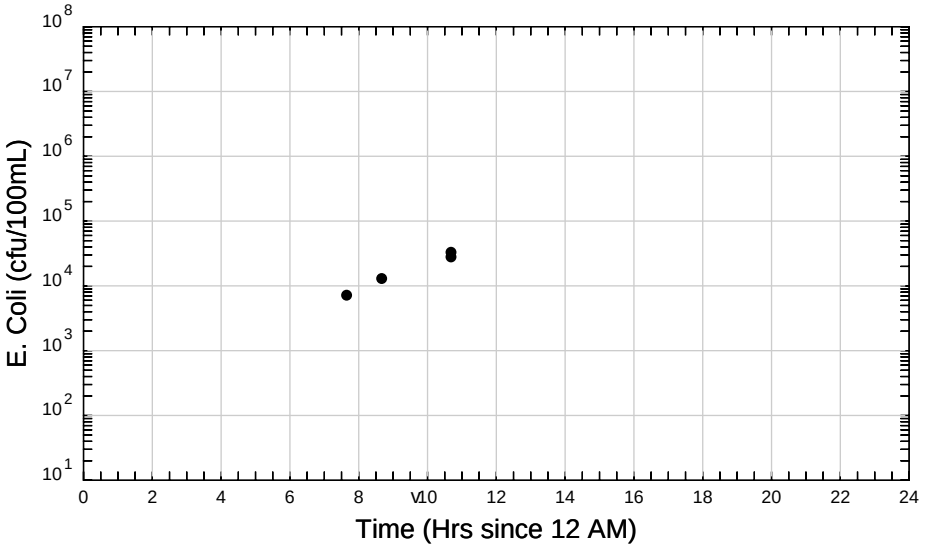

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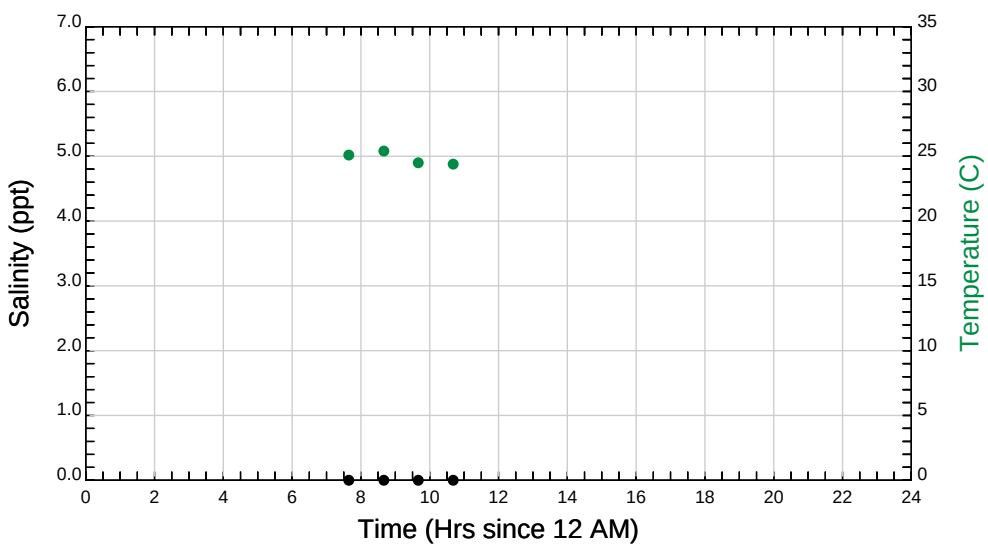

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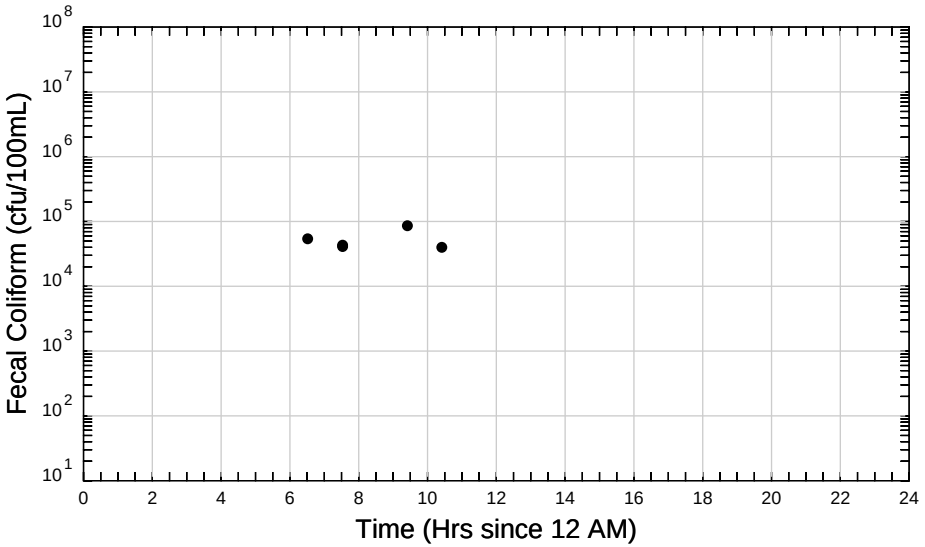

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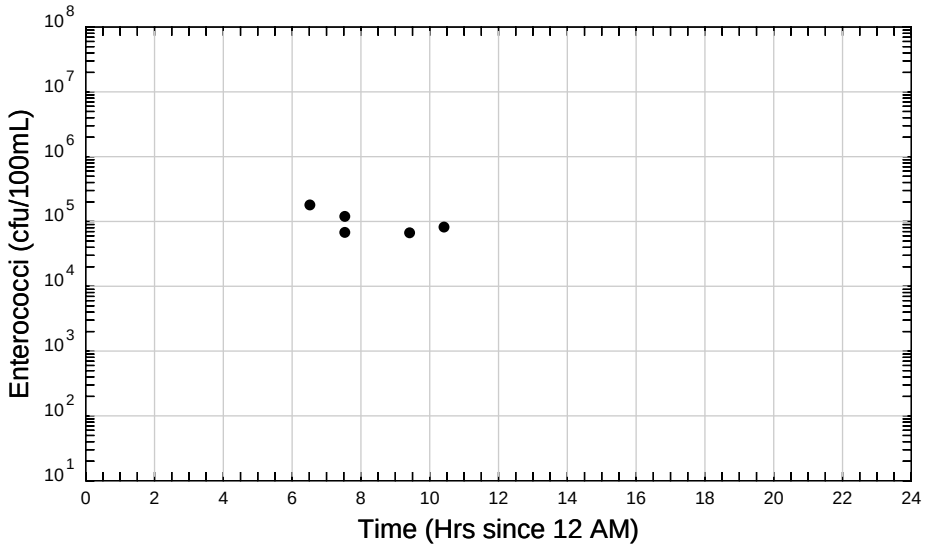

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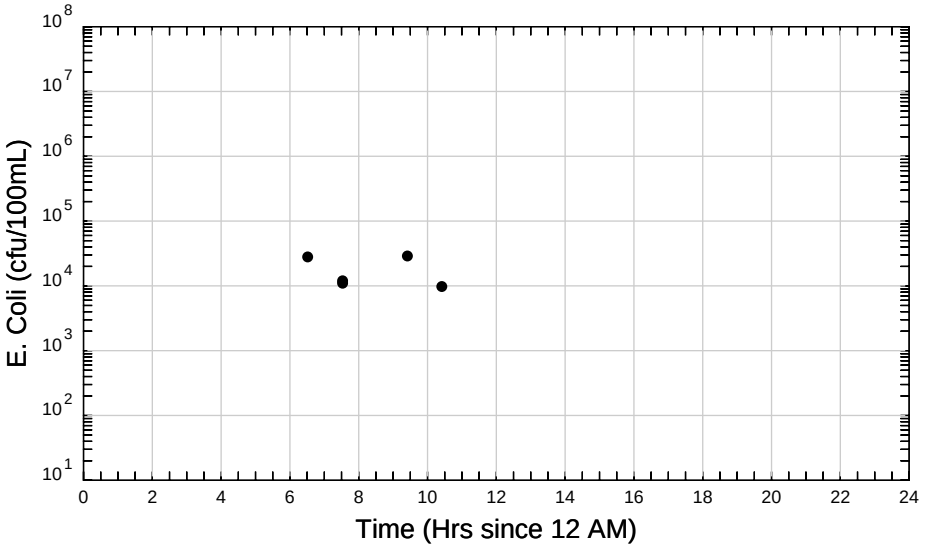

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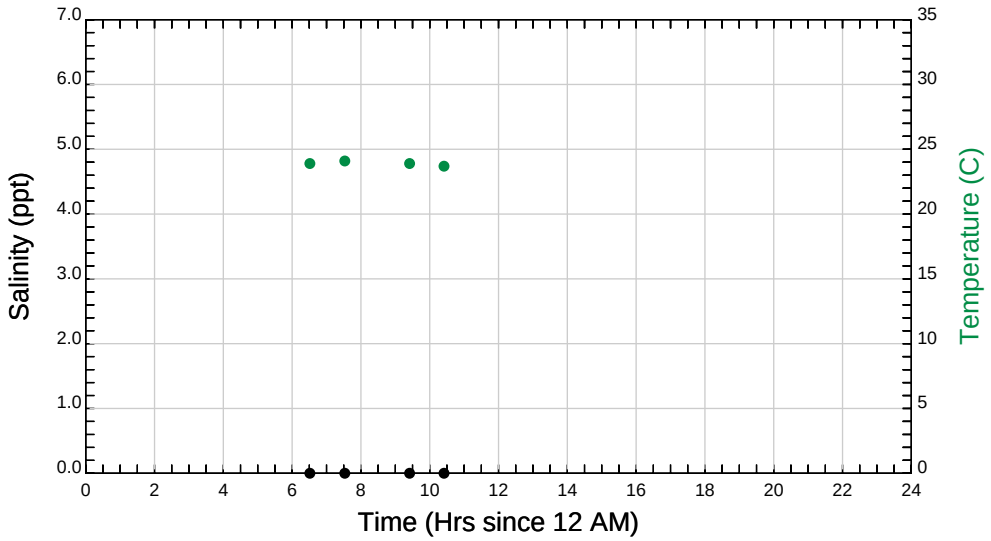

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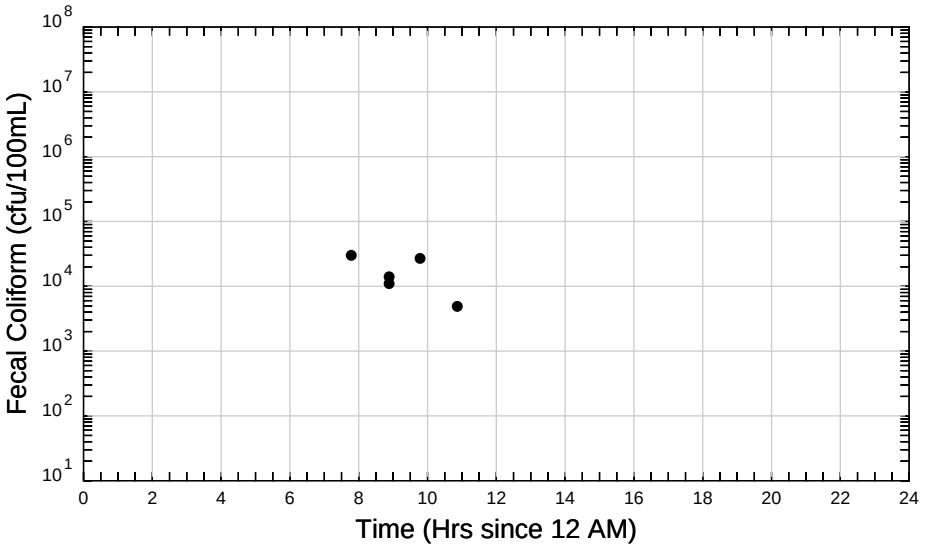

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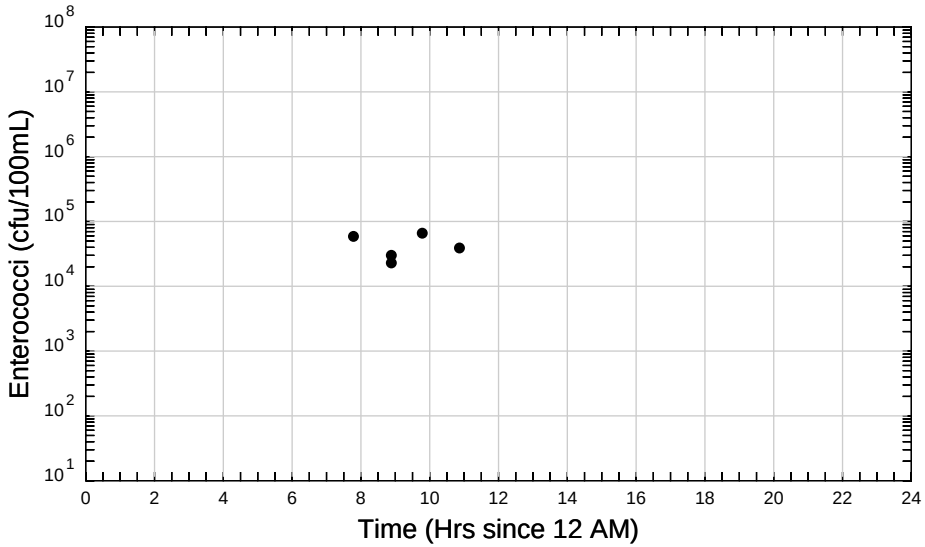

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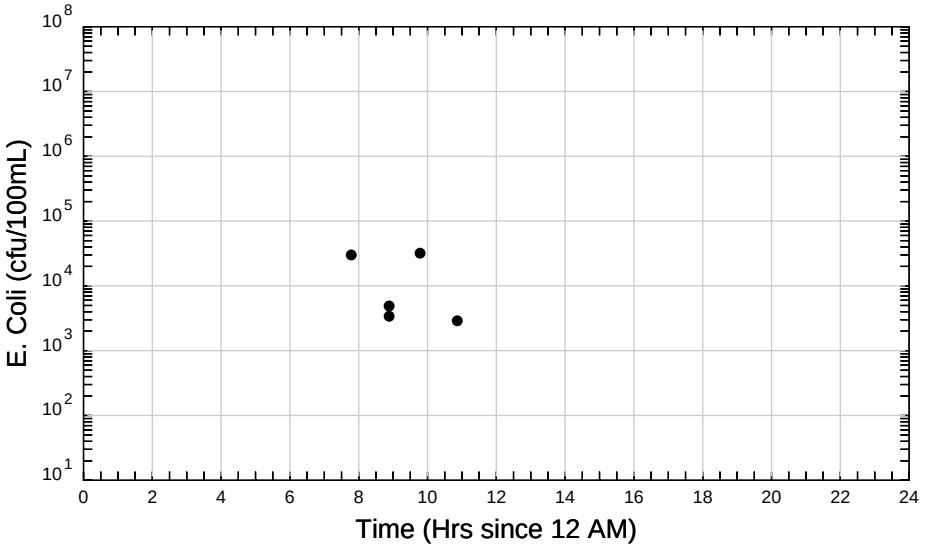

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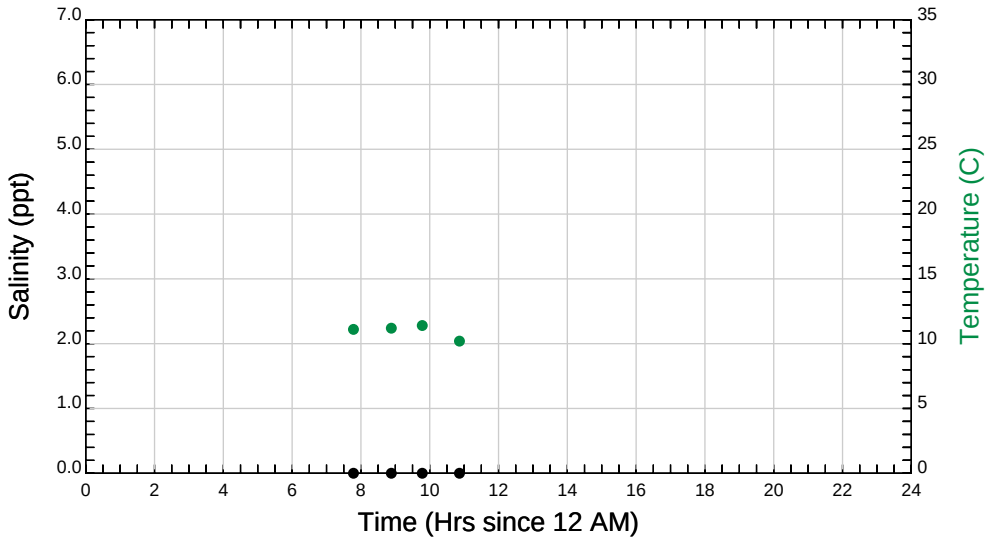

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Salinity (ppt)
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APPENDIX B

~~MEG~~ Model Evaluation Group (MEG) ~~Group~~ Meeting Summary with comments, MEG ~~-~~Memorandum, and Presentations for the following sessions: ~~and Comments:~~

MEG Meeting 1- February 5, 2016
MEG Meeting 2 – March 17, 2017
MEG Meeting 3 – September 15, 2017
MEG Meeting 4 – December 5, 2018

March 7, 2016 Meeting Summary
PVSC Model Evaluation Group (MEG)
Session 1 Notes

Memorandum

To: *PVSC Long Term Control Plan Team*

From: *PVSC Model Evaluation Group: Alan Blumberg, Steve Chapra, Wayne Huber*

Date: *March 7, 2016*

Subject: *Model Evaluation Group – Session 1 Summary*

The PVSC Model Evaluation Group held an initial meeting at the offices of PVSC on February 5, 2016. CDM Smith, Greeley and Hansen, and HDR presented an overview of monitoring and modeling that will be implemented for the PVSC Long-Term Control Plan project. The MEG submits the following comments based on discussion at the meeting and our review of the monitoring and modeling QAPPs.

Responses to MEG comments from the project team are shown in italics following each comment.

Monitoring

General

1. We endorse use of data collected by NYC DEP and other reputable groups even though they do not use NJ-approved QAPPs. These data should be compared with data collected in this project to ensure consistency.

   Agreed.

2. Storm event monitoring is the most critical element of the program. How will we be assured that the program will obtain wet weather data? Timing sampling to capture events is often difficult.

   The sampling QAPP indicates that three wet weather events will be measured at each intensive wet weather sampling station. The team has planned for up to six sampling events to capture the three wet weather events. A project scientist will monitor the weather so that appropriate resources are ready to sample when needed.

3. All collected data should be analyzed and presented as soon as possible.

   Collected data and its analysis will be presented to the MEG at the next meeting subsequent to a sampling event or as soon as practical thereafter.

4. The data should be made available to the public so that others have the chance to use it and possibly discover problems.

We will discuss this issue with PVSC.

5. The role of historical data collected over the last two decades was not adequately discussed. If land use and system configuration haven't changed much, then these data remain valuable for landside modeling. Conversely, deepening of channels in the Kills and other bathymetric changes affect receiving water dynamics.

Agreed.

6. The MEG inquired whether conservative tracers (e.g. select inorganic ions) that could help characterize sewage loads would be monitored and modeled, but the question was not answered.

We will not monitor or model inorganic ions.

Landside

7. We understand that there will be continuous water level monitoring at several stations along the main interceptor and at key CSO locations. This will be important for hydrologic/hydraulic model calibration and verification. Water levels alone are very useful when hydraulics are modeled dynamically.

Agreed.

8. It might be useful to sample sediment in the interceptor if it has sedimentation issues. This would help address the issue of possible first-flush effects. There seemed to be a variety of opinions offered about the first-flush concept at the meeting.

We will not sample sediment quality in sewers, but will measure sediment depths at flow metering sites.

9. Sampling within the collection system was not discussed. How clean is the upstream collection system? Additionally, interceptor geometry is critical for hydraulic grade line determination.

Sediment conditions in the community sewer systems likely vary widely. They have been incorporated to some extent into the existing collection system models. Newark and Bayonne (as well as Jersey City, which is conducting its own collection system study) already have reasonably detailed local collection system models; detail will be added for other communities as needed for assessing CSO. The existing local models and the PVSC interceptor model represent geometry adequately in all major pipes. The integrated PVSC model will incorporate good representation of the geometry of all pipes downgradient of CSO regulators.

10. Infiltration/inflow (I/I) was discussed, but monitoring of sanitary sewers was not adequately described. Will I/I just get merged with downstream sanitary sewage for estimating bacteria concentrations?

PVSC already monitors incoming flows from each of its communities. The modeling can thus discretely represent sanitary flow and I/I. Bacteria concentrations will be separately assigned to each flow component and tracked through the collection system model.

Receiving Water

11. Water quality sampling at predetermined intervals along with a few storm events in detail will provide a start for bacteria calibration, but see comments 15 and 16 below concerning modeling dry-weather bacteria concentrations.

12. Lateral sampling is important; more is needed, especially for bacteria. Stations should be added near the Statue of Liberty, Governors Island, and on the eastern side of Staten Island, perhaps near 455 Front Street, Staten Island.

See Item 12 discussion below.

Summary: The monitoring program will serve the needs of the study with the caveat that the sampling should be designed to characterize the predominant loads. The proposed metering for sewer system hydraulics should be adequate.

Modeling

13. The charge to the MEG (QAPP page 10) should mention review of the model grid prior to running simulations, and should include assessing the validity of calibration and sensitivity simulations.

Agreed.

14. The MEG should be given the chance to evaluate plans for the projection cases and the outcomes.

Agreed.

15. Bacteria are notoriously difficult to quantify from both a precision and accuracy standpoint; an order of magnitude agreement between measurements and the models will be an accomplishment.

We believe that statistical comparisons still have general merit. We will seek further guidance from the MEG, statistical experts, and scientific literature as to what values best represent "central tendency" and "variance" when comparing bacteria concentrations.

16. It is unclear how bacteria loadings will be generated for the model. Probably the most significant contribution will be from sanitary sewage. If most loading is from sanitary sewers, the most useful data will be both influent and effluent strength at the treatment plant, with influent strength used for estimating concentration in CSO during wet weather. Is bacteria concentration at the WWTP monitored regularly?

Bacteria concentration is not monitored at the WWTP. We expect to rely on dry weather sewer system sampling included in the planned field program and prior system characterization.

17. The stormwater contribution will need to be calibrated, as we are unaware of consistent loading rates (e.g., MPN/acre) for stormwater. However, it could turn out that during an overflow, the dominant bacteria load is due to the sanitary contribution even though stormwater quantity might be greater. Both sewage and stormwater mass flux (flowrate times concentration) magnitudes will be important.

Bacteria loads for the calibration will be generated by the following methodology:

CSO flows will be based on permittee/NYC DEP InfoWorks or SWMM model. Concentrations will be assigned based on the mass balance approach in which InfoWorks determines the fraction of sanitary and stormwater flow. Sanitary flow concentrations will be based on system-specific data collected during the monitoring program. Stormwater concentrations will be based on literature-derived concentrations based on land use supplemented by site-specific stormwater sampling. A constant concentration, based on geometric mean of the data, will be assigned to the sanitary and stormwater flow components. These concentrations may be spatially variable, depending on the sampling data.

Stormwater flows will be based on a rainfall-runoff model. Stormwater concentrations will be obtained from literature-derived concentrations based on land-use supplemented by site specific stormwater sampling.

Flows from external rivers entering the model domain at the boundary will be based on USGS gauge flow or flow ratios based on gauged and ungauged drainage areas. Flow versus concentration curves will be developed based on sampling data.

Internal rivers will be based on data collected at source sampling stations.

Illicit dry-weather sources will be identified based on dry-weather sampling data. Loads will be estimated via trial and error to match available water quality data. Depending on the required size of the dry weather source, flows may or may not be added to the model, as flow volumes may be trivial.

Ocean boundary conditions are likely to be inconsequential to driving the model solution; they will set to low bacteria concentrations.

The approach to developing projection condition loads may differ from the calibration process. The MEG will participate in the decision process for developing projection conditions. Decisions will need to be made as to whether illicit dry weather loads are part of the projection analysis, and what river and meteorological conditions will be appropriate to use.

18. Sensitivity analysis was not adequately discussed. For instance, will receiving water concentrations be most sensitive to load, hydrodynamics (transport processes), or decay rate?

It is likely that the degree of sensitivity will vary within the model domain. Non-tidal freshwater sections will probably be more sensitive to transport processes, while some tidal areas may be more sensitive to the decay rate. Peak concentrations may be more sensitive to the load. In some places, illicit dry weather loads may mask these processes.

The intensive storm event sampling data should inform the spatial bacteria loss rate: transport + decay + other (e.g. settling). The calibrated hydrodynamic model will allow us to estimate the transport component of the loss by executing the water quality model with no decay rate. Previous model experience will allow us to bound expected die-off rates. If additional loss mechanisms are required, the effect of solar radiation and/or settling can be examined. Peak concentrations that are too high or too low will require us to reassess how loads were developed. Since bacteria concentrations range over orders of magnitude, factors that affect concentrations by a factor or two or so may be difficult to assess in terms of how much those factors influence model calibration.

19. What is the frequency of sanitary sewer overflow (SSO) across the system?

No SSO has been reported by the communities.

20. Was it stated that there is not a significant groundwater infiltration contribution to the sewer system, or just that it will not be dynamically modeled? How leaky are the regional sewers?

Base flow in regional streams typically varies from 1.5 cfs per square mile (cfsm) in spring to less than 0.5 cfsm in fall; regional sewers can be expected to exhibit similar variation in groundwater-driven infiltration flows. For areas where such seasonality has not already been incorporated into the collection system models, monthly infiltration factors will likely be developed to represent this flow variation based on long-term flow data already collected by PVSC. We will compile long-term flow data for the wastewater treatment plant and key permanent monitoring locations to establish seasonal infiltration factors. (While not directly pertinent to the issue of infiltration in sewers, it is noteworthy that flow in the Hackensack River does not conform to the regional norm. It is strongly regulated by in-line reservoirs and water supply withdrawals; base flow near its mouth averages 0.2 cfsm.)

21. Good coordination with the municipalities will be important if they want to use the landside model for internal analysis of their systems.

Agreed.

Item 12 Discussion

DEP (Marco Alebus): Although the model encompasses the core area of NY/NJ Harbor, the focus of the model calibration/validation should be on New Jersey waters. In addition, given the uncertainty in quantifying the loadings from NYC, detailed calibration of the model in open waters is not a primary objective of this effort. Thus, event sampling at these stations, although useful for the overall model, may not be critical to demonstrating model fitness in most NJ waters. For the purpose of establishing a baseline condition, does NYC sample at or near these locations? Station B28 is located along the shipping channel. Given that this is also an event sampling station, please explain how the sampling location will not jeopardize obtaining the required number of samples during an event sampling.

SJL (Sheldon Lipke Environmental Consultants): Please further explain the MEG's rationale for the additional sampling sites. It would be useful to know why the MEG chose the Governors Island and Statue of Liberty sites, which are relatively close to each other, and the B21 site, which is on the same confined waterbody (the Narrows) as B21A and B21B.

NYC sampling locations are not close to the additional stations suggested by the MEG. We don't see shipping interfering with sampling as an issue; we can move out of the way if a ship is coming by. We only need to be on station for 10 to 15 minutes to collect samples and make measurements.

Background information questions from MEG

Timothy J. Groninger from HDR is identified as Project Manager, but was not at the meeting, while Bill Leo, also from HDR, is not mentioned in the QAPP but participated in the meeting. Please clarify.

The project's consultant team consists of Greeley and Hansen, CDM Smith, and HDR. Greeley and Hansen is the contractual lead and responsible for landside analysis. CDM Smith is the program manager and coordinates modeling efforts. HDR is responsible for water quality sampling and receiving water analysis. Tim Groninger is HDR's project manager; Bill Leo is a senior vice president at HDR with extensive knowledge of the firm's previous work.

Why are pathogens in the receiving waters the emphasis of the study? We understand it is for an NPDES permit, but for what water quality standard? Fishable-swimmable or water contact locally (harbor areas)? Water contact at distant beaches? Shellfish? Is there a TMDL or other standard to be met?

Pathogens have been defined by NJ DEP as the water quality constituent of concern for the LTCP. There is no approved pathogen TMDL. Pathogen water quality standards will be existing NJ DEP standards. In the area of interest, the majority of the waters are secondary contact waters, but the region does contain primary contact waters in areas away from the CSOs. Beaches and shellfish areas also exist within the Harbor but they are in Raritan Bay and are far from any NJ CSOs.

In SSCWP QAPP PART 1.pdf, pp. 57-58, there is a memo from HDR "Modeled CSOs vs. Rainfall." The figures are examples of common rainfall frequency analyses in which it is demonstrated that small storms (by depth) occur much more frequently and contribute more to total annual rainfall depth than do big storms. How was a storm event defined? Event definition is typically done by specifying a minimum inter-event time (MIT, hours) between "independent" events. MIT can be determined probabilistically, although it seldom is. Instead, a number like 6 hours is often used. MIT definition influences the plots and thus the conclusions drawn from the plots. How was an event defined?

The minimum inter-event time was defined as 4 hours in the analyses noted. However, for the purpose of the LTCP, analyses will be continuous simulations using 15 minute to one hour time steps (yet to be determined). In continuous simulation modeling, MIT does not have to be defined.

Long Term Control Plan

MEG Meeting
February 5, 2016 9:00 A.M. - 3:00 P.M.
PVSC WWTP, OEM Main Conference Room

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Meeting Summary

PVSC Model Evaluation Group (MEG)

Session 2

March 17, 2017

Stevens Institute of Technology

Attendees: **See Sign-In Sheet**

Introduction

The PVSC Long Term Control Plan (LTCP) Model Evaluation Group (MEG) held their second meeting at Stevens Institute of Technology on March 17, 2017. Greeley and Hansen, CDM Smith, and HDR presented status updates on the progress of the monitoring and modeling programs being performed for the PVSC Long-Term Control Plan project. The following is a summary of the meeting topics and discussions.

Opening Remarks

- Dr. Alan Blumberg welcomed the members of the MEG, PVSC, NJDEP, the engineering consultants, and other observers to Stevens Institute of Technology.
- The meeting attendees introduced themselves and their affiliation with the project
- Mike Hope provided an overview of the program status:
    - All the NJPDES QAPPS have been submitted to NJDEP and approved by NJDEP
    - The 12-week temporary flow monitoring program is complete
    - The water quality sampling programs are approximately 90% complete
    - The wet-weather sampling program is slightly behind schedule due to the lack of rainfall in 2016.

Flow Monitoring Program – Presented by Yuan Fang

- Yuan Fang provided an overview of the temporary flow monitoring program:
    - 21 temporary flow meters were in place from April 2016 through August 2016
        - 13 of the meters are monitoring flow in an outfall
        - 7 of the meters are monitoring flow in a regulator influent
        - 1 of the meters is monitoring flow on the interceptor (Paterson)

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  - The flow monitoring data was analyzed to determine the period when close to all of the meters appear to be functioning properly so that model calibration events can be identified. The period between May 15th and August 5th.
- Yuan Fang provided an overview of the PVSC permanent flow meter locations.
- Yuan Fang provided an overview of available precipitation records for the proposed model calibration periods:
  - Sub-hourly data is available from Newark Airport, but there is a deficit in the total volume recorded in June 2017 as compared with the hourly and daily data.
  - Bridget McKenna stated that PVSC has a rain gage that might be able to supplement the missing airport information.
  - Tim Dupuis stated that we can also supplement the data by disaggregating the hourly data from the airport.

Water Quality Monitoring Program – Presented by Tim Groninger

- Tim Groninger provided an overview of the sampling programs:
  - The Routine Sampling program is 95% complete and is on schedule.
  - The Intensive Sampling program is 72% complete and is on schedule. One more boat intensive survey remains.
  - The System Characterization Stormwater Sampling program is 79% complete and is nearly on schedule.
  - The System Characterization CSO Sampling program is 12% complete and is behind schedule due to a lack of precipitation in 2016.
- Marco Alebus asked the MEG whether they felt it was critical to complete the CSO sampling program, since they aren't going to be used directly by the models. The models will be applying concentrations based upon the relative mix of stormwater and sanitary flow in the overflow, as predicted by the model.
  - Dr. Wayne Huber responded that the CSO sampling is important since the CSO load will be the largest bacterial source to the receiving waters.
- Tim Groninger presented a summary of the sample data quality, based on the number of laboratory qualified and estimated values:
  - Tim Groninger explained that the laboratory reports estimated values if the bacterial plate count is outside of the range of 20-60 colonies. The laboratory did provide the actual plate count with the sample data if the value was estimated due to being outside of this range.
  - Marco Alebus asked how the estimated values will be used:
    - Tim Groninger responded that we plan to utilize the qualified data for the model calibration, and note the qualifications.
    - Tim Dupuis stated that this is an area where we would like to receive input from the MEG.
      - Dr. Steven Chapra stated that he doesn't have concerns with utilizing the qualified data.

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- Biswarup Guha requested additional information on the upper quantification limit. He suggested that the upper quantification limit be included when reporting the data.
- Marco Alebus asked whether a site-specific correlation can be established between the bacteria indicators, and if it could be used to help evaluate the estimated values.
    - Tim Groninger replied that it is something that would be looked at.

Typical Year – Presented by Mike Hope

- Mike Hope presented the selection criteria utilized for identifying a "typical year".
    - The method is a statistical approach based on multiple rainfall (Newark Airport) and river flow (Passaic River) criteria
    - This method has been used and accepted elsewhere by USEPA
    - Based on the applied ranking methodology, 2004 was ranked #1
        - 2008, the NYC typical year, was ranked as #8
            - New York City utilizes the rain gage at JFK Airport
    - The model was simulated for 20 years to evaluate the relative annual overflow volumes and number of events:
        - 2004 is approximately 1.5% over the average overflow volume, and 6.7% over the average number of overflow events.
    - Selecting a year other than 2008 will require additional coordination with NYC, but this additional coordination has been discussed with NYC and NYC seems to be willing to provide the required model outputs. In turn, PVSC will provide the required model outputs for 2008 to facilitate NYC's LTCP program.
- Biswarup Guha asked whether New York City utilized a similar method for selecting their typical year:
    - Tim Groninger responded that the New York City analysis utilized the same methodology that was previously used to select the JFK 1988 typical year. This included five unweighted statistics at JFK Airport, Newark Airport, LaGuardia Airport, and Central Park.
    - Dr. Steve Chapra suggested that the JFK data be run through the PVSC typical year selection criteria weight to see how 2008 ranks.
- Marco Alebus stated that the perception at NJDEP may be that 2008 is less stringent than the prior typical year (JFK 1988).
- Marco Alebus stated that USEPA may want to utilize 2008 anyway to be consistent with the shared waters.
- Biswarup Guha stated that intensity is critical for selecting critical year:
    - Biswarup Guha requested that a chart or figure be developed showing intensities for each year.
    - Biswarup Guha requested that temporal plots of the actual rainfall be developed for records from Newark Airport and other gages, including JFK Airport.

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- Tim Dupuis stated that the number of back to back rainfall events is one of the critical parameters, and that 2008 was well above the annual average in the number of back to back events. The number of back to back events will impact the effectiveness of green infrastructure in reducing CSO impacts since the capacity will not have time to recover between storms.
    - Biswarup Guha requested a graphical representation on the number of back to back events
- Biswarup Guha stated that updated standards that introduce a Statistical Threshold Value (STV) are being developed for SE1 waters.
    - EPA is also pushing to upgrade the downgraded waters as well.
    - This won't happen before the LTCP plan is done
    - New York City has updated their LTCPs based on the new standards, and upgraded some of the shared waters to primary contact.
- Susan Rosenwinkel suggested that an official approval of the typical year report would be useful.
    - Mike Hope agreed, and asked whether the comparison of 2004 and 2008 should be included.
        - Dr. Steve Chapra stated that the analysis should be done for a range of years, but the comparison of 2004 and 2008 shouldn't be presented.
        - Susan Rosenwinkel suggested that a narrative be included on why the New York City typical year wasn't used by default.
        - Tim Dupuis stated that the planned approach was to submit a document to NJDEP for approval.
- Biswarup Guha requested that a comparison between the PVSC rain gage and the Newark Airport rain gage be performed.
- Nicholas Kim suggested that the Lodi/Saddle River streamflow gage may be more appropriate to look at in comparison to rainfall instead of the Passaic River.
- Marco Alebus requested that timeseries plots of river flow be developed for 2004 and 2008.
- Marques Eley stated that the September 8, 2008 storm was Hurricane Hannah, which was nearly 8". The National Weather Service said that 2008 was one of the driest years on record at that time, prior to that storm.

Regional Drainage Model – Presented by Mitch Heineman

- Mitch Heineman explained that that Regional Drainage Model is needed to simulate continuous flows and loads from the drainage areas not included in the CSO areas.
    - Stream flow records from 7 USGS gages were loaded directly into the model to account for flows from areas upstream of those gages.
    - Rainfall-runoff was simulated in areas downstream of those 7 USGS gages utilizing the SWMM non-linear reservoir method in InfoWorks.
    - Several downstream USGS gages were used for model calibration.

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Hydrologic and Hydraulic Model – Presented by Yuan Fang

- Yuan Fang provided an update on the hydrologic and hydraulic model development.
  - The PVSC, Bayonne, and North Bergen models have been combined into a single integrated model.
  - A simplified Jersey City model was developed to convey flows from North Bergen and to account for the Jersey City flows.
    - Tim Dupuis informed the group that another consultant is working on the Jersey City modeling, and that the PVSC consulting team coordinates with them.
  - Regulator settings were checked and updated.
  - Delineations were updated, particularly in Paterson.
    - Susan Rosenwinkel asked whether Paterson Outfall O-28 is included in the model as a CSO. NJDEP recently confirmed that it is a CSO.
      - Yuan Fang replied that it is being modeled as a CSO.
  - Separately sewered areas were added to the model.
  - Wet-weather operating rules were added at the Newark CSO regulators and the primary storage tanks at PVSC.
- Wet weather calibration events have been identified as:
  - 5/29/16-5/30/16
  - 7/25/16
  - 7/29/16-8/1/16 (back to back storm at 7/29/16 and 7/31/16)
- Biswarup Guha asked whether in-pipe sedimentation is being considered.
  - Yuan Fang responded that sedimentation is not being included in the model.
  - Tim Dupuis stated that CDM Smith is inspecting the PVSC lines as part of another contract and that the information will be provided to the LTCP modeling team as it becomes available.

Hydrodynamic Model – Presented by Nicholas Kim

- Nicholas Kim provided an overview of the hydrodynamic receiving water model.
  - The model calibration period is 2009-2016.
  - The model calibration involves: elevation; currents; temperature; salinity
  - Tidal marsh area was added to account for the required storage volume of the large tidal flux.
  - An overview of the modified grid mesh was shown.
- Marco Alebus asked how "Dundee Lake", the water behind Dundee Dam, was handled in the model.
  - Nicholas Kim responded that the flow recorded at the USGS Little Falls gage is discharged over Dundee Dam.

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- Dr. Alan Blumberg asked about bathymetry, and how the dredging program has been accounted for.
    - Nicholas Kim responded that approximately 90% of the dredging program was complete by 2009 and 2010. It was assumed that the dredging project was complete for the calibration period.
- Nicholas Kim presented model calibration timeseries plots of tide data, temperature, and salinity.
    - Dr. Alan Blumberg asked whether the model calibration will be evaluated in any sort of statistical manner.
        - Nicholas Kim stated that will be done and included in the report.
    - Marco Alebus requested that a statistical means for quantifying the error in the calibration be included.
- Biswarup Guha stated that BCUA collected salinity data that might be useful.
    - Bridget McKenna stated that BCUA is a participant on this project and she will request the data from BCUA.

Water Quality Modeling – Presented by Richard Isleib

- Richard Isleib provided a summary of the receiving water quality data collected between April 2016 and early January 2017.
    - The stormwater sampling results for the Hawthorne low density residential and Paterson commercial/industrial sampling locations are unexpectedly high. Additional investigation on these locations may be required.
    - Dr. Wayne Huber asked whether the industrial and commercial stormwater sampling locations are representative of the all industrial and commercial land uses.
        - Marques Eley stated that the Paterson Commercial/Industrial site may be near a slaughter house in Paterson.
- Dr. Steven Chapra suggested that light be included as a modeling parameter.
- Charlie Dujardins suggested that some of the remaining CSO sampling effort be diverted towards additional stormwater sampling.

Closing Remarks

- The group discussed a schedule for the next MEG meeting(s).
    - Dr. Steven Chapra requests that any information on the receiving water quality model be sent in advance of the next MEG meeting so that the MEG has time to review.
    - Tim Dupuis suggested that two more MEG meetings be held; one prior to the receiving water quality model validation and one afterwards.
    - Biswarup Guha requested that materials be shared with NJDEP ahead of the next meeting.

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- The group decided that the next meeting will be targeted for August 2017.

Attachments

-Agenda
-Sign-in sheet

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PASSAIC VALLEY SEWERAGE COMMISSION

Long Term Control Plan

Modeling Evaluation Group - Session 2
March 17, 2017, 9:00 A.M. - 3:00 P.M.
Stevens Institute of Technology, Babbio Center, 5th Floor

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Meeting Summary

PVSC Model Evaluation Group (MEG)

Session 3

September 15, 2017

Stevens Institute of Technology

Attendees: **See Sign-In Sheet**

Introduction

The PVSC Long Term Control Plan (LTCP) Model Evaluation Group (MEG) held their third meeting at Stevens Institute of Technology on September 15, 2017. Greeley and Hansen, CDM Smith, and HDR presented status updates on the progress of the monitoring and modeling programs being performed for the PVSC Long-Term Control Plan project. The following is a summary of the meeting topics and discussions.

Opening Remarks

- The meeting attendees introduced themselves and their affiliation with the project
- Mike Hope provided an overview of the program status:
    - The program is in the System Characterization Phase.
    - The collection system model calibration is almost complete.
    - The water quality sampling program is complete with the exception of the CSO sampling program.

Water Quality Monitoring and Modeling Program Overview – Presented by Richard Isleib

- Surface water quality sampling program:
    - There are 72 surface water monitoring locations.
    - The applicable water quality standards and waterbody classifications were reviewed.
    - There are locations upstream of the CSOs where the sample results approach or exceed the single sample maximum.
    - The Second River shows some of the highest bacteria concentrations.
        - Sheldon Lipke states that prior investigations on the Second River have shown that both dry and wet weather concentrations can be out of compliance.

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- The Elizabeth River also shows high bacteria concentrations.
- Dr. Blumberg requests that maps of the sample locations be added to the sample results slides in future presentations.
- Tim Groninger stated that the surface water sample data scatter plots will be distributed to the NJ CSO Group along with a memorandum explaining the sampling program and results.
- Sheldon Lipke asked that Richard Isleib email him the figures shown in the presentation.
- Sheldon Lipke suggested that distinguishing between dry-weather and wet-weather samples on the plots may be useful.
- Richard Isleib asked NJDEP whether the State was considering upgrading any of the waterbodies.
    - Biswarup Guha stated that EPA wants the States to update their standards for primary contact waterbodies.
    - For SE1 and SC waters, NJDEP is going to update the criteria to match the EPA standards
    - For downgraded waters, NJDEP might consider the results of the LTCPs to determine whether to modify the standards.

- Stormwater sampling program:
    - There are 8 stormwater sampling locations.
    - There are 18 CSO sampling locations.
    - The stormwater sampling program is complete.
    - The stormwater sampling results were compared with tributary area land use, but definitive distinctions were not found. Therefore, a single stormwater concentration will be utilized.
    - Richard Isleib explained the mass balance approach for to determine the fraction of sanitary and stormwater flow in the overflow using a tracer, and calculating the overflow concentrations based on the percentage of each in the overflow.

- CSO sampling program:
    - Mike Hope stated that the CSO sampling program is the only portion of the overall sampling program that is not yet complete.
        - To date 18 CSO sampling events have been completed, which is 1/3rd of the CSO Sampling Program. 36 additional sampling events are required.
        - 10 of the 18 sampling stations have been sampled at least once.
        - Weather conditions have been a challenge
        - Continuing the current course of the CSO sampling program will negatively impact of the schedule for completing the System Characterization Report.

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        - We are considering collecting additional stormwater sample data in lieu of collecting additional CSO sample.
    - Charlie Dujardins asked whether a difference in CSO concentration was found from location to location, or based on tributary area land use.
        - Richard Isleib stated that there is variability between locations, but there is also variability at the same station when it has been sampled multiple times.
    - Dr. Steven Chapra asked whether the CSO sample concentrations have been normalized to something like the size of the tributary area.
        - Richard Isleib responded that the data was no normalized to the area, but that is something that we can look at.
    - Susan Rosenwinkel stated that NJDEP would like to see all of the data before making a decision to allow a change to the sampling program.
    - Richard Isleib that the results of the InfoWorks model would be used to evaluate how well the model is predicting the existing CSO sample dataset, and then a decision can be made about whether additional CSO sampling data would be required.
    - Marco Alebus asked that a comparison of the results predicted by the model against the data collected be sent.

- Dry and Wet Weather Loads to the Receiving Water Model:
    - Richard Isleib explained the proposed Monte-Carlo regression of using dry weather river flow and bacteria concentration.
        - Dr. Steven Chapra suggested that the actual data be used instead of assuming a geometric distribution for sites with many observations.
    - Richard Isleib explained an approach using a linear regression of concentration vs. precipitation for events above 0.2" to determine a concentration to add to the dry weather concentrations.
        - Dr. Steven Chapra suggested that the slope of the regression be tested to determine whether it is statistically significant, or whether a constant wet weather concentration should be used instead.
        - Dr. Wayne Huber agrees that the significance of the regression slope needs to be confirmed.
    - Richard Isleib stated that the load from the upstream Hudson River will be applied just upstream of the area of interest, instead of trying to model the loads from Albany down to the area of interest.
        - The MEG agrees that this approach is reasonable.
    - Richard Isleib explained the pathogen model kinetics.
        - Dr. Chapra suggests that HDR's knowledge on NYC and available local data be used to determine the loss rate.

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- Dr. Chapra also suggests that the settling velocity can be used as a calibration knob.

Collection System Model Calibration Results – Presented by Yuan Fang

- Yuan Fang provided an overview of the collection system model and the individual CSO communities.
- The group discussed the impacts of not having the detailed Jersey City collection system model in the regional InfoWorks model.
  - Yuan Fang explained that the Jersey City collection system is currently represented as a simplified system.
  - Jersey City is performing their own modeling independently.
  - Bridget McKenna stated that PVSC has requested the Jersey City model, but it hasn't been received yet.
  - Mitch Heineman stated that we currently have a reasonably working model to simulate the flows, but not the detailed model.
- Yuan Fang presented timeseries and scatter plots showing how the collection system model flow predictions compare with the monitored flow data.
  - The model performs best on the interceptor and trunk sewer meters.

Final Discussion

- The group discussed holding another MEG meeting prior to final calibration of the receiving water quality model, most likely in the first quarter of 2018.
- The group discussed the overall project schedule.

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PASSAIC VALLEY SEWERAGE COMMISSION

Long Term Control Plan

Modeling Evaluation Group - Session 3
September 15, 2017, 9:00 A.M. - 3:00 P.M.
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Meeting Summary

PVSC Model Evaluation Group (MEG)

Session 4

December 5, 2018

Location: **CDM Smith Edison, NJ Office**
Attendees: **See Sign-In Sheet**

Introduction

The PVSC Long Term Control Plan (LTCP) Model Evaluation Group (MEG) held its fourth meeting on December 5, 2018. Greeley and Hansen and HDR presented status updates of the monitoring and modeling programs being performed for the PVSC Long-Term Control Plan project. This memorandum summarizes the meeting topics and discussion.

Opening Remarks

- Meeting attendees introduced themselves and their affiliation with the project
- Michael Hope provided an overview of the program status and schedule.
- Mr. Hope requested that the MEG provide a memorandum summarizing their participation in the project and their conclusions.
    - Susan Rosenwinkel agreed that this would be useful. She suggested the memo include an introduction with MEG meeting dates, background on the members, and conclusions.

Hydrologic and Hydraulic Model Overview – Presented by Dr. Yuan Fang

- Dr. Fang provided an overview of the collection system model and the individual CSO communities. She described wet weather operating rules implemented in the model, which include utilizing primary clarifier storage and closing regulator gates when influent flow rate to PVSC from the west exceeds 350 mgd.
    - Marques Eley confirmed that the rules implemented in the model match current standard operating procedures.
- Dr. Fang presented model calibration and validation results
    - Dr. Steven Chapra suggested that the flow monitoring data should be adjusted to eliminate questionable spikes, and then the calibration plots should be updated.

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- Dr. Alan Blumberg suggested that performance statistics, such as root mean square error, should be included.
- Dr. Blumberg requested that monitored vs. modeled scatter plots be developed which show all metered events at all locations; the group agreed that these scatter plots would be useful in evaluating the calibration
- Marzooq (Marco) Alebus acknowledged that calibration was performed, but asked whether an independent validation was also performed using separate storm events.
    - Mitch Heineman responded that collection system models typically have limited data from which calibration and validation can be performed, so it is typical to perform a single calibration/validation.
    - Dr. Chapra stated that validation was performed since calibration results from the four events are based on a single set of model input parameters. Each event thus validates the others. Dr. Chapra stated that this is excellent engineering in terms of considering one's available data, and that he has confidence in the methodology; Charles DuJardin agreed with Dr. Chapra.
- NJDEP suggested that the System Characterization Report be retitled "Calibration/Validation", instead of "Calibration and Validation".
- The MEG requested that scatter plots with all the monitored vs. modeled results be developed, color coded by event.
- Susan Rosenwinkel stated that a 45-day extension would be granted for submission of the revised System Characterization Reports so that MEG comments could be addressed and incorporated.

Hydrodynamic Modeling – Presented by Nicholas Kim

- Mr. Kim provided an overview of the hydrodynamic model. He explained the model input parameters and model domain, and presented salinity and temperature calibration results at various monitoring locations within the model domain.
- Dr. Wayne Huber stated that the model results are generally in good agreement with the monitoring data.
- Mr. Alebus requested that all graphs be presented in the final report; Dr. Blumberg suggested that the main report should contain representative plots, with the remainder relegated to an appendix
- Rich Isleib stated that for the purposes of the water quality model, the hydrodynamics perform as required.
- Mr. DuJardin requested that some level of spatial plots be developed to show how salinity varies along the Hudson River, Passaic River, and Hackensack River.

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Water Quality Modeling Update – Presented by Rich Isleib

- Mr. Isleib provided an overview of the receiving water quality model, beginning with model kinetics and pathogen sources.
- Mr. Isleib presented the monitored stormwater and sanitary bacteria concentrations obtained from the monitoring programs.
    - The results of the stormwater sampling program did not reveal a statistically significant difference in bacteria concentrations in runoff from different land use types. The variation within a land use type was as wide as the variation among land use types.
    - All the monitoring data was thus combined. Uniform fecal coliform (41,000 cfu/100 ml), enterococci (110,000 cfu/100 ml), and E. coli (38,000 cfu/100 ml) concentrations were applied to runoff regardless of land use type.
- Mr. Isleib explained that CSO loadings were determined based upon the fraction of sanitary and stormwater flows in the hydraulic models, multiplied by respective dry and wet weather concentrations. Calculated CSO concentrations were compared with monitored CSO concentrations and found to be in good agreement.
- Mr. Isleib presented the WWTP influent monitored pathogen concentrations.
    - Dr. Chapra asked about the seasonal pattern in bacteria concentration at the WWTP.
    - Mr. Isleib responded that it may be the result of dilution from I&I
- The group discussed the ratio of E. coli: enterococci in sanitary and stormwater data
- Mr. Isleib presented the methodology for assigning river boundary loads using a Monte Carlo approach for dry weather, and maximum likelihood estimation for wet weather.
    - The water quality monitoring data suggest the presence of additional dry-weather loads from sources other than those initially modeled.
    - To check the reasonability of the additional dry weather loads being input into the model, a "person-equivalent" approach was used assuming an average sanitary flow concentration and 150 gallons per day wastewater per capita.
        - The group discussed the person-equivalent approach.
        - Dr. Chapra suggested that it might be a good discussion for an appendix.
- Mr. Isleib presented WWTP, stormwater, baseflow, and Hudson River boundary loads that were applied to the model.
    - Mr. Alebus asked about using a WWTP effluent enterococci concentration of 100 cfu/100 ml even though WWTPs have limits of 35 cfu/100 ml.
        - Mr. Isleib responded that he didn't think the WWTP concentration was that sensitive.
        - Ms. Rosenwinkel responded that she doesn't believe the contributing WWTPs have enterococci limits.
        - Mr. Alebus suggested that an explanation of the 100 cfu/100 ml should be included in the report.

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- Mr. Isleib presented NJ pathogen criteria for primary and secondary contact recreation, followed by model calibration results.
    - Mr. Hope asked if Mr. Isleib's interpretation of evaluating geomean compliance with the model is to use a rolling 30-day geomean.
        - Mr. Isleib responded that this is his interpretation and explained how he performed those calculations.
    - Dr. Chapra asked what model adjustments had to be made for this study as compared to prior studies.
        - Mr. Isleib responds that the base die-off rate for fecal coliform was set to 0.2/day instead of 0.8/day and that temperature adjustments were also made
    - Dr. Chapra stated that in his opinion the model is the best that it can be given the state of knowledge.
    - Mr. DuJardin stated that he would like to see a calculated depth-average solar radiation decay rate in the Hudson River vs. the Passaic River, or other locations.
    - Dr. Huber asked that the report address the sensitivity analysis of all key parameters, not just the die-off coefficient.

Final Discussion

- Dr. Huber suggested that a sensitivity analysis be performed for each model.
- The MEG requested that one additional MEG meeting be held.
- Mr. Hope discussed the next steps
    - Possibly hold another MEG meeting
    - Memo from the MEG
- Dr. Blumberg stated that the System Characterization Report needs a conclusion on the model's performance.

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Long Term Control Plan

Modeling Evaluation Group - Session 4

Dec. November 5, 2018, 10:00 A.M. - 3:00 P.M.

CDM Smith, 110 Fieldcrest Avenue, Edison, New Jersey 08837

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PVSC LTCP
Model Evaluation Group (MEG)
Memorandum dated February 15, 2019

Memo:

February 15, 2019

To: PVSC Consulting Team

From: PVSC MEG: Steve Chapra, Alan Blumberg, Wayne Huber

Re. Comments re. MEG4 meeting of December 5, 2018 and PVSC Characterization Report, revised as of January 19, 2019

Overall Summary

1. The MEG has enjoyed presentations on the overall approach to modeling and its support data for the PVSC Combined Sewer Overflow mitigation efforts for the past three years. We are in broad general agreement with the approach and techniques used for the development of modeling tools to address pathogen receiving water impacts of PVSC CSO discharges. We feel that the consulting Team's efforts have been well conceived and executed within practical limits of budget and technology. In particular, the H&H modeling is very extensive and well done. The MEG is in accord with the direction of the Team to date in developing tools to address PVSC mitigation strategies. The Team is "on track".
   RESPONSE: Acknowledged.

2. The MEG is missing strategies and pathways leading to overall PVSC mitigation efforts, drawn from the modeling to date. We look for H&H modeling conclusions (such as discussed in our Addendum) related to CSO discharges and their impacts. We understand that there will be a sequence of reports dealing with important results such as receiving water impacts of mitigation strategies, e.g., time series and spatial distributions of pathogen concentrations in New Jersey and New York estuaries. We feel that it is incumbent on us to review and comment on results developed in the next phases of this project regarding the effectiveness and use of these strategies to reduce pathogen concentrations. Therefore, we strongly request another opportunity to evaluate these forthcoming efforts.
   RESPONSE: Acknowledged.

Addendum: Comments related to detailed review of PVSC System Characterization Report, Revised 1/2/19. Specific report sections addressed are in response to direction from M. Hope and M. Finizio.

Most comments are editorial in nature. More significant comments:

Section E, comments 2, 3, 6.

Section I, comments 7, 8, 9, 10, 14, 15, 16, 19, 22, 23.

Section G, comment 2.

Section E Collection of Precipitation and Sewer Flow Monitoring Data

1. P. 87. Red revisions delete number of meters for each category. Flow meter locations are summarized in Table E.1. Are we losing any information that we need to know by losing the number in each category? Maybe not, in which case disregard this comment.
   RESPONSE: The category for each meter is included in Table E-1. No information was lost.

2. A huge amount of data was recorded by hundreds of meters. Does the report highlight or give a sense of the relative percentage (or other metric) of regulator and outflow volume that was covered by flow monitoring relative the total CSO and PVSC discharges at the downstream end of its system during the time the monitors were active? The monitors include temporary ones here in Section E, and permanent ones. For example, can we say X % of regulator inflow (to the main trunk sewer) volume was measured? Or maybe a different perspective-type number would be the percentage of project cities' land area (or population or?) that was monitored for contributing inflows to the PVSC trunk and stormwater discharges?
   RESPONSE: Temporary flow meters were installed at eleven (11) outfalls. Based on the results of the typical year model simulation, these 11 outfall locations discharge approximately 30% of the total annual CSO volume. Quantifying the percentage of the monitored regulator influent would be more difficult. However, large CSO drainage basins were targeted for the temporary flow metering.

3. Regarding missing temporary flow meter data (Figure E-2), was there ever a need to infill such data by other than the model that is not indicated in the reports?
   RESPONSE: Figure E-2 in intended to show that all but two of the meters had available metering data from 5/20/2016 through 8/5/2016. That was the period that was selected for model calibration/validation. Records from the two meters located on the Newark 009/010 South and North outfalls were partially missing during this period. No infill of flow data was performed during this period.

4. Data and approaches to diurnal variations, peaking factors, screening of data – all seem good to me. A commendable and huge effort.
   RESPONSE: Acknowledged.

5. Section E.7 Rainfall Frequency Analysis. In the big picture, precision on the return period of the selected calibration events probably doesn't matter. But we point out that intensity-duration-frequency curves (IDF curves), here represented by depth-duration-frequency curves, are not an appropriate way to estimate a return period for individual events. IDF curves are not based on independent events but from some d-hour duration segment of real storms, which may be much longer than for the data point used to construct the contours. Specifically, they represent conditional probabilities that a certain intensity will occur given a duration. The right way is to perform a conventional frequency analysis on the period of record from the gages that contains the candidate events (Table E-4). This would be performed on the long-term period of record for the various the rain gages, by separating the record into likely-independent events by the minimum interevent time chosen, here 6 hours, a common choice. For example, SWMM5 can perform this analysis; it isn't arduous. It may be that only the Newark Airport has a long enough record here, which is fine. Then the events of 2016 could be identified from this separation with their return period or exceedance frequency.

This all seems to have been done in Section H ! Could not the analysis look ahead to tables such as H-2 and do a better (as in more precise and theoretically justified) job of assigning return periods here?

Having said all this, it is still obvious from Figure E-9 that all the chosen events are of high frequency with low return periods. That is the main point of the discussion, and the data are well presented. This is not a "mission critical" analysis. Perhaps the report could include a brief insertion on p. 99: "Newark Airport rainfall was compared to the NOAA's Precipitation Frequency Table to *provide an approximate* estimate *of* the return frequency of these events (Figure E-9)."
RESPONSE: The suggested text has been inserted into Section E.7.

6. Re. Section E.7, has the report stated what time steps are used in the simulations? 15-min? We have very good quality (i.e., 5 to 15-min) rainfall data here.
   RESPONSE: Precipitation is input at a 5-minute time step. This is first stated in Section I.3.1 of the Report and repeated in Section I.6. The model is run at a 1-minute time step and reported at a 5-minute time step.

7. Re. overall Section E, I believe we all understand the difficulty and expense of monitoring such a huge complex area and finding a group of monitored events that will serve for model calibration. We think the team has done a fine job here.
   RESPONSE: Acknowledged.

Section I Hydrologic and Hydraulic Modeling

1. This review will focus on highlights and the H&H modeling presentations.
   RESPONSE: Acknowledged.

2. The PVSC Interceptor Model covers a very large area of primarily old, established cities. Hence, assumptions about constant land use over time should be OK, maybe unless some huge new industrial or other development has occurred or will occur.
   RESPONSE: Acknowledged.

3. Pp. 165 and nearby: text is understandable, but with some awkward grammar, e.g., "…is corresponded to…"
   RESPONSE: The text was modified for grammar.

4. MEG comments and Table I-5 are discussed in a separate section below.
   RESPONSE: Acknowledged.

5. Re. Section I.3, H&H Model Components and inputs, the MEG has enjoyed several presentations on this work. The amount of spatial detail is enormous (e.g., Section I.4), with thousands of SWMM subcatchment parameters provided. Having so much impervious area in the study area helps with parameter choices. Rainfall data are taken from the best available options. Newark Airport data are good for the long-term simulations.
   RESPONSE: Acknowledged.

6. Hydraulic data for the combined sewers and regulators have been reviewed (P. 186) by the Team. We don't see how any better model representation could be constructed without unreasonable, large extra expense.
   RESPONSE: Acknowledged.

7. At the MEG Session 1 (2/5/16, Table I-5) the MEG was assured that interceptor geometry was represented adequately. Does the Characterization Report mention what field surveys were conducted to ensure this? What is the range of dates for PVSC in-situ drawings for pipes and regulators, e.g., paragraph I.3.6?
   RESPONSE: Field surveys were not conducted as part of the current project to confirm the interceptor geometry. The interceptor representation in the model was inherited from prior modeling efforts. Regulator configurations were confirmed using drawings dated from 1997 through 2008.

8. P. 189, re. RDII: Roughly what percentage of flow consists of RDII? Since there are three RDII components, just an average or total is all we request. We are just wondering how important is RDII to overall CSO volumes?
   RESPONSE: The total typical year influent volume to the PVSC collection system is estimated to be 83,500 MG, of which approximately 600 MG is RDII.

9. Section I.4. The report should list the model time step for event calibration runs (short runs?) and long-term simulations (annual). Are the event calibration runs (Section I.5) run over a longer real time period, e.g., to establish antecedent conditions? Or are they just run over a period of several hours? Or maybe there's one long run for 2016 from which these four event simulations are extracted? Please explain.
   RESPONSE: The same time steps were used for the calibration period simulations and the typical year simulations. Precipitation is input at a 5 minute time step. The model is run at a 1 minute time step and reported at a 5 minute time step. The calibration runs were done using two time periods. The simulation for the May 29th calibration event was started on May 27th to establish the antecedent conditions. The simulation for the July 25th through 30th events were started on July 23rd to establish the antecedent conditions.

10. Of course, these reports and all models will be passed along to the PVSC and its consultants for future application. Of more than just geeky interest is information about time steps and run times for individual events (e.g., the calibration events) and annual simulations as well as the computing platforms used. What kind of simulation times are encountered? Did the team or InfoWorks develop post-processers to aid in the analysis? If this information is already included somewhere, please point to it in, say, an appendix. Else, please do include it, at least briefly.
    RESPONSE: The typical year model simulation takes approximately 3 hours without water quality tracers included, 8 to 9 hours with the water quality tracers included. Post processing was performed in Excel.

11. P. 197 re. modeling criteria: It is definitely more important to match volumes than peaks, although both matter, because pathogen loads are driven by volume. Hence, it is good to have a more

stringent goal (-10% - +20%) for volumes than for peaks. In terms of overflows to receiving waters, upstream timing at individual locations mostly gets smeared out in the summation. Hence, overflow volume summary figures are very important. I would expect fits of model vs. monitor volumes to be better than flows in any event, because of the flow integration involved. This is reflected in the useful new Nash-Sutcliffe Efficiency (NSE) plots shown in Section I.5.3 (volume matches have higher R2).

Re. the many, predominantly impressive calibration plots comparing hydrograph flows and volumes, Figures I-27 – I-54:
RESPONSE: Acknowledged.

12. Display of the same hydrograph and scatter plots all on one page, with a separate page showing the hydrographs on larger plots, is a good way to present these analyses.
RESPONSE: A prior version of the report did include the four hydrograph and two scatter plots for each calibration location together on a single page. DEP commented that the figures were too small so they were separated into the separate pages for the scatter plots and the hydrographs.

13. Is there some duplication of figures in Figs. I-27 and I-28? The hydrographs and model-monitoring scatter plots look the same.
RESPONSE: The redline version of the document that the MEG reviewed can be confusing when it comes to replacing figures. As described in the response to Comment #12 above, the prior version of the System Characterization Report included the hydrographs and scatter plots on a single page, in this case that would have been Figure I-27 as found on page 200 of the document. Page 200 is being removed (redlined) and replaced with pages 199 and 201. Figure I-27 now contains only the scatter plots and the site location map. Figure I-28 contains only the hydrograph plots.

14. P. 221, Fig. I-42, errant meter data in the top figure have been smoothed out or in-filled in the lower figure. The text might mention this process somewhere.
RESPONSE: The screening and smoothing/filling of meter data is mentioned in Section E.5. The process has been explained in the updated version.

15. But not at all locations: Fig. I-46 retains the missing (we assume) monitor flows on both sets of hydrographs. That would certainly account for overestimation of volumes by the model for this location and events. Likewise Fig. I-51 for NE_15A. Volumes are not comparable for three of the four events.
RESPONSE: The missing monitored flow data for this meter occurred over a long period of time, making it impossible to interpolate between adjacent data points with any confidence in the resultant timeseries.

16. Yet for location NE_15A_II, Fig. I-52, the missing or no-flow monitoring data are believed. Maybe monitors could be identified as more or less reliable?
RESPONSE: For location NE_15A, which is an overflow meter, the recorded flow during this event was zero. The meter appears to have been operating properly. It is possible that the precipitation used in the model for this particular event didn't occur within the contributing area, or that the

model is simulating an overflow event as a response to a rainfall event that didn't trigger an actual overflow event.

17. Re. Section I.5.3 and NSE, NSE values are very high, and, as noted in the report, well above the threshold (~0.5-0.75) heuristically characterized as a "good fit." Unlike the traditional R2, we don't believe there is a significance test for the NSE. We do note slightly higher NSE-R2 for volume than for peaks.
    RESPONSE: Acknowledged.

18. Figures I-63 – I-65 graphs re. overflow statistics, it would help to have "frequency" include units of #/year, as in Table I-11.
    RESPONSE: The units of #/year have been added to the figures.

19. In the context of comment 11 above, while a few locations/storm events show inferior fits, the large majority of model-monitor fits are good and within the project percentage criteria. But where do/will we see the summary total overflow volume from all outfalls, modeled vs. monitored, shown at the end of the MEG4 H&H modeling presentation (slide 65)? That is an essential figure, needful of inclusion and discussion.
    RESPONSE: This referenced figure and a discussion of the figure has been added to Section I.5.2.

20. The overflow statistics and simple Table I-12 at the end are useful.
    RESPONSE: Acknowledged.

    Section I ends abruptly, with no summary. We understand from discussion with Team staff that future reports will present more pertinent (to the goal of reducing receiving water pathogens) results, such as receiving water analyses.
    RESPONSE: Acknowledged. The intent of this report was to characterize the existing collection system. Future reports will address alternatives for reducing combined sewer overflows, pathogens discharged to the receiving waters, and receiving water quality.

A few additional comments:

21. Sanitary sewer overflows, SSOs: This question may have been addressed earlier, but at this point, it isn't found in prior summations. What is the importance of SSOs in modeling and overall pathogen inputs to the receiving waters? They are not mentioned in the Characterization Report.
    RESPONSE: There are no known SSOs within the PVSC service area.

22. We are still missing a sensitivity analysis or discussion of key H&H calibration parameters? With thousands of individual H&H variables, i.e., for specific subcatchments and pipes, what were the main variables actually used to calibrate the overall H&H model and subarea models? What are the "key model parameters" mentioned at the beginning of Section I.5, p. 195? A good discussion of the various SWMM modeling parameters is given in Section I.3.2, but there had to be some watershed-wide (or sub-watershed or city-wide) parameter adjustments at some time. What global

parameters were typically adjusted? To what parameters was the SWMM model most sensitive to in this highly urbanized area?

RESPONSE: The routing coefficient (RC) for combined sewersheds was the principal calibration parameter for the PVSC model. This parameter controls directly-connected impervious area, and is the principal factor determining total wet weather runoff into the collection system. Other important calibration parameters were subcatchment width (hydrograph shape), sanitary sewershed infiltration/inflow (I/I) coefficients ("R"), and Manning's N in the PVSC interceptor. However, the routing coefficient was by far the most important parameter adjusted.

The model's hydrology was adjusted differently for sanitary and combined sewersheds.

For sanitary sewersheds, the unit hydrograph parameters (known as the RTK method) were adjusted. Three R parameters control total I/I. Overall average R coefficient was calibrated at 0.5 percent for 62,000 acres (97 mi^2) of separate service area (PVSC Model Summary and Update Procedures, April 2018, p. 5). Sanitary collection system I/I typically ranges from 0.1 to 5 percent of rainfall. I/I from sanitary sewersheds affects flow in the PVSC interceptor along the reach between Paterson and Newark, but has minor overall impact on total flow in the collection system, as demonstrated below.

For combined sewersheds, imperviousness (I) was generally computed directly using the National Land Cover Database (System Characterization Report, p. 179), while the routing coefficient was calibrated to match observed runoff rates. Effective imperviousness (EI) can be expressed as EI = I x (1-RC). As shown in Table I-7 of the report, the combined service area comprises 23,200 acres (36 mi^2), averaging 70 percent impervious and a calibrated value of 41 percent effective impervious (corresponding with RC equal to 41 percent).

For 1-month peak rainfall of 0.4 inches per hour, the rational method (Q = CIA) may be used to estimate runoff from both the sanitary and combined service areas, with the assumption of a typical one-hour time of concentration in much of the collection system. For the separate service areas, peak runoff is 0.5% x 0.4"/h x 62000 ac = 124 cfs (80 mgd). For the combined service area, peak runoff is 41% x 0.4"/h x 22000 ac = 3600 cfs (2300 mgd). The combined area runoff greatly exceeds the collection system's wet weather capacity of approximately 300 mgd (550 mgd total conveyance/treatment minus 250 mgd dry weather flow). Combined runoff greatly exceeds sanitary runoff, which is thus relatively inconsequential for overall system performance. Even in small storms or non-peak rainfall, combined runoff can exceed total system conveyance/treatment capacity (e.g. 600 mgd at 0.1"/h rainfall).

The calibrated 41 percent effective imperviousness is lower than would be expected based on the range of values suggested by Sutherland (1995) and presented in the EPA SWMM Hydrology Manual (Rossman and Huber, 2015). Sutherland's method suggests that an area with 70 percent total impervious should have between 49 and 60 percent effective imperviousness. The PVSC project team has found that the low end of this range is typical in northeastern US communities. The fact that the PVSC value is below the end of Sutherland's proposed range is not surprising, as it is

common to find that some areas identified as having combined sewers instead drain to open waterways.

The routing coefficient in the combined service area was thus the principal determinant of total system runoff. It is also the key determinant of CSO volume; while parameters such as subcatchment width affect the timing of hydrographs, runoff across the PVSC combined communities has overland flow distances of at most a few hundred feet, and the timing of hydrographs from individual subcatchments cannot vary across a wide enough range to significantly influence the duration over which the collection system is stressed above its conveyance capacity.

References

PVSC LTCP Consultant Team, Memorandum to PVSC CSO Districts, dated April 24, 2018. PVSC Model Summary and Update Procedures.
Rossman, L. and W. Huber. Storm Water Management Model Reference Manual Volume I, Hydrology. US EPA Office of Research and Development, Washington, DC, EPA/600/R-15/162A, 2015.
Sutherland, R.C. (1995). Methodology for Estimating the Effective Impervious Area of Urban Watersheds. Watershed Protection Techniques 2(1): 47–51.

Section G.3 Overview of Sewer System Quality Monitoring Program and G.4 Sewer System Quality Results

1. A good CSO and stormwater sampling program, with help that the PVSC Water Resources Recovery Facility (WRRF) has continuous monitoring. Given the enormity of the watershed/sewershed, the monitoring seems adequate for model development and calibration.
   RESPONSE: Acknowledged.

2. Two or three representative photographs of monitoring sites, e.g., at/within a CSO location or regulator, would give the reader a sense of the difficulties of CSO monitoring, here or in Section D. The Team provided these on a PPT in one set of responses to MEG comments.
   RESPONSE: Acknowledged. Two representative photos are provided below.



PATTERSON - 025A



GUTTENBERG 01A

Table I.5 and Appendix B re. MEG comments and meeting reviews

1. To the extent of memory and notes, the MEG reviews are adequately characterized. MEG member comments have been addressed other than as noted above. We believe our summary comments have been uniformly positive and supportive of ongoing activities and see no reason why the report might not mention this if desired.
   RESPONSE: Acknowledged.

2. Pp. 173-174 re. MEG affiliations, Huber would prefer his affiliation to be "Oregon State University, emeritus."
   RESPONSE: This report has been updated to reflect Dr. Huber's affiliation.

PVSC LTCP
MEG Meeting 1, 2, 3 and 4 Presentations

PVSC Long Term Control Plan

Model Evaluation Group – Session 1

February 5, 2016



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GREELEY AND HANSEN
CDM Smith
HDR

Agenda

- Introductions
- MEG Mission
- MEG Scope
- Regulatory Drivers
- Site Information/Background
- Long Term Control Plan Process
- Specific Modeling Components
- Discussion/Next Steps

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GREELEY AND HANSEN CDM Smith HDR

CDM Smith

Introductions

- PVSC
  - Bridget McKenna
  - Marques Eley
  - Sheldon Lipke (SJL Environmental)
  - Charles Dujardin (GLEC)
- MEG
  - Alan Blumberg, Stevens Institute of Technology
  - Steve Chapra, Tufts University
  - Wayne Huber, Oregon State University
- LTCP Consultant Team
  - Greeley & Hansen
  - CDM Smith
  - HDR
- NJDEP
  - Marzooq Alebus
  - Susan Rosenwinkel
  - Chang Wu

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MEG Mission

"The Model Evaluation Group (MEG) will review all significant technical aspects of the PVSC Long Term Control Plan model development. Model development will consist of three distinct components: Landside, Hydrodynamic, and Water Quality. The goal is to ensure that these model components are technically viable for use by the engineering team in the assessment of engineering alternatives and with withstand regulatory and public scrutiny.

The MEG will provide guidance, where appropriate, to improve or enhance the approaches and methodologies that lead to model development. The MEG will judge, individually and jointly, the technical acceptability of the major model components. If a component is deemed unacceptable, the MEG will outline steps to improve the technical acceptability of the model components. All findings will be summarized in interim progress reports and a final report."

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Scope of the MEG

- Work Items (separate handout)
  - Review modeling workplans for landside, hydrodynamic and water quality models
  - Review proposed existing data sources
  - Review proposed sampling plans
  - Respond to requests for opinions
  - Provide guidance during sampling, model development and calibration phases
  - Prepare summary report
- Constraints
  - LTCP must stay within NJPDES permit schedule
  - Reasonable balance of new data and cost
  - Models are the "tools" to develop/evaluate CSO control alternatives for the LTCP

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Regulatory Drivers

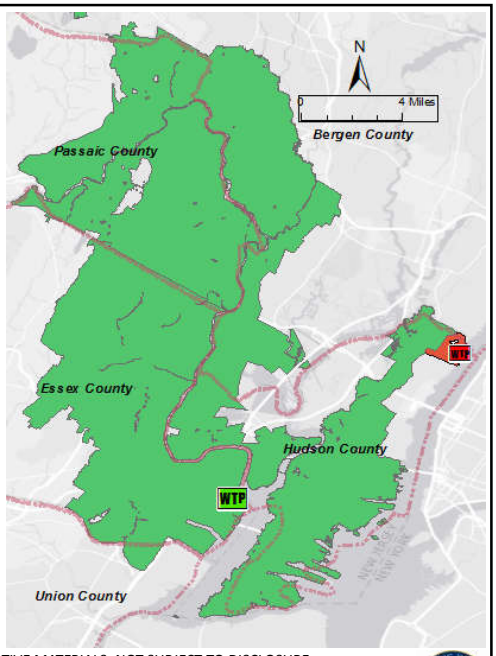
- CSO Long Term Control Plan
  - Required under NJPDES permits pursuant to Clean Water Act and CSO Policy
    - "Approvable" plan to be developed within 5-year timeframe
    - PVSC developing one coordinated LTCP for PVSC and 8 CSO municipalities
  - Goal is to identify appropriate CSO controls needed to achieve or not preclude attainment of waterbody-specific water quality standards
- NJDEP-Required Submittals
  - Sewer System Characterization – QAPP and Report – July 1, 2018
    - Major components - rainfall, CSS characterization, CSO monitoring, model and sensitive areas
  - Baseline Compliance Monitoring Program – QAPP and Report – July 1, 2018
    - Major components – ambient monitoring, CSO discharge, rainfall
  - Public Participation Report – July 1, 2018
  - Consideration of Sensitive Areas Plan – July 1, 2018
  - Development and Evaluation of Alternatives Report – July 1, 2019
  - Selection and Implementation of Alternatives Report – June 1, 2020

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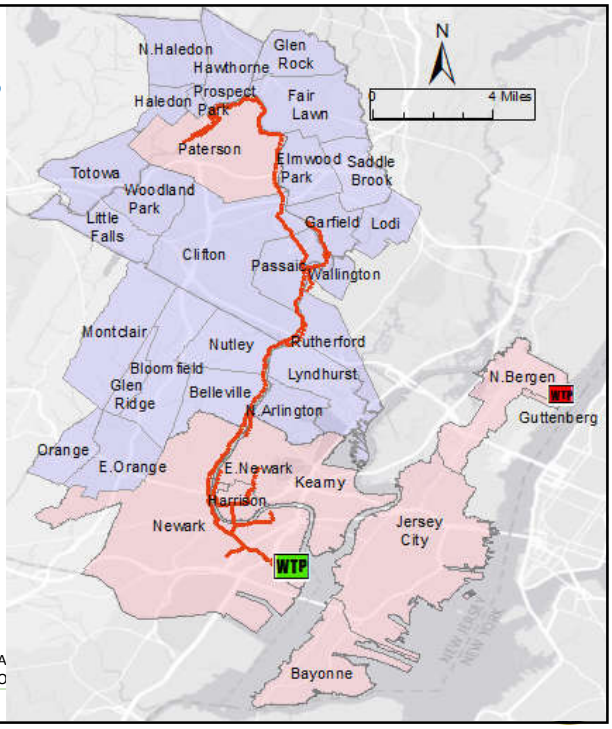
Sewer Systems

- Passaic Valley Sewerage Commission
  - 48 municipalities in Bergen, Essex, Hudson, Union and Passaic Counties
  - 1.5 million residents
  - 147 mi² service area
  - 22 mile interceptor sewer
  - 330 mgd WWTP
- PVSC combined service area
  - 8 municipalities
  - 0.9 million residents
- NBMUA
  - 2 CSO municipalities

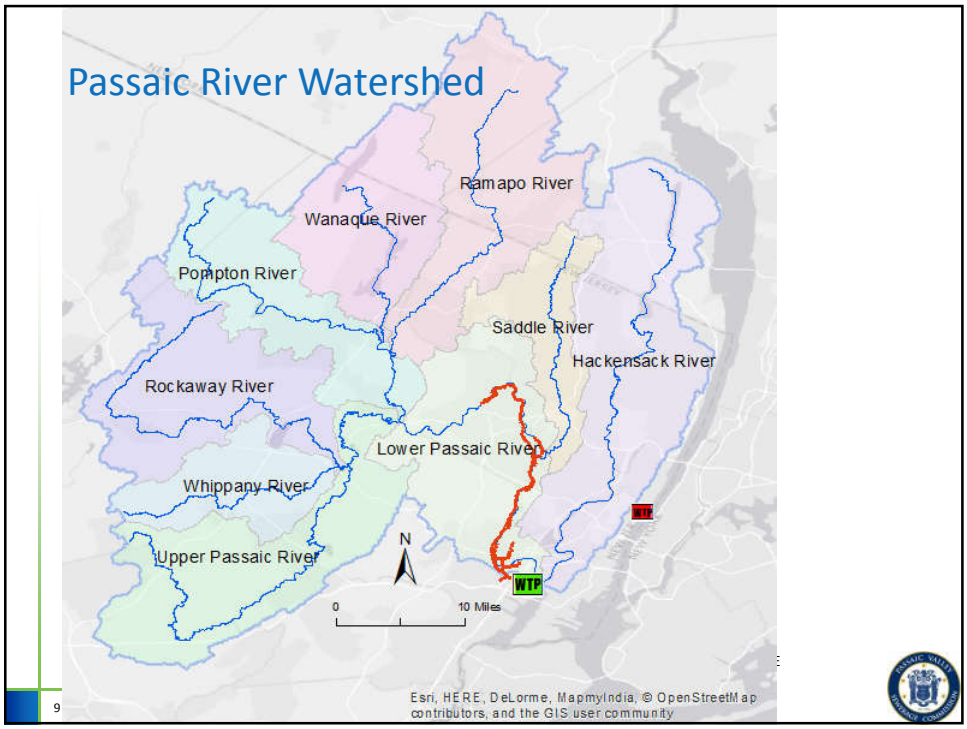


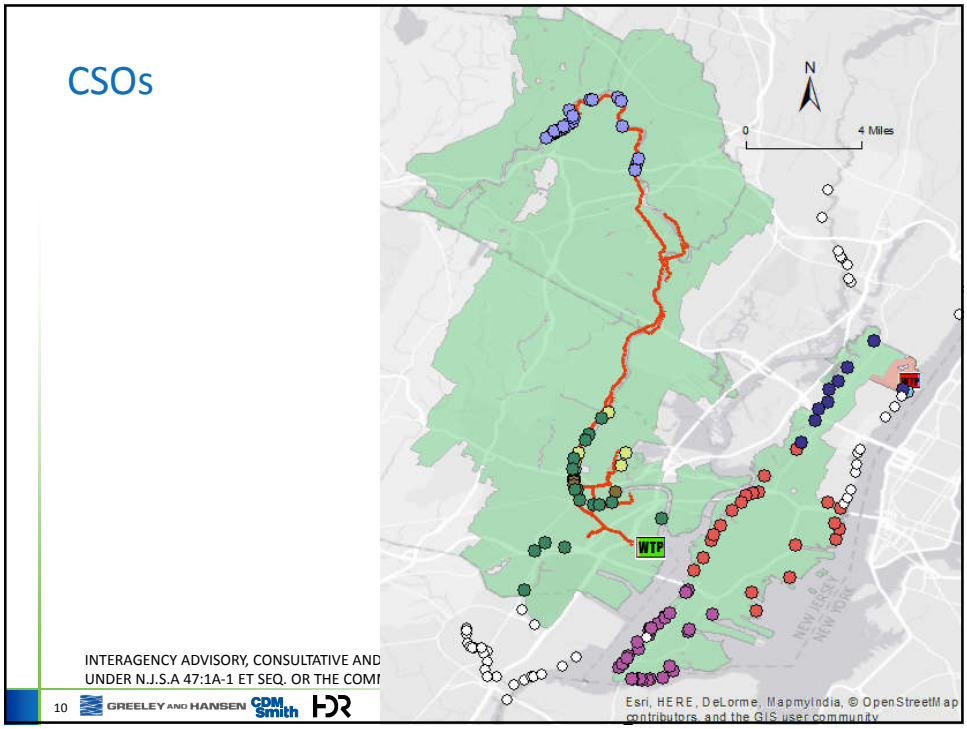
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PVSC Communities



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Passaic River Watershed
Ramapo River
Wanaque River
Pompton River
Saddle River
Hackensack River
Rockaway River
Lower Passaic River
Whippany River
Upper Passaic River
WTP
WTP
N
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10 Miles
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CSOs
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CSO Communities

Municipality	WWTP	Population	Area (mi²)	Sewerage (miles)	CSOs
Bayonne	PVSC	63,000	5.8	94	30
East Newark		2,400	0.1	2	1
Harrison		13,600	1.3	18	7
Jersey City		247,600	14.8	230	21
Kearny		40,700	6.5	52	5
Newark		277,100	22.3	579	18
North Bergen		52,600	4.5	59	7
Paterson		146,200	8.7	164	23
Guttenberg	NBMUA	11,200	0.2	5	1
North Bergen		8,200	0.7	8	1
Total		862,600	84	1,211	114

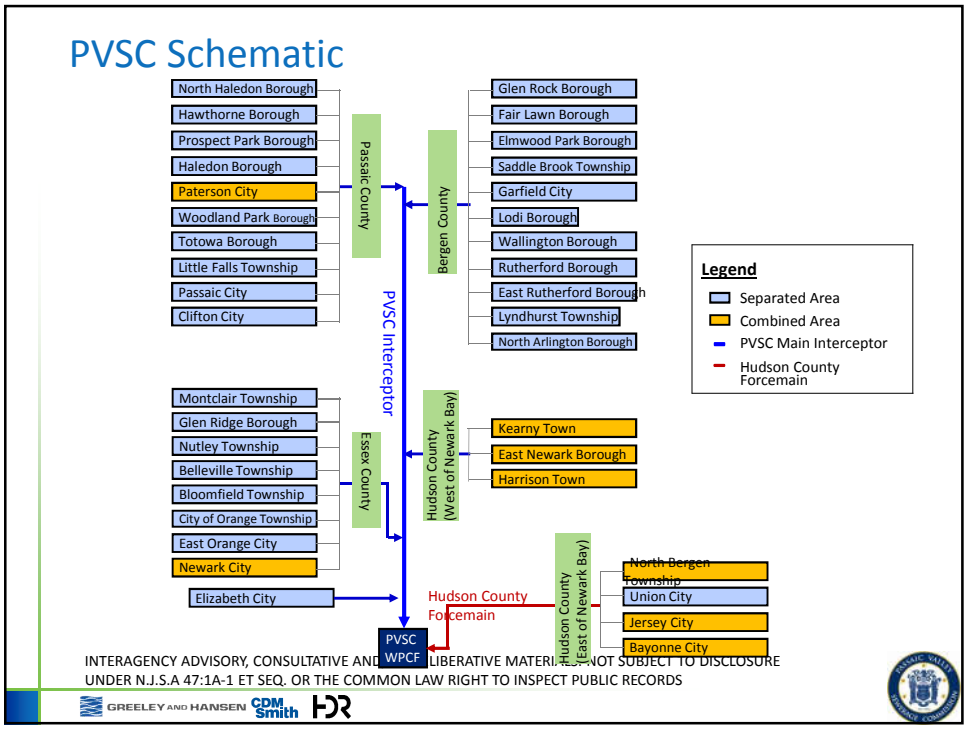
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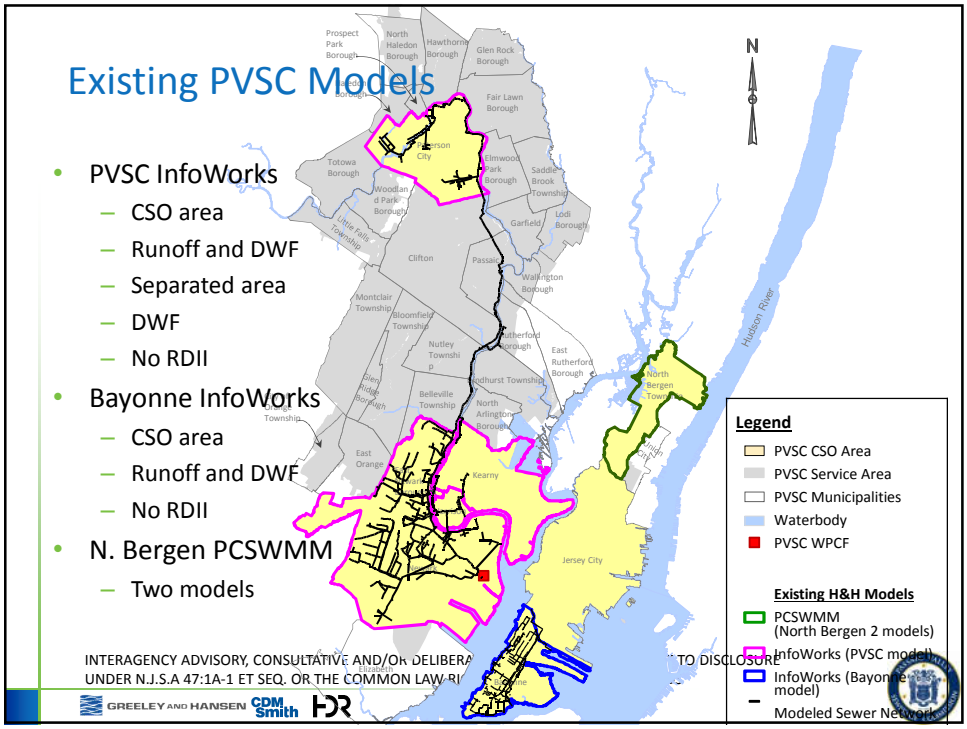
Previous Monitoring and 2016 QAPP

Municipality	WWTP	Previous Study	Internal Flow Meters		CSO Flow Meters		CSO WQ Sampling	
			Previous	*QAPP*	*Previous*	*QAPP*	*Previous*	*QAPP*
Bayonne	PVSC	2005	5	0	3	2	3	3
East Newark		1997	1	0	1	0	1	0
Harrison		1997	7	1	1	0	1	2
Jersey City		2005	59	-	4	-	2	-
Kearny		1997	9	0	2	1	2	1
Newark		2005	32	2	22	5	8	4
North Bergen		2005	10	0	3	2	2	2
Paterson		1997	27	1	7	2	7	5
Guttenberg	NBMUA	2005	0	0	0	1	0	0
North Bergen		2005	1	2	1	0	1	1
Total			**151**	**6**	**44**	**13**	**27**	**18**

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PVSC Schematic
North Haledon Borough
Hawthorne Borough
Prospect Park Borough
Haledon Borough
Paterson City
Woodland Park Borough
Totowa Borough
Little Falls Township
Passaic City
Clifton City
Passaic County
Glen Rock Borough
Fair Lawn Borough
Elmwood Park Borough
Saddle Brook Township
Garfield City
Lodi Borough
Wallington Borough
Rutherford Borough
East Rutherford Borough
Lyndhurst Township
North Arlington Borough
Bergen County
PVSC Interceptor
Montclair Township
Glen Ridge Borough
Nutley Township
Belleville Township
Bloomfield Township
City of Orange Township
East Orange City
Newark City
Essex County
Elizabeth City
Kearny Town
East Newark Borough
Harrison Town
Hudson County (West of Newark Bay)
Hudson County Forcemain
North Bergen Township
Union City
Jersey City
Bayonne City
Hudson County (East of Newark Bay)
PVSC WPCF
Legend
Separated Area
Combined Area
PVSC Main Interceptor
Hudson County Forcemain
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Existing PVSC Models
PVSC InfoWorks
CSO area
Runoff and DWF
Separated area
DWF
No RDII
Bayonne InfoWorks
CSO area
Runoff and DWF
No RDII
N. Bergen PCSWMM
Two models
N
Hudson River
Legend
PVSC CSO Area
PVSC Service Area
PVSC Municipalities
Waterbody
PVSC WPCF
Existing H&H Models
PCSWMM (North Bergen 2 models)
InfoWorks (PVSC model)
InfoWorks (Bayonne model)
Modeled Sewer Network
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Baseline Compliance Monitoring Program QAPP

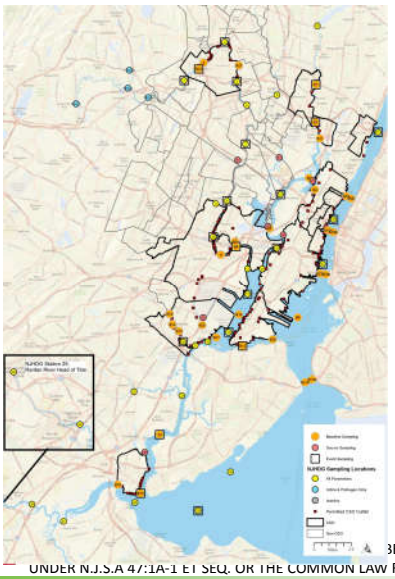


Table 2

Station		Waterbody	Coordinates		Sar
			Lat	Lon	Baseline
Passaic River & Tributaries	PAS-C	Passaic River	40.88217	-74.34000	PVSC
	POM-A	Pompton River	40.91442	-74.27100	PVSC
	PAS-B	Passaic River	40.89700	-74.27300	PVSC
	PAS-A	Passaic River	40.88773	-74.24700	PVSC
	1	Passaic River	40.90416	-74.20066	PVSC
	B24	Passaic River	40.91521	-74.18198	Contractor
	2	Passaic River	40.92120	-74.17550	Contractor
	3	Passaic River	40.94130	-74.14820	PVSC
	B22	Passaic River	40.91816	-74.13024	Contractor
	4	Passaic River	40.90266	-74.13300	PVSC
	5	Passaic River	40.87950	-74.12066	PVSC
	6	Saddle River	40.88900	-74.08166	PVSC
	7	Passaic River	40.84149	-74.12275	PVSC
	S7	Third River	40.82598	-74.13306	
	8	Passaic River	40.78616	-74.14733	PVSC
	9	Second River	40.78350	-74.16150	PVSC
	10^6	Passaic River	40.75120	-74.16530	PVSC
	11	Passaic River	40.73366	-74.15566	Contractor
	B8	Franks Creek	40.74632	-74.13747	Contractor
	B6	Passaic River	40.74148	-74.13632	Contractor
	12	Passaic River	40.71983	-74.12183	PVSC
	13	Hackensack River	40.95610	-74.02880	PVSC

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System Characterization and Landslide Modeling QAPP



PVSC System Characterization and Landside Modeling, Part 1 and Part 2 QAPP

Part 1:

- East Newark
- Harrison
- Kearny
- Newark
- Paterson

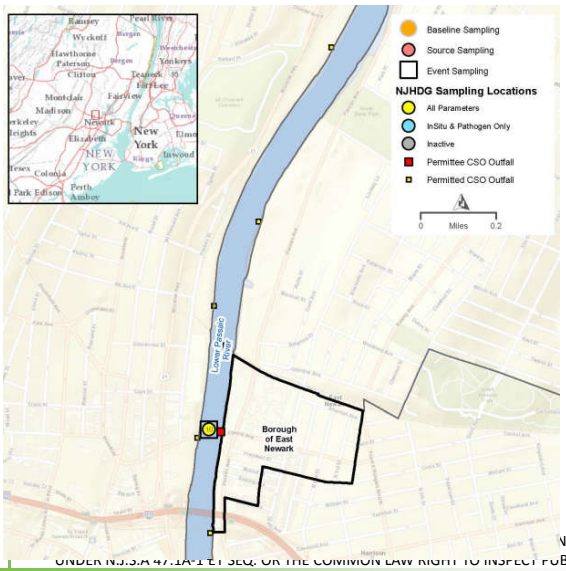
Part 2:

- Bayonne
- North Bergen (portion)

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East Newark

Baseline Compliance Monitoring Program



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Harrison

Baseline Compliance Monitoring Program



System Characterization Wastewater Quality Sampling Stations



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Kearney

Baseline Compliance Monitoring Program



System Characterization Wastewater Quality Sampling Stations



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Newark

Baseline Compliance Monitoring Program



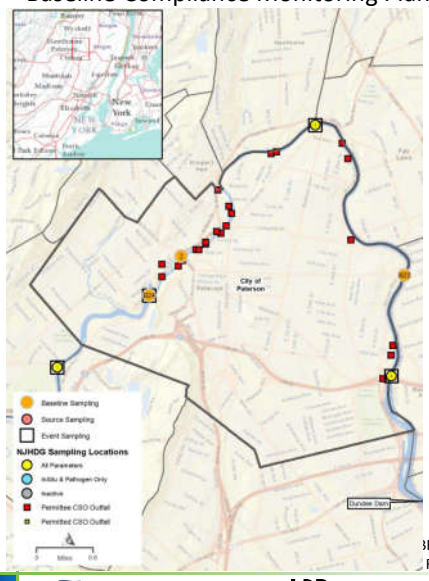
System Characterization Wastewater Quality Sampling Stations



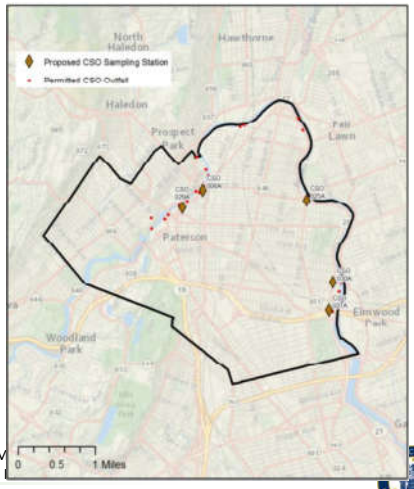
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Paterson

Baseline Compliance Monitoring Plan



System Characterization Wastewater Quality Sampling Stations



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RIGHT TO

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Bayonne

Baseline Compliance Monitoring Program



System Characterization Wastewater Quality Sampling Stations



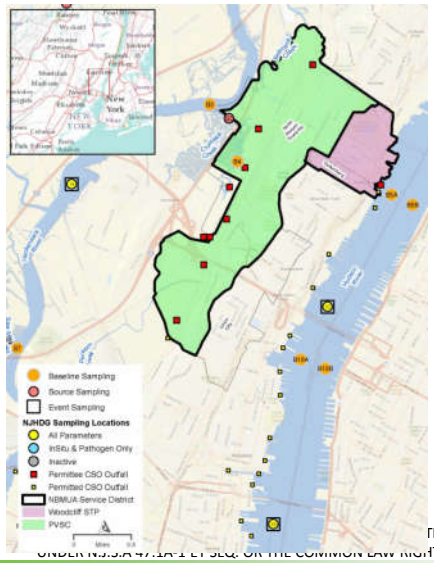
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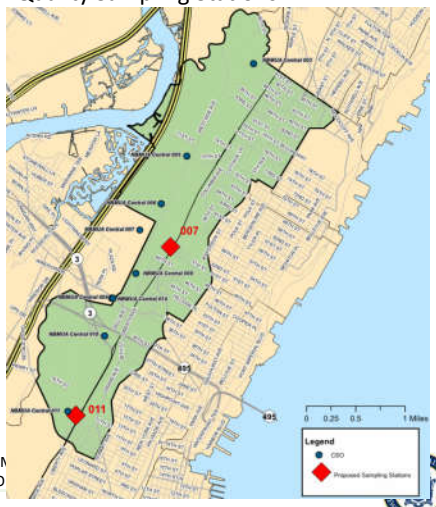
CDM Smith

North Bergen (PVSC)

Baseline Compliance Monitoring Program



System Characterization Wastewater Quality Sampling Stations



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North Bergen Woodcliff WWTP

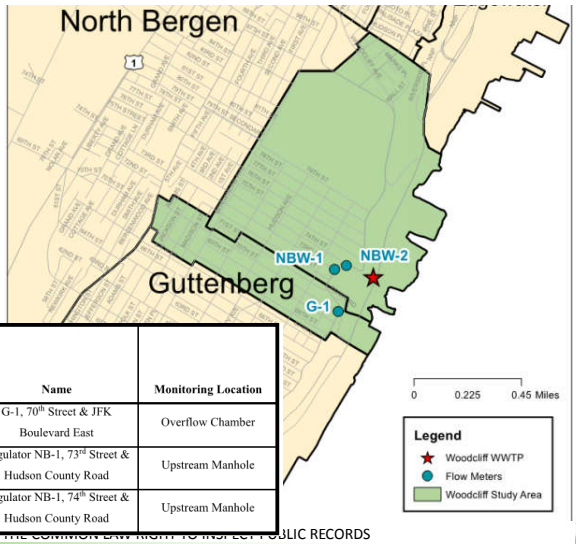
- 477 acres serving 368 acres in North Bergen and all of Guttenberg (109 acres)
- 1 permitted CSO to Hudson River
- 3 mgd Woodcliff WWTP
- North Bergen MUA and Guttenberg cooperatively develop a CSO LTCP. Communities have requested PVSC's LTCP Engineer to develop the System Characterization and Landside Modeling Program on behalf of these permittees



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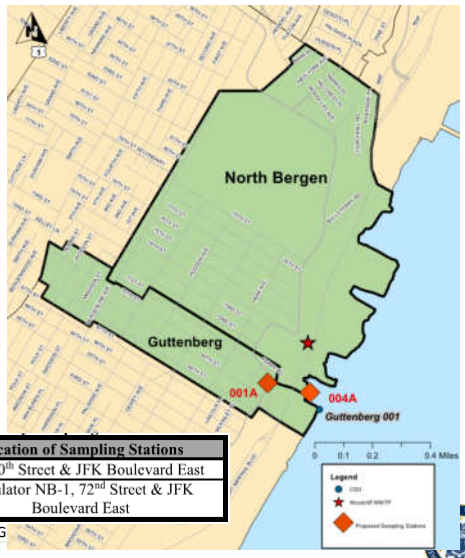
North Bergen Woodcliff WWTP Proposed Temporary Flow Meter Locations



Flow Meter ID	Municipality	NJPDES Permit No.	Name	Monitoring Location
G-1	Guttenberg	001A	G-1, 70th Street & JFK Boulevard East	Overflow Chamber
NBW-1	North Bergen	004A	Regulator NB-1, 73rd Street & Hudson County Road	Upstream Manhole
NBW-2	North Bergen	004A	Regulator NB-1, 74th Street & Hudson County Road	Upstream Manhole

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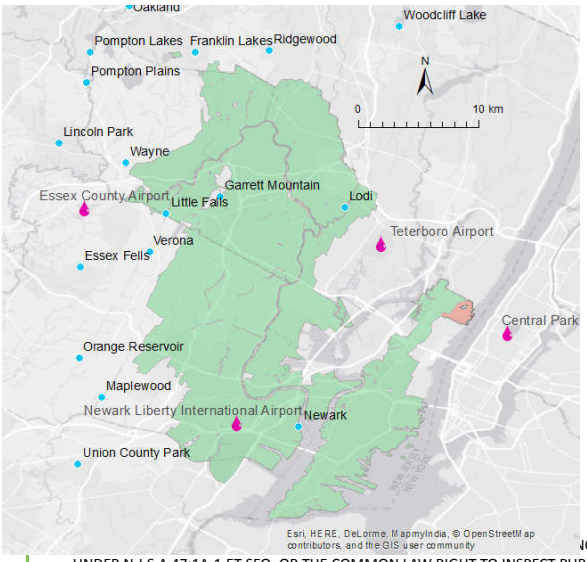
North Bergen Woodcliff WWTP System Characterization Wastewater Quality Sampling Stations

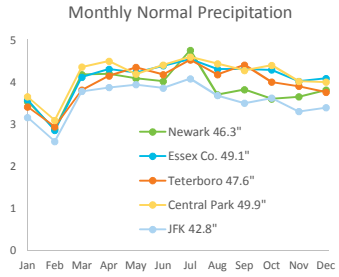


NJPDES Permit No.	Permittee	Location of Sampling Stations
001A	Guttenberg	G-1, 70th Street & JFK Boulevard East
004A	North Bergen	Regulator NB-1, 72nd Street & JFK Boulevard East

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NOAA and USGS Rain Gauges





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Landside Modeling

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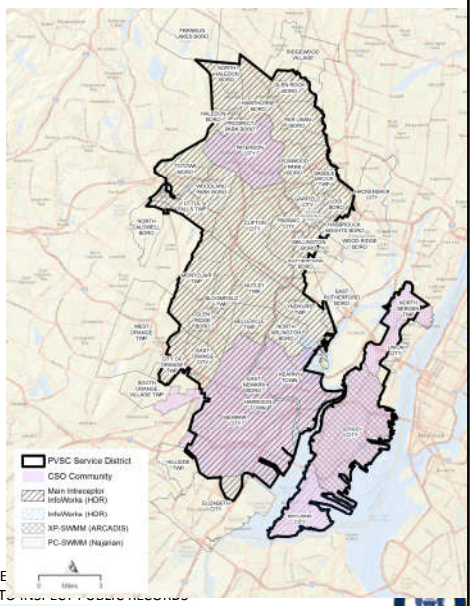
Landside Modeling

- System Review
  - Overview of PVSC Service Area Models
    - North Bergen
    - Bayonne
    - Jersey City
    - PVSC Main Interceptor
- PVSC Interceptor Model Development History
- Current and Historical Data Availability
- Previous Model Status and Ongoing Model Update
- Potential Model Improvement

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PVSC Service Area

- Service Area : ~100 mi²
  - Combined 13K ac
  - Separated 57K ac
  - 48 municipalities
    - 8 CSO communities
  - 1.5 million population
- Plant Flow
  - 330 mgd permitted & design
  - Average day 210 mgd



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Non-PVSC Models

- North Bergen
  - Najarian Associates
  - PCSWMM
  - LTCP Team has model
  - Converted to EPA SWMM for CSO Alert System

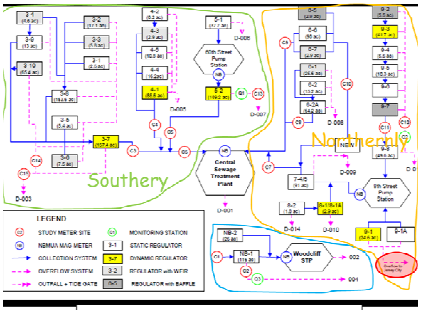


Figure 1-2: CSO System Connecting to North Bergen MUA's Sewage Treatment Plants and Monitoring Program for CSO Characterization Study

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Non-PVSC Models

- Bayonne
  - HDR
  - InfoWorks
  - LTCP Team has model
  - Used for CSO Alert System



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Non-PVSC Models

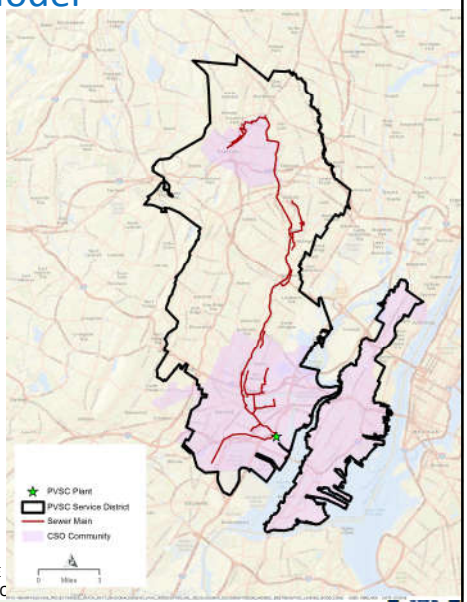
- Jersey City
  - ARCADIS
  - XPSWMM
  - LTCP Team does not have model
  - Model results provided by ARCADIS for CSO Alert System



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PVSC Main Interceptor Model

- Large, Complex System
  - Main interceptor
  - Seven branch interceptors
  - Combined and separate sewers
  - Regulators
  - RTC
  - Pump stations
  - River crossings
  - Treatment plant



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Development History

- NJPDES General Permit for Combined Sewer Systems – 2003 Interceptor Modeling and CSO Characterization Study
  - XPSWMM schematic model
  - Main and branch interceptors
  - Regulators in Paterson, East Newark, Kearny and Harrison
  - Temporary flow and rainfall monitoring
  - Model calibration
  - Event mean concentration development for CSO loads

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Development History

- 2007 Long Term Control Plan
  - Converted From XPSWMM to InfoWorks
    - Still schematic
  - Integrated Newark and PVSC interceptor models
    - Newark XPSWMM model developed in 2005 by LMS Engineers
    - Converted to InfoWorks by LMS in 2006-2007
    - Newark portion of model is geo-referenced
  - Verified model with data used in 2003 study and additional interceptor data from 2005-2006

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Development History: Domain and Level of Detail

- Interceptors and Branch Interceptors
  - Not all manholes included in model
  - Continuous sewers with same size and slope without inflows are simplified as one link in model
  - Ground elevations from as-built drawings in 1940s
- Paterson, East Newark, Kearny and Harrison
  - Included regulators and one pipe section upstream of regulators
  - Combined sewers not modeled
  - Model subcatchments are regulator based, no sub-delineation of regulator drainage areas
  - Runoff parameters such as imperviousness from reported values

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Development History: Domain and Level of Detail

- Newark
  - Combined sewers up to 24” are included
  - Drainage areas are subdivided to subcatchments
- Separately Sewered Area
  - Modeled as dry weather point inflows to interceptor
  - No I&I representation except for Union Outlet
  - Groundwater Infiltration not modeled
- Hudson County Force Main Service Areas
  - Not included

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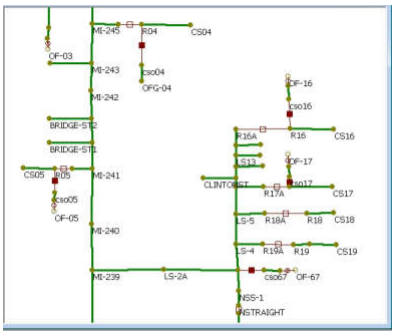
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Development History

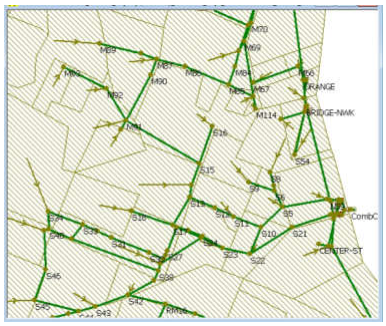
- Geographic Layout - Mixed
  - Newark
    - Sewers laid out per relative geographic location (accuracy unknown, i.e. not survey quality)
    - Subcatchments delineated as polygons
  - Other areas schematic in nature , not geo-referenced
- Suitability
  - Planning level flow and interceptor capacity analysis
  - Not enough detail outside Newark for combined sewer capacity analysis and alternative evaluation, surface flooding analysis or GI evaluation
  - Not applicable for asset management

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Development History: Layout and Level of Detail



Non-Newark



Development History

- Recent Applications
  - Analysis for responses to EPA questions
  - Interceptor plug and release study for REDZONE inspection
  - Interceptor lining capacity analysis
  - PVSC CSO alert system website development

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Development History

- 2015 updates
  - Georeference entire model
  - Calibrate interceptor HGL using data collected May – Oct 2015

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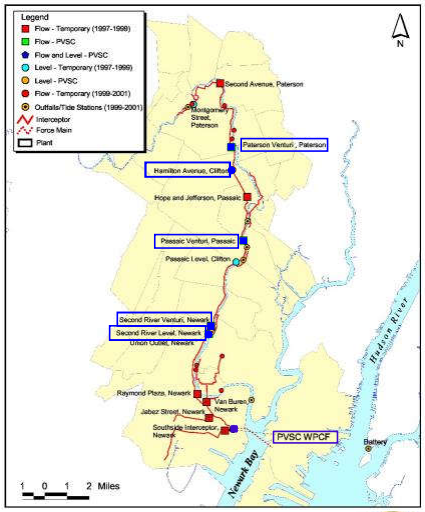
Current and Historic Data Availability

- Permanent In-System Monitoring
- Historic Flow Monitoring and Model Calibrations
- New Level Monitoring Data
- Proposed Flow Metering

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Permanent In-system Monitoring Historically Used For Calibration

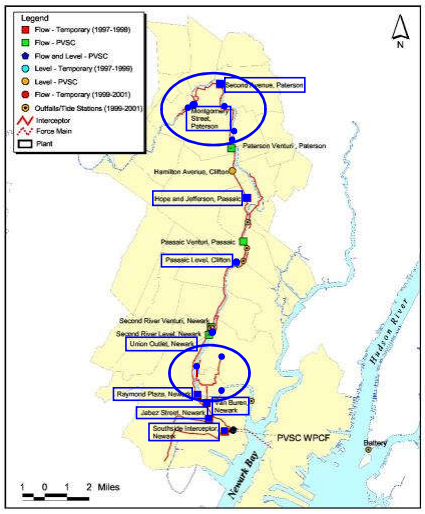
- Flow
  - Plant flow & Hudson County force main
  - 3 venturi meters
- Level
  - Two level meters
- Rain
  - At plant



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Historic Flow Monitoring and Calibration

- 1997-1998 Interceptor Monitoring
  - Flow and level
  - Calibration: 4 dry and 4 wet events
- 1999-2001 CSO Monitoring Program
  - Overflow and concentration at major outfalls
  - Calibration: 3 wet events for each group
- Permanent Meters
  - Verification: 5 wet events in 2005-2006

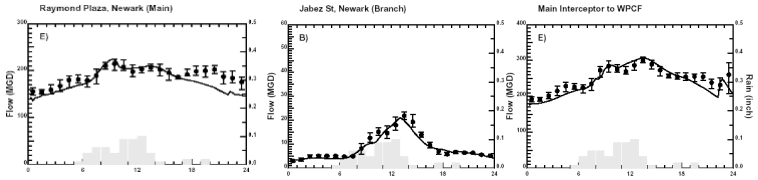


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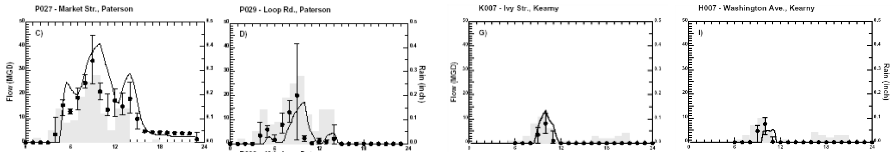
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Historical Calibration Example

- In-system



- Overflow



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Notes on Previous Calibration

- Changes occurred in system, model has been updated but has not been recalibrated
  - Water conservation and dry weather flow changes
  - Market Street regulator and South Side interceptor gates no longer in operation
  - Regulator reconfiguration, area separation
  - Interceptor relining
- In-system monitoring and overflow monitoring did not occur concurrently for the same events, giving limited view of system-wide flow balance
- HGLs were not focus of previous work; level data collected were very limited

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Ongoing Update

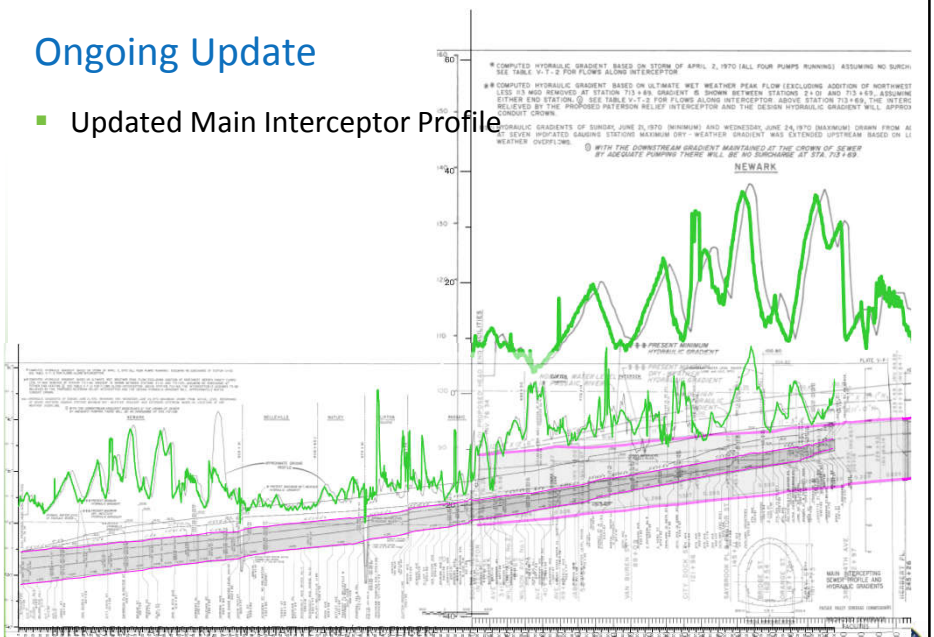
- Geo-referenced main and branch interceptors, regulator and outfall locations
- Refined interceptor and branch interceptor representation by including all manholes
- Updated main and branch interceptor manhole invert and ground elevations with survey data
- Updated from interceptor ground elevations with best available topography
- Development of non-Newark area subcatchment boundaries

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Ongoing Update

- Updated Main Interceptor Profile



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Current Characteristics

- InfoWorks CS 10.5; can be converted to ICM
- 1666 Nodes
  - 75 outfalls
- 1547 Links
  - 7 pumps
  - 71 orifices/sluices
  - 10 Newark gate + plant gate RTCs
- 473 Subcatchments

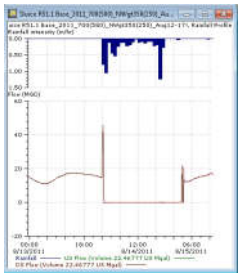


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Current Characteristics



- Automated Gate Operations
  - Main Plant Gates and Regulator Gates in Newark
  - Use Real Time Controls
    - Time-based RTC rules (operational logs) for events
    - General flow based rules (operational criteria) for continuous simulation

CSO REGULATORS

OUTLETS	OUT OF SYSTEM	OUT DATE	OUT TIME	COMPUTER AUTO OPER.	LINE CREW MANUAL	IN DATE	IN TIME	AUTO OPER.	LINE CREW MANUAL
CLAY ST.	X	05/31/15	16:35	X		06/02/15	9:30		X
VERONA	X	05/31/15	16:34	X		06/01/15	18:32	X	
HERBERT	X	05/31/15	16:35	X		06/01/15	18:31	X	
4TH AVE.	X	05/31/15	16:33	X		06/01/15	18:32	X	
CITY DOCK	X	05/31/15	16:30	X		06/01/15	18:30		X
JACKSON	x	05/31/15	19:30	X		06/01/15	18:30	X	
POLK	x	05/31/15	19:29	X		06/01/15	18:29	X	
FREEMAN	x	05/31/15	19:30	X		06/01/15	18:30	X	
SAYBROOK	X	05/31/15	16:34	X		06/01/15	18:30	X	
RECTOR	X	05/31/15	16:36	X		06/01/15	18:33	X	

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UNDER N.J.S.A 47:1A-1

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Current Characteristics

- Boundary Condition
  - Upstream of Dundee Dam
    - River elevation
  - Downstream Tidal Area
    - Tidal elevation
  - Internal Overflows
    - Free discharge



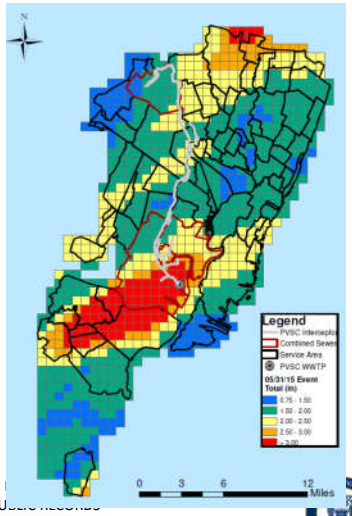
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2015 Calibration - Rain

- Gauge Adjusted Radar Rainfall Collected (GARR)
  - Long interceptor system, spatial rainfall differences exists between upstream and downstream drainage areas
  - 2015 radar rainfall
    - 5-min
    - hourly

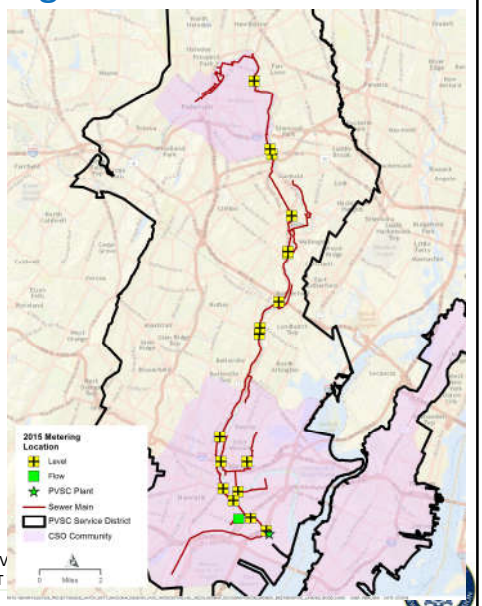


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2015 Calibration - Metering

- Flow Assessment Level Monitoring
  - 18 level (1 with flow) meters along main interceptor
  - May 8th - Oct 10th, 2015
  - 5-minute data
- PVSC Permanent Meters
  - Flow
  - Level

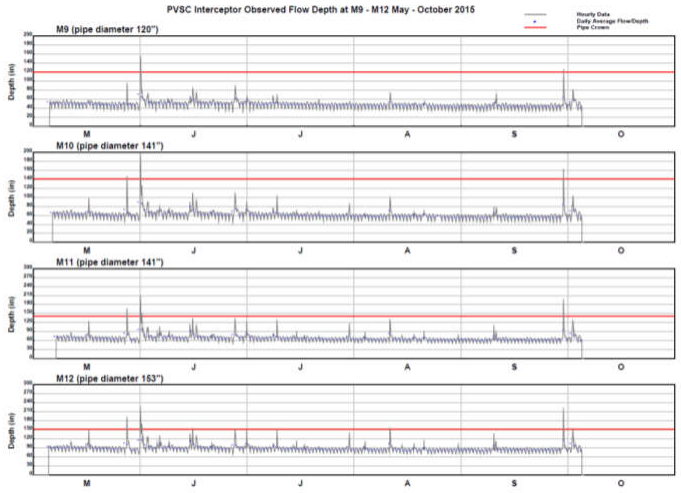


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2015 Calibration: Flow Assessment Levels



Sample Level Data

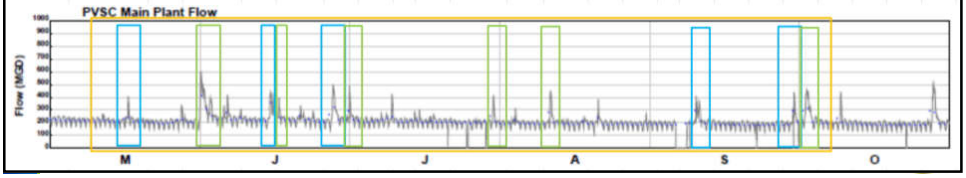
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2015 Calibration: Events

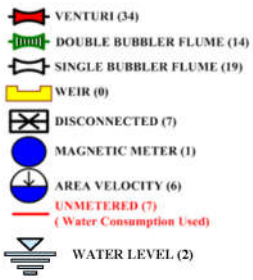
- Selection of Calibration and Validation Events

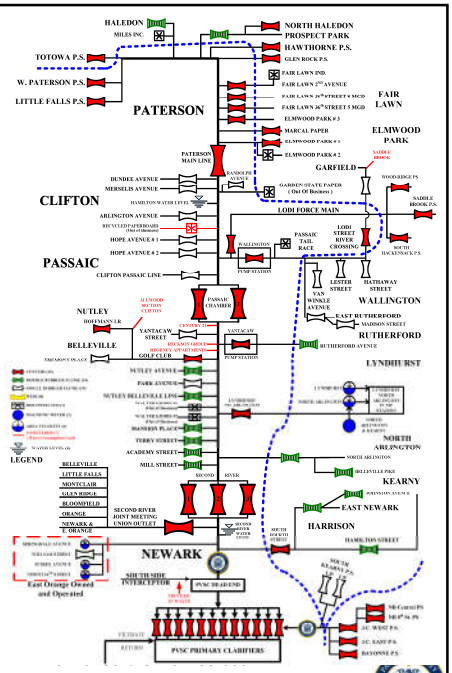
Station	EWR					TEB					
Calibration/Val	Start time	Duration (hrs.)	Volume (in.)	Ave inten (in./hr.)	Max inten (in./hr.)	Start time	Duration (hrs.)	Volume (in.)	Ave inten (in./hr.)	Max inten (in./hr.)	Delta (hrs.)
Validation	5/16/15 19:00	6	0.67	0.11	0.45	5/16/15 19:00	9	0.18	0.02	0.07	15
Calibration	5/31/15 14:00	23	2.68	0.12	0.74	5/31/15 15:00	14	1.86	0.13	0.53	98
Validation	6/14/15 21:00	9	0.77	0.09	0.24	6/14/15 22:00	7	0.82	0.12	0.39	146
Calibration	6/15/15 14:00	4	0.66	0.17	0.33	6/15/15 14:00	4	0.38	0.1	0.26	14.5
Validation	6/27/15 15:00	15	1.37	0.09	0.28	6/27/15 16:00	16	1.25	0.08	0.19	150.5
Calibration	7/1/15 4:00	1	0.99	0.99	0.99	7/1/15 4:00	1	0.99	0.99	0.99	76.5
Calibration	7/30/15 14:00	3	0.84	0.28	0.54	7/30/15 13:00	4	0.35	0.09	0.3	294.5
Calibration	8/11/15 5:00	6	0.96	0.16	0.38	8/11/15 5:00	6	0.84	0.14	0.37	172
Validation	9/10/15 3:00	17	0.98	0.06	0.19	9/10/15 1:00	9	0.45	0.05	0.16	717.5
Validation	9/29/15 23:00	11	1.31	0.12	0.77	9/29/15 22:00	9	1.5	0.17	0.73	394
Calibration	10/2/15 2:00	30	1.5	0.05	0.23	10/2/15 7:00	22	1.27	0.06	0.21	22.5



2015 Calibration: PVSC Permanent Meters

- Flow
- Level

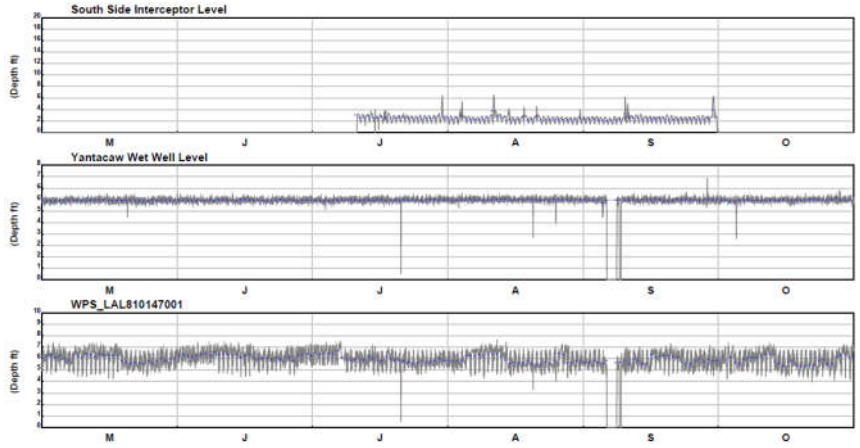




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2015 Calibration: PVSC Data



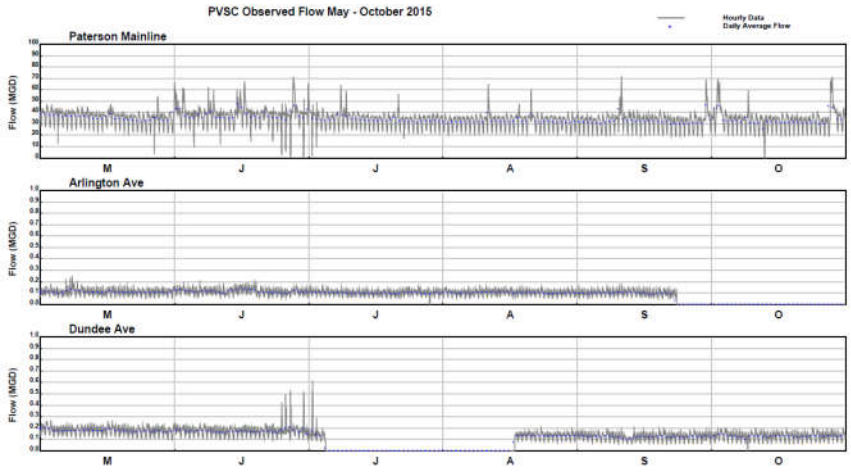
Sample Level Data

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2015 Calibration: PVSC Data

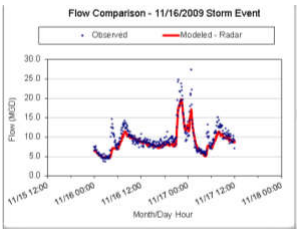


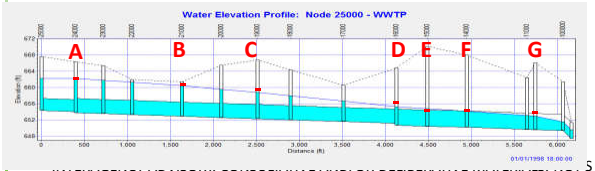
Sample Flow Data

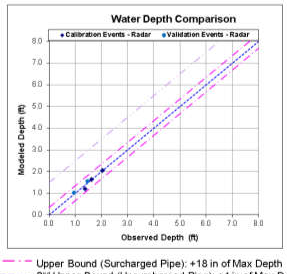
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2015 Calibration: – Example Results

- Hydrograph Comparison
- Profile Comparison
- Goodness-of-fit Comparison







Upper Bound (Surcharged Pipe): +18 in of Max Depth
2nd Upper Bound (Unsurcharged Pipe): +4 in of Max Depth
Lower Bound: -4 in of Max Depth
1:1 Line

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Potential Improvements

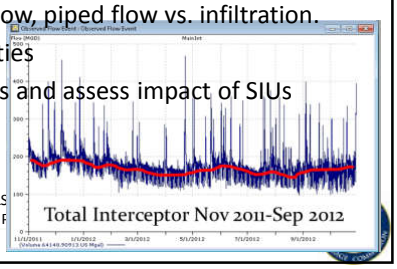
- Expand and Build-out
  - Current model does not include detailed combined sewer network in areas outside Newark (Subcatchments at regulators)
  - Data Required
    - Field survey and development of GIS database of major sewer network
    - Development of drainage area maps for subcatchments delineations, along with other data such as: imperviousness, landuse, population, slope, etc.
    - Additional flow monitoring within municipalities
  - Benefits
    - Asset management, municipality level sewer capacity analysis, alternatives evaluation (storage, GI, etc.)

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Potential Improvements

- Update base flow and include GI and I&I characterization
  - Currently GWI and I&I not modeled, base dry-weather flow distributions based on 1990s data
  - Requirements
    - Updated water usage/billing info for modeled flow distribution and identifying SIU (significant industrial users)
    - Monitored flow from separate sanitary areas for I&I calculation
    - Expanded to include subcatchments from separate areas
  - Benefits
    - Better characterize dry flow vs. wet flow, piped flow vs. infiltration.
    - Quantify I&I from non-CSO communities
    - Conduct infiltration reduction analysis and assess impact of SIUs



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Potential Improvements

- Update Calibration with Built-out Network
  - Recently collected data does not include outfall monitoring
  - Requirement
    - Additional flow and level data in combined system, interceptor and outfalls (Part of CSO Characterization)
  - Benefit:
    - Verify changes made to model
    - Verify modeled flow components (storm runoff, infiltration, plant flow, outfall flow)
    - Verify HGLs for flooding analysis and assessing system capacity
    - Evaluate plan alternatives (rehabilitation, storage, flow control, GI, etc.)

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Hydrodynamic Modeling

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Hydrodynamic Modeling

- History of NY-NJ Models
- Proposed Model Grid
- Model Summary
- Calibration Data
- Challenges

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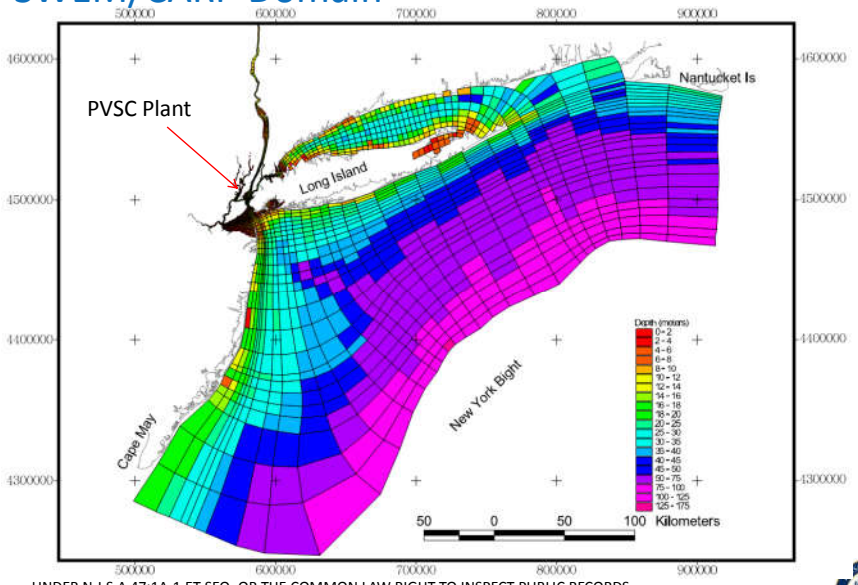
Overview of NY-NJ Harbor Models

- Early 1990s – Inner and Outer Harbor CSO Studies for NYCDEP
- Mid 1990s – System Wide Eutrophication Model (SWEM)
- Early 2000s – NY-NJ Pathogen TMDL, CARP (Contamination Assessment and Reduction Project)
- 2005 to Present: Lower Passaic River/ Newark Bay EPA Superfund Studies

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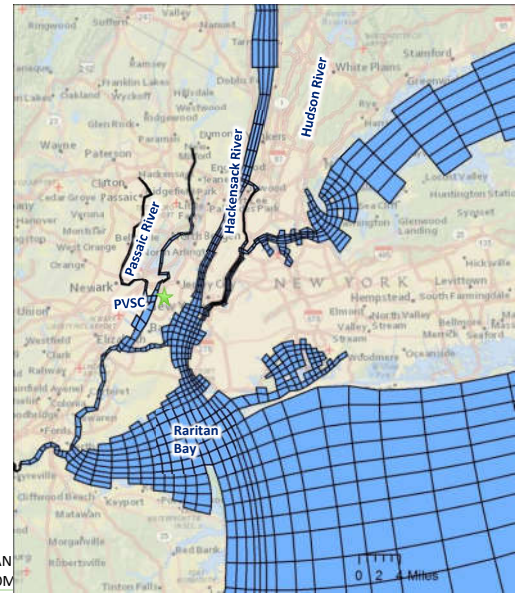
SWEM/CARP Domain



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SWEM/CARP: NY-NJ Harbor Area



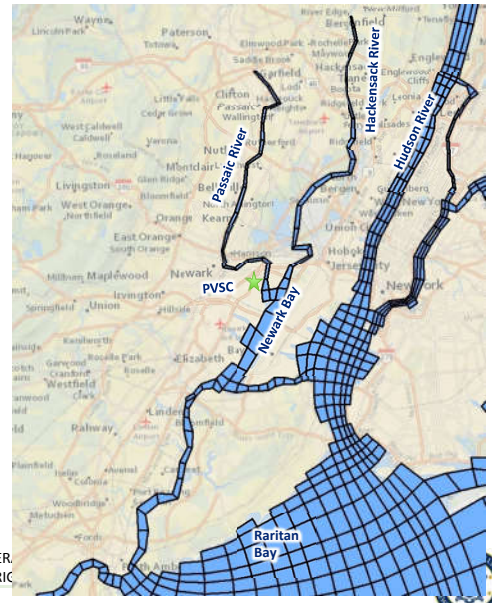
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SWEM/CARP: NJ LTCP Area

- Coarse resolution in:
  - Lower Passaic River (~1-2 km)
  - Hackensack River (~1-2 km)
  - No Meadowlands
  - Newark Bay: single grid (7 grid cells of 2 km size)
  - Arthur Kill & Kill van Kull: single grid cells
  - Hudson River and Upper Bay (~300x1500 m)

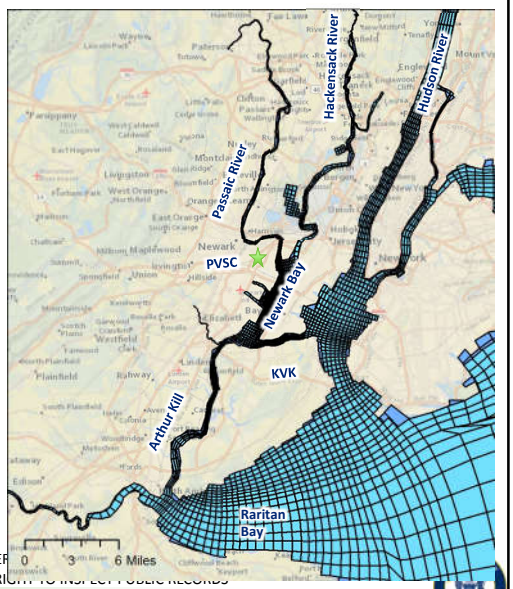


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2015 Refined Grid

- Improved Resolution
  - Lower Passaic River (200-500 m)
  - Hackensack River (200-500 m)
  - NJ Meadowlands
  - Newark Bay (100x200 m)
  - Arthur Kill & Kill van Kull: 3-5 lateral cells (100x250 m)
  - Hudson River and Upper Bay (200x600 m)
- Expanded Domain
  - Dundee Dam to Little Falls
  - Overpeck Creek (100x300 m)
  - Elizabeth River (40x150 m)



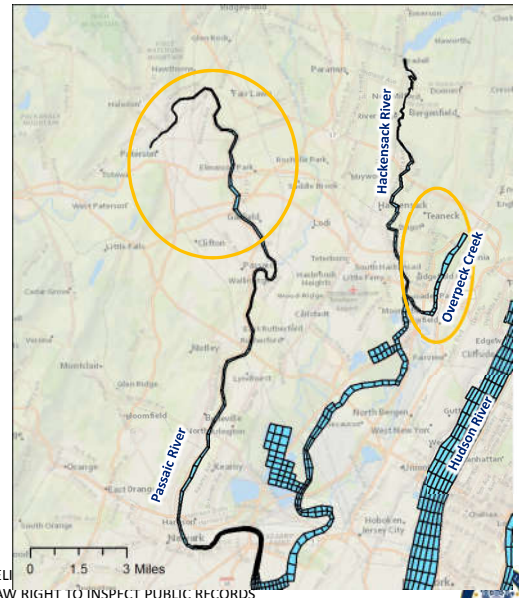
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2015 Refined Grid

- Expanded Domain
  - Dundee Dam to Little Falls
  - Overpeck Creek

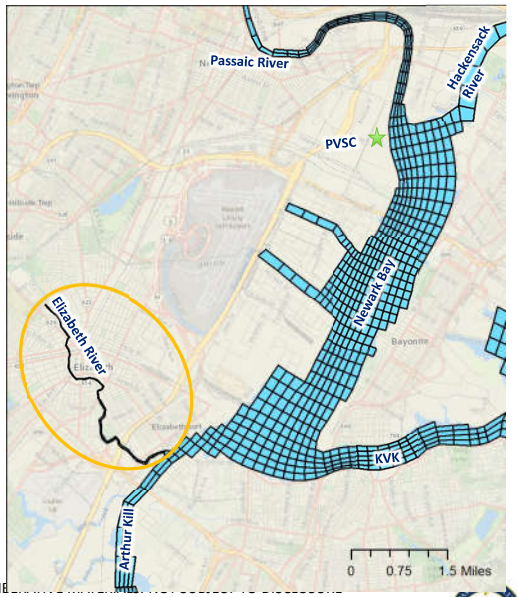


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2015 Refined Grid

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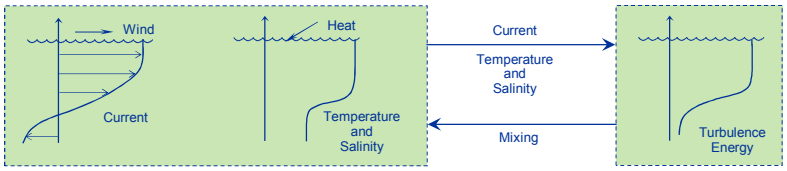
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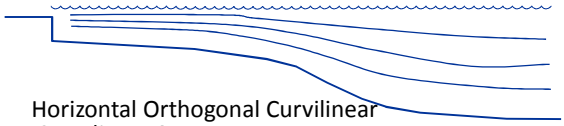
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ECOMSED Features

- 3D Hydrodynamic Model
  - Current
  - Temperature
  - Salinity
  - Water Levels
- Turbulence Model



- Sigma (σ) Coordinate System: 10 layers for PVSC model



$$\sigma = \frac{z - h}{H + h}$$

- Horizontal Orthogonal Curvilinear Coordinate System

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Inputs

- Tidal Forcing
  - Mid-Atlantic Bight
- Freshwater
  - Rivers
  - CSOs
  - Stormwater outfalls & direct drainage
  - Wastewater treatment plants
- Thermal Loads
  - Power plants
- Meteorological Forcing
  - Winds
  - Air temperature
  - Barometric pressure
  - Solar radiation

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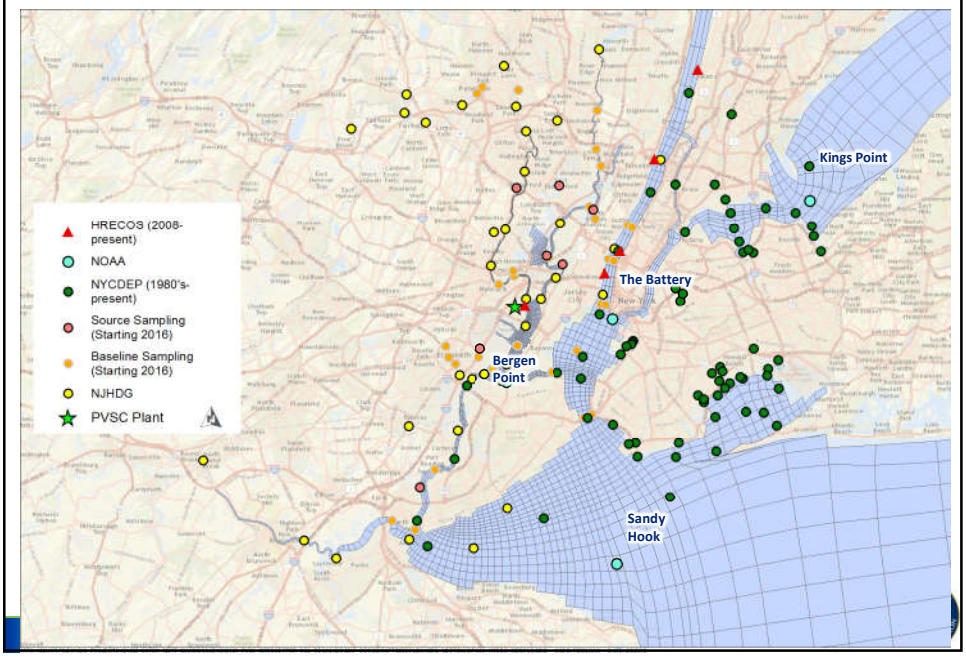
Available Calibration Data

- NYC DEP Harbor Survey Program: T/S
- NOAA/USGS/Hudson River Environmental Conditions Observing System (HRECOS) monitoring data: tides, T/S
- NJ Harbor Dischargers Group: T/S
- Meadowlands Environmental Research Institute (MERI): T/S
- Rutgers: 2008 – 2009 (ADCP, T/S)
- Tierra Solutions: 2010 – 2011 (ADCP, T/S)
- NJ LTCP WQ Sampling Program: 2016 (T/S)

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Available Calibration Data



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Meadowlands Environmental Research Institute Water Quality Monitoring Network

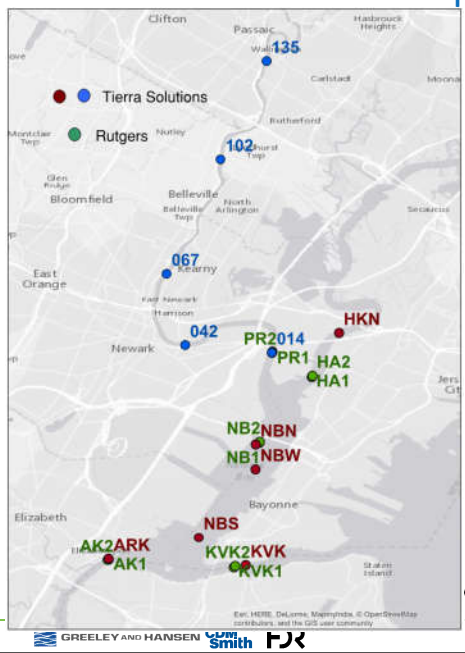
- 2004 – present



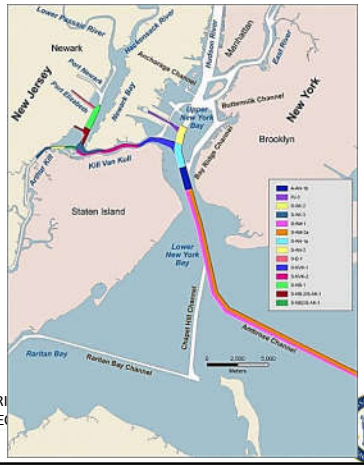
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2008 - 2011 ADCP & Temperature/Salinity



- ADCP: Acoustic Doppler Current Profiler
- Note: These data were collected during USACE NY District Harbor Deepening Projects



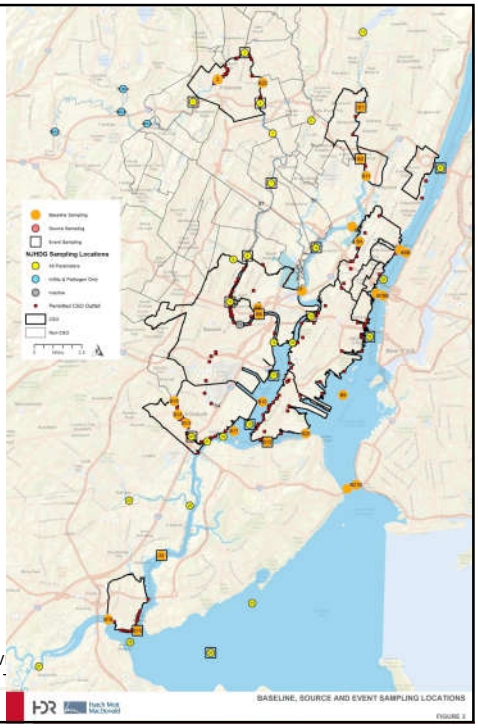
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Sampling Location Modifications

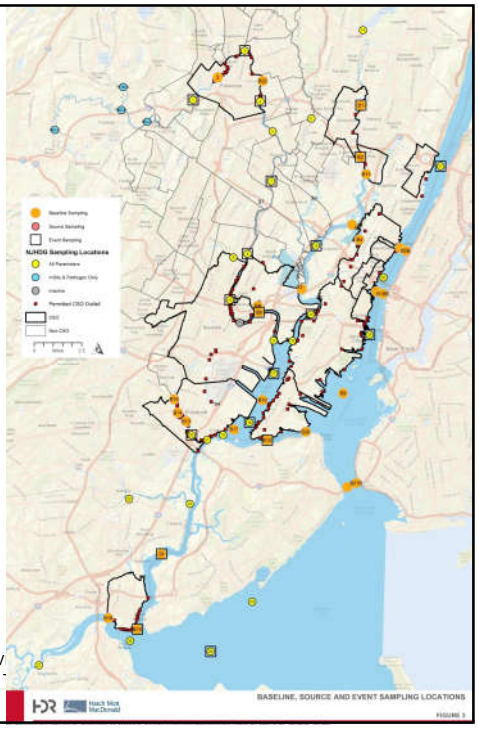
- Lateral stations in Hudson River
- Some locations based on field recon
- Additional baseline and event stations in Upper Passaic River
- Additional source stations
  - Frank's Creek
  - Third River
  - Woodbridge Creek
- Additional station in Kill van Kull
- Additional stations at The Narrows



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Sampling Stations

- 32 Baseline
- 7 Source
- 22 Intensive Event
- Sampling frequency
  - Baseline and Source
    - Jan-Apr: Monthly
    - May-Jun: Bi-weekly
    - Jul-Sept: Weekly
    - Oct-Dec: Monthly
  - Intensive event
    - 3 events
    - 3 days/event
    - Sampled twice a day



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Calibration Objectives

- Accurate Volume Exchange in the Meadowlands:
  - Total: 8,400 acres (~13 mi^2) vs. Wet Areas: 3,500 acres (~5.5 mi^2)
  - Needed for proper tidal dynamics (amplitude and phases)
  - Potential importance of groundwater seepage (~100 cfs)
- Correct net fluxes through the Kills (counter-clockwise)
- Correct net fluxes through the East River
- Proportion of fresh and saline areas in the Meadowlands

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Meadowlands

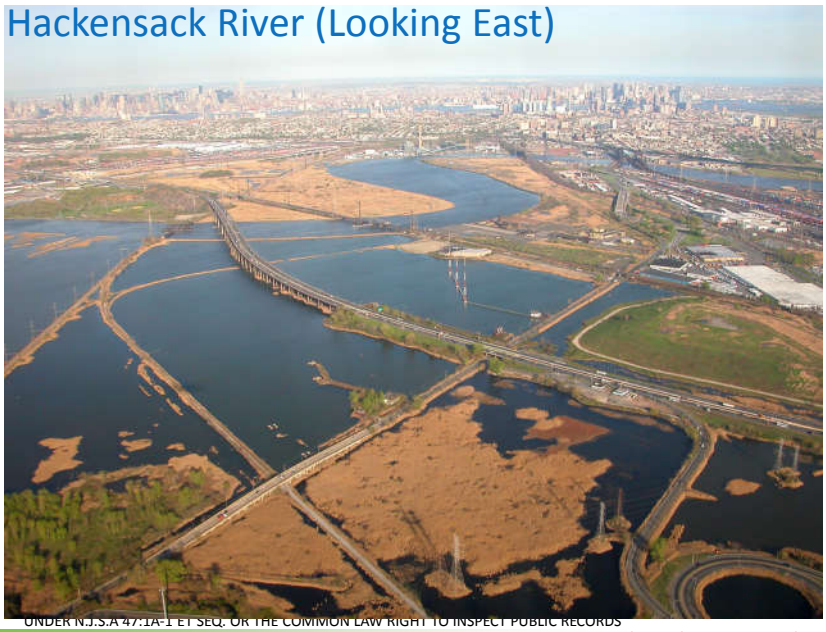


Photo by Doc Searls

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Hackensack River (Looking East)

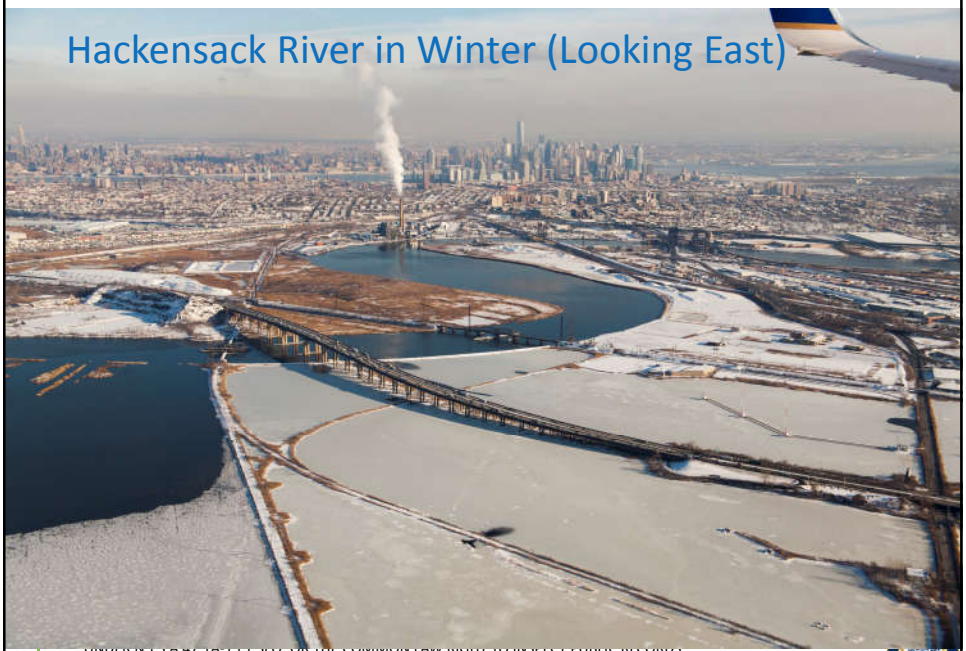


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Hackensack River in Winter (Looking East)



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Water Quality Modeling

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Water Quality Modeling

- Previous work (Pathogen TMDL)
- Proposed bacteria model
- Inputs
- Calibration
- Projections

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Water Quality Modeling Approach

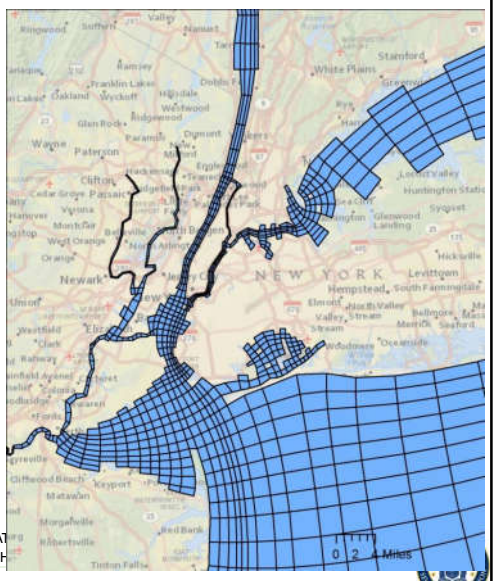
- Use Pathogen TMDL work as starting point
- Update landside modeling from RAINMAN to InfoWorks for NJ CSO Communities
- Update NYC landside modeling using RAINMAN and IW loads
- Refine water quality model segmentation in key areas
- Recalibrate WQ model using
  - 2016-2017 New Jersey Harbor Dischargers Group (NJHDG) data
  - 2016-2017 Baseline monitoring sampling data
  - 2016-2017 Event-based WQ sampling data

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Pathogen TMDL Modeling

- Work conducted 2005-2007
- Endpoints (attainment)
  - Total coliform
  - Fecal coliform
  - Enterococci
- MEG reviewed original work
- TMDL not finalized



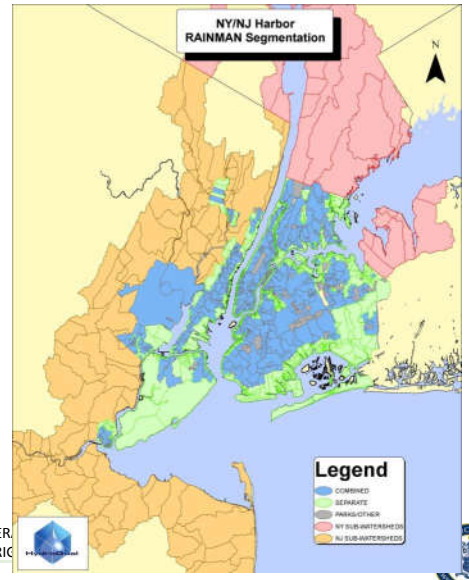
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Basis of Pathogen TMDL Loading

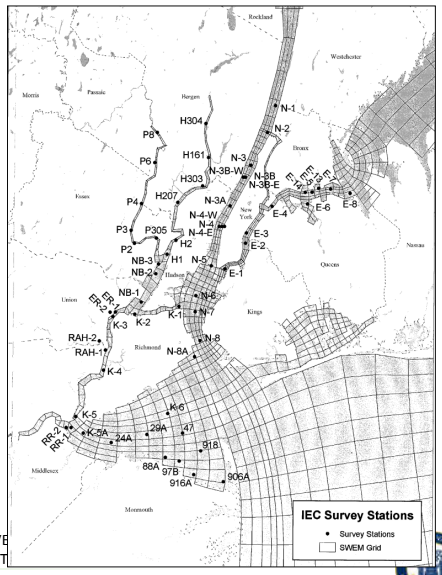
- CSO loadings by RAINMAN
  - Cross-calibrated to SWMM or IW for NJ
  - RAINMAN for NYC
  - Loads based on a mass balance approach
- Stormwater loadings by RAINMAN



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Pathogen TMDL Calibration

- WQ Model
- Calibration
  - Periods in 2002 and 2003
  - Total coliform
  - Fecal coliform
  - Enterococci
- No intensive wet-weather data available



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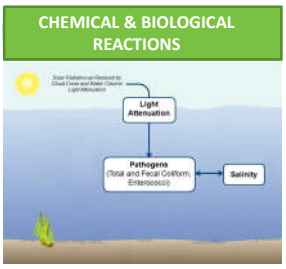
Program Enhancements

- Upgrade from RAINMAN to InfoWorks for NJ-based sources
- Add source sampling locations to provide better accounting of source loads
- Add receiving water sampling stations and wet-weather event sampling to provide additional data for model re-calibration
- Enhance model grid resolution
- Model skill assessment as outlined in draft QAPP

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Bacteria Model

- RCA (Row-Column AESOP)
- State variables
  - Salinity
  - Tracer
  - E. coli
  - Fecal coliform
  - Enterococci



WATER QUALITY MODEL

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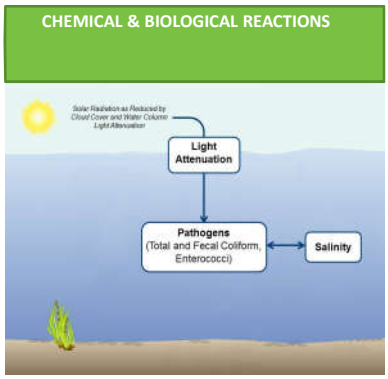
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Bacteria Model Kinetics

$$N = N_0 \exp(\quad KBt)$$

$K_B = [0.8 + 0.006(\%seawater)]1.07^{(T-20)}$
$+ \alpha I_0(t)/K_eH[1-\exp(-K_eH)]$
$+ V_s/H$
(Mancini, 1978)

N = Bacteria concentration
K_B = Bacteria loss rate
T = Temperature (°C)
α = proportionality constant (~1)
I_0 = Surface solar radiation
t = time
K_e = Extinction coefficient (1/m)
H = Depth (m)
V_s = Net settling rate (m/d)



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Required Inputs

- Hydrodynamics
- Loads
  - CSOs
  - Storm drains
  - Direct drainage
  - Dry-weather sources
  - WWTPs
- Boundary Conditions
  - Rivers
  - Ocean
- Constants and Parameters
  - Die-off rates
  - Additional constants or parameters as necessary

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Input Development

- CSO Flows and Volumes
- Generate NJ CSOs with InfoWorks
- Use 2008 Characterization Study models
- Convert SWMM to InfoWorks as necessary
- PVSC InfoWorks Model
  - Paterson, Newark, Kearny, Harrison, East Newark
  - Bayonne, North Bergen to be added
- Other local CSO municipalities (provided by others)
  - Elizabeth, Ridgefield Park, Hackensack, Fort Lee, Guttenberg, Perth Amboy, North Hudson Sewerage Authority, Jersey City

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Sources of CSO Flow/Volumes

- Greeley and Hansen
  - PVSC/NBMUA communities
    - Paterson
    - Newark
    - Kearny
    - Harrison
    - East Newark
    - Bayonne
    - North Bergen
    - Guttenberg
- Arcadis
  - Hackensack
  - Jersey City (PVSC)
- CDM Smith
  - Perth Amboy
- Hatch Mott
  - Elizabeth
  - Ridgefield Park
- CH2M
  - North Hudson
- AECOM and H&S
  - NYC
- HDR
  - Fort Lee

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Approaches to CSO Loading

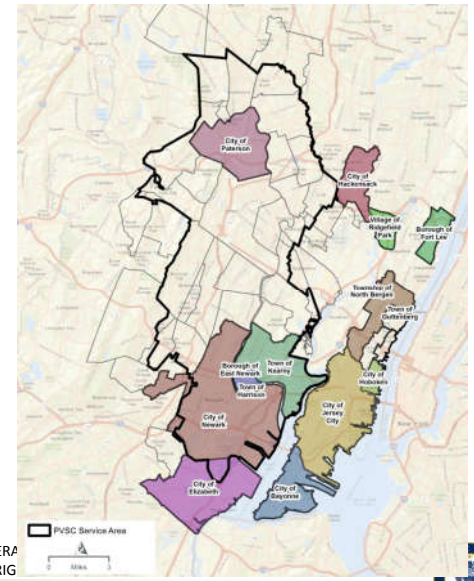
- Event Mean Concentration: Constant concentrations
  - Pros: simple, commonly used
  - Cons: does not represent observed variability
- Mass Balance : Constant sanitary and stormwater concentrations mixed based on IW calculations
  - Pros: simple, consistent, predictive
  - Cons: less variability, IW-dependent
- Monte Carlo: Concentrations from a generated probability distribution based on observed data
  - Pros: reproduces observed magnitude and variability of data
  - Cons: requires site specific data, random, non-predictive
- Hybrid Mass Balance/Monte Carlo: Mass Balance with concentrations generated by Monte Carlo
  - Pros: reproduce observed data while including predictive capabilities
  - Cons: data requirements, IW-dependent, untested

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Proposed CSO Loading Approach – NJ

- Use IW/SWMM flows provided by consultants
- Use 2008 CSO Characterization Study measured data
- Supplement with LTCP 2016 data as necessary
- Bacteria concentrations
- Mass balance (approach used for Pathogen TMDL)



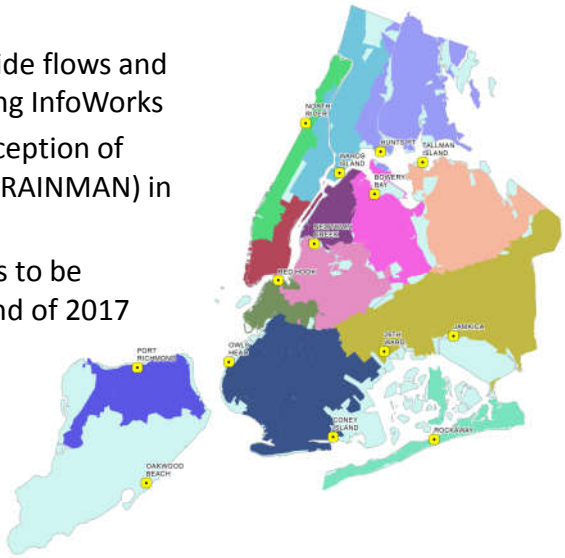
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GREELEY AND HANSEN CDM Smith HDR

CDM Smith

Proposed CSO Modeling Approach – NYC

- NYCDEP will provide flows and loads using existing InfoWorks
- All areas, with exception of Oakwood Beach (RAINMAN) in InfoWorks
- InfoWorks models to be recalibrated by end of 2017



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Proposed Approach to Stormwater Loads

- Use InfoWorks or gauged flow regression
- Calibrate to gauge data and 2016-2017 measurements
- Bacteria concentrations based on literature values for land uses, supplemented with 2016-2017 stormwater monitoring results
  - Geometric mean concentrations
  - Constant in time
  - Spatially varying depending on literature/sampling data

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Proposed Approach to Upstream Flows

- Use available flow data from USGS gauges
  - Hackensack River
  - Saddle River
  - Elizabeth River
  - Second River
  - Third River
- Develop runoff using InfoWorks or methodologies used for Passaic River Superfund Project for other tributaries

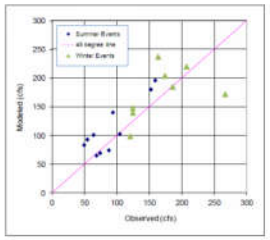


Figure 4-8(a). Goodness-of-Fit (Measured vs. Modeled) Plot of Storm Peak Flow at USGS Gauge below Pelham Lake (Source: Westchester County, 2012)

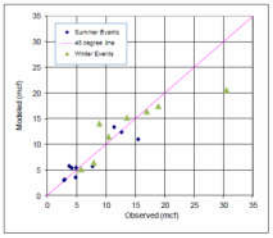


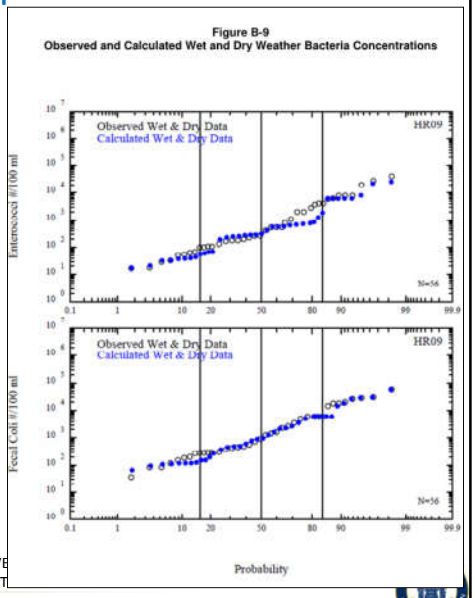
Figure 4-8(b). Goodness-of-Fit (Measured vs. Modeled) Plot of Storm Volume at USGS Gauge below Pelham Lake (Source: Westchester County, 2012)

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Proposed Approach to Upstream Concentrations

- Develop functional relationships based on 2016-2017 sampling data and historical data
  - NJHDG
  - Third party



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CDM Smith

Data for Water Quality Calibration/Validation

- Calibration
  - 2016-2017 NJHDG data
    - Weekly (July-September)
    - Every other week (May, June)
    - Monthly (January-April, October-December)
  - 2016-2017 LTCP Baseline Compliance Monitoring data
    - Same frequency as NJHDG
  - 2016-2017 Intensive Sampling Event data
    - Three 3-day events
  - Other: NYCDEP Harbor Survey, Citizens, etc.
- Validation
  - Historical NJHDG, NYCDEP, IEC, Meadowlands Research Institute data

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Calibration Assessment

- Graphical Comparisons
  - Spatial transect plots of model output versus observed
  - Graphical time-series plots of observed and predicted data
  - Comparisons between observed and calculated probability distributions
  - Scatter plots of observed versus predicted values
- Statistical Comparisons (geometric means)
  - Mean error
  - Absolute
  - Relative error

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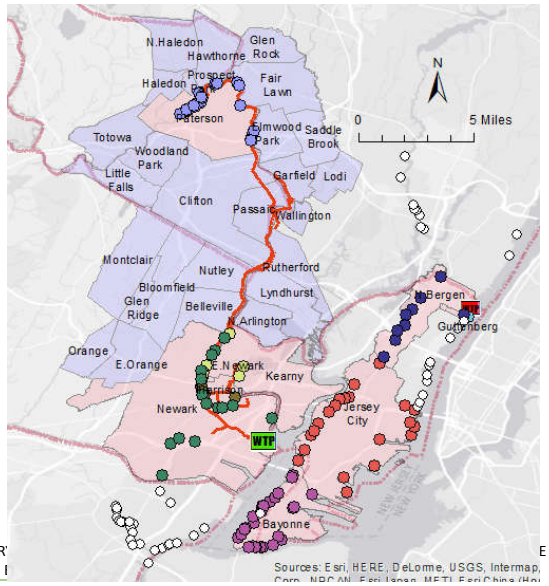
CDM Smith

Projection Simulations

- Baseline
- Gap Analysis (100% CSO Removal)
- Component Analysis
  - NYC sources
  - NJ CSOs
  - NJ non-CSOs
  - Upstream/downstream boundary conditions
- CSO Control Alternatives
  - Permittee-related
  - Area-wide
  - Final selected plan

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Discussion / Next Steps



INTERAGENCY ADVISOR
UNDER N.J.S.A 47:1A-1 I

PVSC – Long Term Control Plan
Modeling Evaluation Group – Session 2
Hydrologic and Hydraulic Model

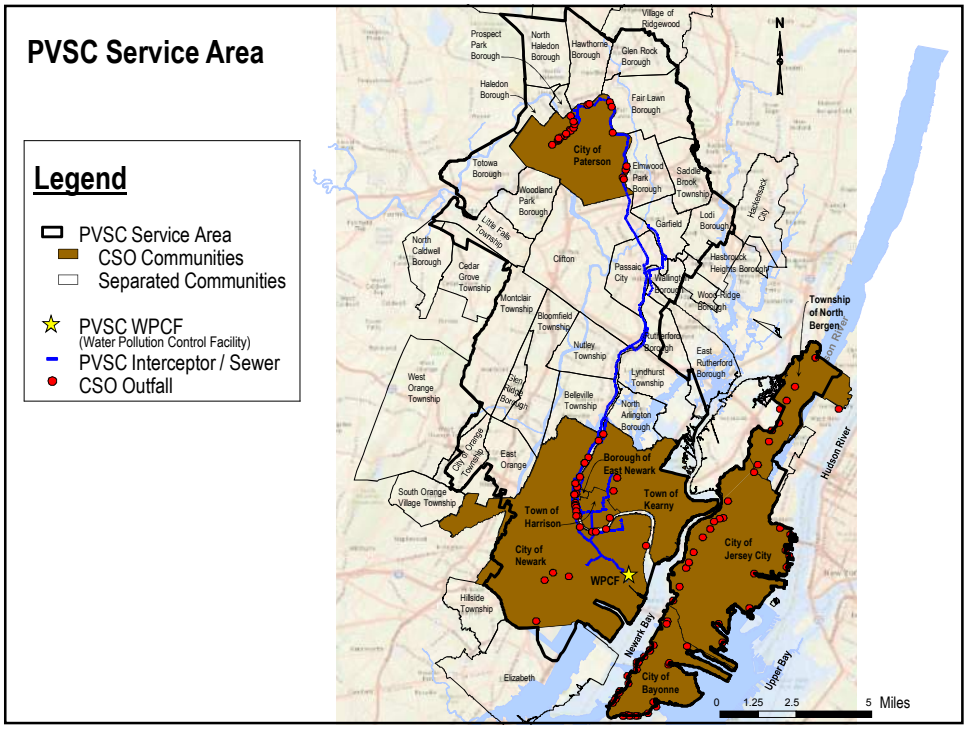
Greeley and Hansen LLC
March 17, 2017

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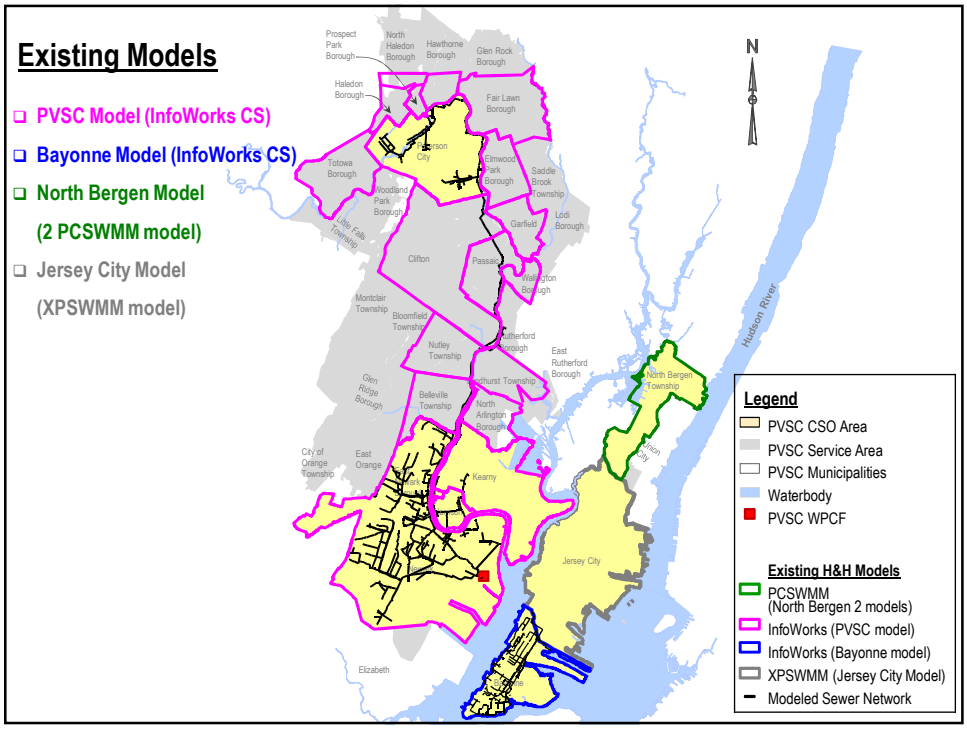
Outline

- Hydrologic and Hydraulic (H&H) Model Update
  - Model Integration
  - Regulator Update
  - Paterson Re-delineation
  - Separated Service Area
  - Wet Weather Operating Rules
- Next Step

PVSC Service Area



Existing Models



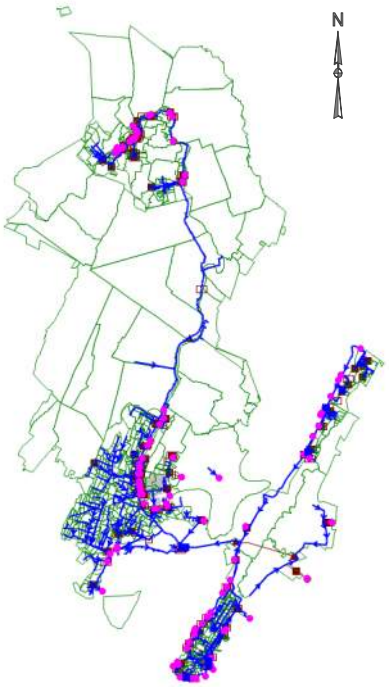
A Snapshot of Integrated Model…

- ❑ **48 PVSC communities**
- ❑ **8 CSO communities**
  - ✓ Paterson
  - ✓ Newark
  - ✓ East Newark
  - ✓ Harrison
  - ✓ Kearny

(Above 5 discharge to interceptor by gravity to WPCF)

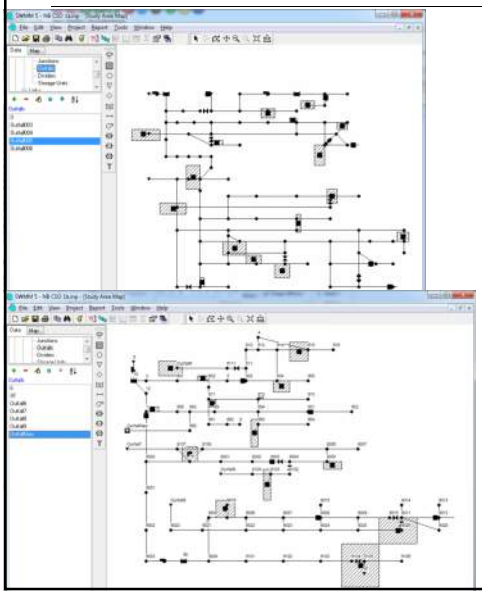
  - ✓ Bayonne
  - ✓ Jersey City
  - ✓ North Bergen

(Above 3 discharge to Hudson County Forcemain to WPCF)



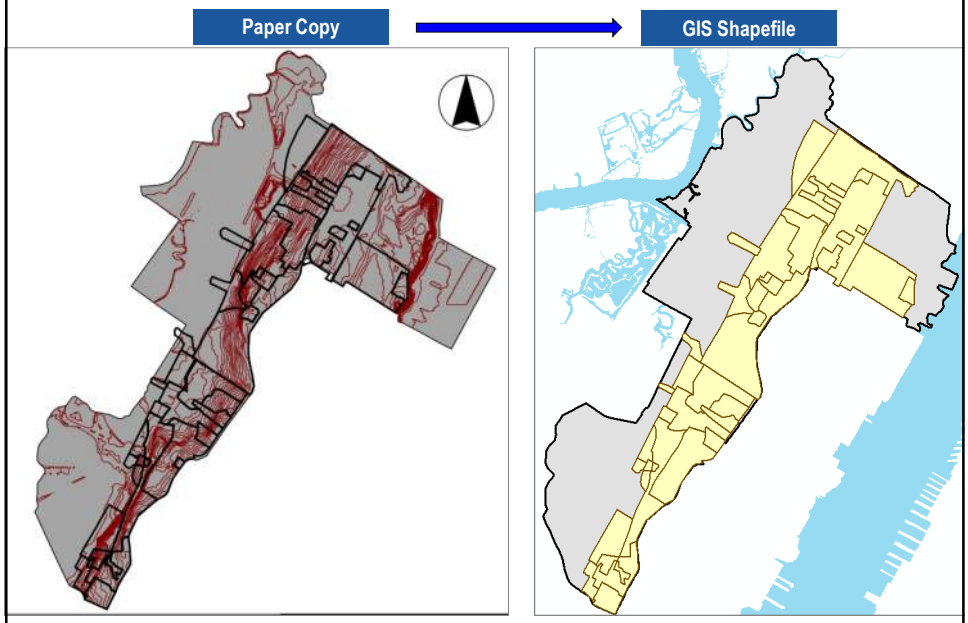
Model Integration

Recreate North Bergen Model from PCSWMM



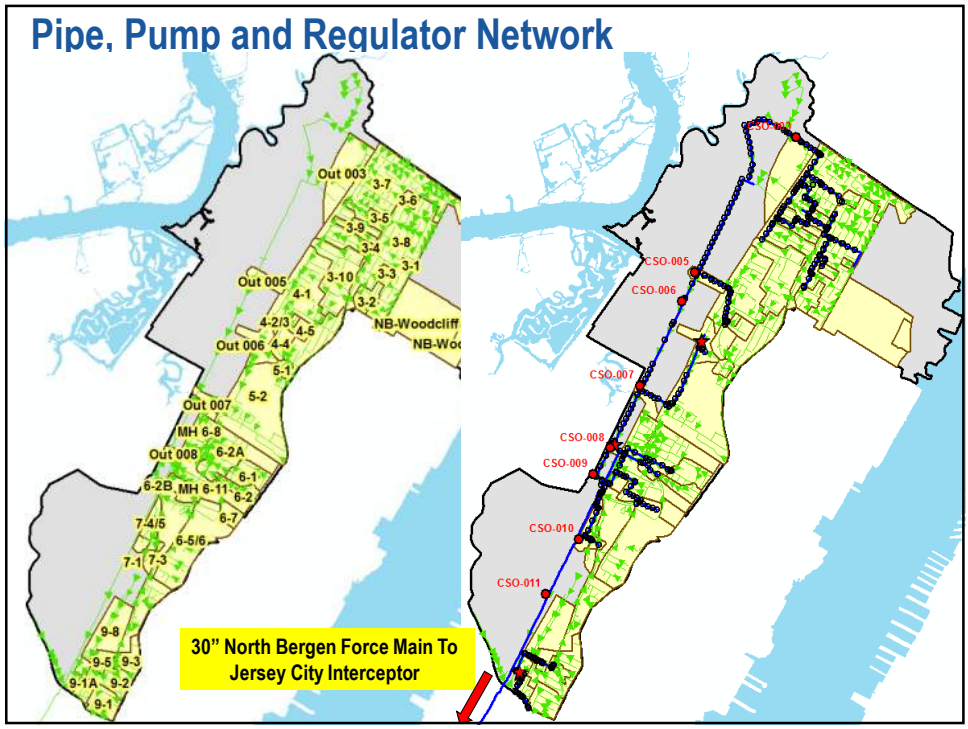


NB Delineation

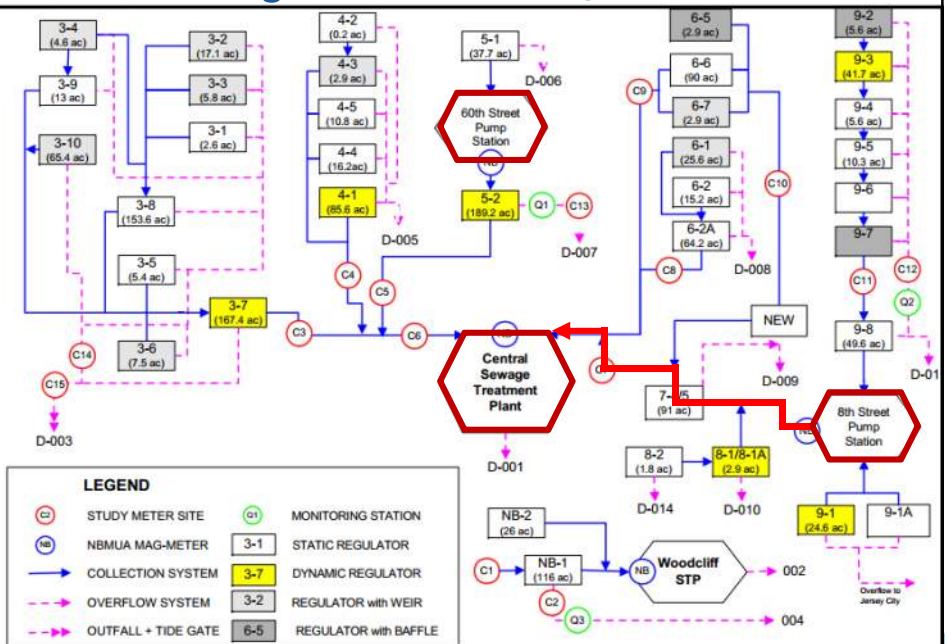


❑ *Digitize model subcatchment based on paper copy*

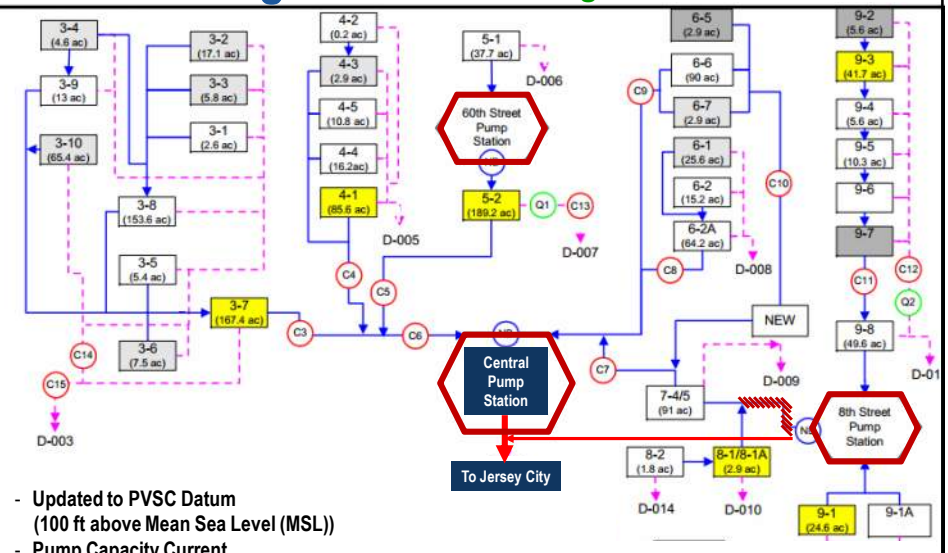
Pipe, Pump and Regulator Network



Model Integration/*North Bergen Model*



Model Integration/*North Bergen Model*



- Updated to PVSC Datum (100 ft above Mean Sea Level (MSL))
- Pump Capacity Current

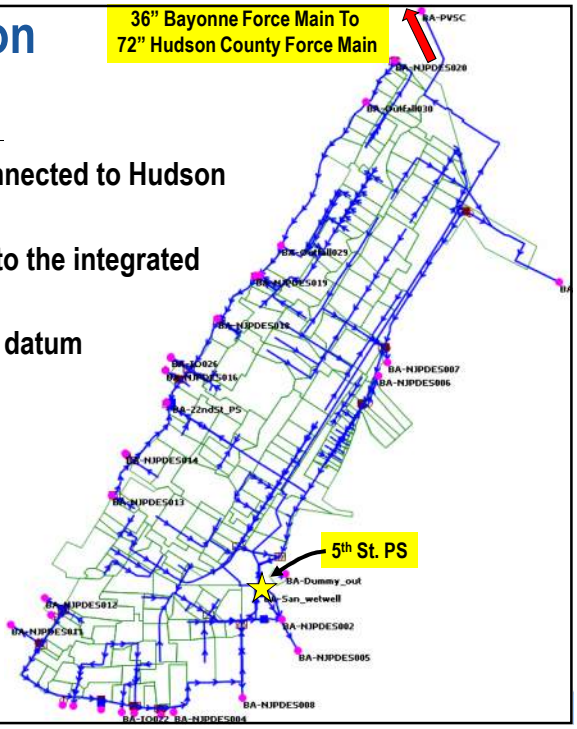
Flow to Jersey City = Central PS +8th St. PS

Max: 18.6 MGD 16 MGD 2.6 MGD

Model Integration

Bayonne Model

- Bayonne force main Connected to Hudson County Force Main
- 11 RTC rules appended to the integrated model
- Datum updated to PVSC datum



Model Integration

Jersey City Model

- **Simplified model network to**
  - represent Jersey City flow
  - connect North Bergen and Bayonne models to the PVSC model

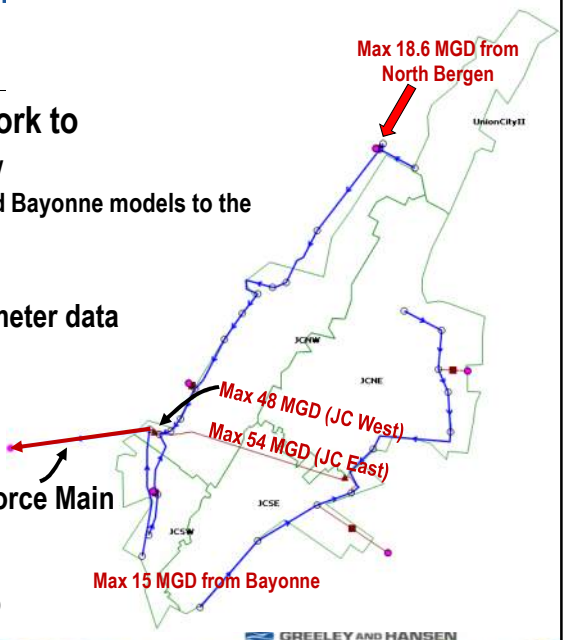
Max pump rate based on meter data

Jersey City East: Peak 54 MGD
Jersey City West: Peak 48 MGD

Flows in Hudson County Force Main

- Jersey City East: Peak 54 MGD
- Jersey City West: Peak 48 MGD
- Bayonne: Peak 15 MGD

Total Maximum: 117 MGD

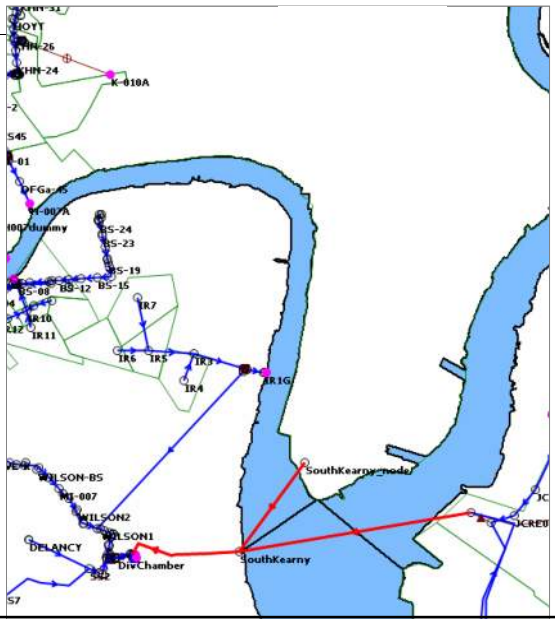


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Model Integration

Force Mains

- Hudson County Force Main was extended to the PVSC WPCF based on drawing
- South Kearny PS 30" force main was created and tied into the Hudson County Force Main

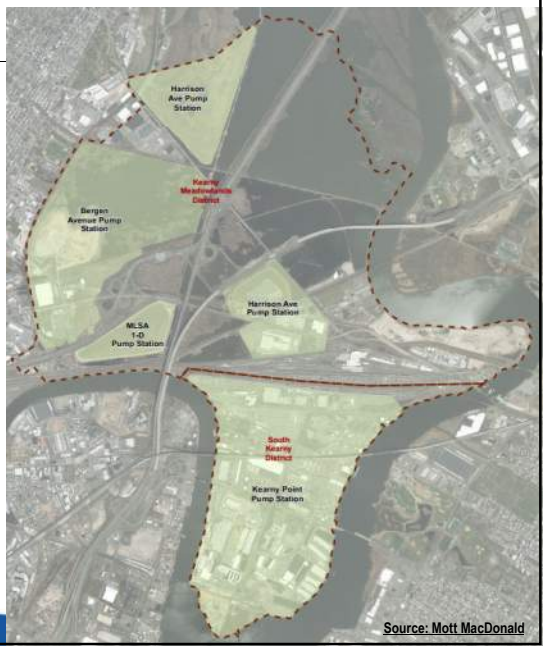


South Kearny Pump Station Service Area

- Kearny Meadowlands District
- South Kearny District
- Both Separated

South Kearny Pump Station

- Capacity: 17.5 MGD
- DWF: 1.6 MGD



Source: Mott MacDonald

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Regulator Update

Regulator Modification

Regulator	Overflow Weir				Regulating Sluice Gate / Orifice					
	Drawing		Original Model		Drawing			Original Model		
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height
P_015A (S.U.M. Park)	152.9	2.5	152.9	2.5	151.87	1.25		151.87	1.25	
P-001A (Curtis Pl.)	146.9	3.83	146.9	3.83	143.94	3	1	143.94	2.25	
P-003A (West Broadway)	139.5	4	139.5	4	137.4	1.25		137.4	1.25	
P-005A (Bridge St.)	133.4	5	136.71	5	131.7	0.833	1.667	131.7	1.25	
P-006A (Montgomery St.)	134.2	8.0	135.25	8	129.53	2		129.53	2	
P-007A (Straight St.)	133.8	6	133.8	5	130.1	1.83	3	130.1	1.25	
P-009A (Keen St.)	135.4	4	135.4	4	133.44	1.67	0.83	133.44	1.25	
P-010A (Warren St.)	133.85	4	135.21	3						
P-016A (Northwest St., modified)	138.8	8	140.94	8.5	136.25	2.5		136.25	2.5	
P-017A (Arch St.)	135.7	4.5	135.69	3.67	132.6	1		132.6	1	
P-032A (Hudson St.)	135.2	4	135.2	4						
P-022A (Short St.)	132.6	4.5	132.6	4.5	130.63	2		130.63	2	
P-021A (Bergen St.)	132.7	4.5	132.7	4.5	130.75	1		130.75	1	
P-013A (East Eleventh St.)	133.4	4.83	133.4	4.83	131.7	1.67	0.83	131.7	1.25	
P-014A (Fourth Ave.)	140.9	4.5	140.9	3	137.76	1.67	0.83	137.76	1.25	
P-023A (Second Ave.)	129.8	5	130.56	5	127.4	Not available	Not available	127.4	1.25	
P-024A (Third Ave.)	130.3	4.5	130.3	5	128.2	1.67	0.83	128.2	1.25	
P-025A (East 33rd Ave.)	128.9	8.58	129.87	8.58	127.07	3	1	127.07	2	
P-026A (East 20th Ave.)	129.2	5.5	128.92	5.5	126.95	1.67	0.83	126.95	1.66	0.83
P-027A (Market St.)	131.1	7.11	131.1	4.0	129.6	3.5	1.167	129.6	3.5	2.0
					129.6	3.5	1.167	129.6	3.5	0.0

Regulator Modification

Regulator	Overflow Weir				Regulating Sluice Gate / Orifice					
	Drawing		Original Model		Drawing			Original Model		
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height
N-002A (modified, Verona)	110.43	41	103	6	102.65	2.5	2.5	99.33	2	2
N-004A/005A (modified, Herbert Pl.)	114.34	41	105.55	6.667	107.06	2	2	103.6	1.5	1.5
N-008A (4th Ave.)	103.5	6	103.5	6	100.7	1.5	1.5	100.7	1.5	1.5
N-009A (Passaic St.)	103.24	4	103.24	4	102.4	1.66	0.83	102.4	1.66	0.83
N-010A (Clay St.)	105.12	8.42	105.12	8.42	101.24	6	3	101.24	6	3
	105.12	8.42	105.12	8.42	101.24	6	3	101.24	6	3
	105.12	8.42	105.12	8.42						
N-014A (Rector St., modified)	102.56	5.5	103.66	5.5	99.97	1.5	1.5	101.07	1.5	1.5
N-014A (Saybrook Pl., modified)	102.33	7	103.43	7	99.02	2	2	100.12	2	2
N-015A (City Dock, modified)	98.67	14	98.67	14	95.67	3.5	2.5	95.67	3.5	2.5
N-016A (Jackson St.)	97.62	7	97.62	4.5	96	1.5	1.5	96	1.33	1.33
N-017A (Polk St.)	97.8	8	97.8	7	95.2	1.5	1.5	95.35	1.33	1.33
N-018A (Freeman St.)	100.26	4	100.26	4	99	2	2	99	2	2
N-022A (Roanoke Ave.)	98.93	6	98.93	6						
N-027A/029A	102	4.5	102	4.5	96.4	4	2.33	96.4	4	2.33
N-025A (Peddie St.)	98.6	8	98.6	8	93	4	2.33	93	4	2.33
	98.6	8	98.6	8						
	98.6	8	98.6	8						
	98.6	8	98.6	8						
N-030A	102.32	10	102.32	10	99.04	4	3	99.04	4	3
N-023A	98.54	7	98.54	7						

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Regulator Modification

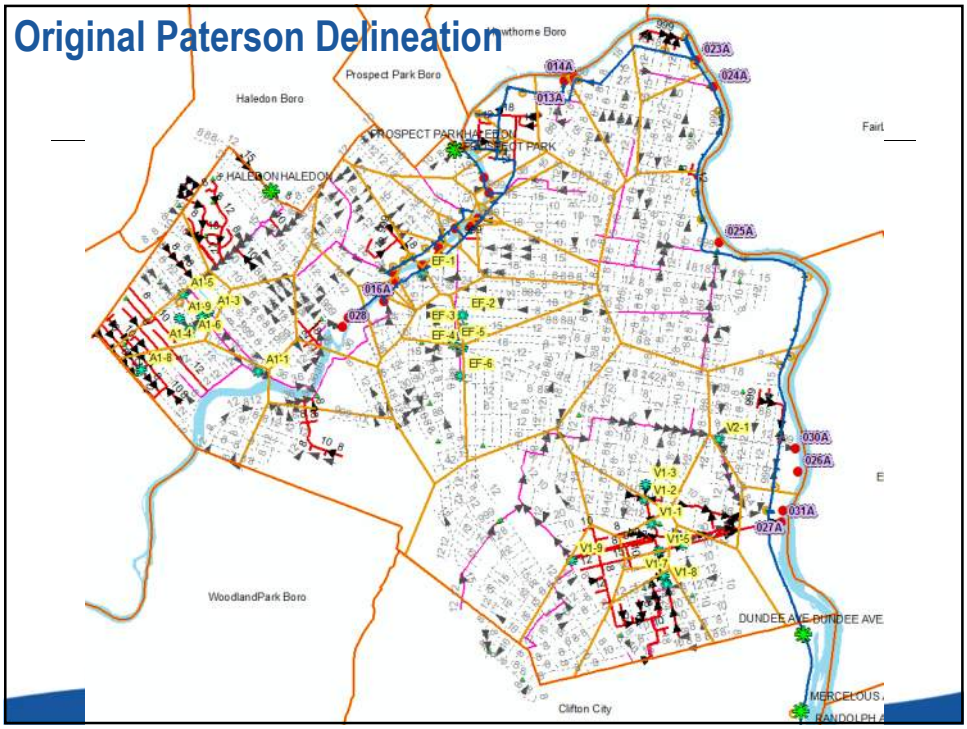
Regulator	Overflow Weir				Regulating Sluice Gate / Orifice					
	Drawing		Original Model		Drawing			Original Model		
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height
K-001A (Stewart Ave.)	120.85	4.5	120.27	1.5	119.07	1		119	1	
K-004A	107.9	1.5	108	1.5	106.9	1		107	1	
K-006A (Johnston Ave.)	99.9	5	100.9	10	98.7	1.5		98.2	1.5	
	99.9	5								
K-007A	103	9	103	9	100.2	3	1	100.2	3	1
K-010A (Duke St.)	102.5	4	102.5	4.5	98.84	1	1	100.45	1	
E-001A	101.6	4	101.6	4	99.2	1.25		99.2	1.25	
H-001A	101.2	4	101.2	4	99.8	1.25		99.8	1	
H-002A	102.2	4	102.2	4	101	1		101.2	1	
H-003A	103.9	4	103.9	4	101.4	1.25		101.4	1.25	
H-004A (Dey St.)	102.2	4	102.2	3.5	100.58	1		100.58	1	
H-005A	100.8	3.5	100.8	3.5	99.1	1		99.1	1	
H-006A	99.9	4	99.9	4	97.9	1		97.9	1	
H-007A	102.4	4.5	102.4	4.5	101.2	1		101.2	1	

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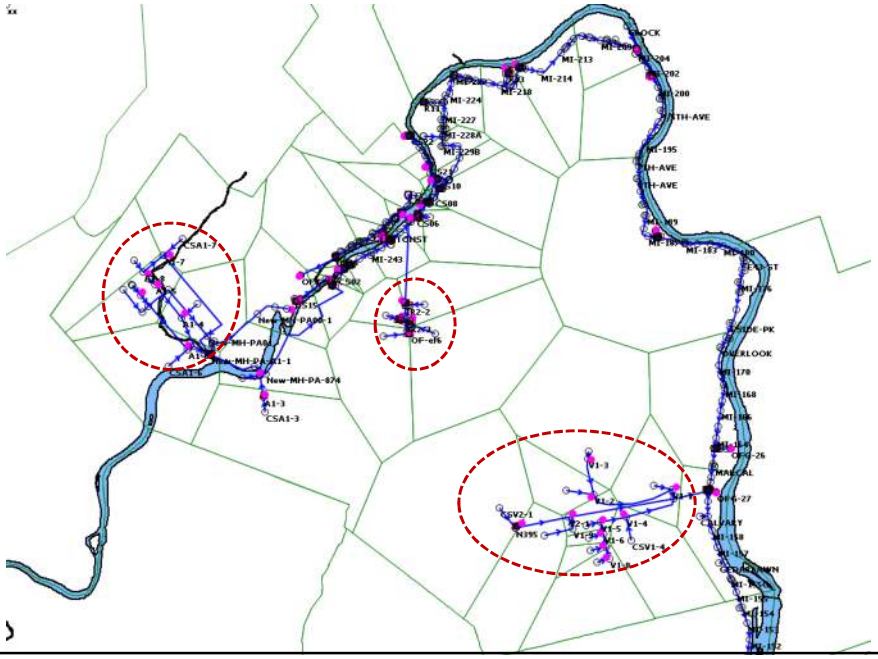
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Paterson Update

Original Paterson Delineation



Paterson Internal Regulator

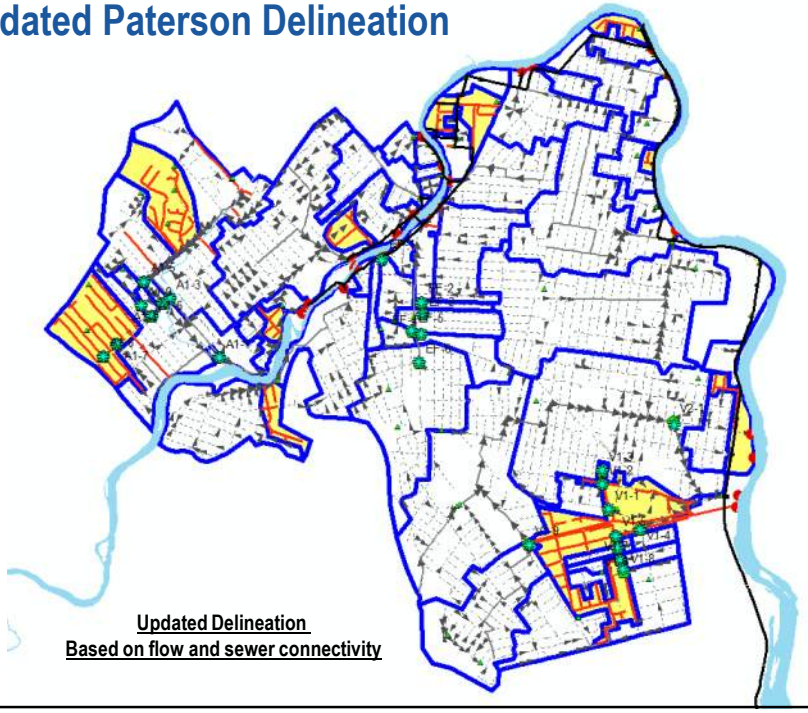


Paterson Internal Regulator Connectivity

Regulator #	Normal Flow Connection	Overflow Connection
A1-1 to A1-9 (8)	P_001A Regulator	P_028A
EF-2 to EF-6 (5)	P_006A Regulator	P_029A
V2-1	P_027A Regulator	P_030A
V1-1 to V1-9 (9)	P_027A Regulator	P_031A
EF-1	PVSC Interceptor MH 243	P_033A

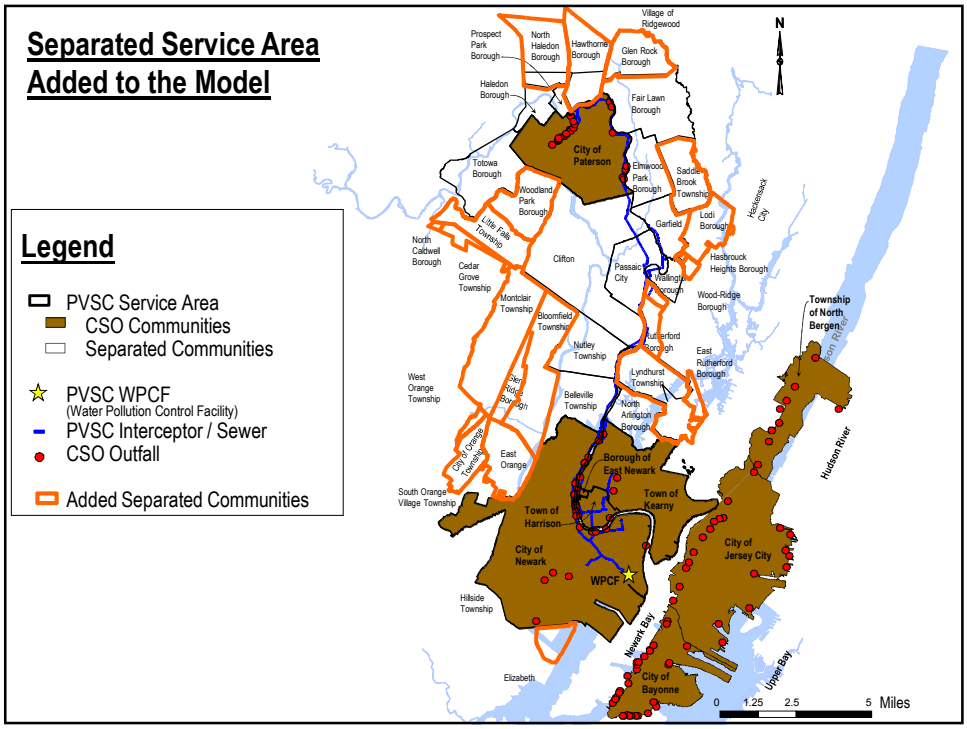
GREELEY AND HANSEN

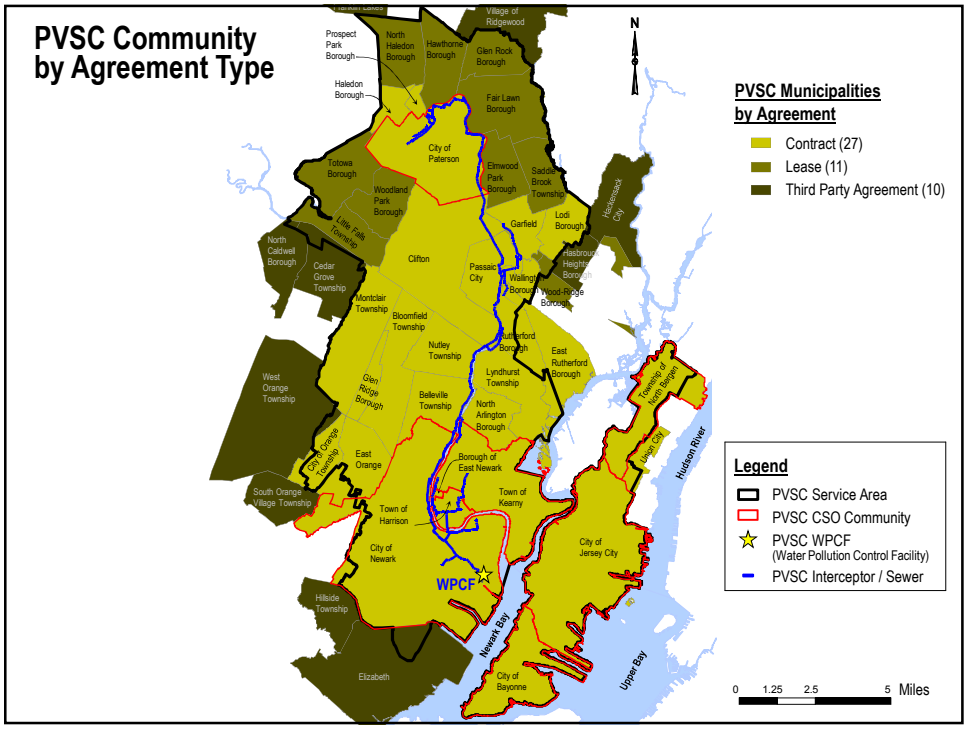
Updated Paterson Delineation



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Separated Service Area

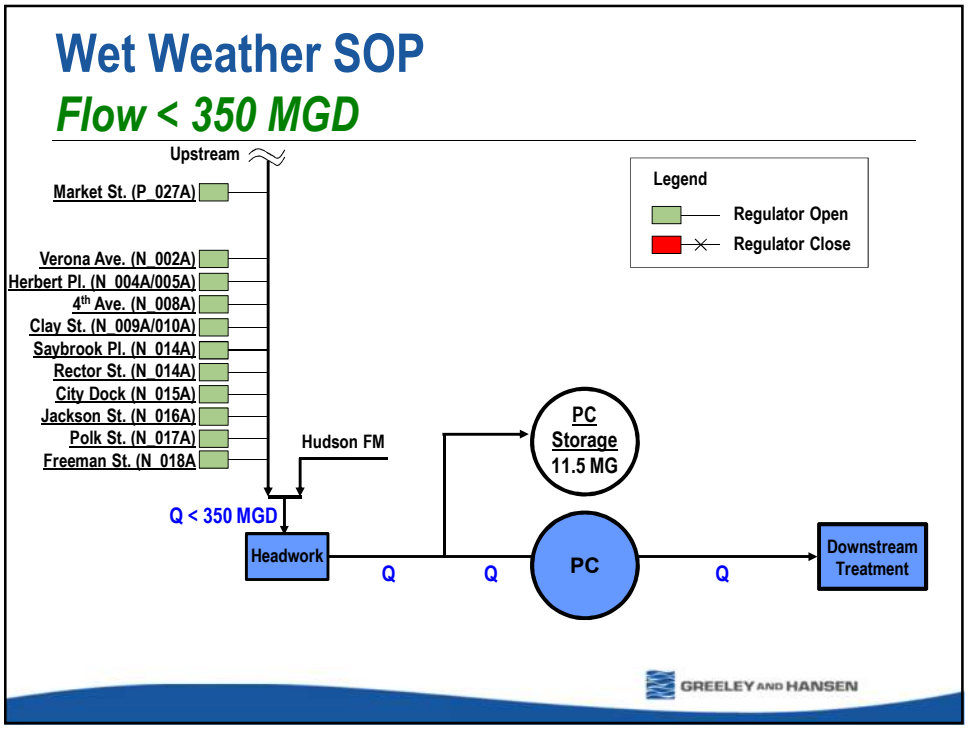

Separated Service Area Added to the Model
Legend
PVSC Service Area
CSO Communities
Separated Communities
PVSC WPCF
(Water Pollution Control Facility)
PVSC Interceptor / Sewer
CSO Outfall
Added Separated Communities
N
Village of Ridgewood
Prospect Park Borough
North Haledon Borough
Hawthorne Borough
Glen Rock Borough
Haledon Borough
Fair Lawn Borough
City of Paterson
Totowa Borough
Elmwood Park Borough
Saddle Brook Township
Woodland Park Borough
Little Falls Township
Garfield
Lodi Borough
Hackensack City
North Caldwell Borough
Cedar Grove Township
Clifton
Passaic City
Wallington Borough
Hasbrouck Heights Borough
Montclair Township
Wood-Ridge Borough
Bloomfield Township
Township of North Bergen
Nutley Township
Rutherford Borough
East Rutherford Borough
West Orange Township
Glen Ridge Borough
Lyndhurst Township
Belleville Township
North Arlington Borough
City of Orange Township
East Orange
Borough of East Newark
Town of Kearny
South Orange Village Township
Town of Harrison
City of Jersey City
City of Newark
WPCF
Hudson River
Hillside Township
Newark Bay
Upper Bay
Elizabeth
City of Bayonne
0 1.25 2.5 5 Miles

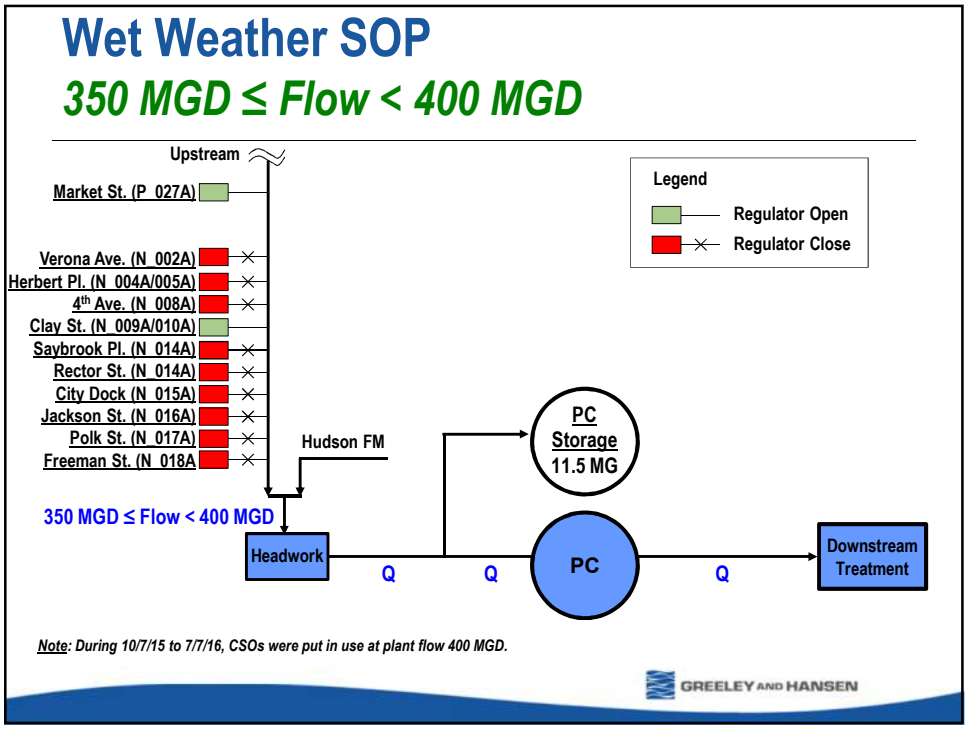

PVSC Community by Agreement Type
PVSC Municipalities by Agreement
Contract (27)
Lease (11)
Third Party Agreement (10)
Legend
PVSC Service Area
PVSC CSO Community
PVSC WPCF
(Water Pollution Control Facility)
PVSC Interceptor / Sewer
N
Village of Ridgewood
Prospect Park Borough
North Haledon Borough
Hawthorne Borough
Glen Rock Borough
Haledon Borough
Fair Lawn Borough
City of Paterson
Totowa Borough
Elmwood Park Borough
Saddle Brook Township
Woodland Park Borough
Little Falls Township
Garfield
Lodi Borough
Hackensack City
North Caldwell Borough
Cedar Grove Township
Clifton
Passaic City
Wallington Borough
Hasbrouck Heights Borough
Wood-Ridge Borough
Montclair Township
Bloomfield Township
Nutley Township
Rutherford Borough
East Rutherford Borough
West Orange Township
Glen Ridge Borough
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City of Orange Township
East Orange
Borough of East Newark
Town of Kearny
South Orange Village Township
Town of Harrison
City of Jersey City
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Newark Bay
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City of Bayonne
0 1.25 2.5 5 Miles

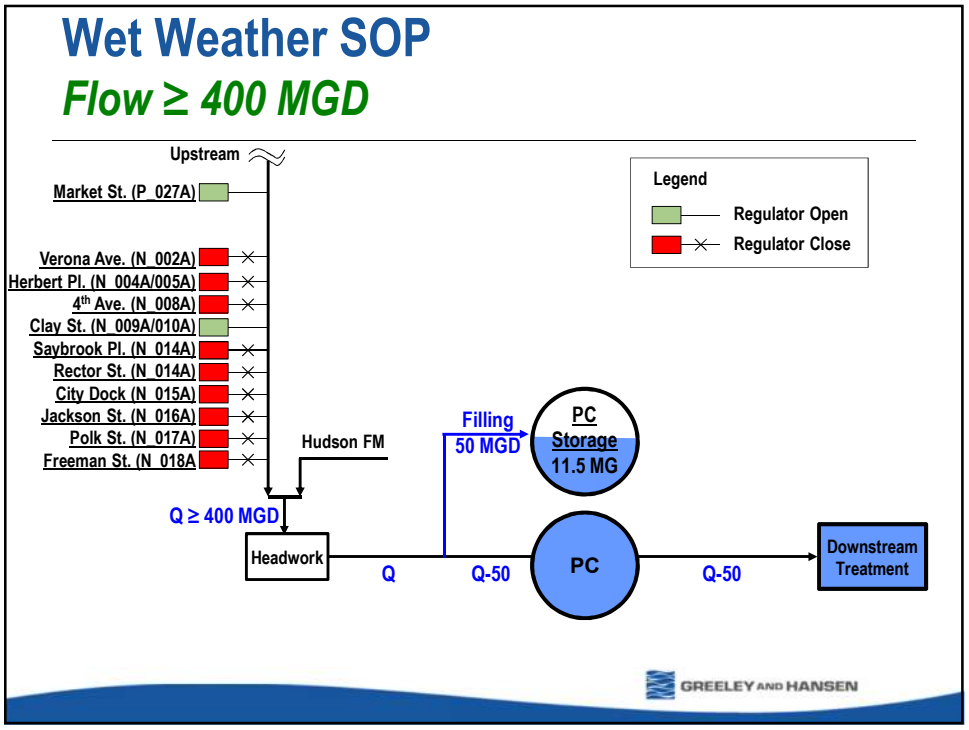
Municipality	Type of Agreement	Lease/ Contract Date	Agreed Average Daily Flow (MGD)	Agreed Max Rate of Flow (MGD)	Comments
Passaic County					
Township of Little Falls	Lease	9/29/1986	2.2		
Borough of Woodland Park	Lease	4/25/1984	2	2	
Borough of Totowa	Lease	1/7/1986	2.4	2.4	
Borough of North Haledon	Lease	8/13/1980	1	1.8	
Borough of Hawthorne	Lease	3/23/1944	2	3	
Bergen County					
Township of South Hackensack	Lease	4/5/2010	0.05	0.1	
Borough of Hasbrouck Heights	Third Party Agreement				Via Lodi
City of Garfield	Contract	1/1/1965	16.11	16.11	
Borough of Lodi	Contract	8/8/1960	4.5	4.5	
City of Hackensack	Third Party Agreement				Via Lodi
Township of Saddle Brook	Lease	11/10/1960	2	2	
Borough of Elmwood Park	Lease	10/20/1943	1	1.5 (max day)	
Borough of Wood-Ridge	Lease	11/15/2006	0.25		Lodi & Wood Ridge
Village of Ridgewood	Third Party Agreement				Via Glen Rock & Hawthorne
Borough of Franklin Lakes	Third Party Agreement				Via North Haledon
Borough of Fair Lawn	Lease	1/3/1945	2.25	2.5 (max day)	
Borough of Glen Rock	Lease	10/23/1944	1	1.5 (max day)	
Essex County					
Township of Cedar Grove	Third Party Agreement				Via Little Falls and Montclair
Borough of North Caldwell	Third Party Agreement				Via Little Falls
Township of West Orange	Third Party Agreement				Via Orange
Township of South Orange Village	Third Party Agreement				Via Orange
Hudson County					
City of Bayonne	Contract	11/25/1986	11	17.6	
Township of North Bergen	Contract	3/9/2006	10	16	
City of Union City	Contract	9/25/1985	1.5	2.4	
City of Jersey City	Contract	9/24/1985	50	80	
Union County					
City of Elizabeth	Third Party Agreement				Via Airport / Port Newark to South Side Interceptor @ Waverly
Township of Hillside	Third Party Agreement				Via Newark South Side Interceptor

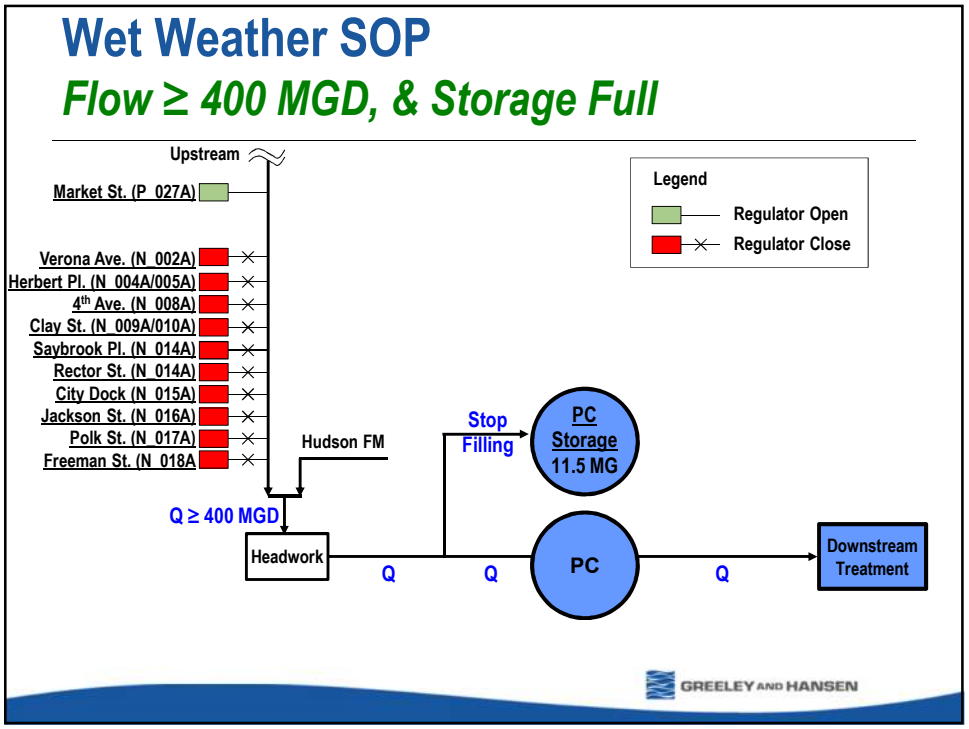
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Wet Weather Operating Rules


Wet Weather SOP
Flow < 350 MGD
Upstream
Market St. (P_027A)
Verona Ave. (N_002A)
Herbert Pl. (N_004A/005A)
4th Ave. (N_008A)
Clay St. (N_009A/010A)
Saybrook Pl. (N_014A)
Rector St. (N_014A)
City Dock (N_015A)
Jackson St. (N_016A)
Polk St. (N_017A)
Freeman St. (N_018A
Hudson FM
Q < 350 MGD
Headwork
Q
Q
PC
Storage
11.5 MG
PC
Q
Downstream
Treatment
Legend
Regulator Open
Regulator Close
GREELEY AND HANSEN

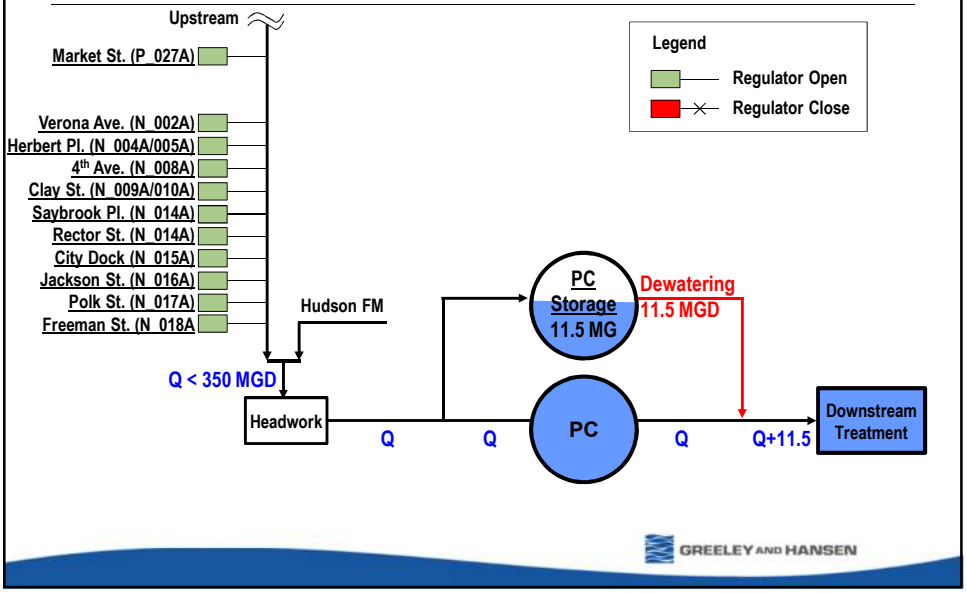

Wet Weather SOP
350 MGD ≤ Flow < 400 MGD
Upstream
Market St. (P_027A)
Verona Ave. (N_002A)
Herbert Pl. (N_004A/005A)
4th Ave. (N_008A)
Clay St. (N_009A/010A)
Saybrook Pl. (N_014A)
Rector St. (N_014A)
City Dock (N_015A)
Jackson St. (N_016A)
Polk St. (N_017A)
Freeman St. (N_018A
Hudson FM
350 MGD ≤ Flow < 400 MGD
Headwork
Q
Q
PC
Storage
11.5 MG
PC
Q
Downstream
Treatment
Legend
Regulator Open
Regulator Close
Note: During 10/7/15 to 7/7/16, CSOs were put in use at plant flow 400 MGD.
GREELEY AND HANSEN


Wet Weather SOP
Flow ≥ 400 MGD
Upstream
Market St. (P_027A)
Verona Ave. (N_002A)
Herbert Pl. (N_004A/005A)
4th Ave. (N_008A)
Clay St. (N_009A/010A)
Saybrook Pl. (N_014A)
Rector St. (N_014A)
City Dock (N_015A)
Jackson St. (N_016A)
Polk St. (N_017A)
Freeman St. (N_018A
Hudson FM
Q ≥ 400 MGD
Headwork
Filling
50 MGD
PC
Storage
11.5 MG
PC
Q
Q-50
Q-50
Downstream
Treatment
Legend
Regulator Open
Regulator Close
GREELEY AND HANSEN

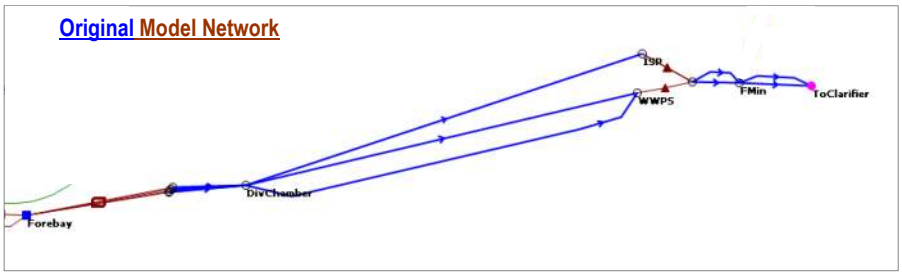

Wet Weather SOP
Flow ≥ 400 MGD, & Storage Full
Upstream
Market St. (P_027A)
Verona Ave. (N_002A)
Herbert Pl. (N_004A/005A)
4th Ave. (N_008A)
Clay St. (N_009A/010A)
Saybrook Pl. (N_014A)
Rector St. (N_014A)
City Dock (N_015A)
Jackson St. (N_016A)
Polk St. (N_017A)
Freeman St. (N_018A
Hudson FM
Q ≥ 400 MGD
Headwork
Stop
Filling
PC
Storage
11.5 MG
PC
Q
Q
Q
Downstream
Treatment
Legend
Regulator Open
Regulator Close
GREELEY AND HANSEN

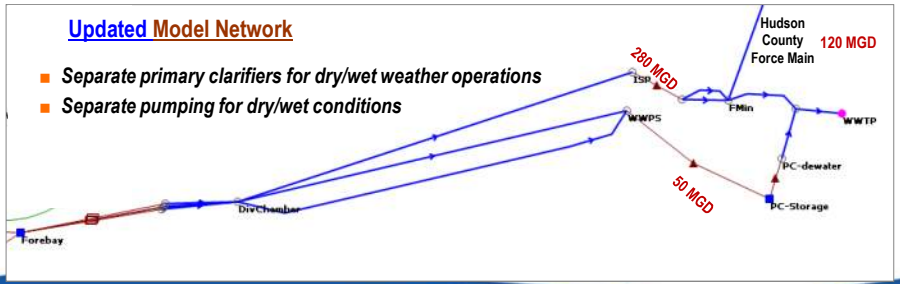
Wet Weather SOP

Flow Drops to 350 MGD



Model Network around PVSC Wastewater Facility





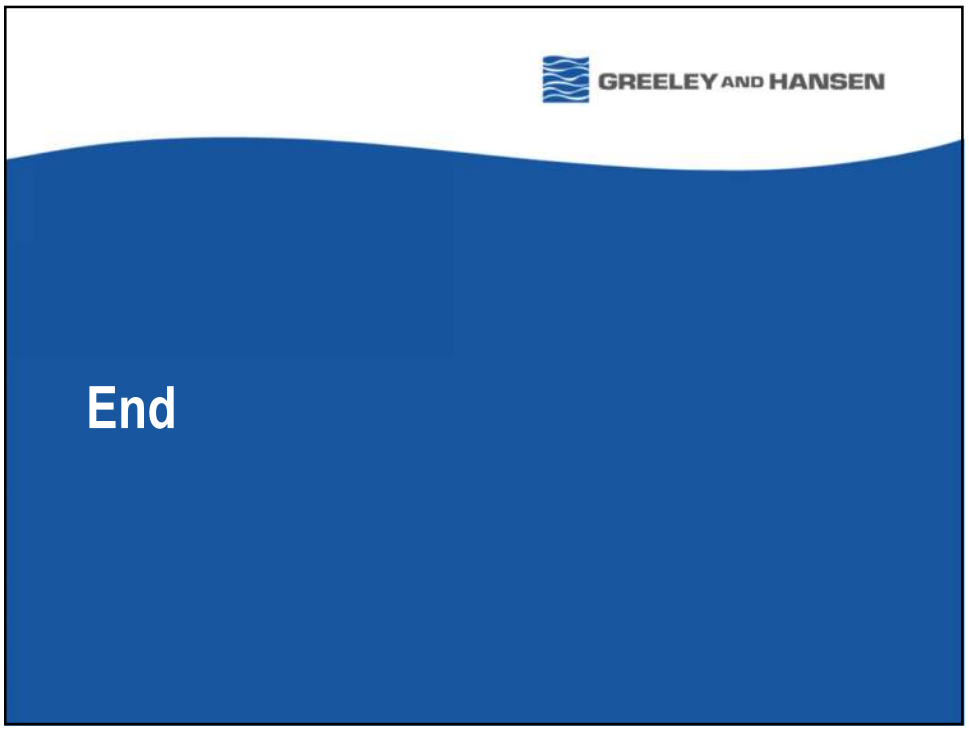
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Next Step

Model Calibration/Validation Approach

- Dry Weather Flow Calibration
  - DWF distribution based on metershed
  - Weekday/Weekend Diurnal
- Wet Weather Flow Calibration
  - 2-3 storm events
  - CSO area runoff
  - Separated area RDII (RTK)
  - Wet weather flow peak and volume

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End

PVSC – Long Term Control Plan
Modeling Evaluation Group – Session 2
Flow Metering Data

Greeley and Hansen LLC
March 17, 2017

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Outline

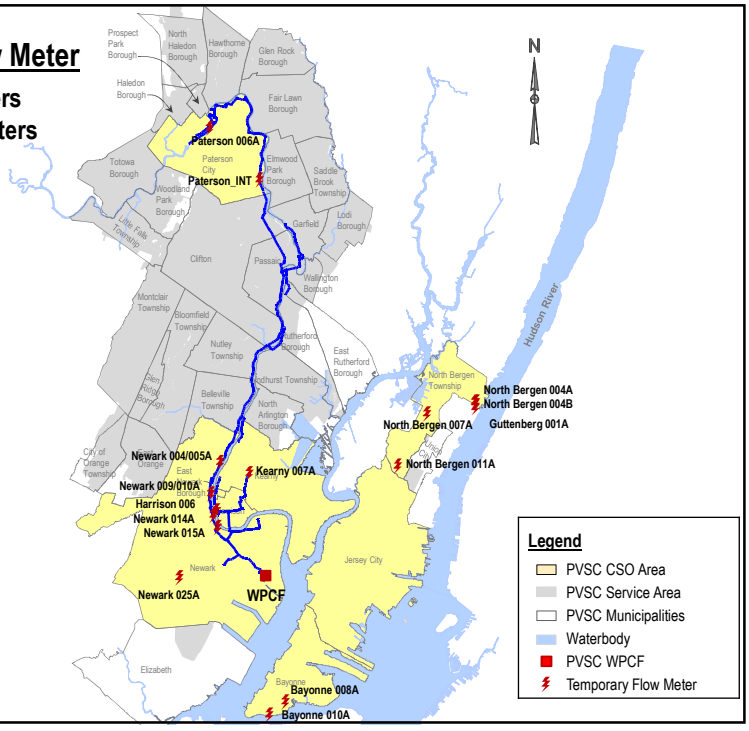
- Flow Monitoring Data
  - Temporary Flow Meter
  - Permanent Meter Data
- Rainfall Data
  - Rainfall Stations
  - Rainfall Data Analysis
- Calibration Event

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Temporary Flow Meter

Temporary Flow Meter

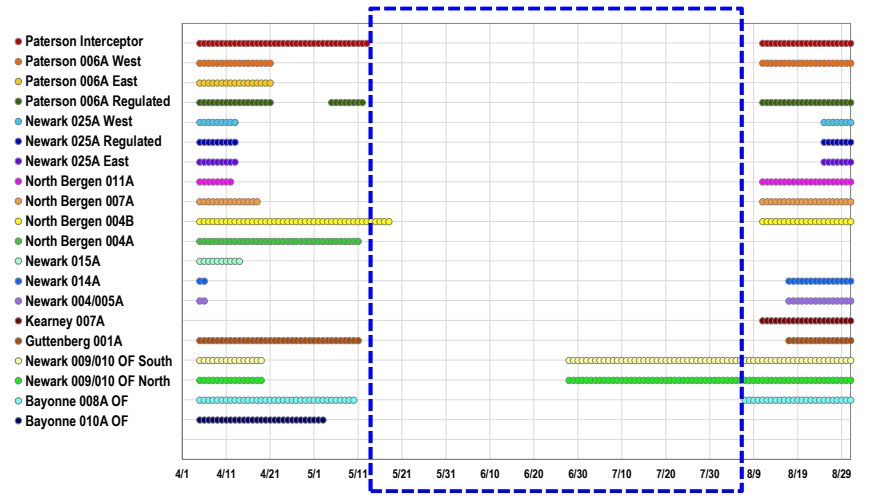
- 21 Flow Meters
- 3 Inclinometers



Meter Summary Table

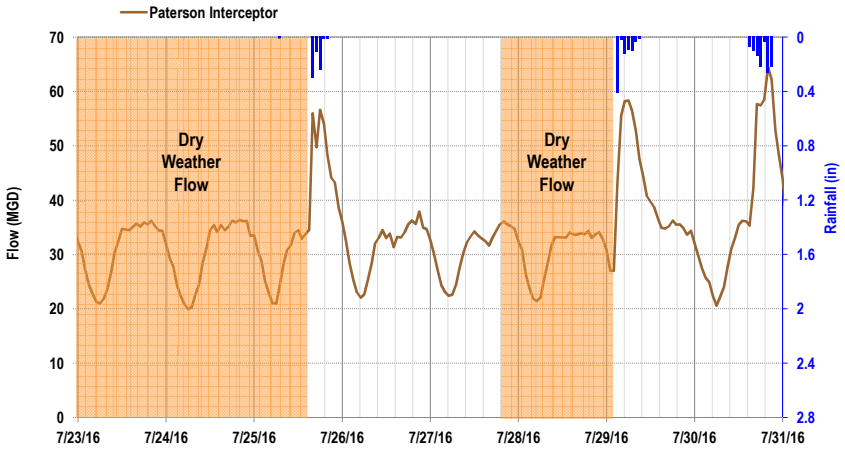
Meter ID	Municipality	Location	Category
Bayonne 008A OF	Bayonne	East 5th and Ingham Ave	Outfall
Bayonne 010A OF	Bayonne	W 1st and Avenue C	Outfall
Guttenberg 001A	Guttenberg	70th and JFK Blvd	Outfall
Harrison 006 Influent	Harrison	Bergen and Dey	Regulator Influent
Kearny 007A	Kearny	King and Ivy Street	Outfall
Newark 004/005A	Newark	Herbert Place under elevated Hwy	Outfall
Newark 009/010 OF North	Newark	Clay Street - inside facility	Outfall
Newark 009/010 OF South	Newark	Clay Street - inside facility	Outfall
Newark 015A	Newark	City Dock	Outfall
Newark 014A	Newark	Saybrook in pull off	Outfall
Newark 025A East	Newark	Peddie - access through parking, near railroad	Regulator Influent
Newark 025A West	Newark	Peddie - access through parking, near railroad	Regulator Influent
Newark 025A Regulated	Newark	Peddie - access through parking, near railroad	Regulator Effluent
North Bergen 004A	North Bergen	73td and Hudson County 693	Outfall
North Bergen 004B	North Bergen	Near 74th and Hudson County in grassy lot	Outfall
North Bergen 007A	North Bergen	53rd and Tonnelle Ave in Concrete Plant driveway	Outfall
North Bergen 011A	North Bergen	1101 Tonnelle Ave	Outfall
Paterson 006A East	Paterson	Montgomery and River St	Regulator Influent
Paterson 006A West	Paterson	Montgomery and River St	Regulator Influent
Paterson 006A Regulated	Paterson	Montgomery and River St	Regulator Effluent
Paterson_INT	Paterson	McLean Boulevard at Cemetary entrance	Interceptor

Missing Data Period for Each Flow Meter



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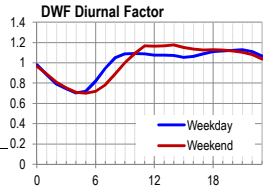
Dry Weather Flow Analysis

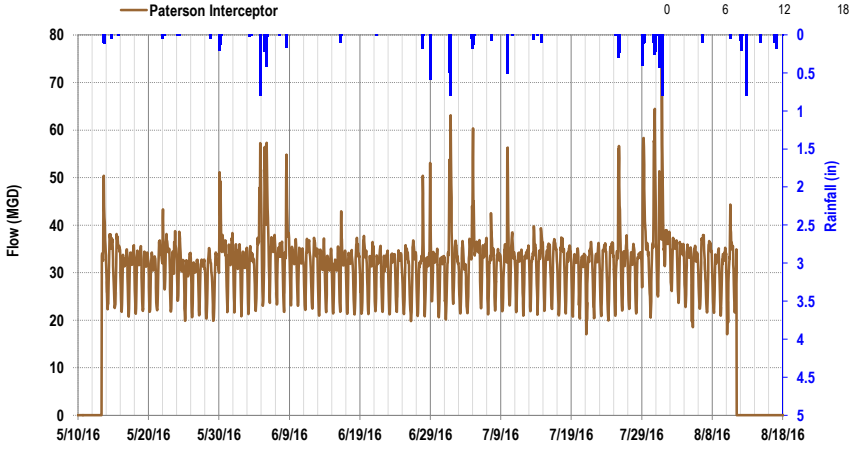


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Hydrograph

Paterson Interceptor

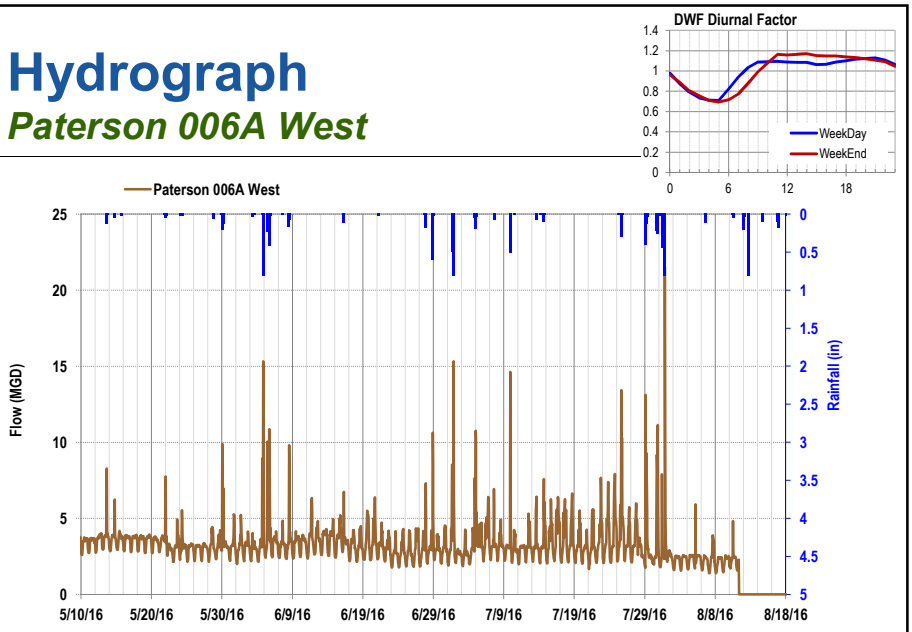




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Hydrograph

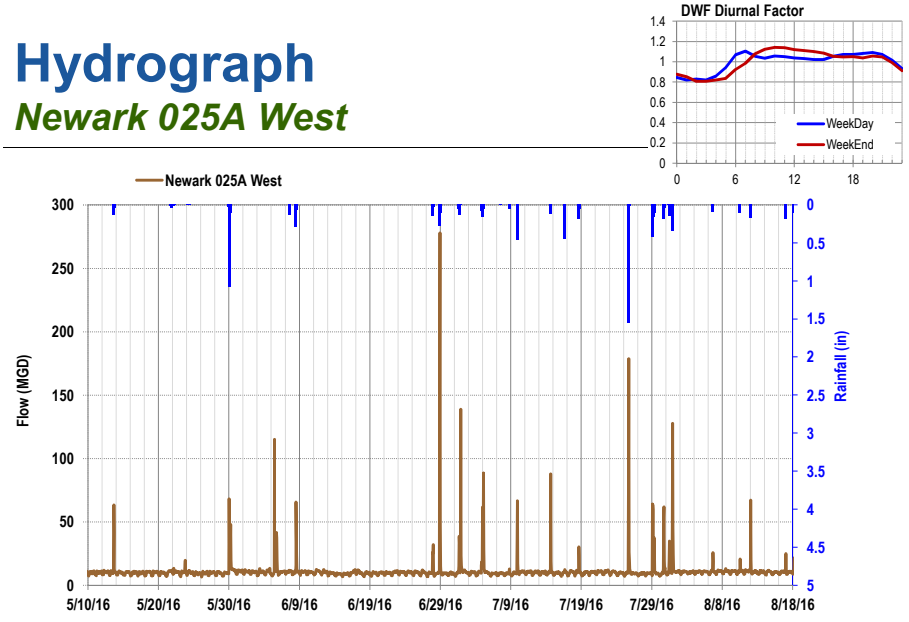
Paterson 006A West



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Hydrograph

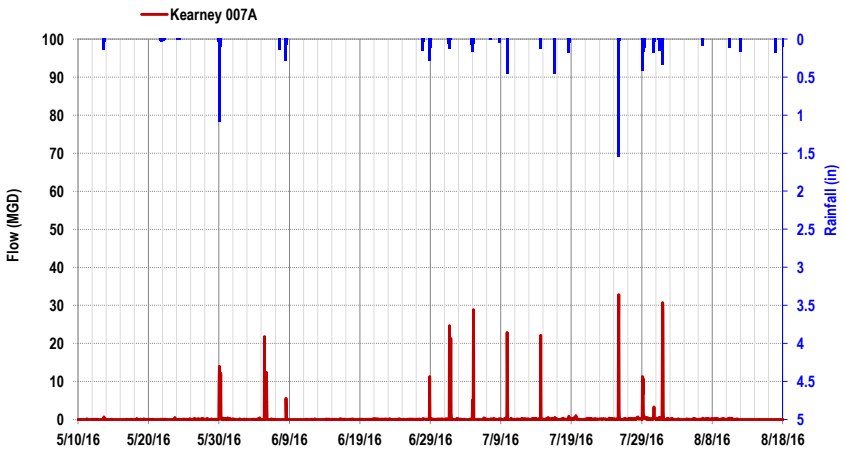
Newark 025A West



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Hydrograph

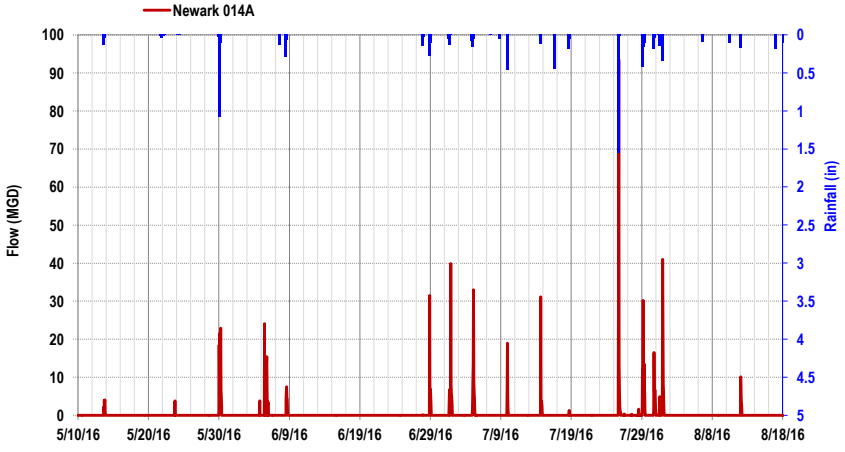
Kearny 007A Overflow



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Hydrograph

Newark 014A Overflow



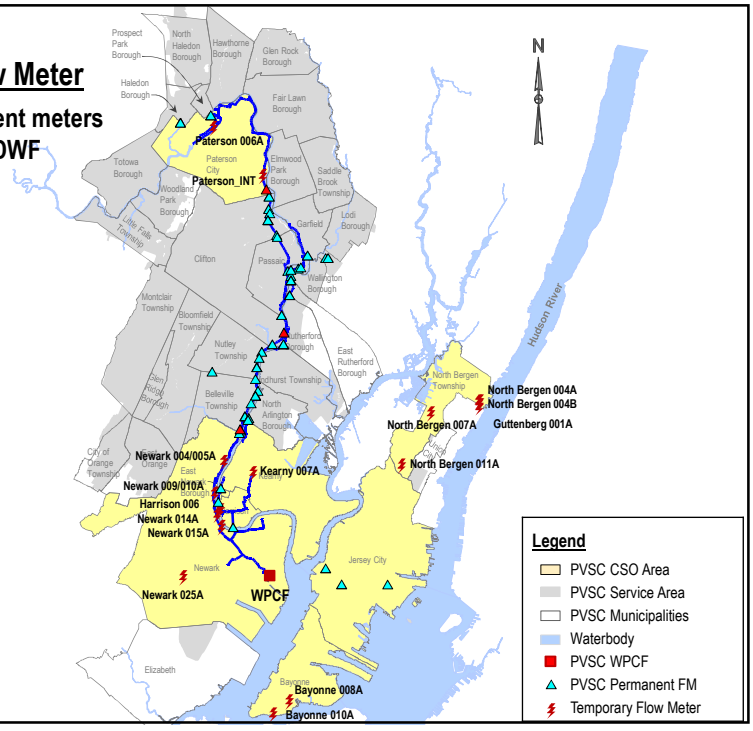
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GREELEY AND HANSEN

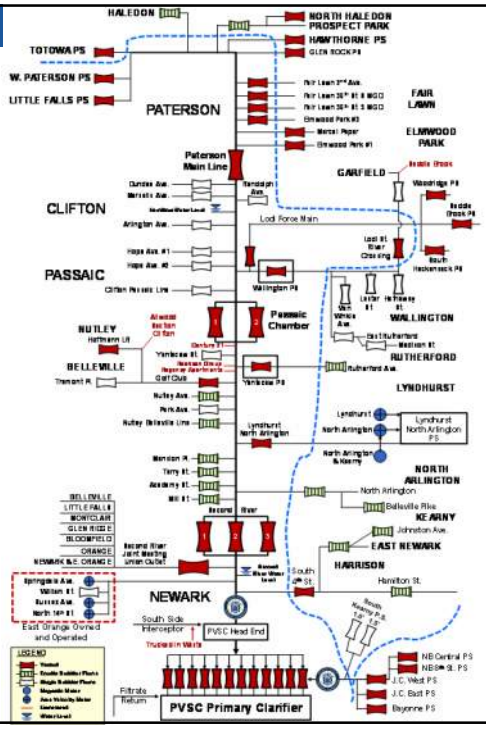
Permanent Flow Meters

PVSC Map
Permanent Flow Meter

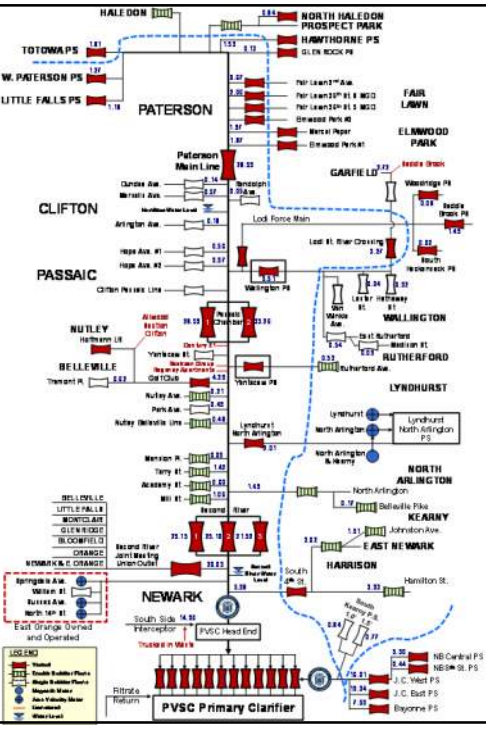
- Over 70 permanent meters
- 58 analyzed for DWF



Flow Meter Diagram

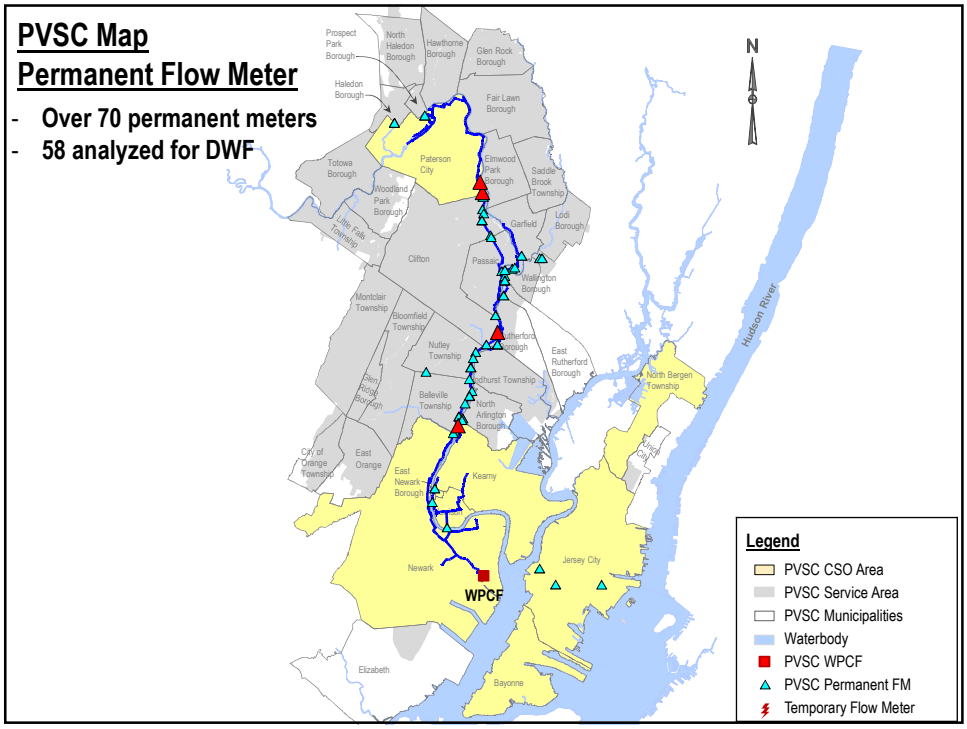


Flow Meter Diagram
Dry Weather Flow (MGD)



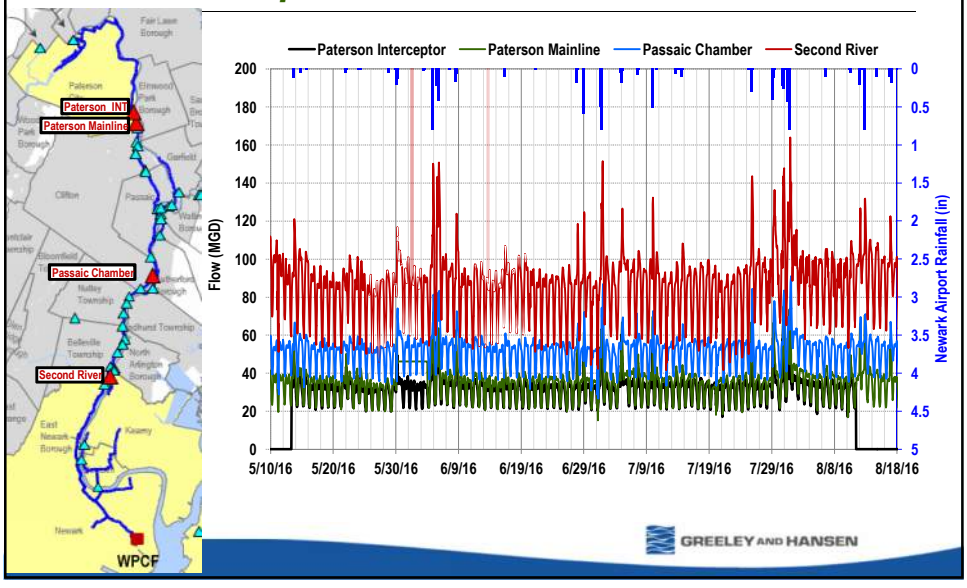
PVSC Map
Permanent Flow Meter

- Over 70 permanent meters
- 58 analyzed for DWF



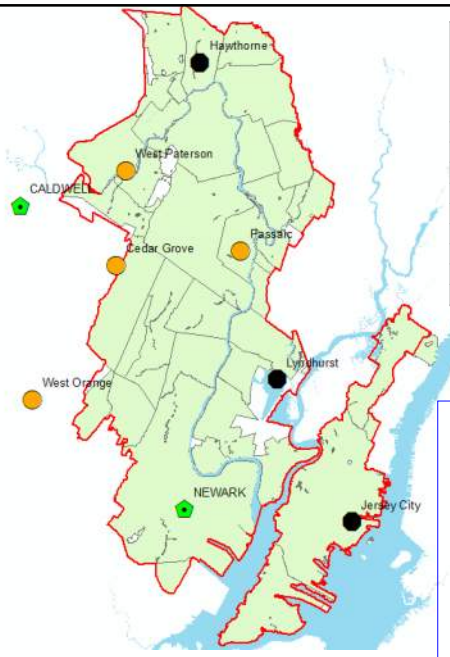
Hydrograph

Main Interceptor Meters

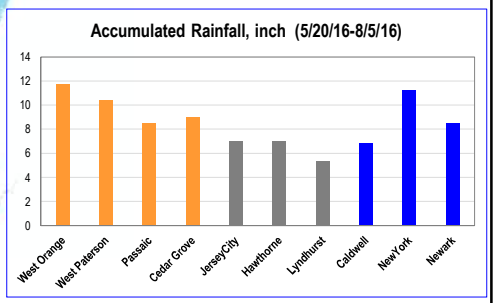


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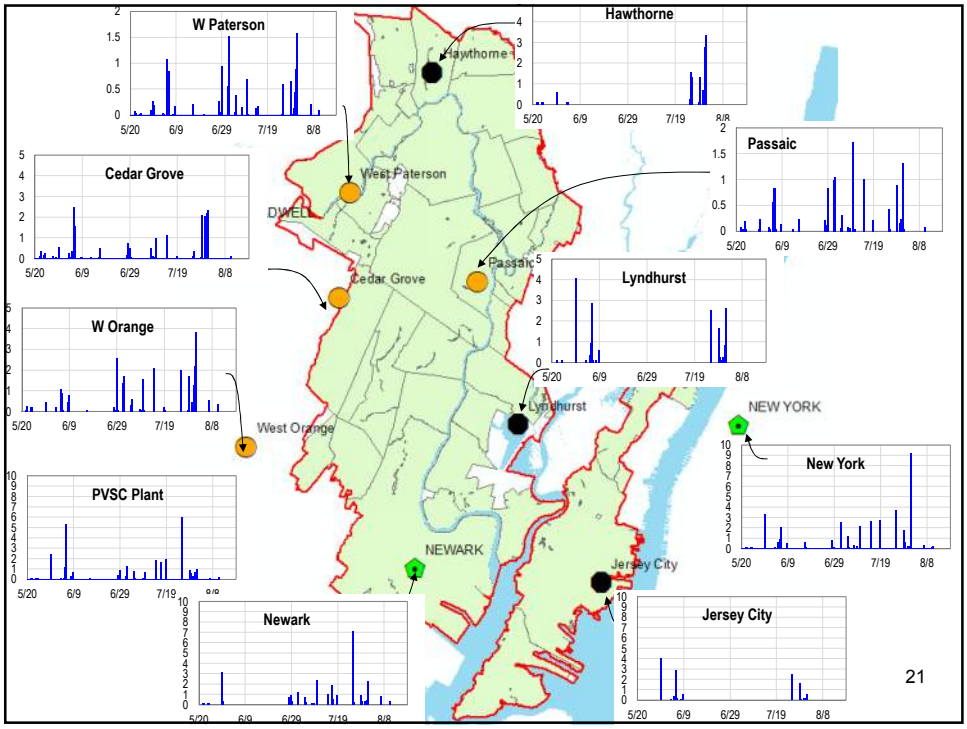
Rainfall Data Analysis



Rain Gauge Summary			
Source	RG ID	Data Time Interval (Min.)	Total Rainfall (5/20/16-8/05/16)
NJ Weather	Hawthorne	5	6.97
NJ Weather	Lyndhurst	5	5.39
NJ Weather	jersey City	5	7.04
CWOP	West Paterson	30	10.4
CWOP	Passaic	15	8.46
CWOP	Cedar Grove	10-50	8.98
CWOP	West Orange	10	11.72
NWS ASOS	Caldwell	1	6.84
NWS ASOS	New York	1	11.23
NWS ASOS	Newark	1	8.47



20



Candidate Storm Events for Calibration

Rain Start	Rain End	Duration (hr)	Depth (in)	Max Intensity (in/hr)	Average Intensity (in/hr)
7/25/16 16:05	7/25/16 18:50	2.75	**1.81**	1.68	0.66
5/29/16 23:50	5/30/16 5:20	5.50	**1.6**	1.09	0.29
7/29/16 0:20	7/29/16 8:35	8.25	**0.85**	0.42	0.10
5/2/16 22:40	5/3/16 9:50	11.17	**0.7**	0.17	0.06
7/31/16 8:35	7/31/16 22:35	14.00	**0.69**	0.49	0.05
7/4/16 19:20	7/5/16 2:50	7.50	**0.63**	0.23	0.08
5/6/16 2:30	5/6/16 12:25	9.92	**0.6**	0.19	0.06
7/16/16 14:50	7/16/16 15:35	0.75	**0.56**	0.75	0.75
6/8/16 11:25	6/8/16 14:10	2.75	**0.49**	0.3	0.18
7/9/16 21:30	7/9/16 22:05	0.58	**0.48**	0.82	0.82
4/4/16 7:45	4/4/16 17:00	9.25	**0.43**	0.12	0.05

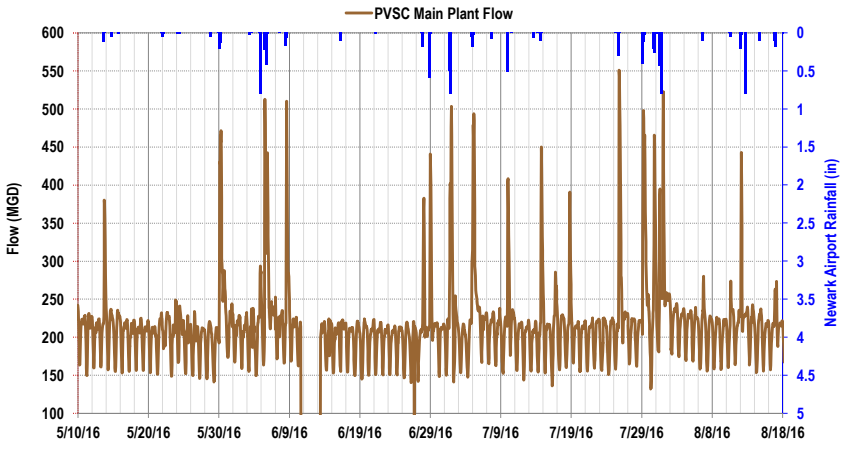
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Discussion

Hydrograph

PVSC Main Plant Flow



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PVSC – Long Term Control Plan
Modeling Evaluation Group – Session 3

Hydrologic and Hydraulic Model Update and Calibration

Greeley and Hansen LLC
September 15, 2017

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Agenda

- Background: PVSC Sewer System
- PVSC Hydrologic and Hydraulic (H&H) Model Snapshot
- H&H Model Update
- H&H Model Calibration and Validation
- Summary & Next Step

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Background

Sewer Systems

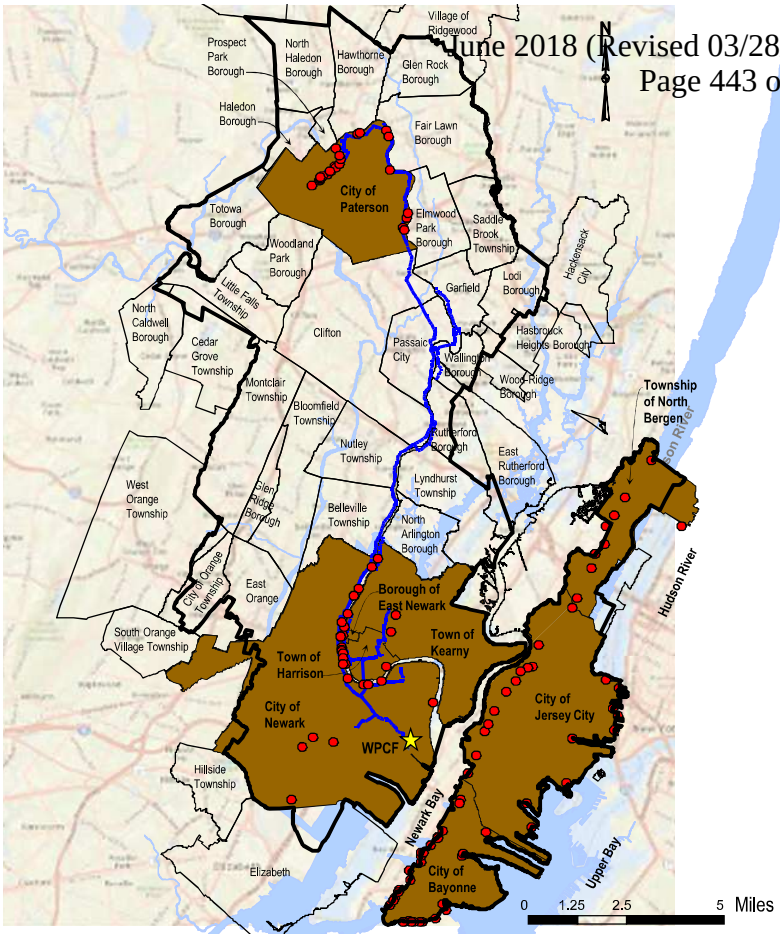
- Passaic Valley Sewerage Commission
  - 48 municipalities
    - 8 CSO municipalities (0.9 million residents)
  - 1.5 million residents
  - 147 mi² service area
  - 22 mile interceptor sewer
  - 330 mgd WPCF
- NBMUA Woodcliff WWTP
  - 2 CSO municipalities
  - 3 mgd Woodcliff WWTP
  - 477 acres (368 acres in North Bergen)



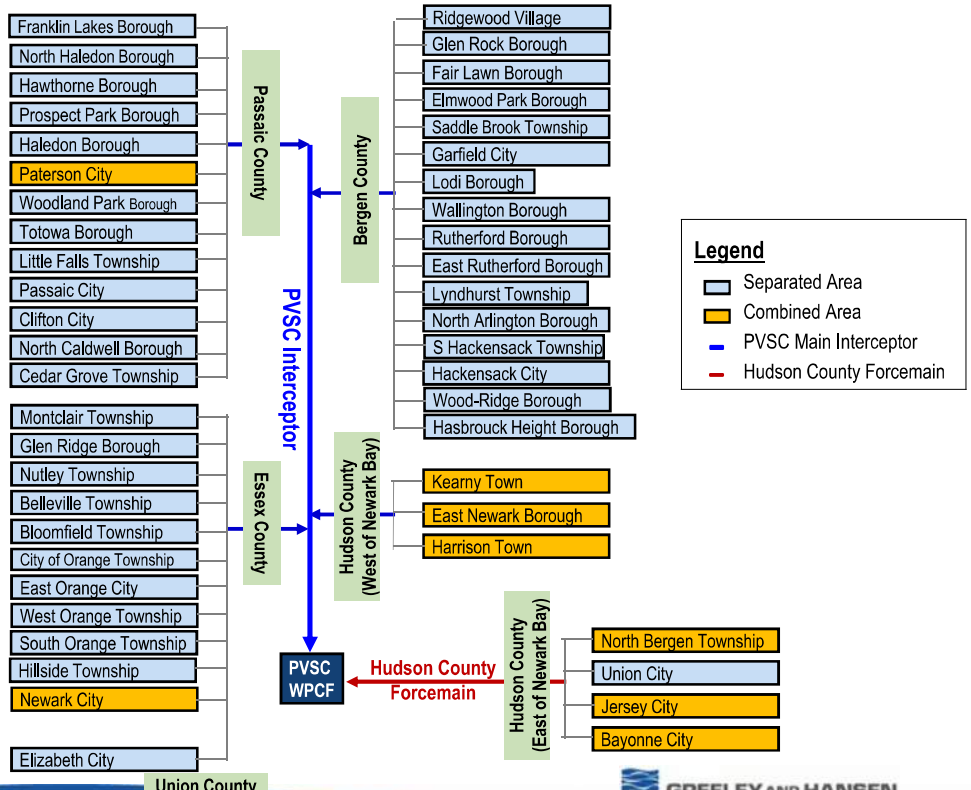
PVSC Service Area

Legend

- PVSC Service Area
- CSO Communities
- Separated Communities
- PVSC WPCF (Water Pollution Control Facility)
- PVSC Interceptor / Sewer
- CSO Outfall

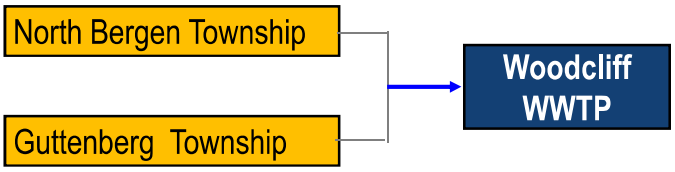


PVSC WPCF Schematic



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NBMUA Woodcliff WWTP Schematic



CSO Communities

Municipality	WWTP	Population	Area (mi²)	Sewerage (miles)	CSOs
Bayonne	PVSC	63,000	5.8	94	30
East Newark		2,400	0.1	2	1
Harrison		13,600	1.3	18	7
Jersey City		247,600	14.8	230	21
Kearny		40,700	6.5	52	5
Newark		277,100	22.3	579	18
North Bergen		52,600	4.5	59	7
Paterson		146,200	8.7	164	23
Guttenberg	NBMUA	11,200	0.2	5	1
North Bergen		8,200	0.7	8	1
Total		**862,600**	**84**	**1,211**	**114**

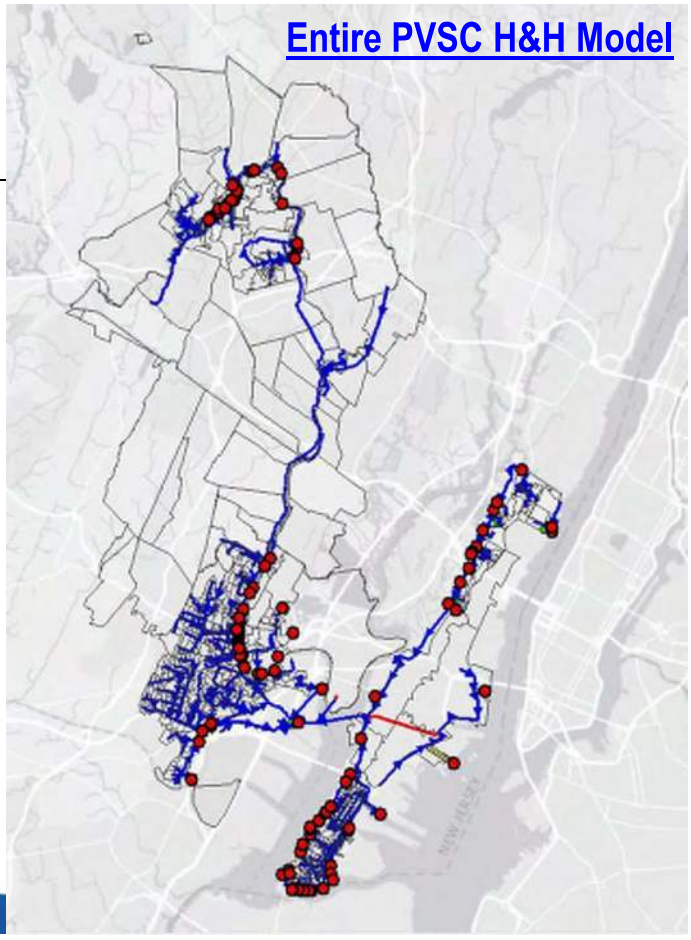
GREELEY AND HANSEN

Current H&H Model Snapshots

9

Entire PVSC H&H Model

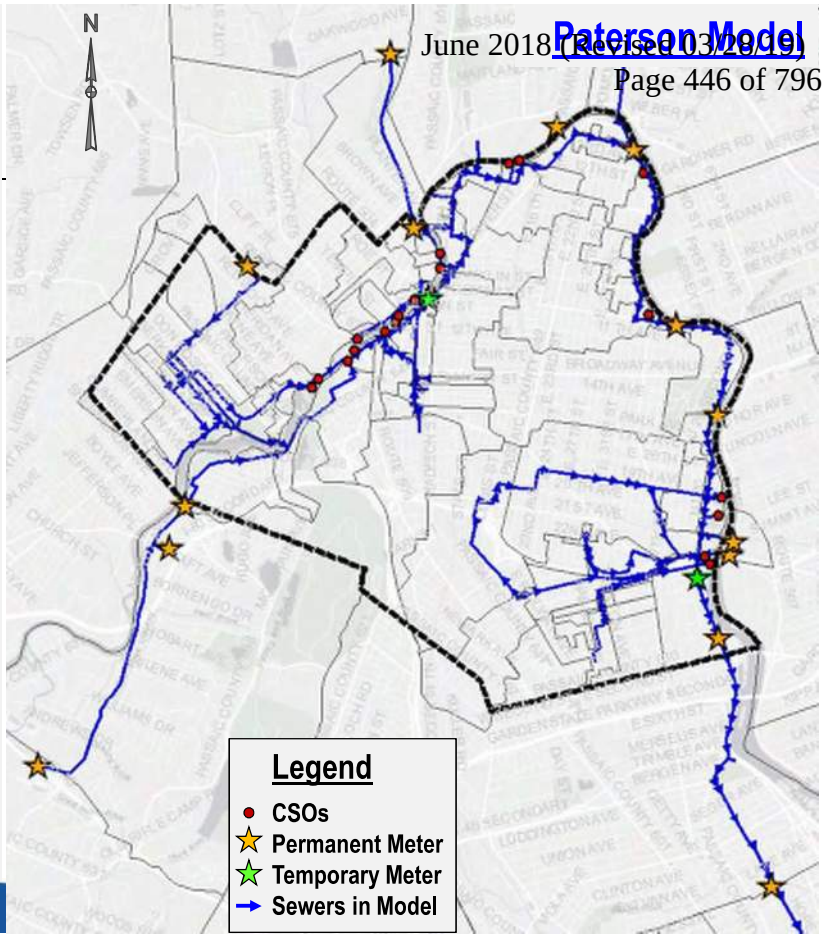
- Subcatchment: 732
- Nodes (2735)
  - Manhole: 2621
  - Outfall: 103
  - Storage: 11
- Link (2873)
  - Conduit: 2567
  - Flap Valve: 82
  - Orifice: 33
  - Pump: 14
  - Sluice: 74 (30 variable)
  - Weir: 103



10

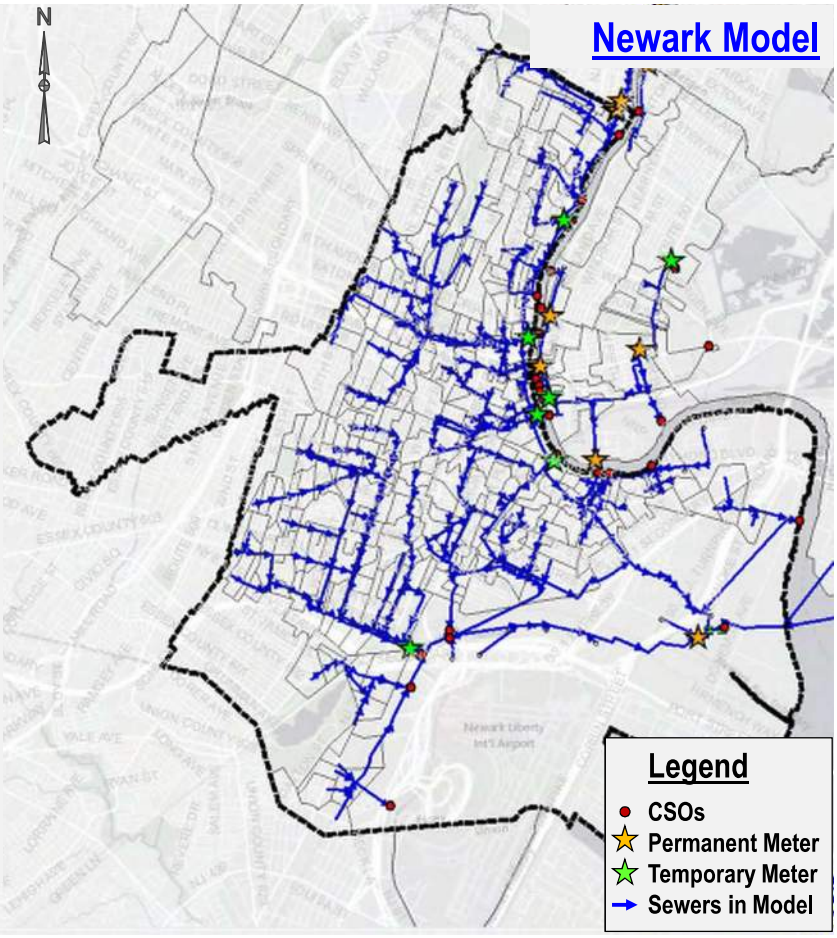
Paterson Model

- Subcatchment: 67
- Nodes (585)
  - Manhole: 562
  - Outfall: 23
  - Storage: 0
- Link (657)
  - Conduit: 503
  - Flap Valve: 82
  - Orifice: 14
  - Pump: 0
  - Sluice: 16 (2 variable)
  - Weir: 42



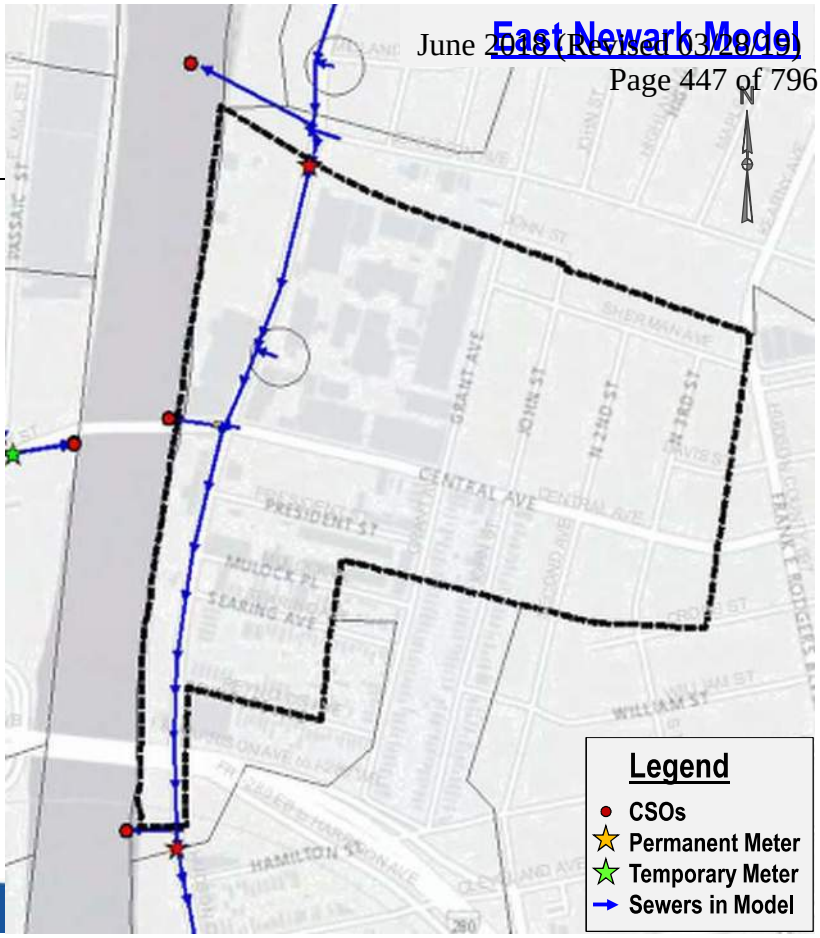
Newark Model

- Subcatchment: 310
- Nodes (758)
  - Manhole: 738
  - Outfall: 18
  - Storage: 2
- Link (819)
  - Conduit: 746
  - Flap Valve: 17
  - Orifice: 3
  - Pump: 3
  - Sluice: 27 (17 variable)
  - Weir: 23



East Newark Model

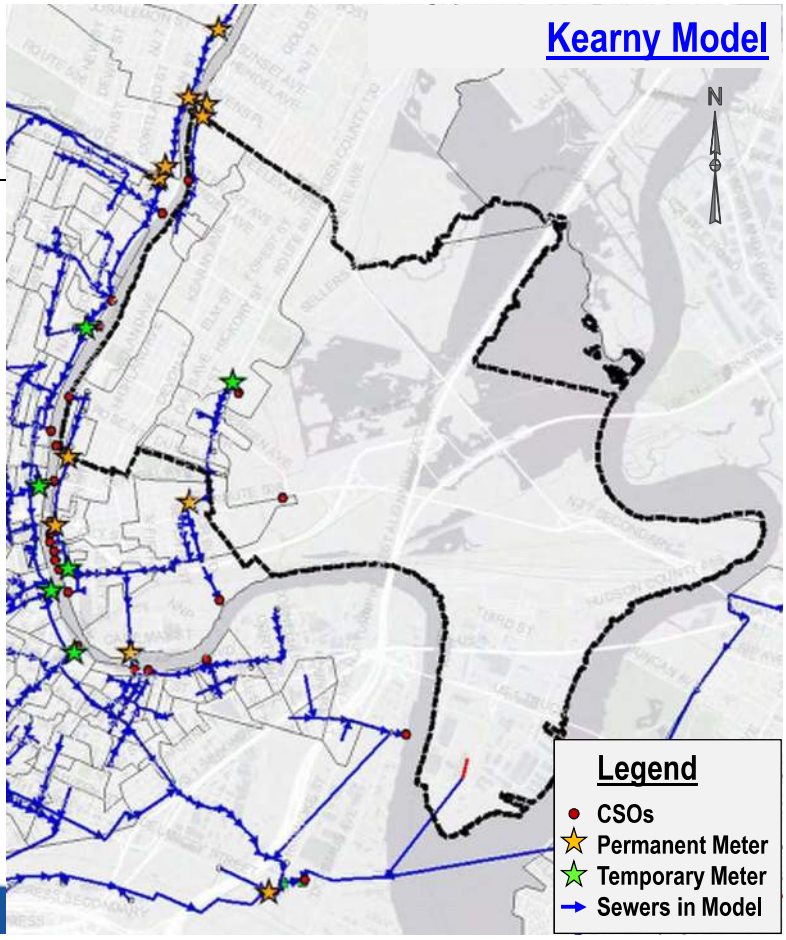
- Subcatchment: 1
- Nodes (22)
  - Manhole: 21
  - Outfall: 1
  - Storage: 20
- Link (22)
  - Conduit: 19
  - Flap Valve: 1
  - Orifice: 1
  - Pump: 0
  - Sluice: 0
  - Weir: 1



13

Kearny Model

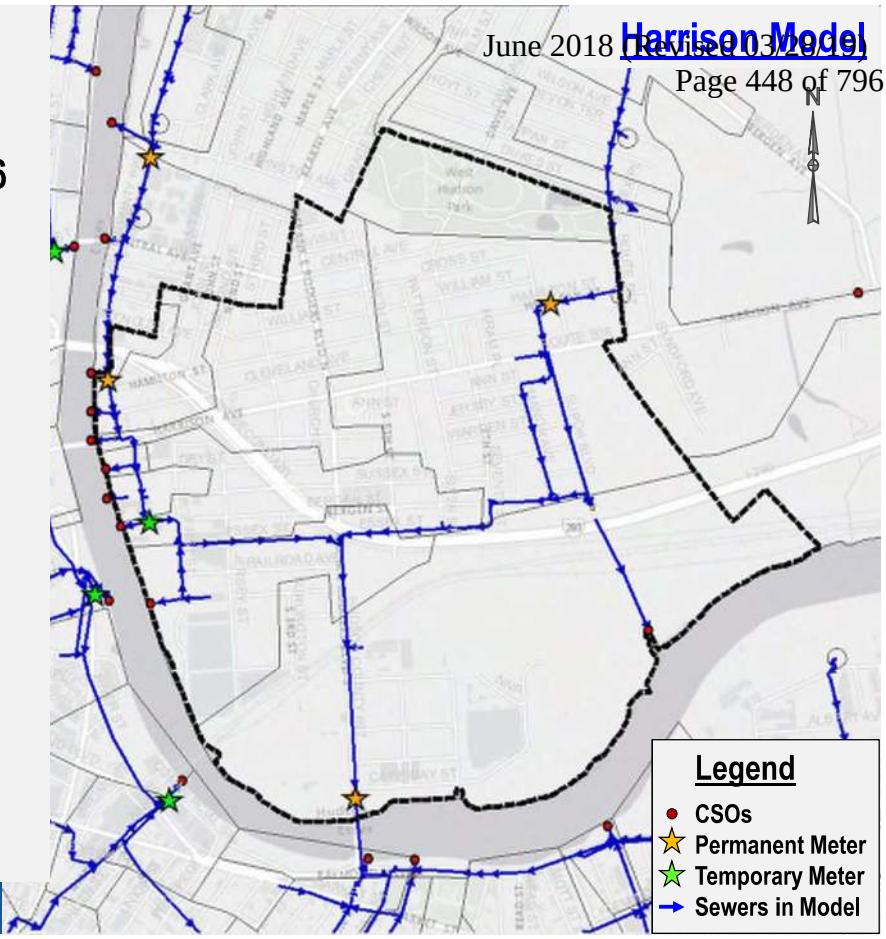
- Subcatchment: 16
- Nodes (97)
  - Manhole: 91
  - Outfall: 5
  - Storage: 1
- Link (97)
  - Conduit: 78
  - Flap Valve: 5
  - Orifice: 7
  - Pump: 1
  - Sluice: 1
  - Weir: 5



14

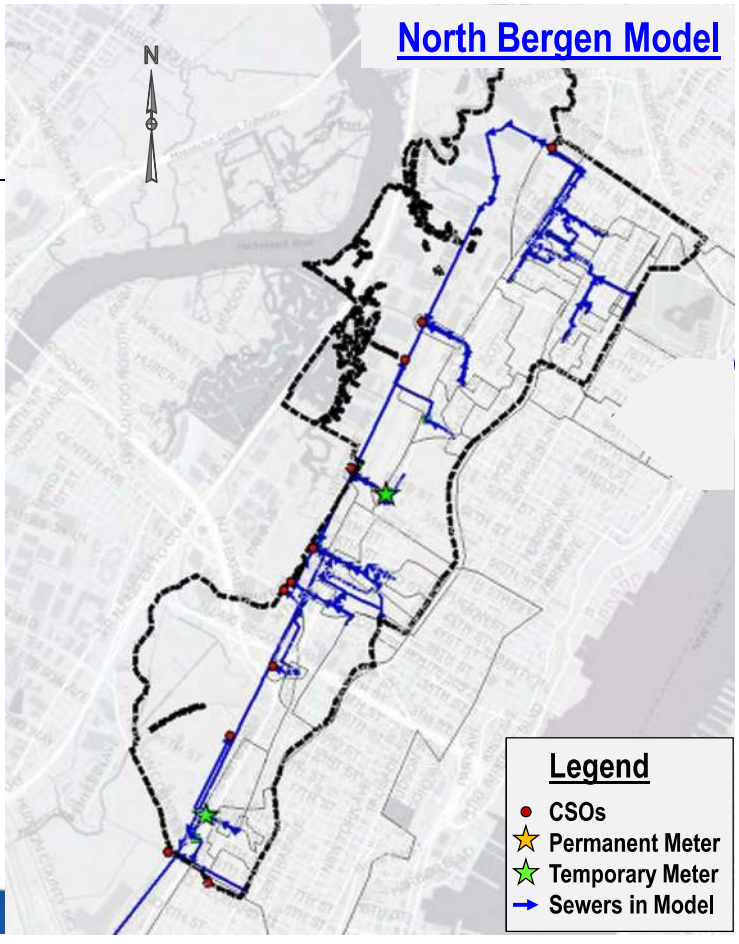
Harrison Model

- Subcatchment: 16
- Nodes (117)
  - Manhole: 110
  - Outfall: 7
  - Storage: 0
- Link (118)
  - Conduit: 97
  - Flap Valve: 7
  - Orifice: 7
  - Pump: 0
  - Sluice: 0
  - Weir: 7



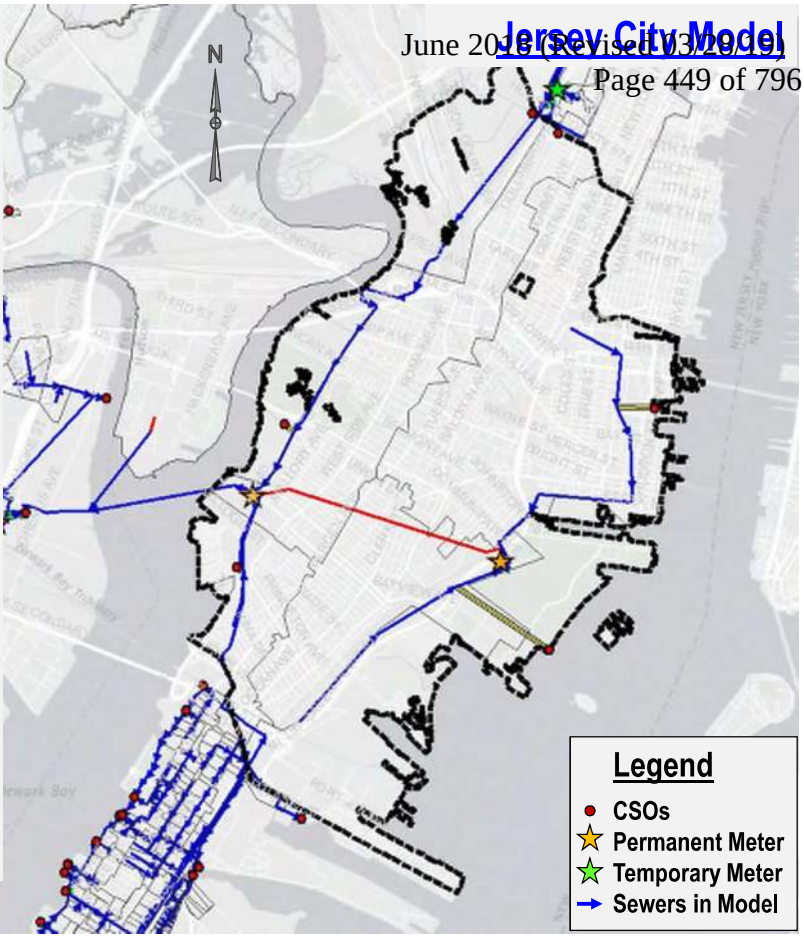
North Bergen Model

- Subcatchment: 41
- Nodes (178)
  - Manhole: 166
  - Outfall: 9
  - Storage: 3
- Link (199)
  - Conduit: 183
  - Flap Valve: 0
  - Orifice: 0
  - Pump: 3
  - Sluice: 5
  - Weir: 8



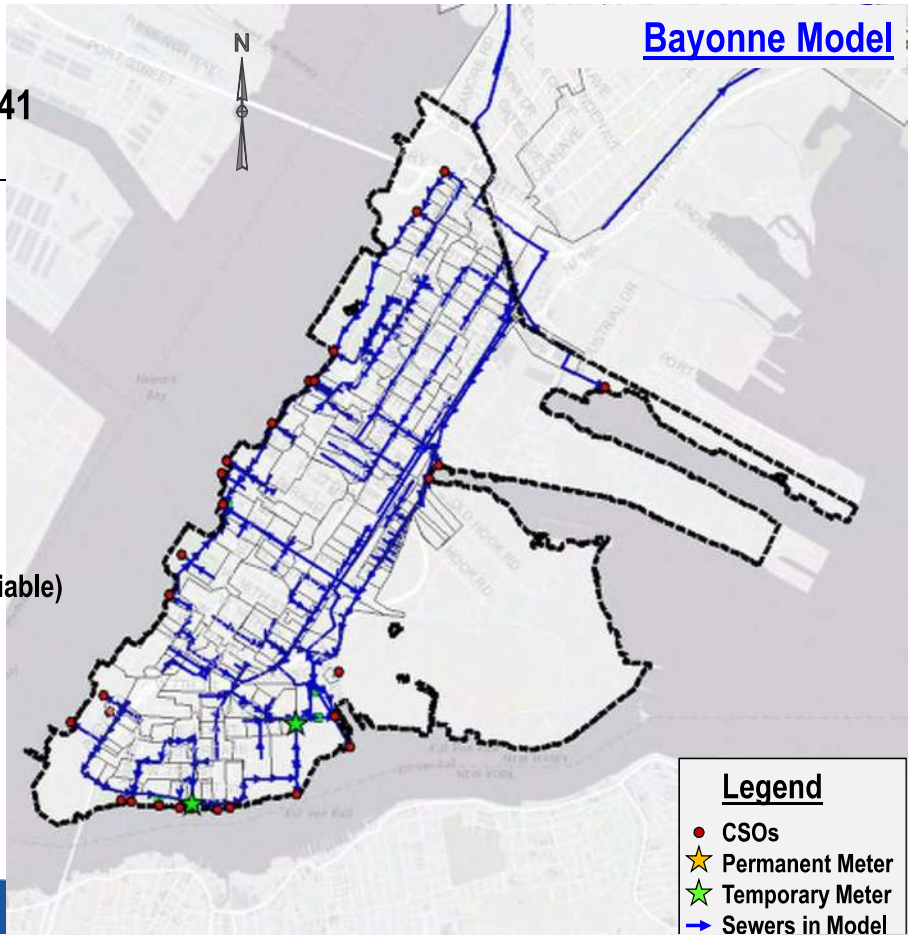
Jersey City Model

- Subcatchment: 5
- Nodes (34)
  - Manhole: 29
  - Outfall: 5
  - Storage: 0
- Link (36)
  - Conduit: 24
  - Flap Valve: 5
  - Orifice: 0
  - Pump: 2
  - Sluice: 5
  - Weir: 0



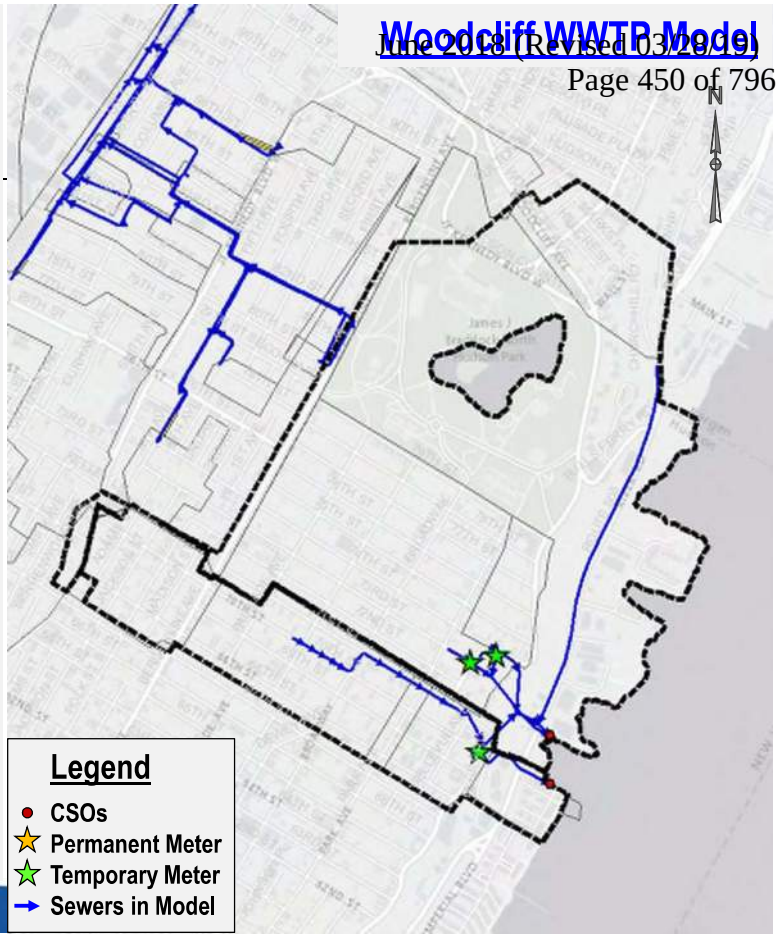
Bayonne Model

- Subcatchment: 41
- Nodes (685)
  - Manhole: 651
  - Outfall: 29
  - Storage: 5
- Link (712)
  - Conduit: 648
  - Flap Valve: 27
  - Orifice: 0
  - Pump: 5
  - Sluice: 20 (11 variable)
  - Weir: 12



Woodcliff WWTP Model

- Subcatchment: 5
- Nodes (38)
  - Manhole: 35
  - Outfall: 2
  - Storage: 1
- Link (39)
  - Conduit: 37
  - Flap Valve: 0
  - Orifice: 0
  - Pump: 0
  - Sluice: 1
  - Weir: 1



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Model Update

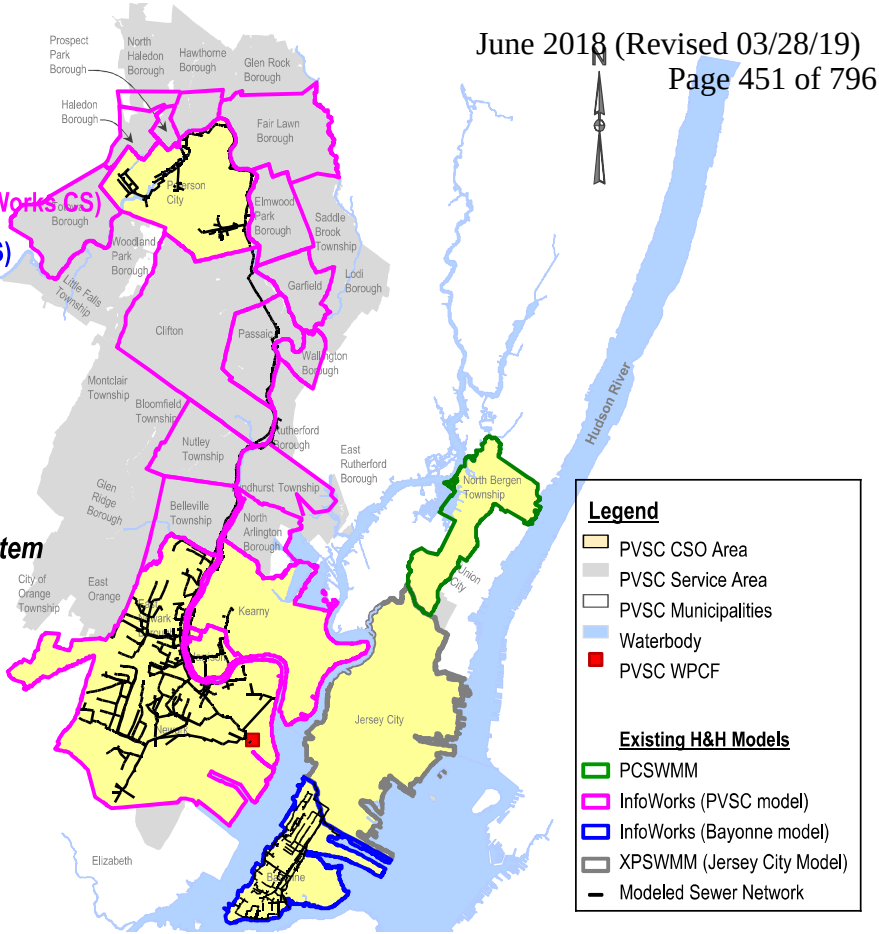
Existing Models

PVSC WPCF System

- PVSC Interceptor Model (InfoWorks CS)
- Bayonne Model (InfoWorks CS)
- North Bergen Model
  (2 PCSWMM model)
- Jersey City Model
  (XPSWMM model)

NBMUA Woodcliff WWTP System

- North Bergen Model
  (1 PCSWMM model)
- Guttenberg Model
  (1 PCSWMM model)



North Bergen Models

- North Bergen
  - Najarian Associates
  - 3 PCSWMM Models
  - LTCP Team has model
  - Converted to EPA SWMM for CSO Alert System

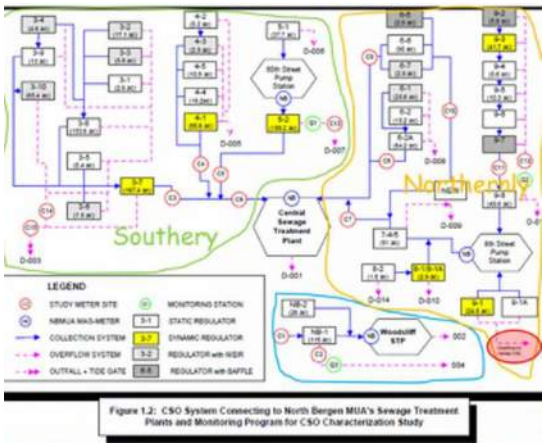


Figure 1.2: CSO System Connecting to North Bergen MUA's Sewage Treatment Plants and Monitoring Program for CSO Characterization Study

Bayonne Models

- Bayonne
  - HDR
  - InfoWorks CS
  - LTCP Team has model
  - Used for CSO Alert System



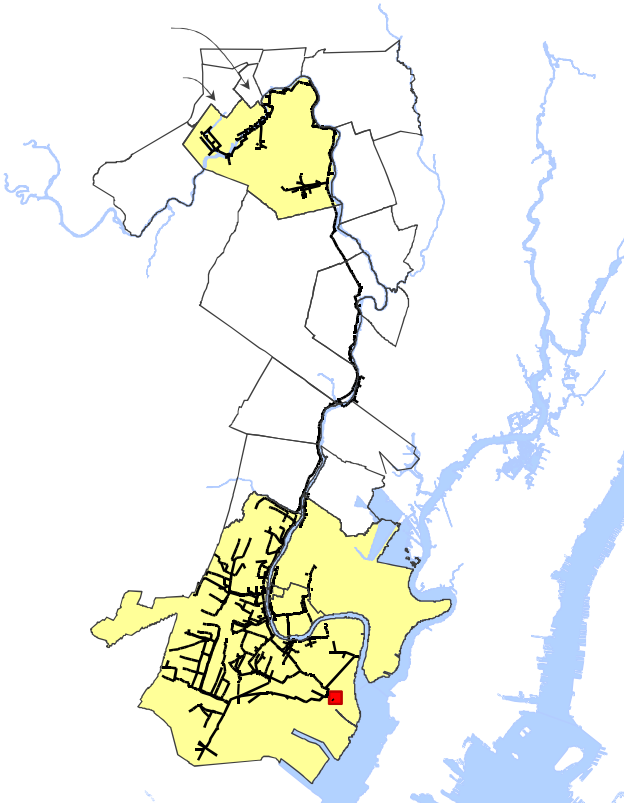
Jersey City Models

- Jersey City
  - ARCADIS
  - XPSWMM
  - LTCP Team does not have model
  - Model results provided by ARCADIS for CSO Alert System



PVSC Main Interceptor Model

- **Large, Complex System**
  - Main interceptor
  - Seven branch interceptors
  - Combined and separate sewers
  - Regulators
  - RTC
  - Pump stations
  - River crossings
  - Treatment plant



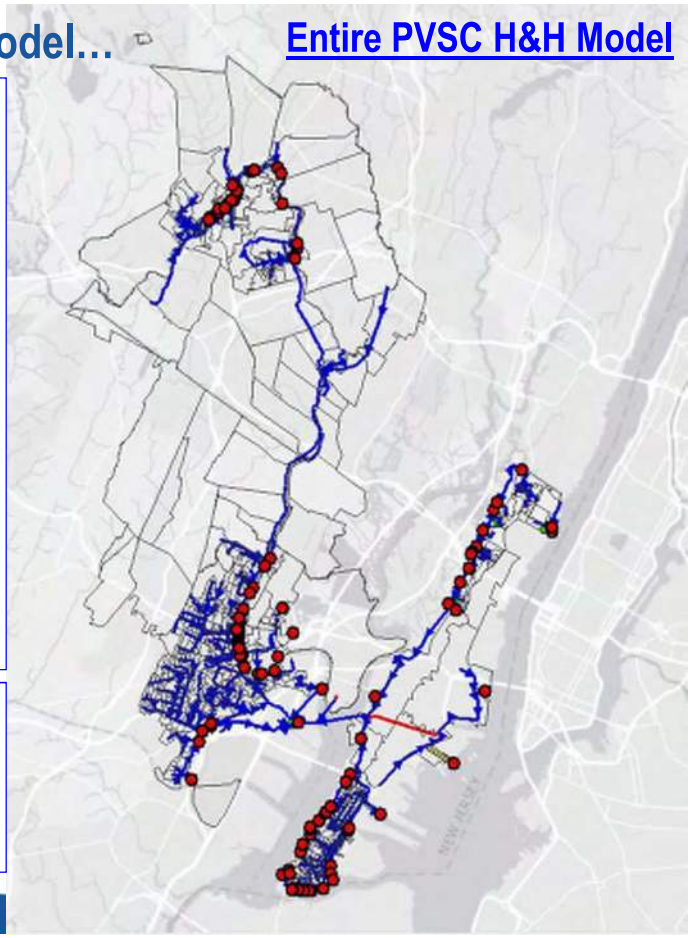
A Snapshot of Integrated Model…

Entire PVSC H&H Model

- ❑ **48 PVSC communities**
- ❑ **8 CSO communities**
  - ✓ Paterson
  - ✓ Newark
  - ✓ East Newark
  - ✓ Harrison
  - ✓ Kearny

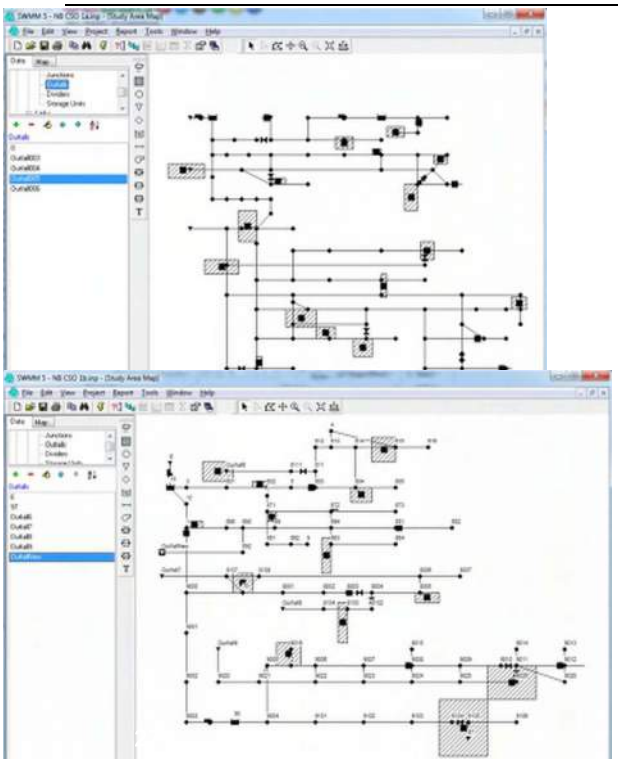
  (Above 5 discharge to interceptor by gravity to WPCF)
  - ✓ Bayonne
  - ✓ Jersey City
  - ✓ North Bergen

  (Above 3 discharge to Hudson County Forcemain to WPCF)
- ❑ **2 NBMUA Woodcliff WWTP CSO communities**
  - ✓ North Bergen
  - ✓ Guttenberg



Model Integration

Recreate North Bergen Model from PCSWMM

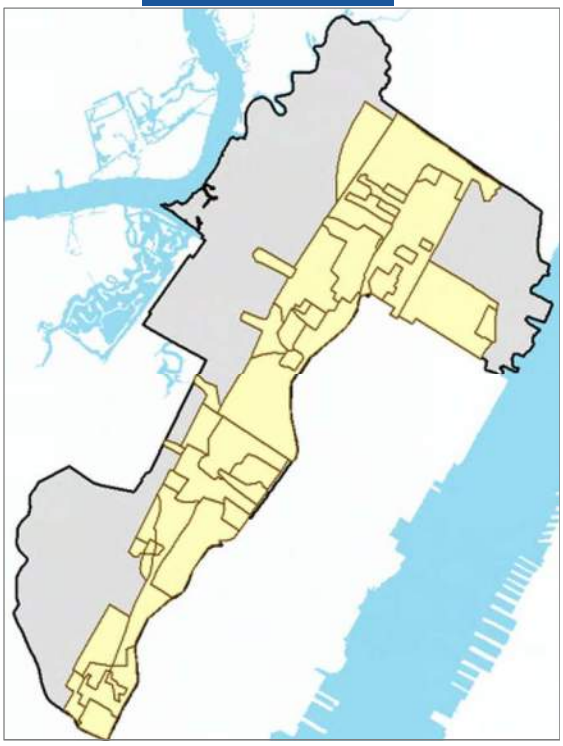




NB Delineation

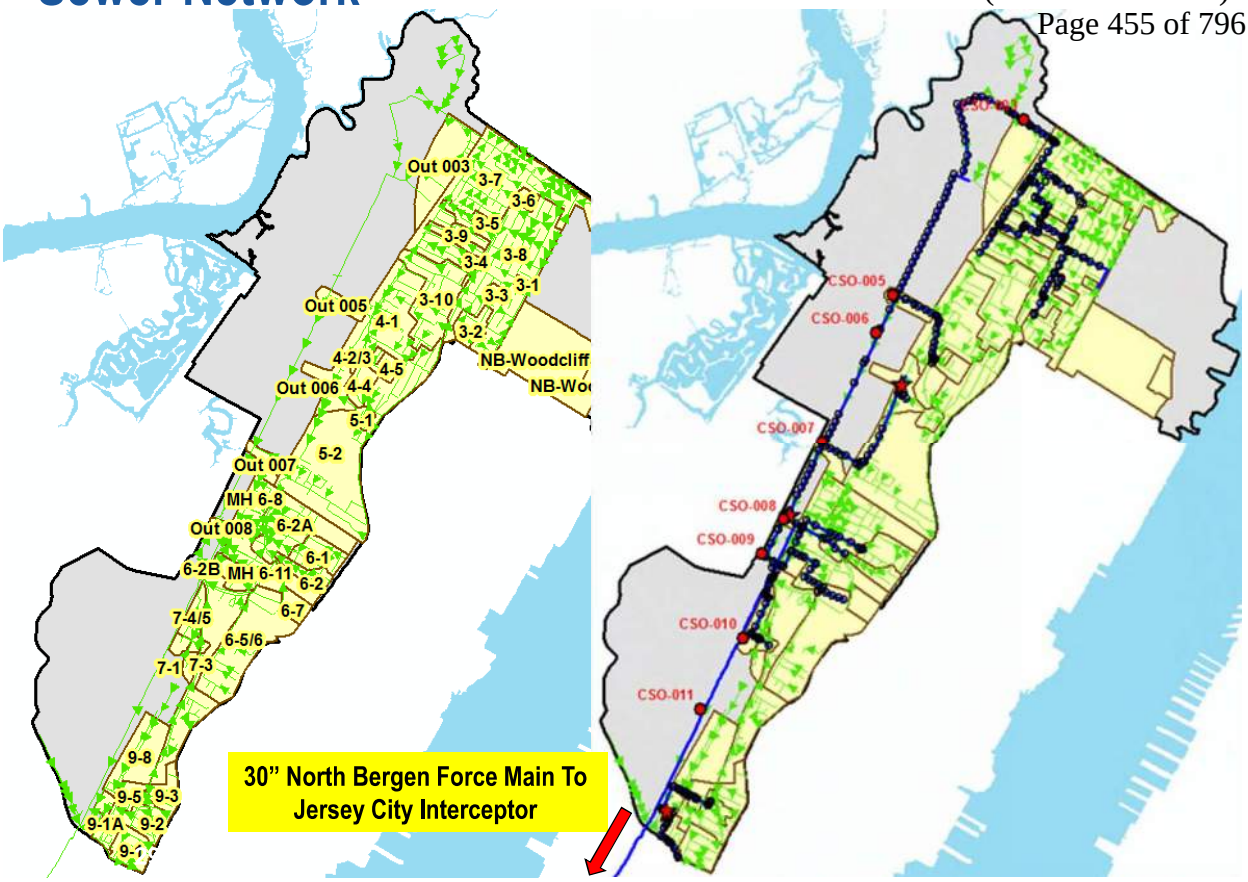
Paper Copy → **GIS Shapefile**



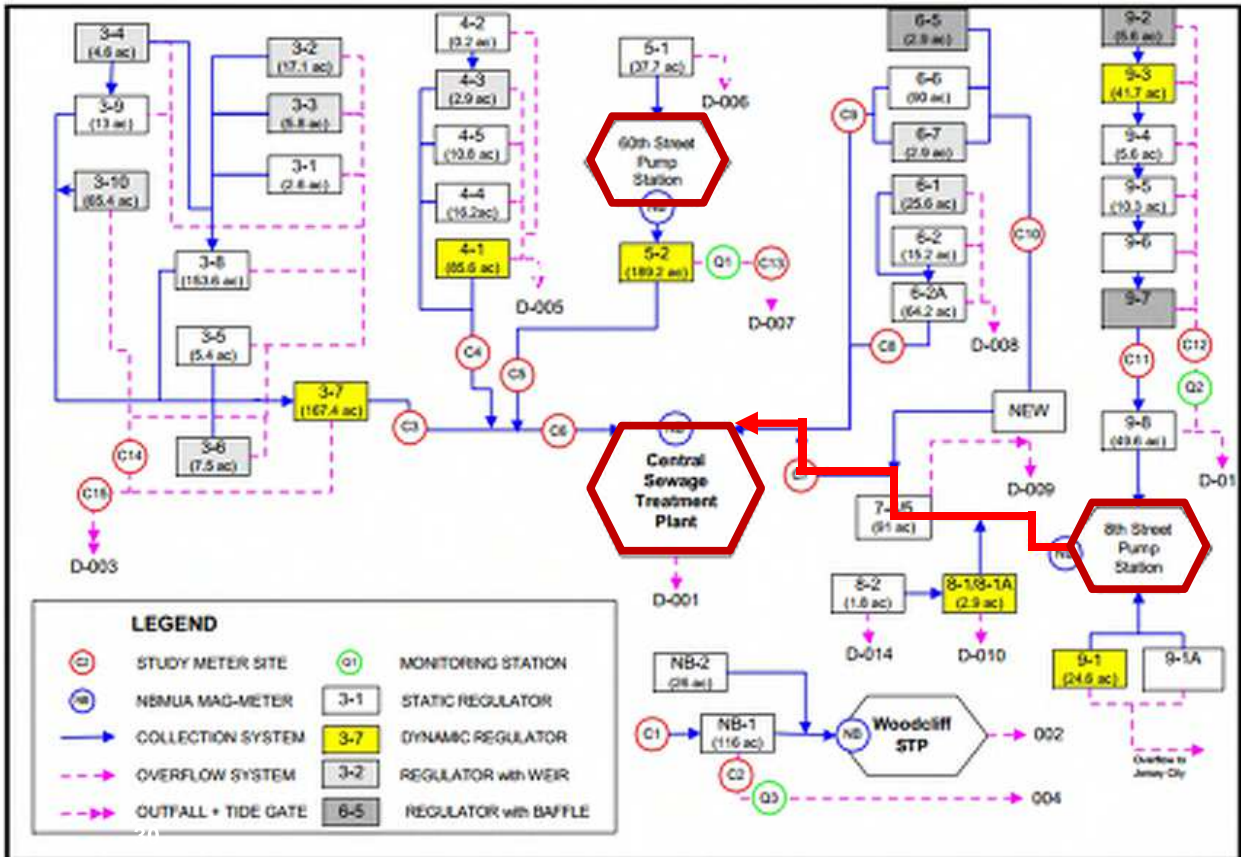


❑ ***Digitize model subcatchment based on paper copy***

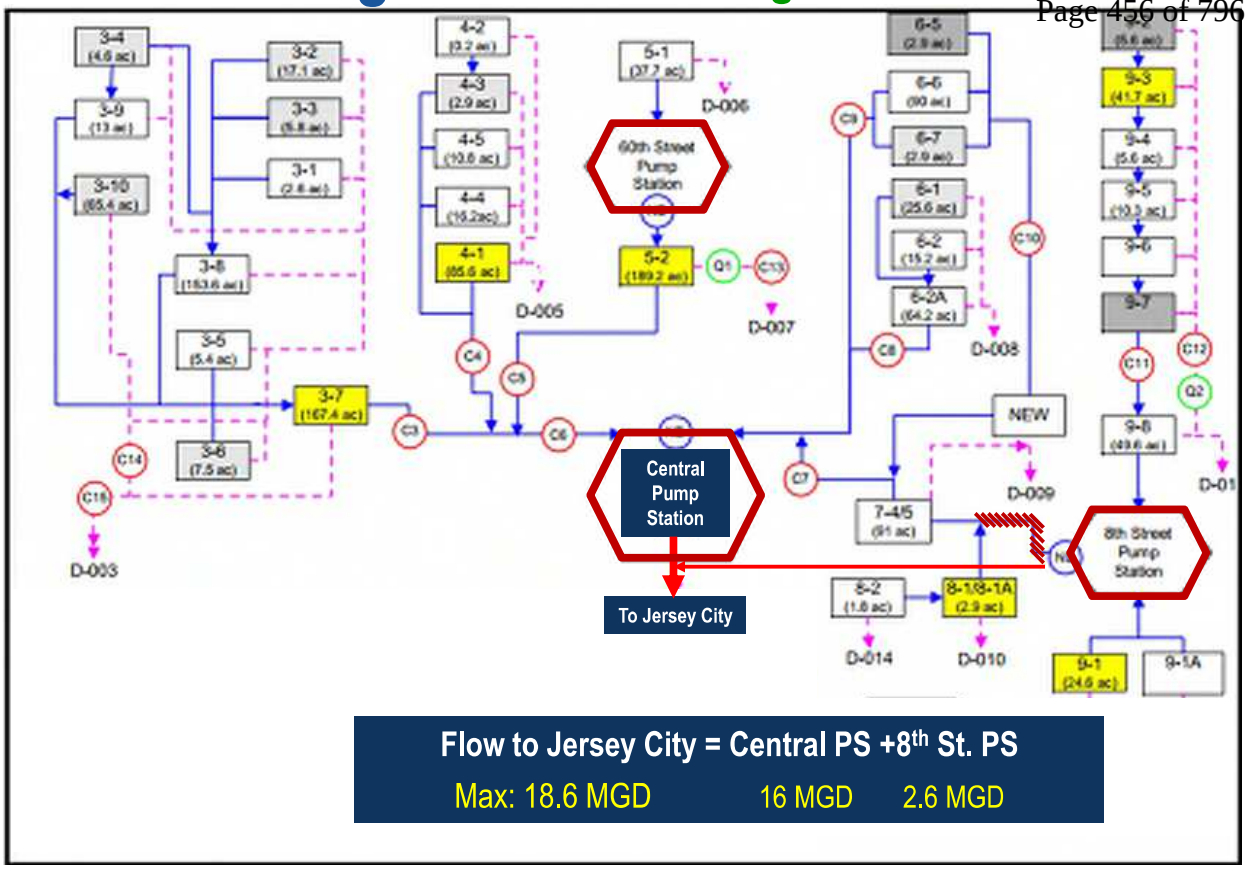
Sewer Network



Model Integration/*North Bergen Model*



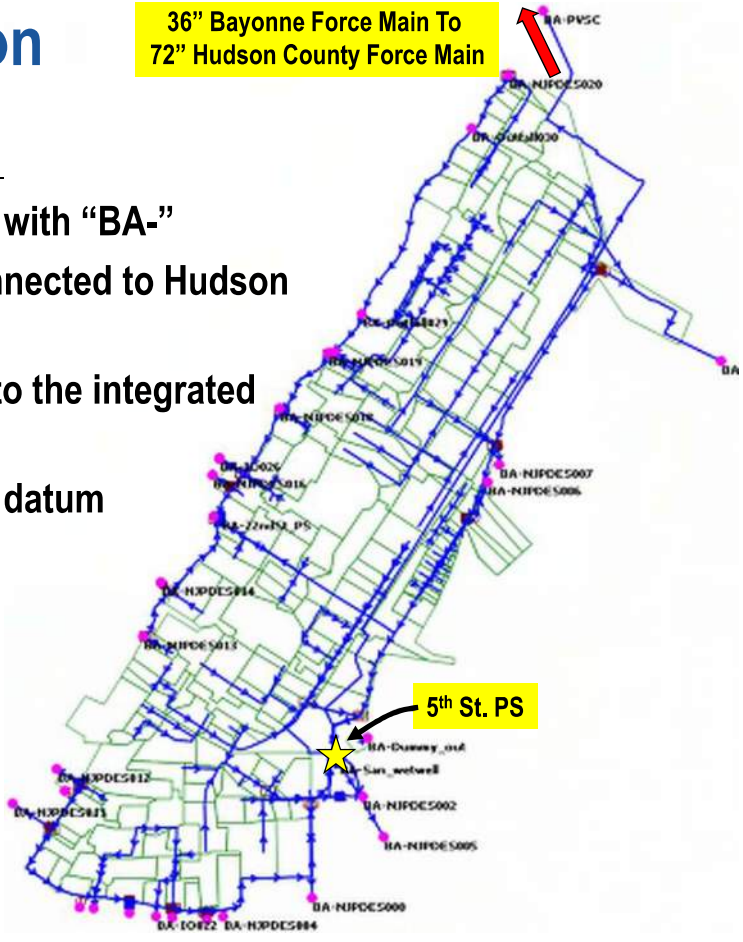
Model Integration/*North Bergen Model*



Model Integration

Bayonne Model

- With unique IDs starting with "BA-"
- Bayonne force main Connected to Hudson County Force Main
- 11 RTC rules appended to the integrated model
- Datum updated to PVSC datum



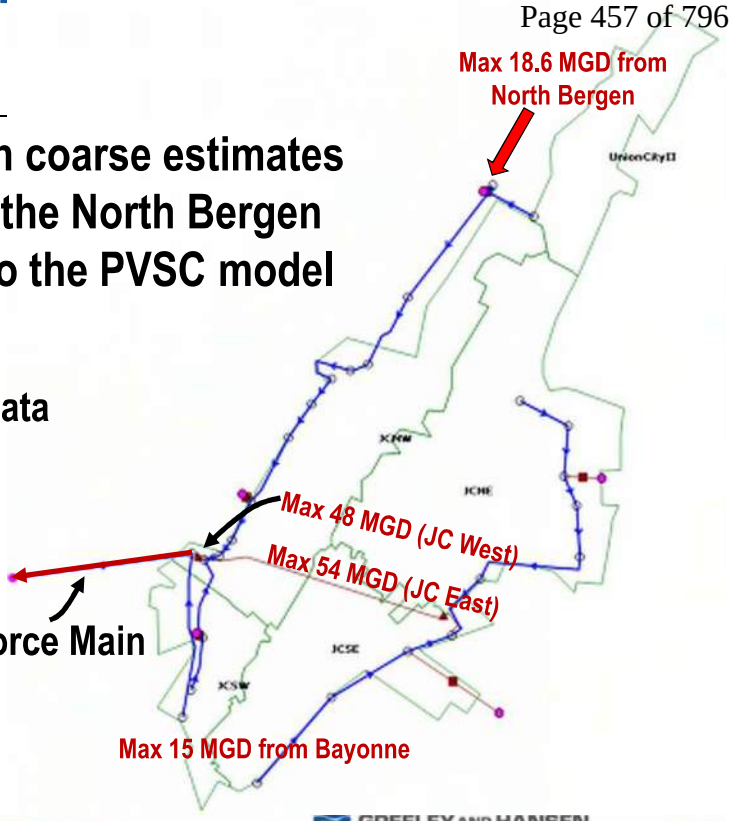
Model Integration

Jersey City Model

- **Model was created with coarse estimates to allow connection of the North Bergen and Bayonne models to the PVSC model**

Max pump rate based on data

Jersey City East: Peak 54 MGD
Jersey City West: Peak 48 MGD



Flows in Hudson County Force Main

- Jersey City East: Peak 54 MGD
- Jersey City West: Peak 48 MGD
- Bayonne: Peak 15 MGD

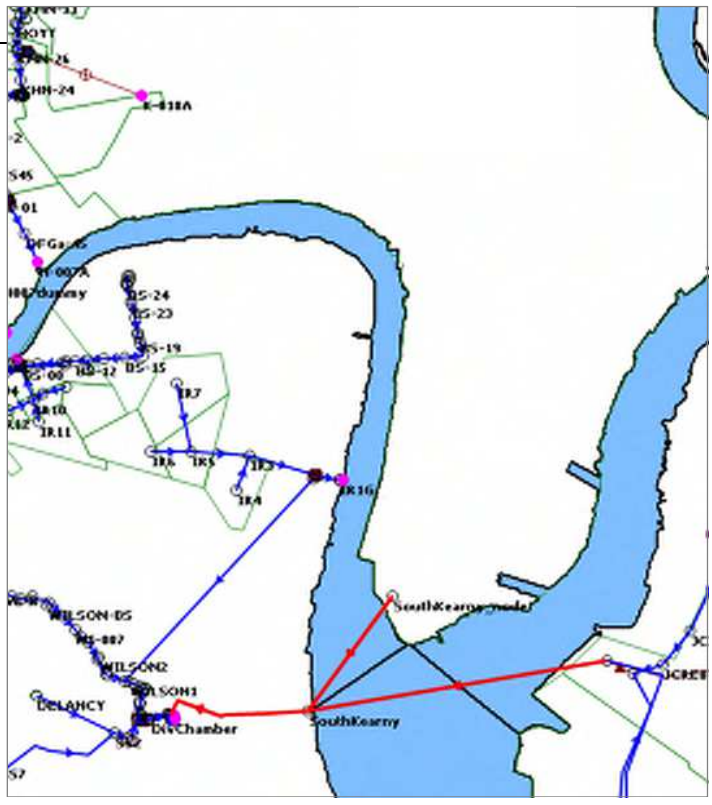
Total Maximum: 117 MGD

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Model Integration

Force Mains

- **Hudson County Force Main was extended to the PVSC WPCF based on drawings**
- **South Kearny PS 30” force main was created and tied into the Hudson County Force Main**

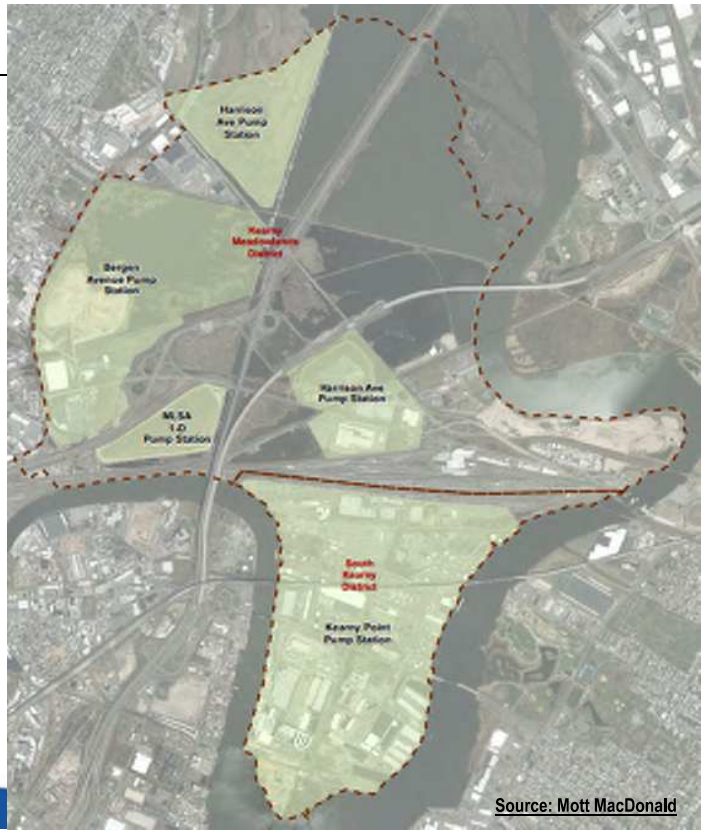


South Kearny Pump Station Service Area

- Kearny Meadowlands District
- South Kearny District
- Both Separated

South Kearny Pump Station

- Capacity: 17.5 MGD
- DWF: 1.6 MGD



Source: Mott MacDonald

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Regulator Update

Regulator Modification

Regulator	Overflow Weir				Regulating Sluice Gate / Orifice					
	Drawing		Original Model		Drawing			Original Model		
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height
P_015A	152.9	2.5	152.9	2.5	151.87	1.25		151.87	1.25	
P-001A	146.9	3.83	146.9	3.83	143.94	3	1	143.94	2.25	
P-003A	139.5	4	139.5	4	137.4	1.25		137.4	1.25	
P-005A	133.4	5	136.71	5	131.7	0.833	1.667	131.7	1.25	
P-006A	134.2	8.0	135.25	8	129.53	2		129.53	2	
P-007A	133.8	6	133.8	5	130.1	1.83	3	130.1	1.25	
P-010A	135.4	4	135.4	4	133.44	1.67	0.83	133.44	1.25	
P-010A	133.85	4	135.21	3						
P-016A (modified)	138.8	8	140.94	8.5	136.25	2.5		136.25	2.5	
P-017A	135.7	4.5	135.69	3.67	132.6	1		132.6	1	
P-032A	135.2	4	135.2	4						
P-022A	132.6	4.5	132.6	4.5	130.63	2		130.63	2	
P-021A	132.7	4.5	132.7	4.5	130.75	1		130.75	1	
P-013A	133.4	4.83	133.4	4.83	131.7	1.67	0.83	131.7	1.25	
P-014A	140.9	4.5	140.9	3	137.76	1.67	0.83	137.76	1.25	
P-023A	129.8	4.5	130.56	5	127.4	Not available	Not available	127.4	1.25	
P-024A	130.3	4.5	130.3	5	128.2	1.67	0.83	128.2	1.25	
P-025A	128.9	8.58	129.87	8.58	127.07	3	1	127.07	2	
P-026A	129.2	5.5	128.92	5.5	126.95	1.67	0.83	126.95	1.66	0.83
P-027A	131.1	7.11	131.1	4.0	129.6	3.5	1.167	129.6	3.5	2.0
					129.6	3.5	1.167	129.6	3.5	0.0

Regulator Modification

Regulator	Overflow Weir				Regulating Sluice Gate / Orifice					
	Drawing		Original Model		Drawing			Original Model		
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height
N-002A (modified, Verona)	110.43	41	103	6	102.65	2.5	2.5	99.33	2	2
N-004A/005A (modified, Herbert Pl.)	114.34	41	105.55	6.667	107.06	2	2	103.6	1.5	1.5
N-008A	103.5	6	103.5	6	100.7	1.5	1.5	100.7	1.5	1.5
N-009A	103.24	4	103.24	4	102.4	1.66	0.83	102.4	1.66	0.83
N-010A	105.12	8.42	105.12	8.42	101.24	6	3	101.24	6	3
	105.12	8.42	105.12	8.42	101.24	6	3	101.24	6	3
	105.12	8.42	105.12	8.42						
N-014A (modified, Rector)	102.56	5.5	103.66	5.5	99.97	1.5	1.5	101.07	1.5	1.5
N-014A (modified, Saybrook)	102.33	7	103.43	7	99.02	2	2	100.12	2	2
N-015A (modified)	98.67	14	98.67	14	95.67	3.5	2.5	95.67	3.5	2.5
N-016A	97.62	7	97.62	4.5	96	1.5	1.5	96	1.33	1.33
N-017A	97.8	8	97.8	7	95.2	1.5	1.5	95.35	1.33	1.33
N-018A	100.26	4	100.26	4	99	2	2	99	2	2
N-022A	98.93	6	98.93	6						
N-027A/029A	102	4.5	102	4.5	96.4	4	2.33	96.4	4	2.33
N-025A	98.6+	6	98.6	8	93	4	2.33	93	4	2.33
	98.6+	8	98.6	8						
	105.85	5	98.6	8						
	105.85	5	98.6	8						
N-030A	102.32	10	102.32	10	99.04	4	3	99.04	4	3
N-023A	98.54	7	98.54	7						

Regulator Modification

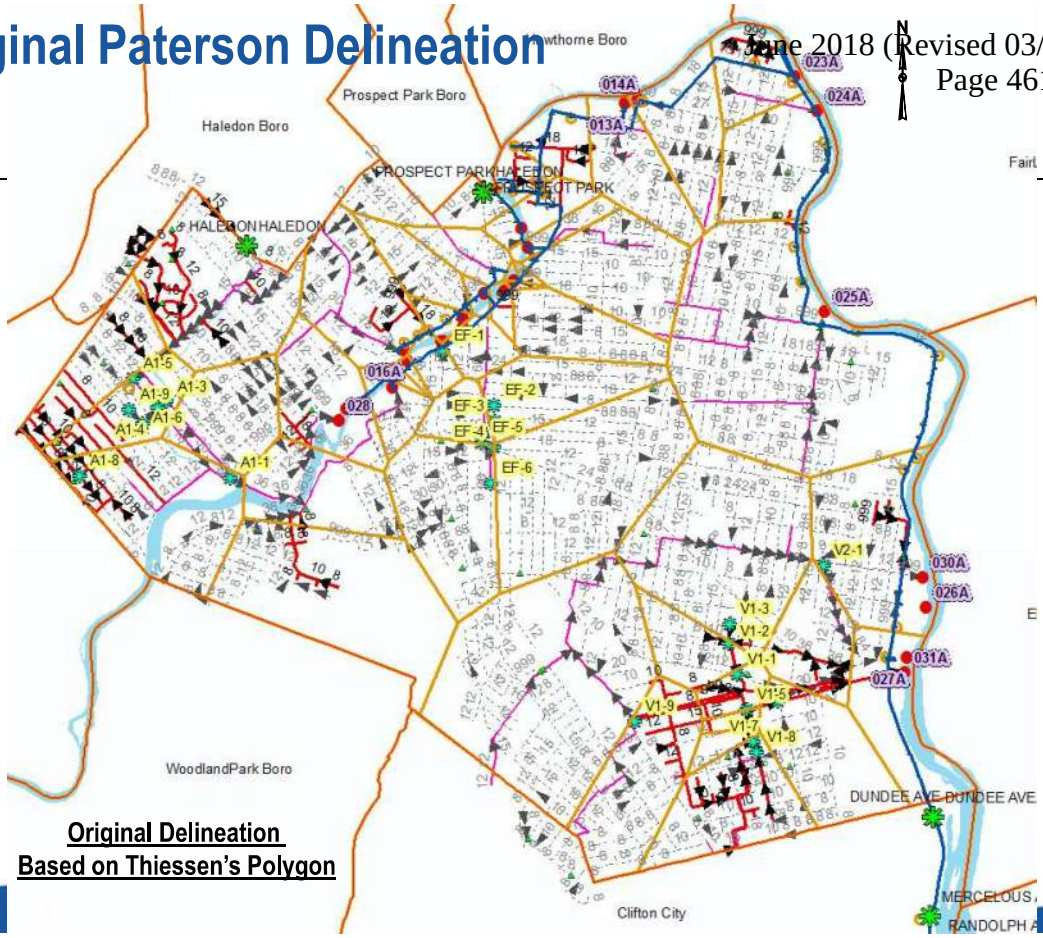
Regulator	Overflow Weir				Regulating Sluice Gate / Orifice					
	Drawing		Original Model		Drawing			Original Model		
	Crest	Width	Crest	Width	Invert	Width	Height	Invert	Width	Height
K-001A	120.85	4.5	120.27	1.5	119.07	1		119	1	
K-004A	107.9	1.5	108	1.5	106.9	1		107	1	
K-006A	99.9	5	100.9	10	98.7	1.5		98.2	1.5	
	100.1	5								
K-007A	103	9	103	9	100.2	3	1	100.2	3	1
K-010A	102.5	4	102.5	4.5	98.84	1	1	100.45	1	
E-001A	101.6	4	101.6	4	99.2	1.25		99.2	1.25	
H-001A	101.2	4	101.2	4	99.8	1.25		99.8	1	
H-002A	102.2	4	102.2	4	101	1		101.2	1	
H-003A	103.9	4	103.9	4	101.4	1.25		101.4	1.25	
H-004A	102.2	4	102.2	3.5	100.58	1		100.58	1	
H-005A	100.8	3.5	100.8	3.5	99.1	1		99.1	1	
H-006A	99.9	4	99.9	4	97.9	1		97.9	1	
H-007A	102.4	4.5	102.4	4.5	101.2	1		101.2	1	

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GREELEY AND HANSEN

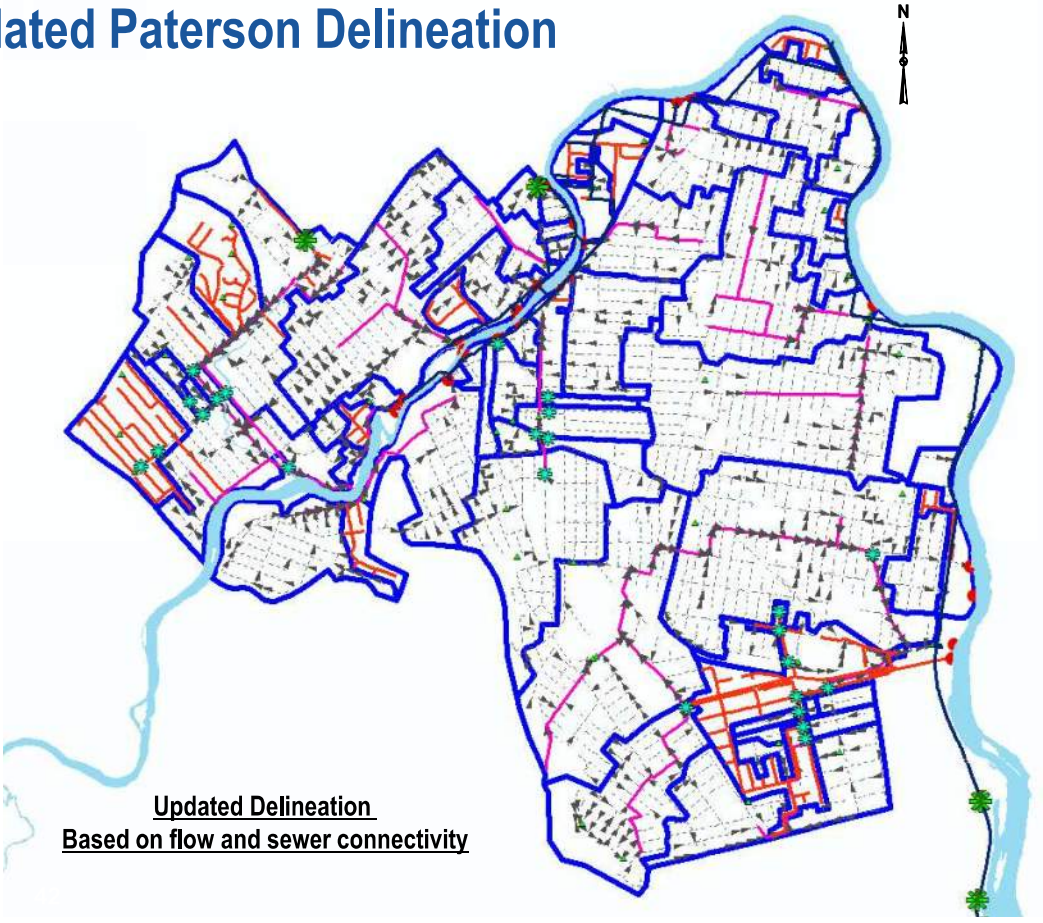
Paterson Update

Original Paterson Delineation



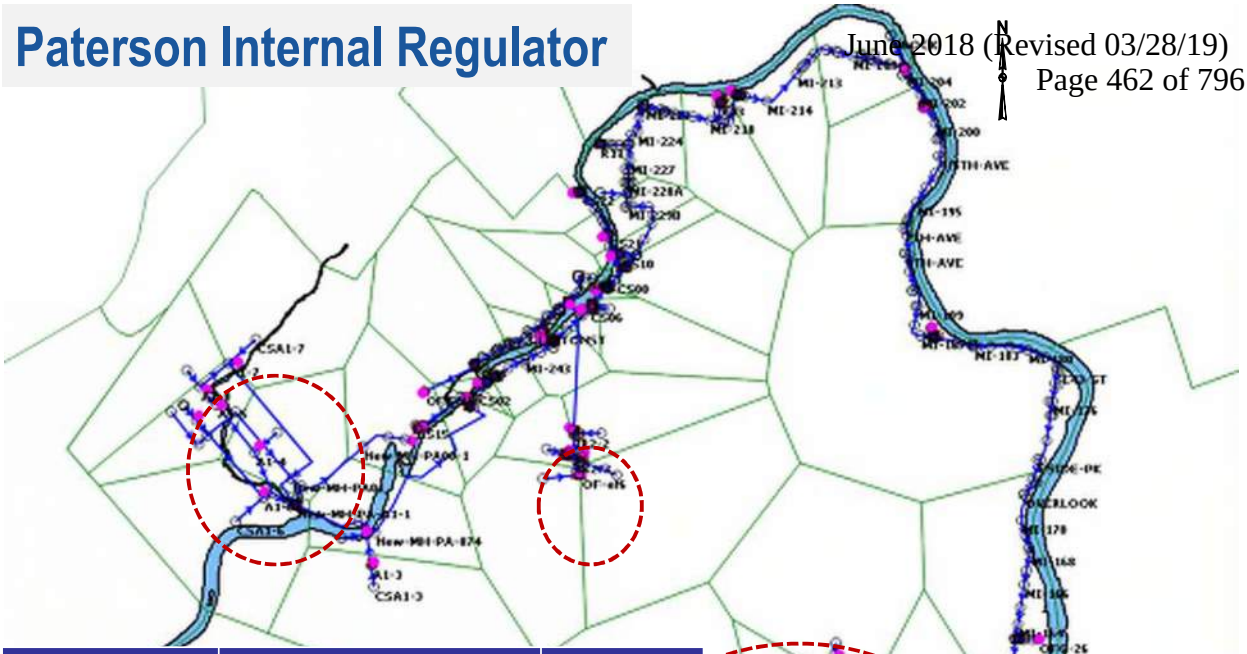
Original Delineation
Based on Thiessen's Polygon

Updated Paterson Delineation



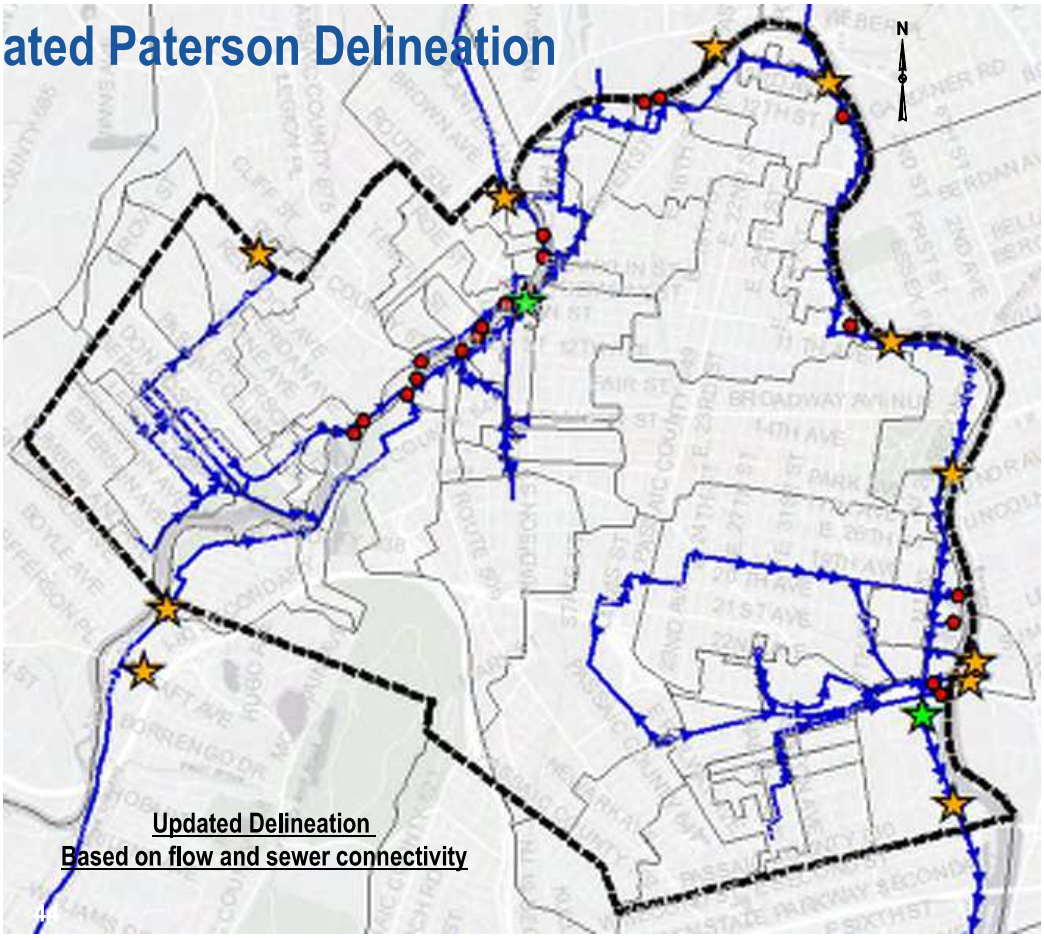
Updated Delineation
Based on flow and sewer connectivity

Paterson Internal Regulator



Regulator #	Normal Flow	Overflow
A1-1 to A1-9 (8)	P_001A Regulator	P_028A
EF-2 to EF-6 (5)	P_006A Regulator	P_029A
V2-1	P_027A Regulator	P_030A
V1-1 to V1-9 (9)	P_027A Regulator	P_031A
EF-1	PVSC Interceptor MH 243	P_033A

Updated Paterson Delineation



Updated Delineation
Based on flow and sewer connectivity

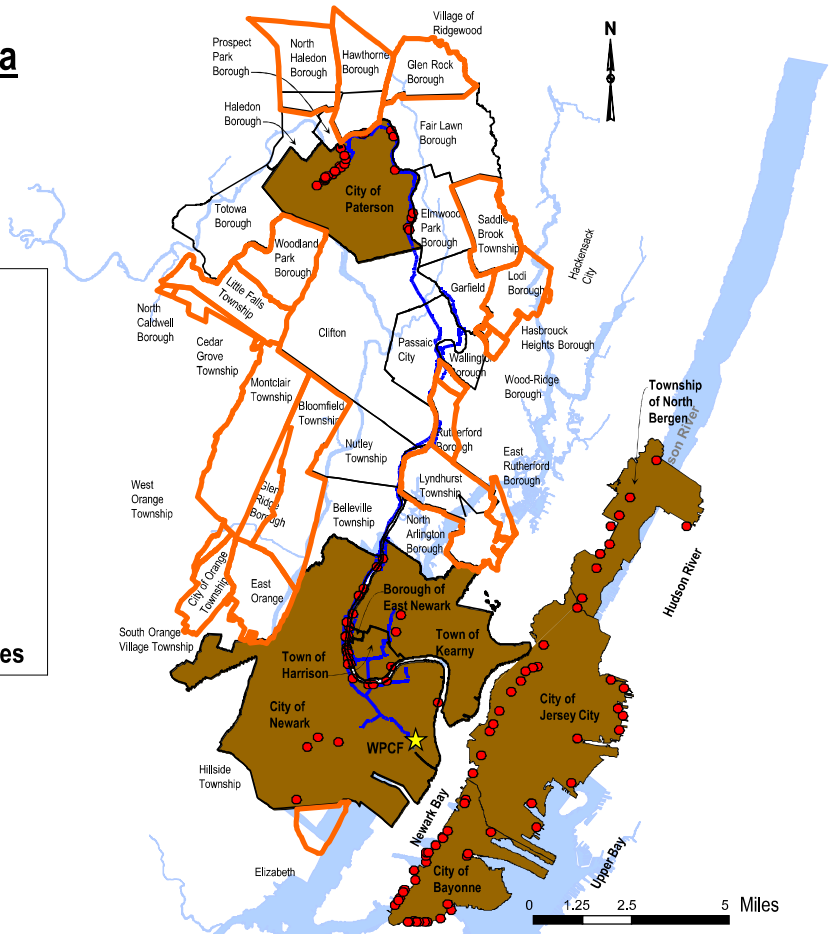
GREELEY AND HANSEN

Separated Service Area

Separated Service Area Added to the Model

Legend

- PVSC Service Area
- CSO Communities
- Separated Communities
- PVSC WPCF (Water Pollution Control Facility)
- PVSC Interceptor / Sewer
- CSO Outfall
- **Added Separated Communities**



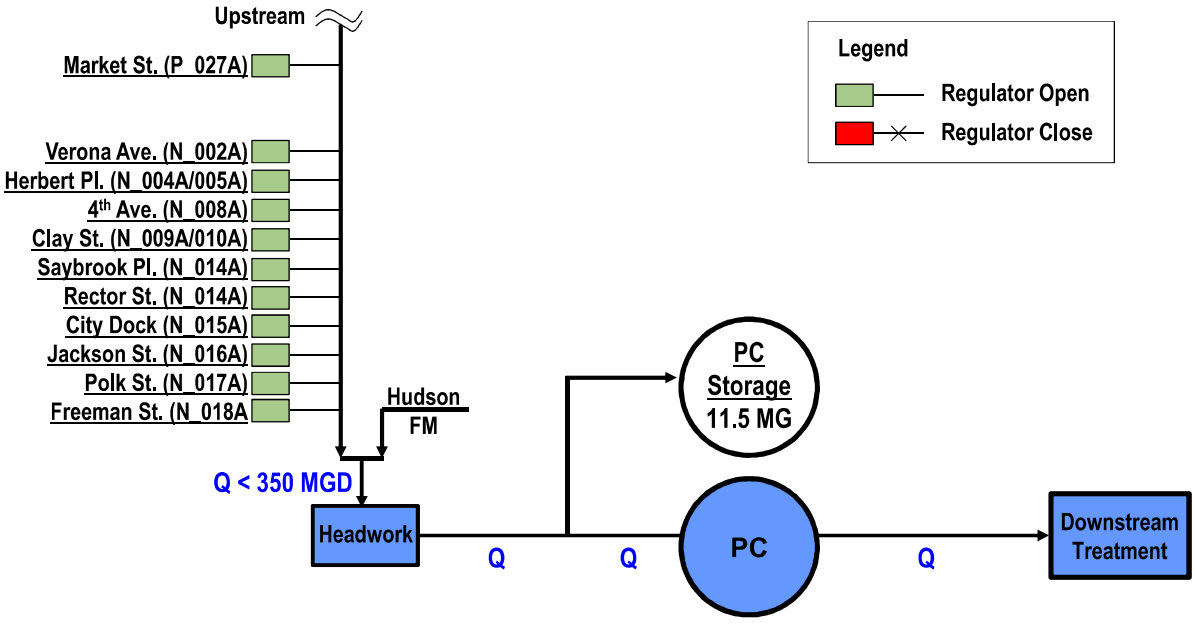
GREELEY AND HANSEN

Wet Weather Operating Rules

47

Wet Weather SOP

Flow < 350 MGD

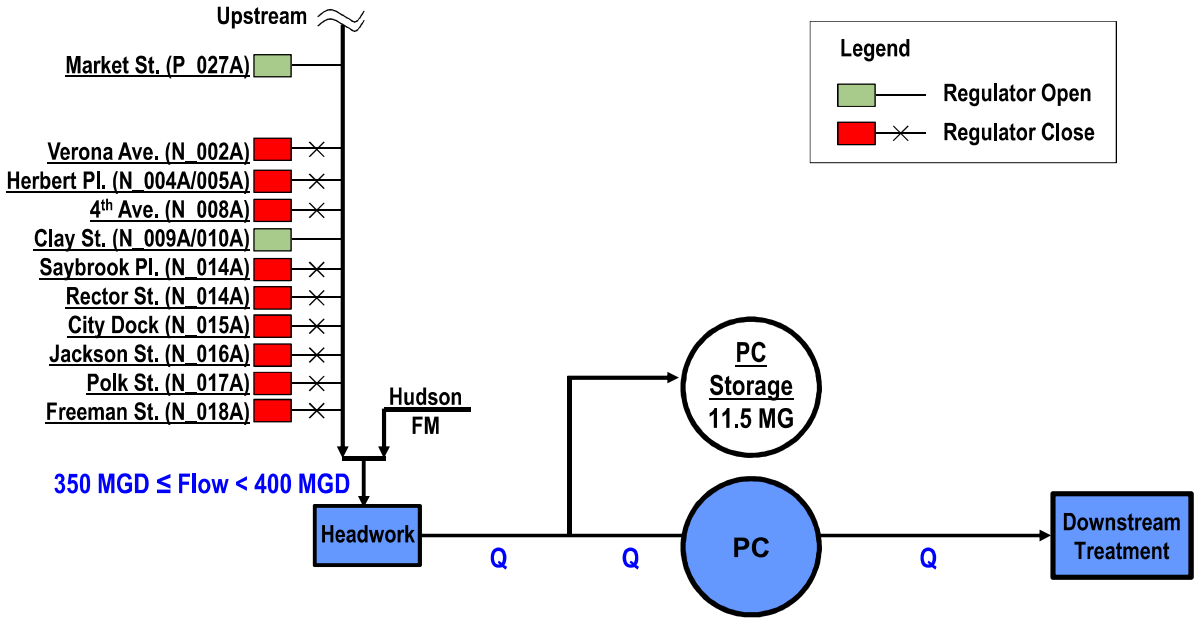


GREELEY AND HANSEN

48

Wet Weather SOP

350 MGD ≤ Flow < 400 MGD

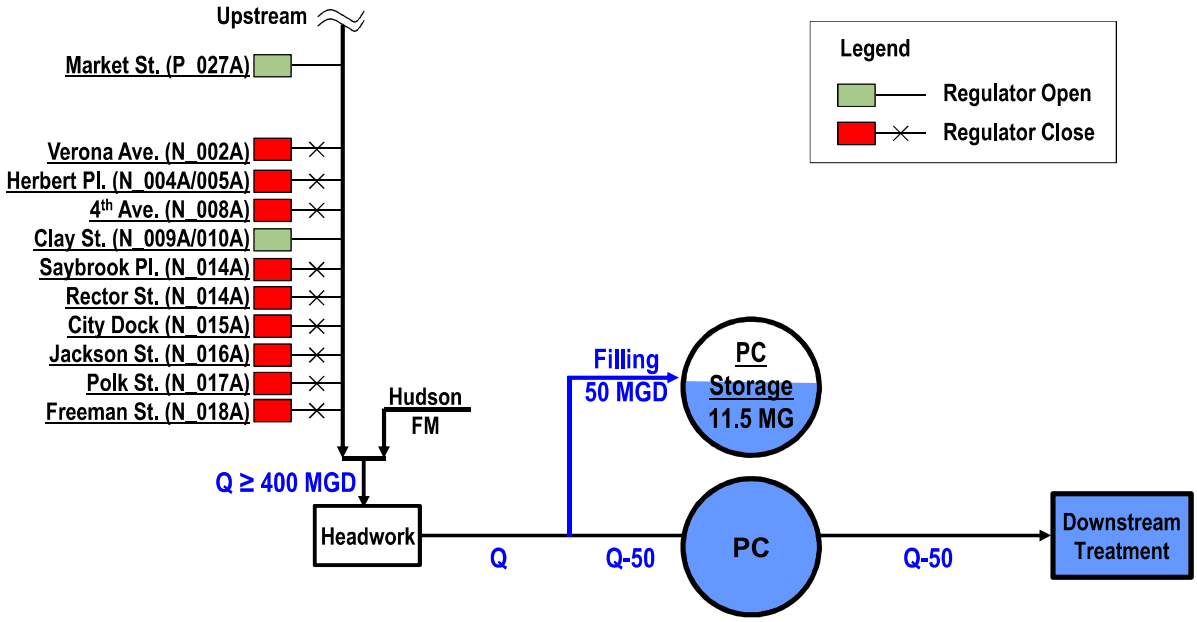


Note: During 10/7/15 to 7/7/16, CSOs were put in use at plant flow 400 MGD.

GREELEY AND HANSEN

Wet Weather SOP

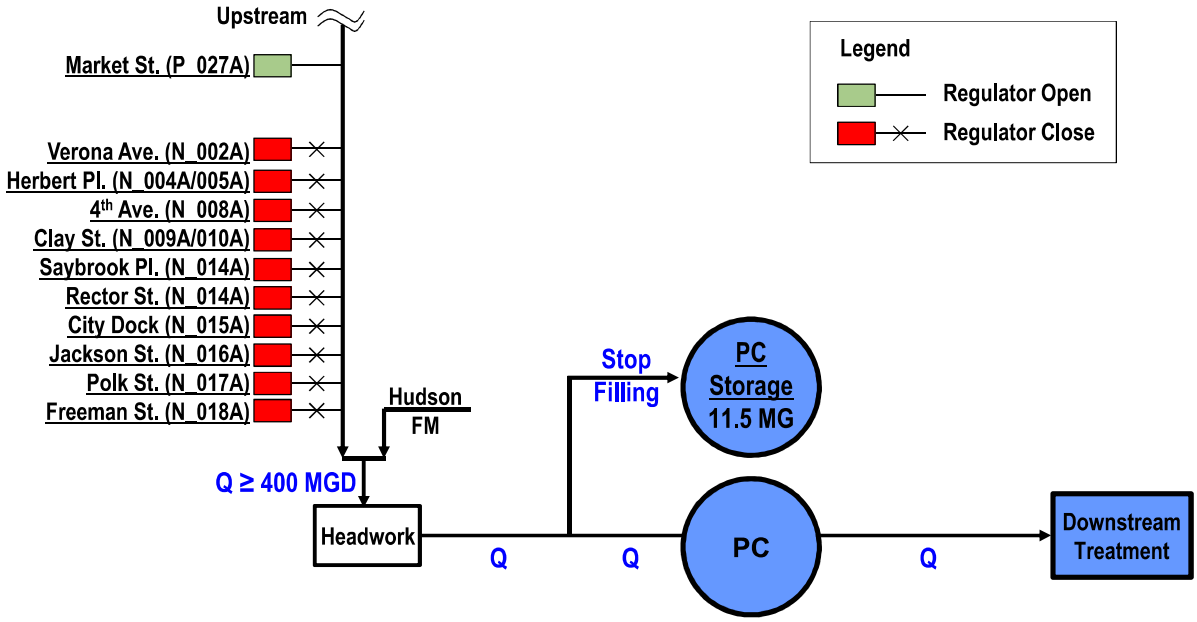
Flow ≥ 400 MGD



GREELEY AND HANSEN

Wet Weather SOP

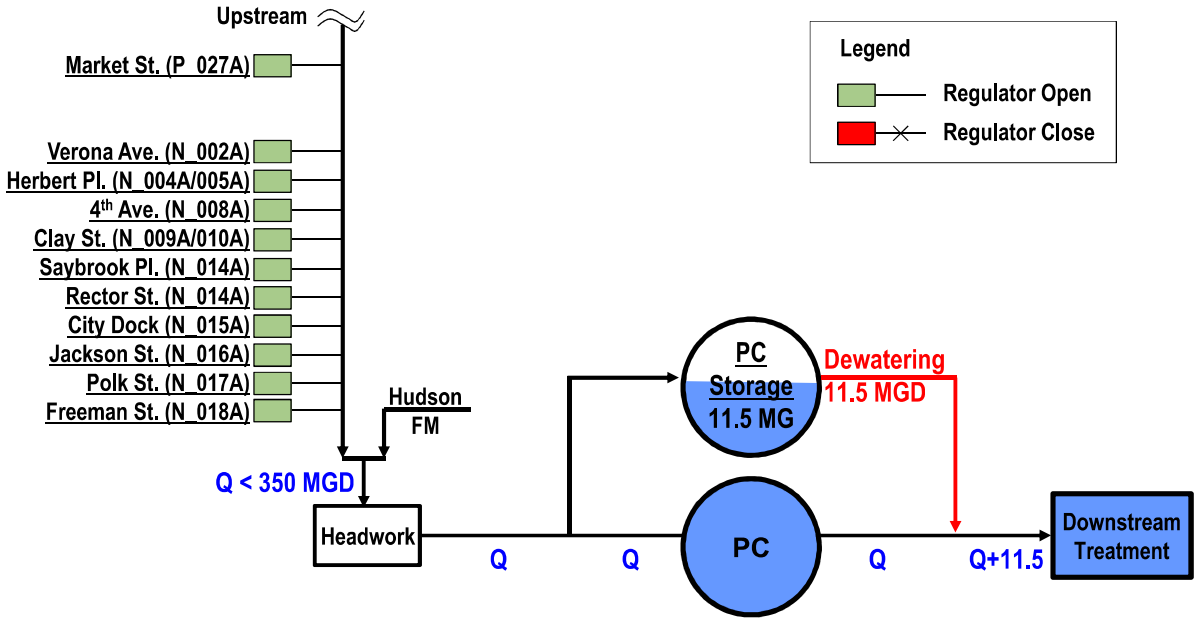
Flow ≥ 400 MGD, & Storage Full



GREELEY AND HANSEN

Wet Weather SOP

Flow Drops to 350 MGD



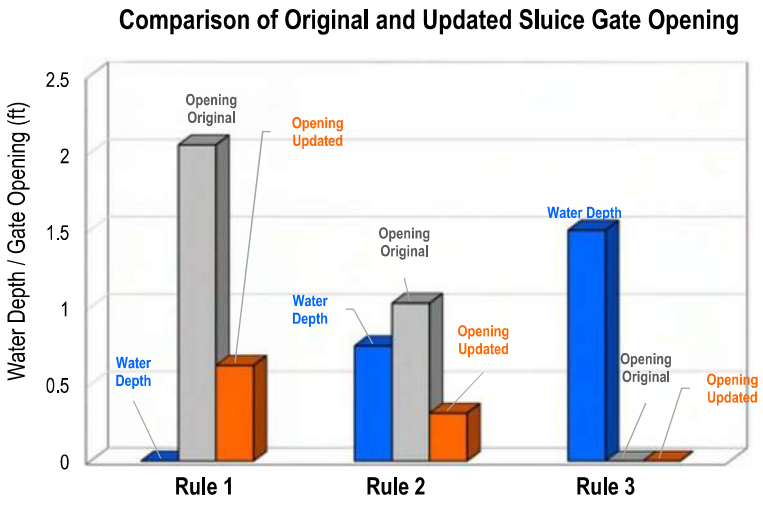
GREELEY AND HANSEN

Bayonne Real Time Control Rule Update

एक फुट = 0.3048 मीटर
एक मीटर = 3.28 फुट

Original RTC Closing Table		
	Input ft	Output
Rule 1	0	0.625
Rule 2	0.751	0.313
Rule 3	1.499	0

Updated RTC Closing Table		
	Input ft	Output
Rule 1	0	0.190
Rule 2	0.751	0.095
Rule 3	1.499	0



GREELEY AND HANSEN

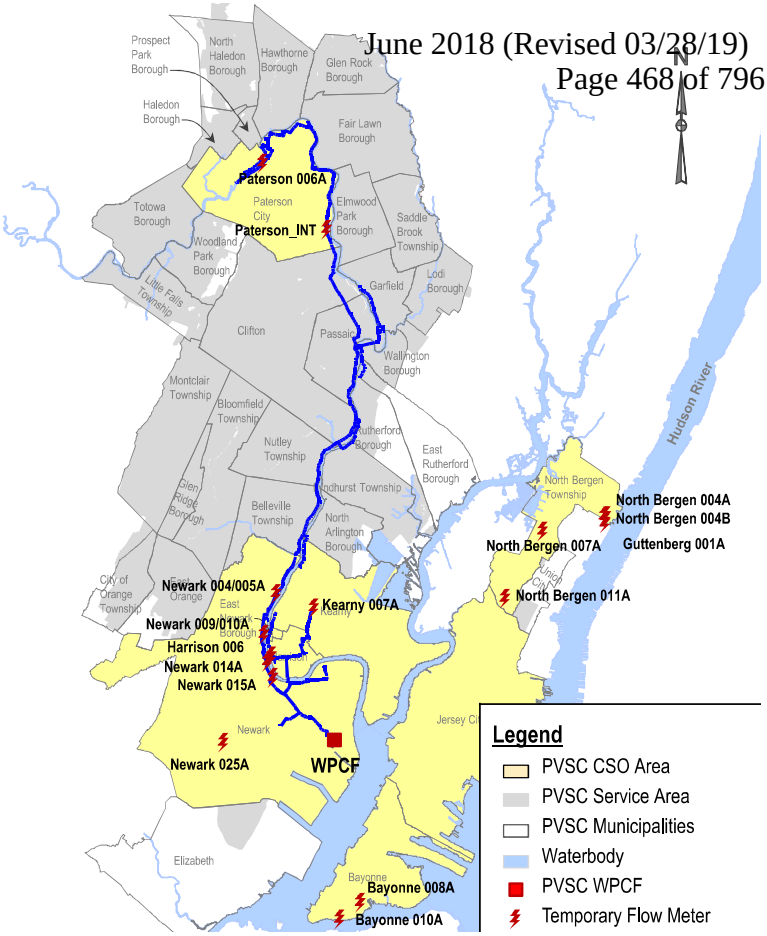
GREELEY AND HANSEN

PVSC H&H Model Calibration and Validation

Temporary Flow Meter

21 Flow Meters

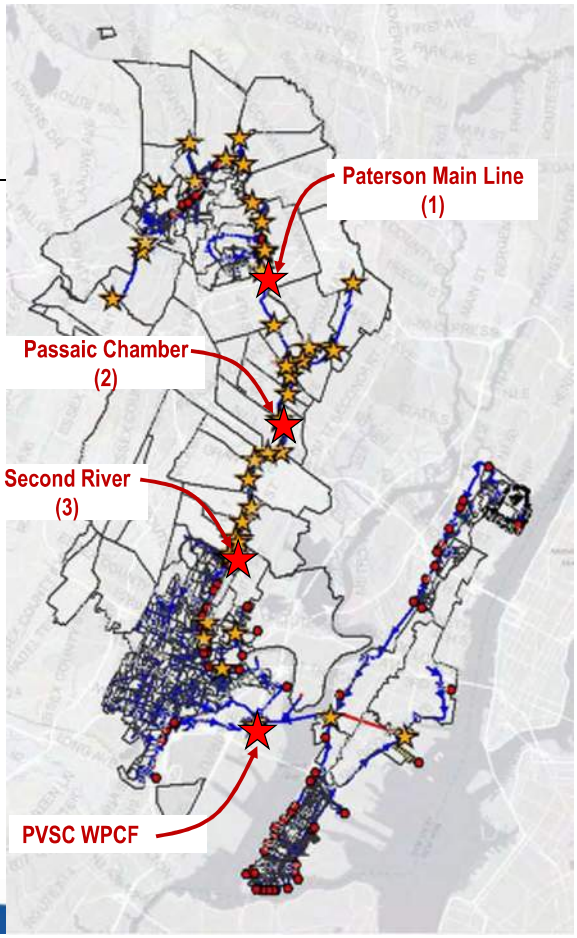
- 13 outfall pipe
- 5 regulator influent
- 2 regulator effluent
- 1 interceptor



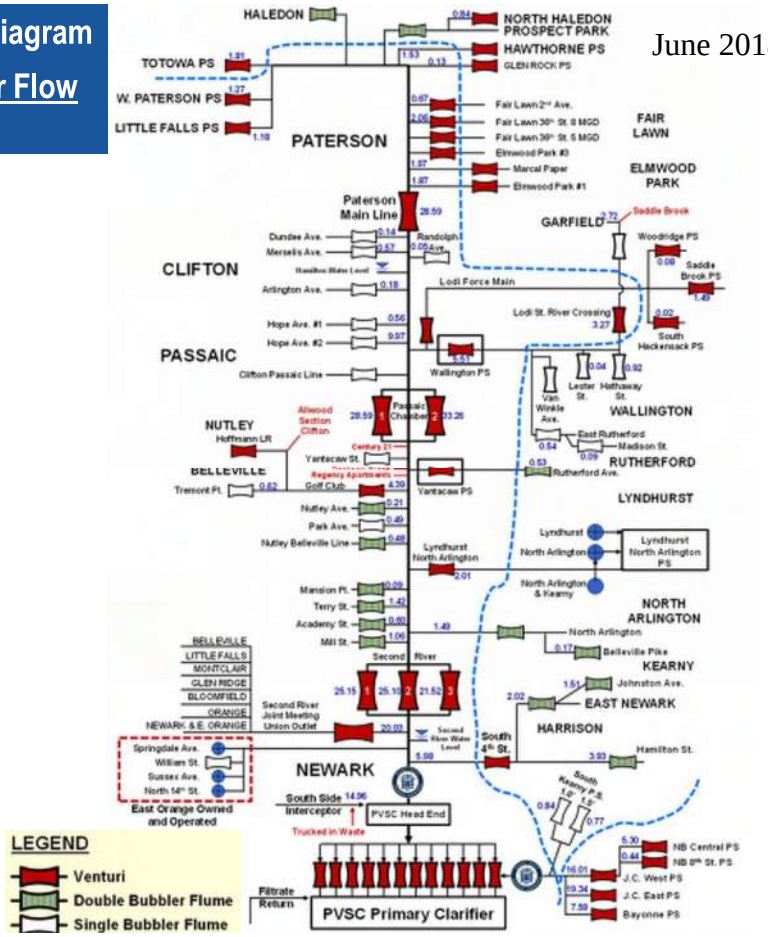
PVSC Permanent Flow Meters

Over 70 Flow Meters, 55 was analyzed for DWF and model calibration

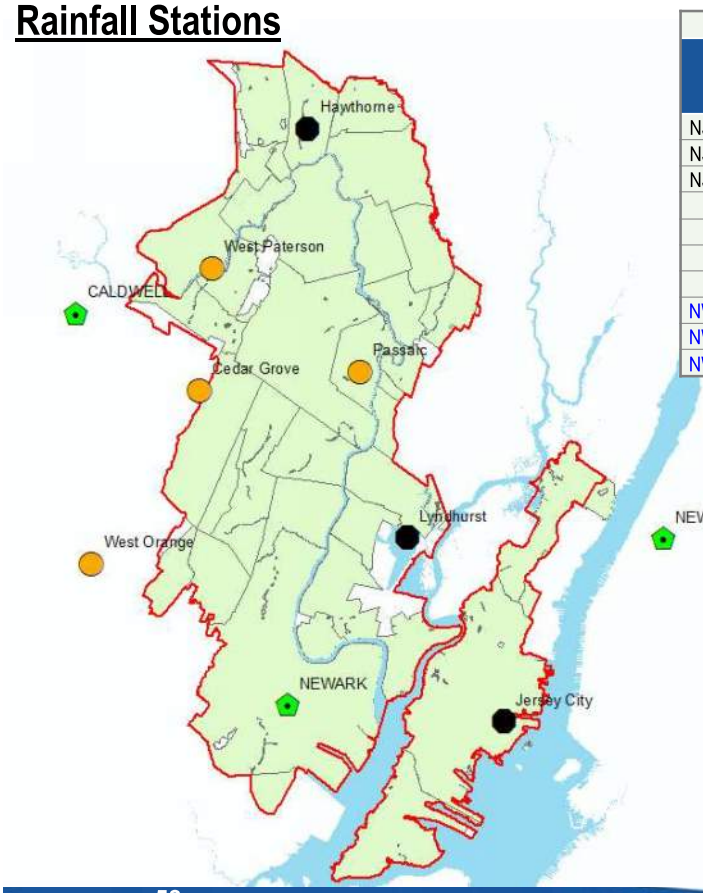
- PVSC Interceptor: 6
- Pump Station: 6
- Combined area: 5
- Separated Area: 38



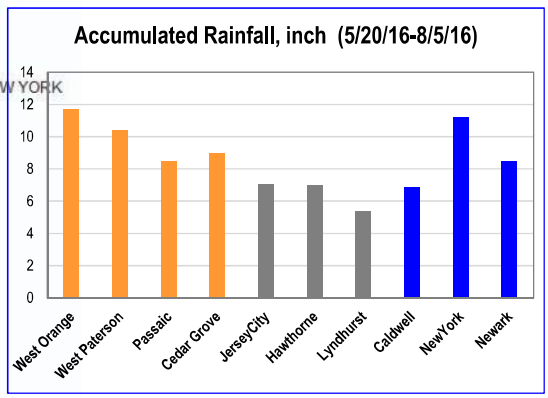
Flow Meter Diagram
Dry Weather Flow (MGD)



Rainfall Stations

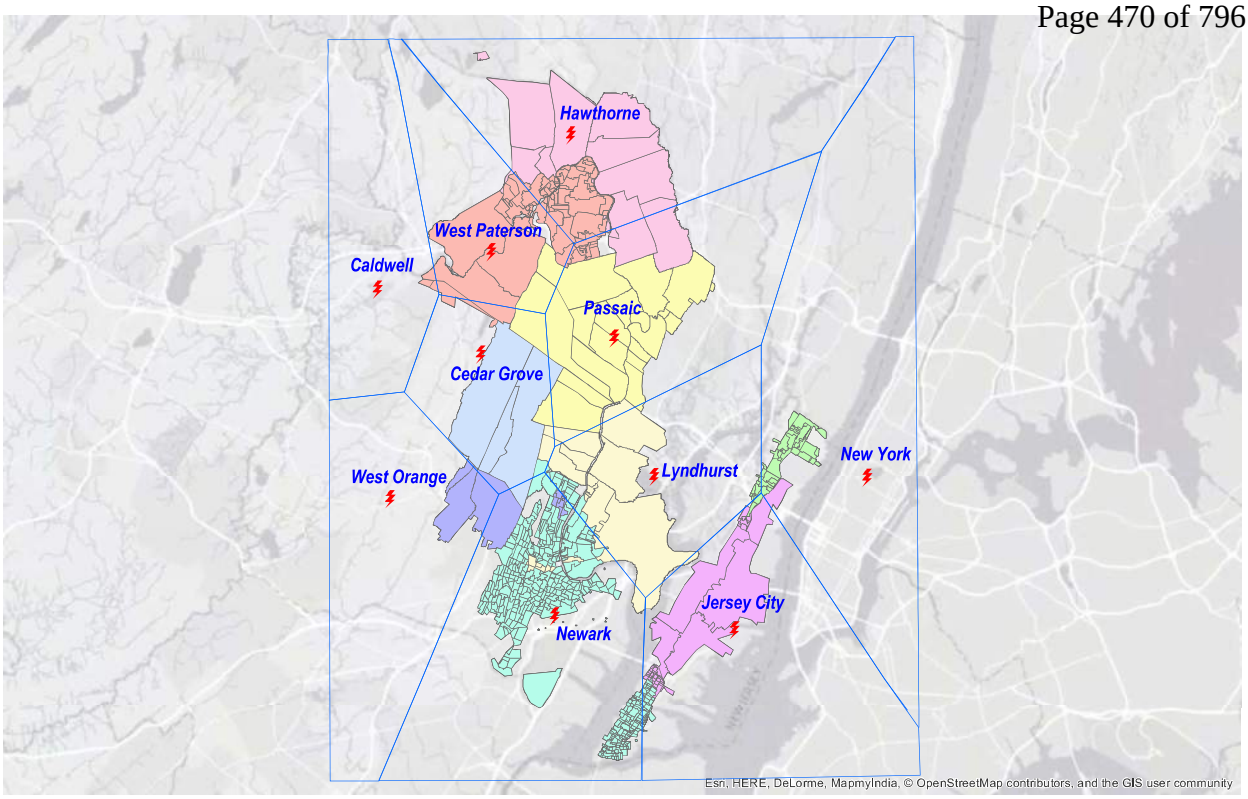


Rain Gauge Summary			
Source	RG ID	Data Time Interval (Min.)	Total Rainfall (5/20/16-8/05/16)
NJ Weather	Hawthorne	5	6.97
NJ Weather	Lyndhurst	5	5.39
NJ Weather	jersey City	5	7.04
CWOP	West Paterson	30	10.4
CWOP	Passaic	15	8.46
CWOP	Cedar Grove	10-50	8.98
CWOP	West Orange	10	11.72
NWS ASOS	Caldwell	1	6.84
NWS ASOS	New York	1	11.23
NWS ASOS	Newark	1	8.47



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Rainfall Station Assignment



Candidate Storm Events for Calibration

Rainfall Based on Newark

Rain Start	Rain End	Duration (hr)	Depth (in)	Max Intensity (in/hr)	Average Intensity (in/hr)
7/25/16 16:05	7/25/16 18:50	2.75	**1.81**	1.68	0.66
5/29/16 23:50	5/30/16 5:20	5.50	**1.6**	1.09	0.29
7/29/16 0:20	7/29/16 8:35	8.25	**0.85**	0.42	0.10
5/2/16 22:40	5/3/16 9:50	11.17	**0.7**	0.17	0.06
7/31/16 8:35	7/31/16 22:35	14.00	**0.69**	0.49	0.05
7/4/16 19:20	7/5/16 2:50	7.50	**0.63**	0.23	0.08
5/6/16 2:30	5/6/16 12:25	9.92	**0.6**	0.19	0.06
7/16/16 14:50	7/16/16 15:35	0.75	**0.56**	0.75	0.75
6/8/16 11:25	6/8/16 14:10	2.75	**0.49**	0.3	0.18
7/9/16 21:30	7/9/16 22:05	0.58	**0.48**	0.82	0.82
4/4/16 7:45	4/4/16 17:00	9.25	**0.43**	0.12	0.05

Model Calibration and Validation Goals

- Visual match
- +/- 20% volume and
- +25%/-15% peak

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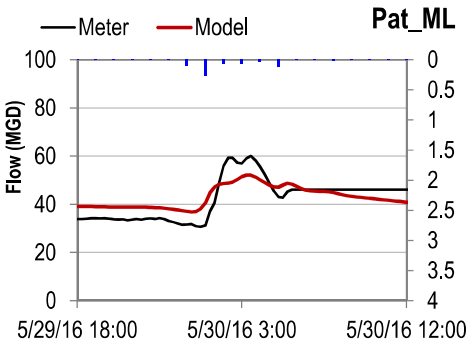
GREELEY AND HANSEN

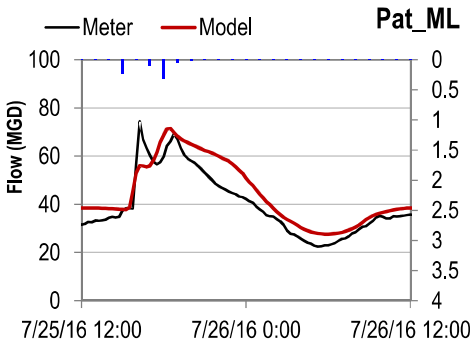
Major Interceptor

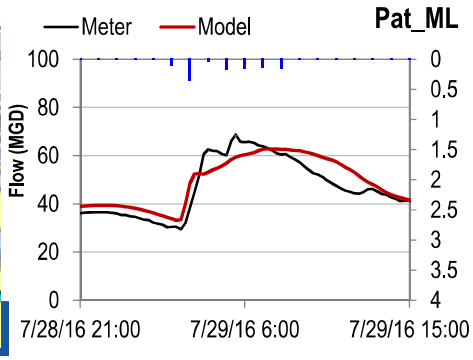
Calibration Results – Main Interceptor

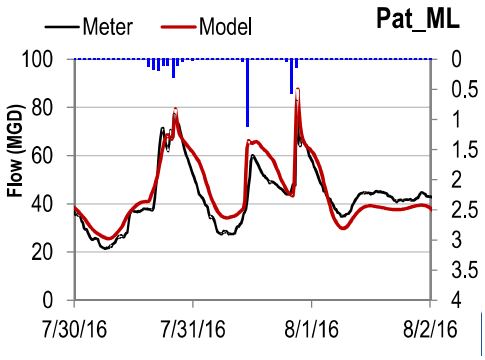
Paterson Main Line







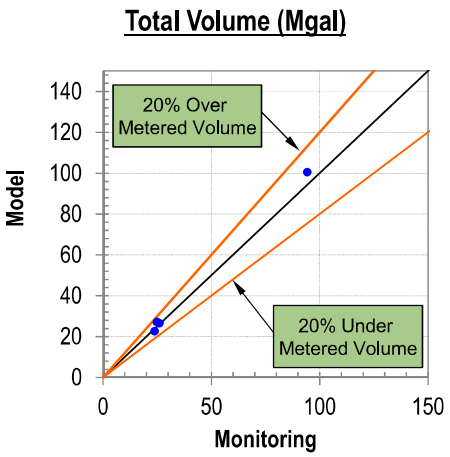


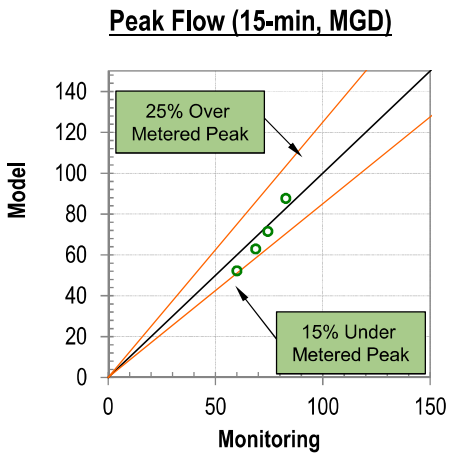


Calibration Results – Main Interceptor

Paterson Main Line: Goodness-of-Fit

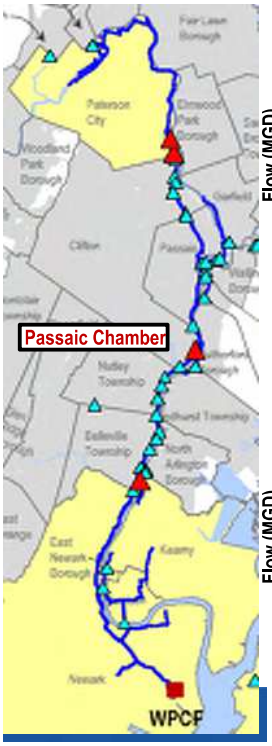


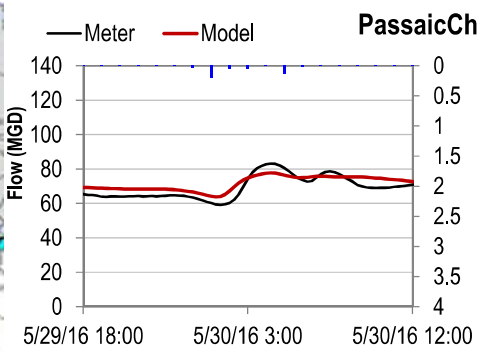


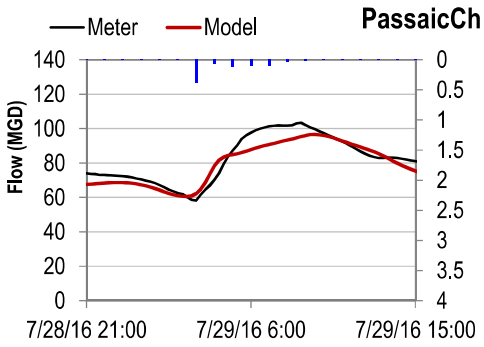


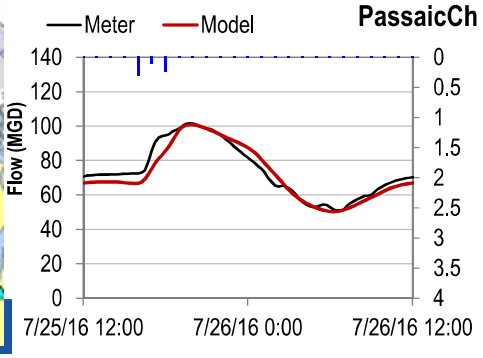
Calibration Results – Main Interceptor

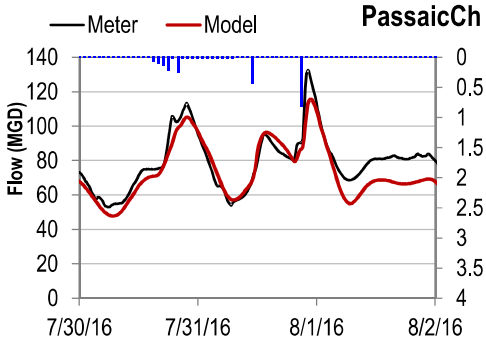
Passaic Chamber





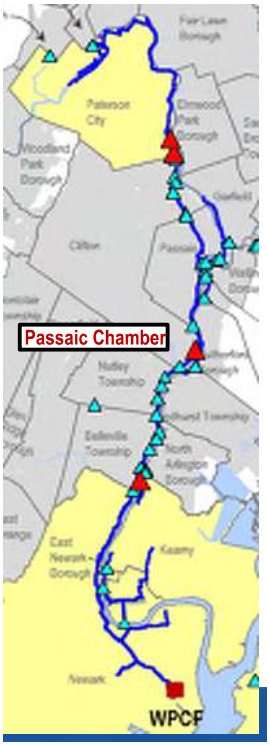


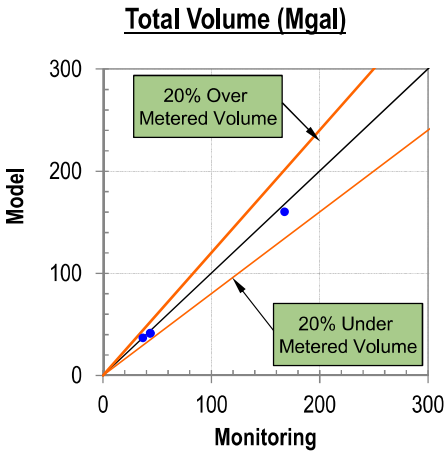


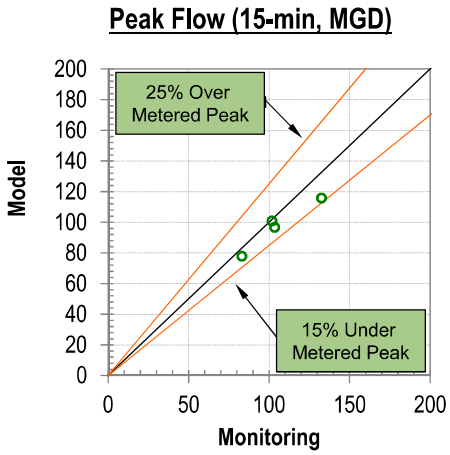


Calibration Results – Main Interceptor

Passaic Chamber: Goodness-of-Fit



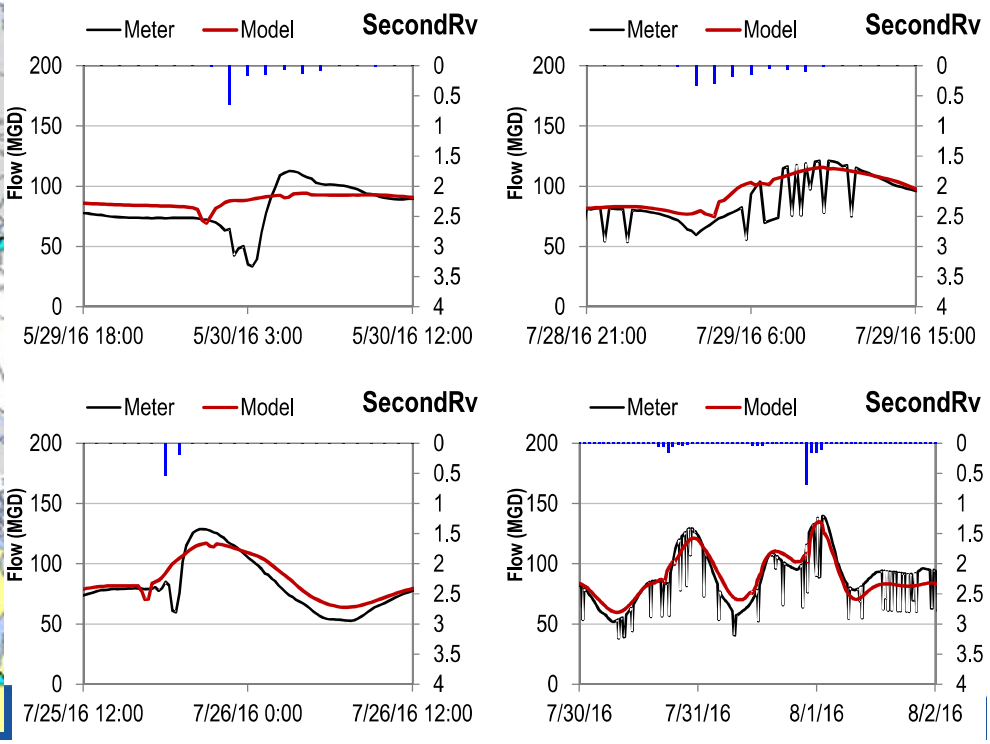




Calibration Results – Main Interceptor

Second River Crossing

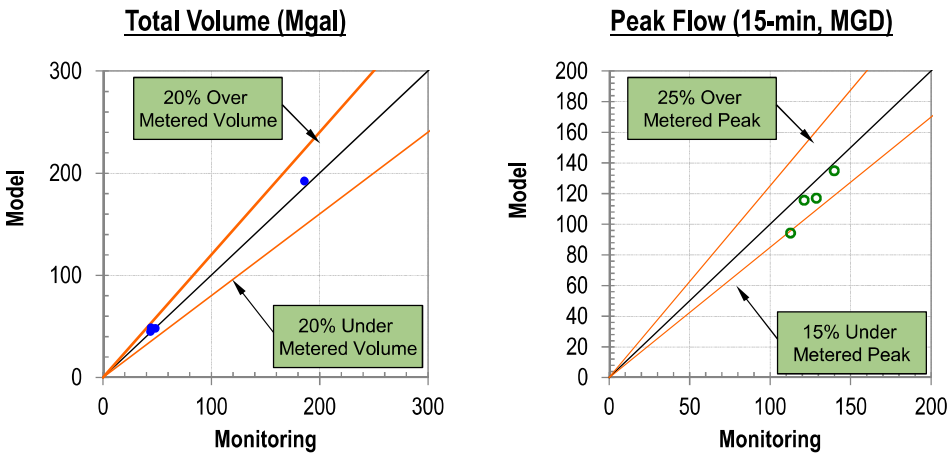




Calibration Results – Main Interceptor

Second River Crossing: Goodness-of-Fit

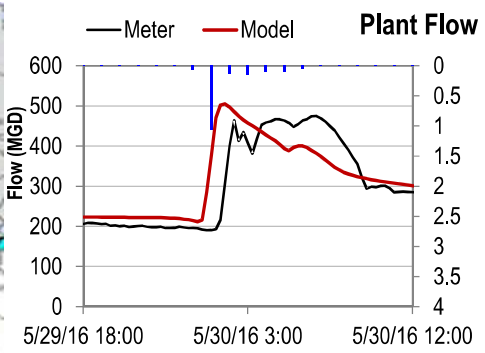


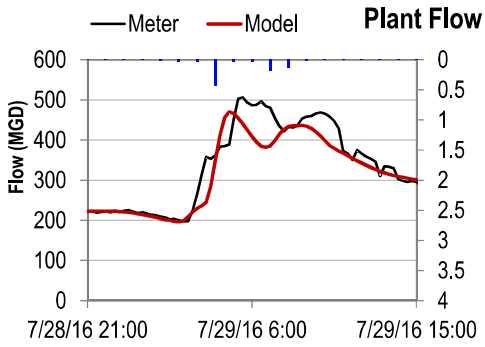


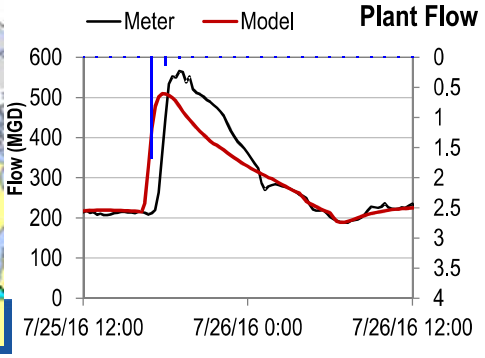
Calibration Results – Main Interceptor

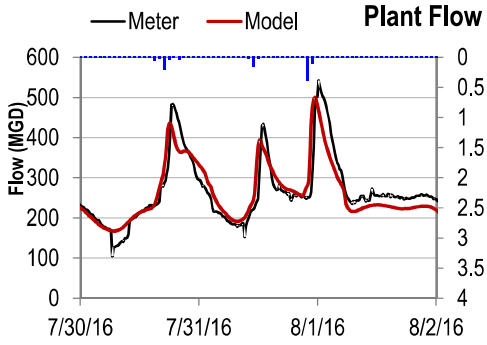
PVSC WPCF







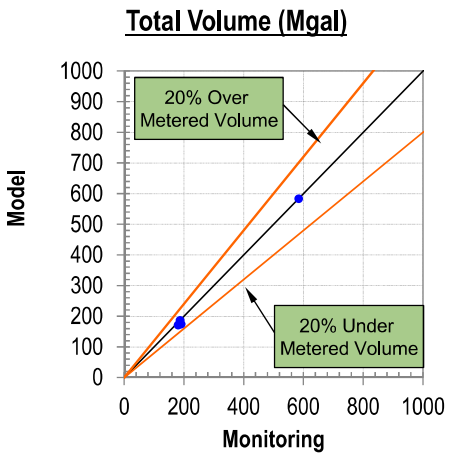


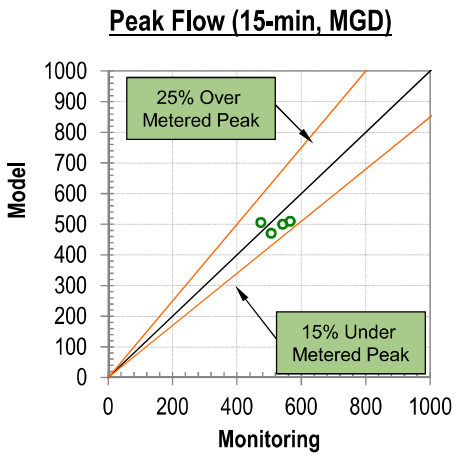


Calibration Results – Main Interceptor

PVSC WPCF: Goodness-of-Fit





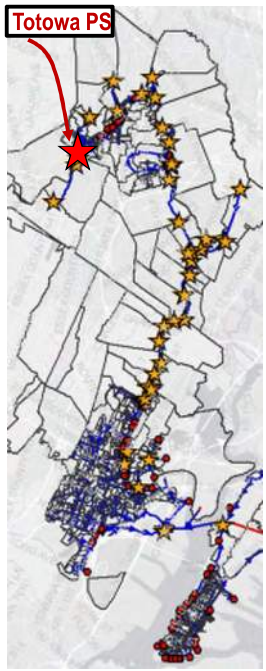


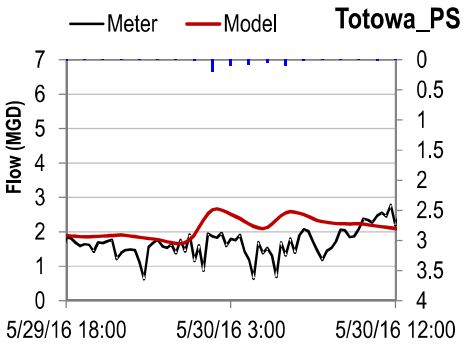
GREELEY AND HANSEN

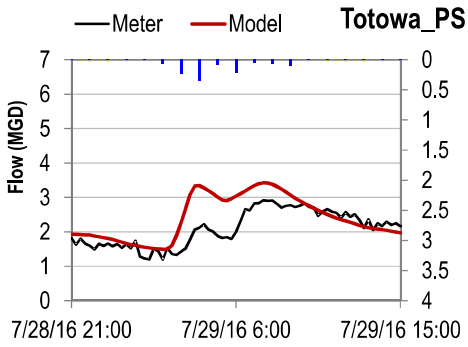
Separated Area

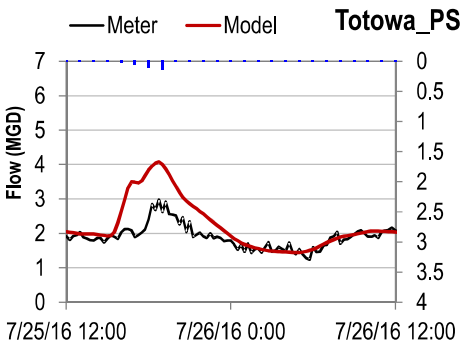
Calibration Results – Separated Area

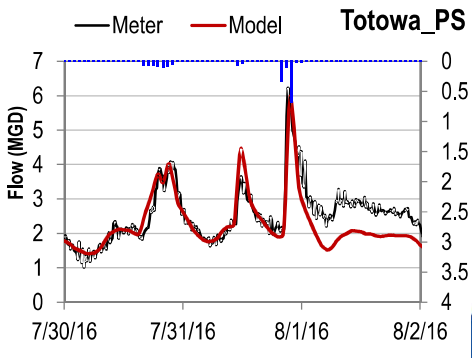
Totowa PS





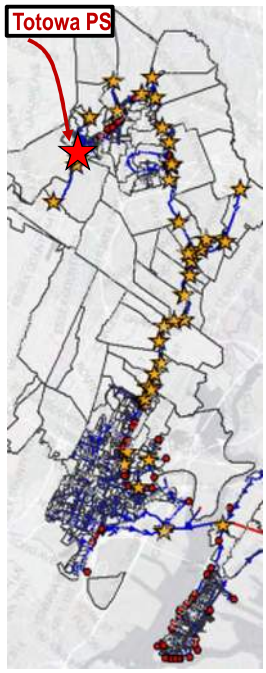


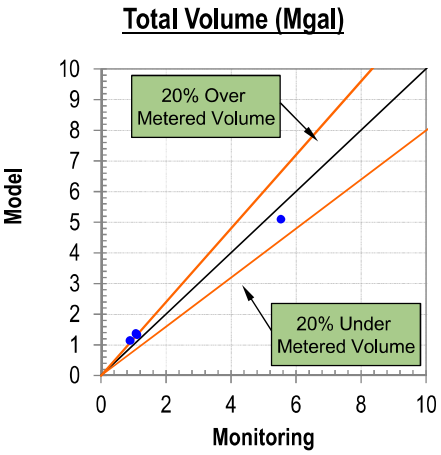


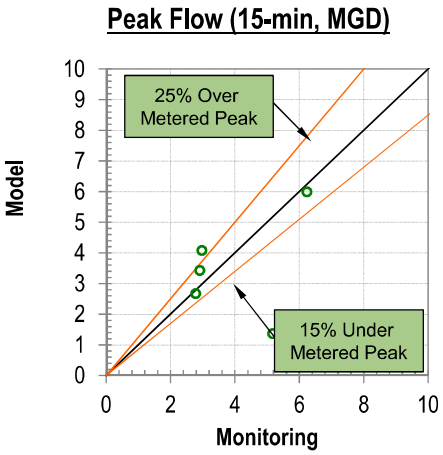


Calibration Results – Separated Area

Totowa PS: Goodness-of-Fit

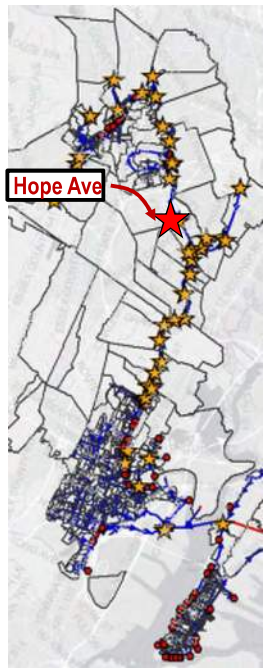


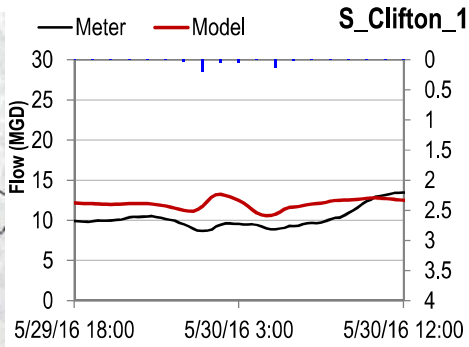


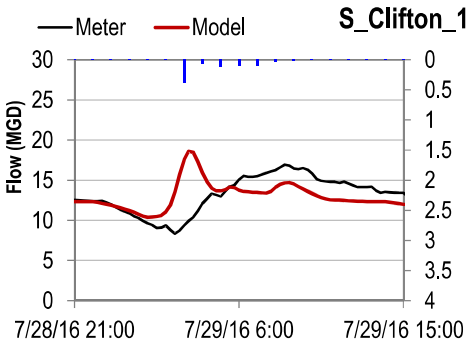


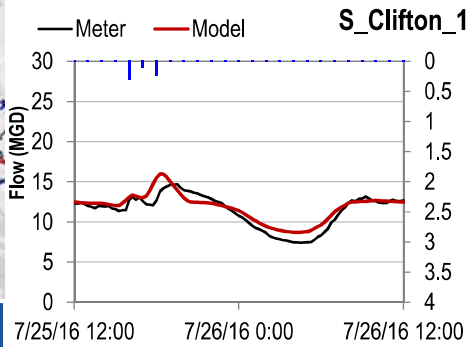
Calibration Results – Separated Area

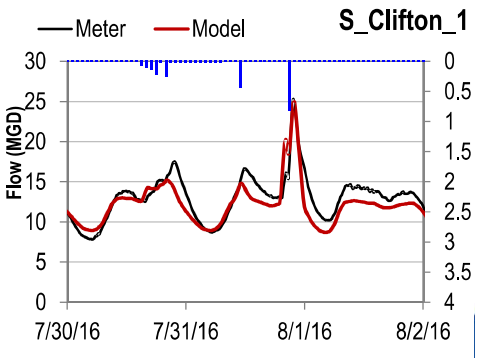
Hope Ave





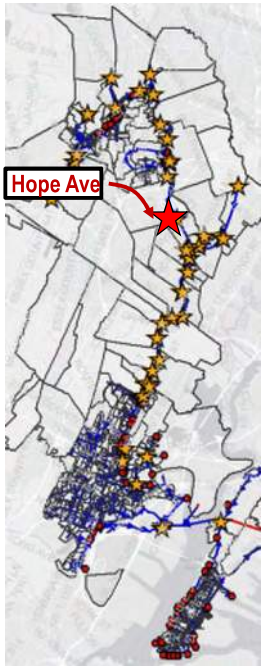


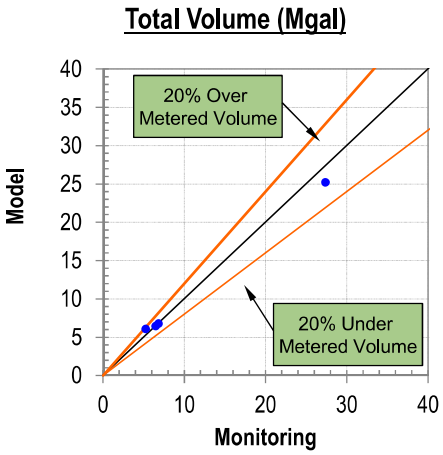


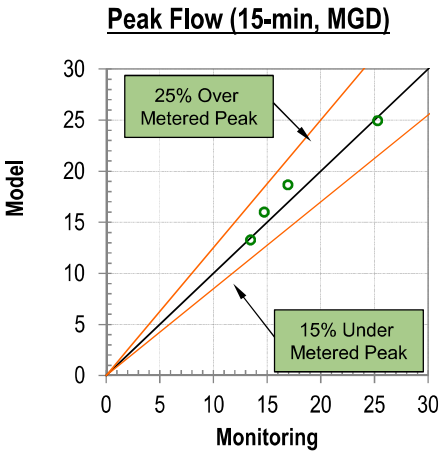


Calibration Results – Separated Area

Hope Ave: Goodness-of-Fit

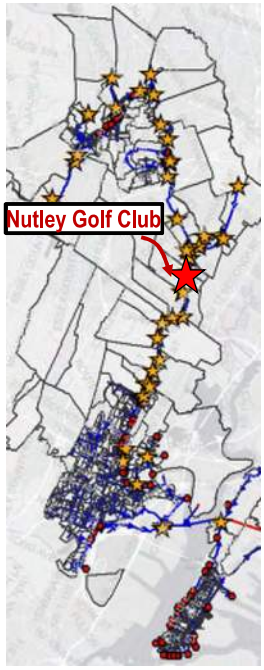


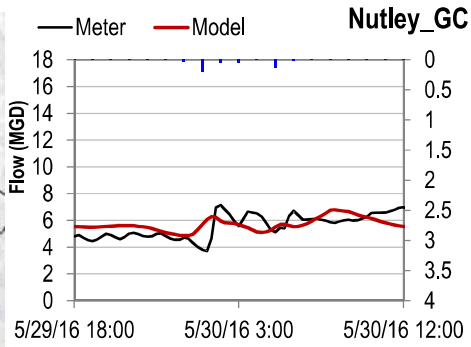


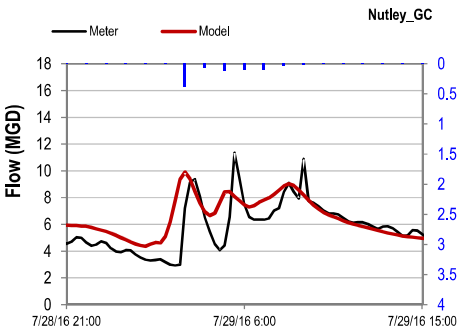


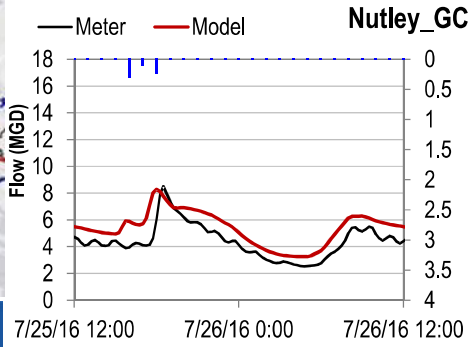
Calibration Results – Separated Area

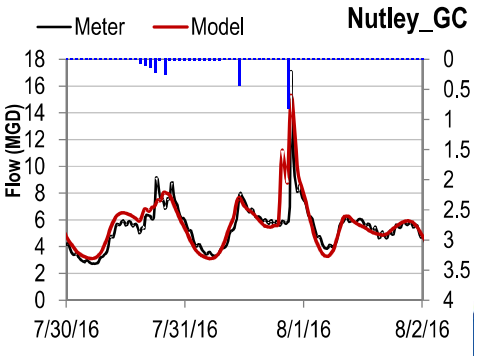
Nutley Golf Club





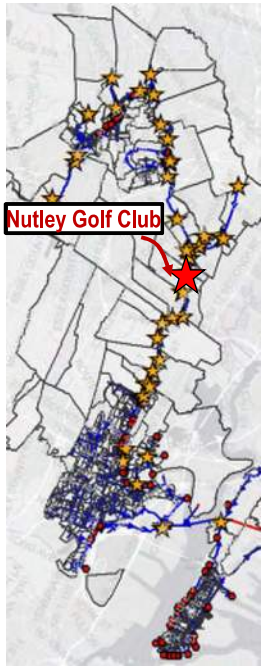


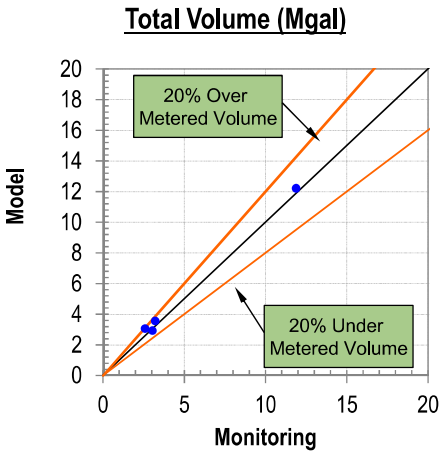


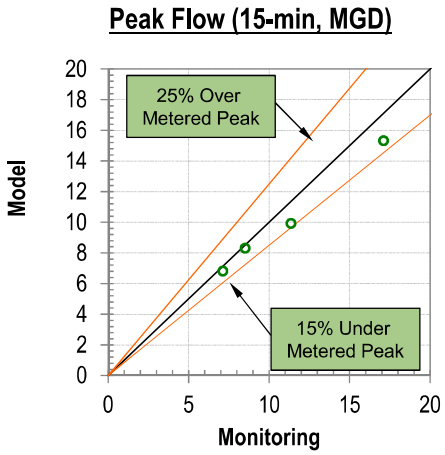


Calibration Results – Separated Area

Nutley Golf Club: Goodness-of-Fit

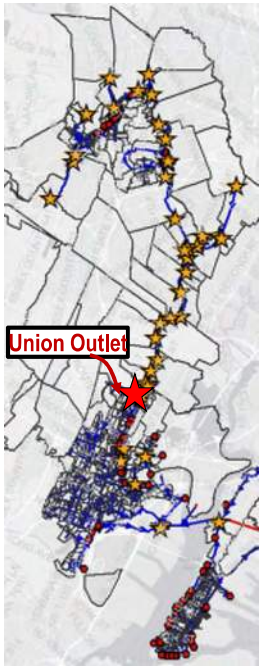


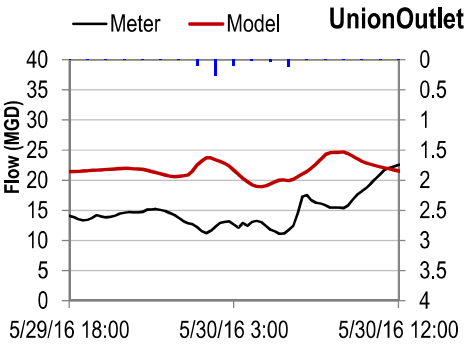


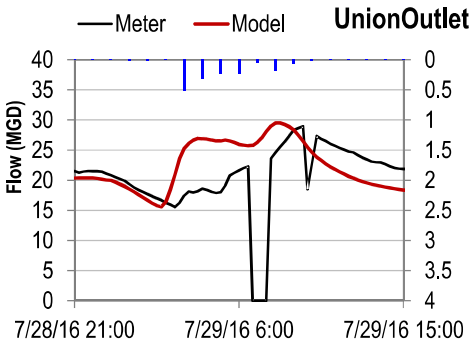


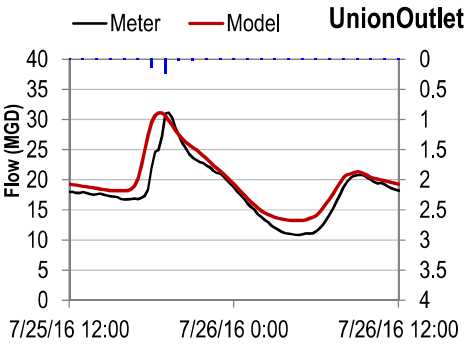
Calibration Results – Separated Area

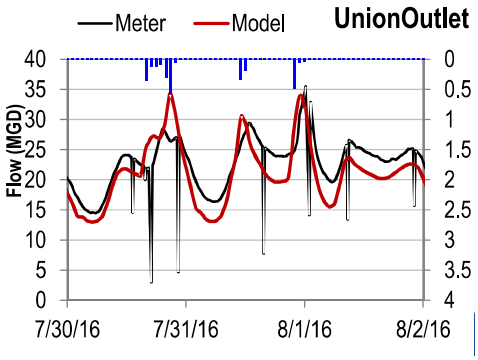
Union Outlet





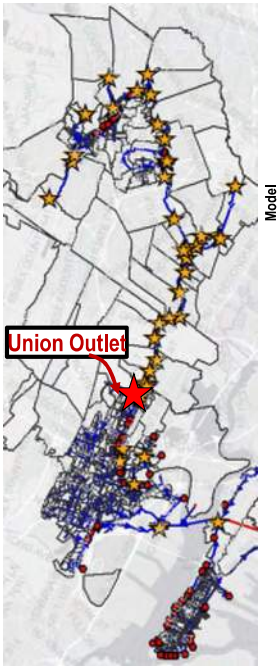




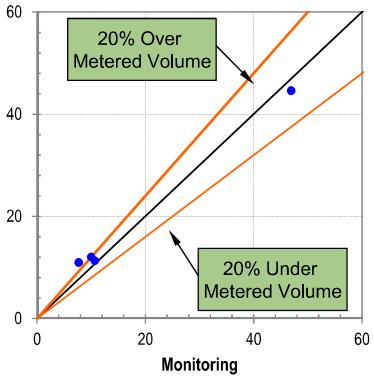


Calibration Results – Separated Area

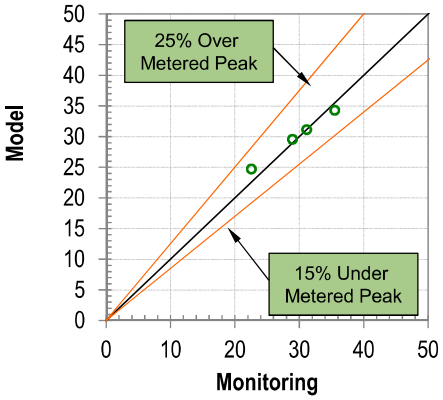
Union Outlet



Total Volume (Mgal)



Peak Flow (15-min, MGD)

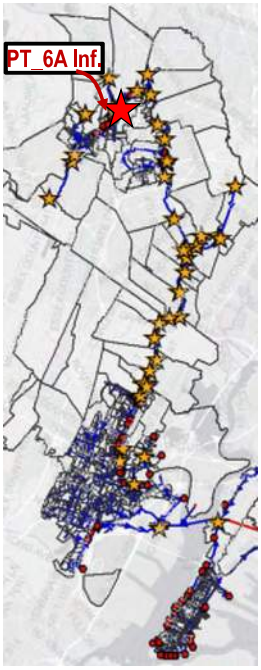


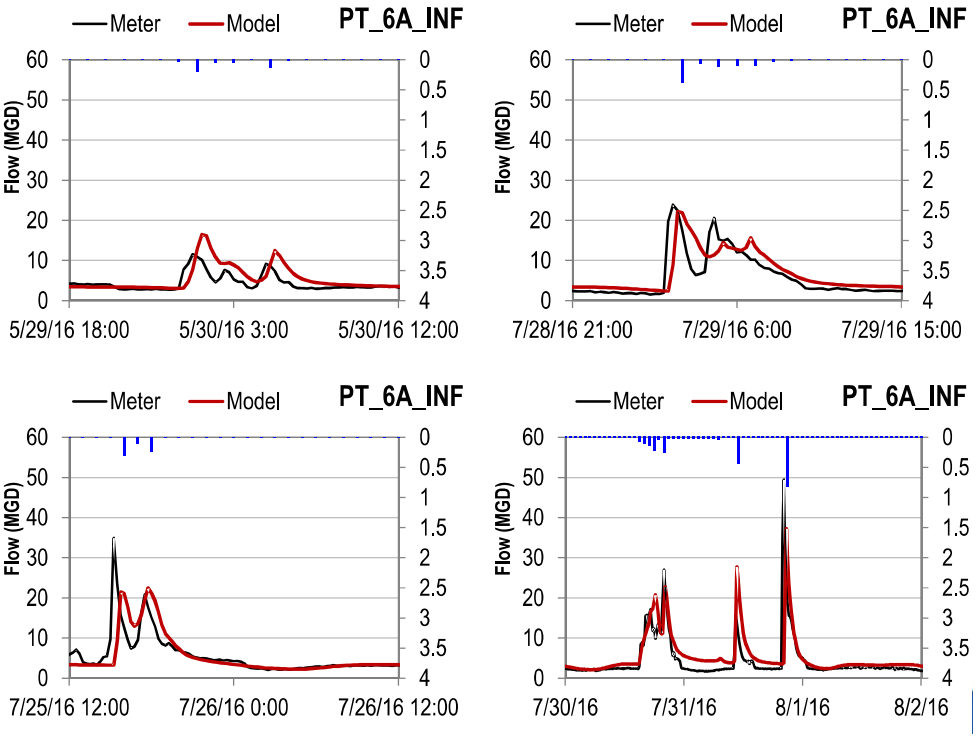
GREELEY AND HANSEN

Combined Area

Calibration Results – Combined Area

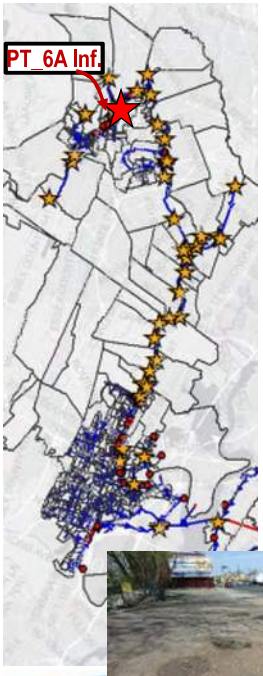
Paterson 6A Influent

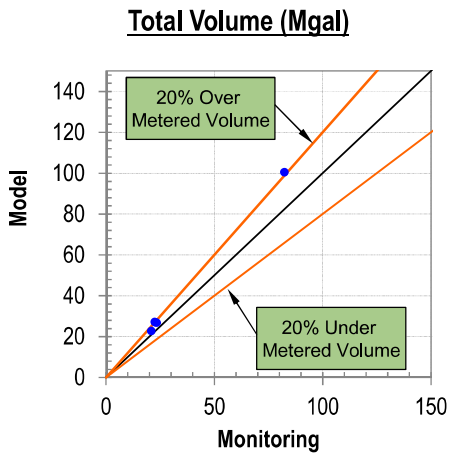


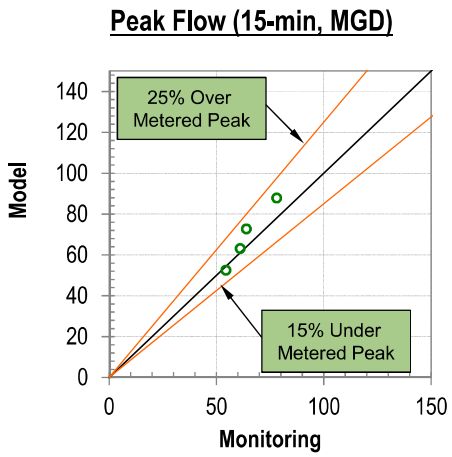


Calibration Results – Combined Area

Paterson 6A Influent



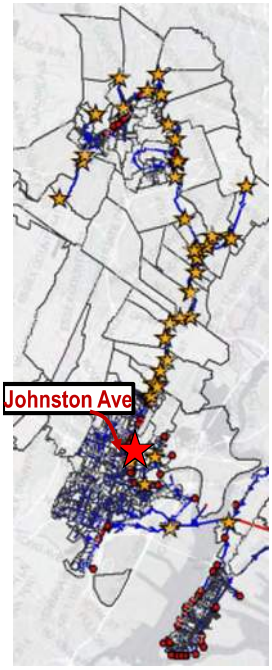


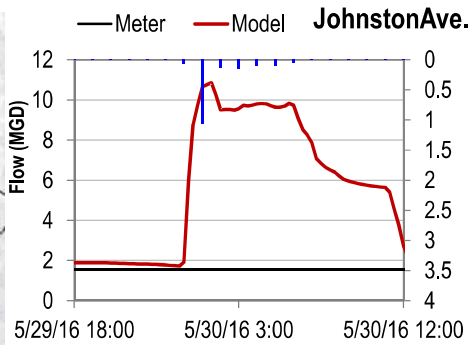


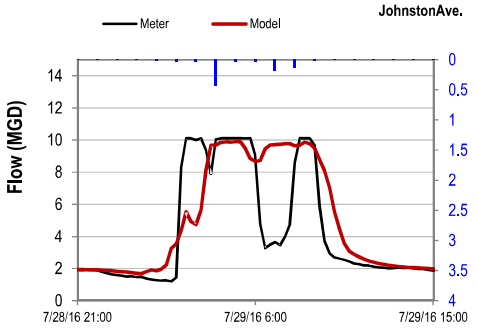


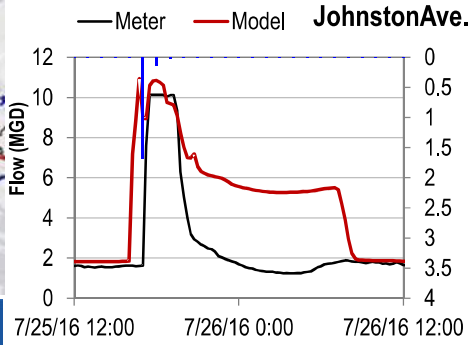
Calibration Results – Combined Area

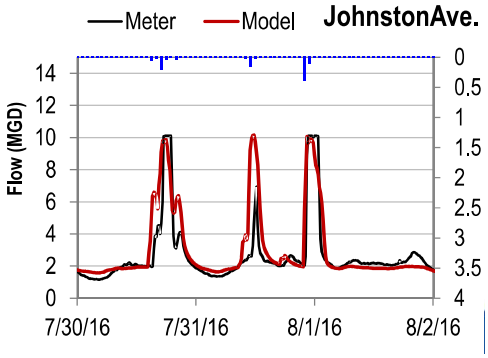
Johnston Ave.





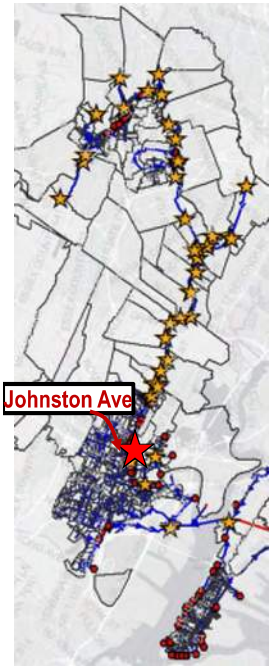


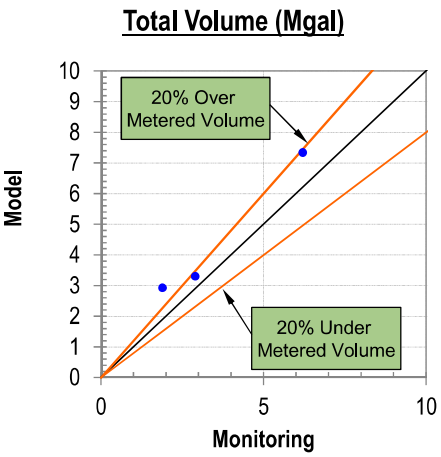


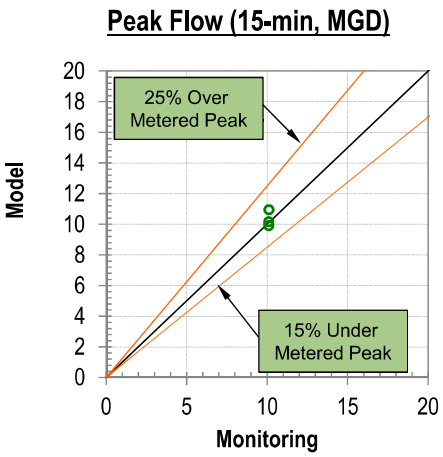


Calibration Results – Combined Area

Johnston Ave.

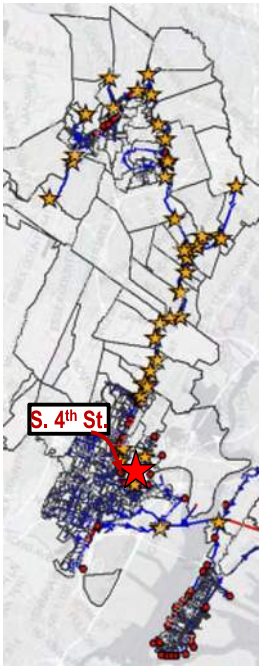


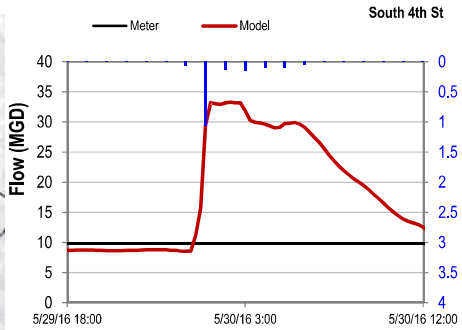


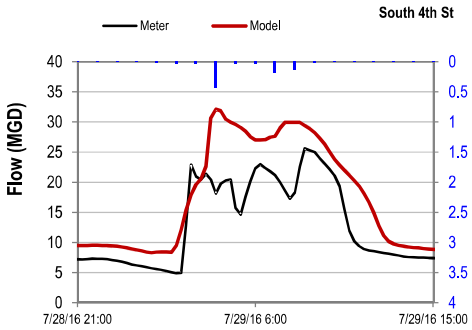


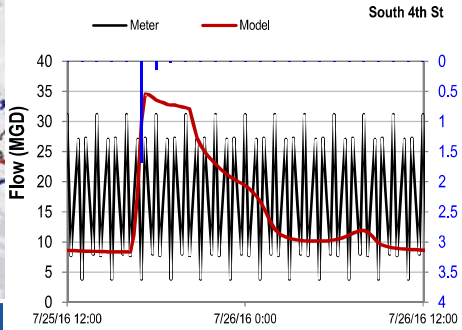
Calibration Results – Combined Area

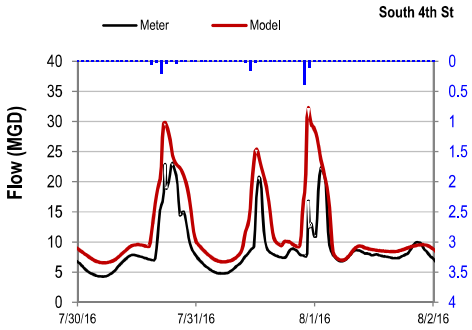
South 4th St.





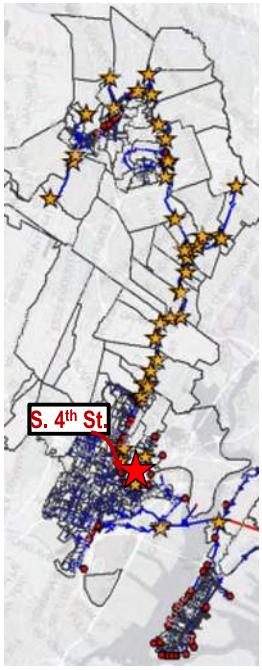


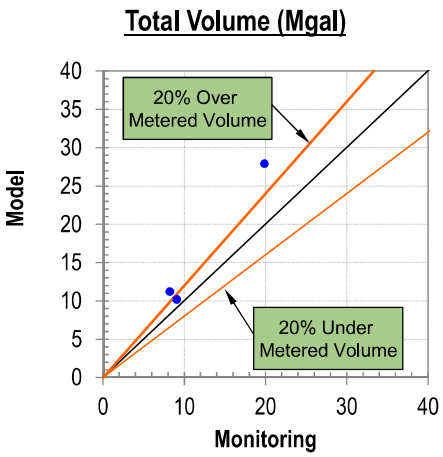


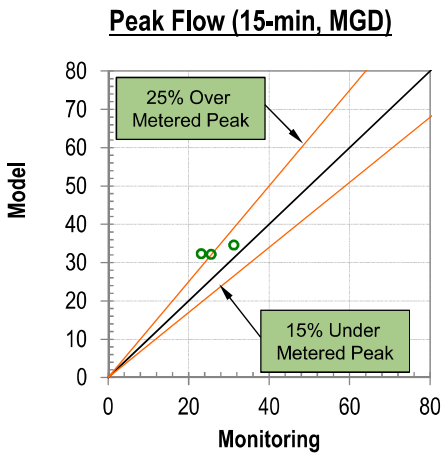


Calibration Results – Combined Area

South 4th St.

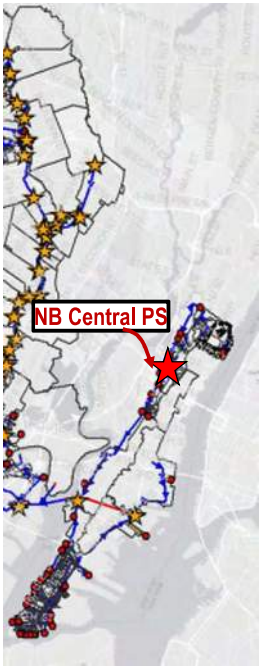


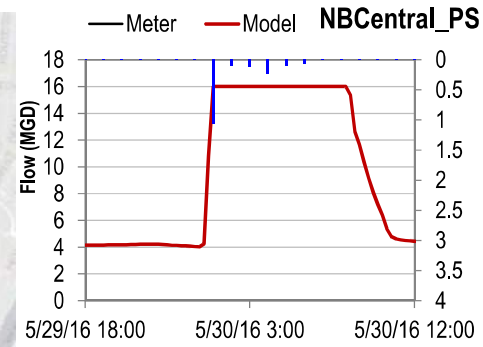


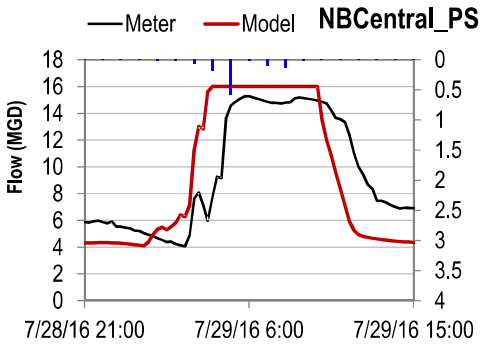


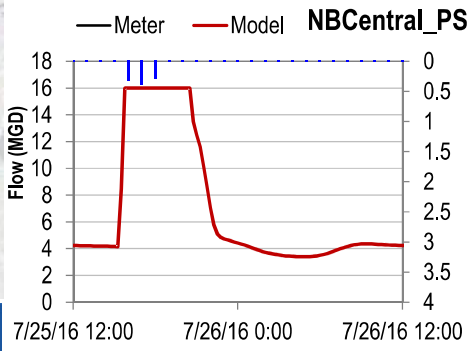
Calibration Results – Combined Area

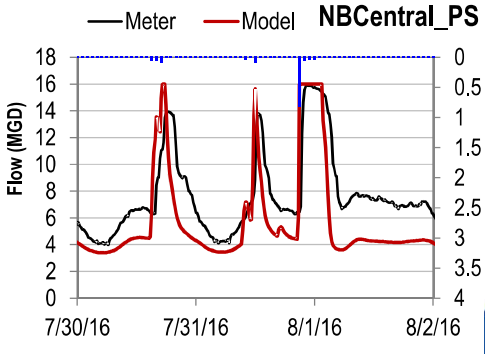
NB Central PS.





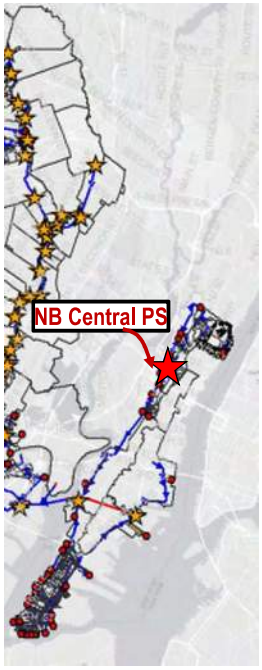


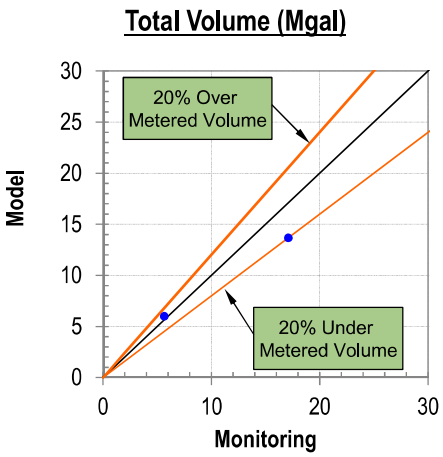


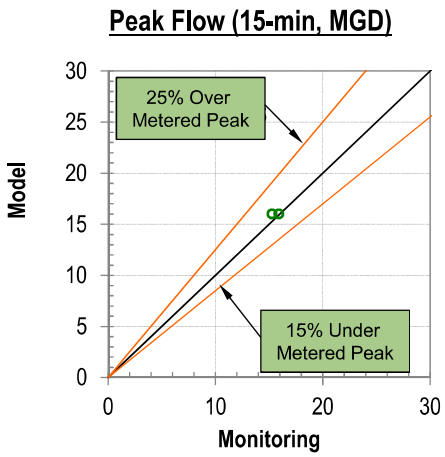


Calibration Results – Combined Area

NB Central PS.





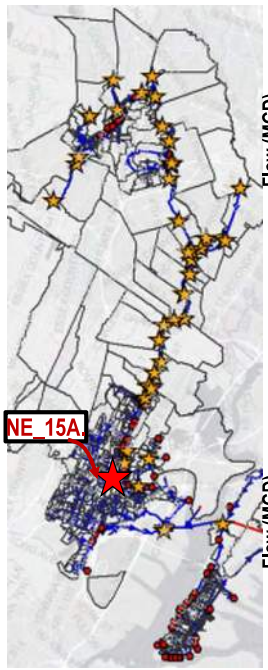


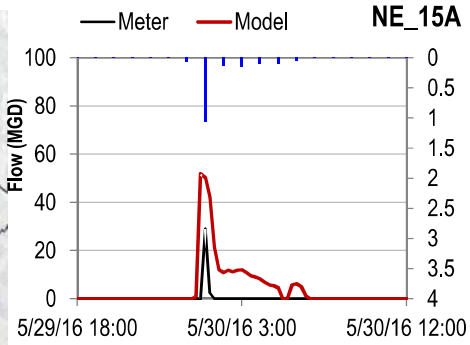
GREELEY AND HANSEN

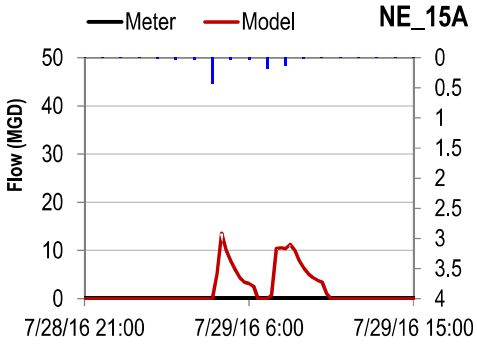
CSO Meters

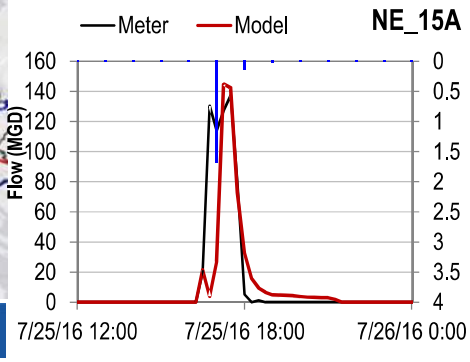
Calibration Results – CSO Overflow

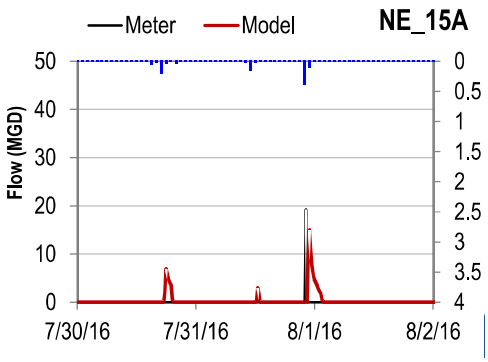
NE_15A





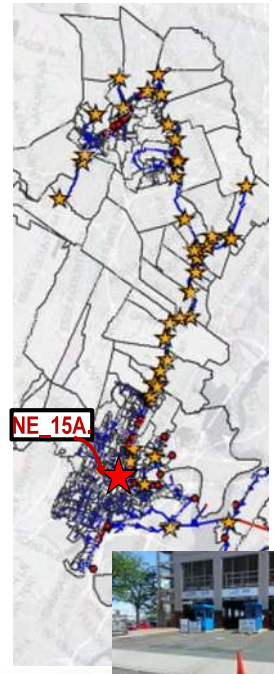


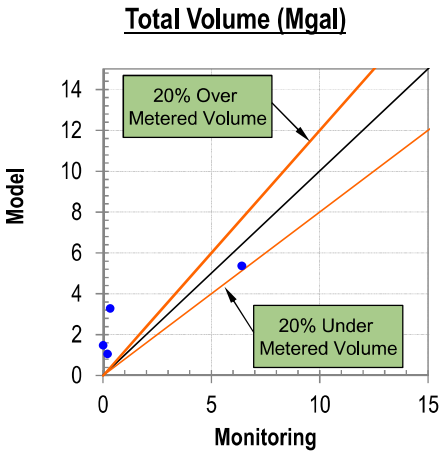


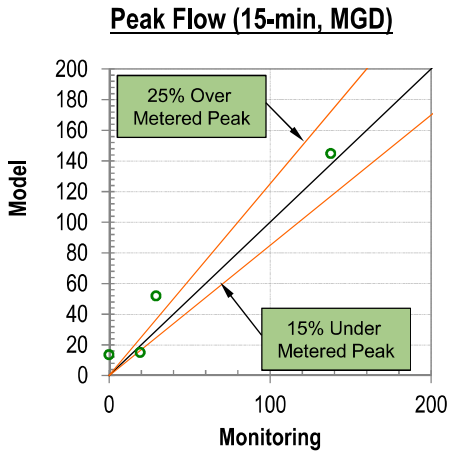


Calibration Results – CSO Overflow

NE_15A



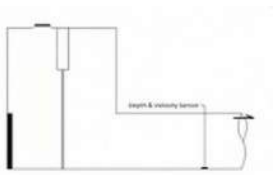






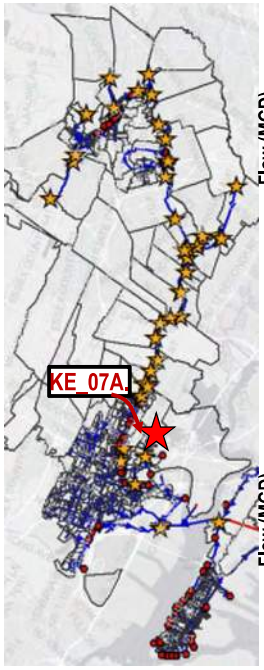


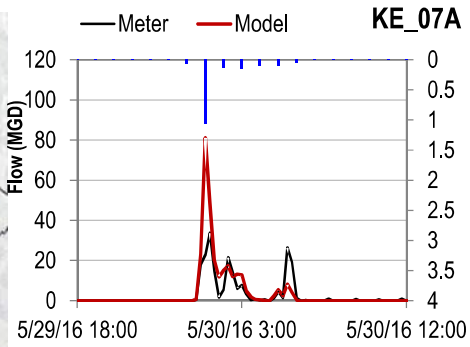


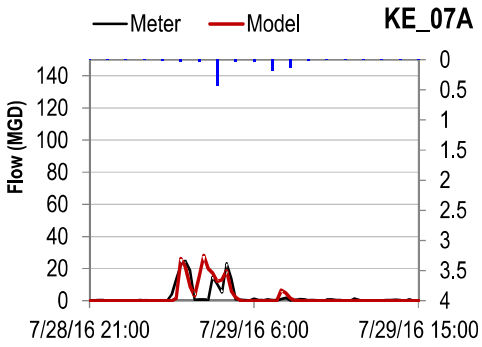


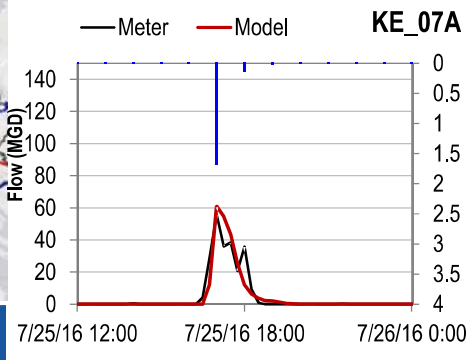
Calibration Results – CSO Overflow

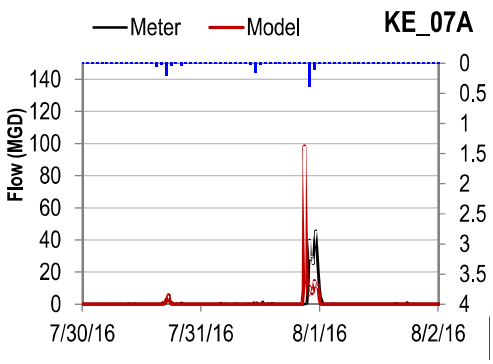
KE_07A





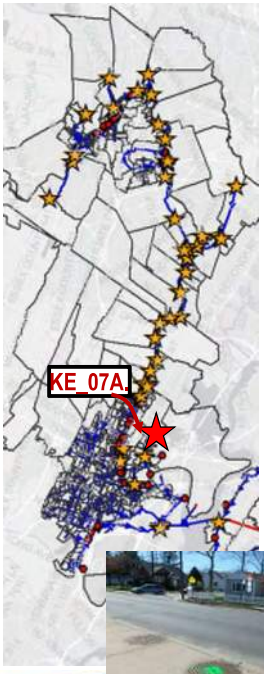


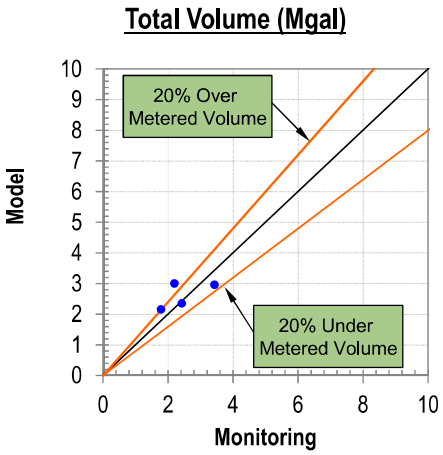


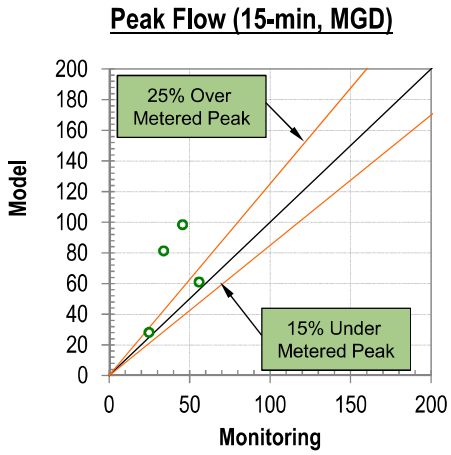


Calibration Results – CSO Overflow

KE_07A



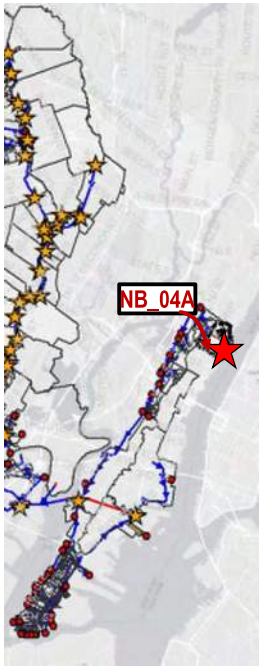


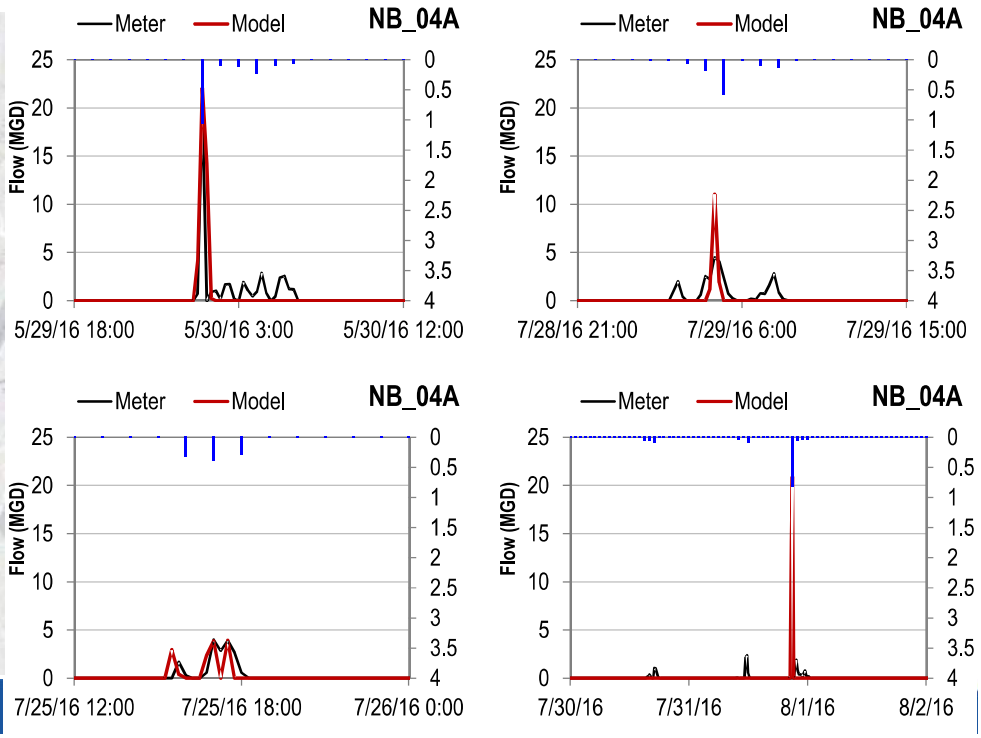




Calibration Results – CSO Overflow

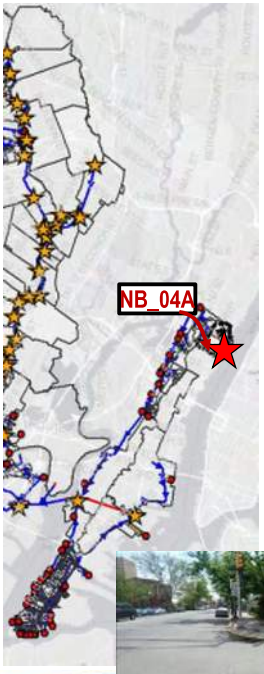
NB_04A

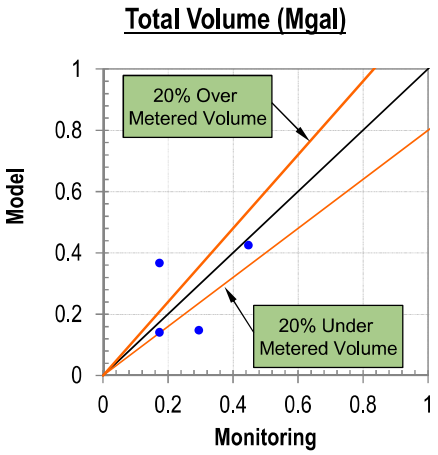


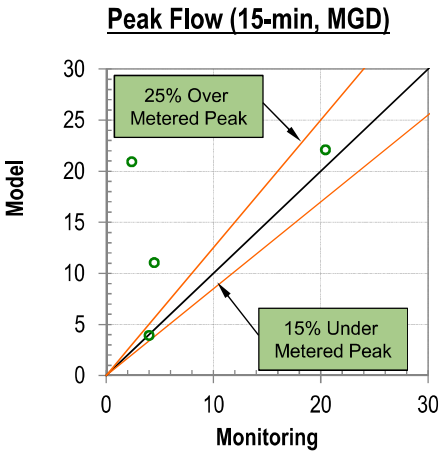


Calibration Results – CSO Overflow

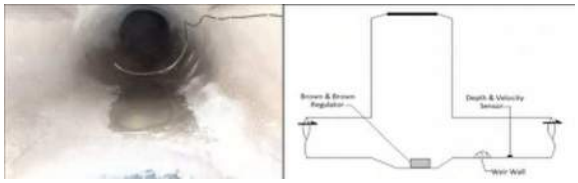
NB_04A







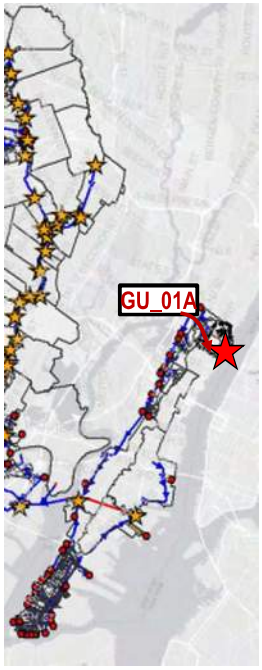


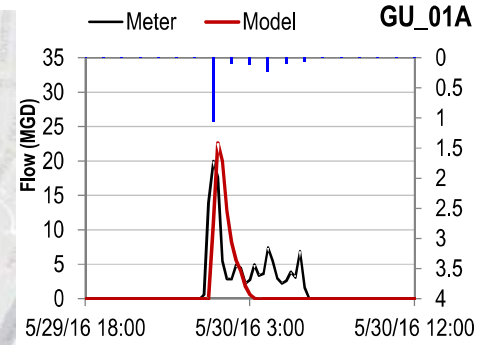


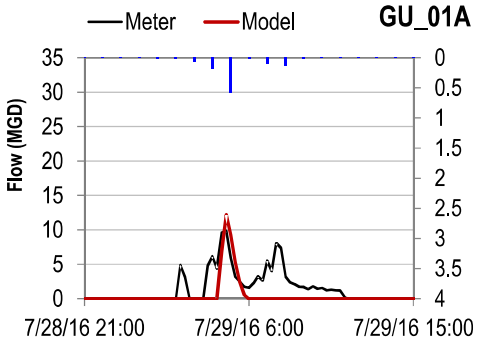
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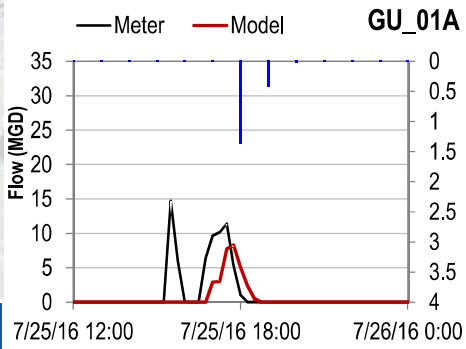
Calibration Results – CSO Overflow

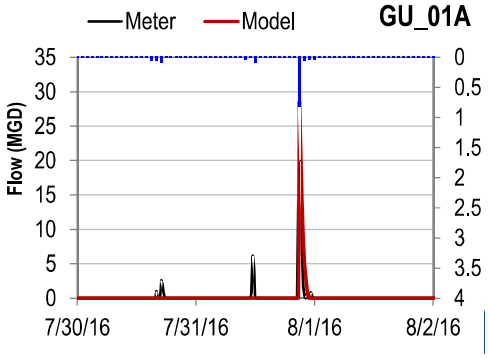
GU_01A







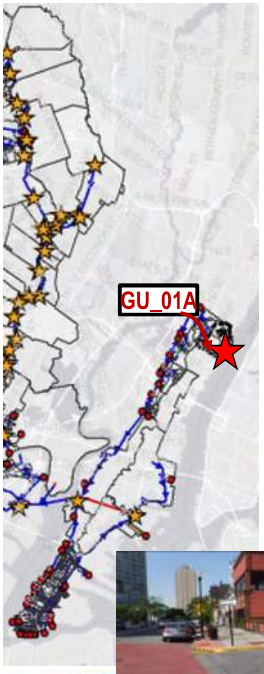


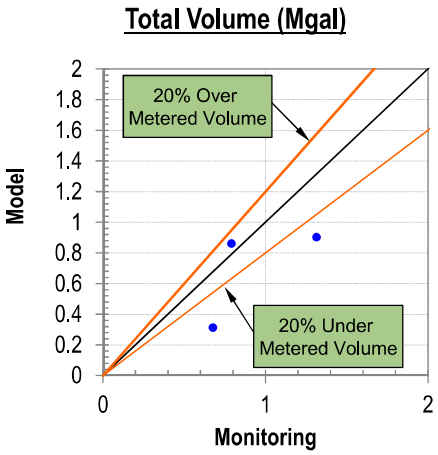


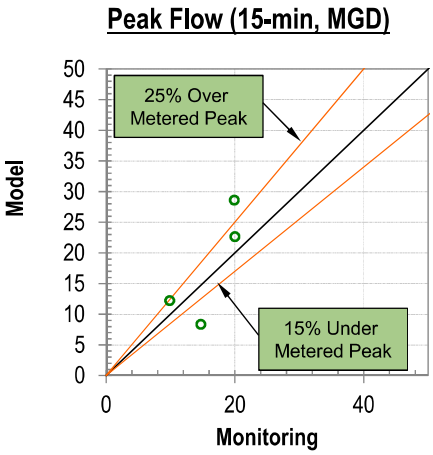
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Calibration Results – CSO Overflow

GU_01A



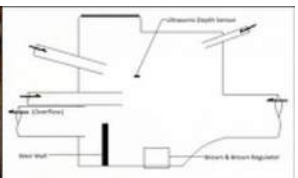






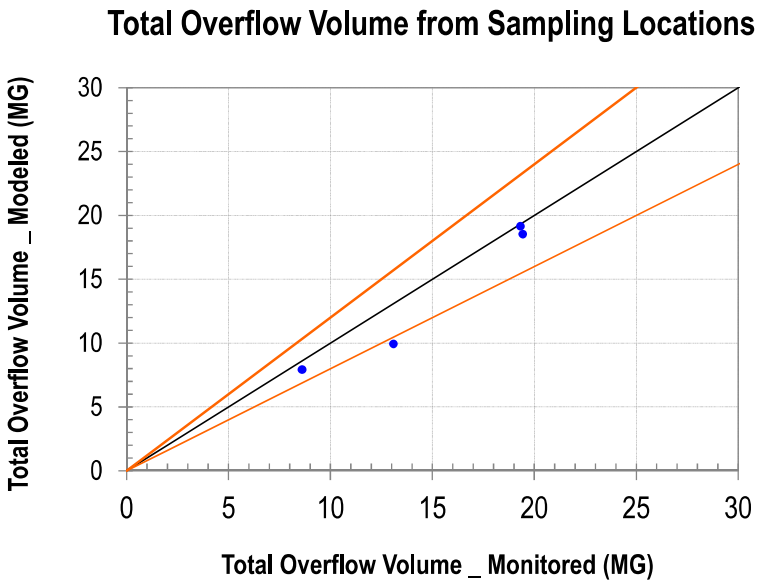






Total Overflow Volume

NE_04&05, NE_09&10, NE_14A , NE_15A , KE_07A , BA_08A , BA_10A ,NB_11A , NB_07A, NB_04A, NB_04B, GU_01A



GREELEY AND HANSEN

Summary & Next Step

Summary

- The updated PVSC H&H model includes
  - 48 municipalities served by the PVSC WPCF
  - 2 municipalities served by the NBMUA Woodcliff WWTP
  - Dry weather flow based on 2016 flow monitoring data
  - Wet weather flow simulated as runoff from the combined areas and RDII from the separated areas
  - Current PVSC WPCF wet weather operating rules
- The model is calibrated and validated to 2016 flow monitoring data

Next Step

- Finalize model
- Address comments received
- Generate CSO flows for WQ model
- Distribute model to CSO permittees

GREELEY AND HANSEN

The End

Water Quality Modeling Update

Model Evaluation Group – Session 3

Rich Isleib, HDR

September 15, 2017



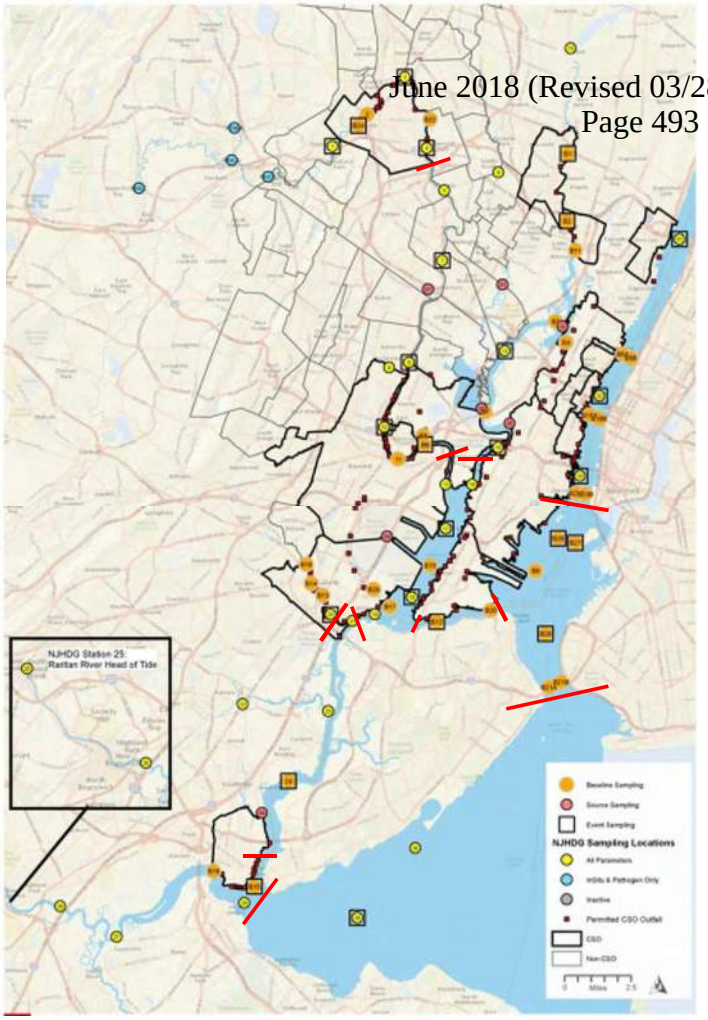
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Agenda

- Receiving Water Data Summary
- Source Loading Approach
  - Stormwater
  - CSO
  - Rivers
- Model Calibration
- Next Steps

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Receiving Water Sampling Locations



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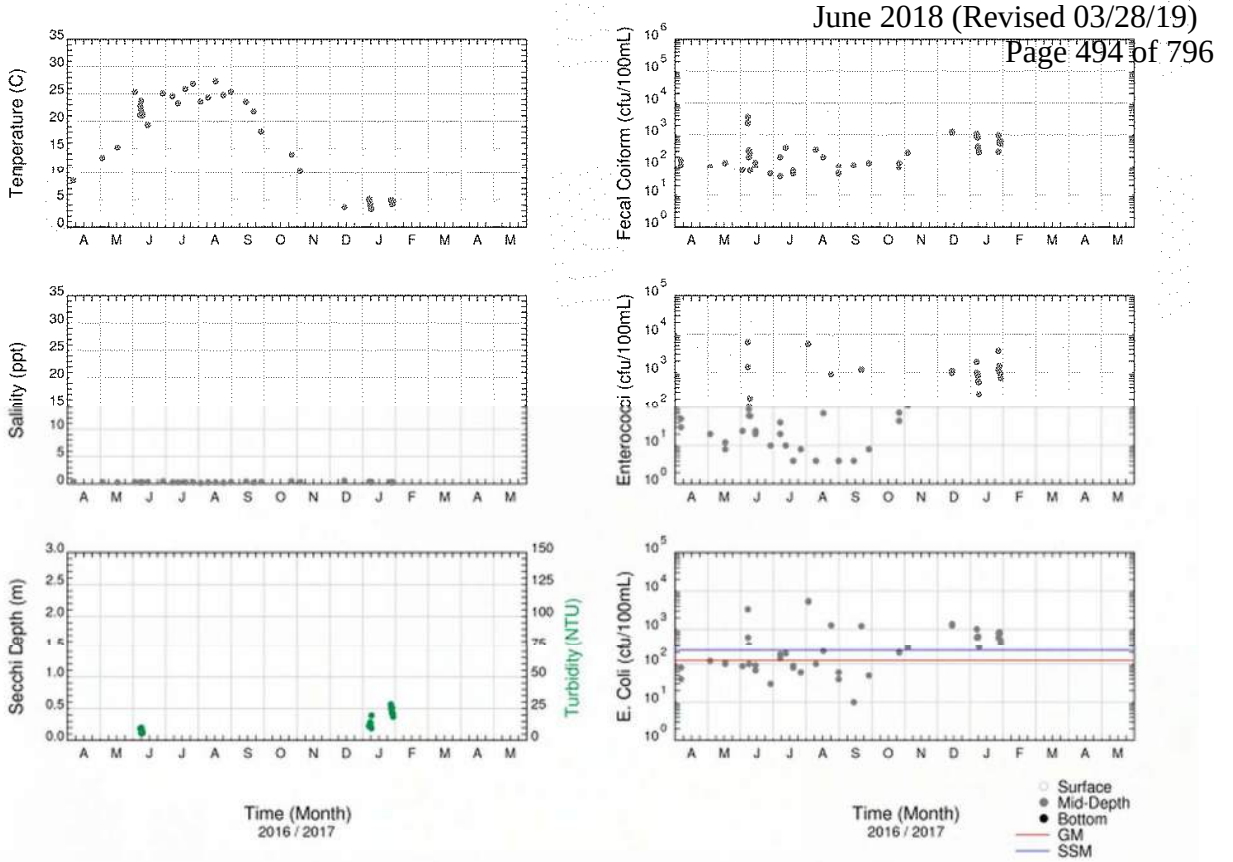
NJ Pathogen Criteria

- Primary Contact Recreation:
  - Enterococci levels shall not exceed a geometric mean of **35/100 ml**, or a single sample maximum of **104/100 ml**. (SE1 and SC)
    - Hackensack R. (upper), Hudson R. (north of Harlem R.), Raritan R., Raritan Bay
  - E. coli levels shall not exceed a geometric mean of **126/100 ml** or a single sample maximum of **235/100 ml**. (All FW2)
    - Elizabeth R., Passaic R., Raritan R.

- Secondary Contact Recreation:
  - Fecal coliform levels shall not exceed a geometric mean of **770/100 ml**. (SE2)
    - Arthur Kill (lower), Hackensack R. (mid), Hudson R., Passaic R. (mid), Rahway R.
  - Fecal coliform levels shall not exceed a geometric mean of **1500/100ml**. (SE3)
    - Arthur Kill (upper), Elizabeth R., Hackensack R. (lower), Kill Van Kull, Newark Bay, Passaic R. (lower)

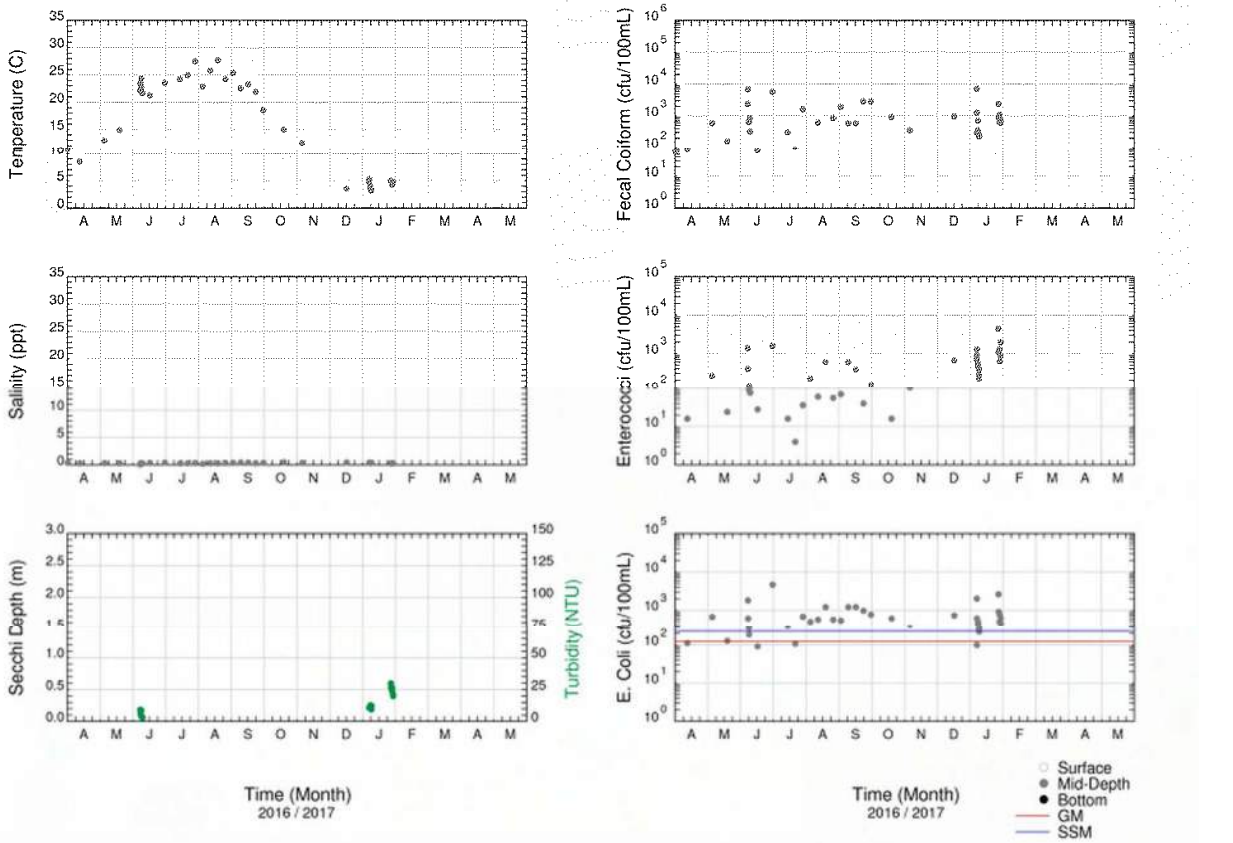
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Passaic River & Tributaries, Passaic River, 1, (FW2)



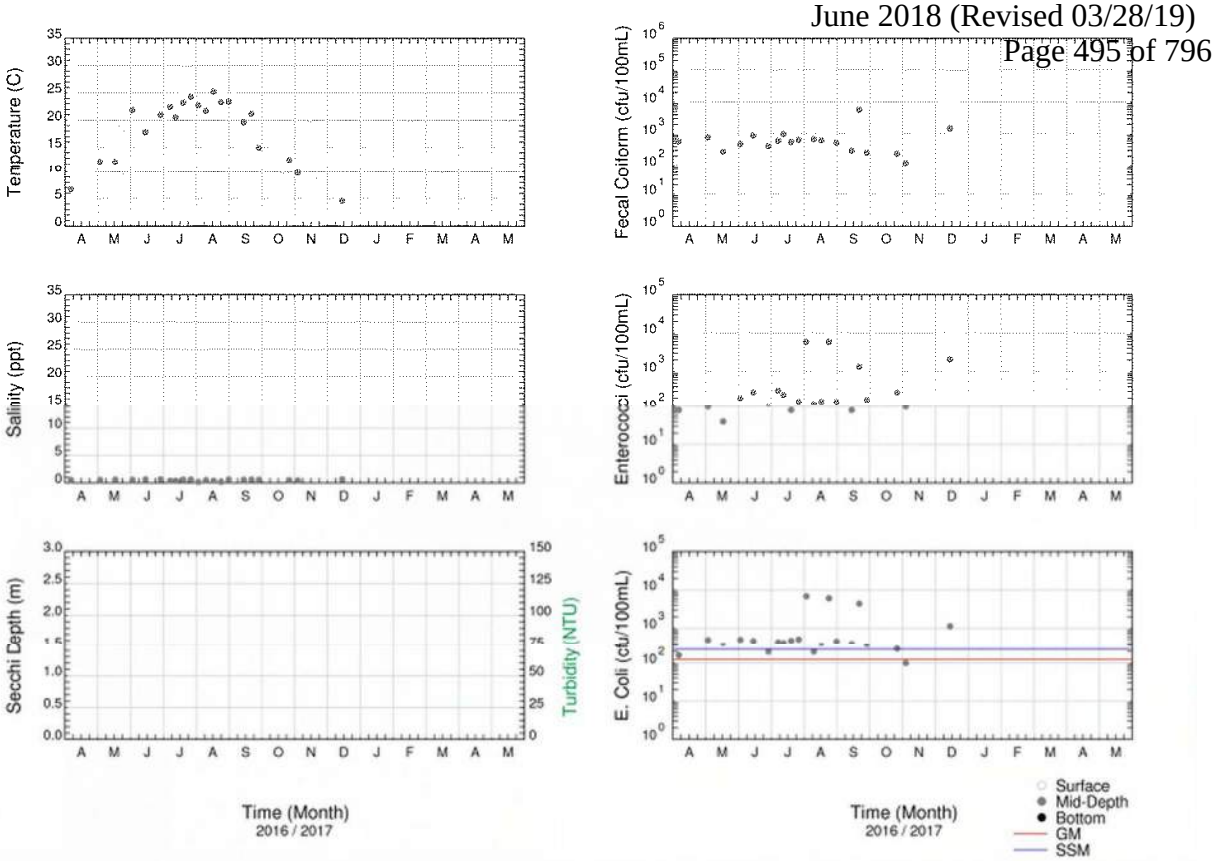
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Passaic River & Tributaries, Passaic River, 3, (FW2)



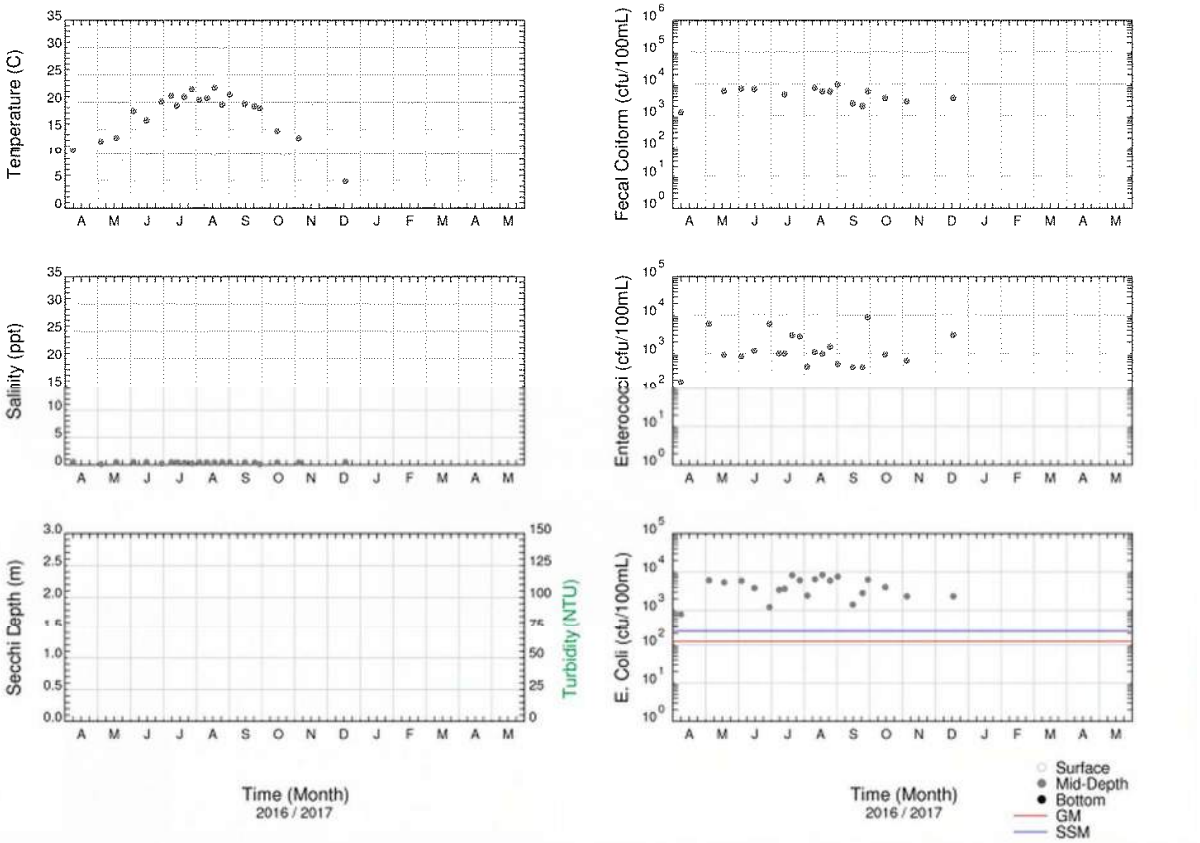
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NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Passaic River & Tributaries, Saddle River, 6, (FW2)



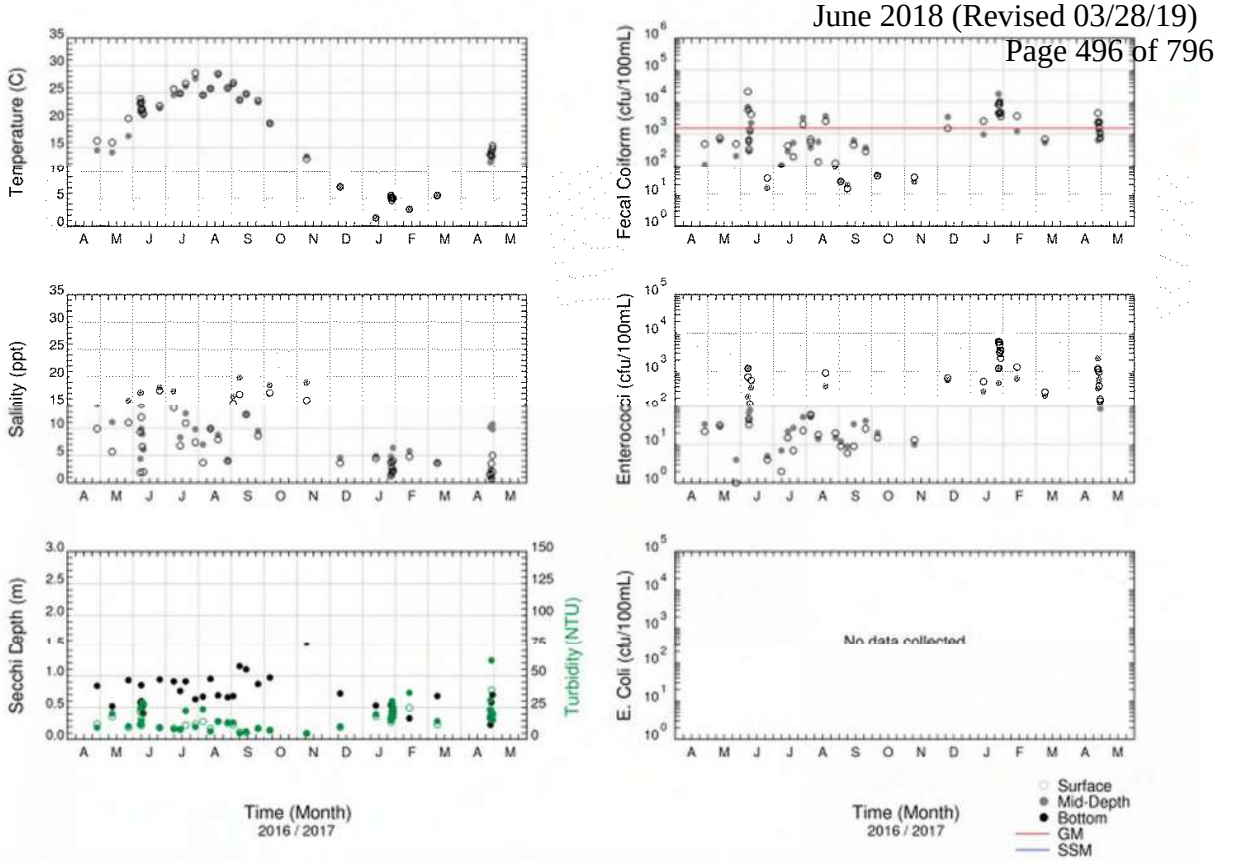
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NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Passaic River & Tributaries, Second River, 9, (FW2)



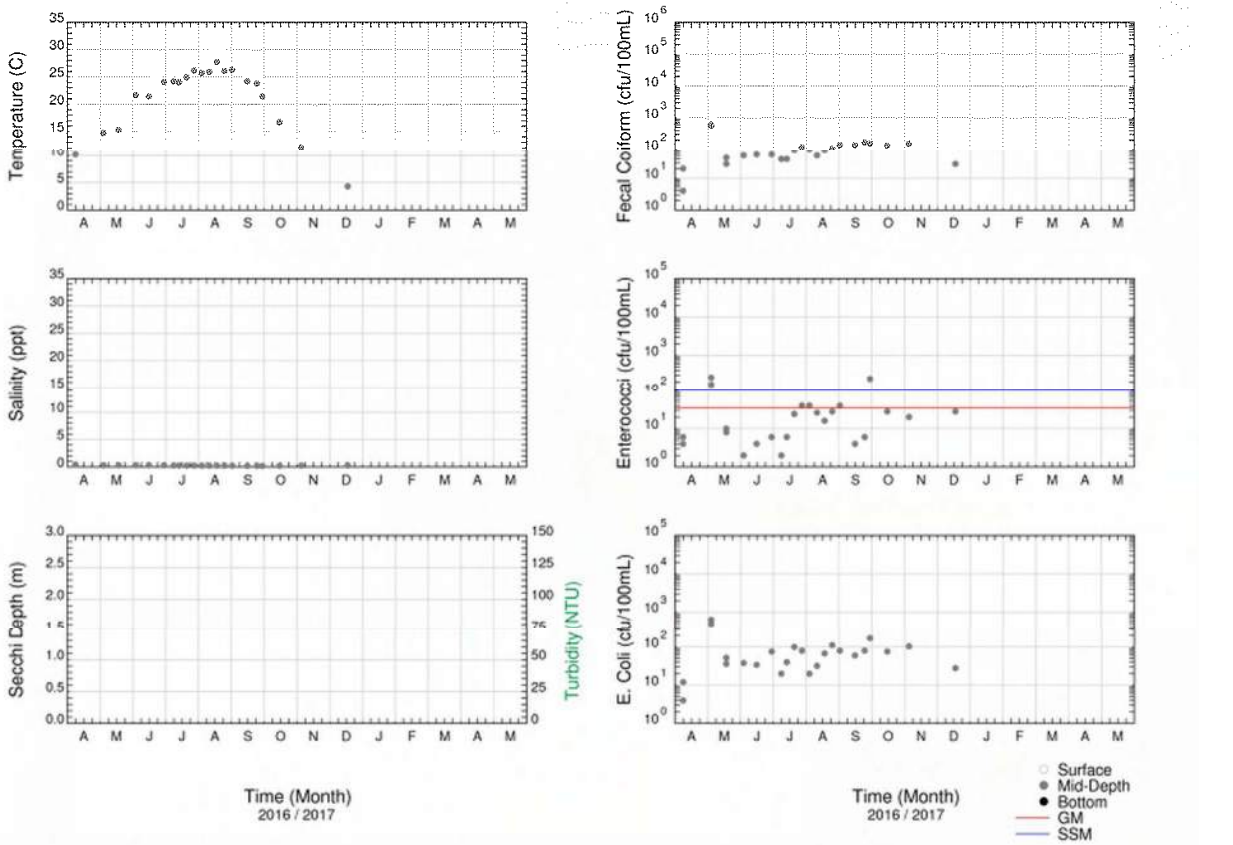
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Passaic River & Tributaries, Passaic River, B6, (SE3)



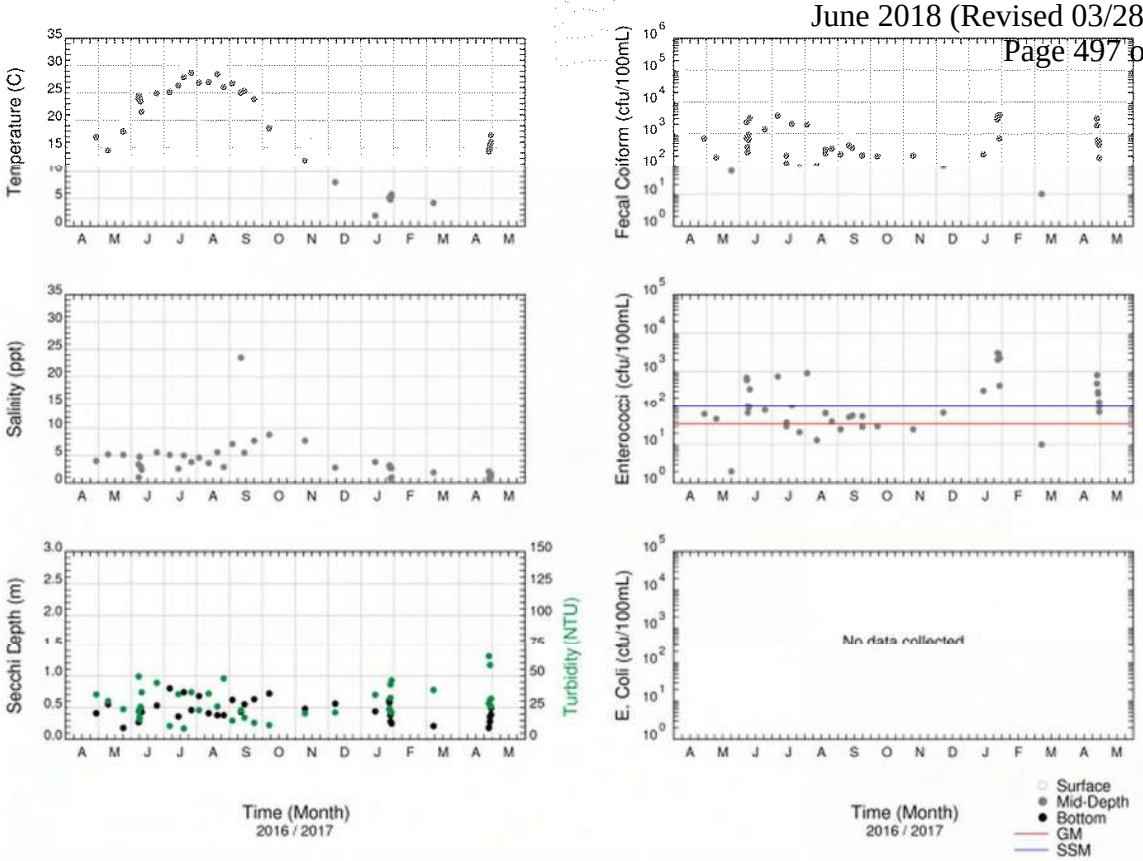
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Hackensack River & Tributaries, Hackensack River, 13, (SE1)



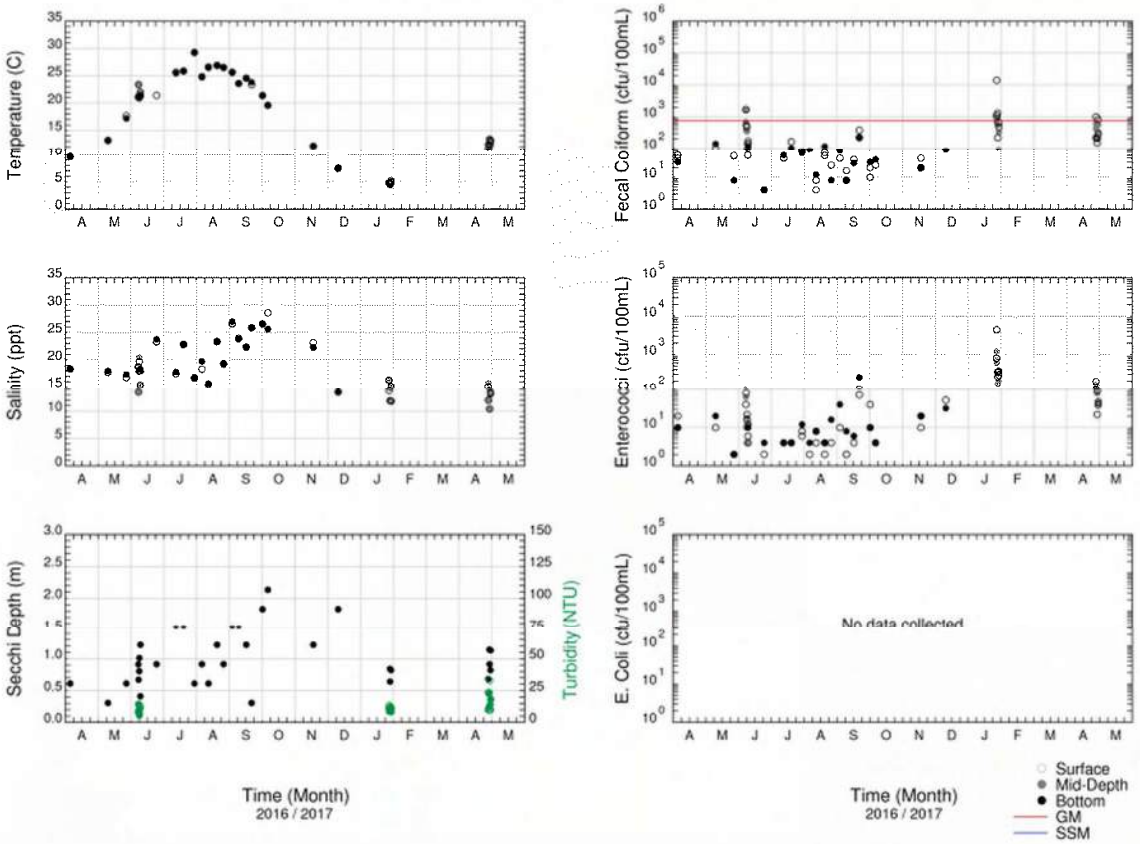
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Hackensack River & Tributaries, Hackensack River, B2, (SE1)



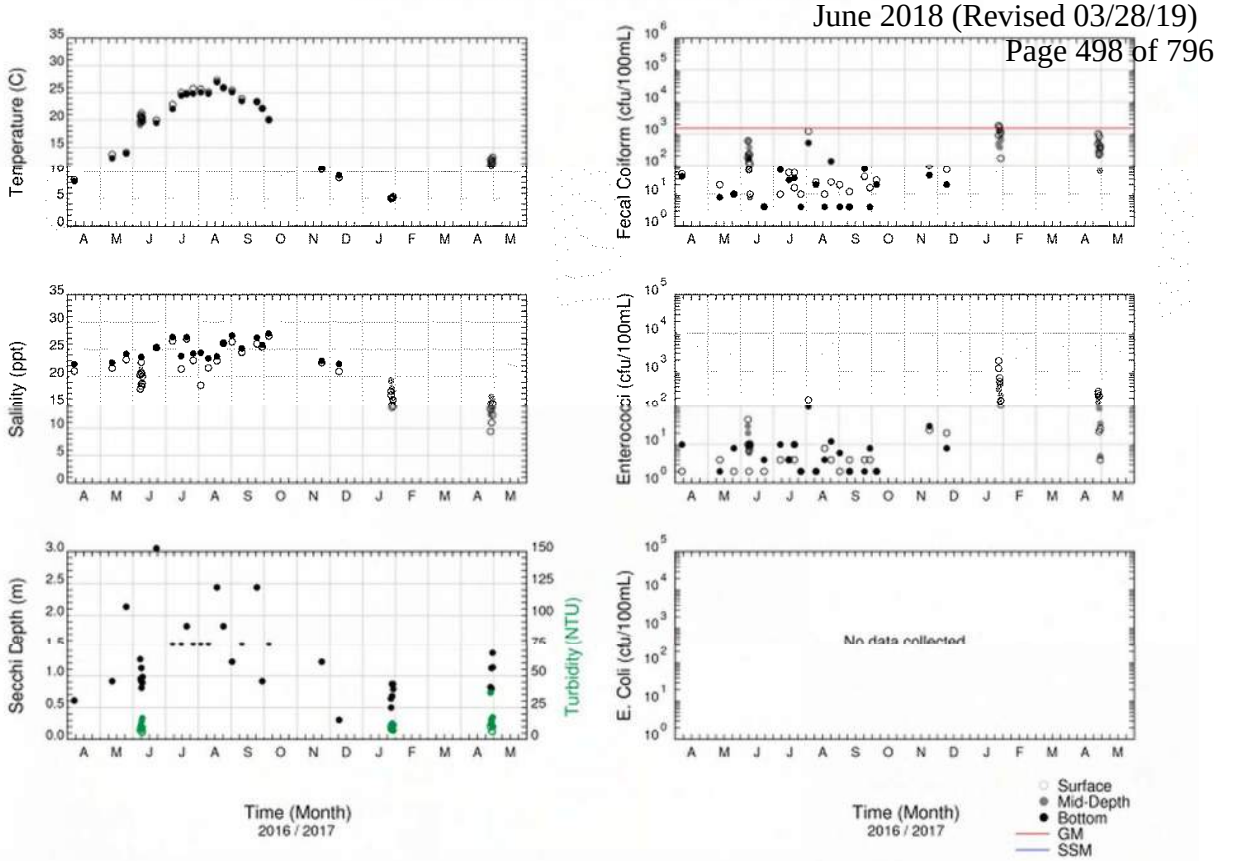
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Hackensack River & Tributaries, Hackensack River, 15, (SE2)



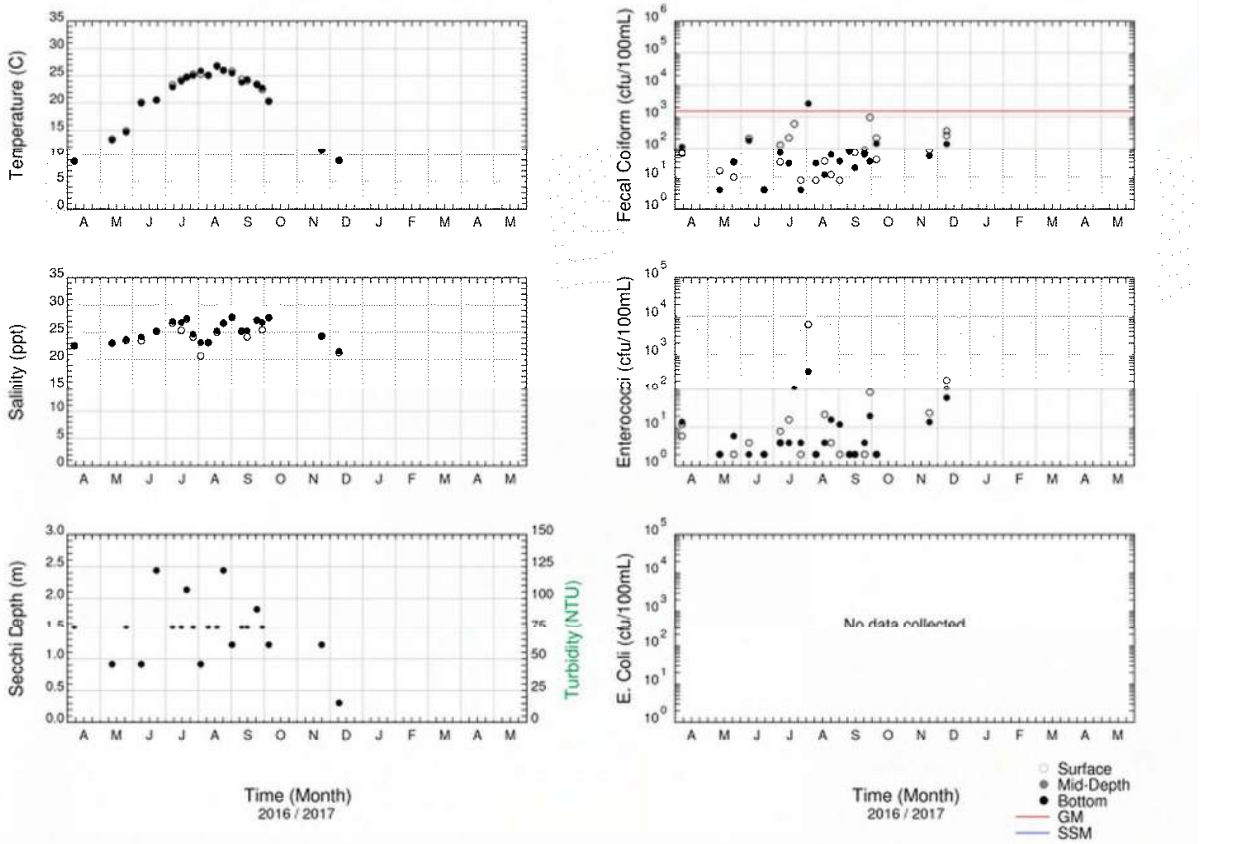
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NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
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Newark Bay & Tributaries, Newark Bay, 17, (SE3)



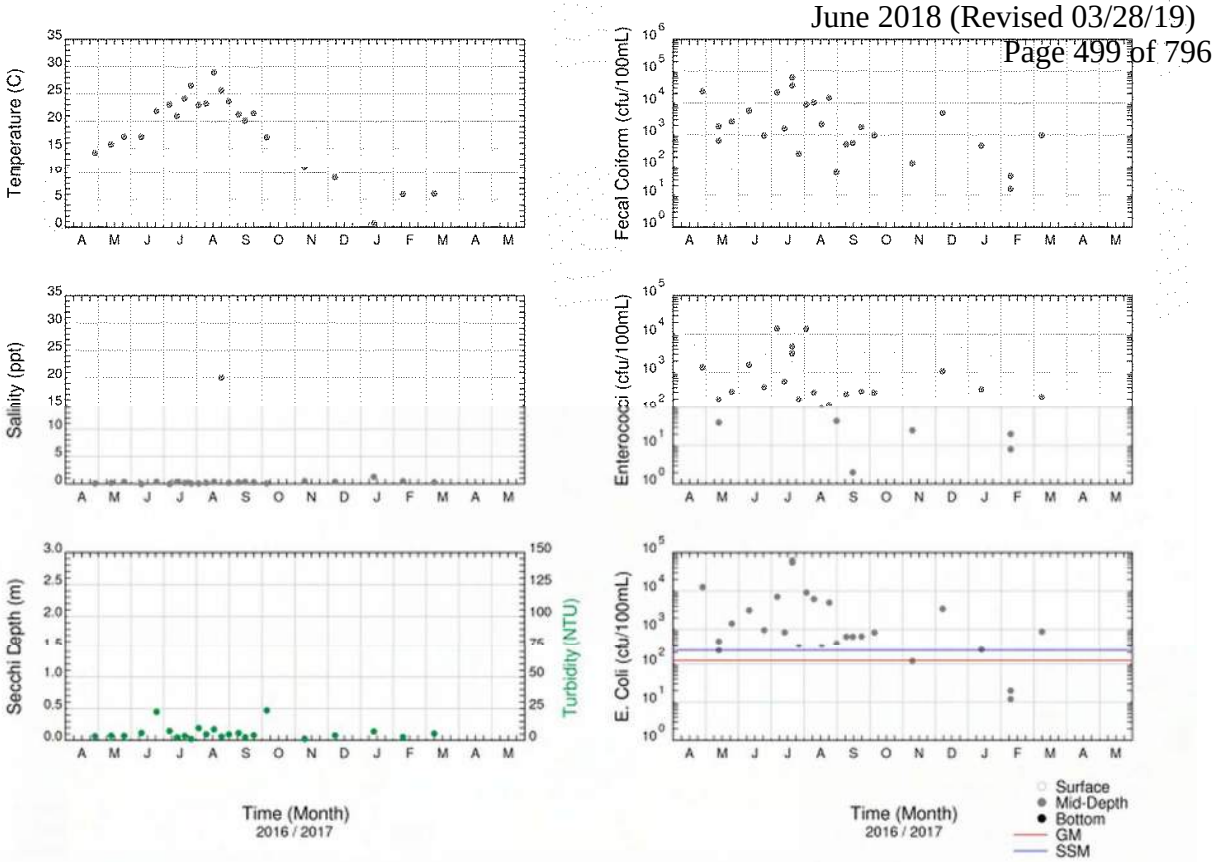
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Newark Bay & Tributaries, Arthur Kill, 21, (SE3)



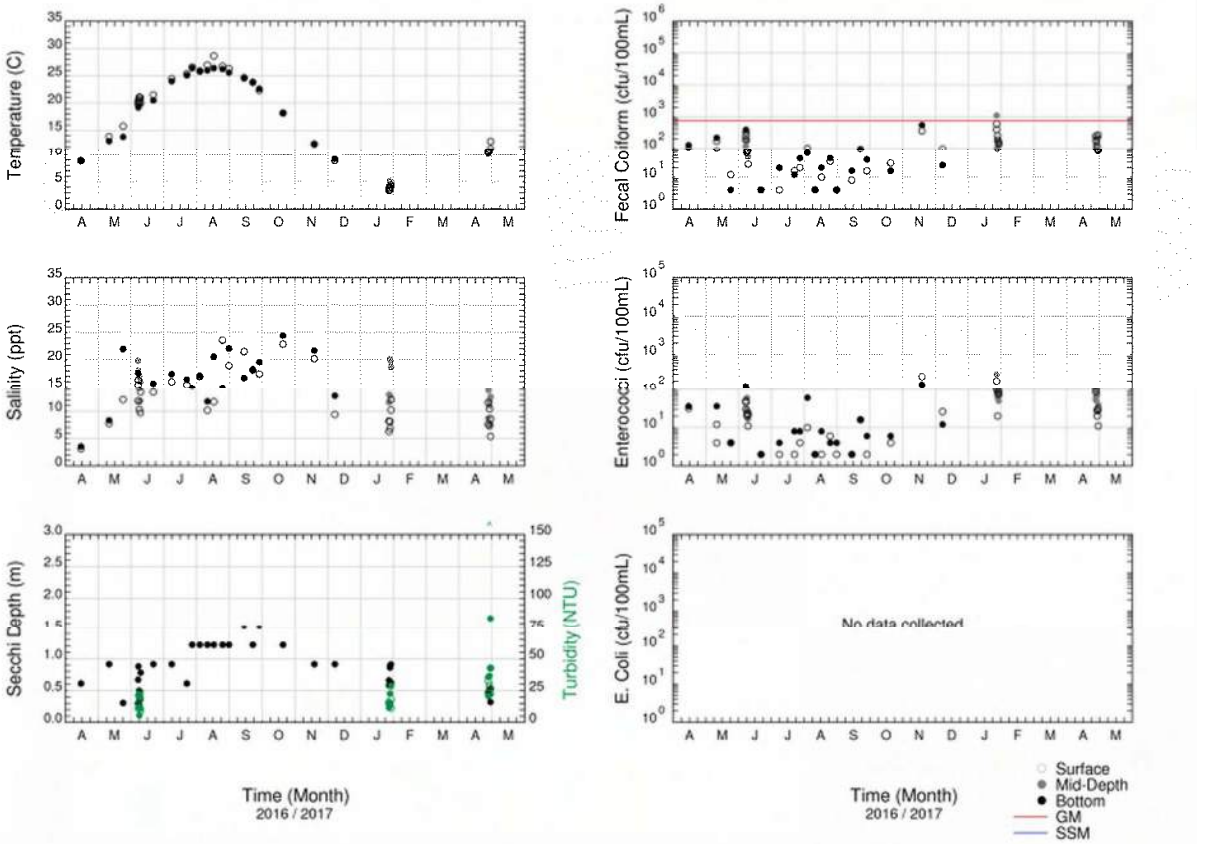
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Newark Bay & Tributaries, Elizabeth River, B16, (FW2)



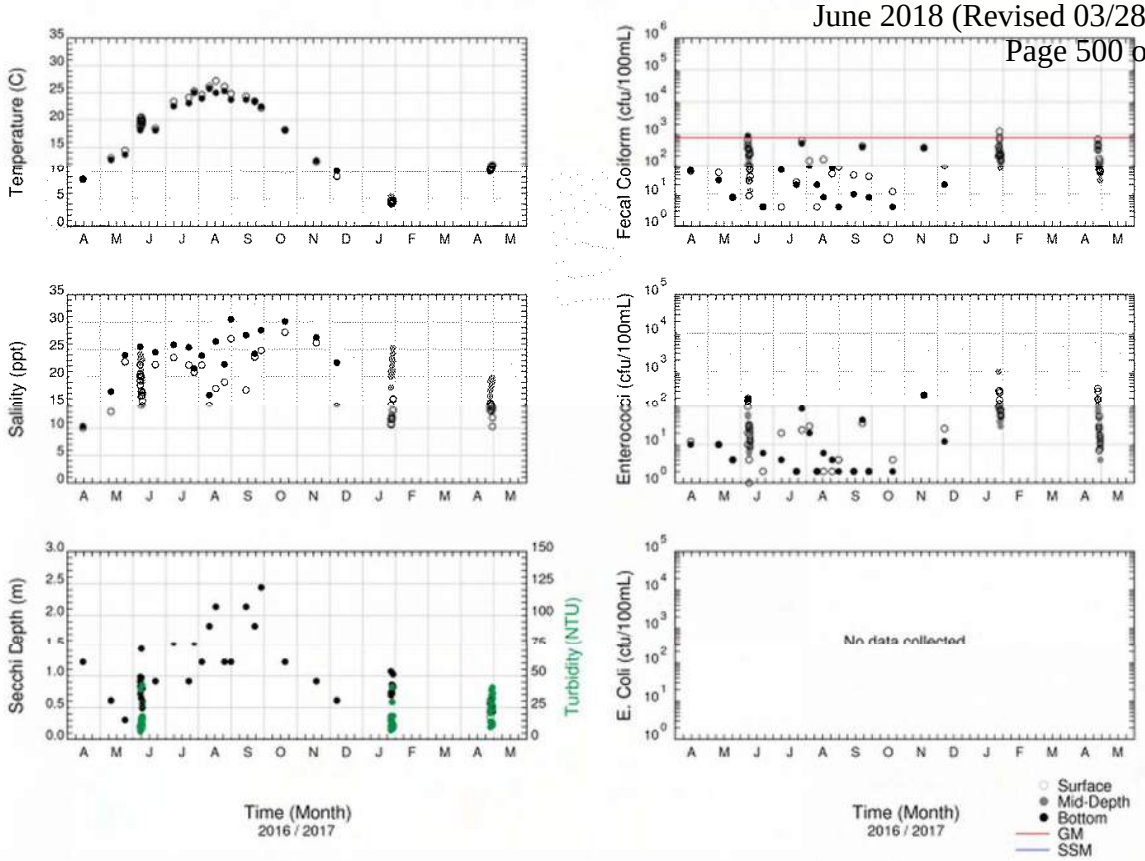
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Hudson River, Upper Bay, Hudson River, 31, (SE2)



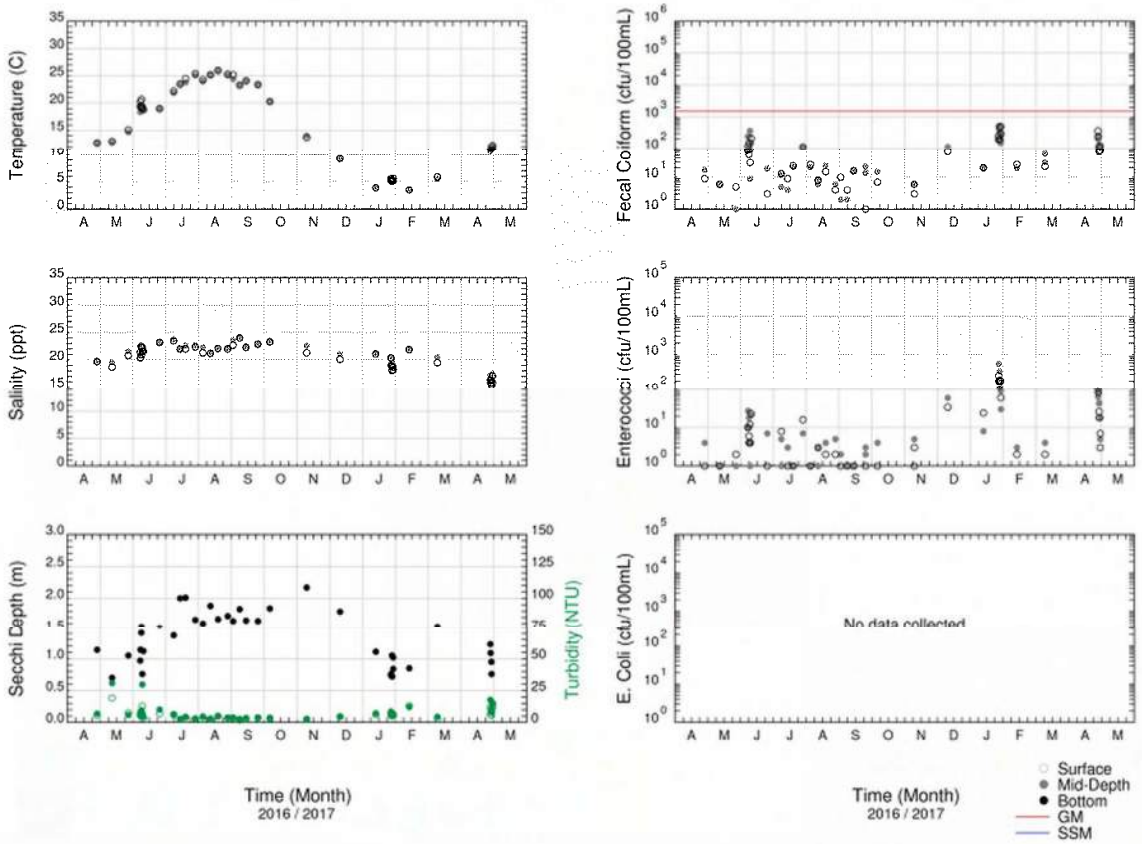
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Hudson River, Upper Bay, Hudson River, 33, (SE2)



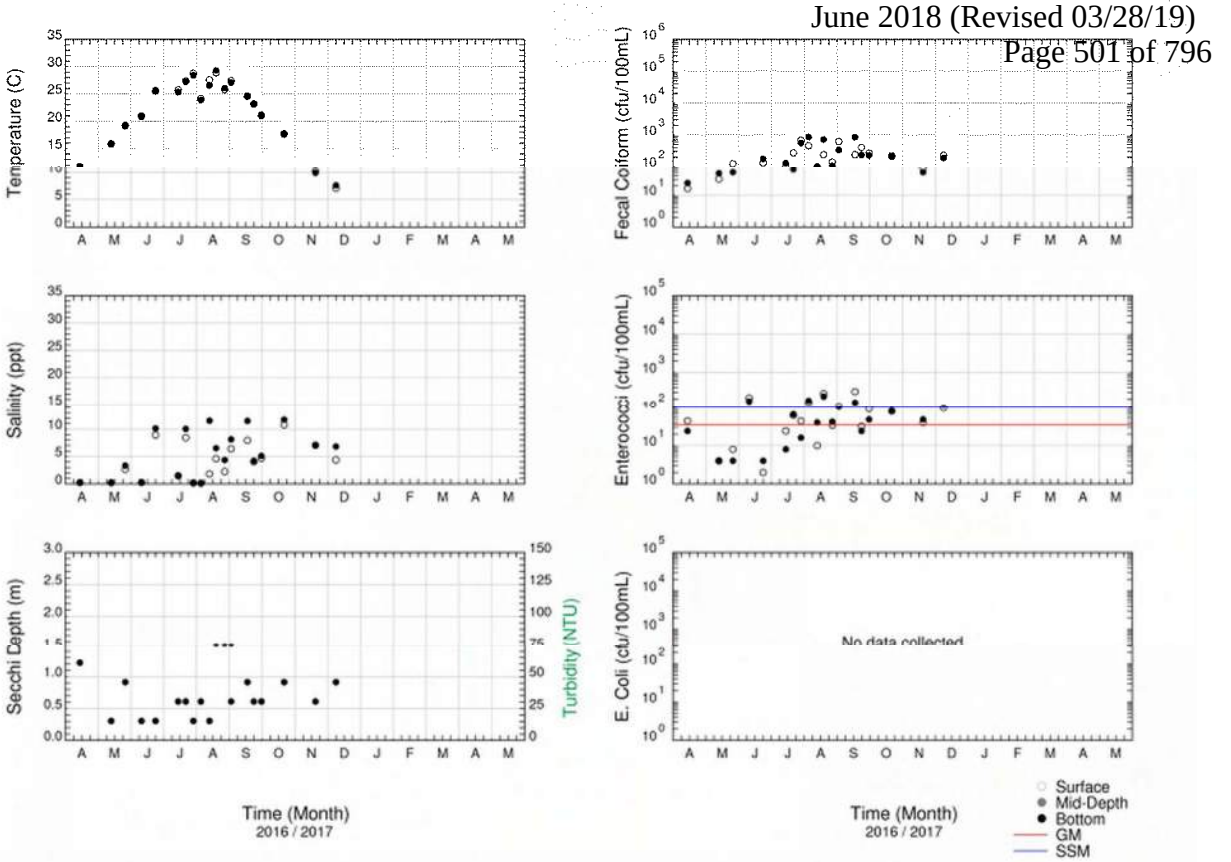
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Hudson River, Upper Bay, Kill Van Kull, B12, (SE3)



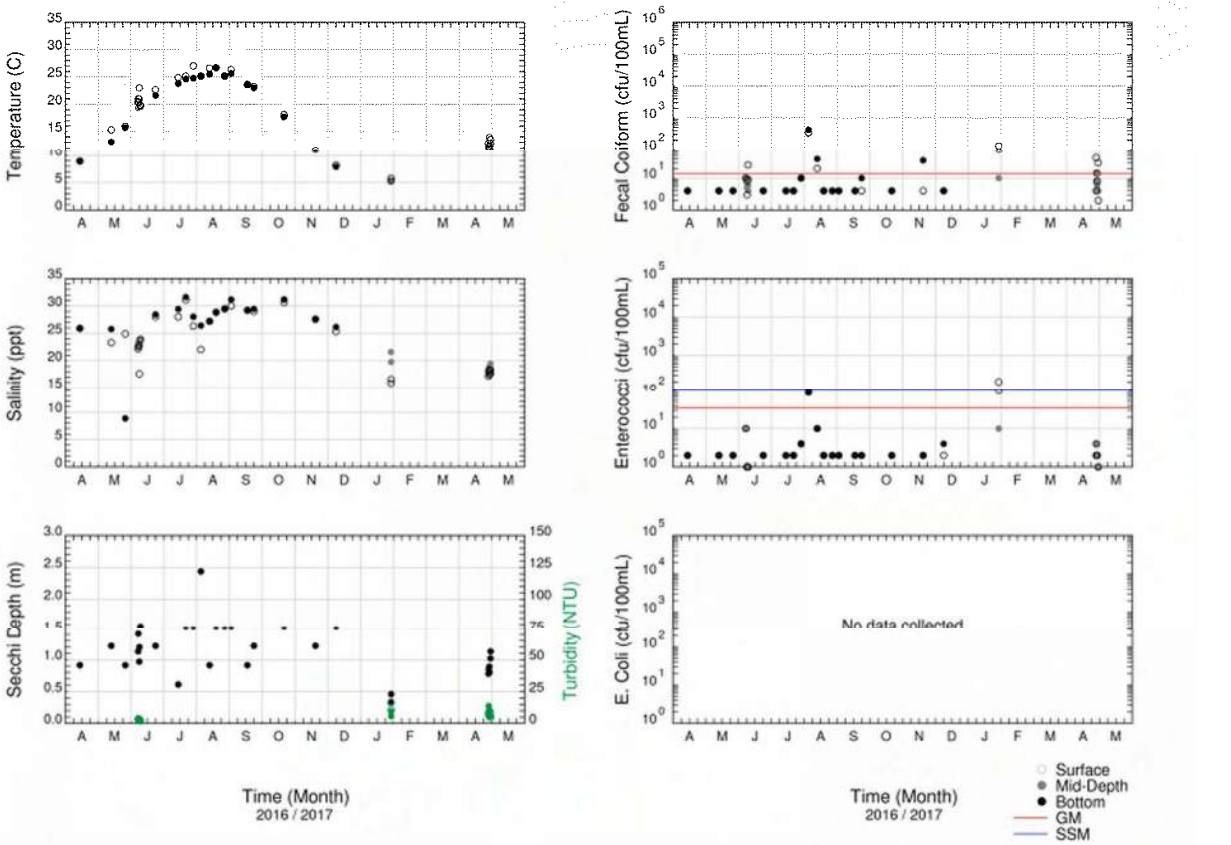
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Arthur Kill, Raritan River/Bay & Tributaries, Raritan River, 26, (SE1)

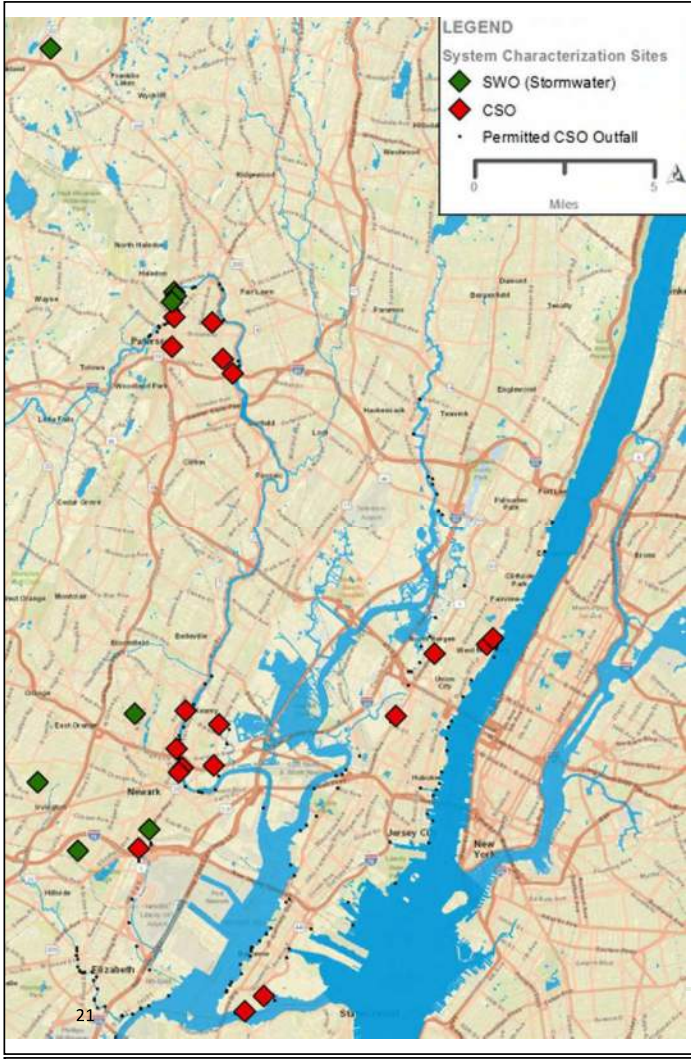


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Arthur Kill, Raritan River/Bay & Tributaries, Raritan Bay, 29, (Shellfish)



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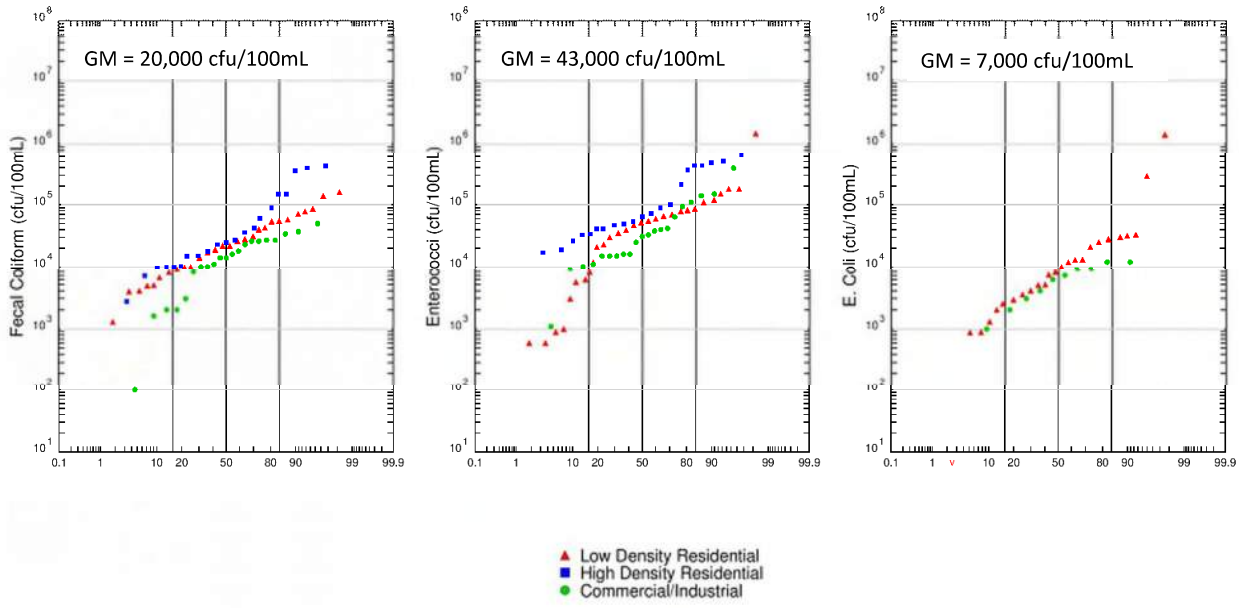


Landside Pathogen Concentration Stations

- Stormwater – 8 locations
  - Low Density Residential (4)
  - High Density Residential (2)
  - Commercial / Industrial (2)
- CSO – 18 Locations
  - Paterson (5)
  - Newark (4)
  - North Bergen (3)
  - Harrison (2)
  - Bayonne (2)
  - Guttenberg (1)
  - Kearny (1)

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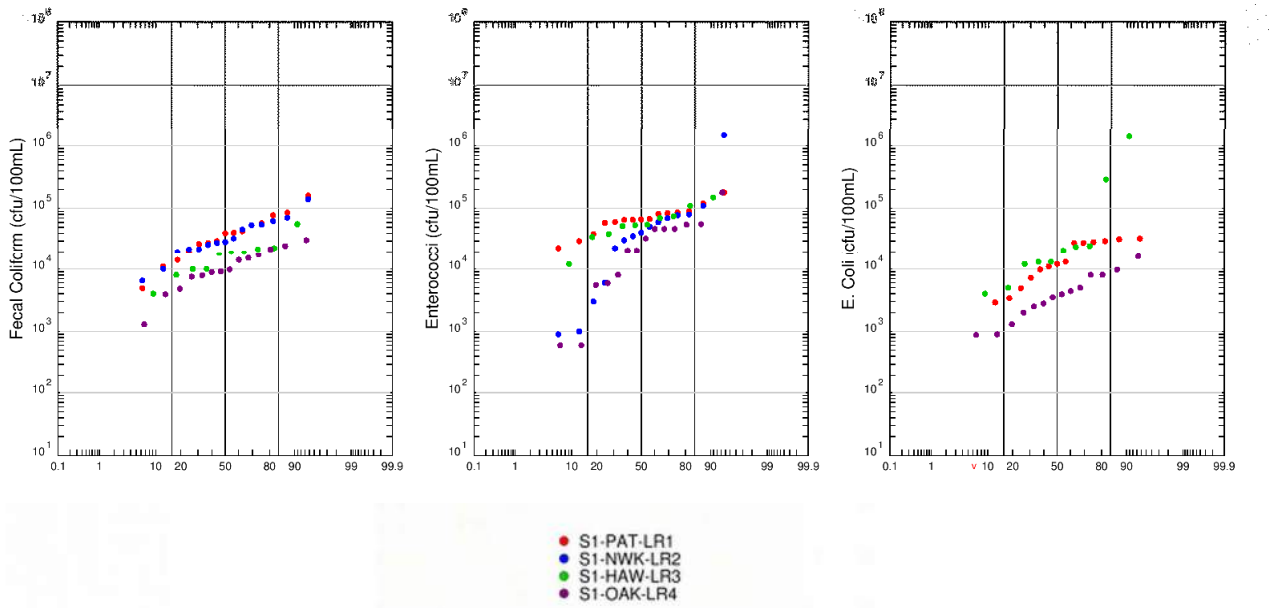
Probability Plot of Stormwater Pathogen Data
By Land Use
2016-2017



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Probability Plot of Stormwater Pathogen Data
By Individual Location
2016-2017

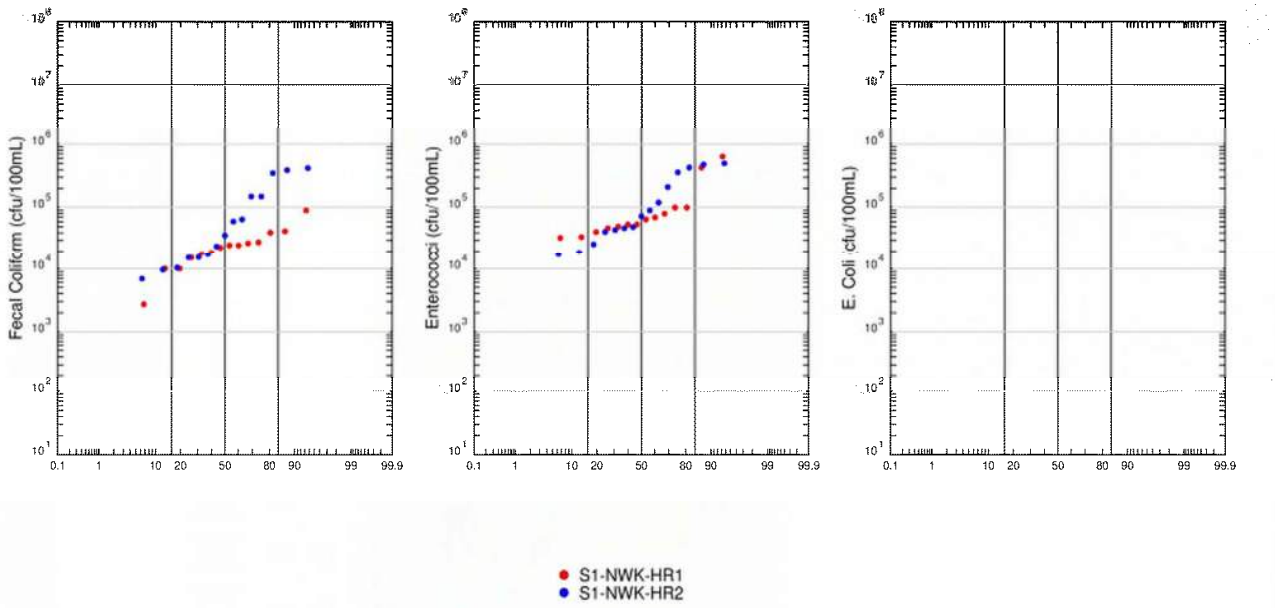
Low Density Residential



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By Individual Location
2016-2017

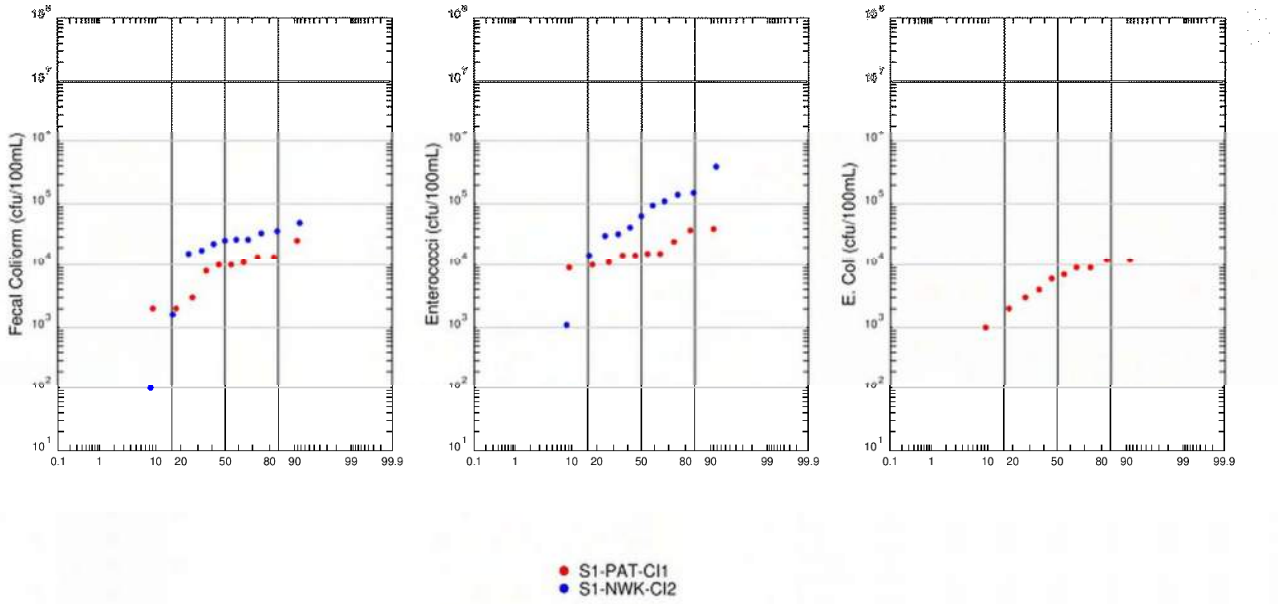
High Density Residential



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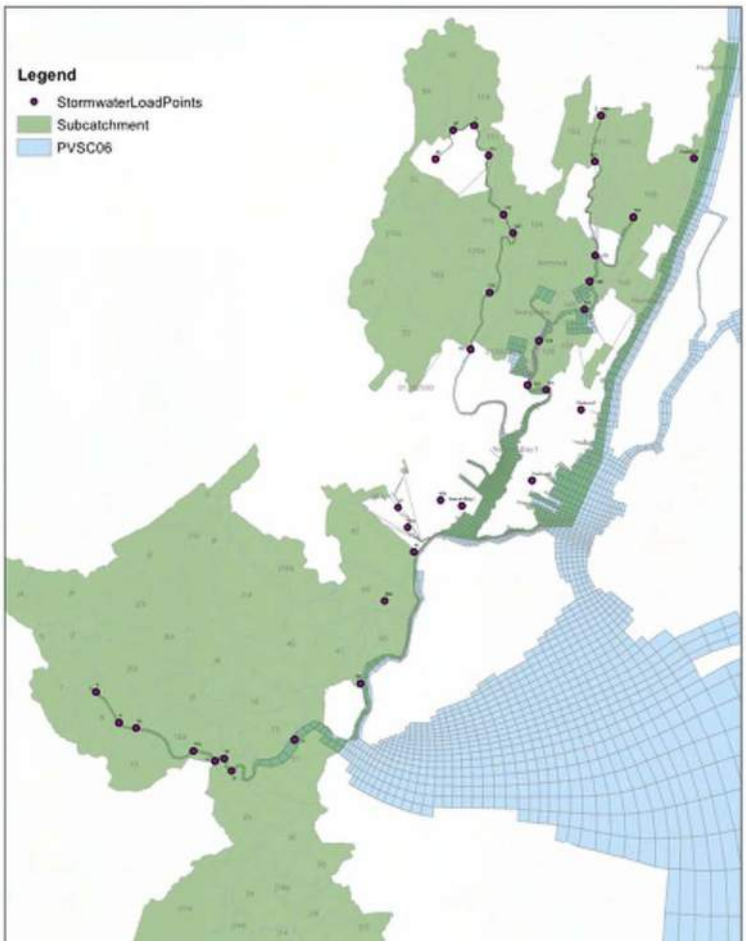
GREELEY AND HANSEN CDM Smith HDR

Commercial/Industrial



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Stormwater Flows



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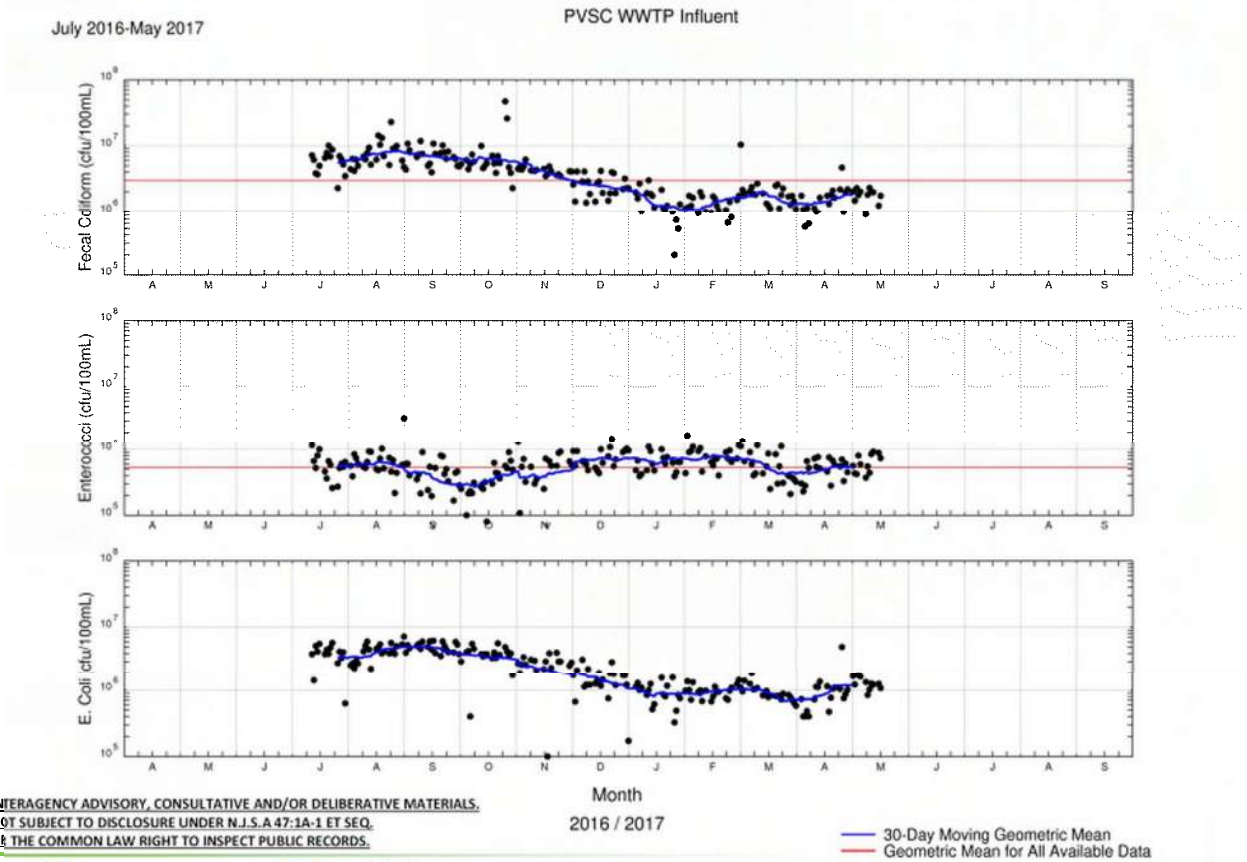
GREELEY AND HANSEN CDM Smith HDR

CSO Loading Calculations

- The Mass Balance approach will be used to assign loading to the CSOs
- The hydraulic models will provide flow and the sanitary/stormwater flow fractions.
  - The hydraulic models are still undergoing calibration
- CSO concentrations will be calculated using sanitary and stormwater concentrations.
- Estimated CSO concentrations will be compared to CSO concentration data.
  - Sampling program is behind schedule due to lower than normal precipitation.
- In some cases, the approach to calculating the CSO loads will need to be modified if the Mass Balance approach does not compare well to the data.

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PVSC WWTP Pathogen Influent Concentrations



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Measured CSO Concentrations

- 10 Locations have been sampled
- 17 events have been sampled

	CSO Bacteria Concentrations (cfu/100mL)	
	Fecal Coliform	Enterococci
Geometric Mean[1]	305,300	110,400
Average[2]	469,300	186,200
Range[3]	53,200 – 1,414,000	21,800-782,200
WWTP Sanitary	~3,000,000	~500,000
Event Sanitary	2,100,000	690,000

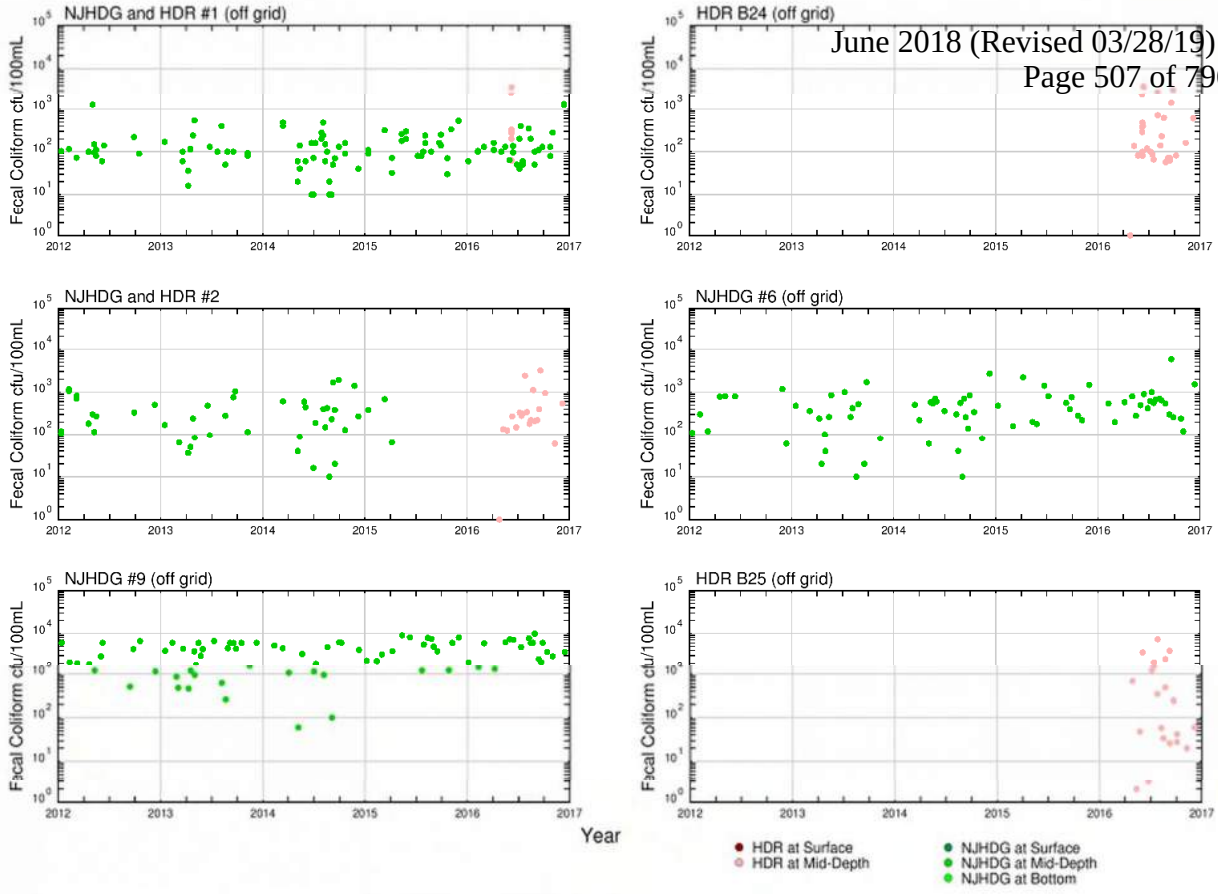
1 - GM of event GMs
2 - Average of event GMs
3 –Range of event GMs

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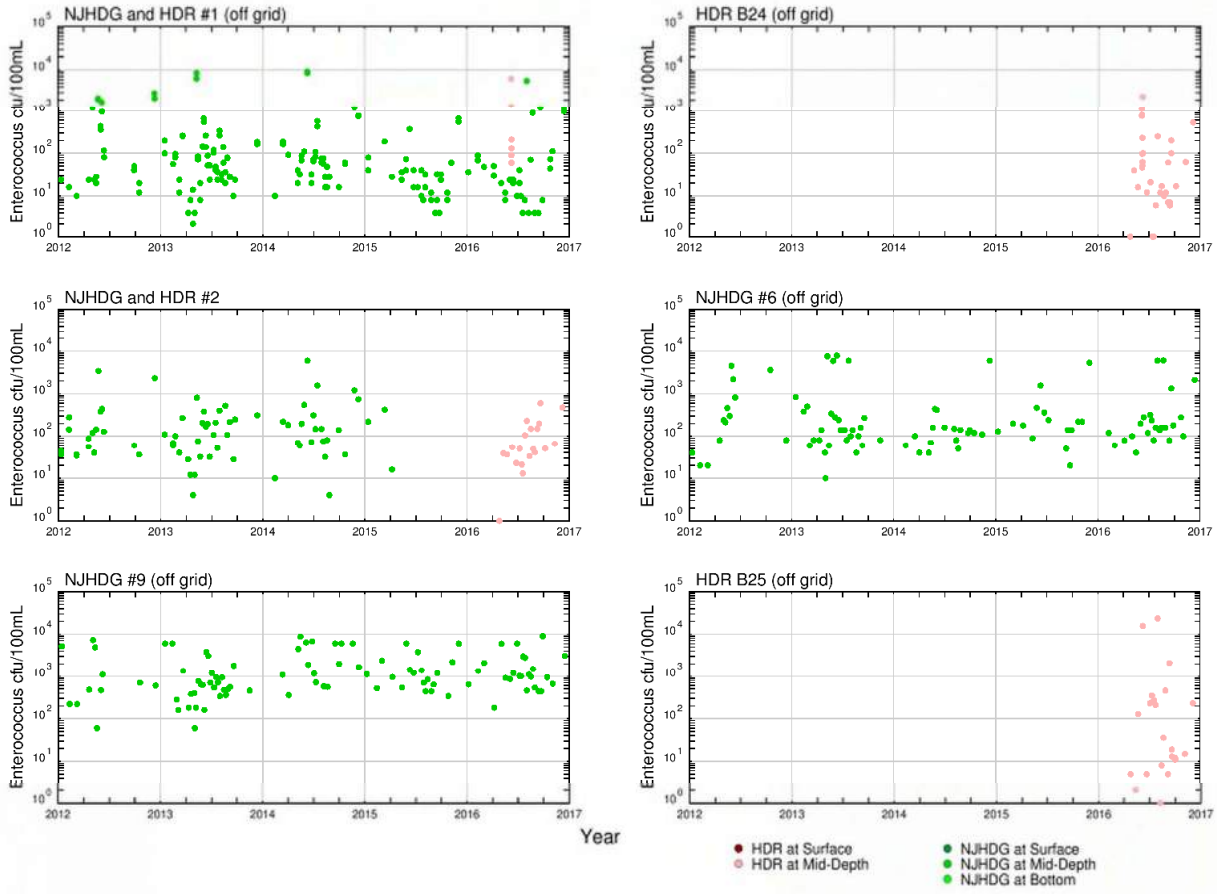
River Loads

- Dry-weather
  - "Monte Carlo"
- Wet-weather
  - Concentration vs. 24-hr rainfall

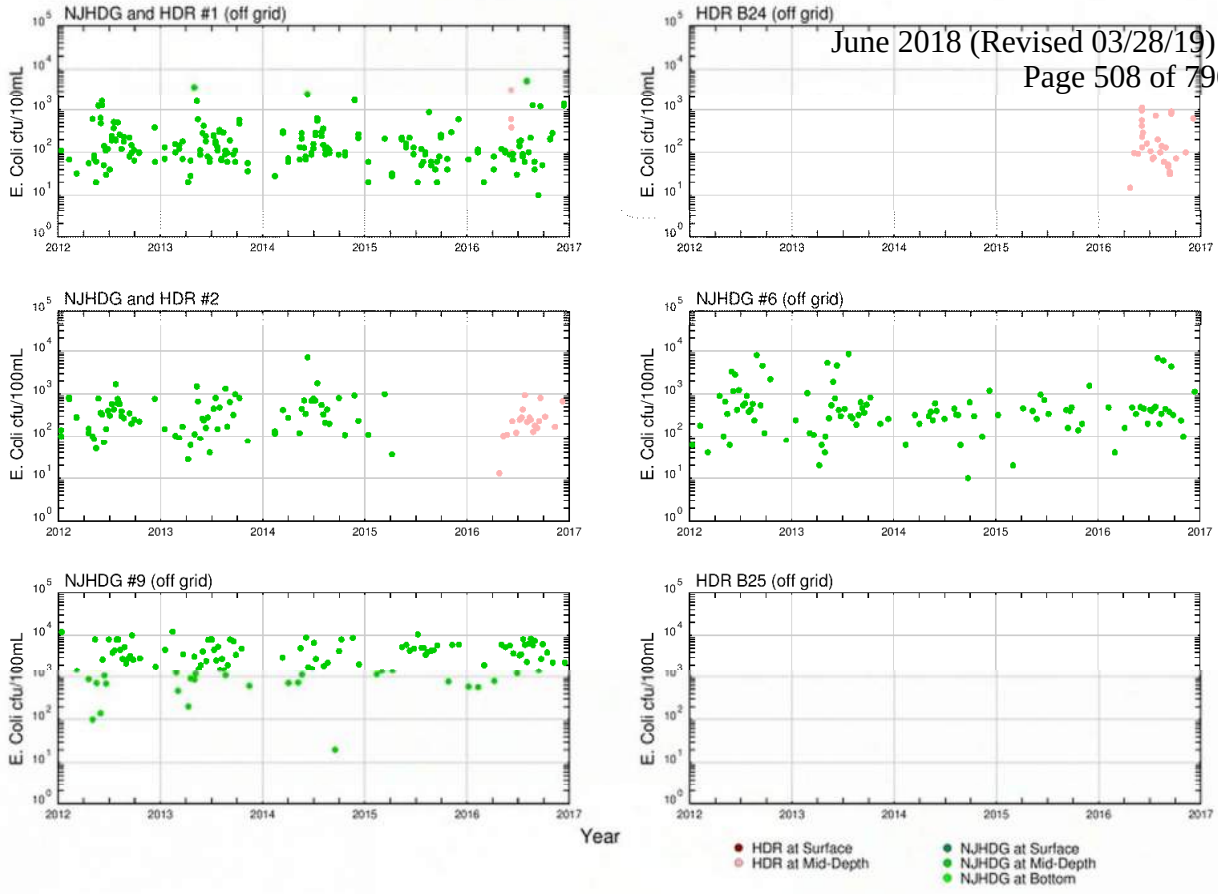
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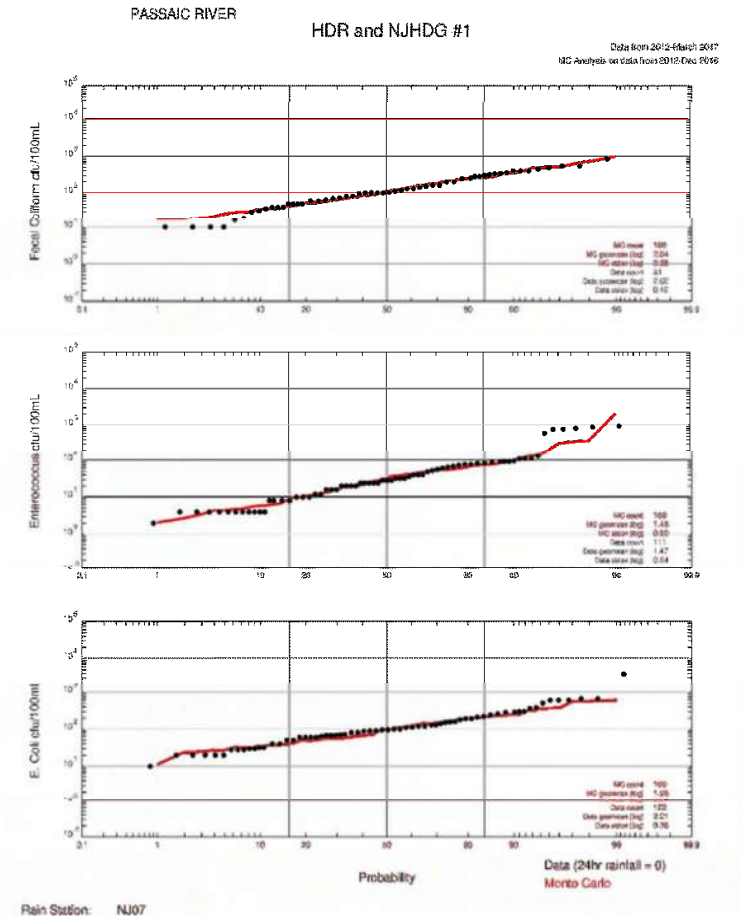


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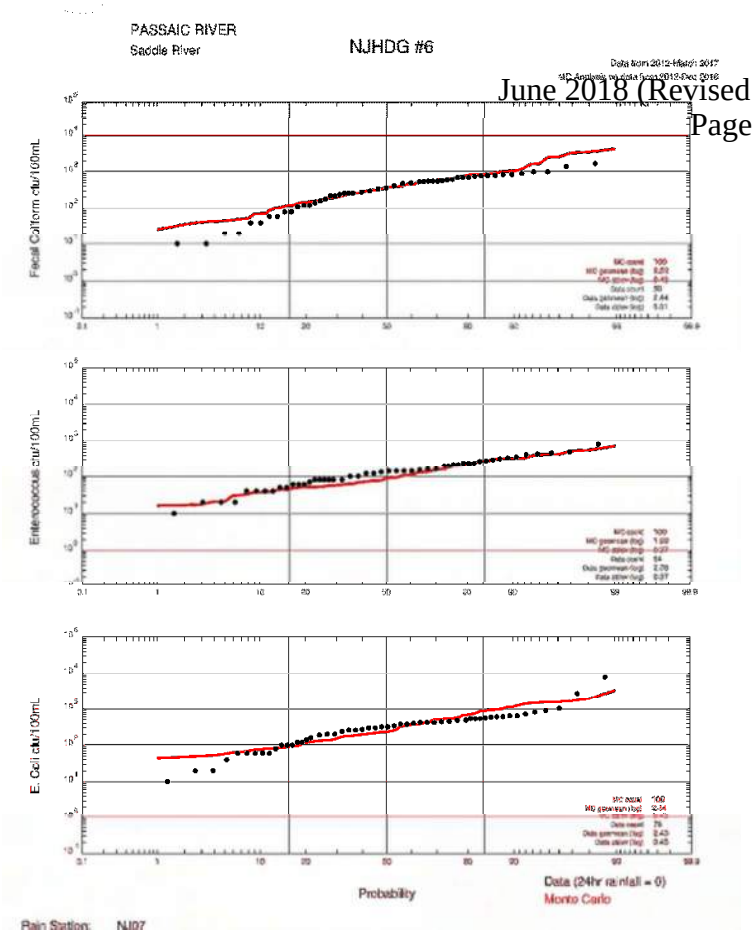
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Dry-weather concentrations



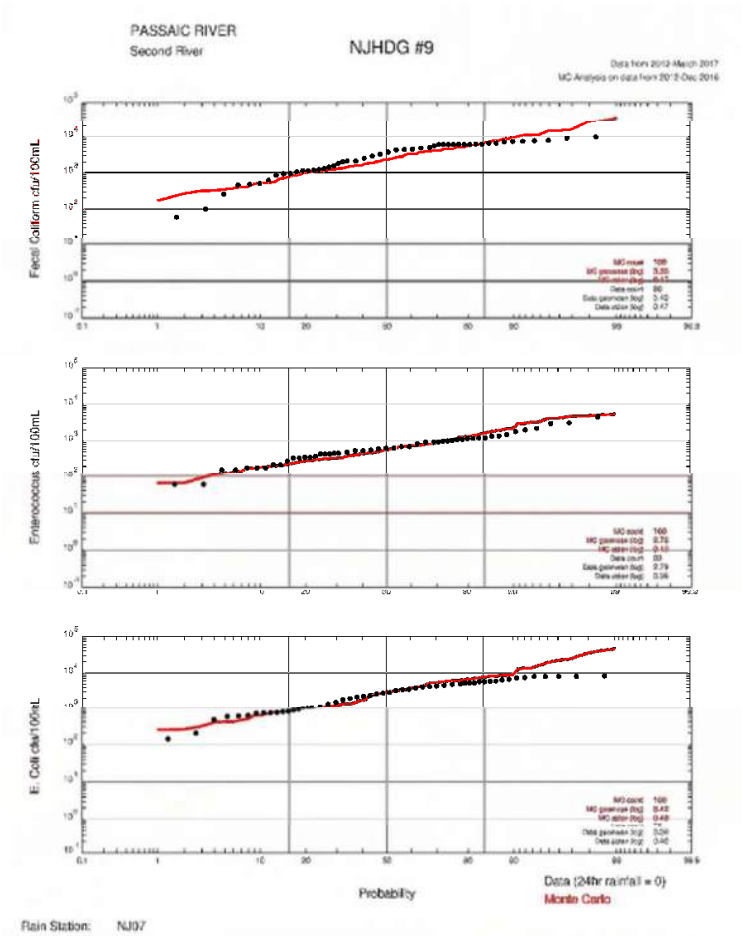
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Dry-weather concentrations



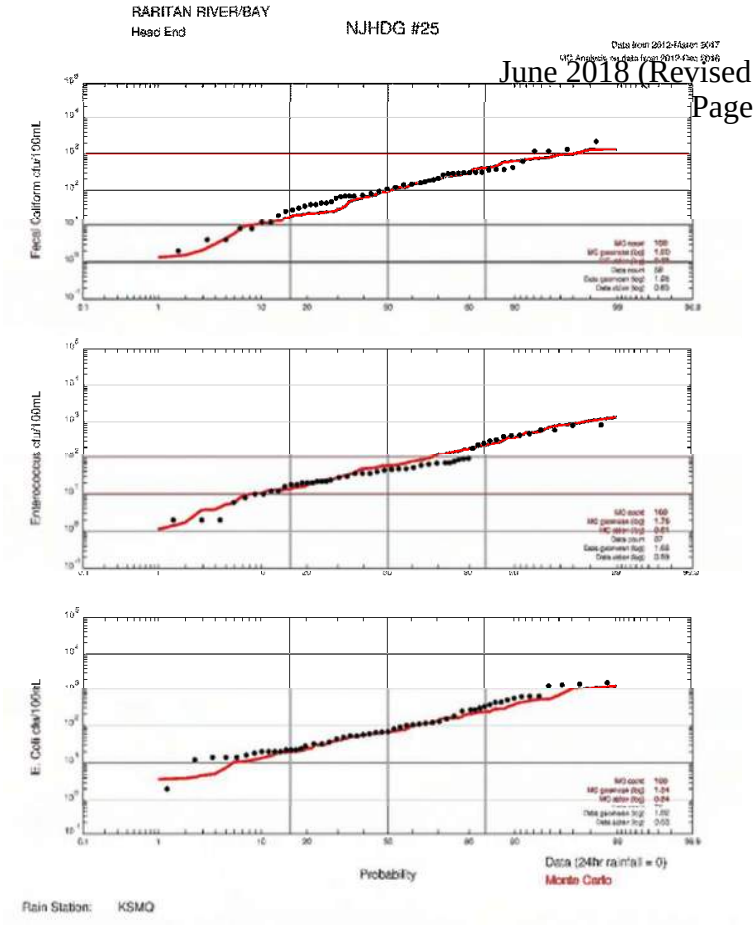
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Dry-weather concentrations



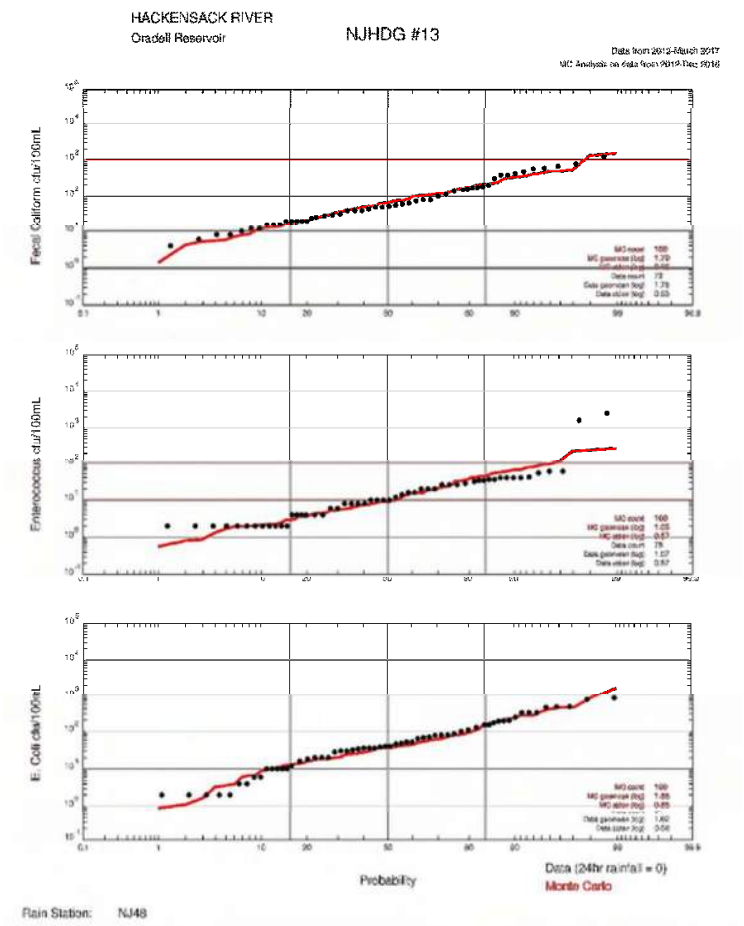
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Dry-weather concentrations



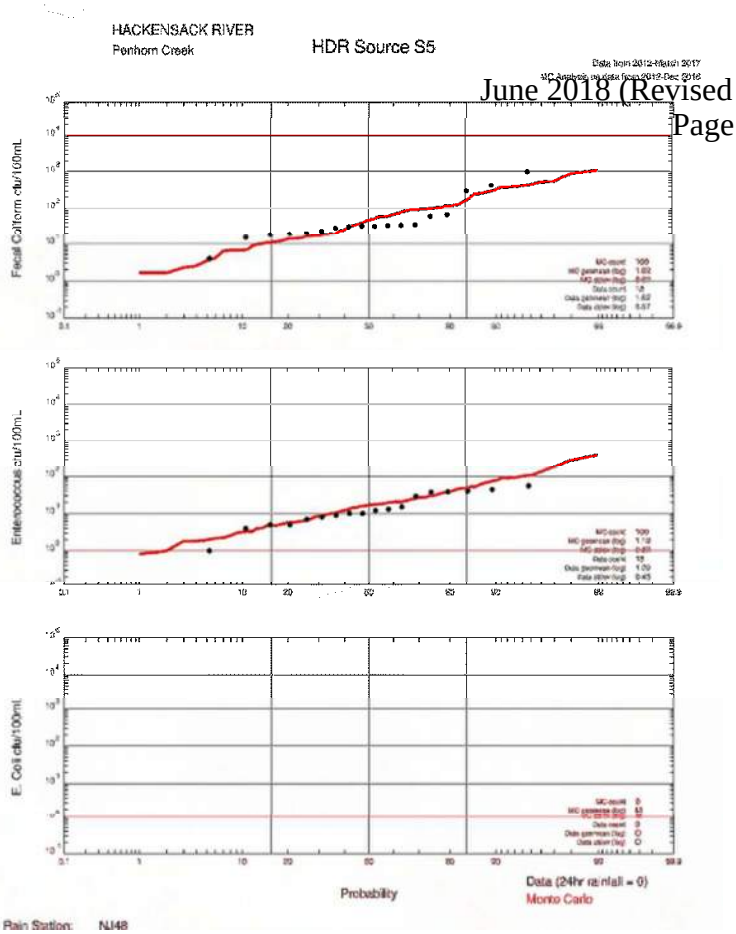
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Dry-weather concentrations



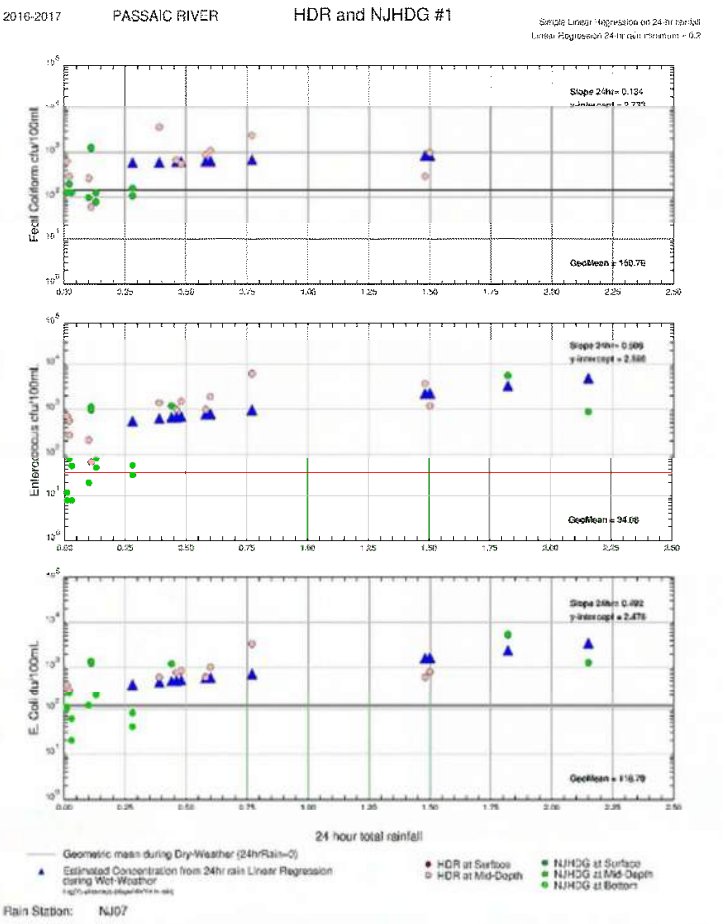
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Dry-weather concentrations



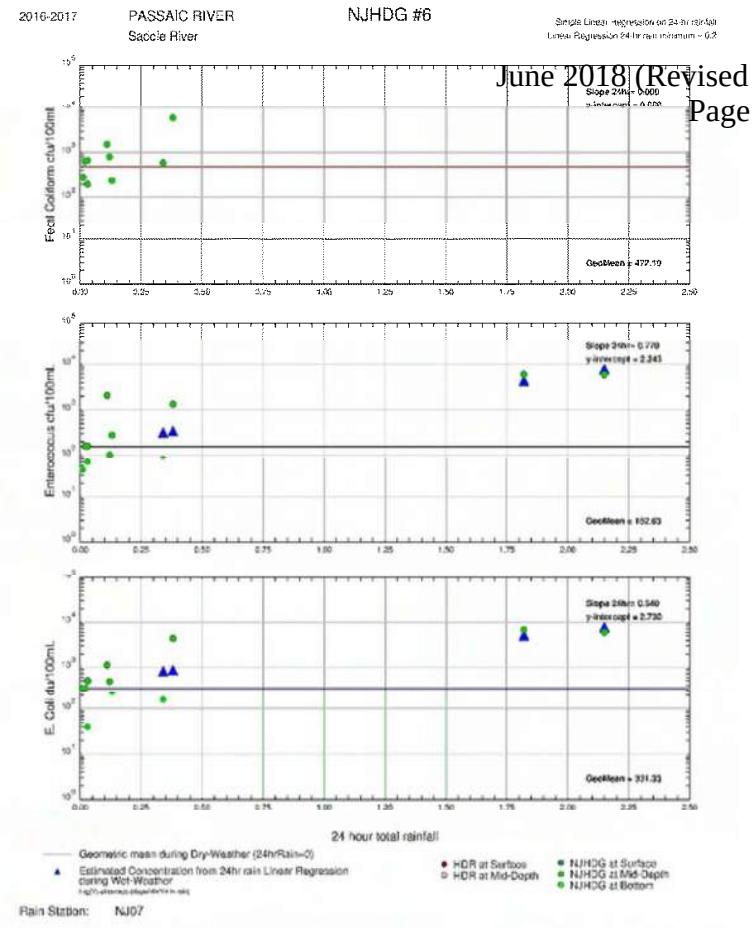
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Wet-weather concentrations



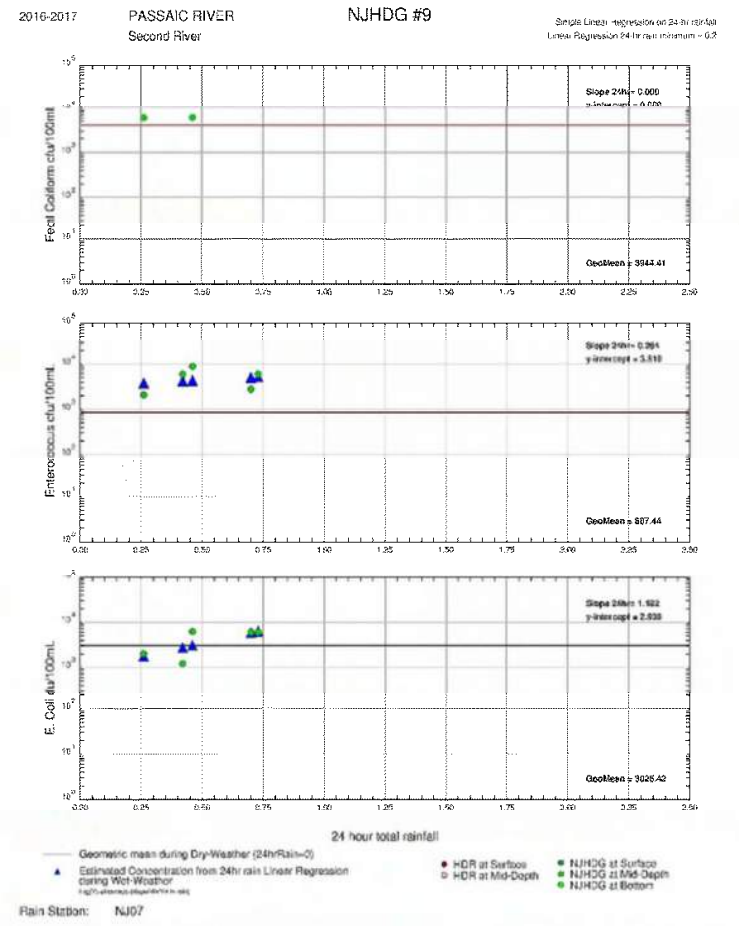
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Wet-weather concentrations



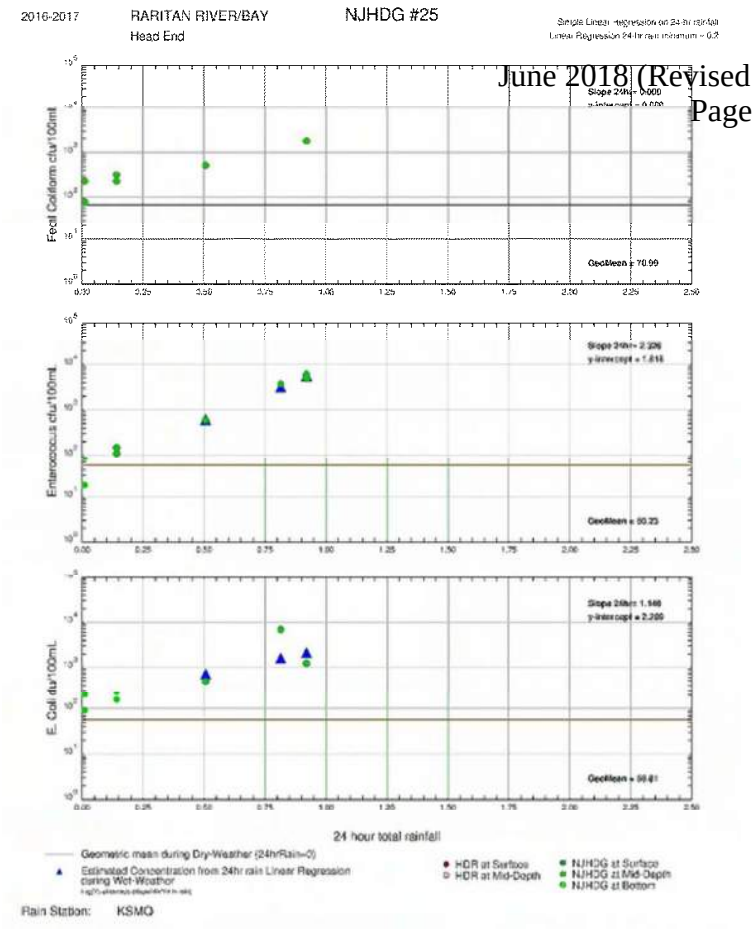
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Wet-weather concentrations



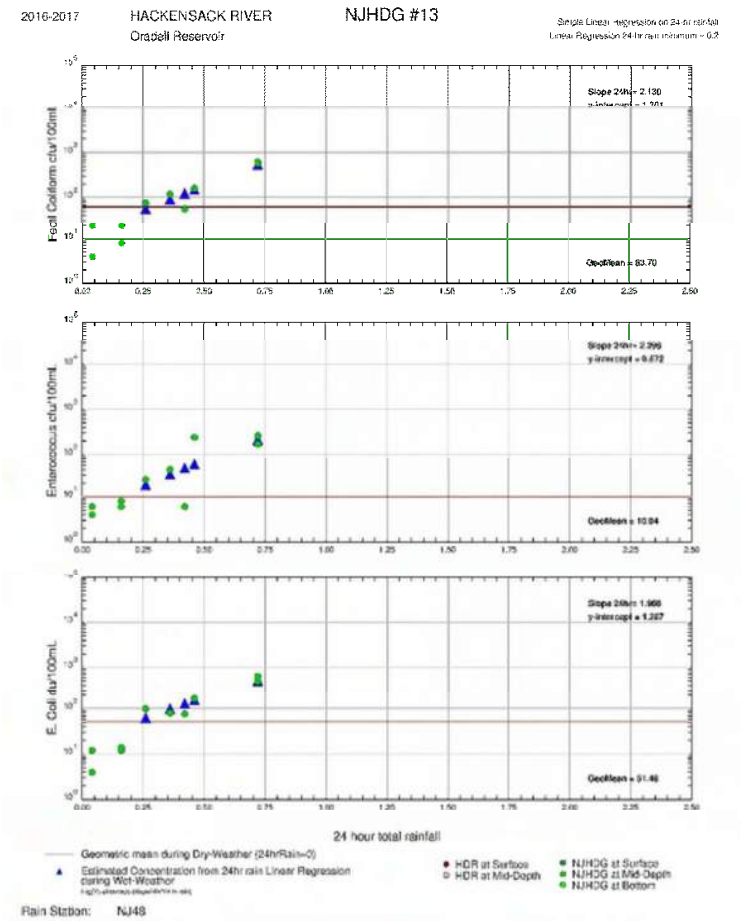
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Wet-weather concentrations



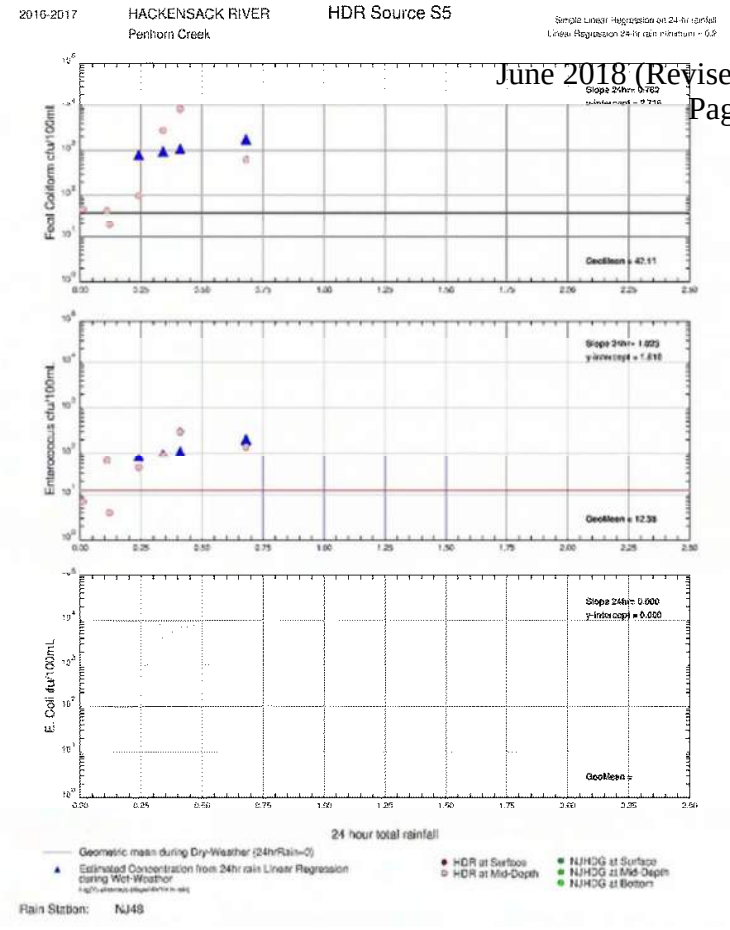
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Wet-weather concentrations

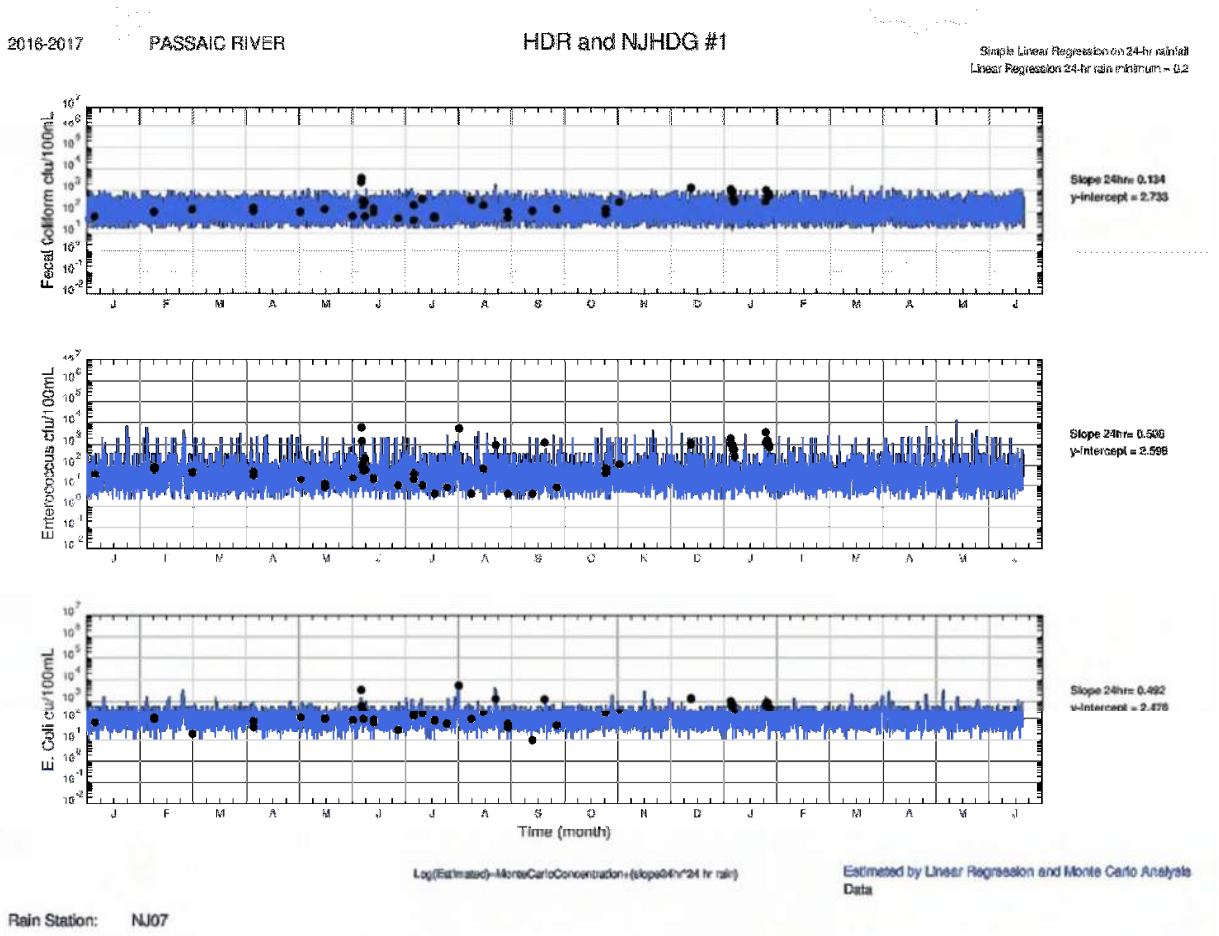


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Wet-weather concentrations



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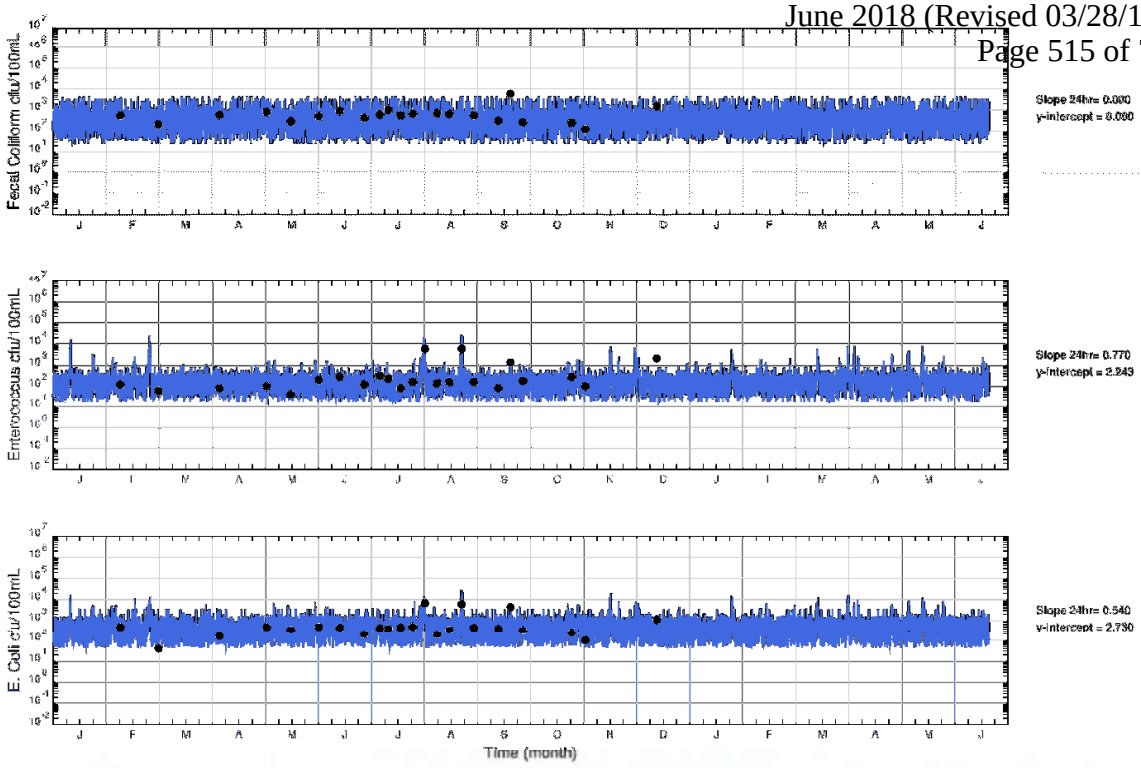


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2016-2017 PASSAIC RIVER
Saddle River

NJHDG #6

Simple Linear Regression on 24-hr rainfall
Linear Regression 24-hr rain minimum = 0.2



Log(Estimated)=MonteCarloConcentration+(slope24hr*24 hr rain)

Estimated by Linear Regression and Monte Carlo Analysis
Data

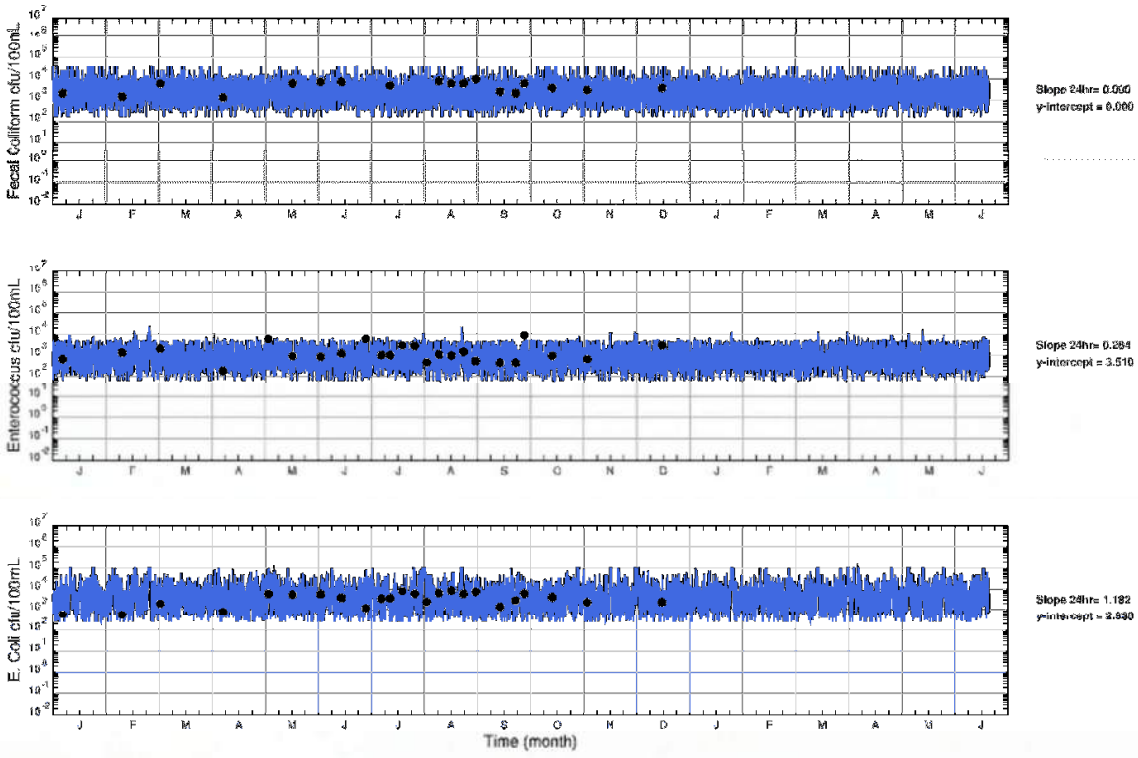
Rain Station: NJ07

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2016-2017 PASSAIC RIVER
Second River

NJHDG #9

Simple Linear Regression on 24-hr rainfall
Linear Regression 24-hr rain minimum = 0.2



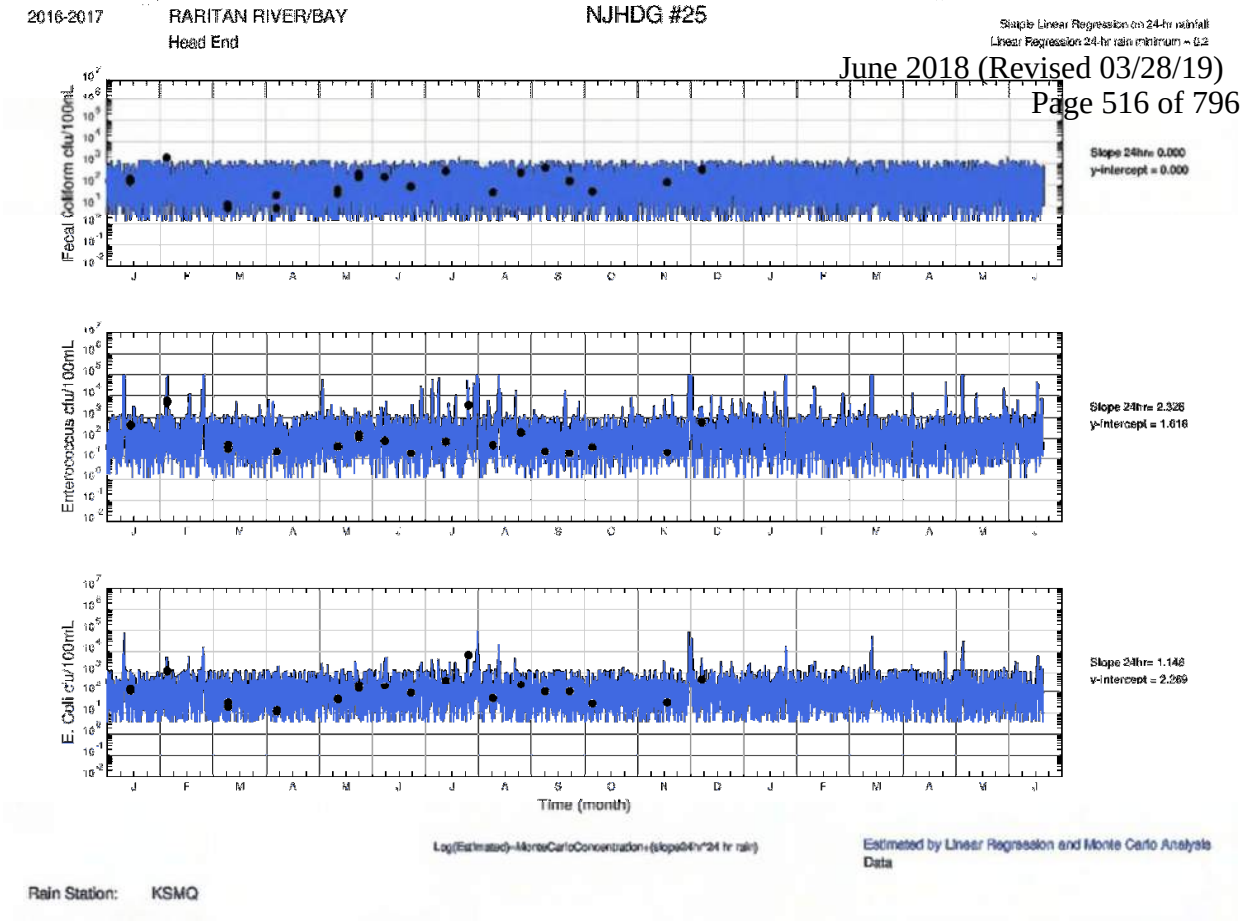
Log(Estimated)=MonteCarloConcentration+(slope24hr*24 hr rain)

Estimated by Linear Regression and Monte Carlo Analysis
Data

Rain Station: NJ07

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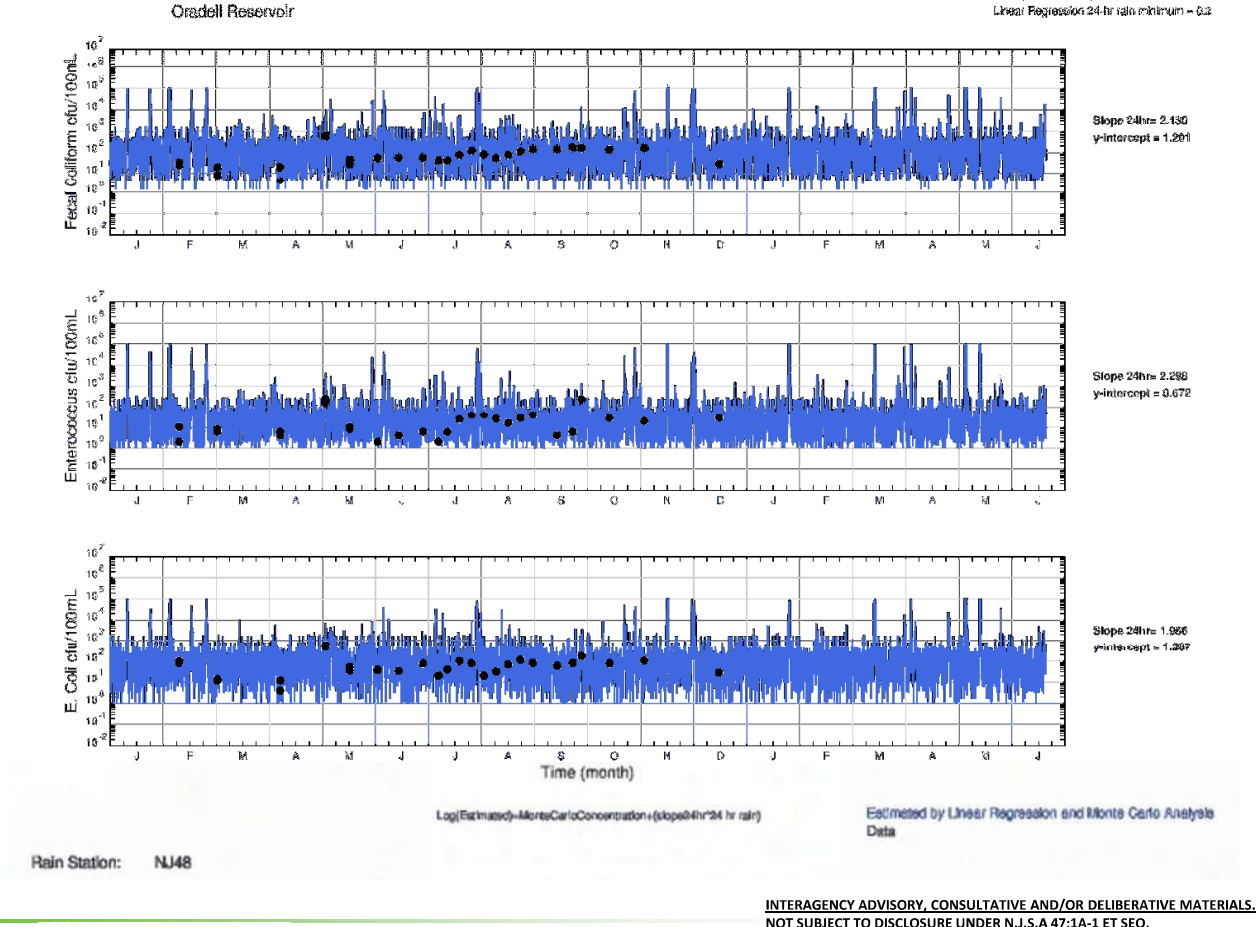
2016-2017 RARITAN RIVER/BAY NJHDG #25
Head End



Rain Station: KSMQ

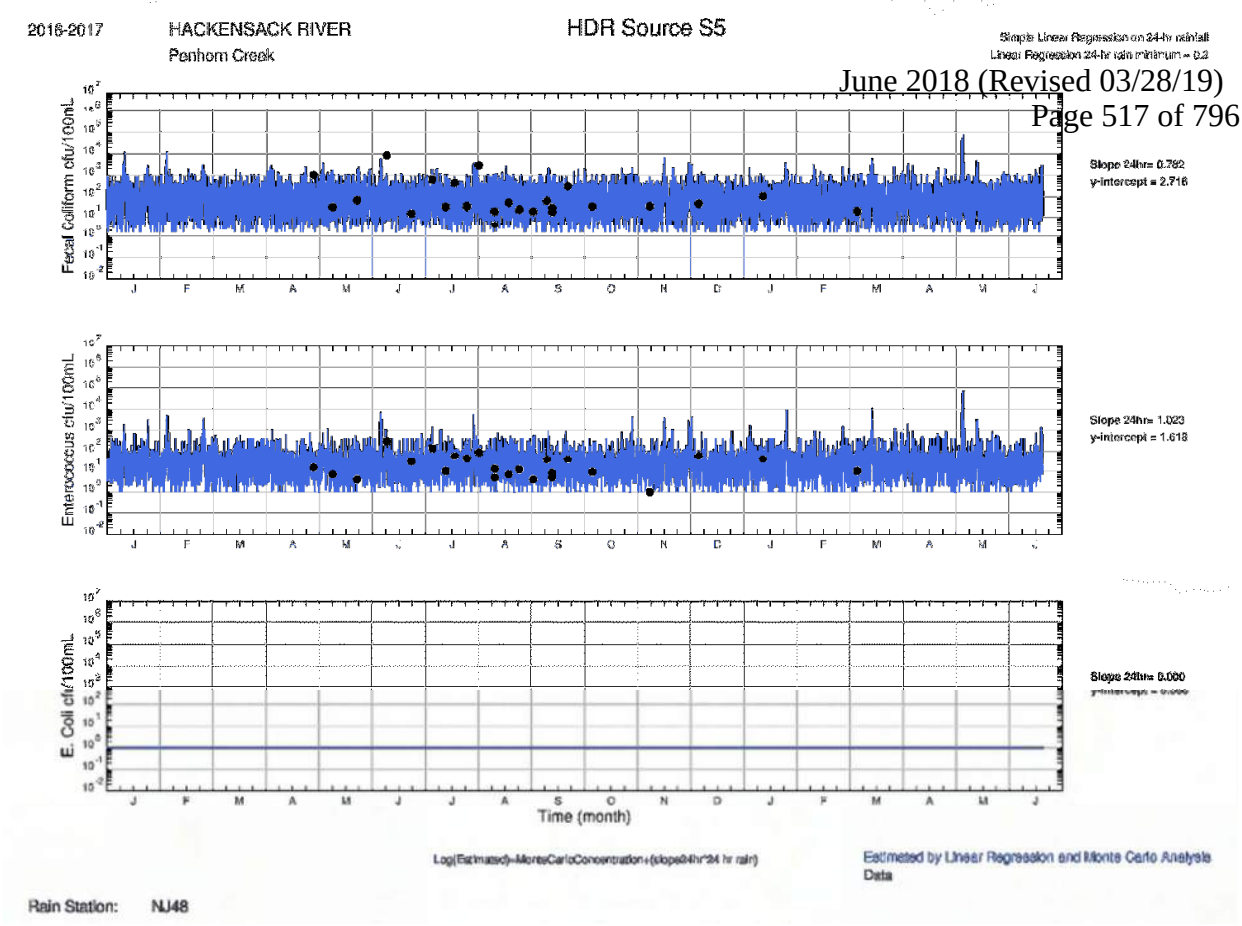
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2016-2017 HACKENSACK RIVER NJHDG #13
Oradell Reservoir



Rain Station: NJ48

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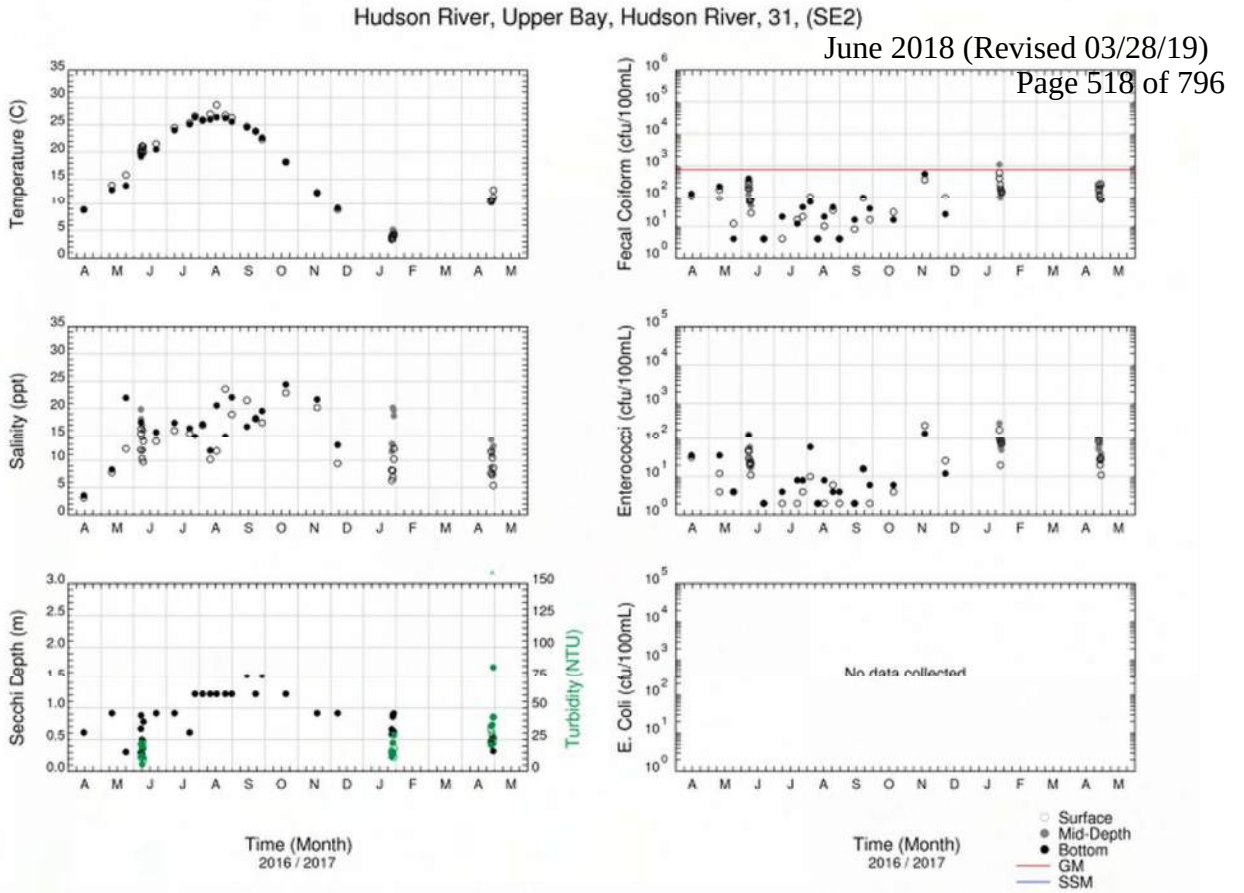


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Other Loads

- Dry-weather sources
  - May be need for calibration during dry-weather
  - Projection conditions?
- Hudson River

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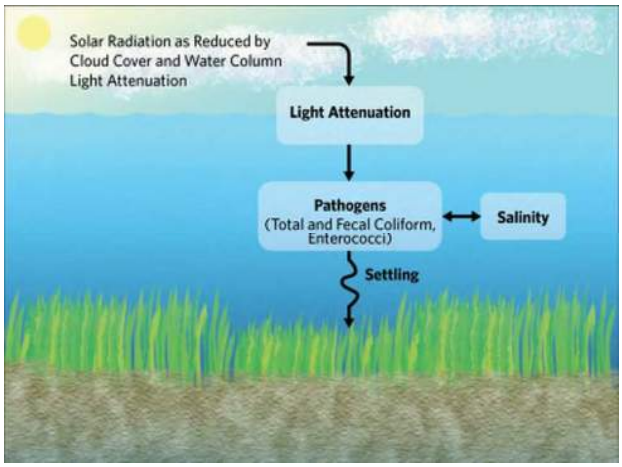
Pathogen Model Kinetics

$$N = N_0 \exp(-KBt)$$

$K_B = [0.8 + 0.006(\%seawater)]1.07^{(T-20)}$

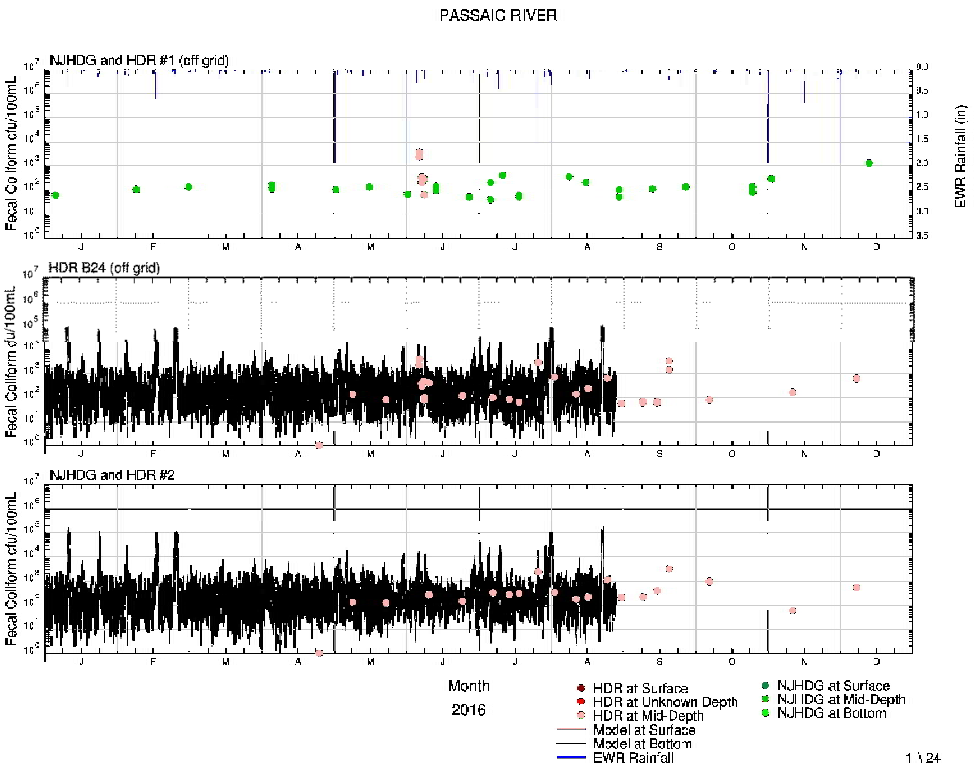
$+ \alpha I_0(t)/K_e H[1-\exp(-K_e H)]$

$+ V_s/H$ (Mancini, 1978)



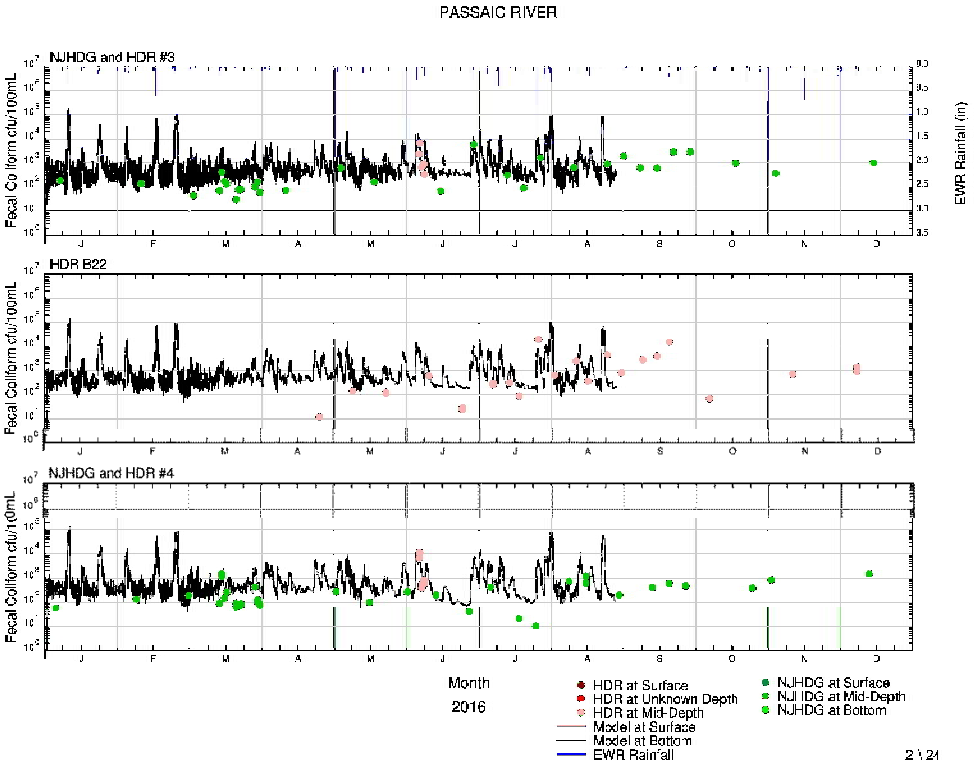
N = Bacteria concentration
K_B = Bacteria loss rate
T = Temperature (°C)
α = proportionality constant
I_0 = Surface solar radiation
t = time
K_e = Extinction coefficient (/m)
H = Depth (m)
V_s = Net settling rate (m/d)

Model Calibration



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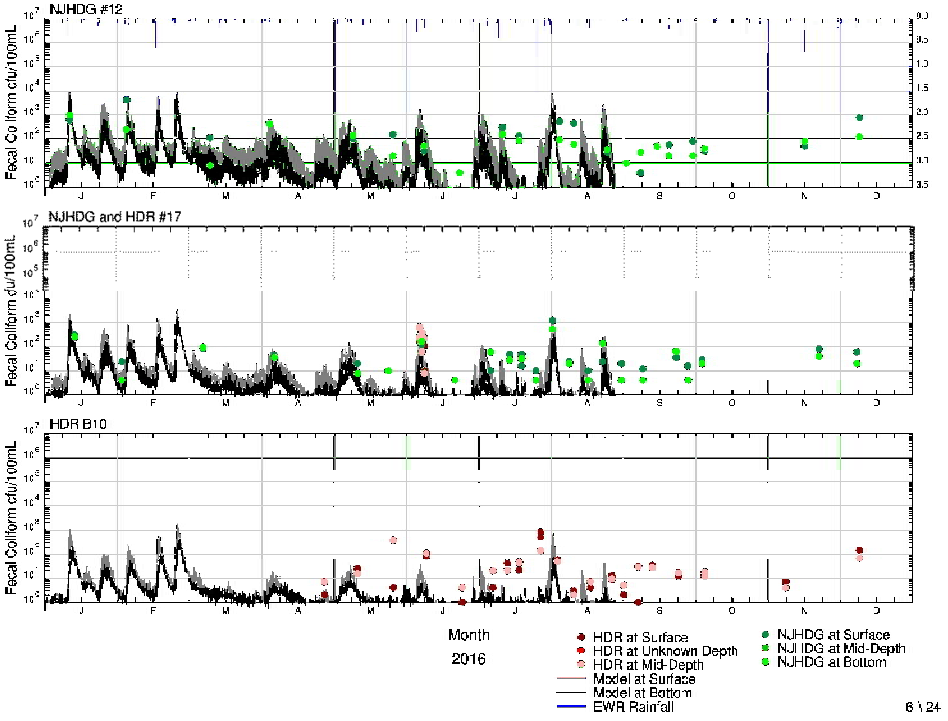
Model Calibration



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Model Calibration

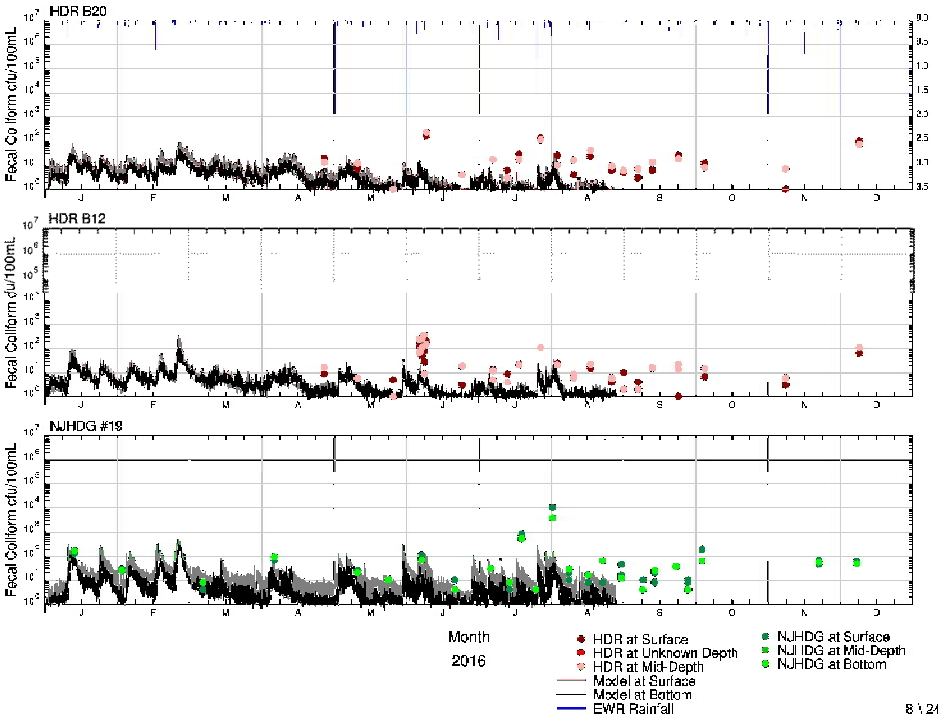
PASSAIC RIVER



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Model Calibration

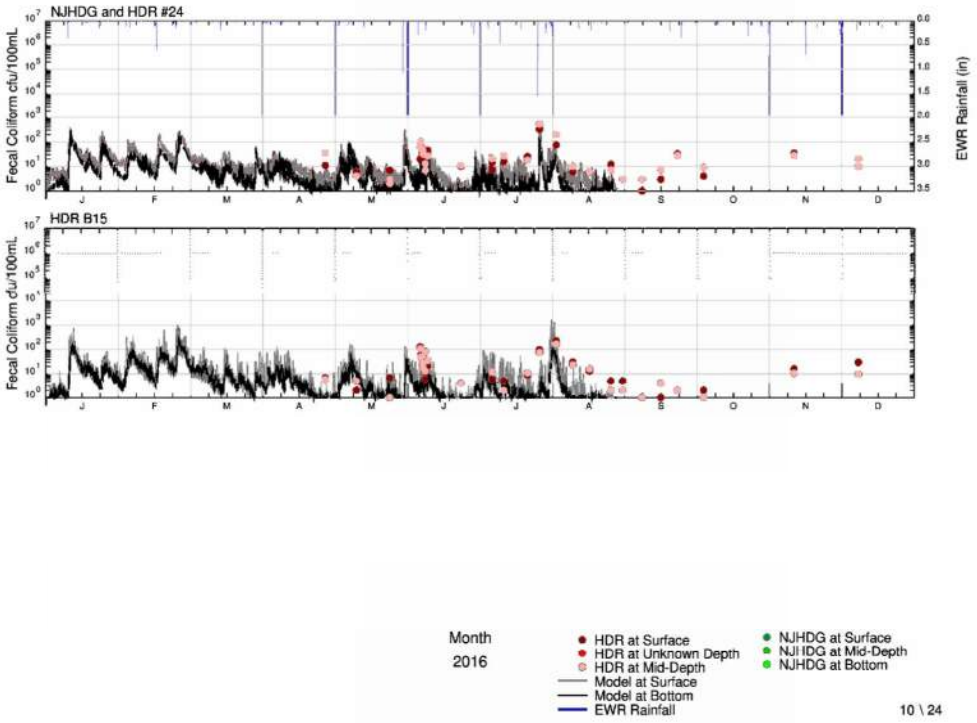
KILL VAN KULL



INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
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Model Calibration

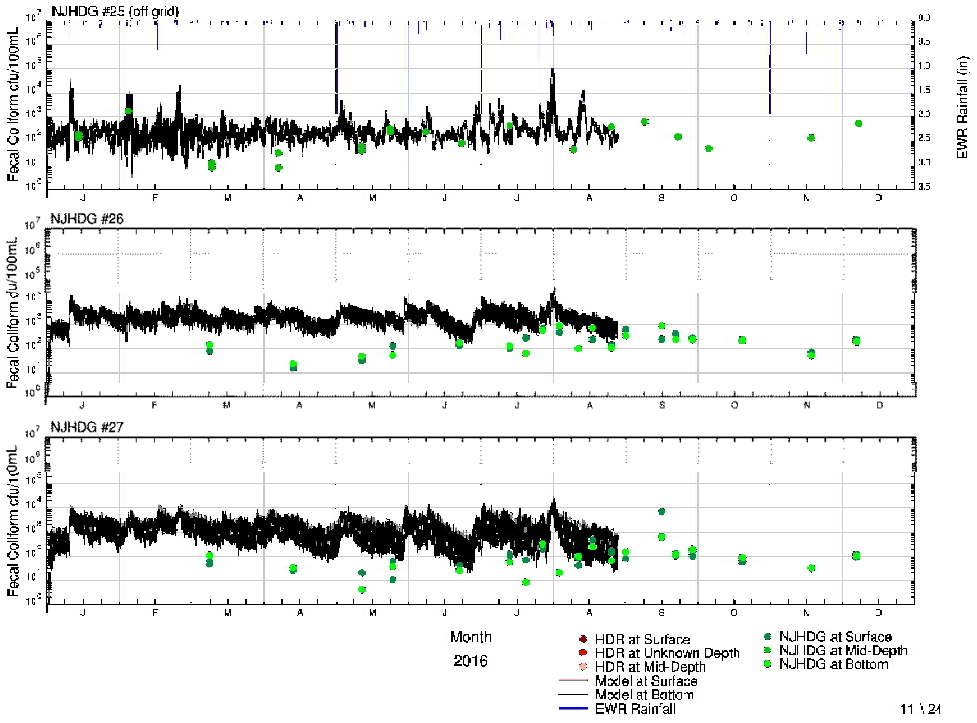
KILL VAN KULL



INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
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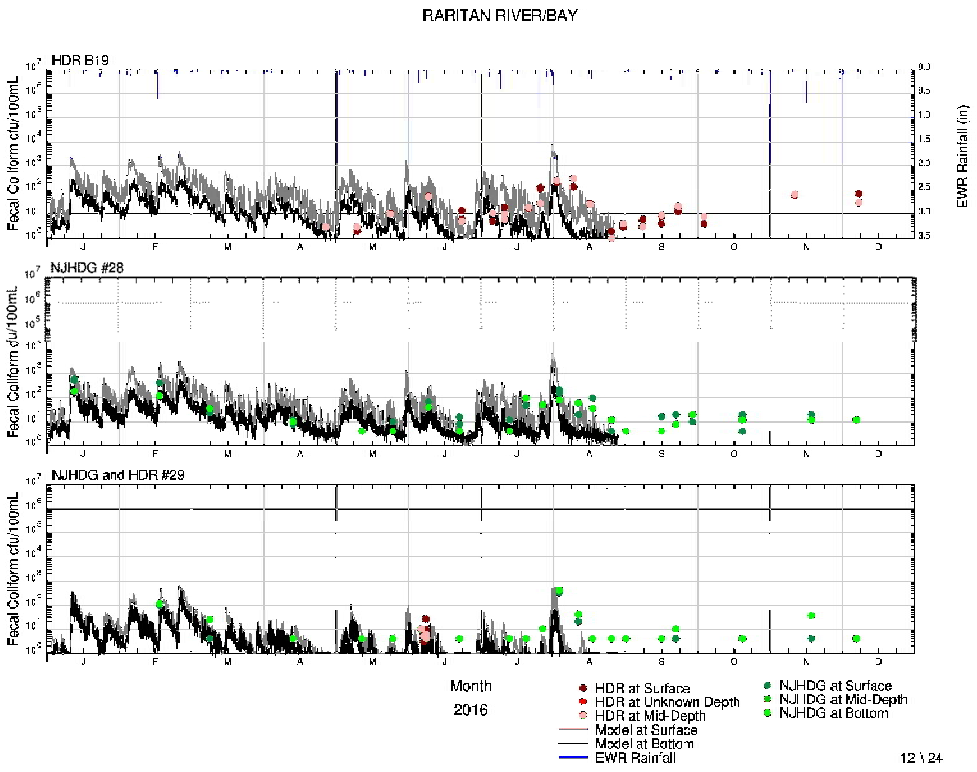
Model Calibration

RARITAN RIVER/BAY



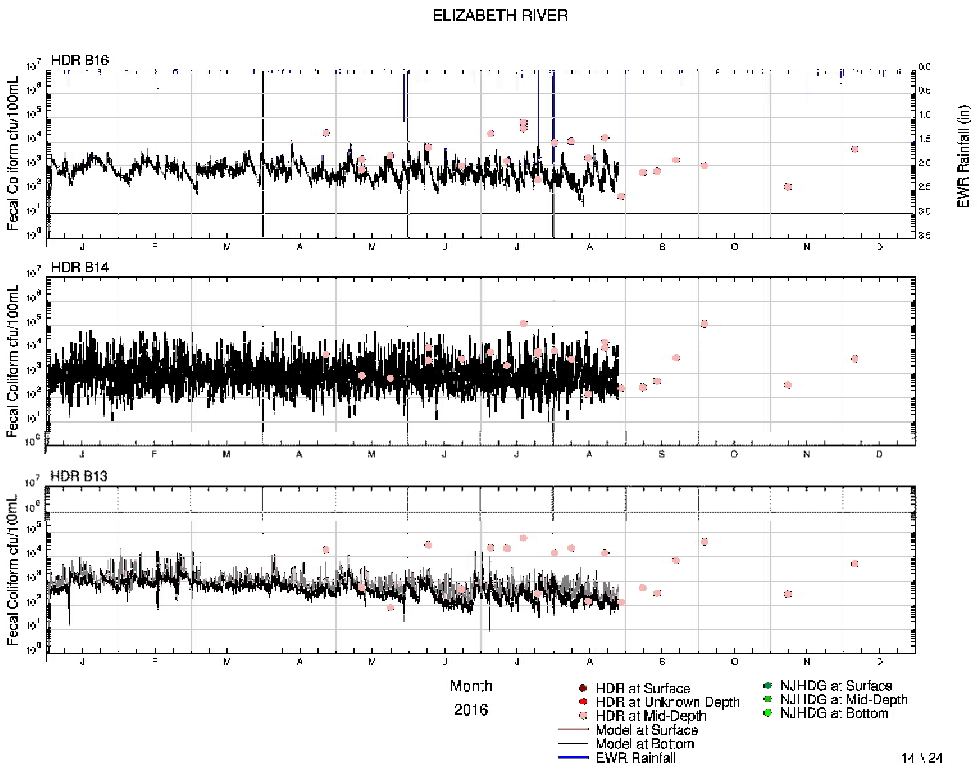
INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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Model Calibration



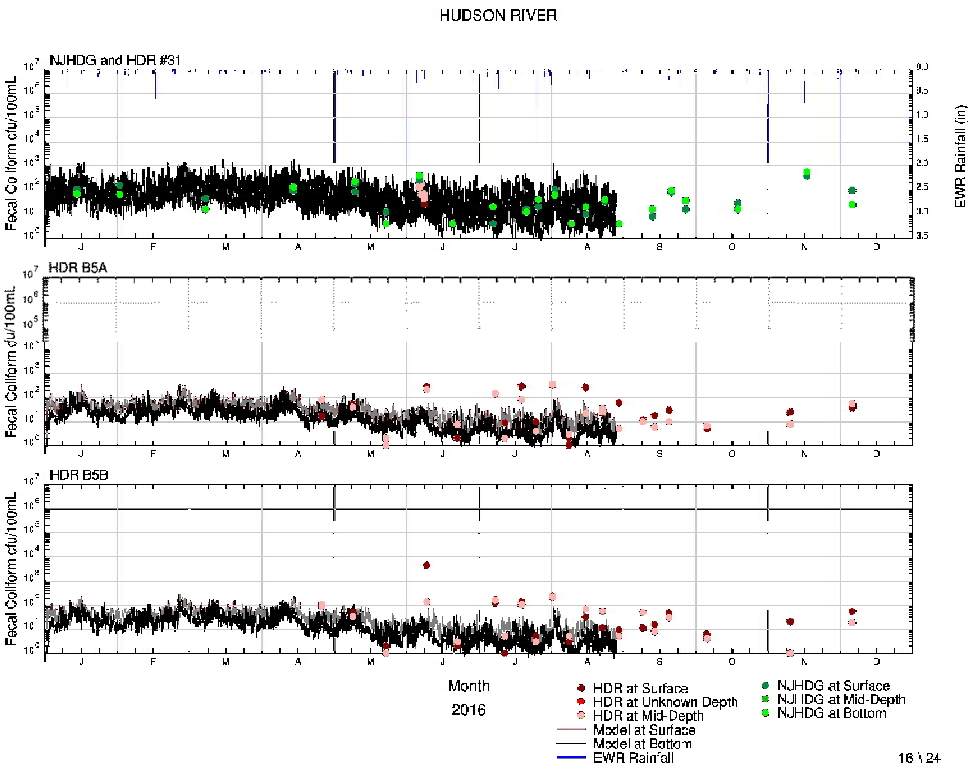
INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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Model Calibration



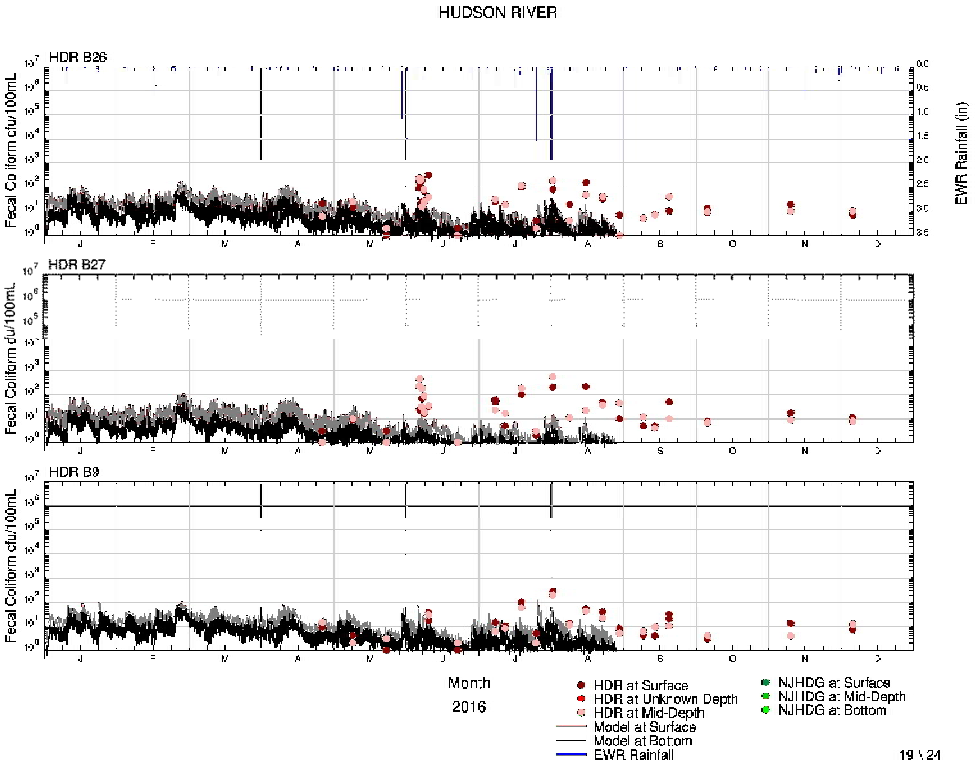
INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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Model Calibration



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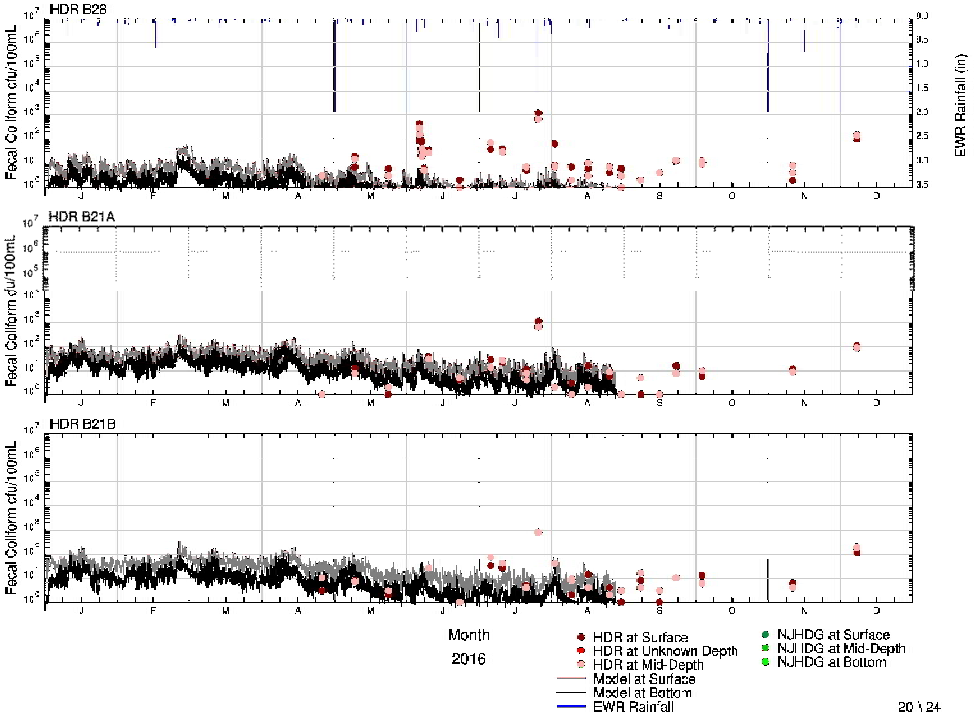
Model Calibration



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Model Calibration

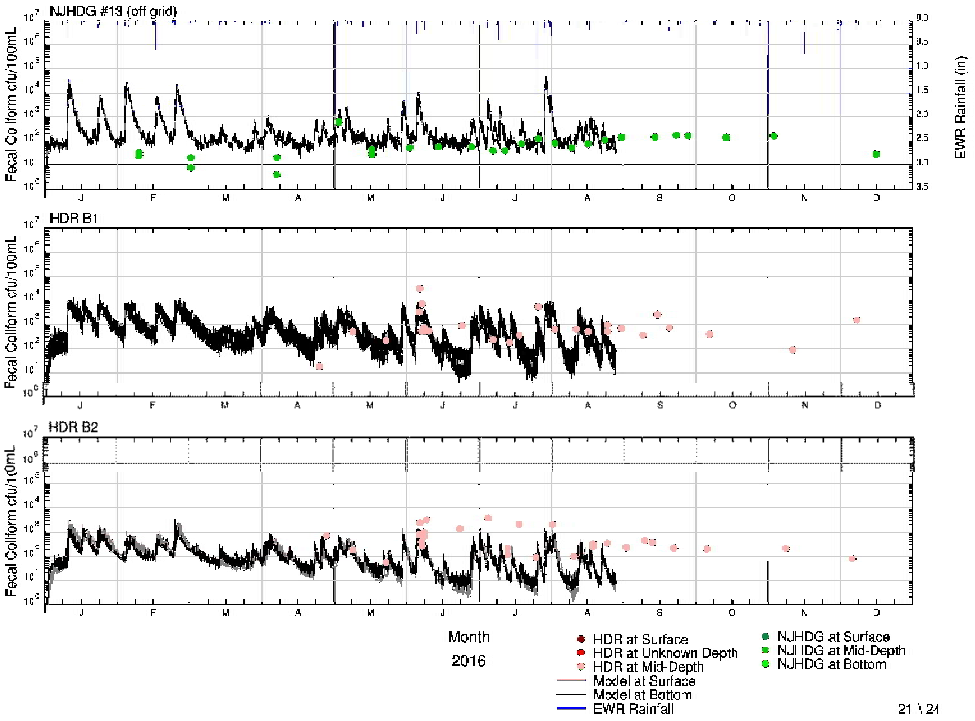
HUDSON RIVER



INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
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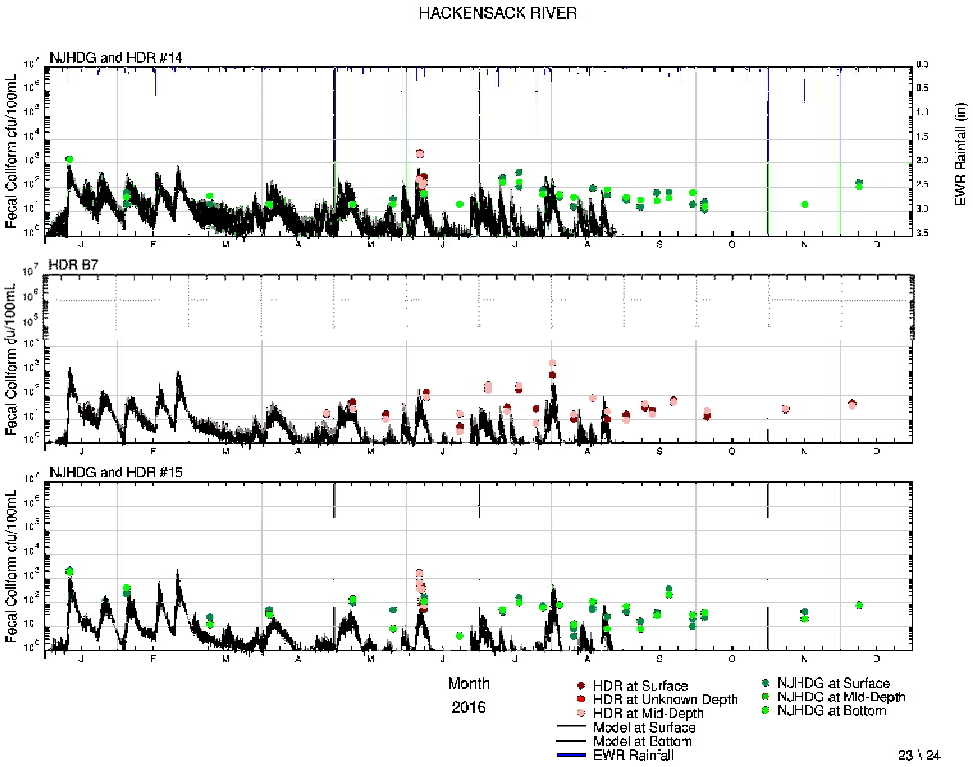
Model Calibration

HACKENSACK RIVER



INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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Model Calibration



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Next Steps

- CSO data
- Obtain CSO flow and load files from consultant teams
- Continue model calibration

INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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PVSC – Long Term Control Plan
Modeling Evaluation Group – Session 4

Hydrologic and Hydraulic Model Overview

Greeley and Hansen LLC
December 5, 2018

INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS. NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ. OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS

Agenda

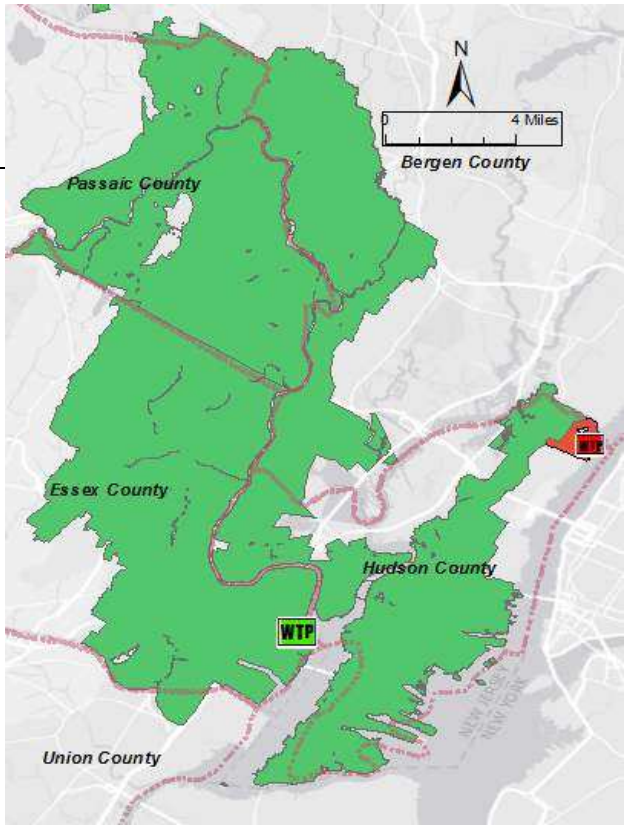
- Overview of PVSC H&H Model
  - Model Service Area and Network
  - Wet Weather Operating Rules
- H&H Model Calibration & Validation
- H&H Model Application

GREELEY AND HANSEN

PVSC H&H Model Overview

Sewer Systems

- Passaic Valley Sewerage Commission
  - 48 municipalities
    - 8 CSO municipalities (0.9 million residents)
  - 1.5 million residents
  - 147 mi² service area
  - 22 mile interceptor sewer
  - 330 mgd WPCF
- NBMUA Woodcliff WWTP
  - 2 CSO municipalities
  - 3 mgd Woodcliff WWTP
  - 477 acres (368 acres in North Bergen)



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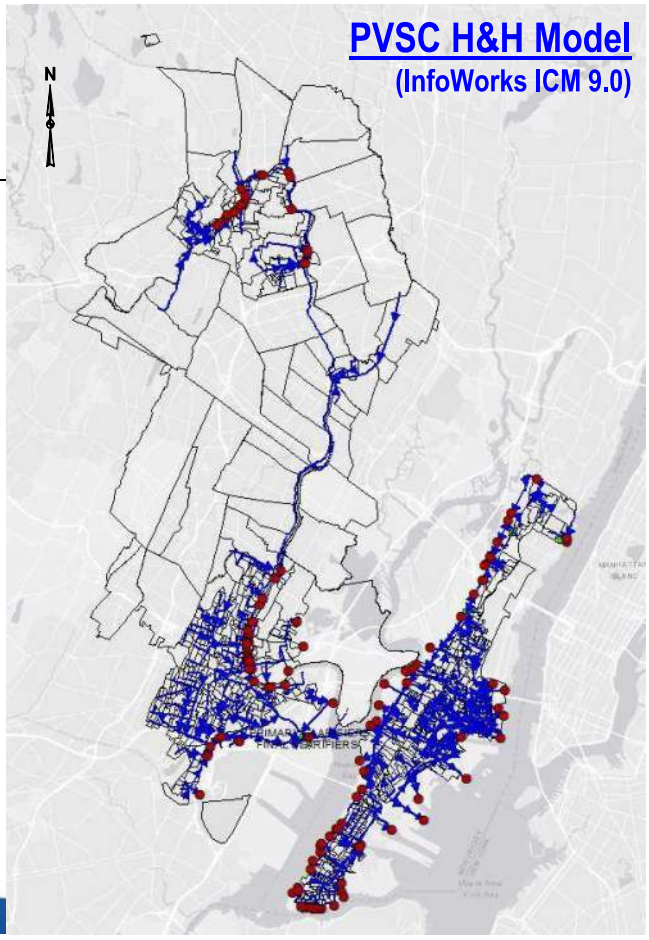
CSO Communities

Municipality	WWTP	Population	Area (mi²)	Sewerage (miles)	CSOs
Bayonne	PVSC WRRF	63,000	5.8	94	30
East Newark		2,400	0.1	2	1
Harrison		13,600	1.3	18	7
Jersey City		247,600	14.8	230	21
Kearny		40,700	6.5	52	5
Newark		277,100	22.3	579	18
North Bergen		52,600	4.5	59	7
Paterson		146,200	8.7	164	23
Guttenberg	NBMUA Woodcliff	11,200	0.2	5	1
North Bergen		8,200	0.7	8	1
Total		**862,600**	**84**	**1,211**	**114**

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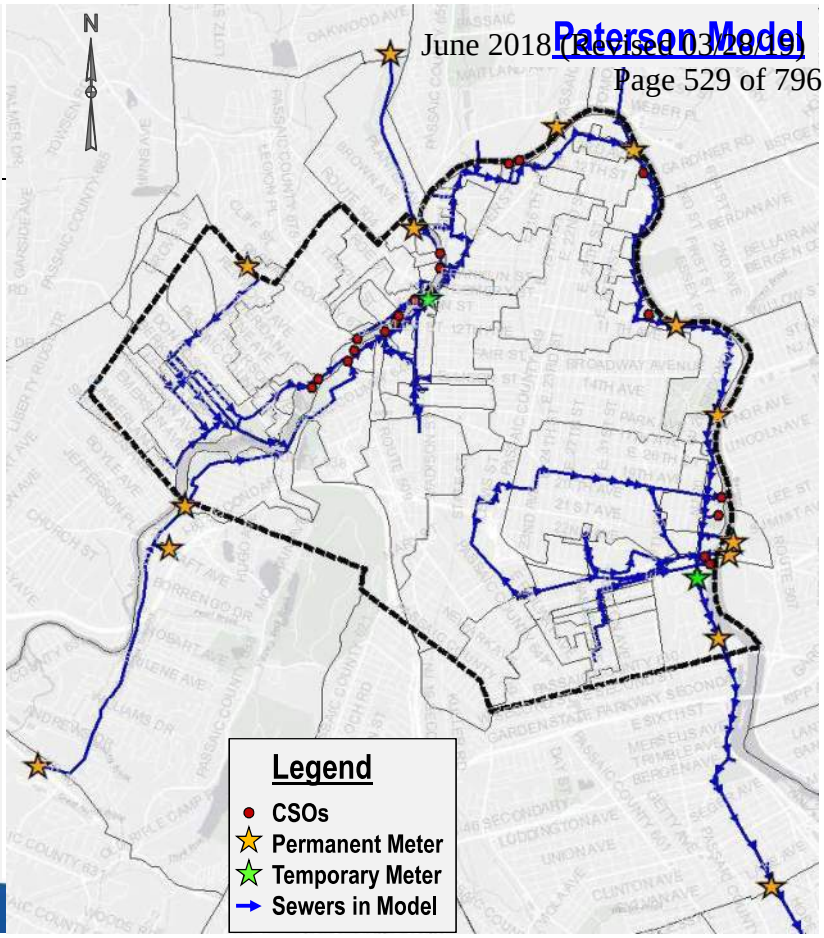
Entire PVSC H&H Model

- Subcatchment: 1121
- Nodes (4216)
  - Manhole: 4081
  - Outfall: 123
  - Storage: 12
- Link (4413)
  - Conduit: 4039
  - Flap Valve: 101
  - Orifice: 42
  - Pump: 16
  - Sluice: 95 (34 variable)
  - Weir: 120



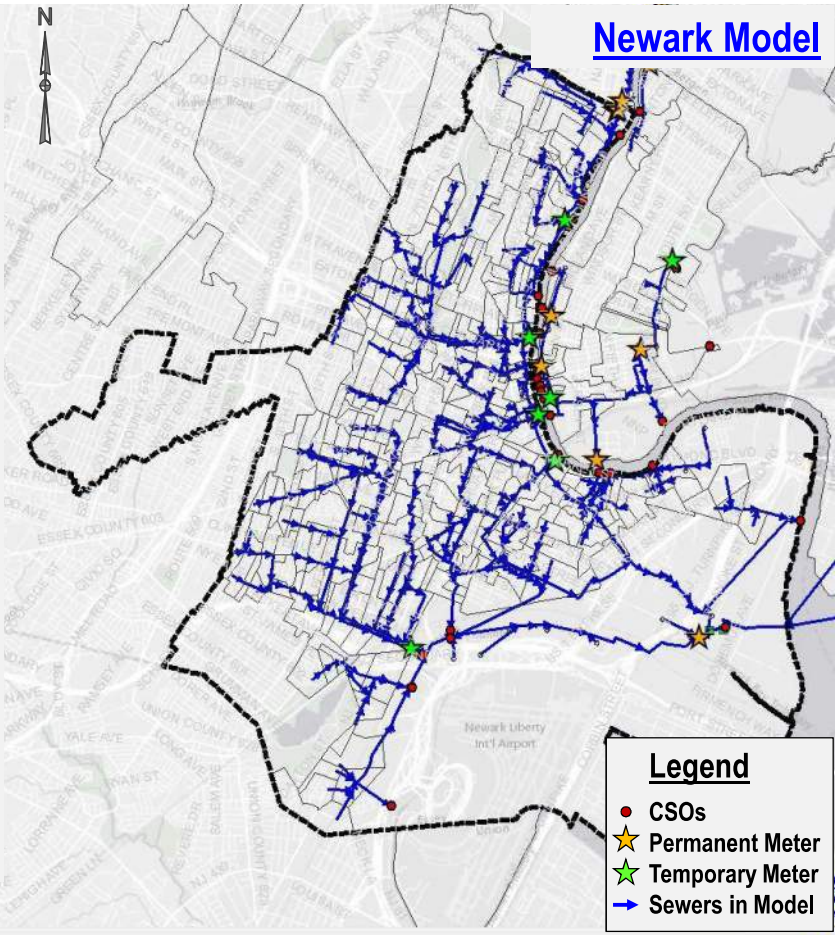
Paterson Model

- Subcatchment: 67
- Nodes (585)
  - Manhole: 562
  - Outfall: 23
  - Storage: 0
- Link (657)
  - Conduit: 503
  - Flap Valve: 82
  - Orifice: 14
  - Pump: 0
  - Sluice: 16 (2 variable)
  - Weir: 42



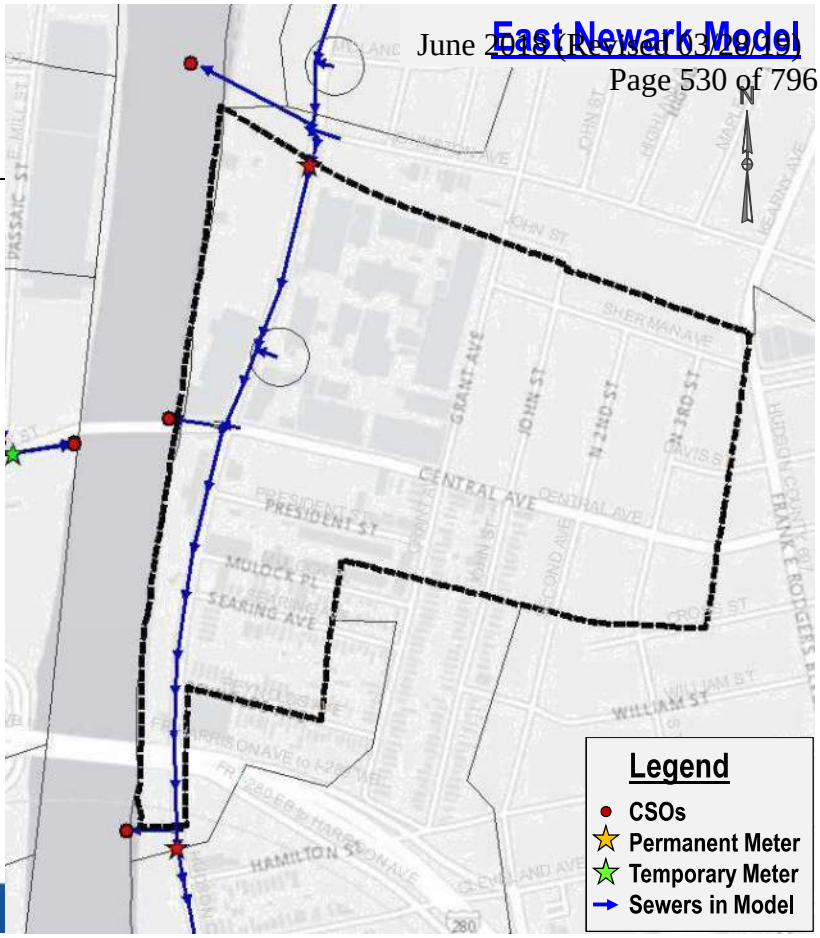
Newark Model

- Subcatchment: 310
- Nodes (758)
  - Manhole: 738
  - Outfall: 18
  - Storage: 2
- Link (819)
  - Conduit: 746
  - Flap Valve: 17
  - Orifice: 3
  - Pump: 3
  - Sluice: 27 (17 variable)
  - Weir: 23



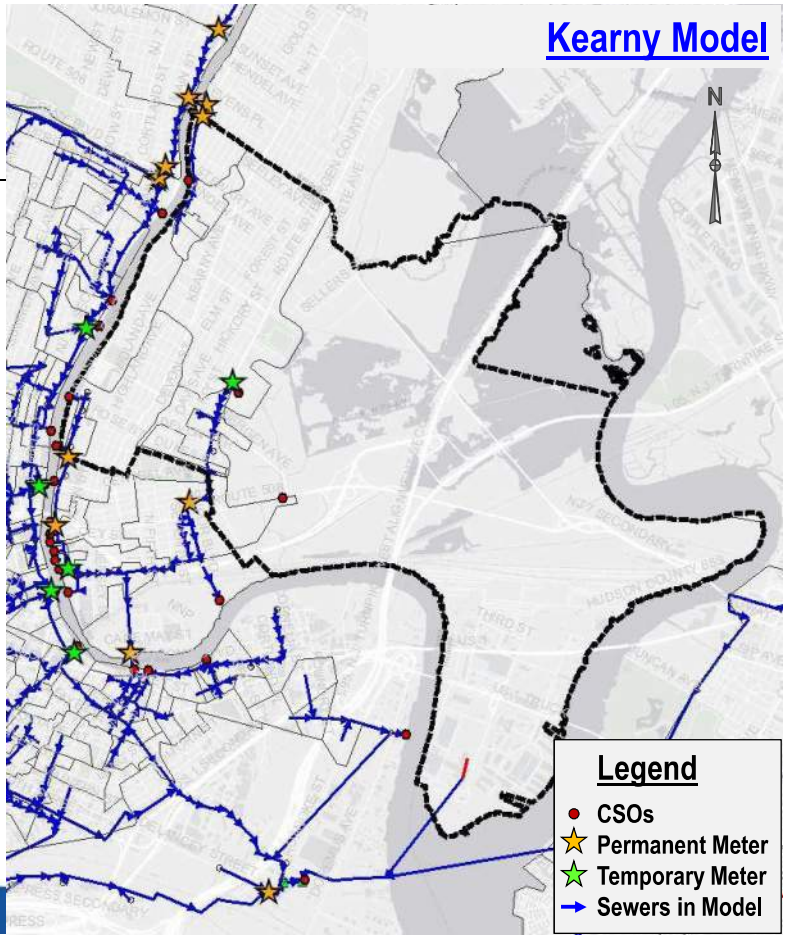
East Newark Model

- Subcatchment: 1
- Nodes (22)
  - Manhole: 21
  - Outfall: 1
  - Storage: 0
- Link (22)
  - Conduit: 19
  - Flap Valve: 1
  - Orifice: 1
  - Pump: 0
  - Sluice: 0
  - Weir: 1



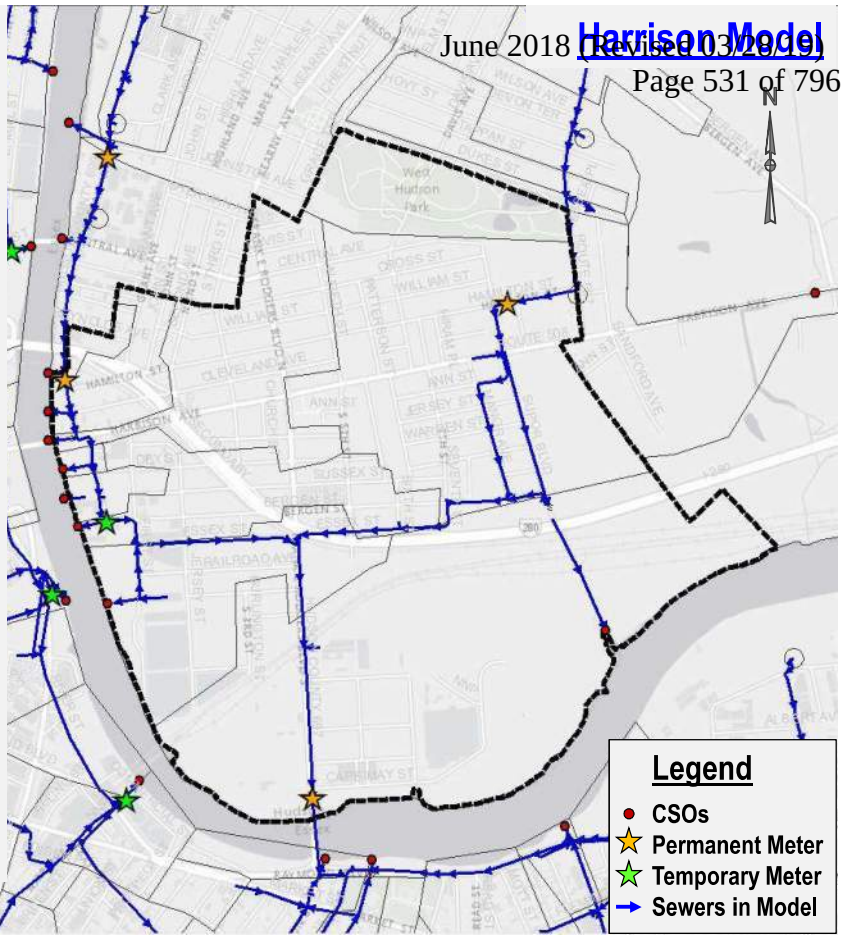
Kearny Model

- Subcatchment: 16
- Nodes (97)
  - Manhole: 91
  - Outfall: 5
  - Storage: 1
- Link (97)
  - Conduit: 78
  - Flap Valve: 5
  - Orifice: 7
  - Pump: 1
  - Sluice: 1
  - Weir: 5



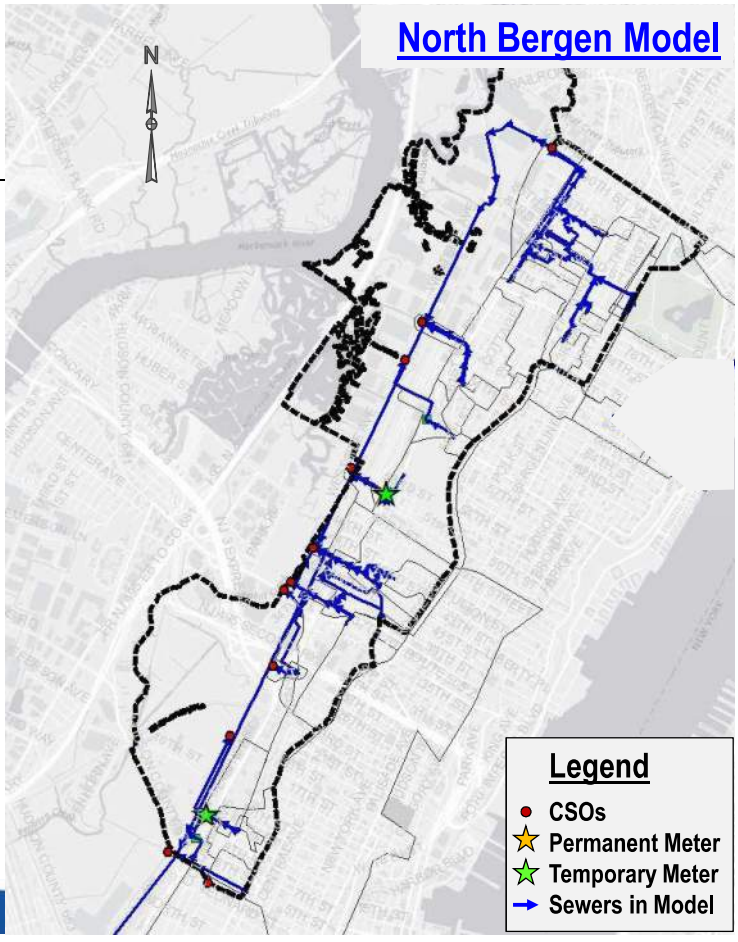
Harrison Model

- Subcatchment: 16
- Nodes (117)
  - Manhole: 110
  - Outfall: 7
  - Storage: 0
- Link (118)
  - Conduit: 97
  - Flap Valve: 7
  - Orifice: 7
  - Pump: 0
  - Sluice: 0
  - Weir: 7



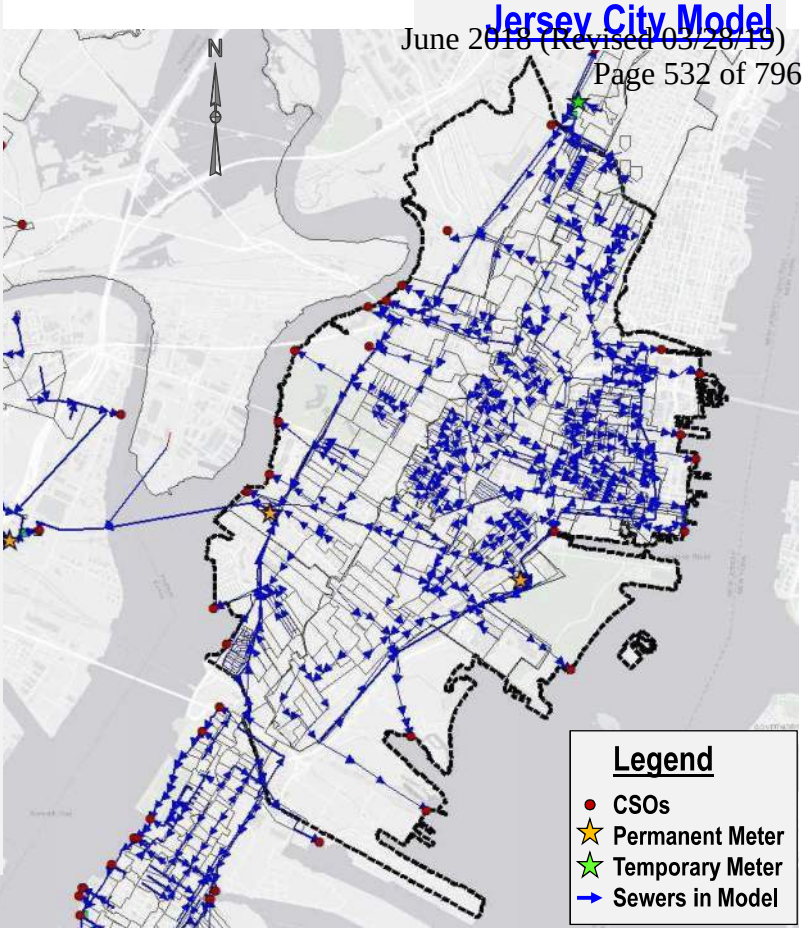
North Bergen Model

- Subcatchment: 41
- Nodes (178)
  - Manhole: 166
  - Outfall: 9
  - Storage: 3
- Link (199)
  - Conduit: 183
  - Flap Valve: 0
  - Orifice: 0
  - Pump: 3
  - Sluice: 5
  - Weir: 8



Jersey City Model

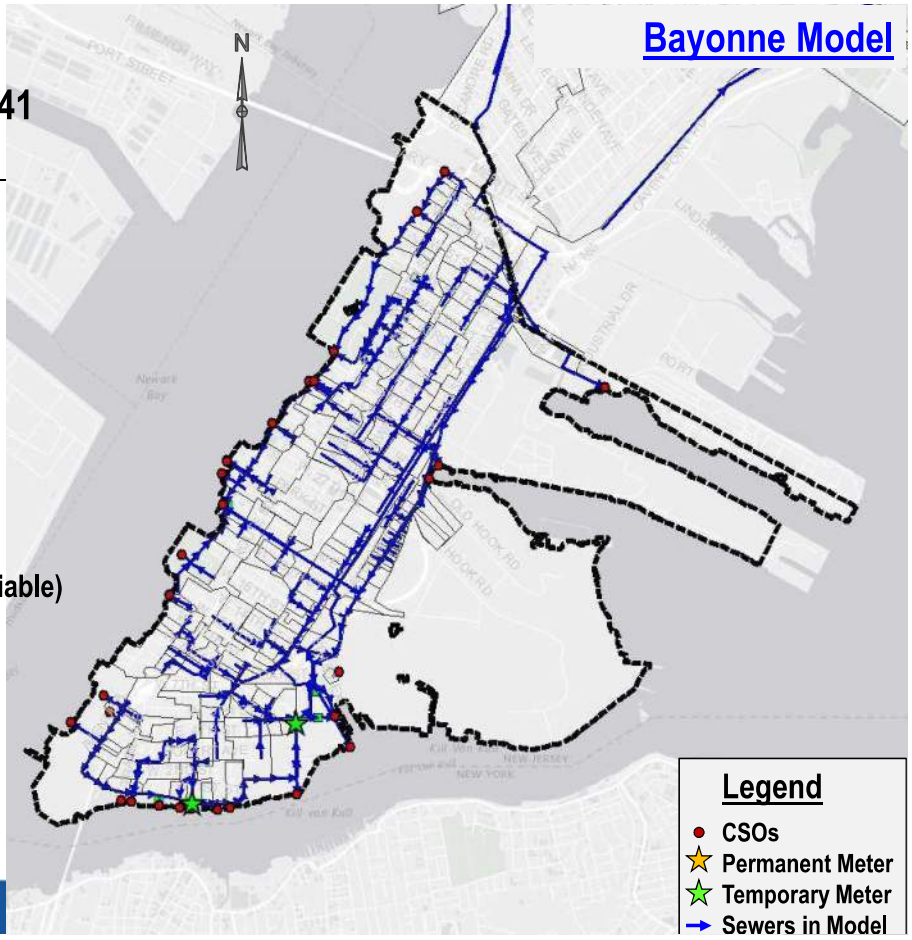
- Subcatchment: 393
- Nodes (1498)
  - Manhole: 1476
  - Outfall: 21
  - Storage: 1
- Link (1552)
  - Conduit: 1487
  - Flap Valve: 21
  - Orifice: 1
  - Pump: 3
  - Sluice: 27 (4 variable)
  - Weir: 13



13

Bayonne Model

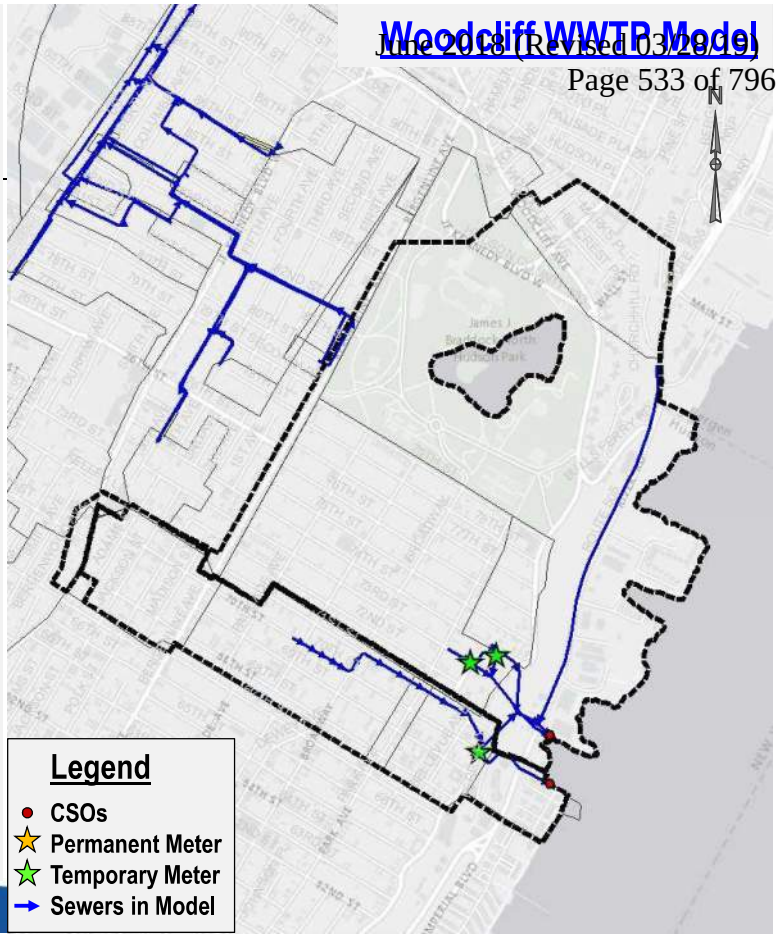
- Subcatchment: 41
- Nodes (685)
  - Manhole: 651
  - Outfall: 29
  - Storage: 5
- Link (712)
  - Conduit: 648
  - Flap Valve: 27
  - Orifice: 0
  - Pump: 5
  - Sluice: 20 (11 variable)
  - Weir: 12



14

Woodcliff WWTP Model

- Subcatchment: 5
- Nodes (38)
  - Manhole: 35
  - Outfall: 2
  - Storage: 1
- Link (39)
  - Conduit: 37
  - Flap Valve: 0
  - Orifice: 0
  - Pump: 0
  - Sluice: 1
  - Weir: 1

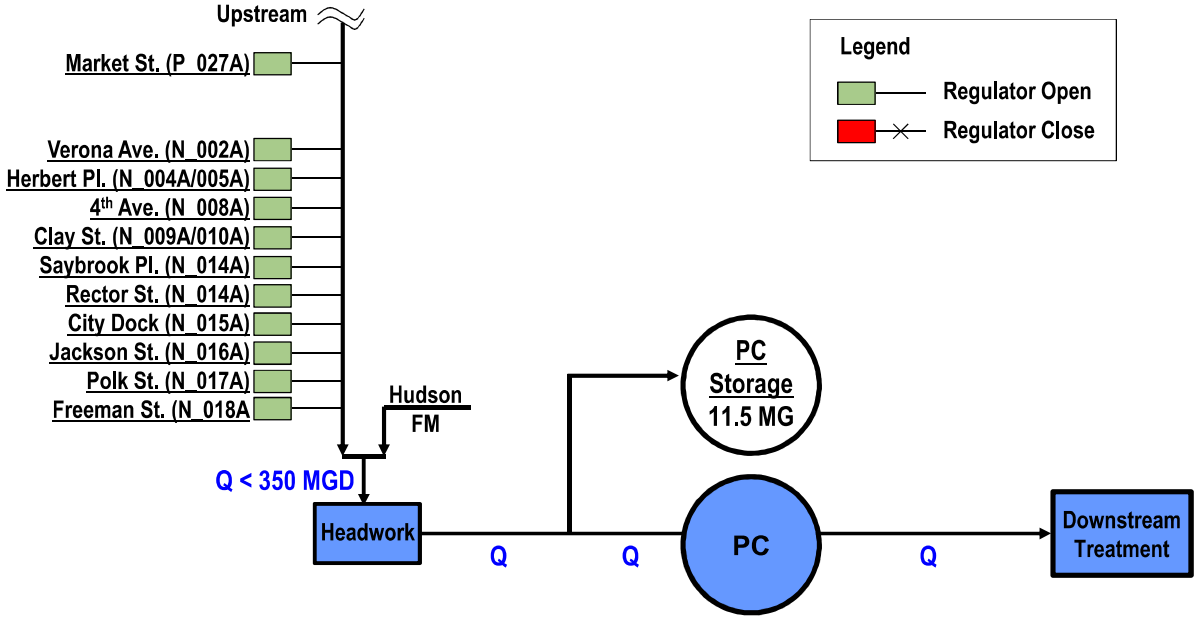


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Wet Weather Operating Rules

Wet Weather SOP

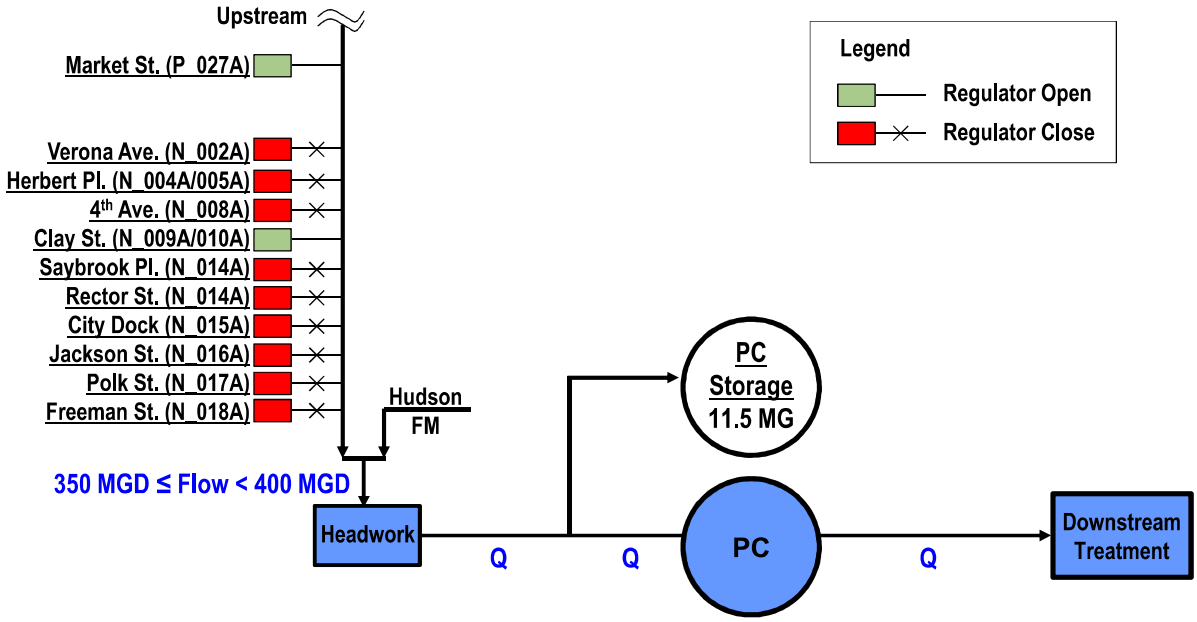
Flow < 350 MGD



GREELEY AND HANSEN

Wet Weather SOP

350 MGD ≤ Flow < 400 MGD

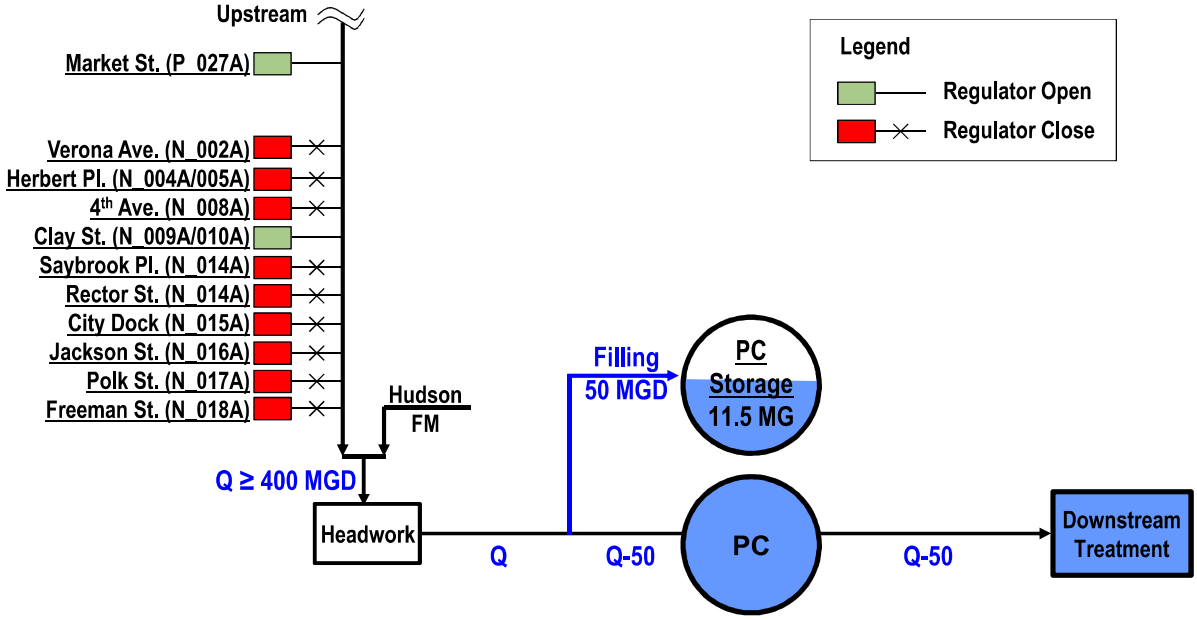


Note: During 10/7/15 to 7/7/16, CSOs were put in use at plant flow 400 MGD.

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Wet Weather SOP

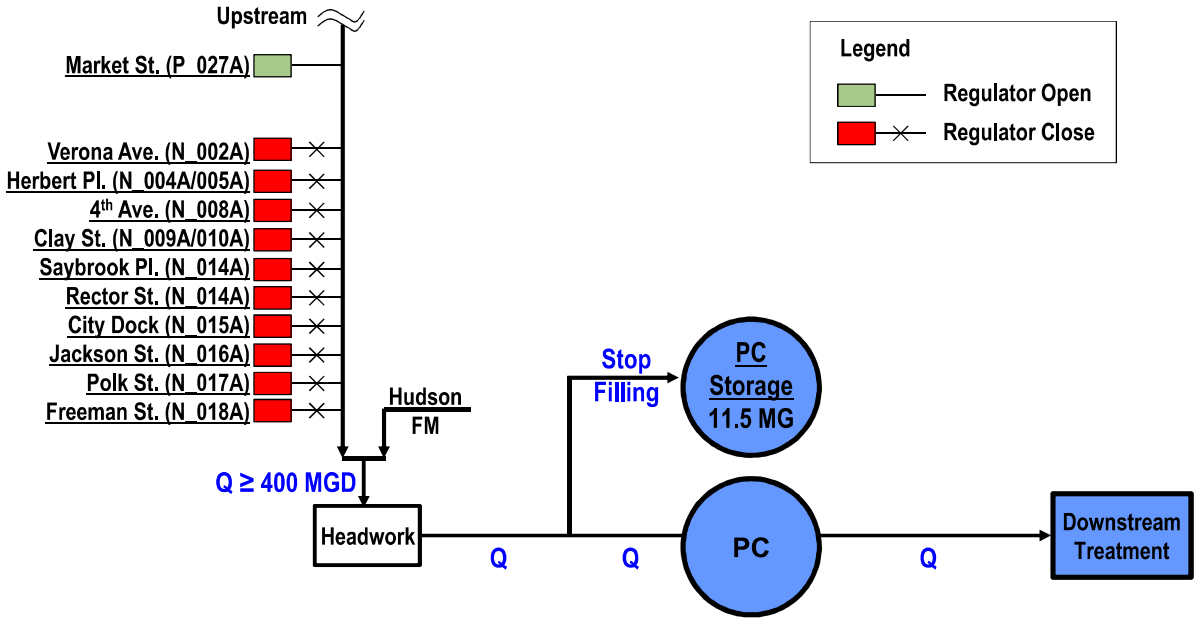
Flow ≥ 400 MGD



GREELEY AND HANSEN

Wet Weather SOP

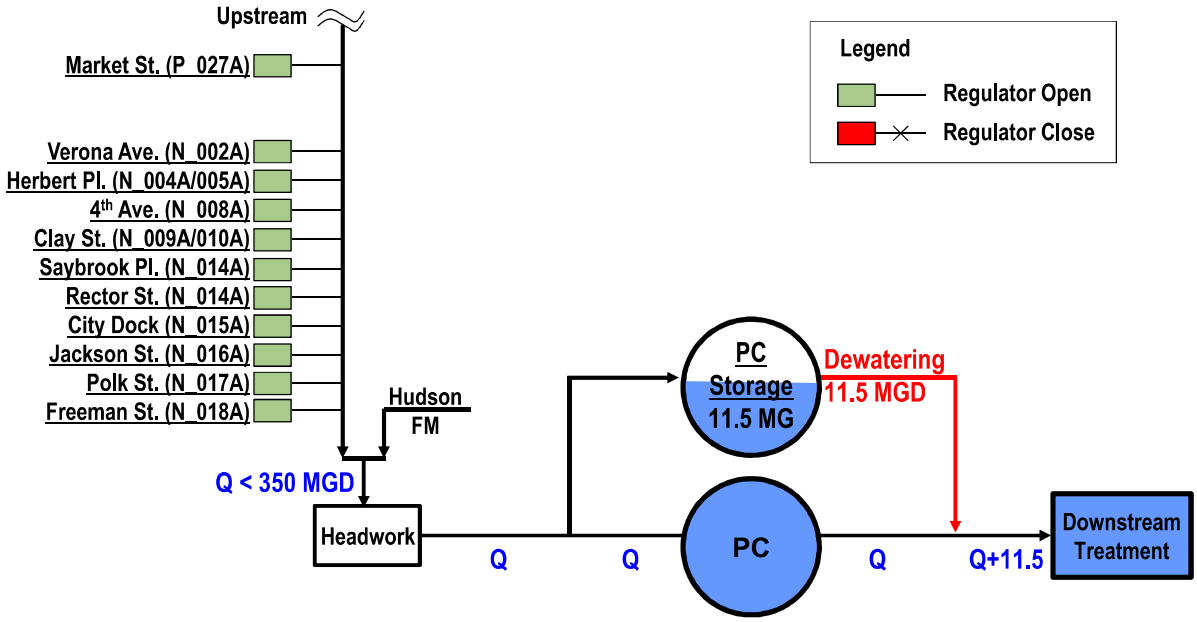
Flow ≥ 400 MGD, & Storage Full



GREELEY AND HANSEN

Wet Weather SOP

Flow Drops to 350 MGD



GREELEY AND HANSEN

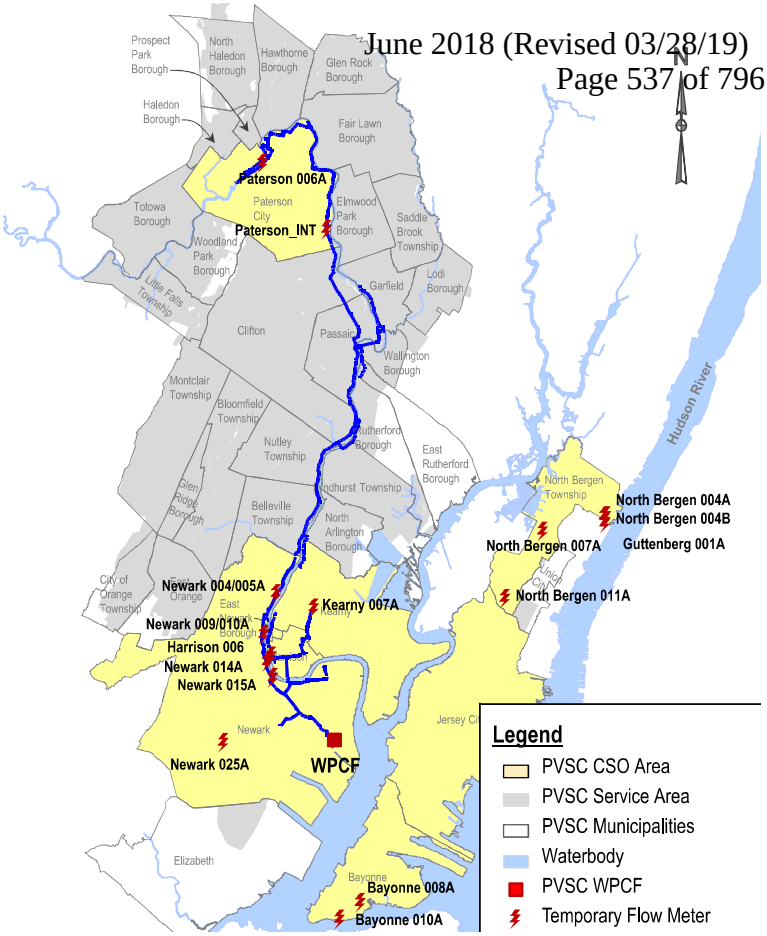
GREELEY AND HANSEN

PVSC H&H Model Calibration and Validation

Temporary Flow Meters (April to August 2016)

21 Flow Meters

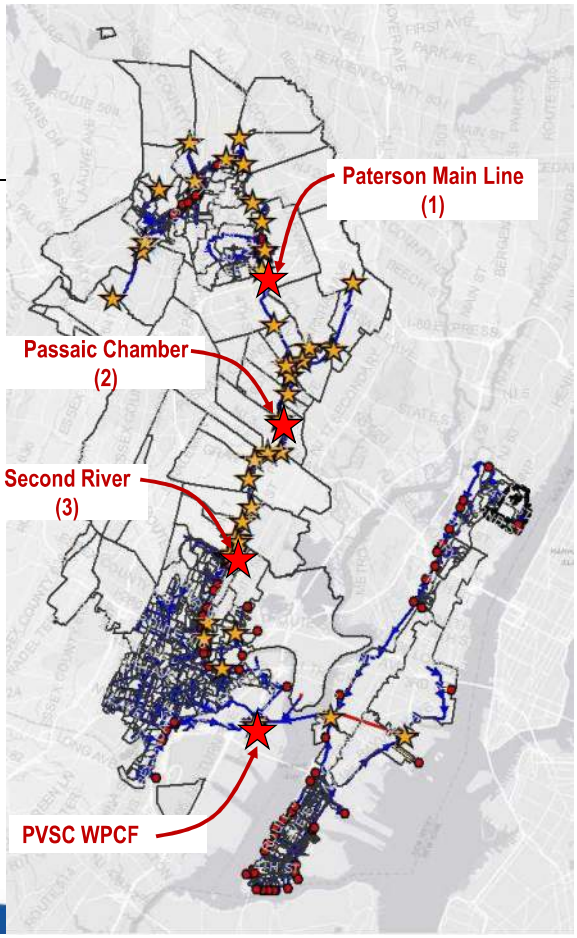
- 13 outfall pipe
- 5 regulator influent
- 2 regulator effluent
- 1 interceptor



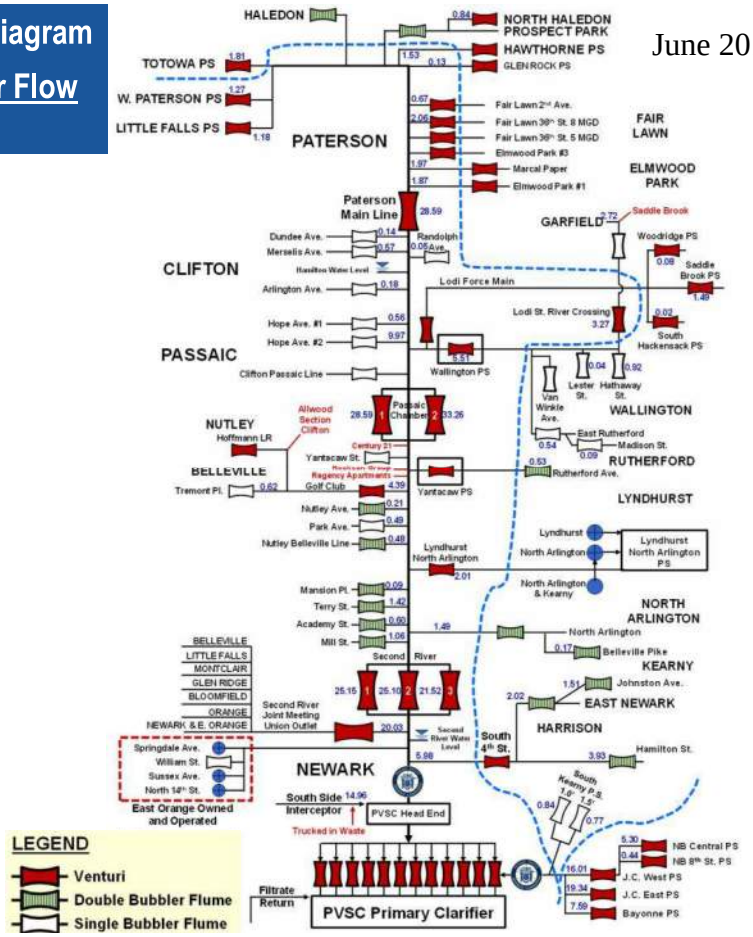
PVSC Permanent Flow Meters

Over 70 Flow Meters, 55 was analyzed for DWF and model calibration

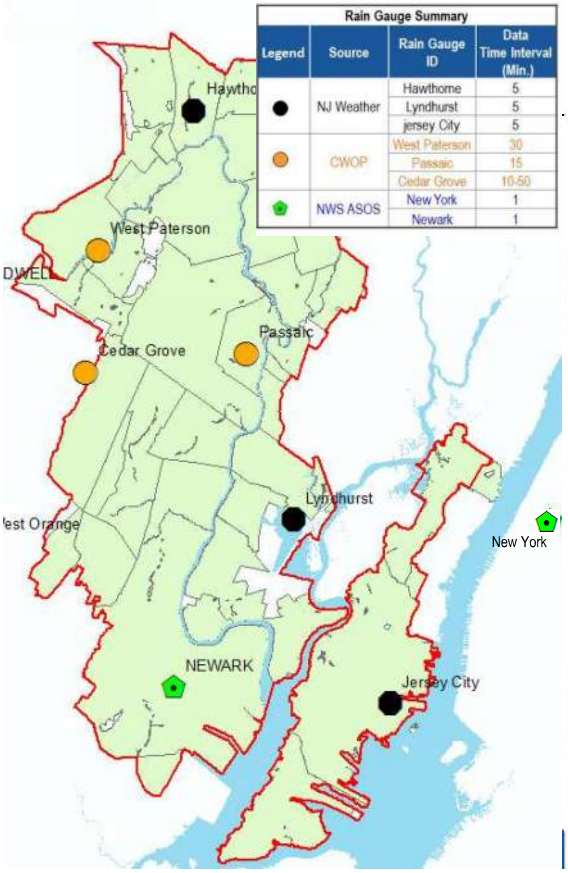
- PVSC Interceptor: 6
- Pump Station: 6
- Combined area: 5
- Separated Area: 38

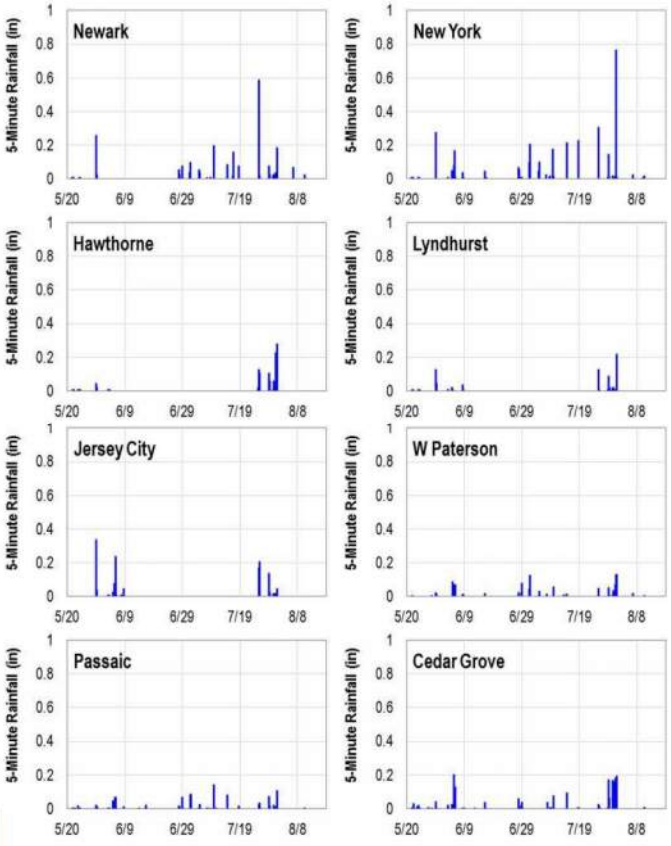


Flow Meter Diagram
Dry Weather Flow (MGD)

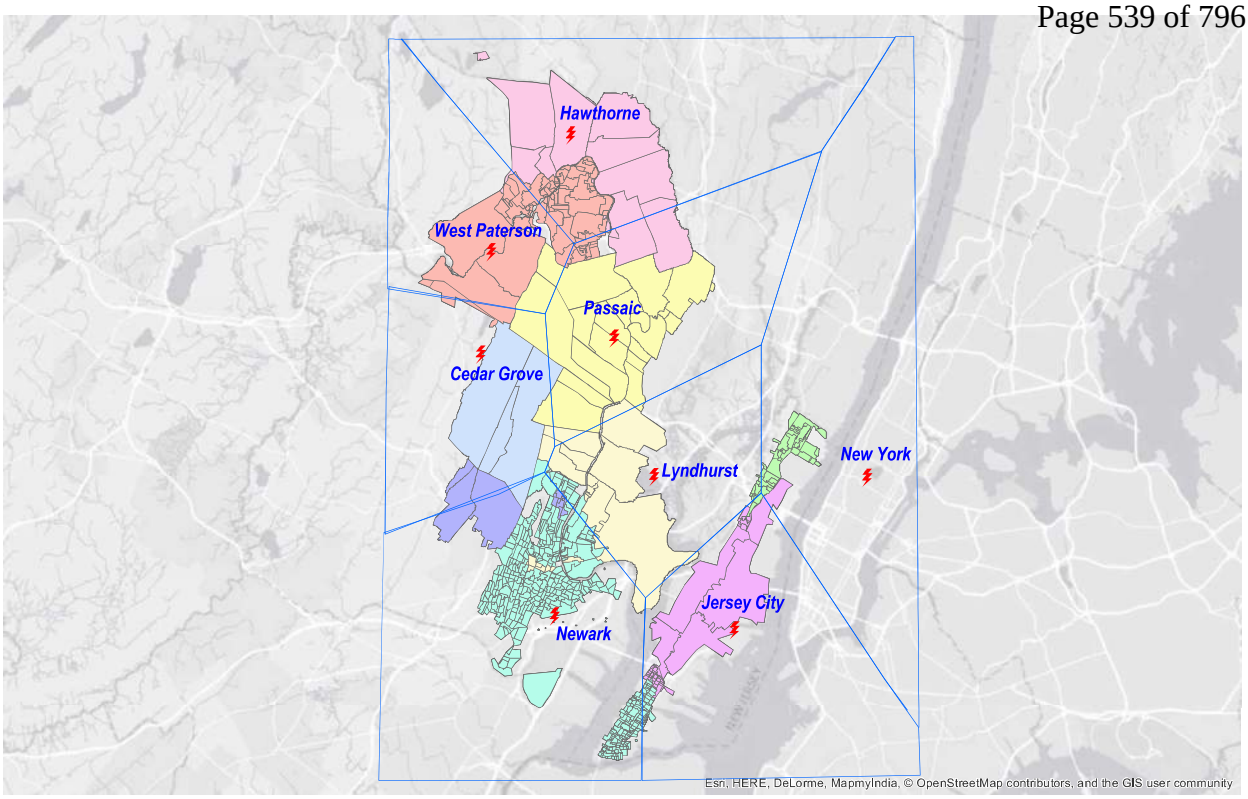


Rainfall Stations





Rainfall Station Assignment



Candidate Storm Events for Calibration

Rainfall Based on Newark

Rain Start	Rain End	Duration (hr)	Depth (in)	Max Intensity (in/hr)	Average Intensity (in/hr)
7/25/16 16:05	7/25/16 18:50	2.75	**1.81**	1.68	0.66
5/29/16 23:50	5/30/16 5:20	5.50	**1.6**	1.09	0.29
7/29/16 0:20	7/29/16 8:35	8.25	**0.85**	0.42	0.10
5/2/16 22:40	5/3/16 9:50	11.17	**0.7**	0.17	0.06
7/31/16 8:35	7/31/16 22:35	14.00	**0.69**	0.49	0.05
7/4/16 19:20	7/5/16 2:50	7.50	**0.63**	0.23	0.08
5/6/16 2:30	5/6/16 12:25	9.92	**0.6**	0.19	0.06
7/16/16 14:50	7/16/16 15:35	0.75	**0.56**	0.75	0.75
6/8/16 11:25	6/8/16 14:10	2.75	**0.49**	0.3	0.18
7/9/16 21:30	7/9/16 22:05	0.58	**0.48**	0.82	0.82
4/4/16 7:45	4/4/16 17:00	9.25	**0.43**	0.12	0.05

Model Calibration and Validation Goals

- Visual match
- +20/-10% volume and
- +25%/-15% peak

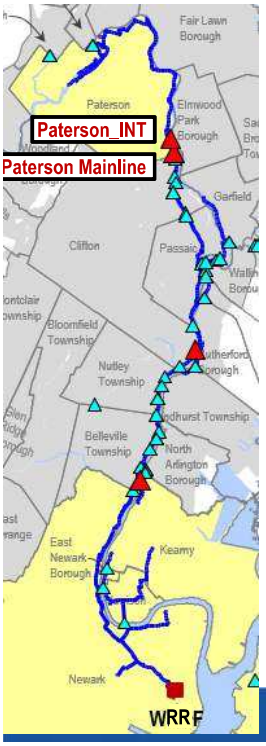
GREELEY AND HANSEN

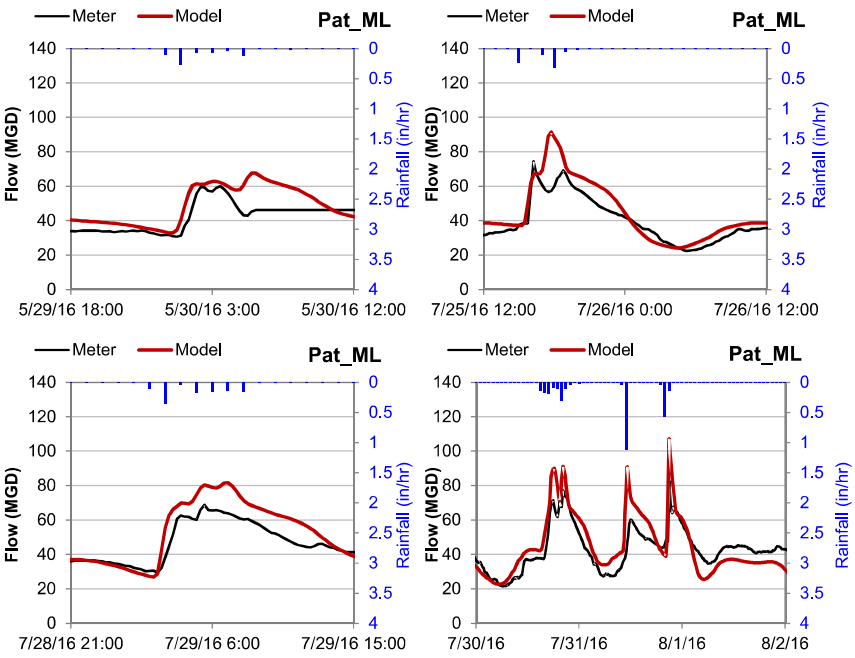
GREELEY AND HANSEN

Major Interceptor

Calibration Results – Main Interceptor

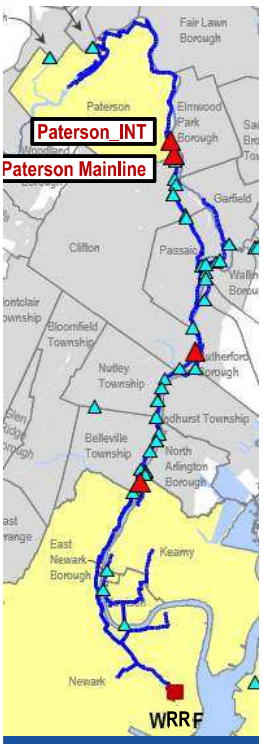
Paterson Main Line

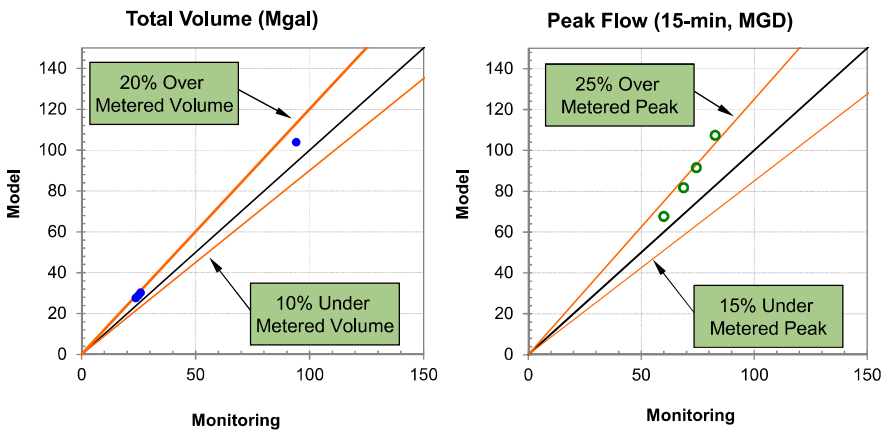




Calibration Results – Main Interceptor

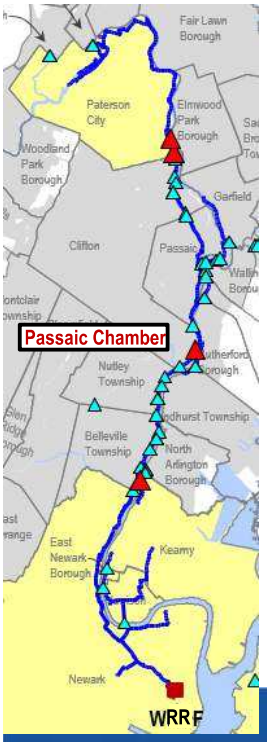
Paterson Main Line: Goodness-of-Fit

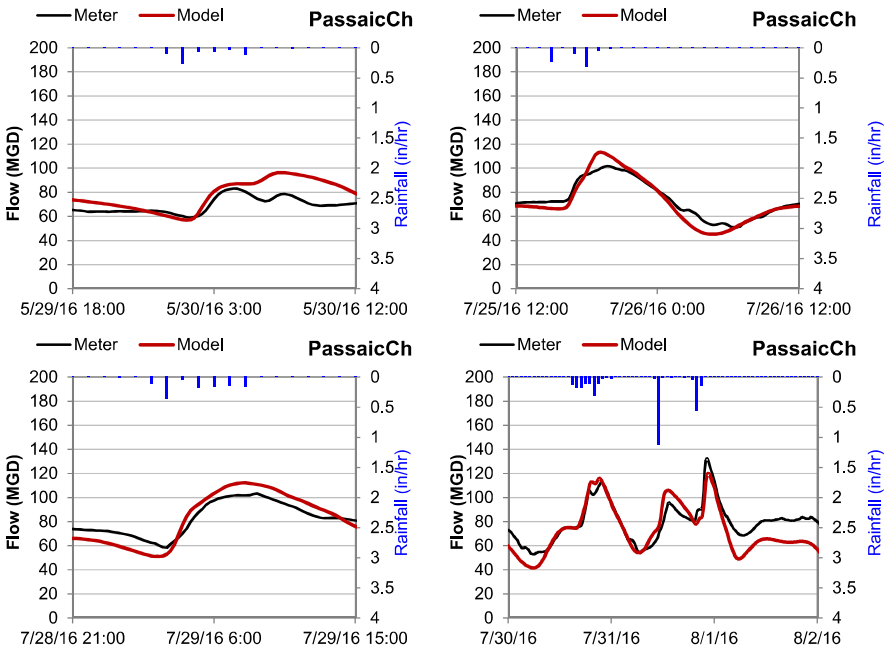




Calibration Results – Main Interceptor

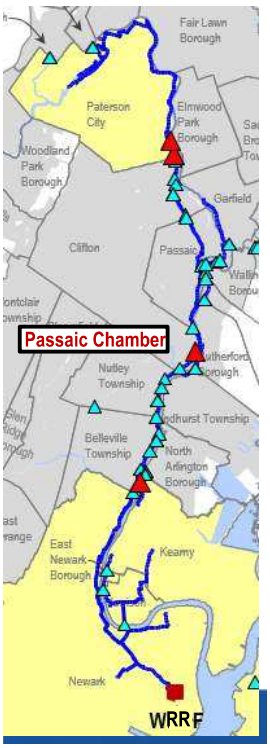
Passaic Chamber

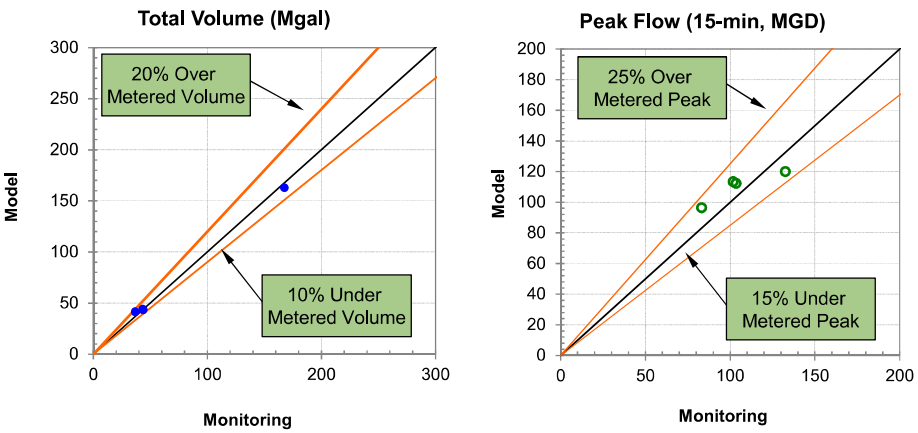




Calibration Results – Main Interceptor

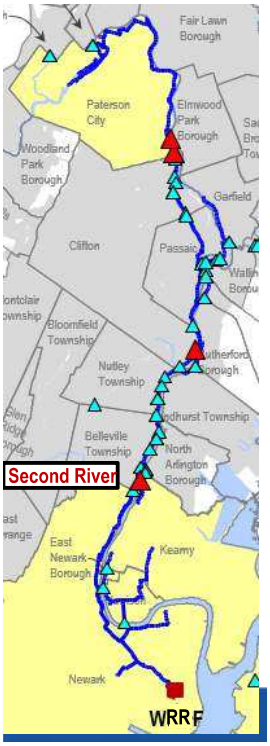
Passaic Chamber: Goodness-of-Fit

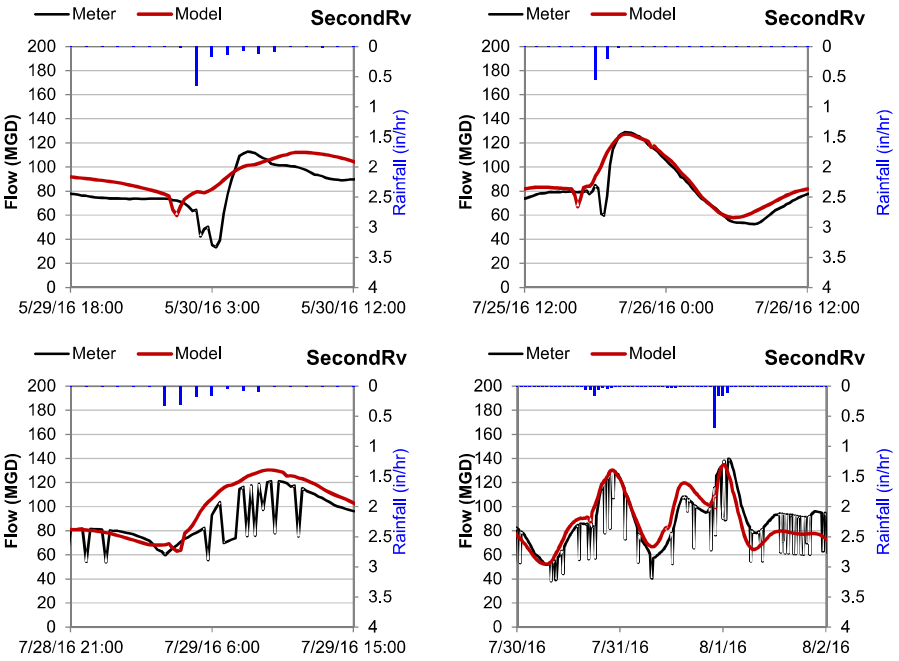




Calibration Results – Main Interceptor

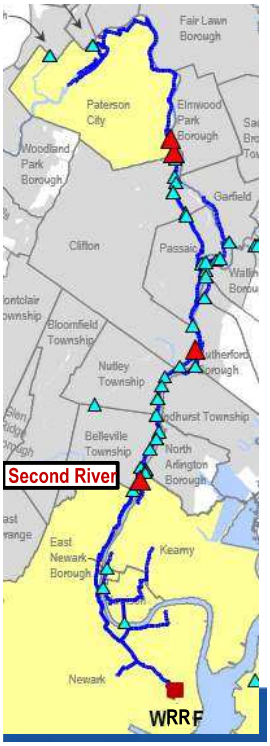
Second River Crossing

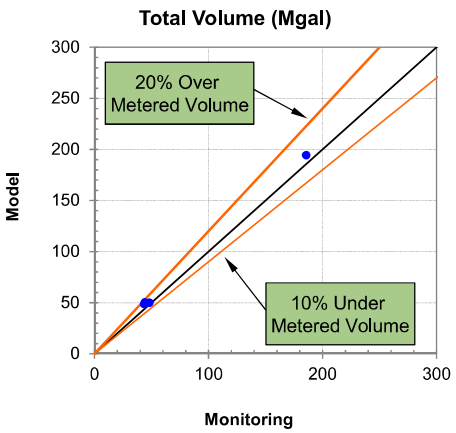


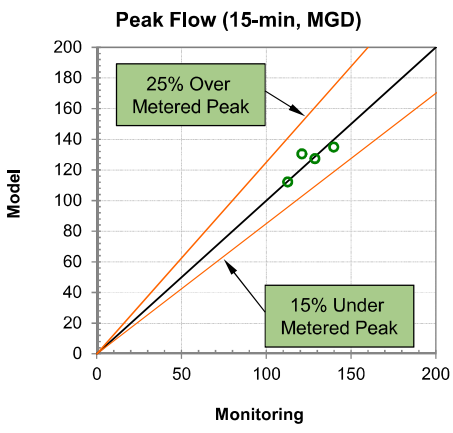


Calibration Results – Main Interceptor

Second River Crossing: Goodness-of-Fit

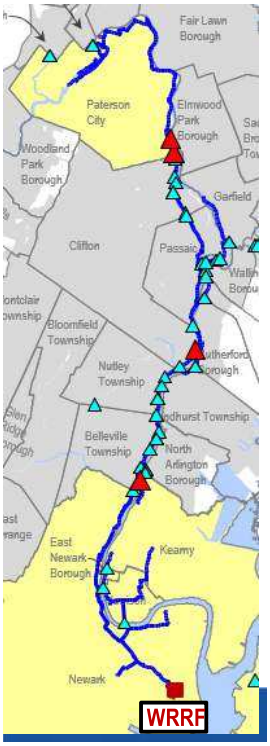


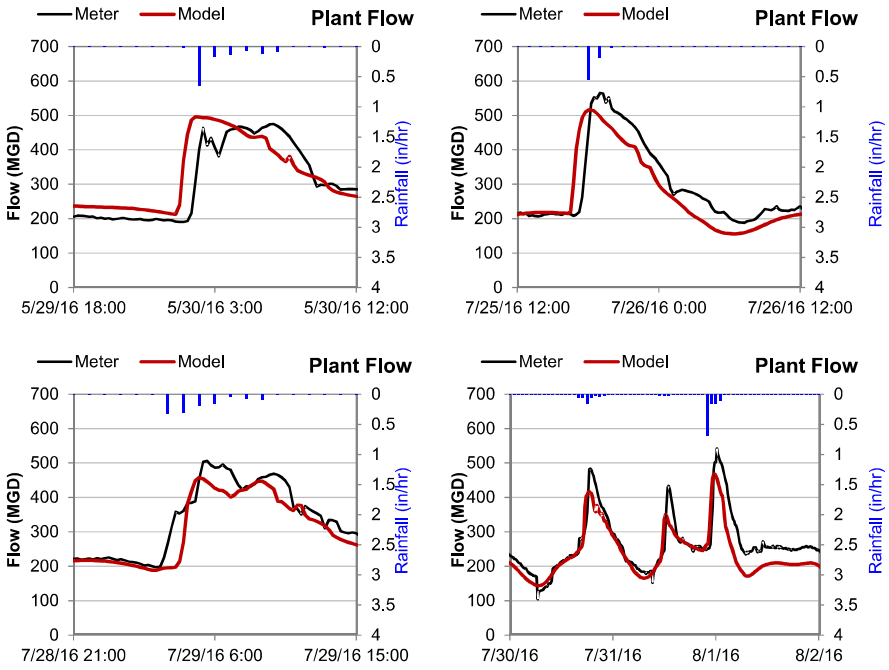




Calibration Results – Main Interceptor

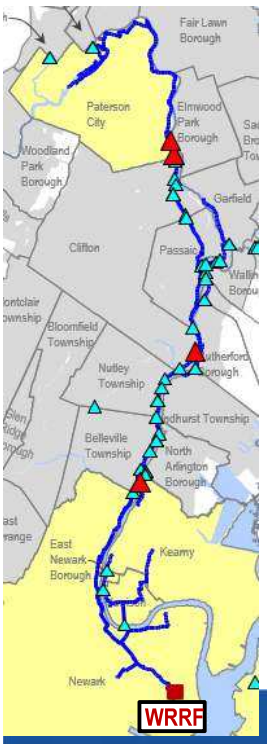
PVSC WPCF

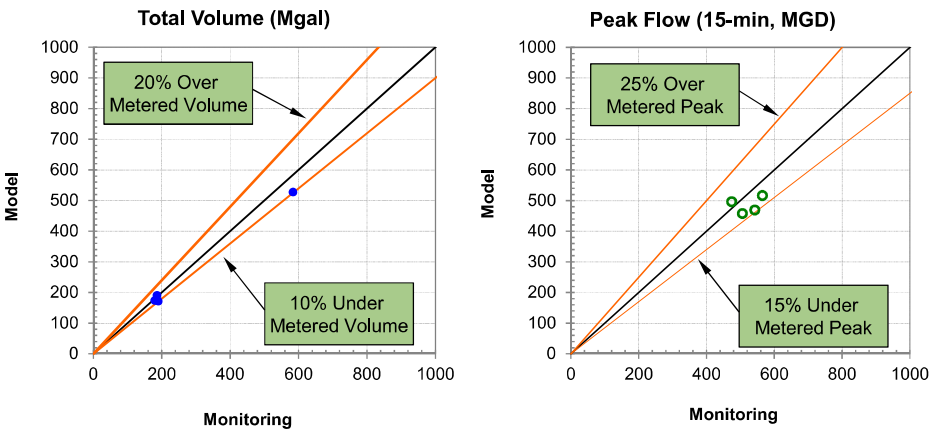




Calibration Results – Main Interceptor

PVSC WPCF: Goodness-of-Fit



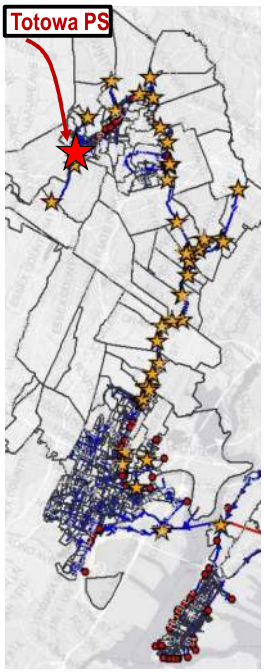


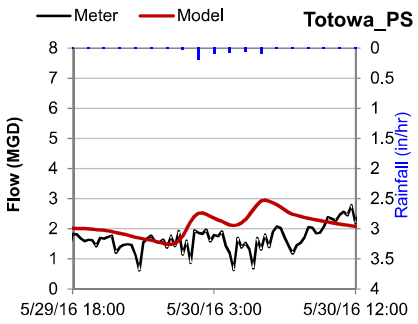
GREELEY AND HANSEN

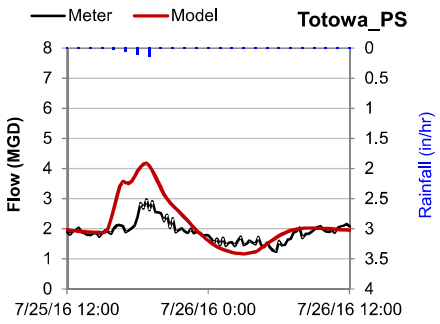
Separated Area

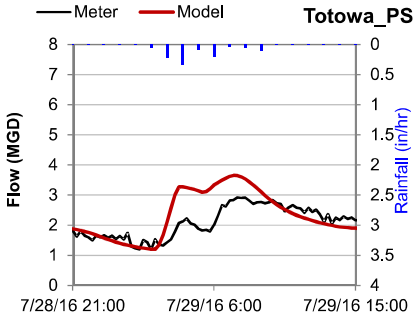
Calibration Results – Separated Area

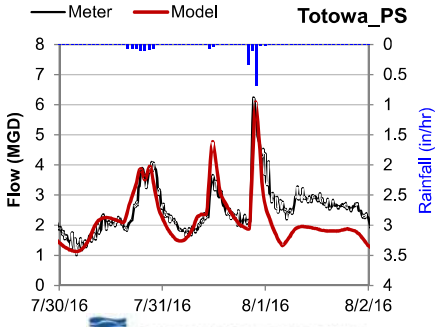
Totowa PS







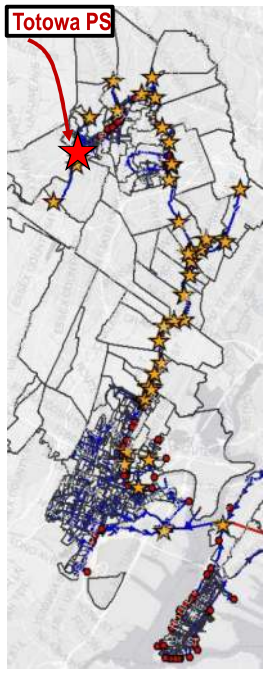


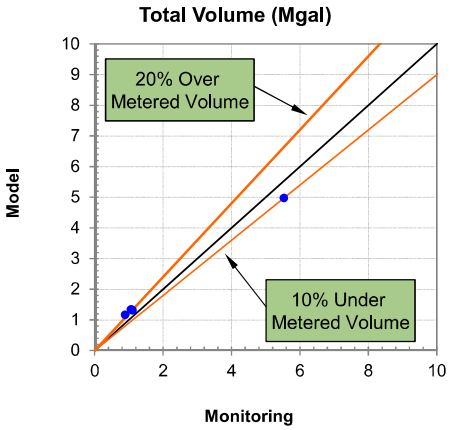


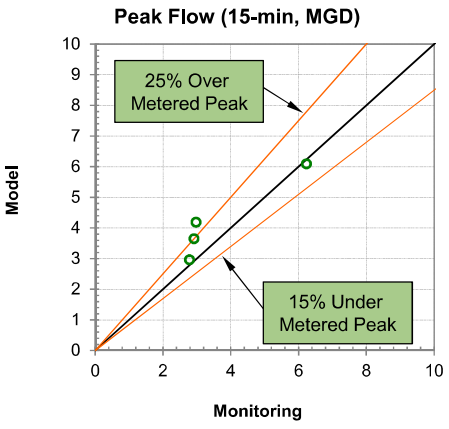
GREELEY AND HANSEN

Calibration Results – Separated Area

Totowa PS: Goodness-of-Fit

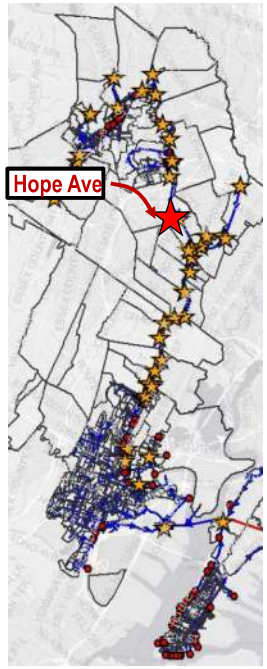


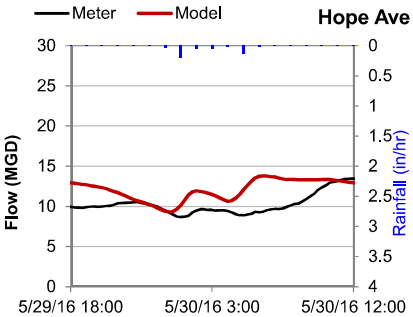


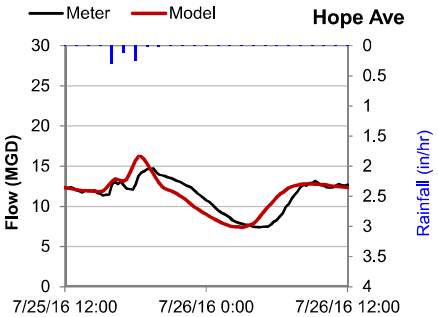


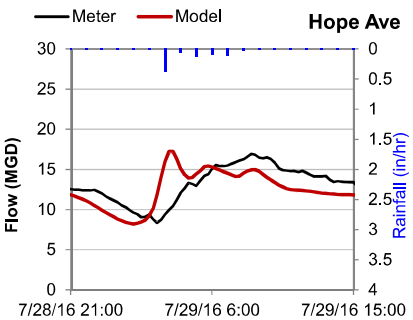
Calibration Results – Separated Area

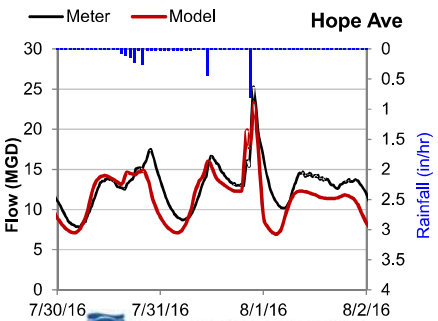
Hope Ave





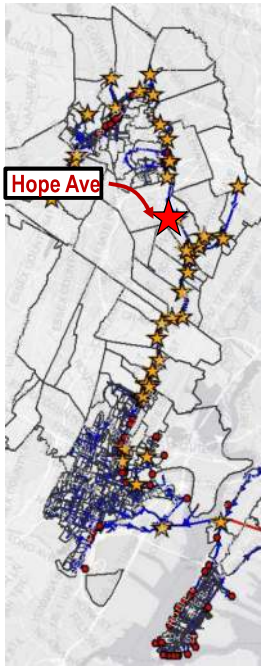


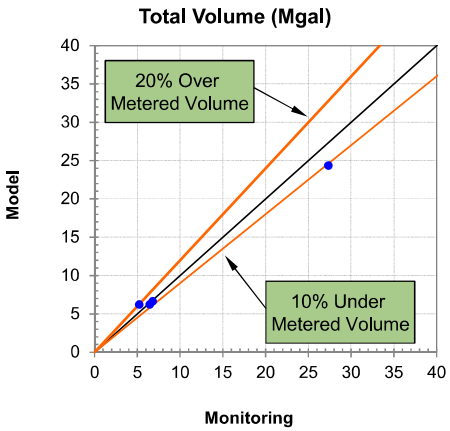


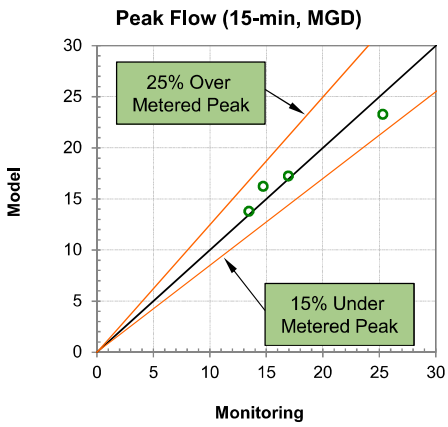


Calibration Results – Separated Area

Hope Ave: Goodness-of-Fit

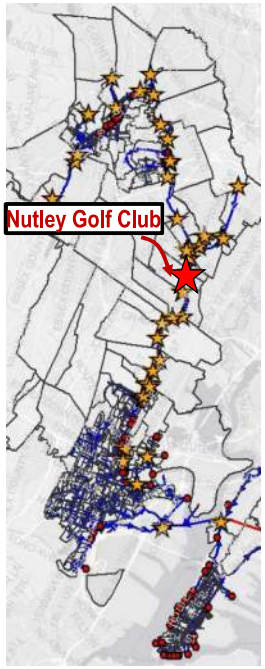


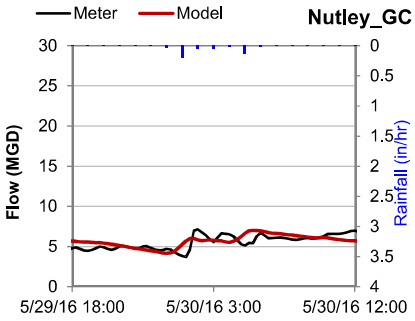


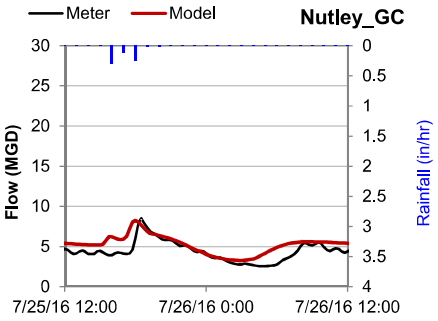


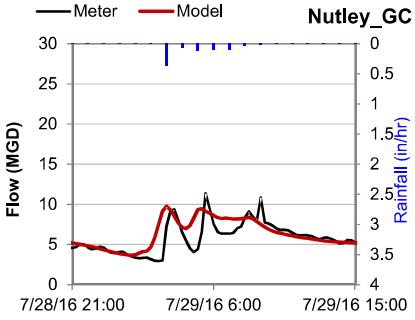
Calibration Results – Separated Area

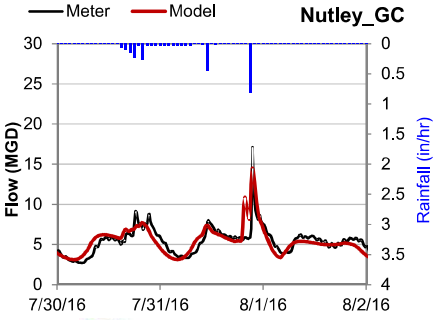
Nutley Golf Club





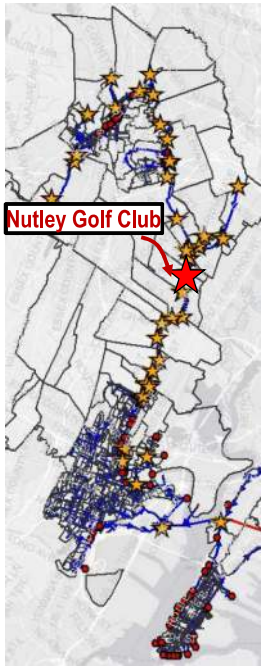


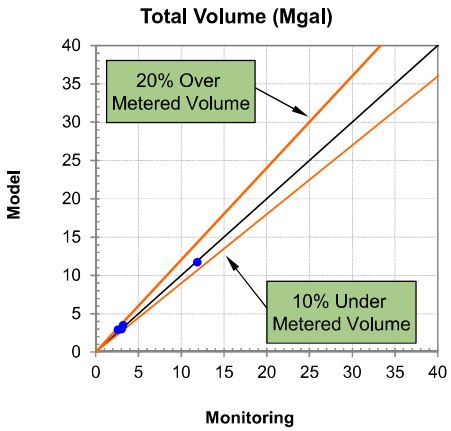


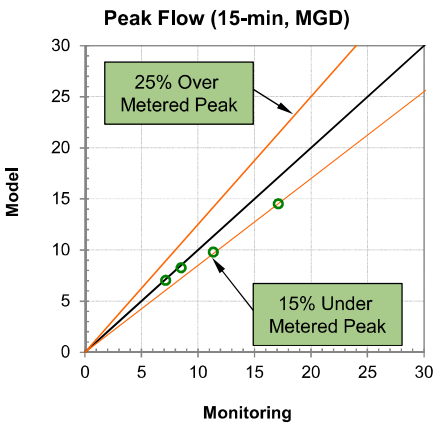


Calibration Results – Separated Area

Nutley Golf Club: Goodness-of-Fit



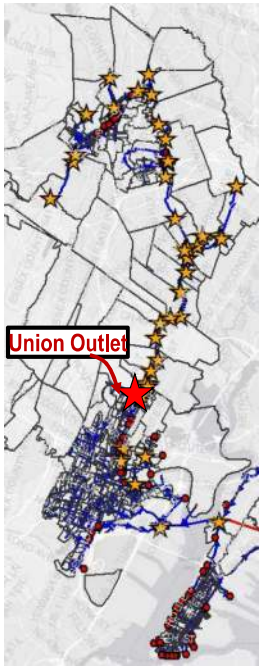


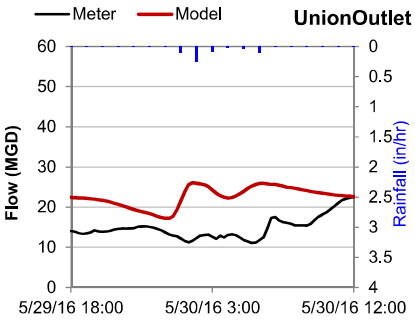


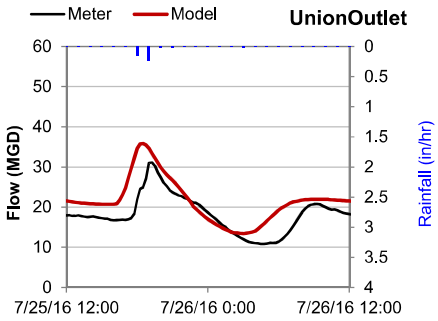
GREELEY AND HANSEN

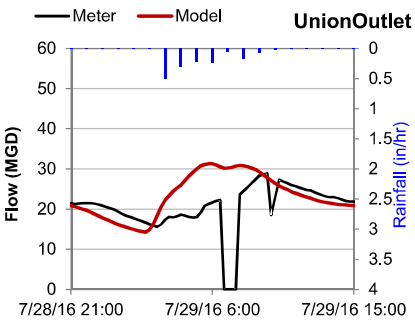
Calibration Results – Separated Area

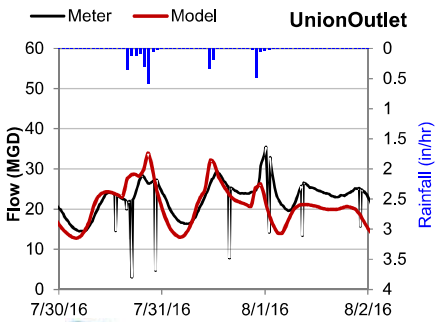
Union Outlet







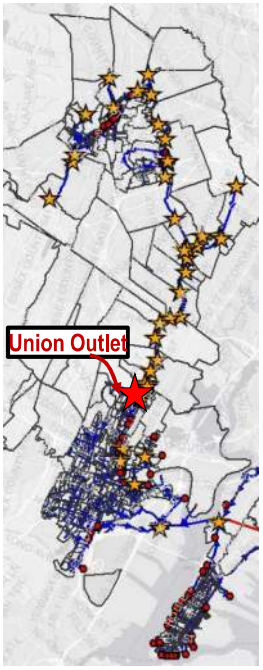


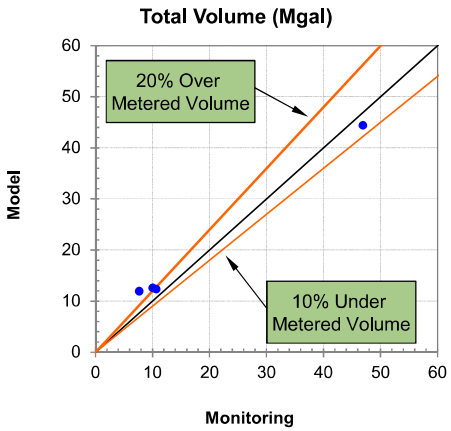


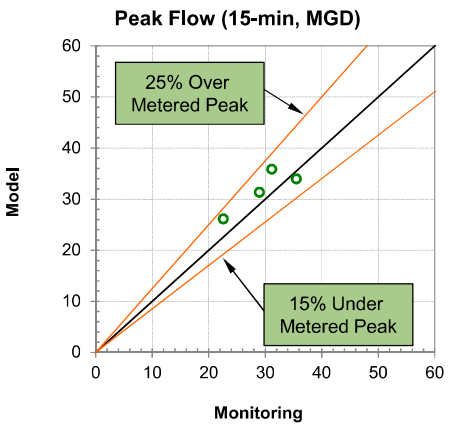
GREELEY AND HANSEN

Calibration Results – Separated Area

Union Outlet







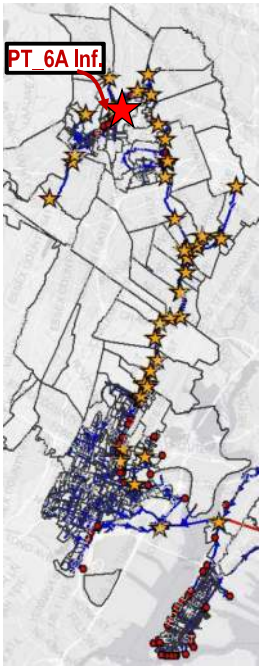
GREELEY AND HANSEN

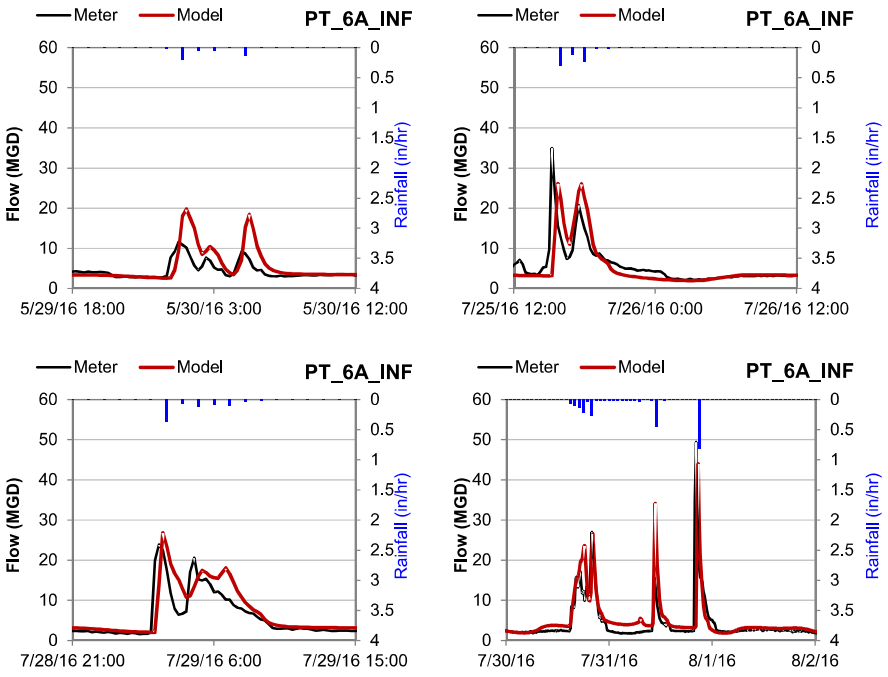
GREELEY AND HANSEN

Combined Area

Calibration Results – Combined Area

Paterson 6A Influent

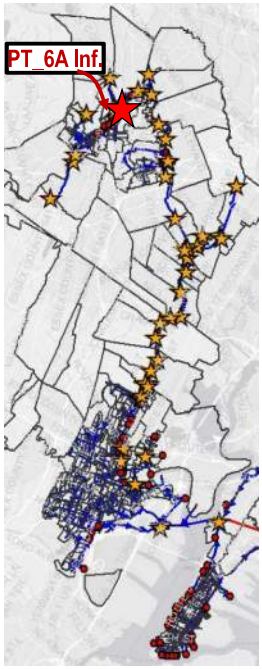


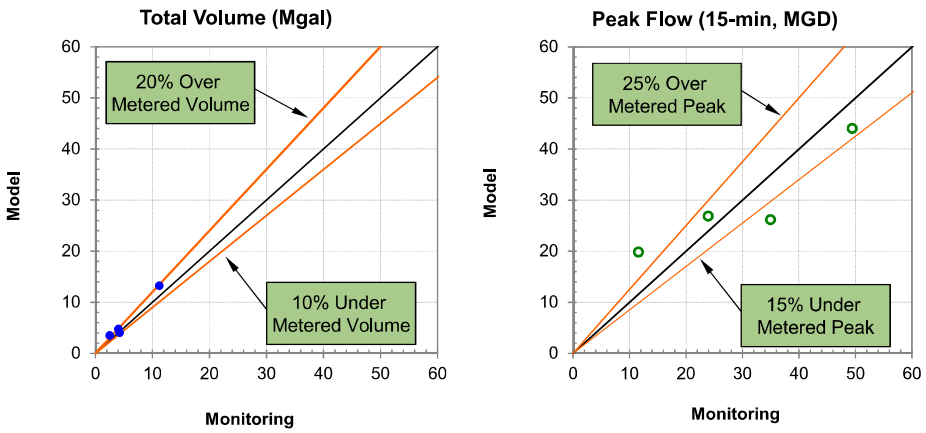


GREELEY AND HANSEN

Calibration Results – Combined Area

Paterson 6A Influent

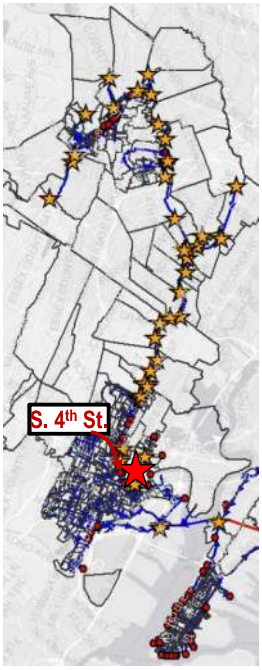


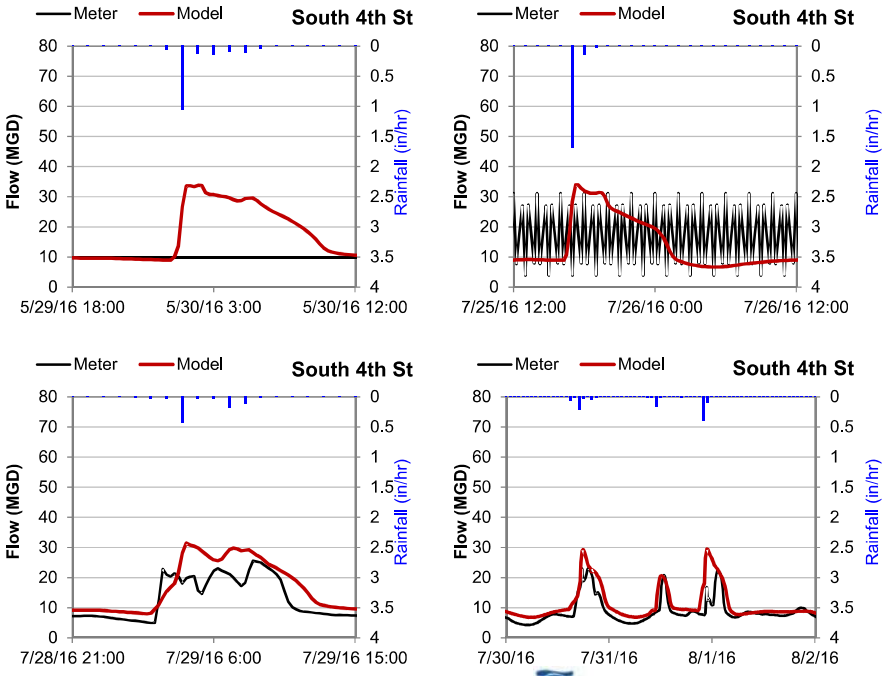


GREELEY AND HANSEN

Calibration Results – Combined Area

South 4th St.

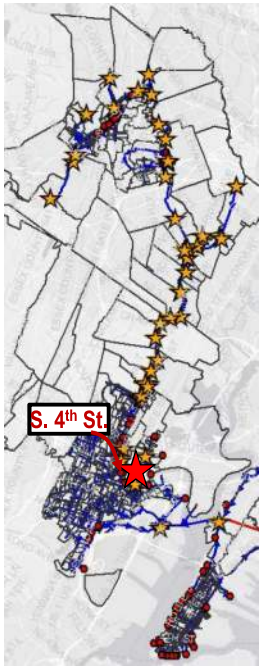


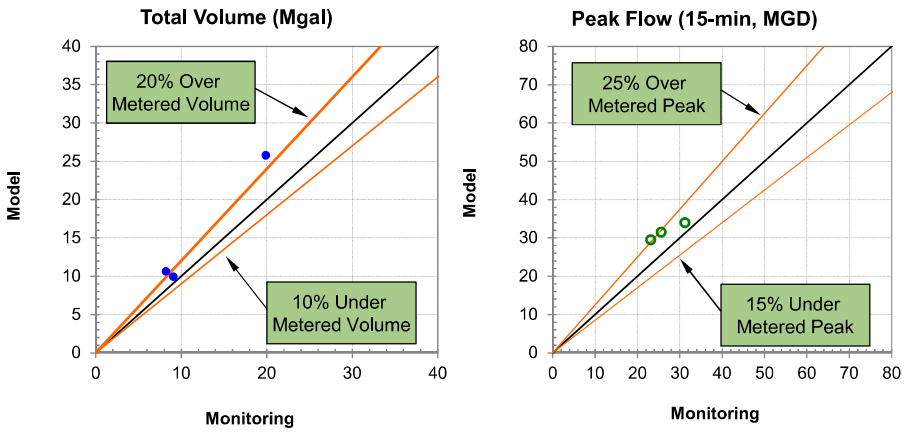


GREELEY AND HANSEN

Calibration Results – Combined Area

South 4th St.

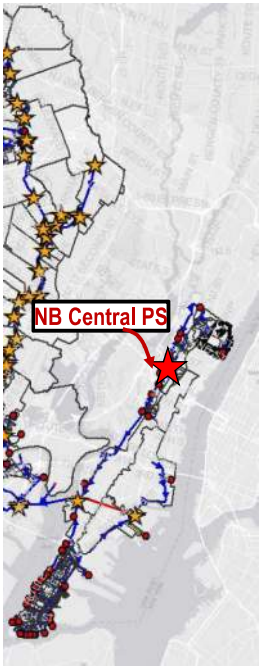


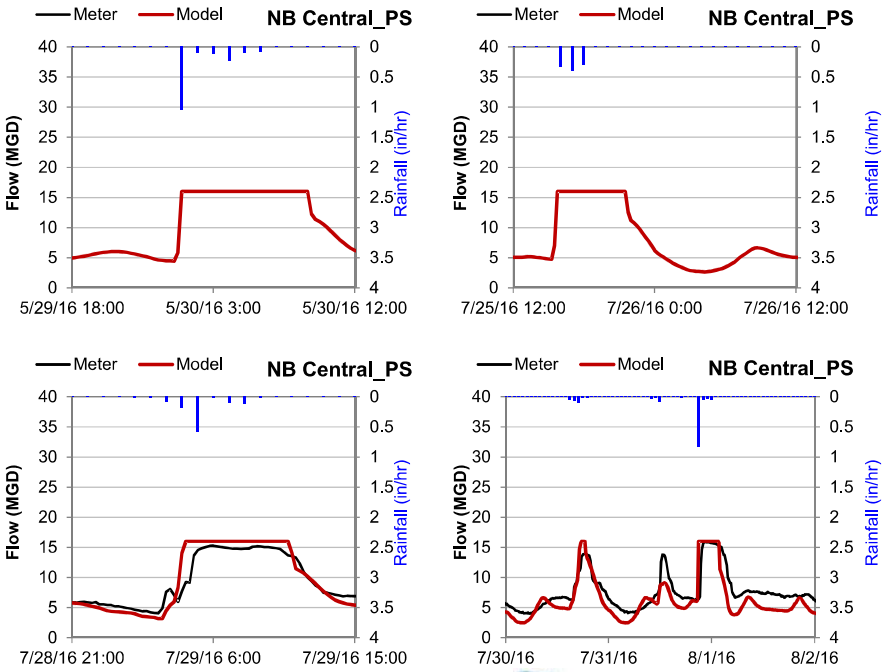


GREELEY AND HANSEN

Calibration Results – Combined Area

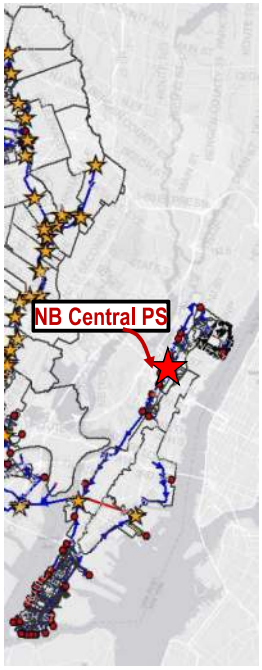
NB Central PS.

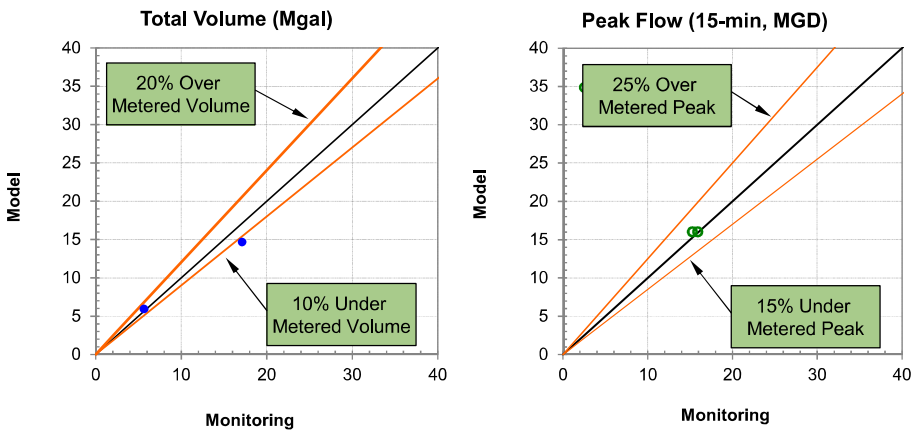




Calibration Results – Combined Area

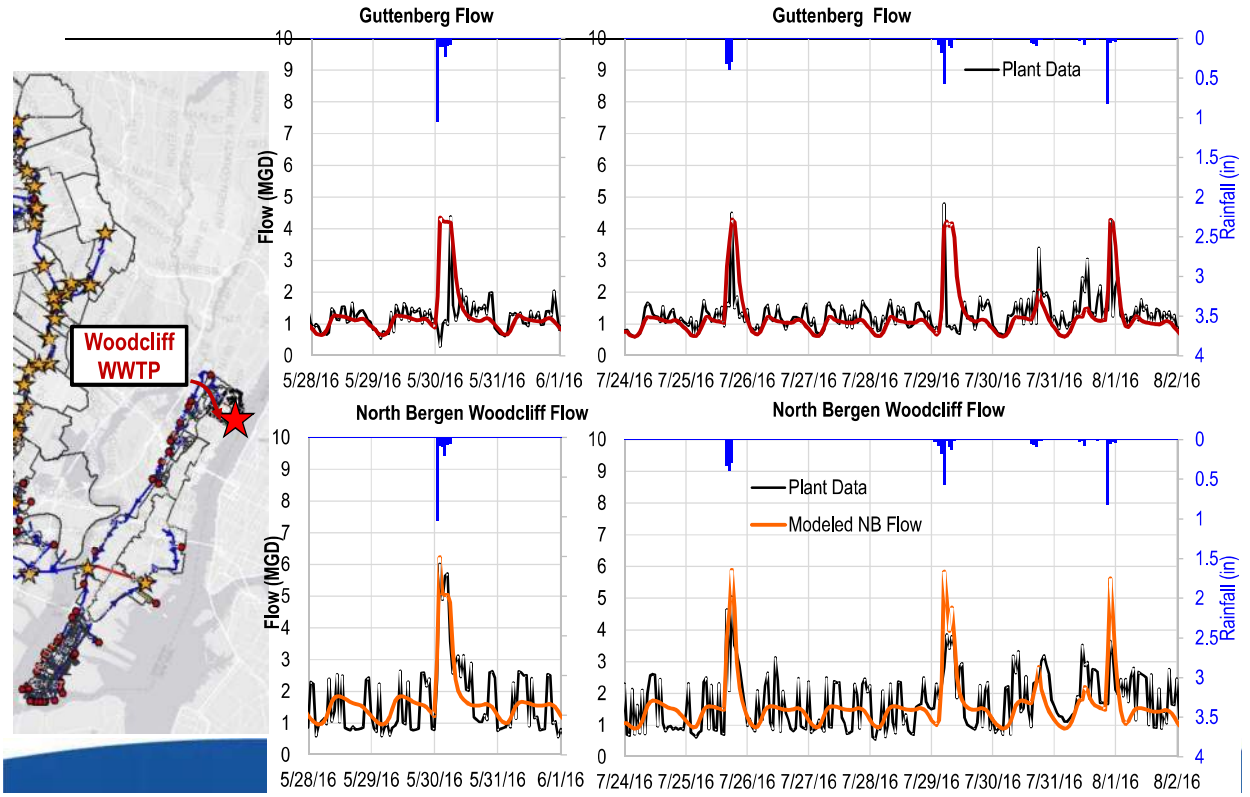
NB Central PS.





Calibration Results – Woodcliff WWTP

Influent Flows

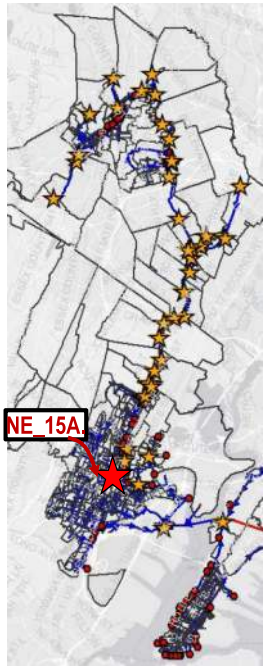


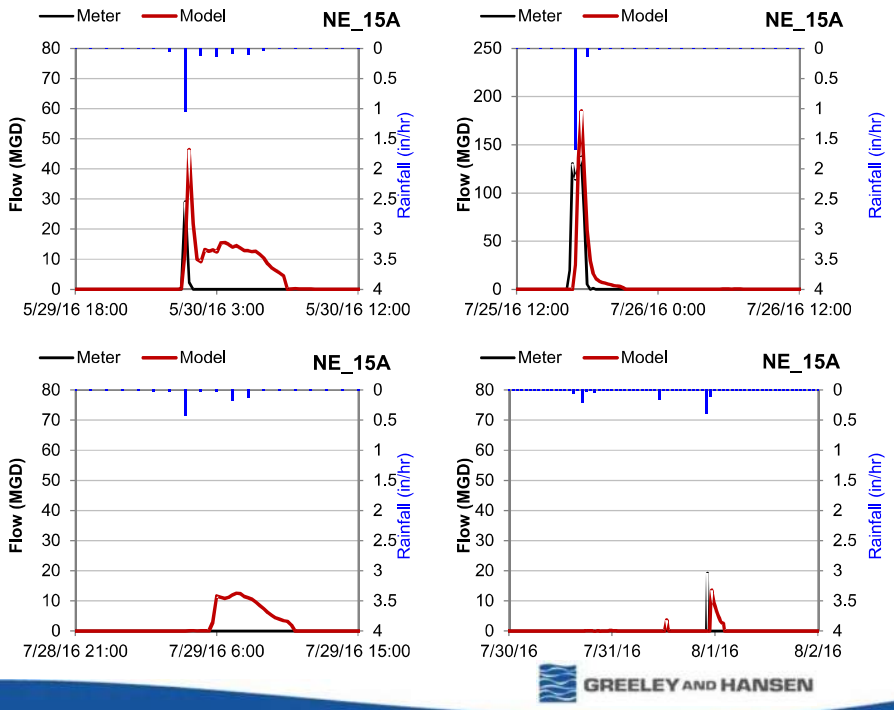
GREELEY AND HANSEN

CSO Meters

Calibration Results – CSO Overflow

NE_15A

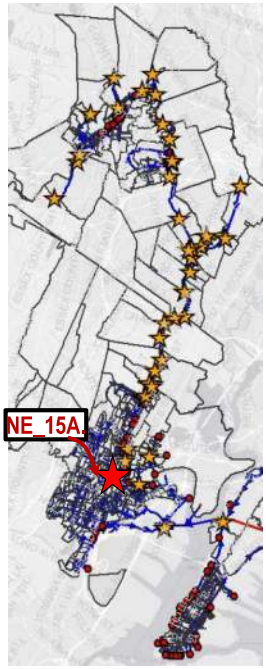


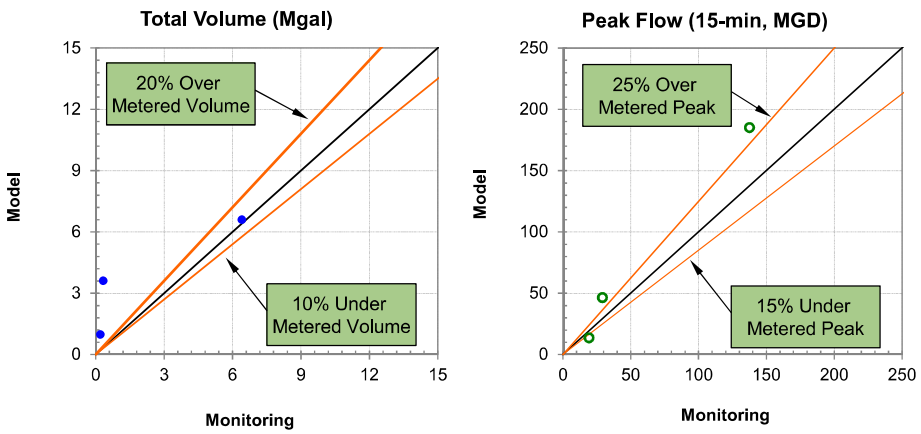


GREELEY AND HANSEN

Calibration Results – CSO Overflow

NE_15A

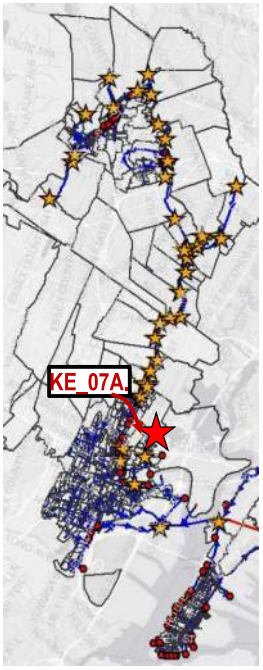


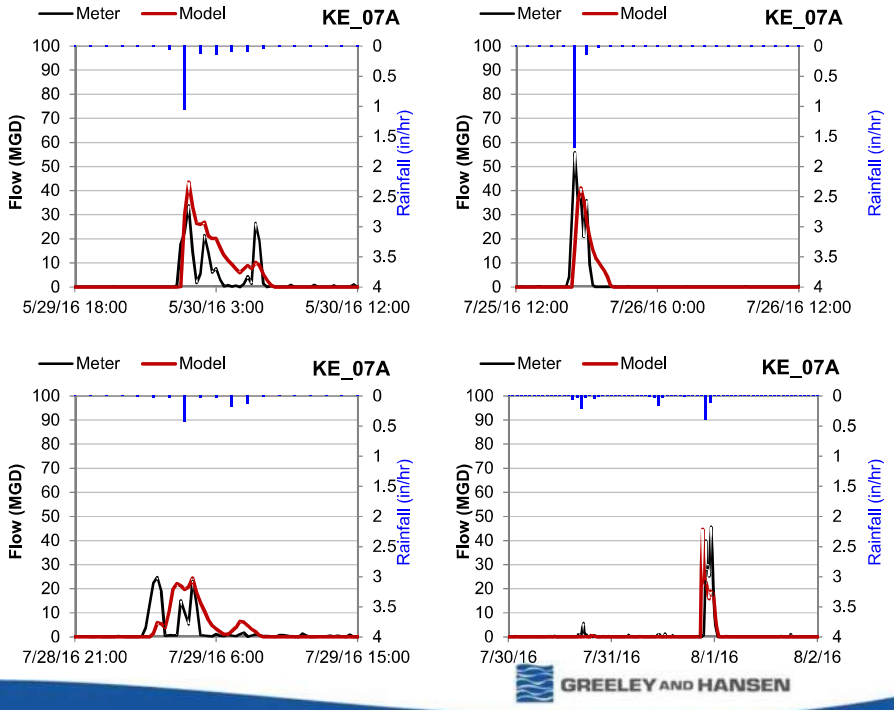


GREELEY AND HANSEN

Calibration Results – CSO Overflow

KE_07A

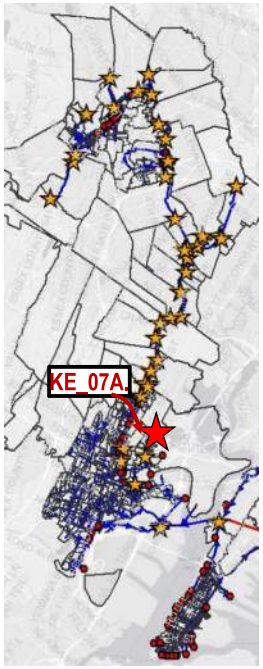


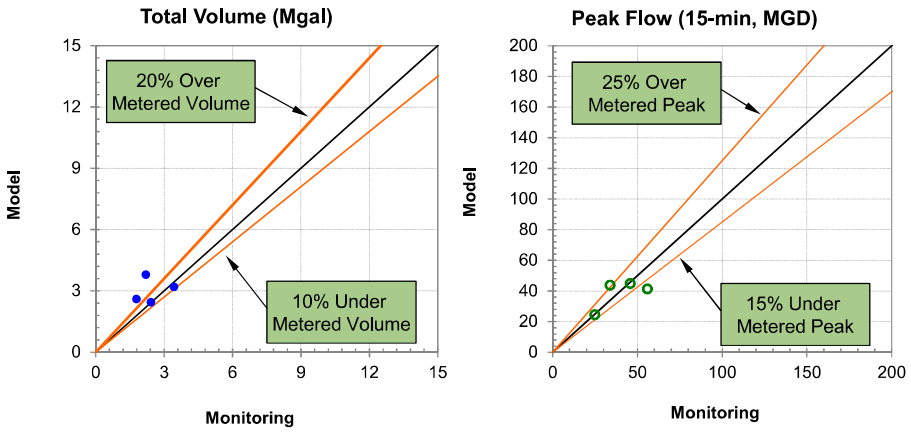


GREELEY AND HANSEN

Calibration Results – CSO Overflow

KE_07A

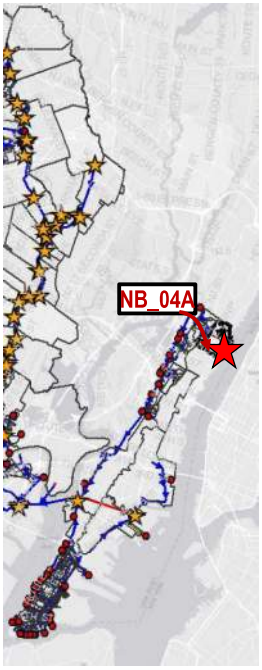


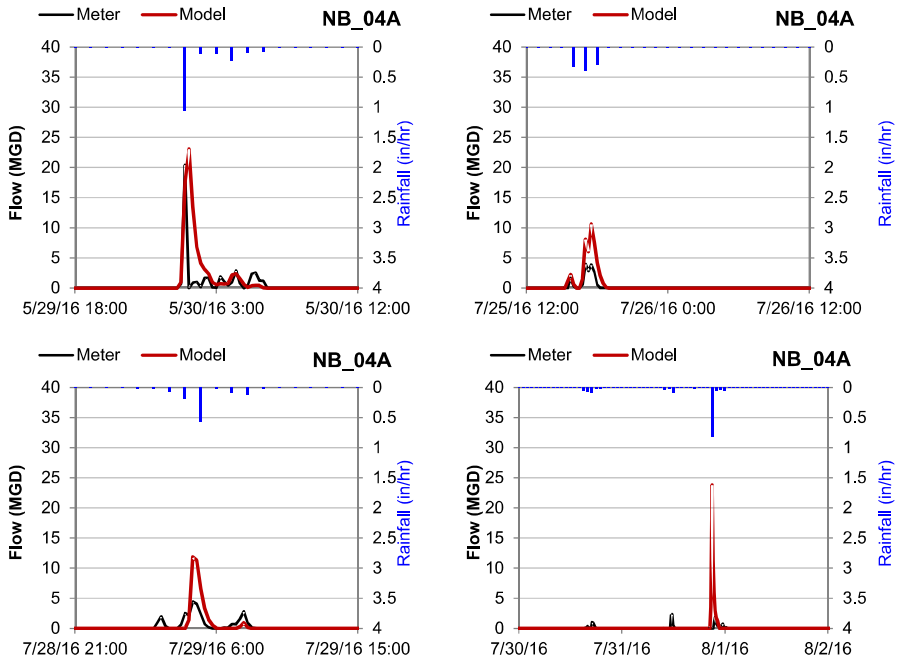


GREELEY AND HANSEN

Calibration Results – CSO Overflow

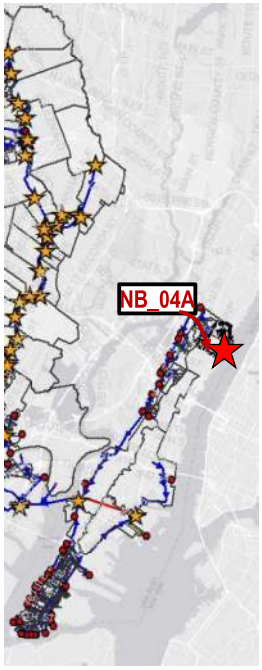
NB_04A

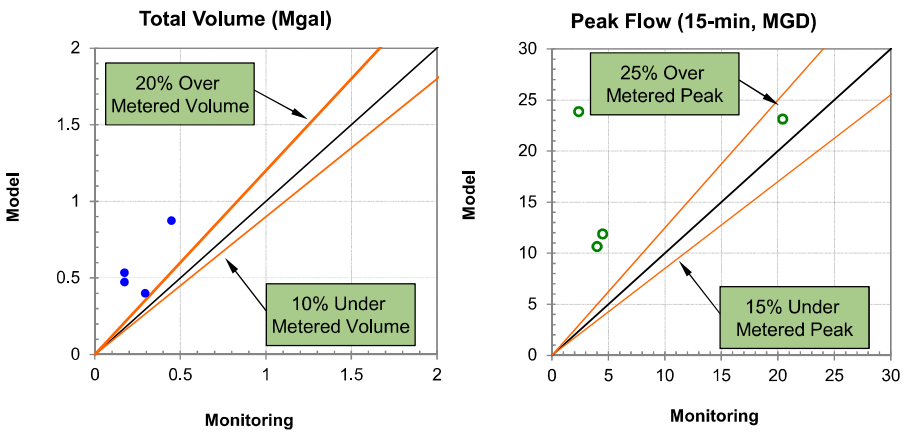




Calibration Results – CSO Overflow

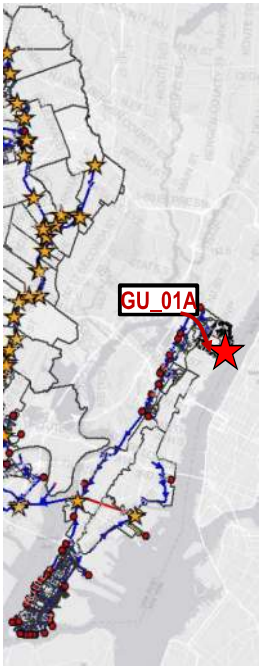
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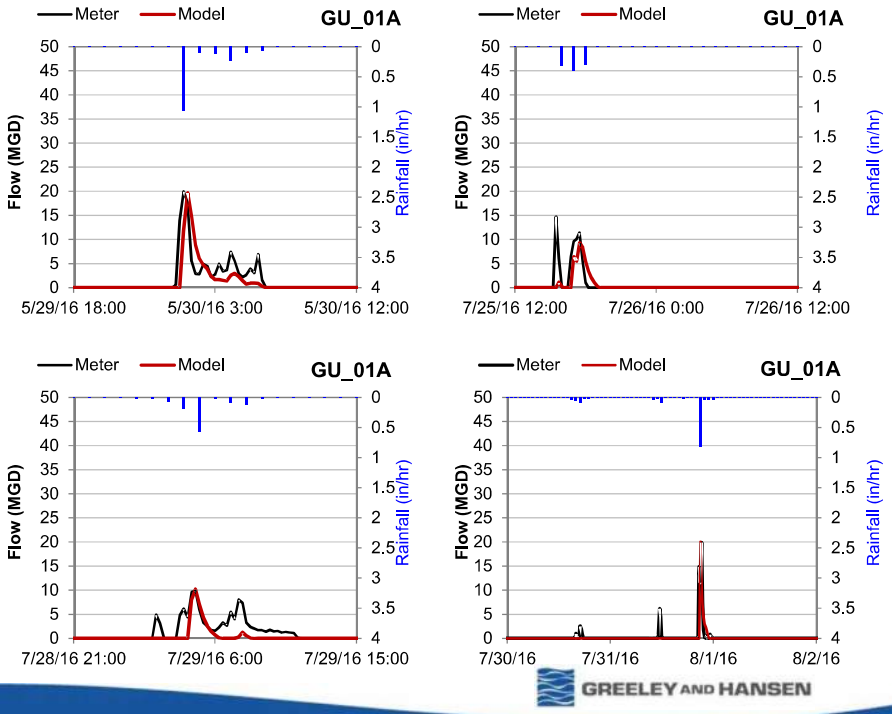




Calibration Results – CSO Overflow

GU_01A

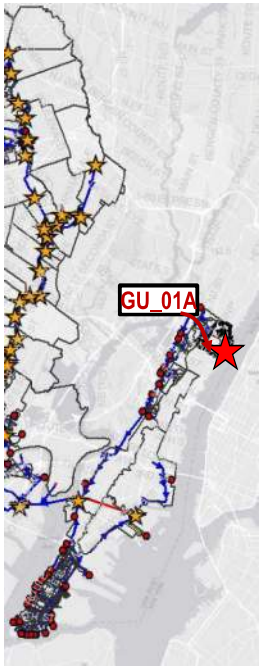


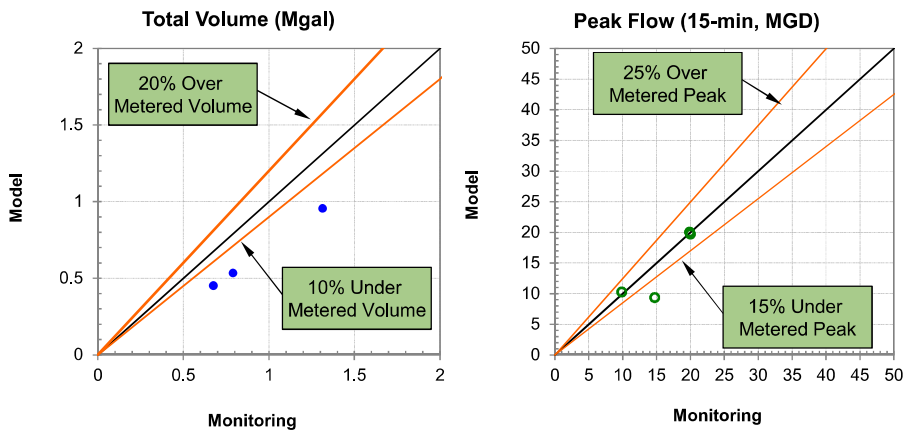


GREELEY AND HANSEN

Calibration Results – CSO Overflow

GU_01A

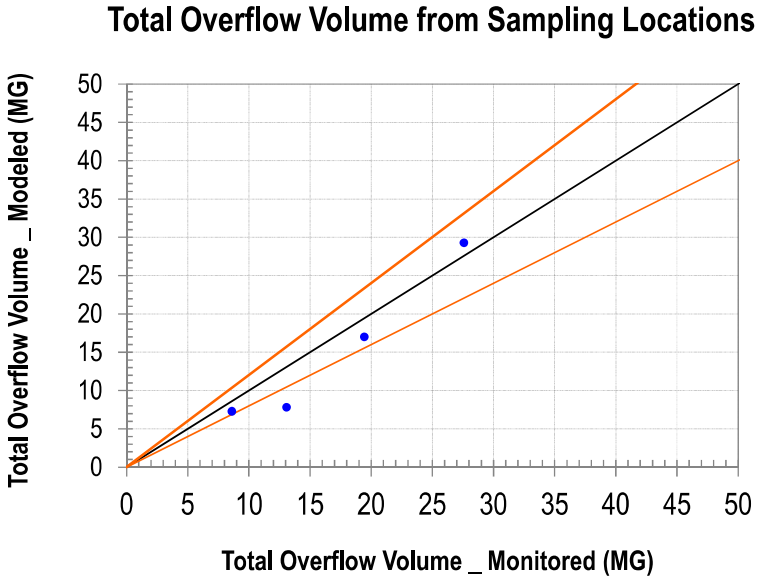




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Total Overflow Volume

NE_04&05, NE_09&10, NE_14A , NE_15A , KE_07A , BA_08A , BA_10A ,NB_11A , NB_07A, NB_04A, NB_04B, GU_01A



Summary

- The updated PVSC H&H model includes
  - 48 municipalities served by the PVSC WPCF
  - 2 municipalities served by the NBMUA Woodcliff WWTP
  - Dry weather flow based on 2016 flow monitoring data
  - Wet weather flow simulated as runoff from the combined areas and RDII from the separated areas
  - Current PVSC WPCF wet weather operating rules
- The model is calibrated and validated to 2016 flow monitoring data

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PVSC H&H Model Application

PVSC H&H Model Application

- Typical Year Simulation
- CSO Control Alternative Simulation
- Generate CSO flows for WQ model

CSO ID	Overflow		
	Volume (MG)	# per Year	Duration (Hour)
PT001	24.9	38	162
PT003	1.8	20	27
PT005	6.5	27	77
PT006	76.6	38	161
PT007	42.8	37	155
PT010	9.7	26	68
PT013	11.4	29	71
PT014	0.1	5	3
PT015	0.5	18	11
PT016	12.3	30	55
PT017	8.7	33	106
PT021	5.0	30	112
PT022	17.4	33	141
PT023	3.0	17	25
PT024	8.3	31	52
PT025	87.9	56	120
PT026	0.5	15	7
PT027	41.0	46	83
PT028	10.0	28	48
PT029	92.4	48	178
PT030	4.5	4	3
PT031	9.5	27	39
PT032	30.2	32	122

CSO ID	Overflow		
	Volume (MG)	# per Year	Duration (Hour)
EN001	16.6	37	97
HR001	1.3	30	36
HR002	2.8	34	50
HR003	13.6	33	60
HR005	18.8	36	133
HR006	6.7	30	48
HR007	13.3	49	133
KE001	3.9	33	54
KE004	12.3	58	177
KE006	118.8	63	246
KE007	86.0	36	165
KE010	26.0	54	144
NE002	91.5	46	268
NE003	0.0	0	0
NE004	1.4	23	29
NE005	21.2	43	249
NE008	93.3	52	327
NE009	163.7	42	210
NE010	163.7	42	210
NE014	180.1	52	387
NE015	74.7	43	248
NE016	54.3	49	252
NE017	107.4	51	281
NE018	75.5	53	326
NE022	45.7	69	262
NE023	16.8	35	108
NE025	58.2	16	30
NE026	16.6	17	25
NE027	11.3	17	39
NE030	10.4	19	21

CSO ID	Overflow		
	Volume (MG)	# per Year	Duration (Hour)
NB003	171	51	286
NB005	30.1	55	255
NB006	0.0	0	0
NB007	6.6	32	98
NB008	15.1	30	82
NB009	25.6	45	175
NB010	1.2	25	41
NB011	5.1	37	121
NB014	0.5	7	6
BA001	373.3	71	533
BA002	8.7	9	14
BA003	11.2	34	108
BA004	0.0	3	1
BA006	16.0	37	138
BA007	72.1	37	125
BA008	10.0	34	88
BA009	4.2	33	58
BA010	17.3	52	178
BA011	5.9	34	71
BA012	14.0	57	142
BA013	0.8	33	35
BA014	12.7	43	127
BA015	46.6	54	231
BA016	6.5	48	130
BA017	54.2	62	350
BA018	14.6	58	232
BA019	38.8	35	112
BA020	10.1	33	65
BA021	62.9	54	212
BA022	0.0	0	0
BA024	0.1	3	2
BA026	1.3	9	4
BA028	0.0	0	0
BA029	6.8	24	41
BA030	1.5	16	10
BA034	0.1	7	4
BA037	0.9	8	8

PVSC H&H Model Typical Year CSO Overflow Volume, Frequency, & Duration

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The End

Hydrodynamic Modeling

Northern NJ CSO Long-Term Control Plan

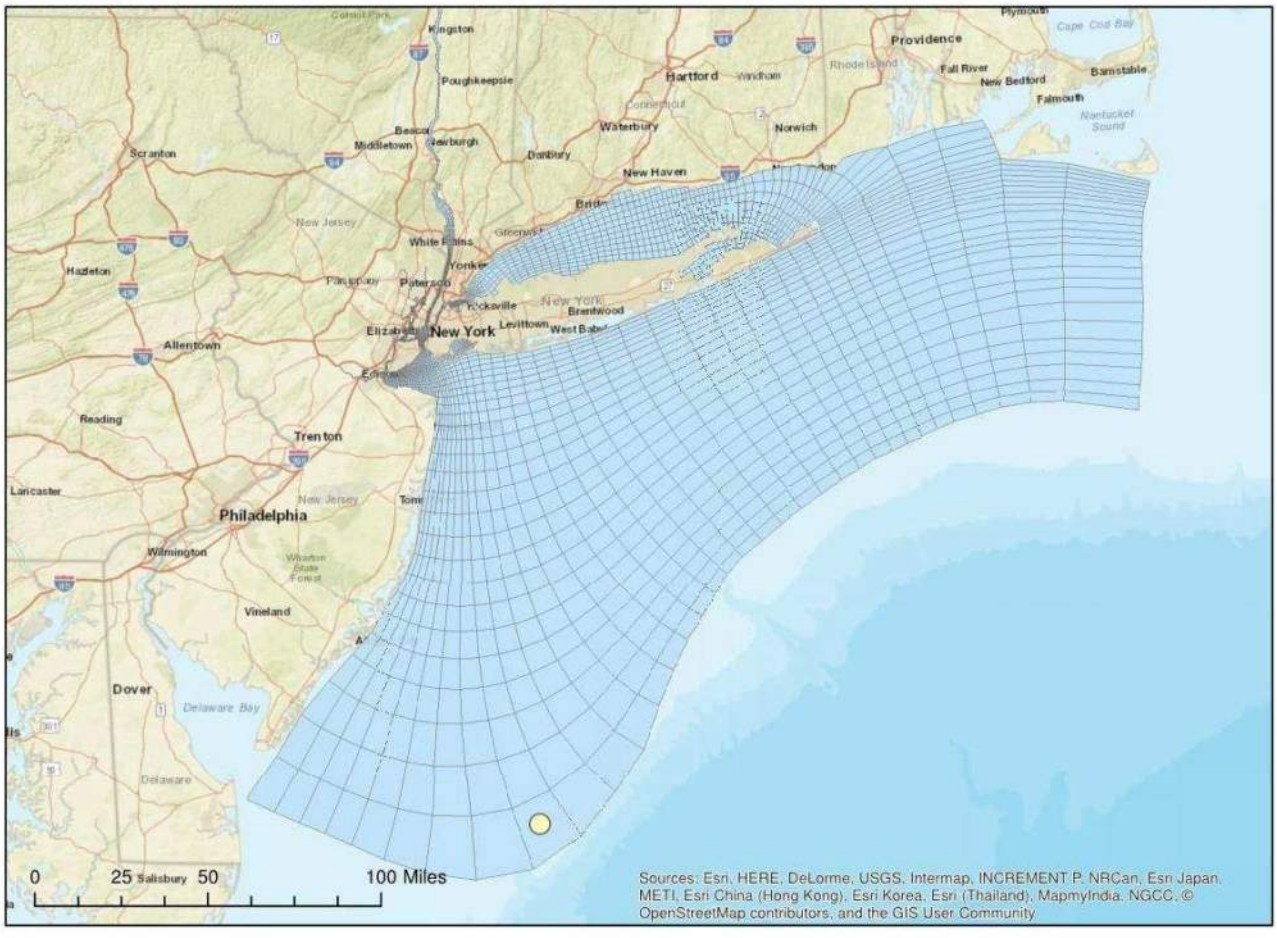
December 5, 2018
Nicholas Kim, HDR

Agenda

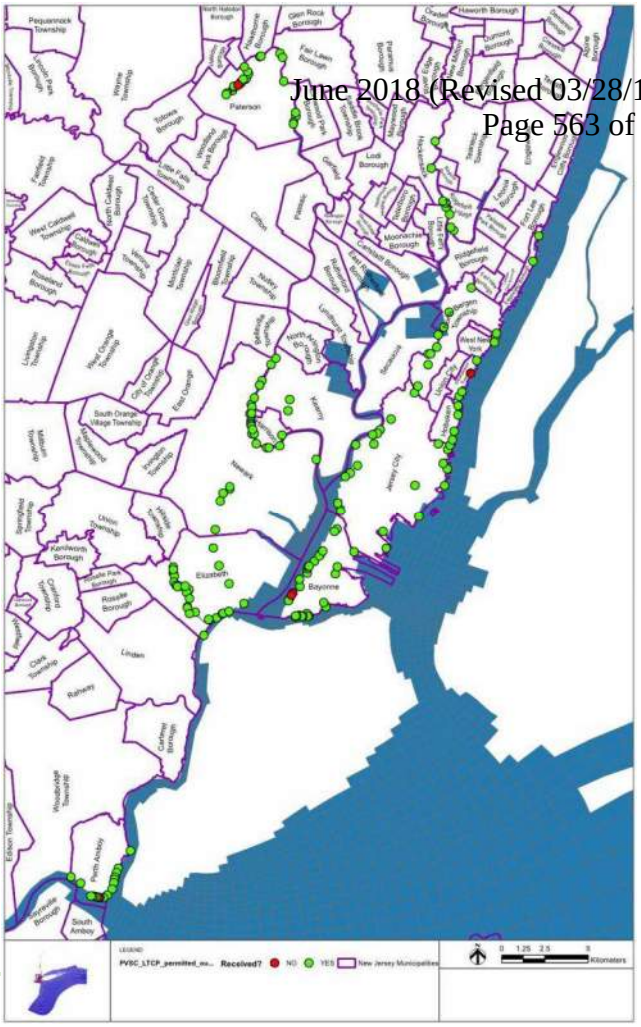
- Calibration Period: 2016 – 2017
- Model Calibration
  - Temperature
  - Salinity
  - Note: Tidal elevation and current calibration results were presented in March 2017 MEG

Model Input

- Tidal Forcing:
  - Mid-Atlantic Bight: Global Tidal Prediction Program and observed low frequency variation
- Freshwater Sources:
  - Rivers: USGS gages (28)
  - CSOs: NJ and NYC
  - Stormwater : CDM Smith landside model
  - STP
- Meteorological Forcing: North America Regional Reanalyses (NARR) Model: 30km resolution; 3-hourly
  - Winds
  - Air temperature
  - Barometric pressure
  - Relative humidity
  - Shortwave solar radiation



- Landside Input
  - Stormwater
  - CSO
  - STP



Available Calibration Data

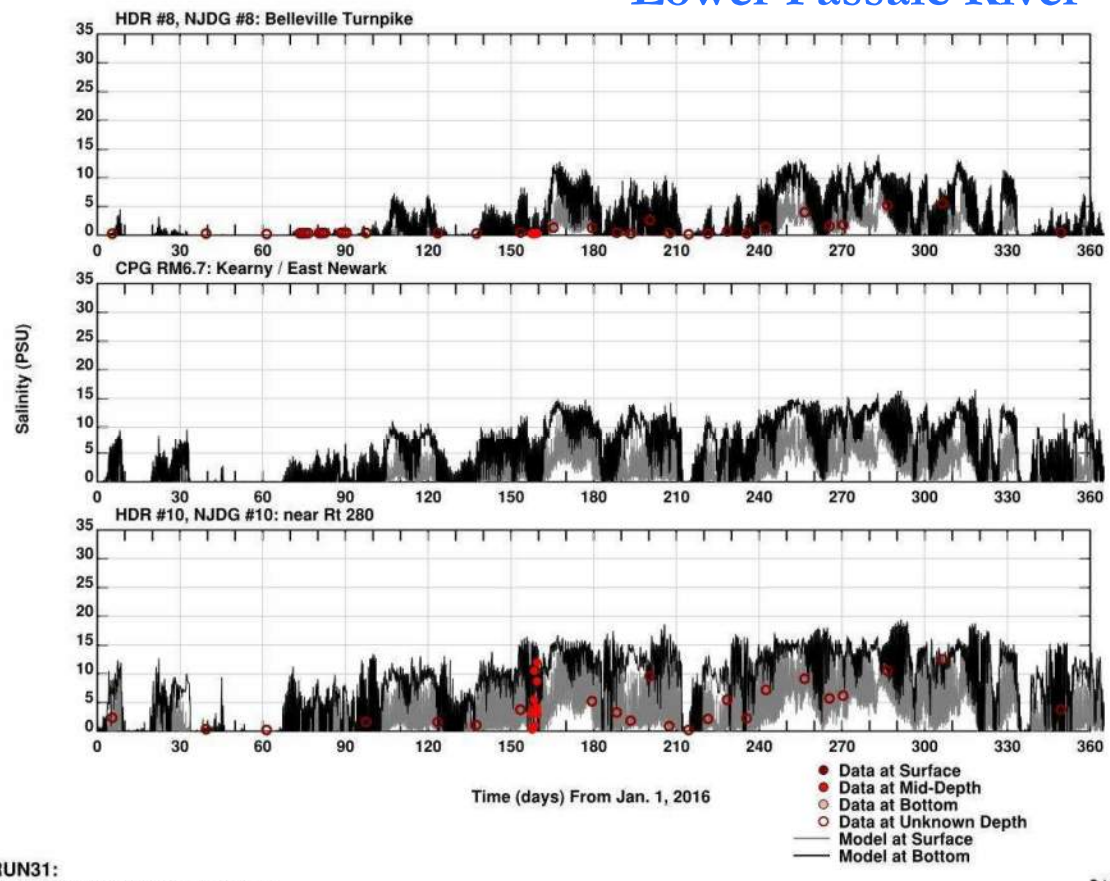
- NJ Harbor Dischargers Group: 2003-2017 (T/S)*
- NJ LTCP WQ Sampling Program: 2016 - 2017 (T/S)
- NYC DEP Harbor Survey Program: 1980's – 2017 (T/S)
- HRECOS *in-situ* monitoring data: T/S
- Meadowlands Environmental Research Institute (MERI): T/S (grab and moored): 2008 - present

* At times, the quality of NJ Harbor Discharge Group salinity data are questionable.

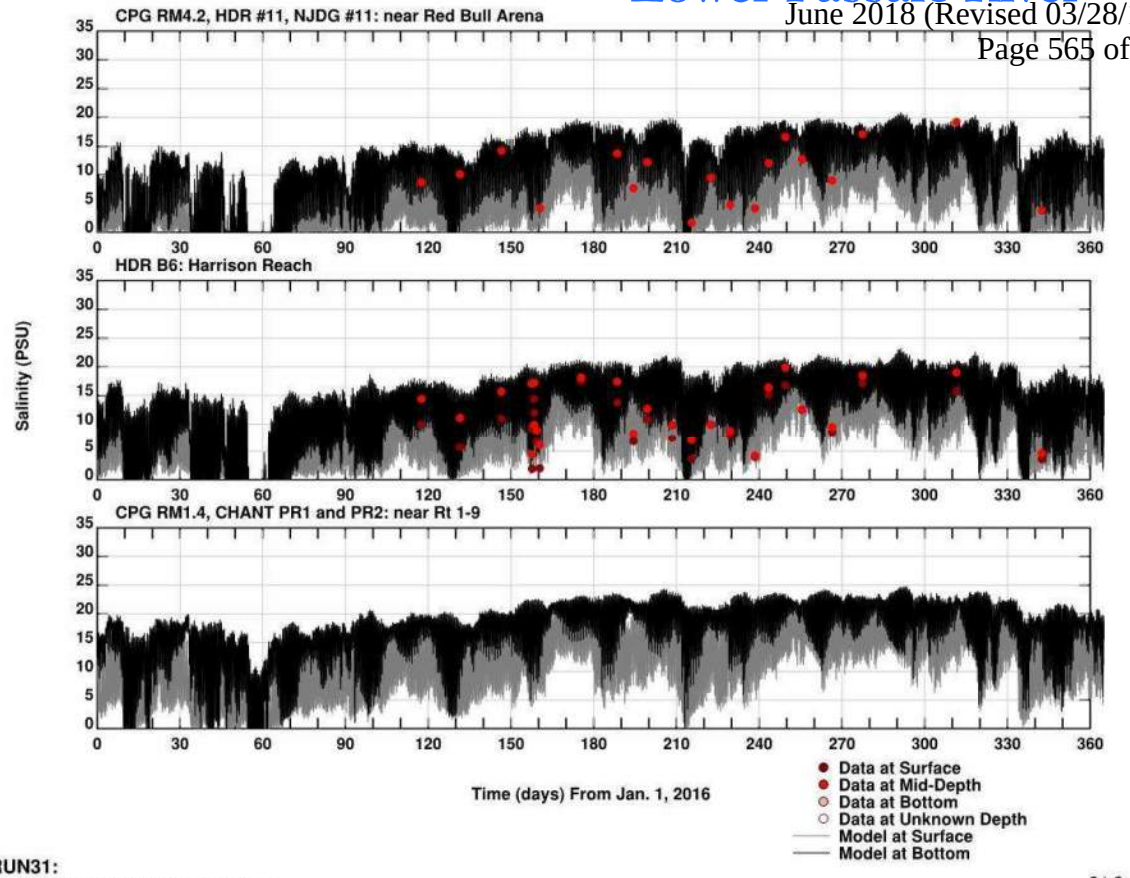
Salinity Results

- Lower Passaic River
- Hackensack River
- Newark Bay
- Kill van Kull
- Arthur Kill
- Raritan Bay
- Hudson River/Upper Bay

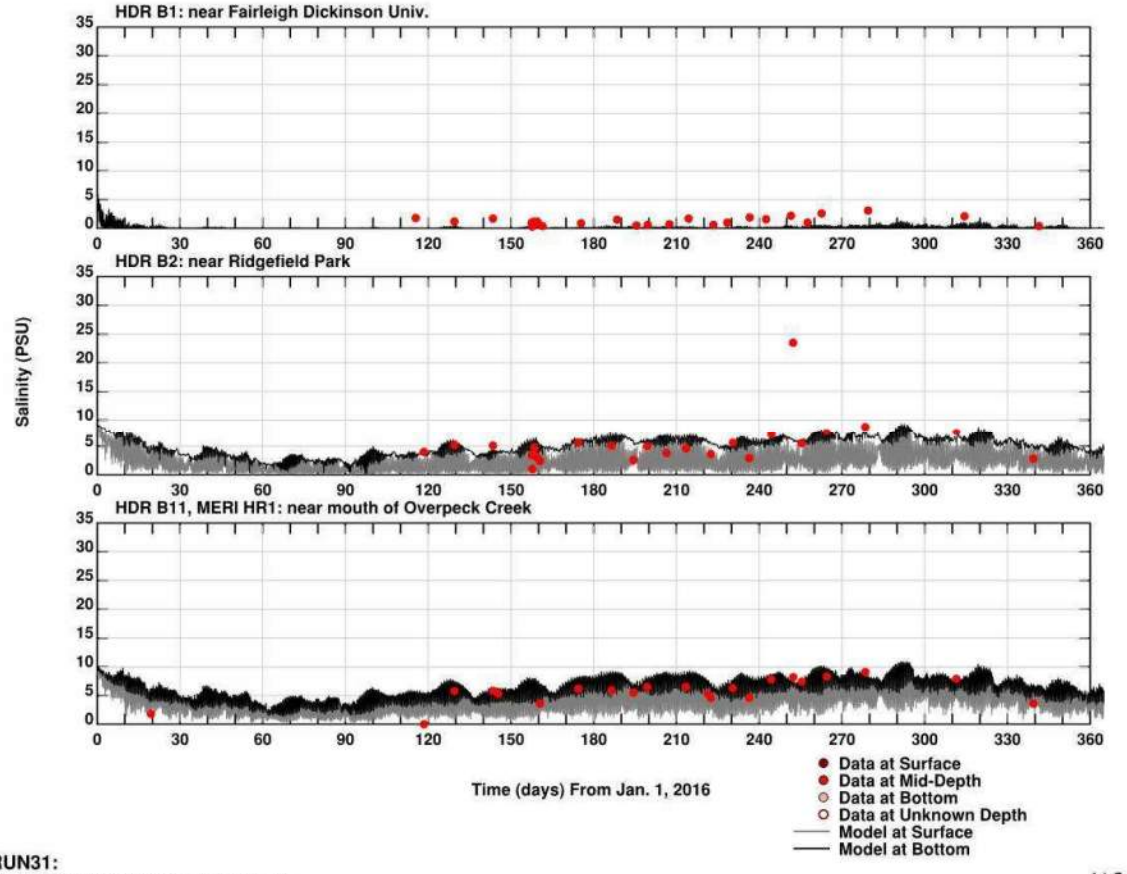
Lower Passaic River



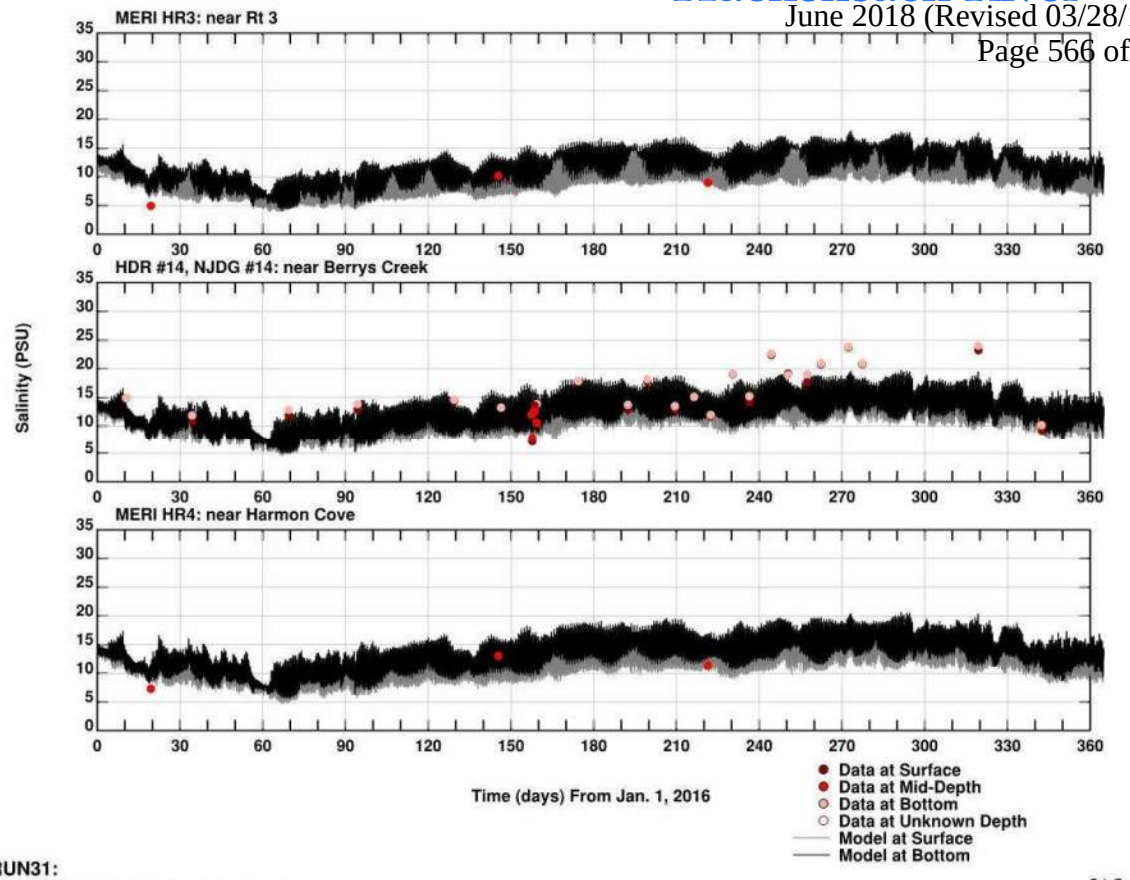
Lower Passaic River



Hackensack River



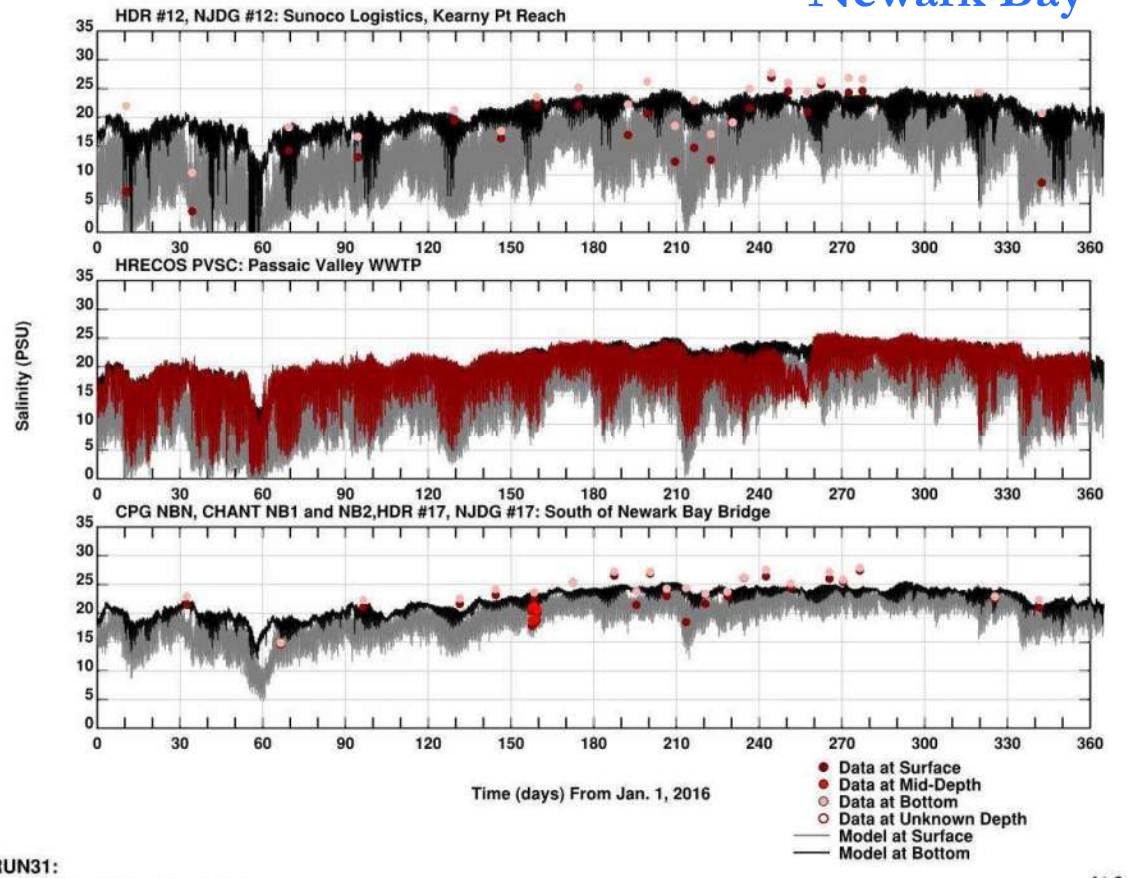
Hackensack River



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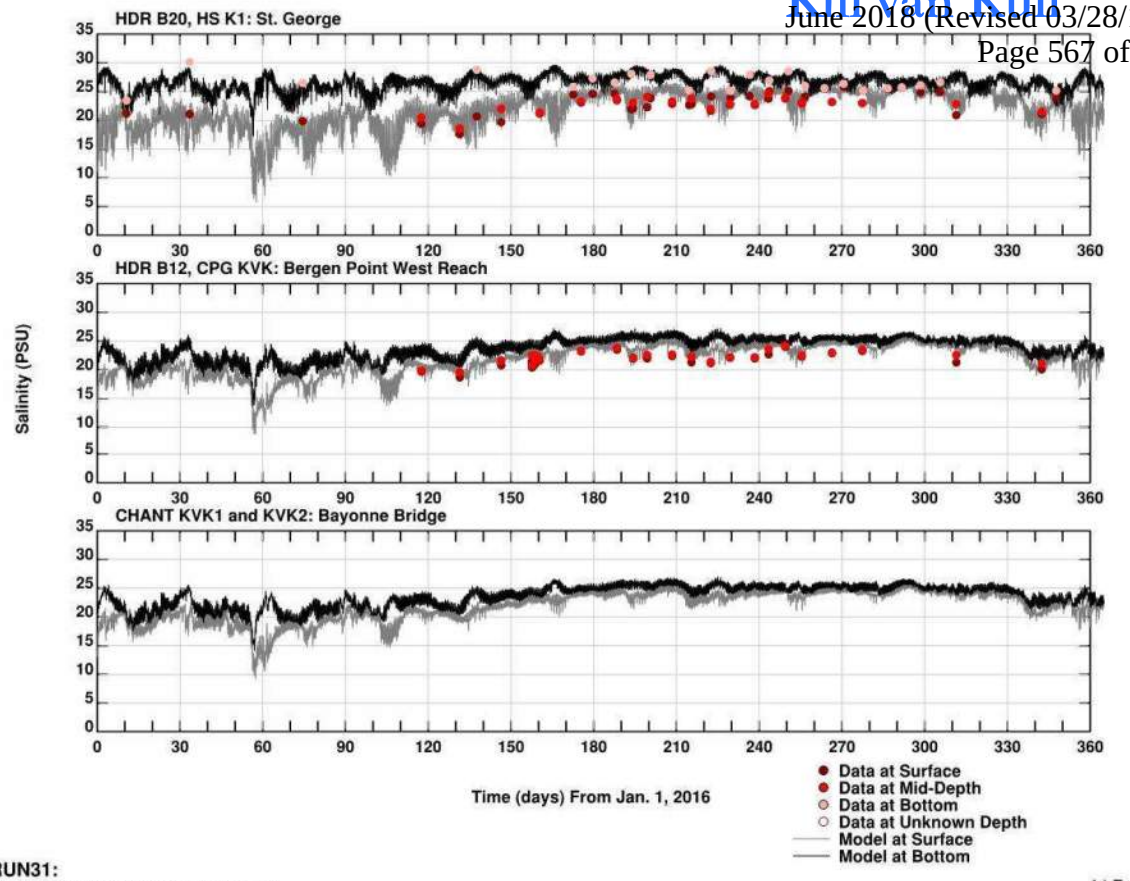
3 \ 5

Newark Bay

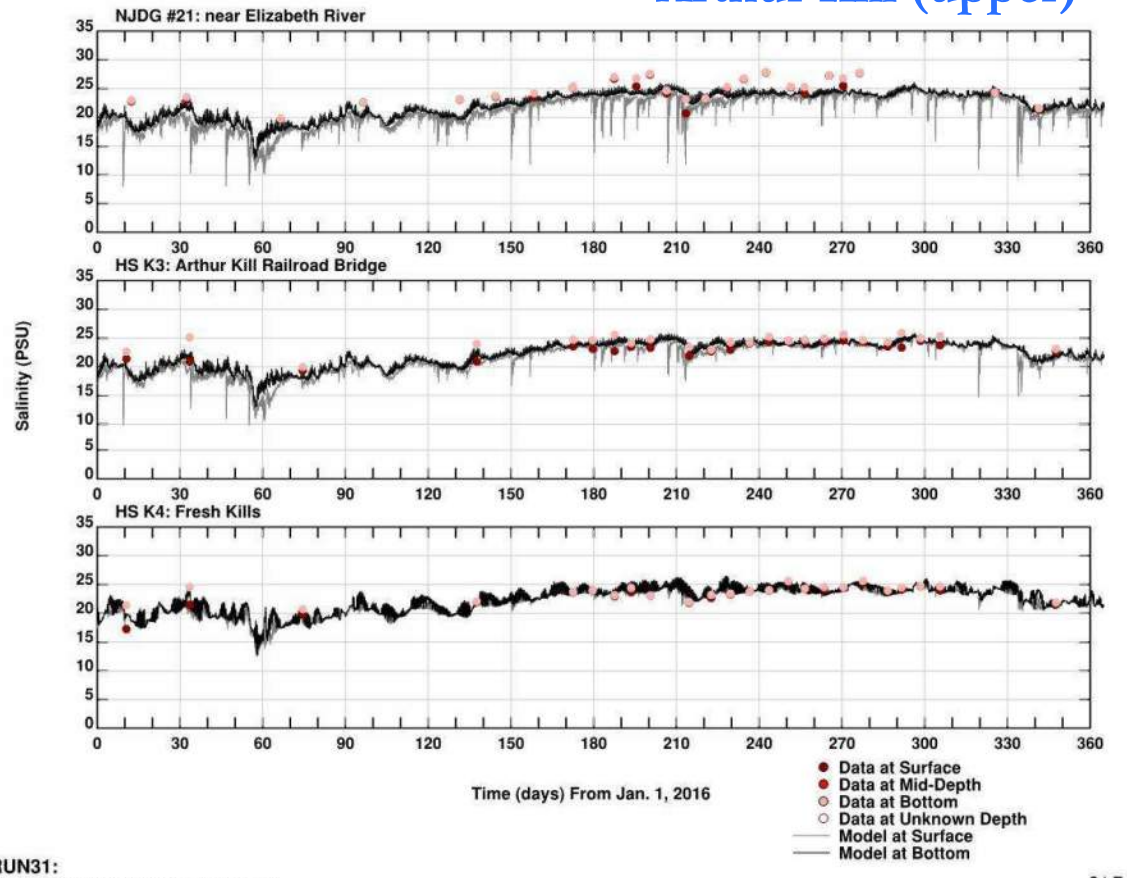


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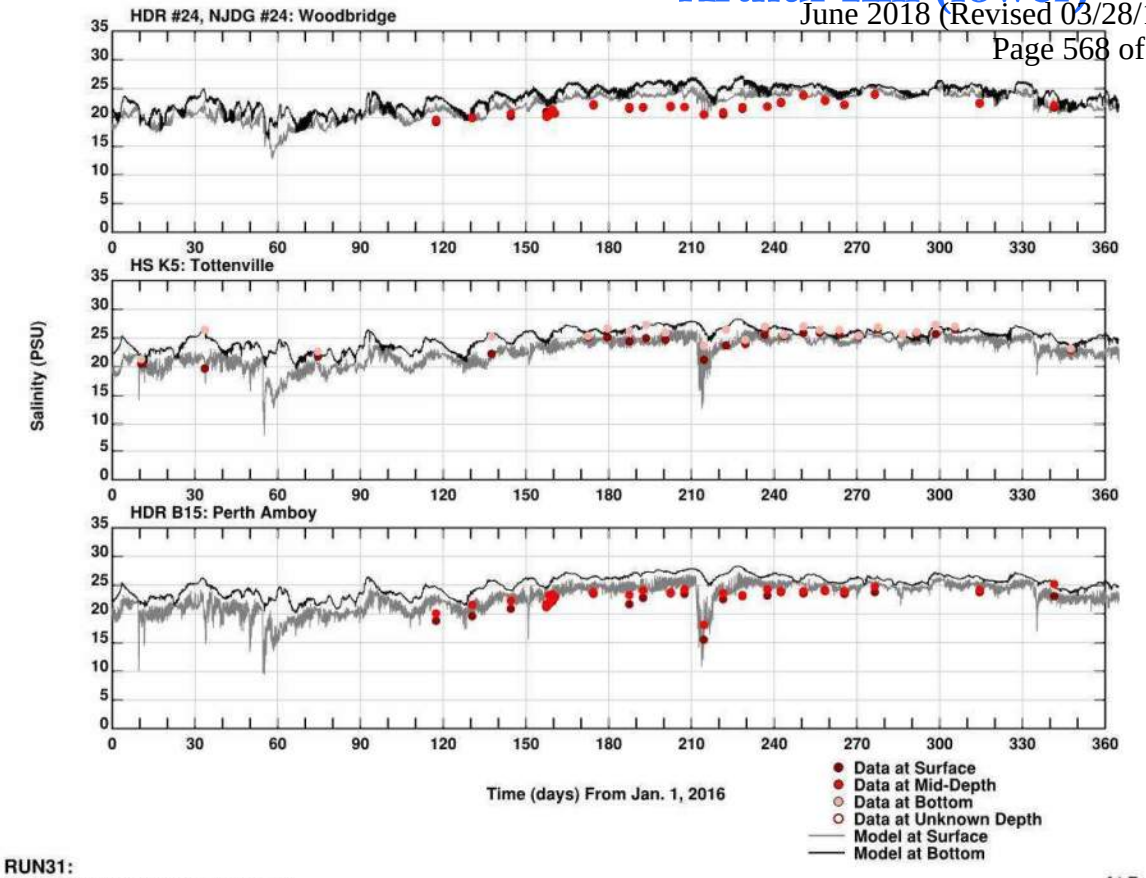
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Arthur Kill (upper)



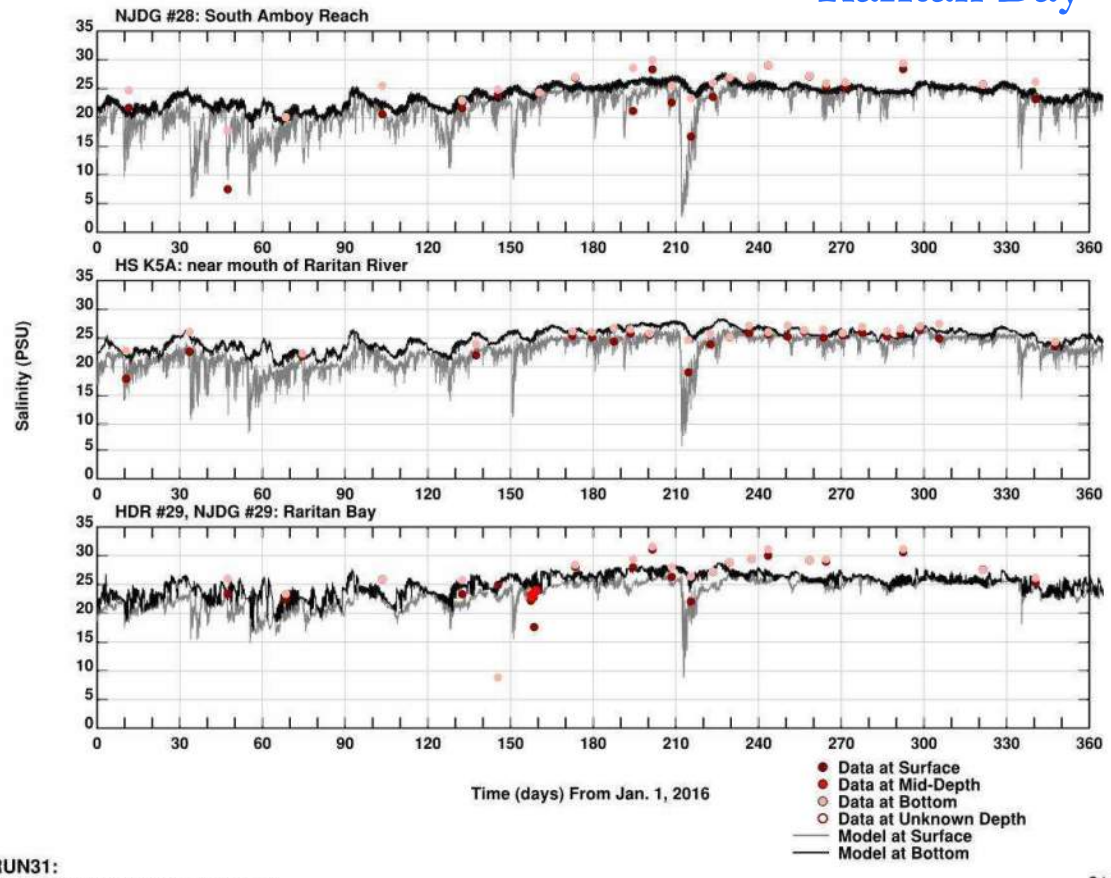
Arthur Kill (lower)



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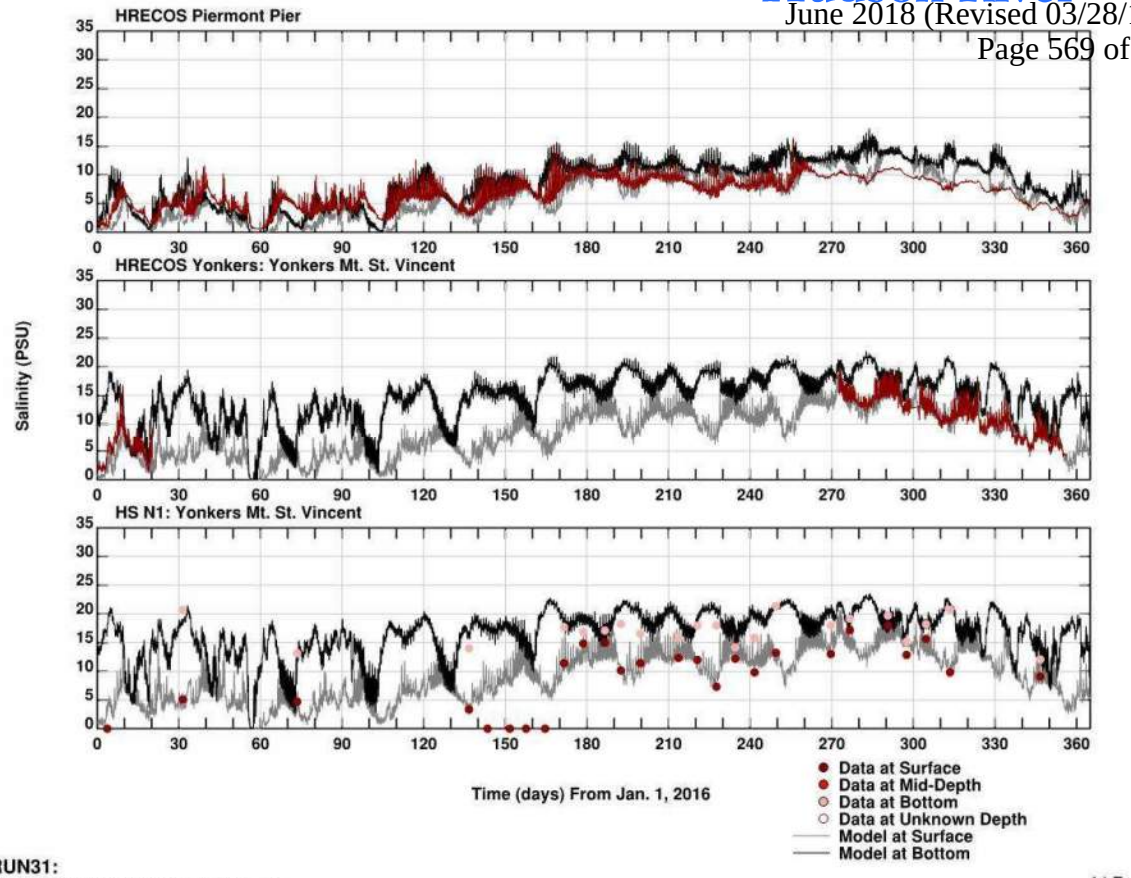
4 \ 7

Raritan Bay



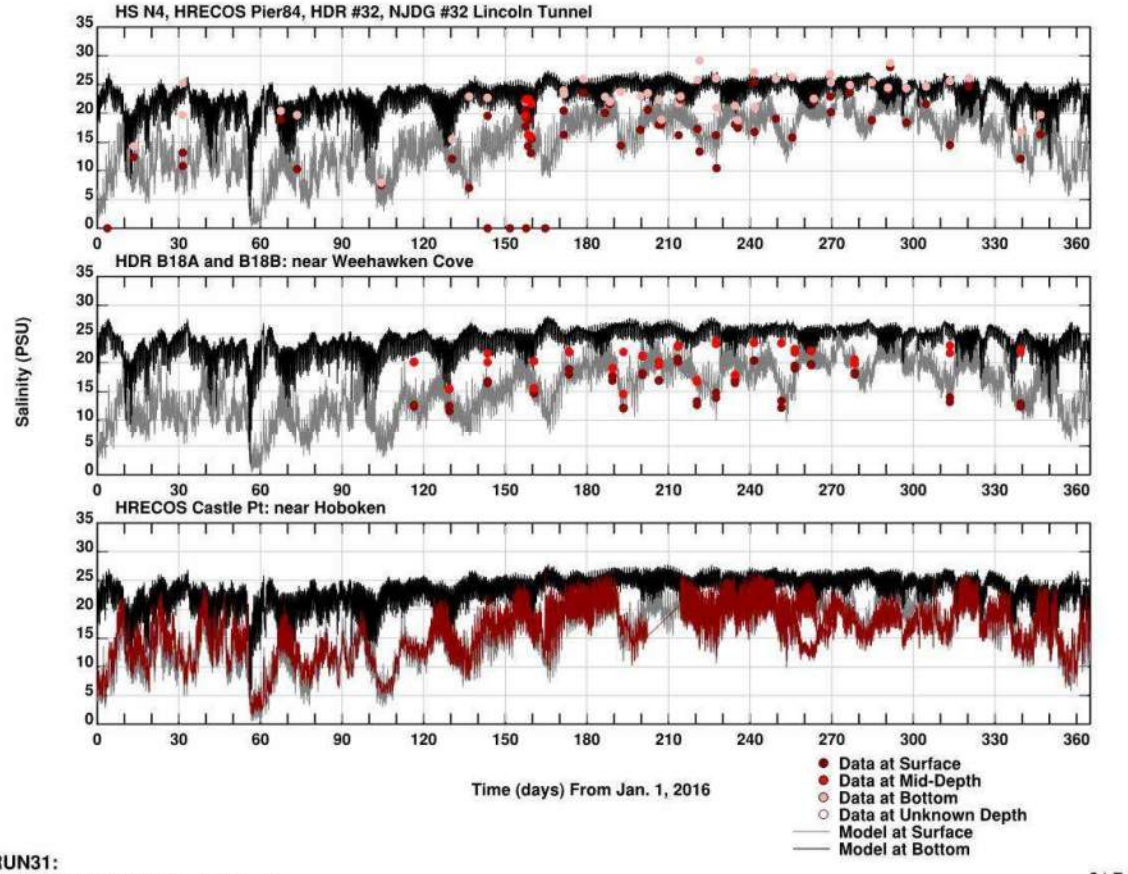
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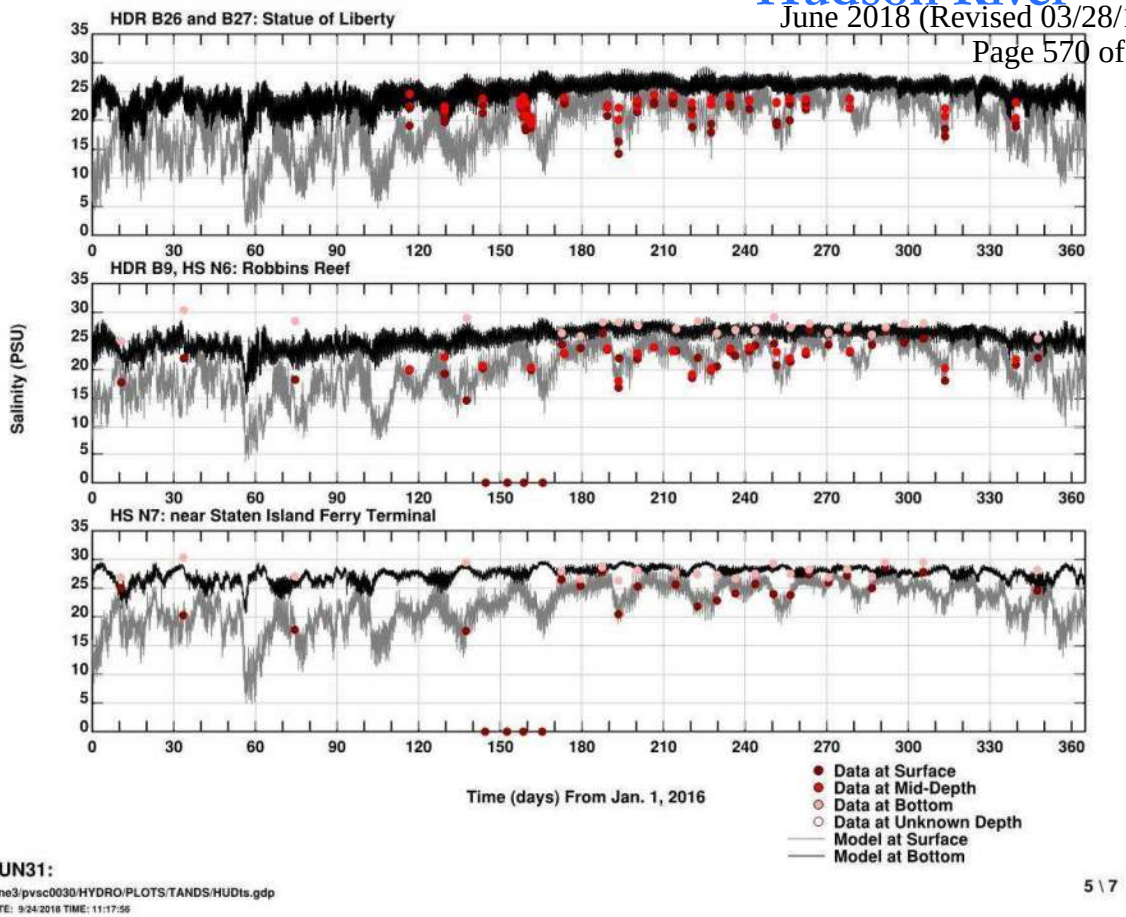


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Hudson River



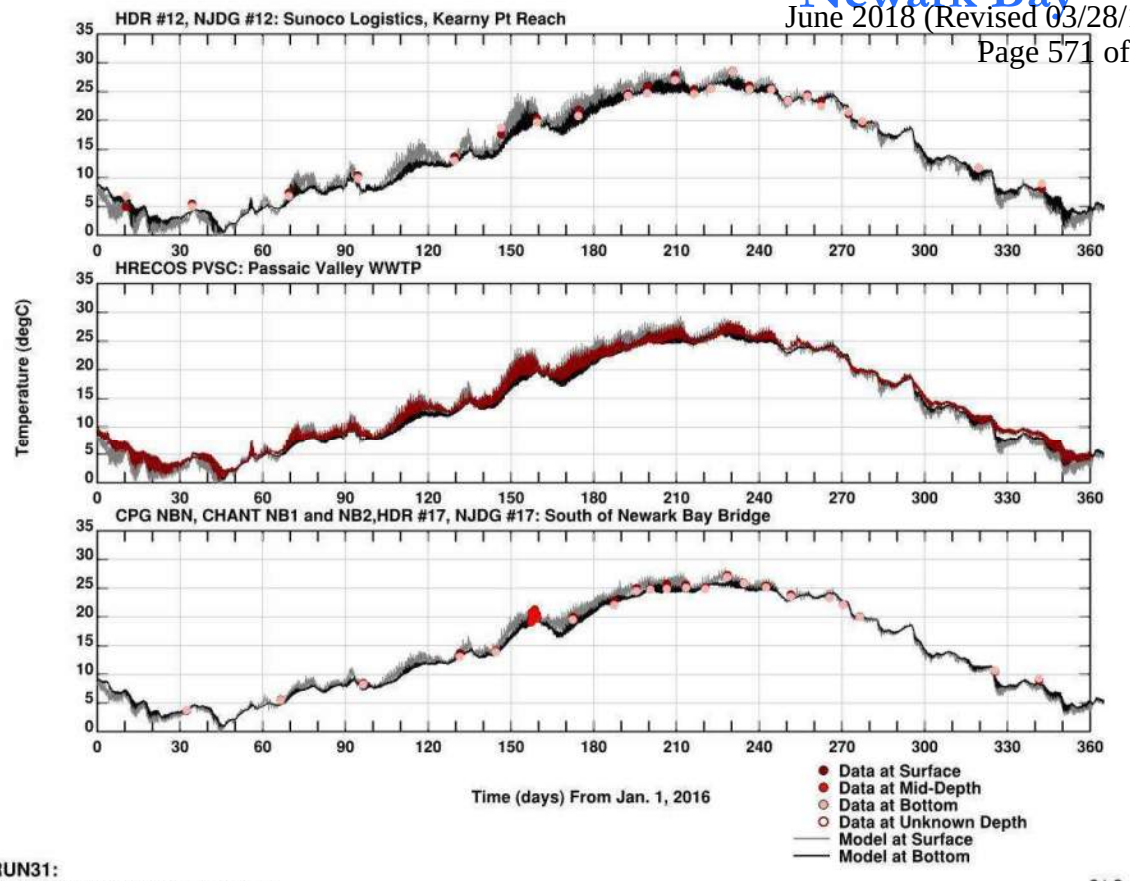
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Temperature Results

- Newark Bay
- Hudson River

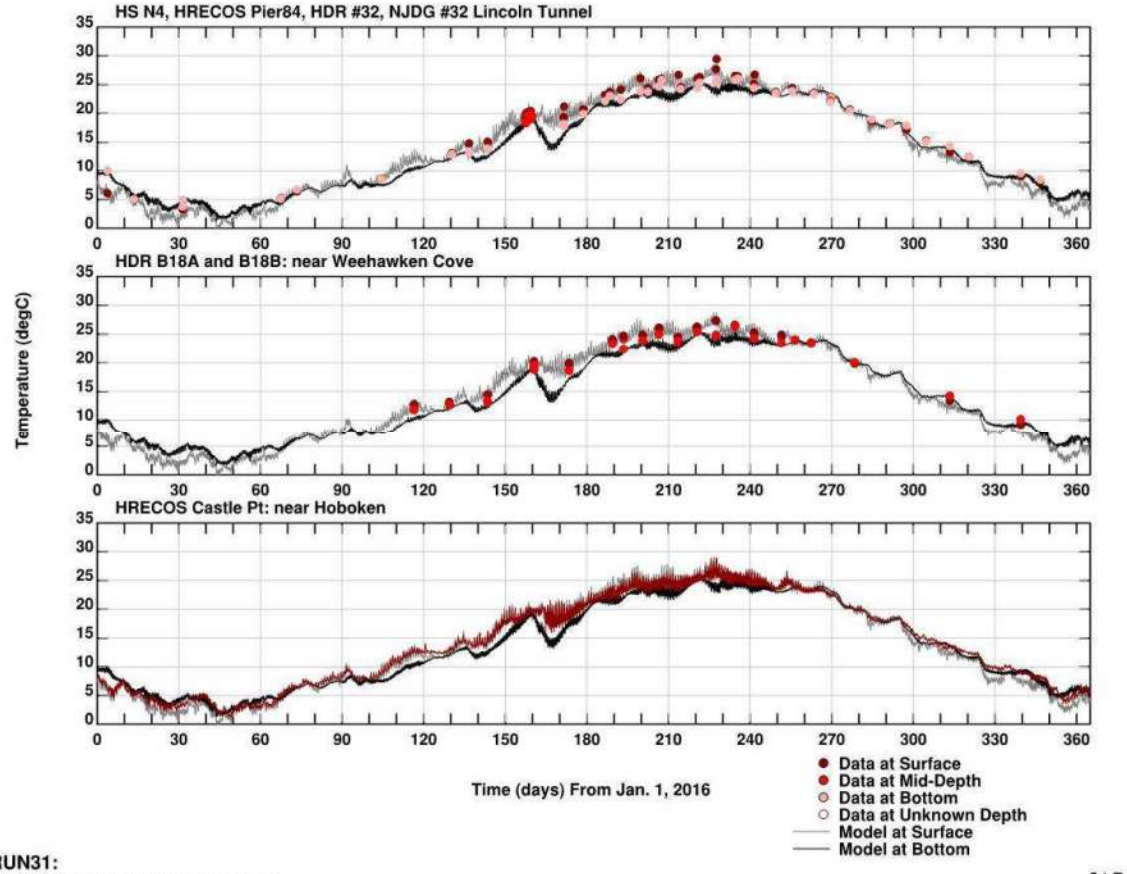
Newark Bay



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6 \ 8

Hudson River



RUN31:
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DATE: 9/24/2018 TIME: 11:19:18

3 \ 7

Summary of Hydrodynamic Model Calibration

- Model has been configured for 2016-2017 with comprehensive model input and compared with data from various sources
- Reasonable reproduction of hydrodynamics in the regions (i.e. water temperature, and salinity) during dry periods and wet events.
- Setup 2004 Projection Conditions

Water Quality Modeling Update

Model Evaluation Group – Session 4

Rich Isleib, HDR

December 5, 2018



PASSAIC VALLEY SEWERAGE COMMISSION

GREELEY AND HANSEN
CDM Smith
HDR

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NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Agenda

- Model Kinetics
- Model Inputs
  - Source Loading
    - Stormwater
    - CSO
    - Rivers
    - Other
    - Bacteria Ratios
  - Constants
- Model Calibration/Validation
  - Time Series
    - Annual
    - Events
  - Probability
- Baseline

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Pathogen Model Kinetics

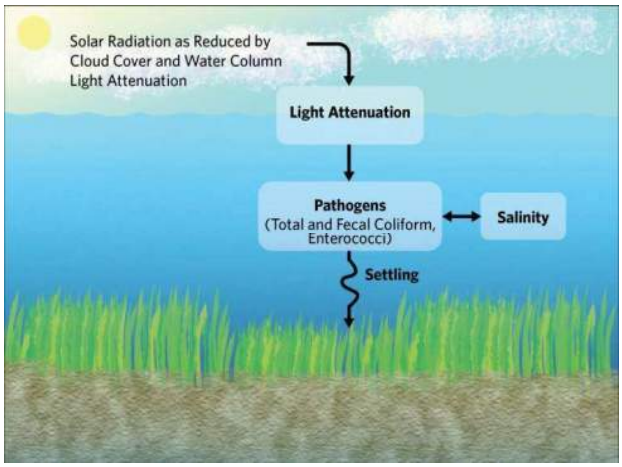
$$N = N_0 \exp(-KBt)$$

$K_B = [0.8 + 0.006(\%seawater)]1.07^{(T-20)}$

$+ \alpha I_0(t)/K_e H[1-\exp(-K_e H)]$

$+ V_s/H$ (Mancini, 1978)

N = Bacteria concentration
K_B = Bacteria loss rate
T = Temperature (°C)
α = proportionality constant
I_0 = Surface solar radiation
t = time
K_e = Extinction coefficient (/m)
H = Depth (m)
V_s = Net settling rate (m/d)

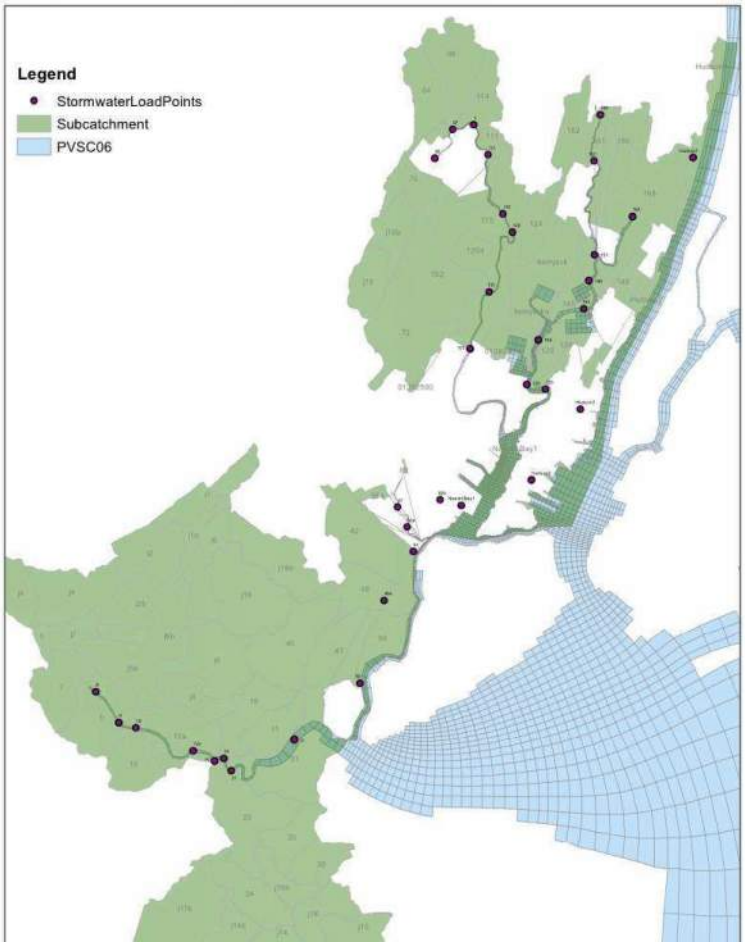


Pathogen Sources

- Source Loading
  - Stormwater
  - CSO
  - Rivers
  - Other
  - Bacteria Ratios

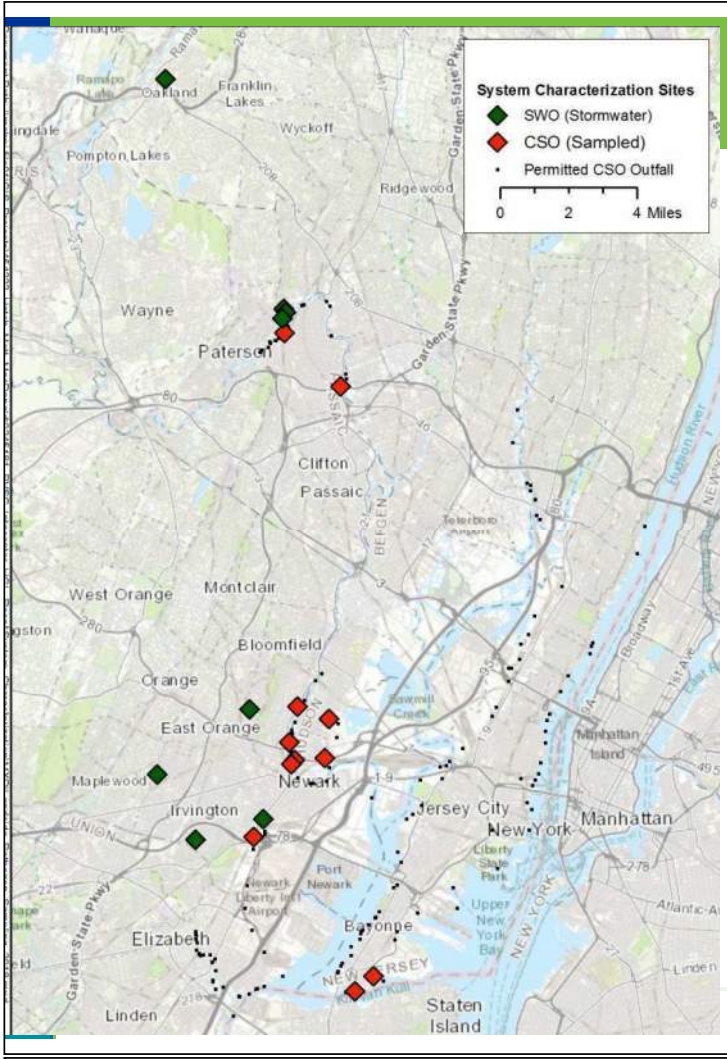
Stormwater Flows

- Flows derived from an InfoWorks model
- Loads were based on constant concentrations



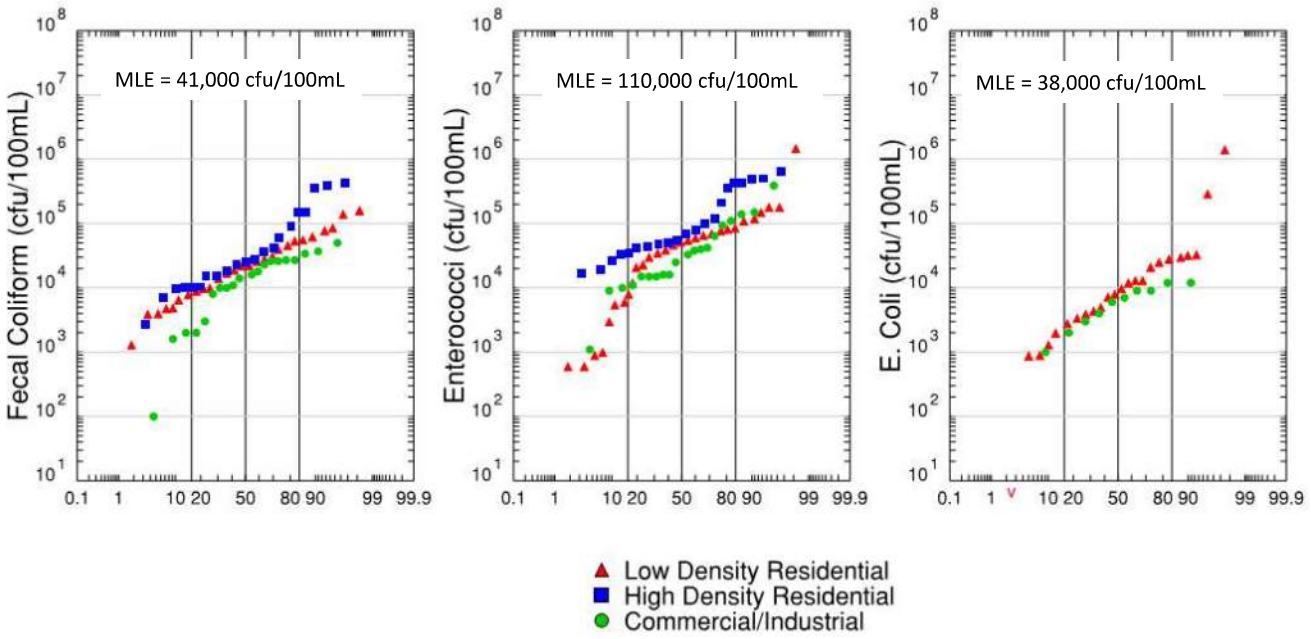
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Landside Pathogen Concentration Stations



- Stormwater – 8 locations
  - Low Density Residential (4)
  - High Density Residential (2)
  - Commercial / Industrial (2)
- CSO – 11 Locations/(18 Planned)
  - Paterson (2)
  - Newark (4)
  - Harrison (2)
  - Kearny (1)
  - Bayonne (2)

Stormwater Pathogen Concentrations



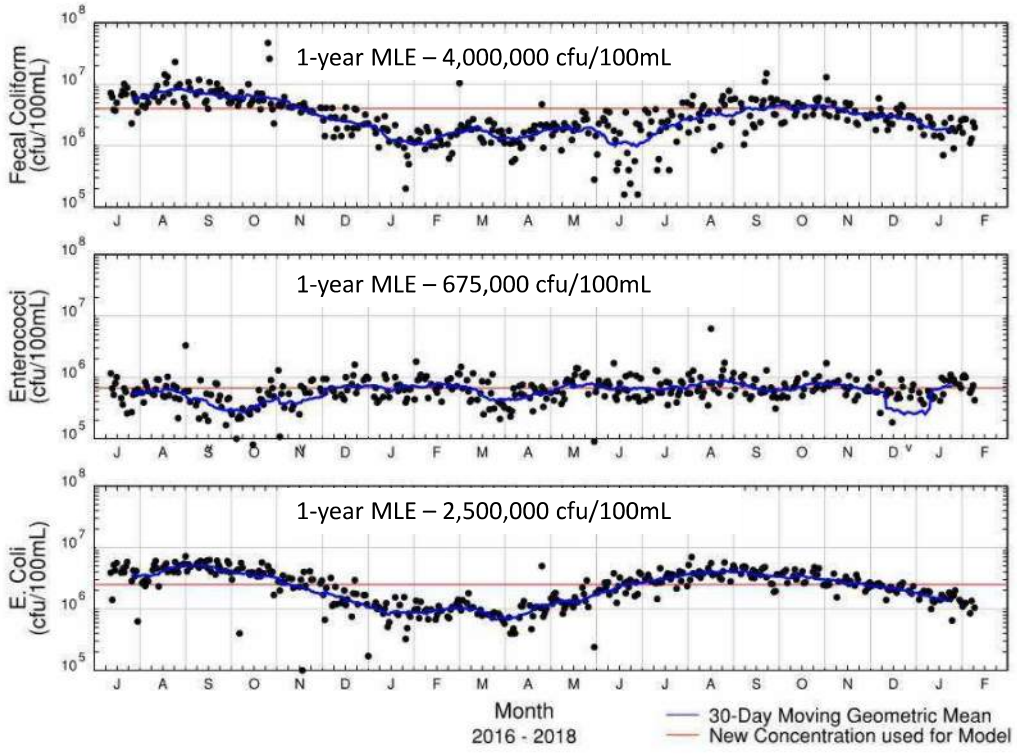
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CSO Loading Calculations

- The Mass Balance approach was used to assign loading to the CSOs
- The hydraulic models provided flow and the sanitary/stormwater flow fractions.
- CSO concentrations were calculated using sanitary and stormwater concentrations.
- Estimated CSO concentrations were compared to CSO concentration data.

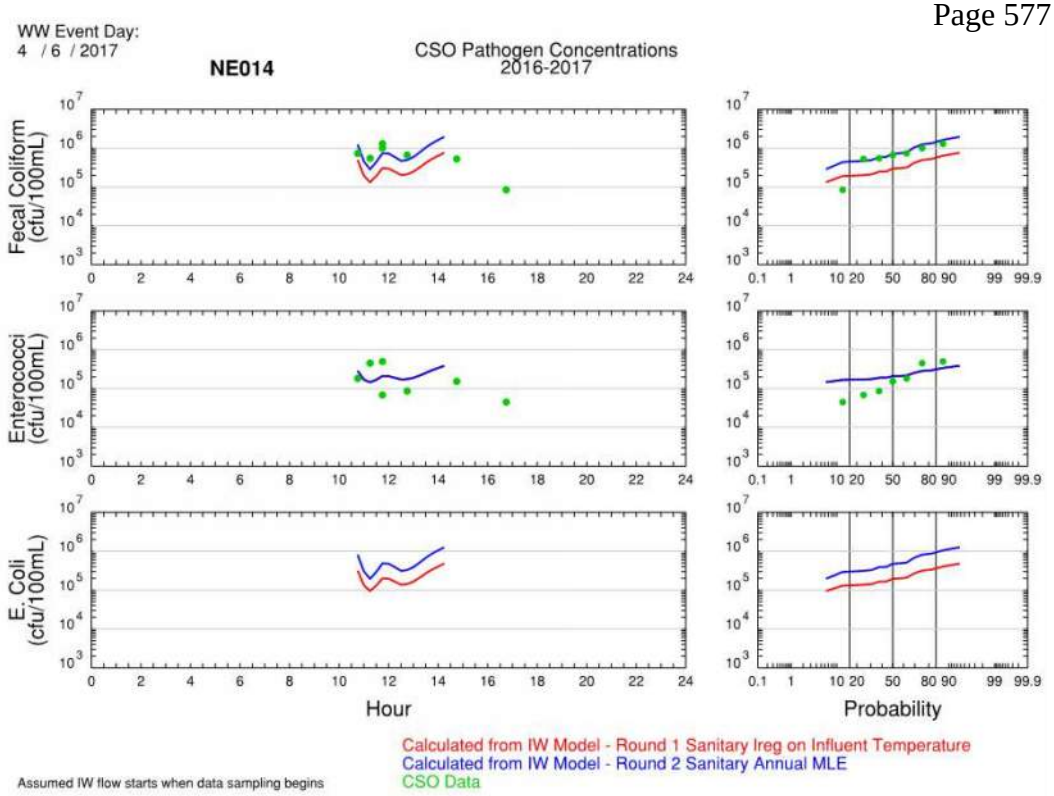
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PVSC WWTP Pathogen Influent Concentrations



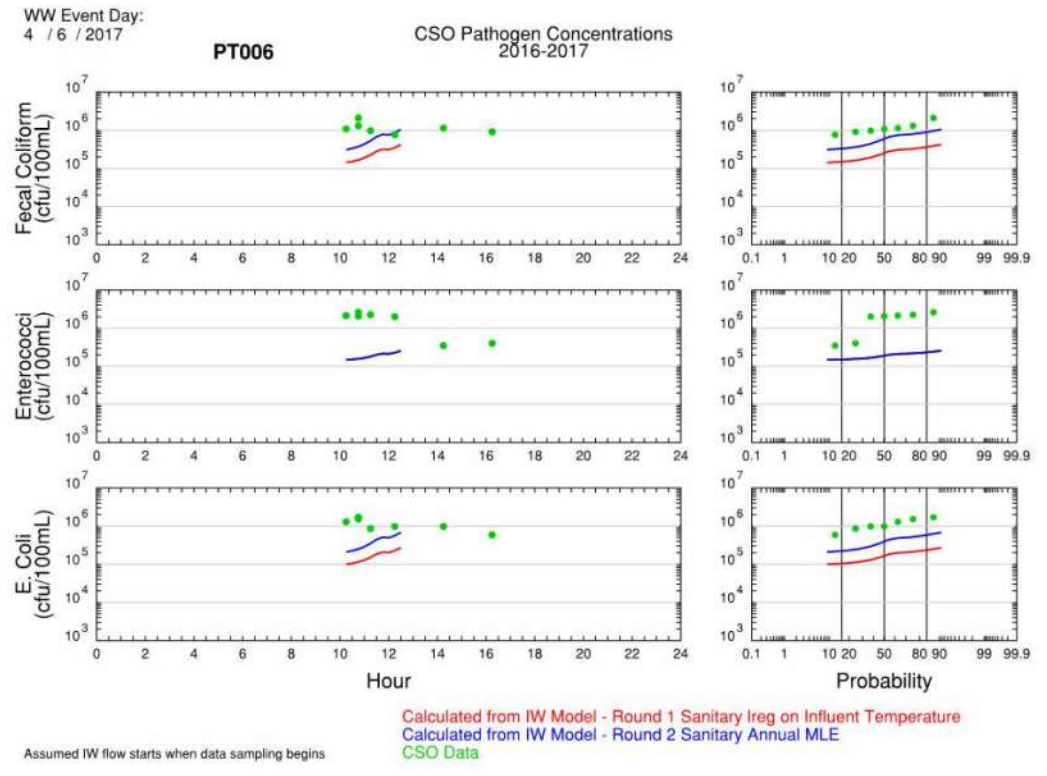
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CSO Mass Balance Check



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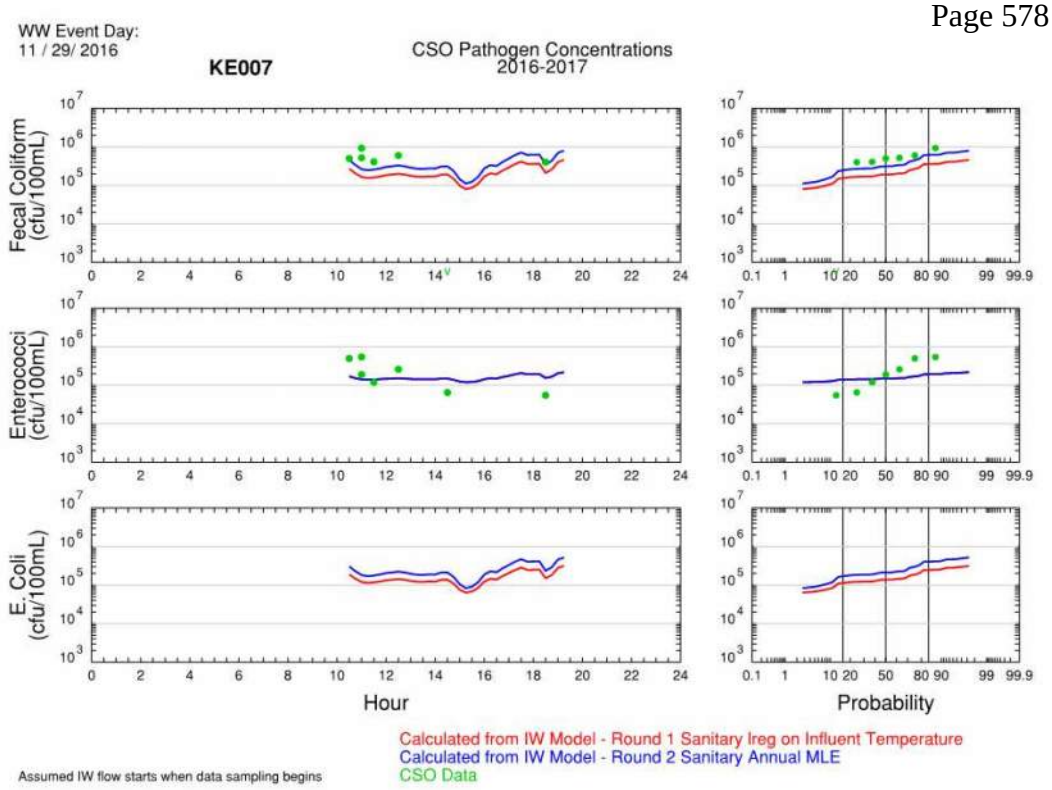
CSO Mass Balance Check



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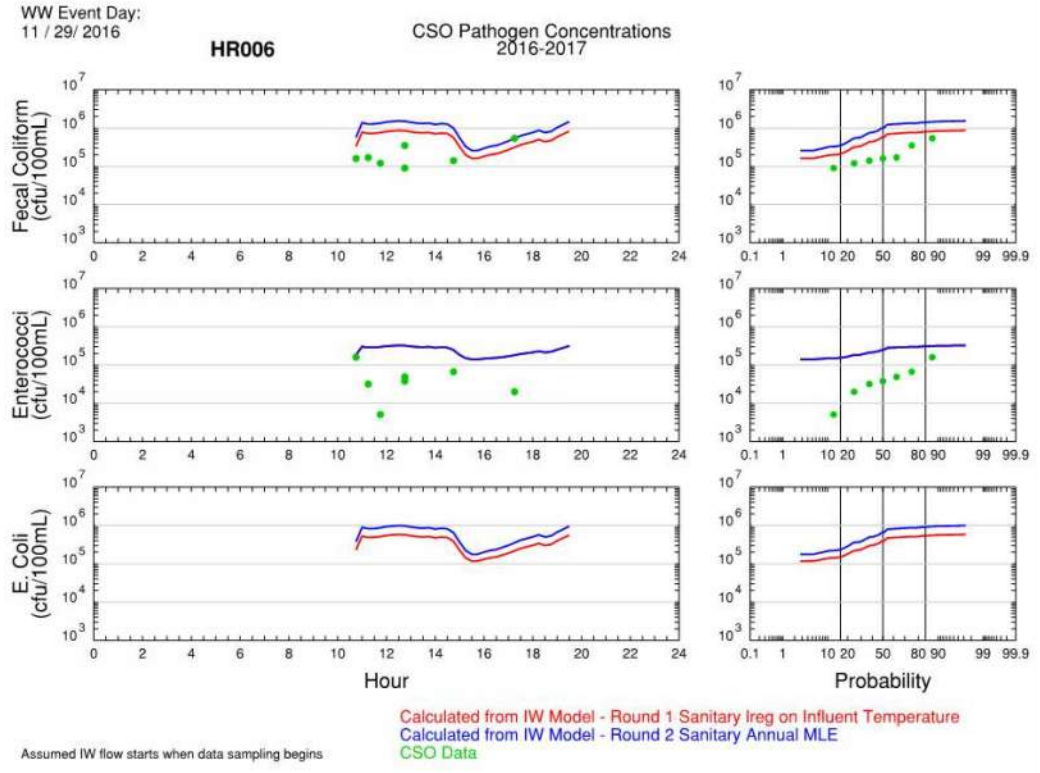
GREELEY AND HANSEN CDM Smith HDR

CSO Mass Balance Check



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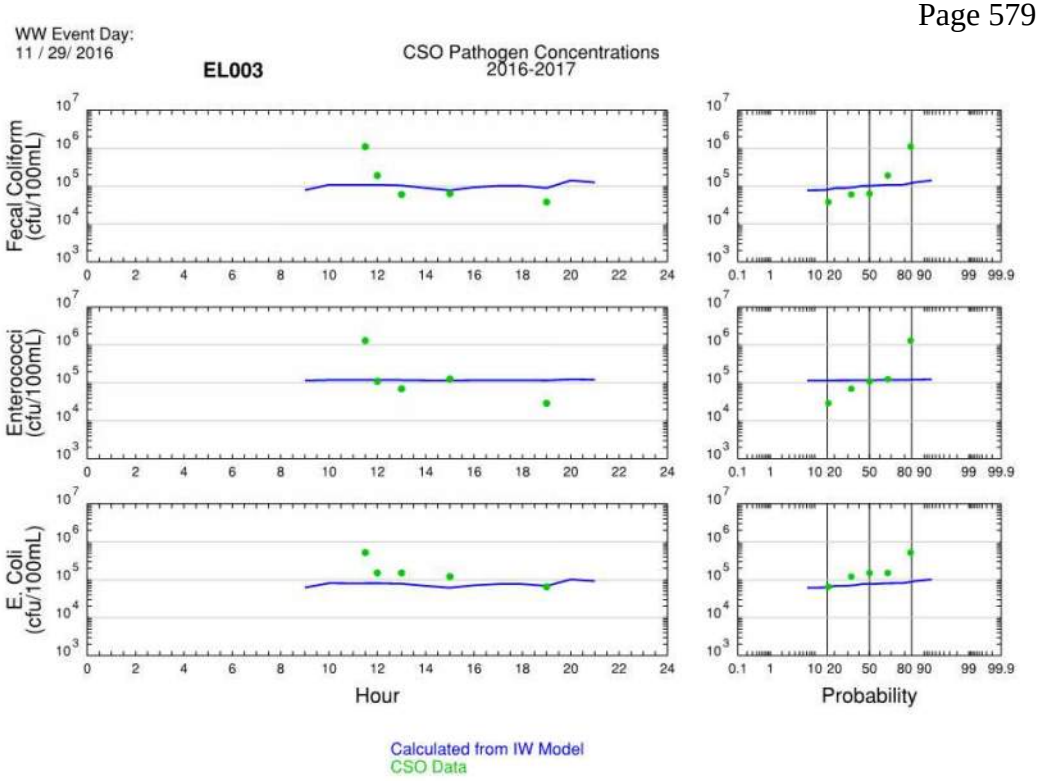
CSO Mass Balance Check



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CSO Mass Balance Check



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River Loads

- Dry-weather
  - "Monte Carlo" ✔
  - Data Interpolation
  - Data Average
- Wet-weather
  - MLE ✔
  - Concentration vs. Flow

River Boundaries, Stations used for Loading Calculations										
		2004			2016			2017		
Waterbody	Data Station	Data EC	Data FC	Data EN	Data EC	Data FC	Data EN	Data EC	Data FC	Data EN
Hudson River	31	N	Y	Y	N	Y	Y	N	Y	Y
Hackensack River	13	N	Y	Y	Y	Y	Y	Y	Y	Y
Passaic River	1	N	Y	Y	Y	Y	Y	Y	Y	Y
Saddle River	6	N	Y	Y	Y	Y	Y	Y	Y	Y
Raritan River	25	N	Y	Y	Y	Y	Y	Y	Y	Y

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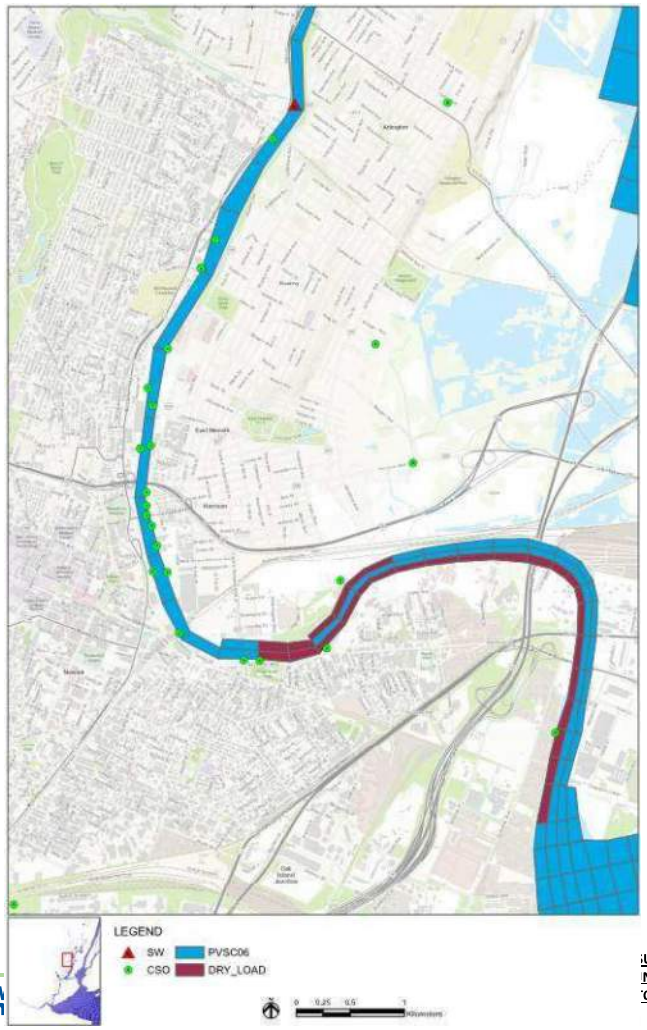
Dry-weather Loads

- Clear need for dry-weather sources based on water quality data
- Assumed sanitary flow concentrations
- 150 gal/day-person

Waterbody	Equivalent People
Passaic River	405
Hackensack River	945
Newark Bay	765
Elizabeth River	105
Kill van Kull	300
Arthur Kill	360
Hudson River	405
Upper Bay	1,380

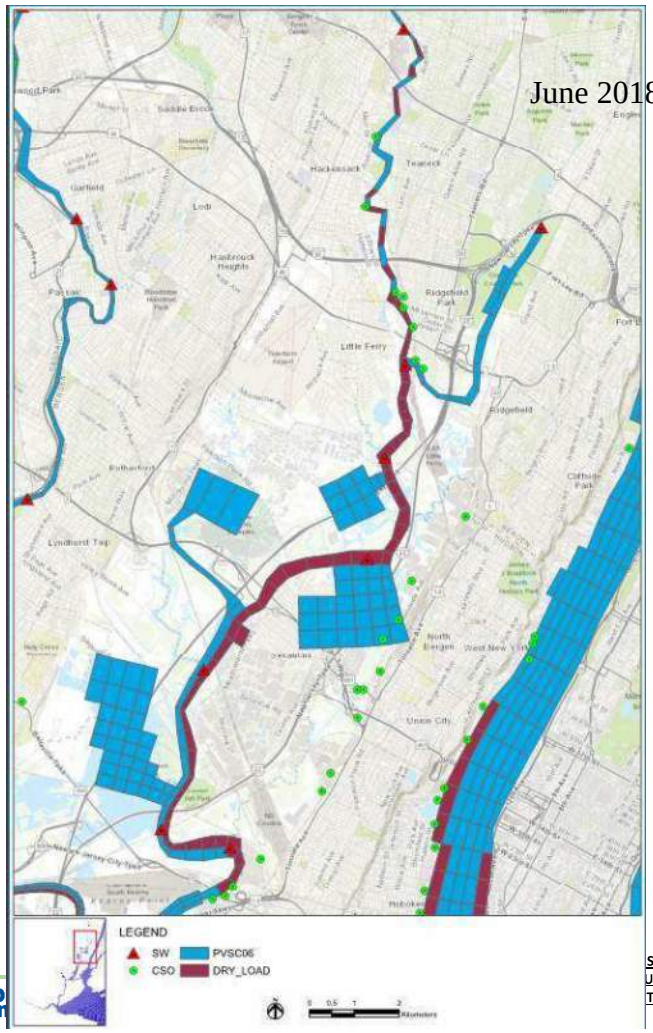
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Dry-weather Loads – Passaic River



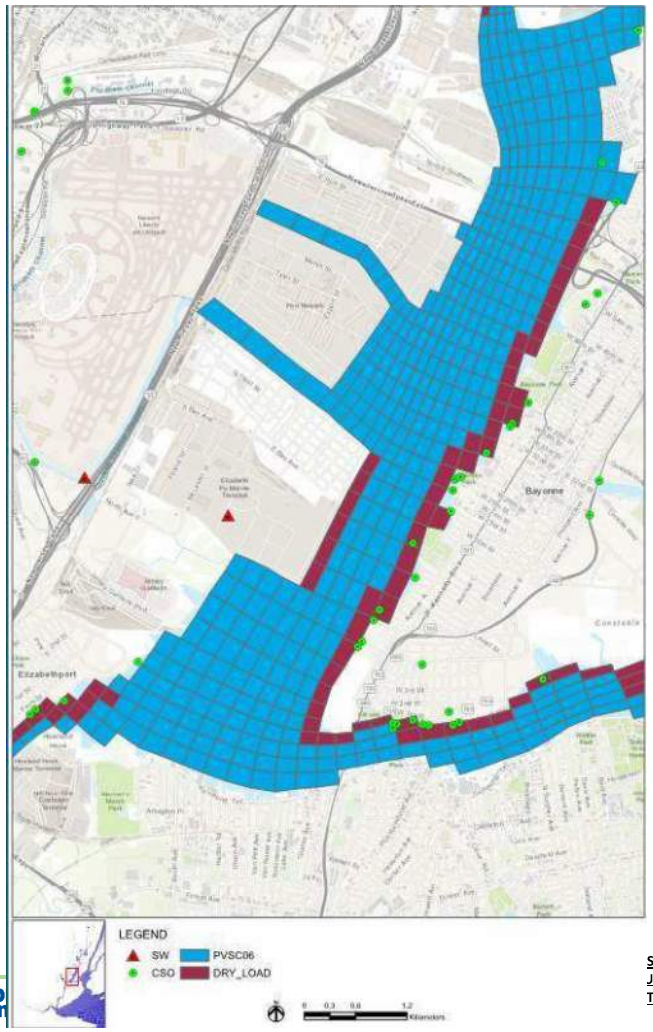
ULTATIVE AND/OR DELIBERATIVE MATERIALS.
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Dry-weather Loads – Hackensack River



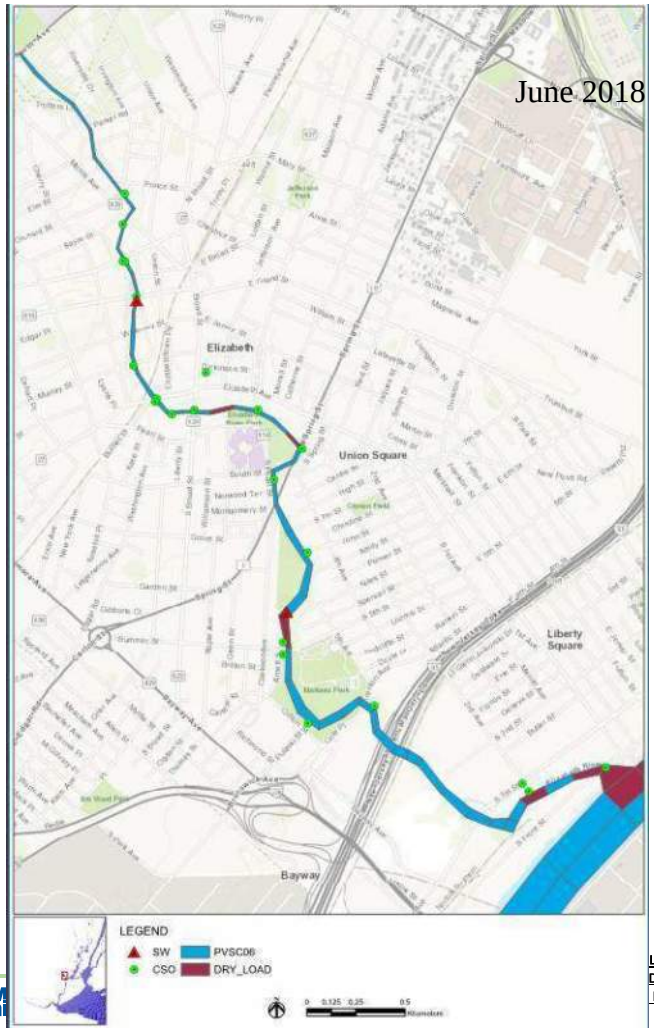
SULTATIVE AND/OR DELIBERATIVE MATERIALS.
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Dry-weather Loads – Newark Bay



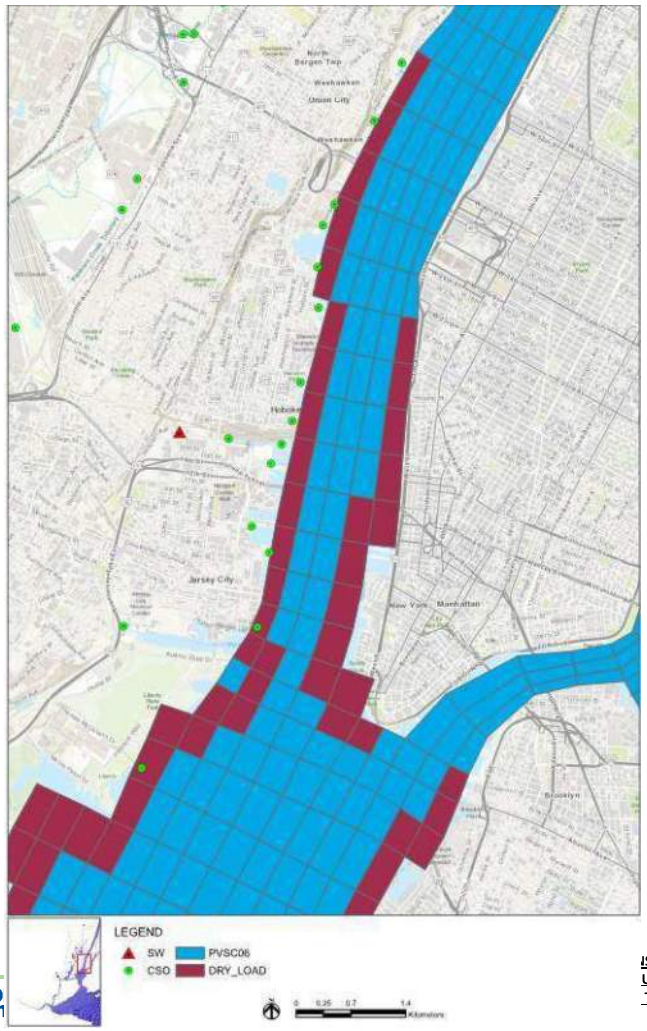
SULTATIVE AND/OR DELIBERATIVE MATERIALS.
JNDER N.J.S.A 47:1A-1 ET SEQ.
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Dry-weather Loads – Elizabeth River



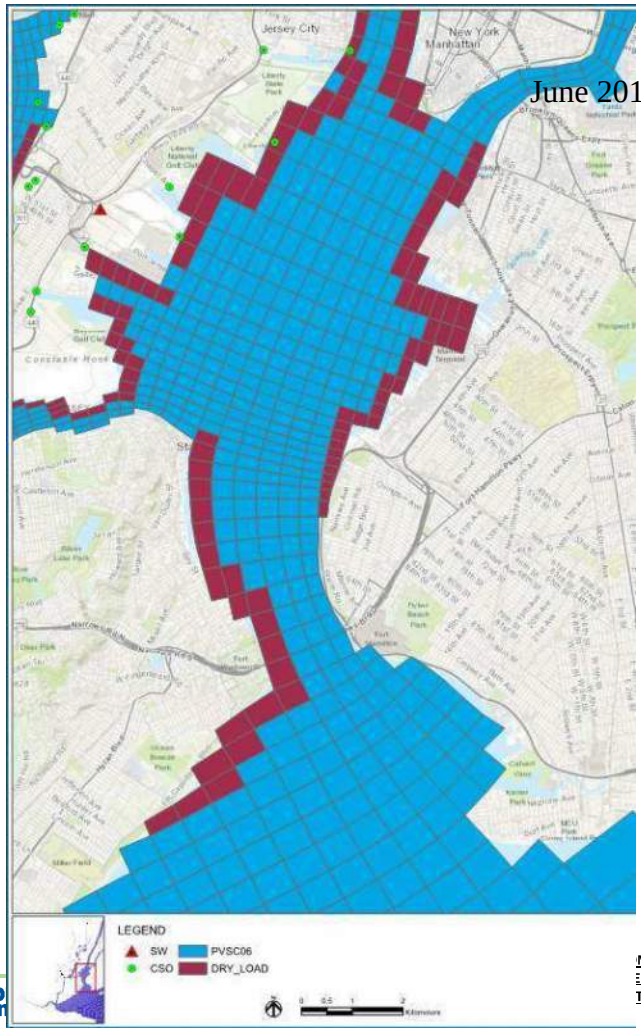
LTATIVE AND/OR DELIBERATIVE MATERIALS.
DER N.J.S.A 47:1A-1 ET SEQ.
INSPECT PUBLIC RECORDS.

Dry-weather Loads – Hudson River



ISULTATIVE AND/OR DELIBERATIVE MATERIALS.
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Dry-weather Loads – Upper Bay



NSULTATIVE AND/OR DELIBERATIVE MATERIALS.
E UNDER N.J.S.A 47:1A-1 ET SEQ.
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Other Loads

- WWTP
  - Fecal coliform = 200 cfu/100mL
  - E. Coli = 100 cfu/100mL
  - Enterococci = 100cfu/100mL
- Base flow from stormwater model
  - Fecal Coliform = 10 cfu/100mL
  - E. Coli = 5 cfu/100mL
  - Enterococci = 1 cfu/100mL
- Hudson River
  - Artificial load created near study area so that upstream loads did not have to be estimated

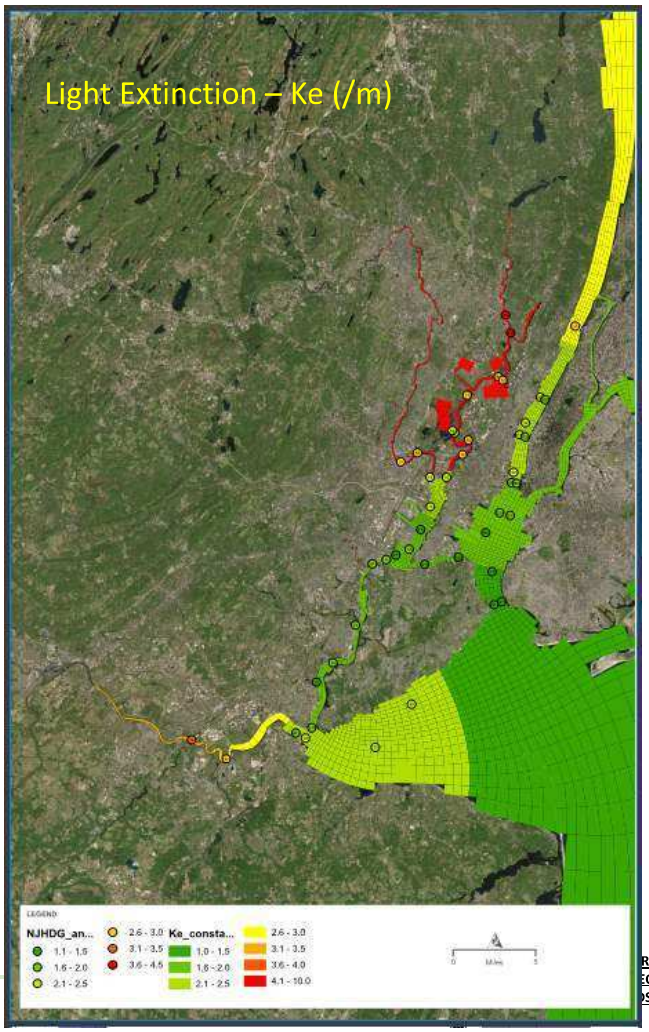
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Pathogen Loading Ratios

Source	FC:ENT Ratio
Sanitary	5.9
Stormwater	0.4
CSO	0.4-4.6
Hudson River	2.7
Hackensack River	2.7
Passaic River	0.5
Raritan River	0.5

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Calibration Constants and Parameters



RATIVE MATERIALS.
EQ.
S.

Calibration Constants and Parameters

Constant	F. Coliform & E. Coli	Enterococci
Base Mortality Rate	0.2/day	0.68/day
Temperature Coefficient	1.07	1.07
Seawater Die-off Rate	0.01875/day	0.01875/day
Solar Radiation Die-off Rate	0.003/ly-day	0.00824/ly-day

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Calibration Rates

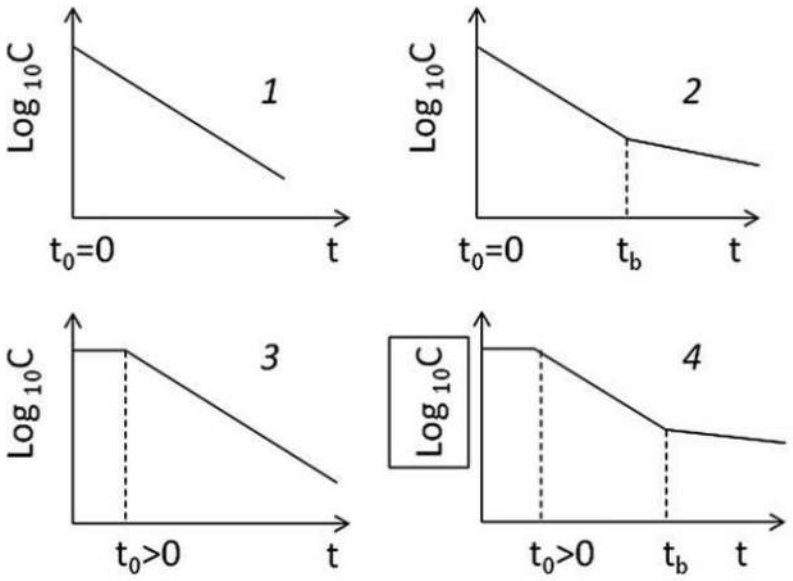
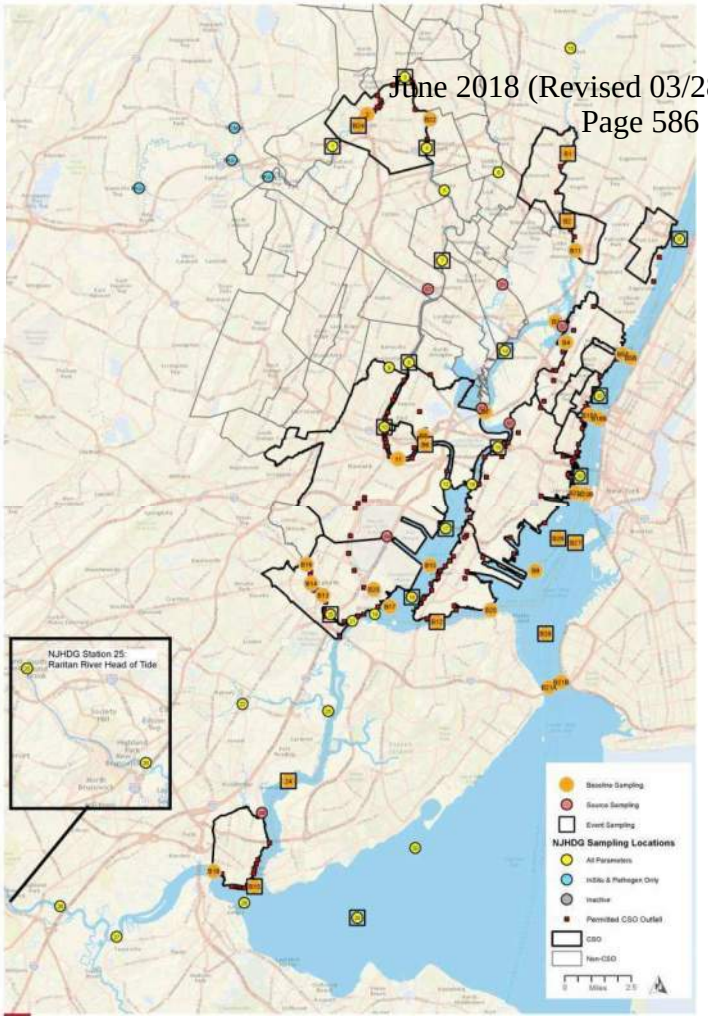


Fig. 1 – Patterns found in data on *E. coli* inactivation in waters.

Blaustein et al., 2013

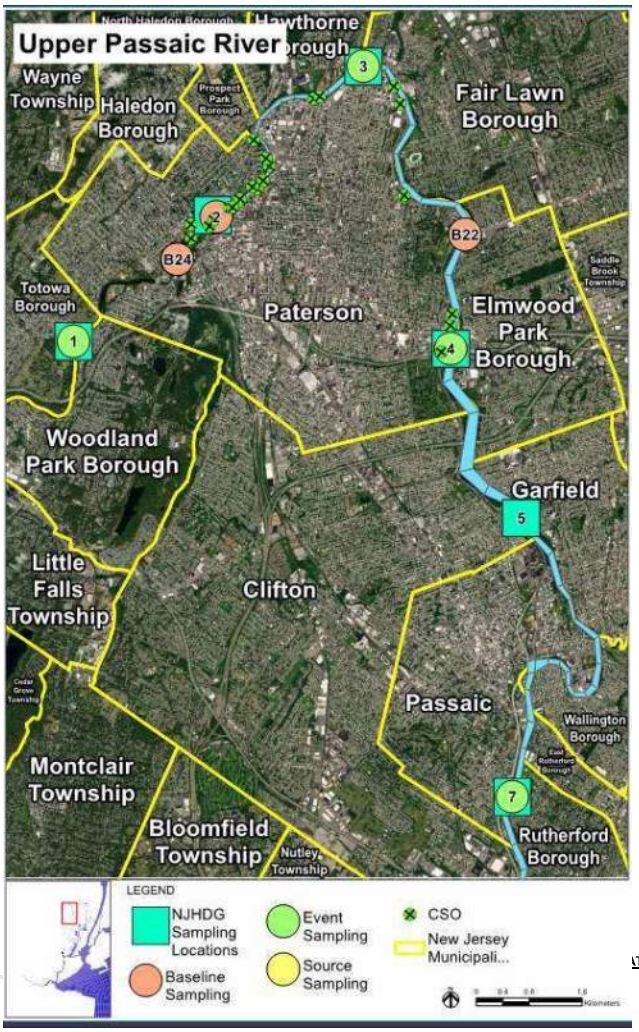
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Receiving Water Sampling Locations



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Model Calibration

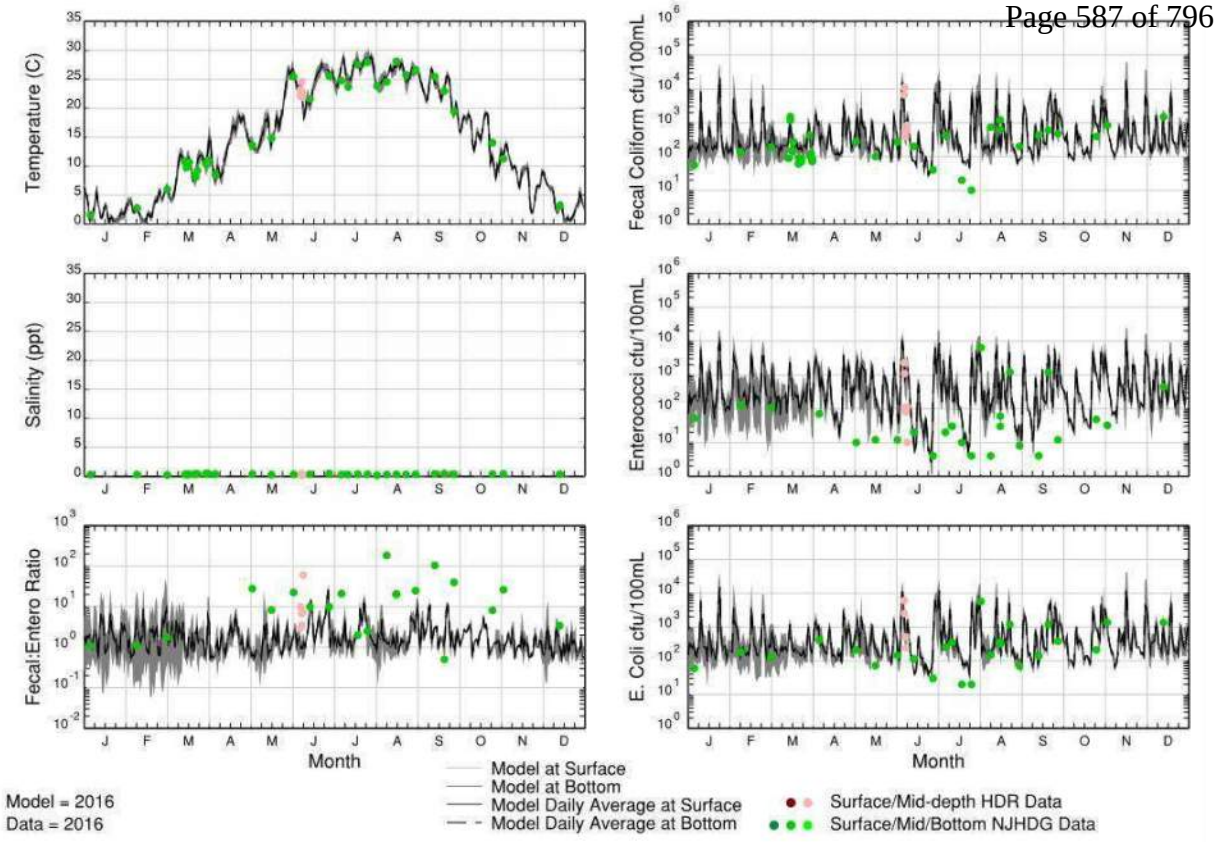


...TERIALS.

PASSAIC RIVER

Station: 4

FW2

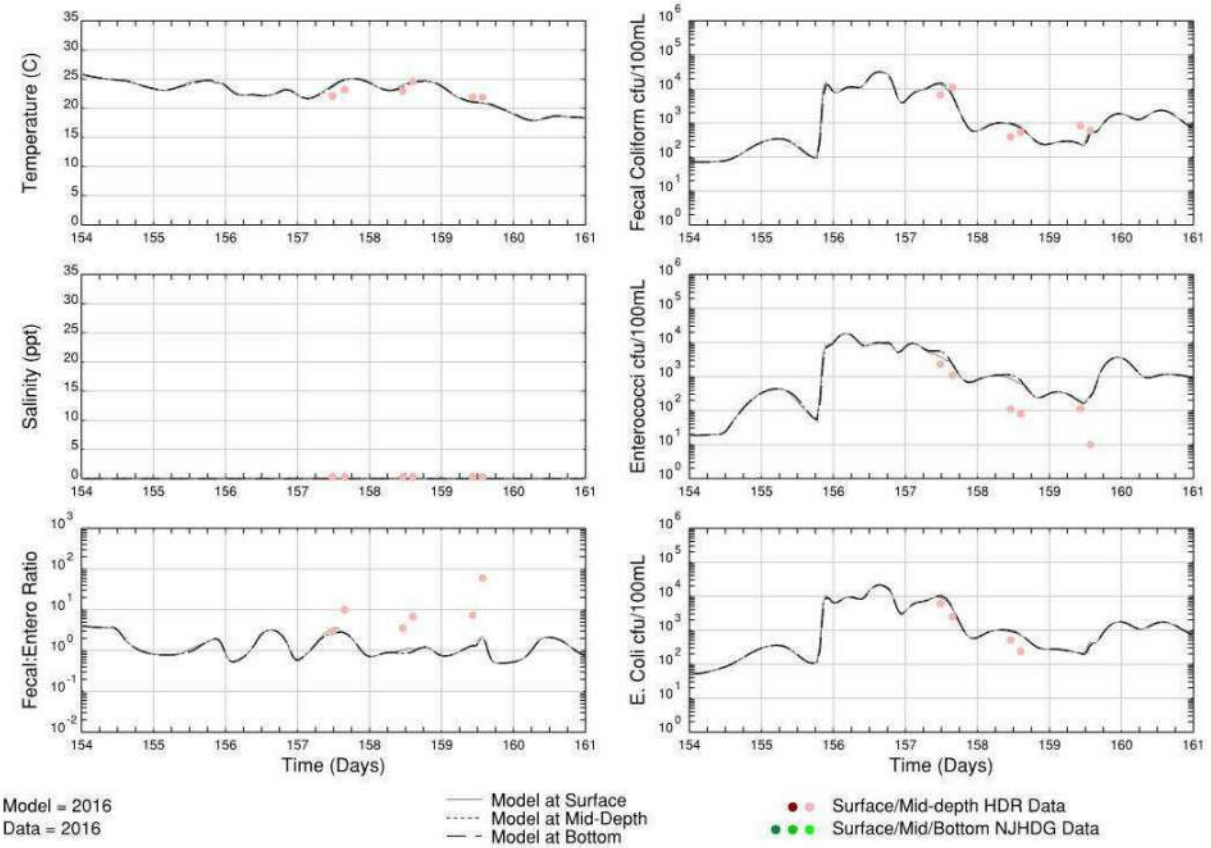


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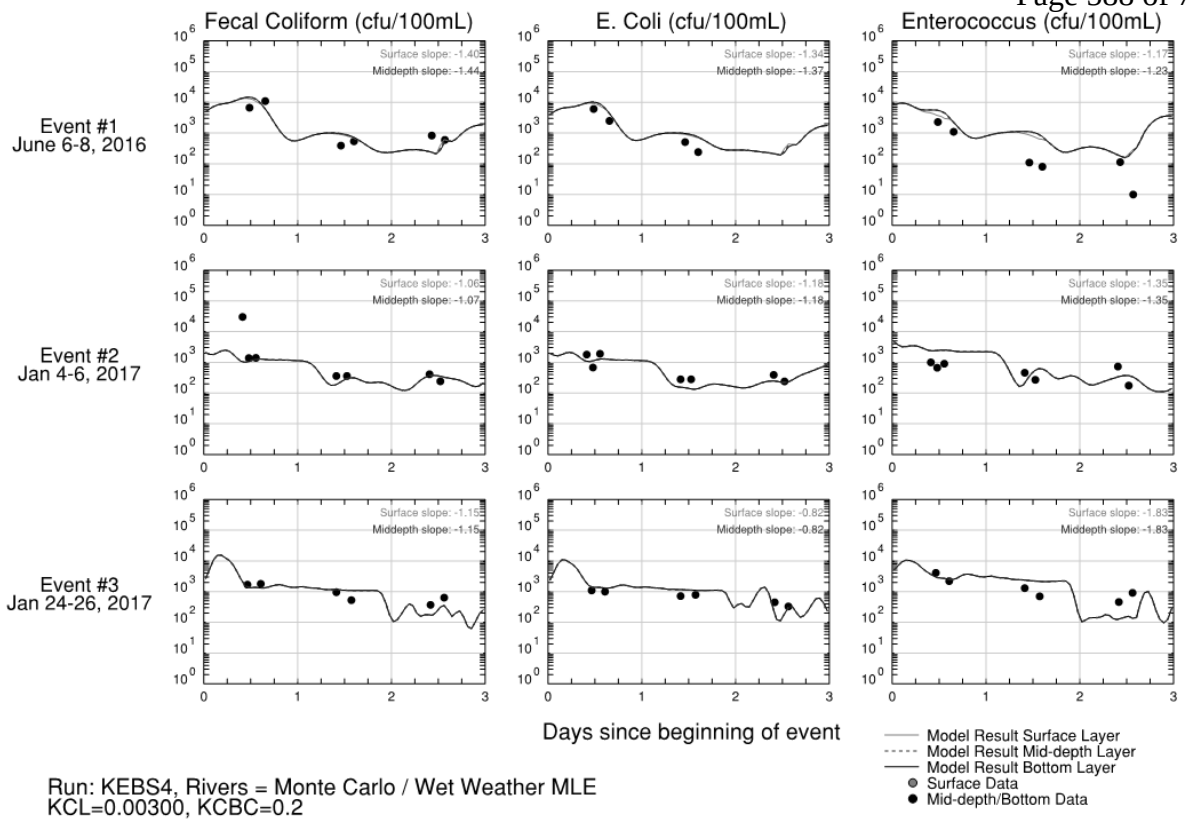
Passaic River & Tributaries
Passaic River

Station: 4 Event 1 (June 3-9)

FW2



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Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00300, KCBC=0.2

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NJ Pathogen Criteria

- Primary Contact Recreation:
  - Enterococci levels shall not exceed a geometric mean of **35/100 ml**, or a single sample maximum of **104/100 ml**. (SE1 and SC)
    - Hackensack R. (upper), Hudson R. (north of Harlem R.), Raritan R., Raritan Bay
  - E. coli levels shall not exceed a geometric mean of **126/100 ml** or a single sample maximum of **235/100 ml**. (All FW2)
    - Elizabeth R., Passaic R., Raritan R.

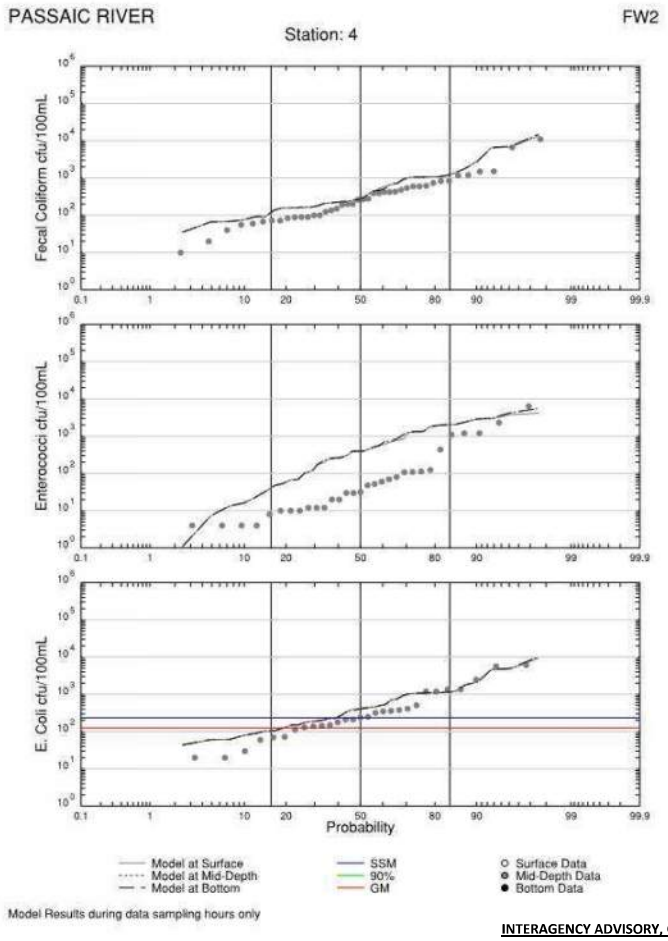
- Secondary Contact Recreation:
  - Fecal coliform levels shall not exceed a geometric mean of **770/100 ml**. (SE2)
    - Arthur Kill (lower), Hackensack R. (mid), Hudson R., Passaic R. (mid), Rahway R.
  - Fecal coliform levels shall not exceed a geometric mean of **1500/100ml**. (SE3)
    - Arthur Kill (upper), Elizabeth R., Hackensack R. (lower), Kill Van Kull, Newark Bay, Passaic R. (lower)

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NJ Pathogen Criteria

The Department shall **utilize a geometric mean to assess compliance** with the bacterial quality indicators at N.J.A.C.7:9B-1.14(d)1ii-iii. The geometric mean shall be calculated using a minimum of five samples collected over a thirty-day period. The **single sample maximum shall be used for beach notification** in accordance with N.J.A.C. 8:26 and to identify where additional ambient water quality sampling is needed to calculate a geometric mean.

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Assessment of Model's Ability to Calculate Attainment

- Passaic River – GM Criterion – Mid-depth
- Do Data and Model Exceed Criterion (Using imaginary 30-day period)?

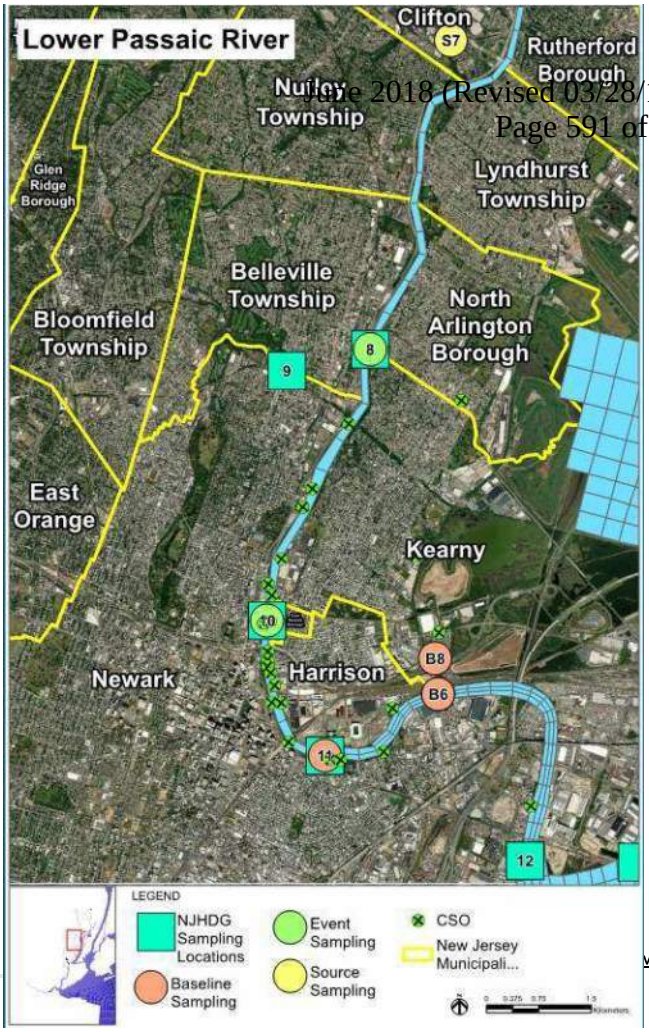
Station	Class	Criterion	2016 Data	2016 Model	2017 Data	2017 Model
B24	FW2	126	**Y**	**Y**	**Y**	**Y**
2	FW2	126	**Y**	**Y**	-	-
3	FW2	126	**Y**	**Y**	**Y**	**Y**
B22	FW2	126	**Y**	**Y**	-	-
4	FW2	126	**Y**	**Y**	**Y**	**Y**
5	FW2	126	**Y**	**Y**	**Y**	**Y**
7	FW2-SE2	126	**Y**	**Y**	**Y**	**Y**
8	FW2-SE2	126	**Y**	**Y**	**Y**	**Y**

Assessment of Model's Ability to Calculate Attainment

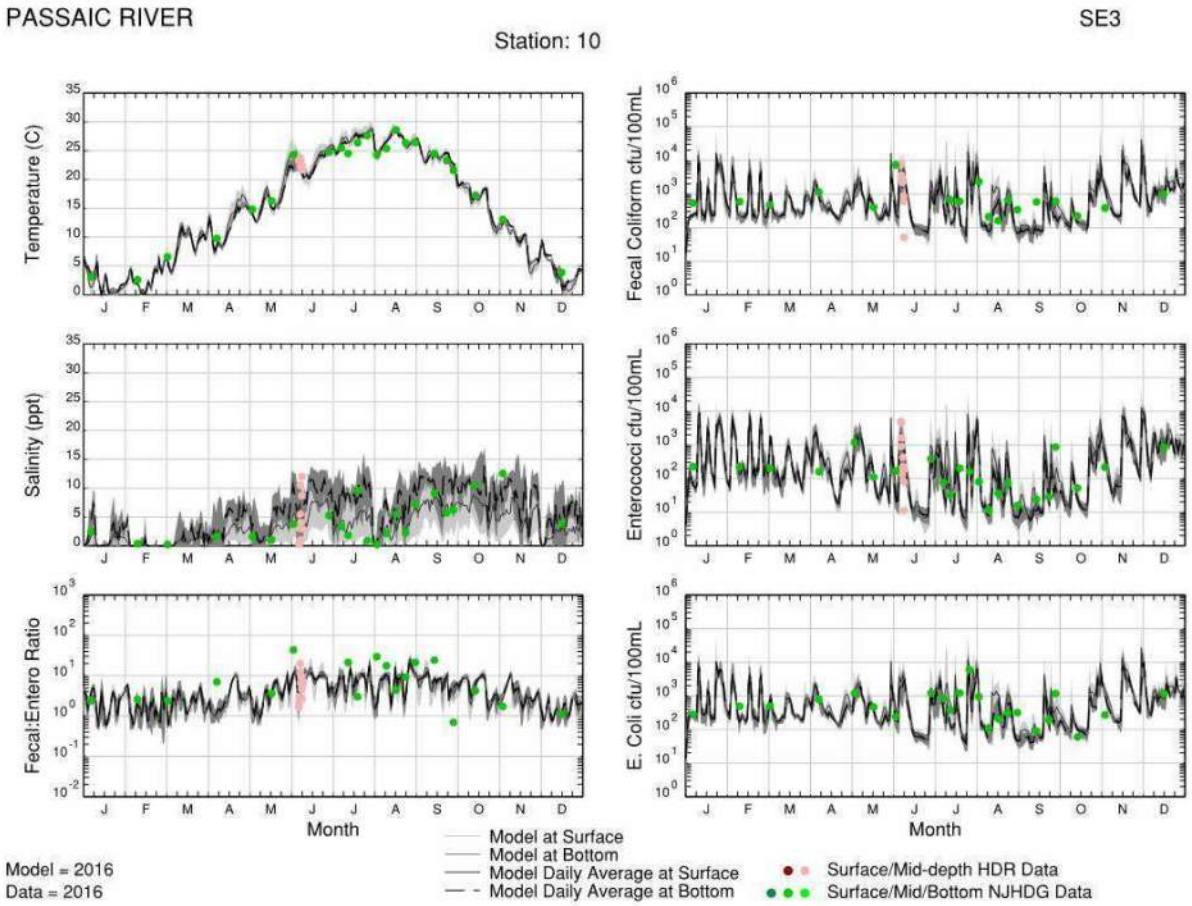
- Passaic River – SSM Criterion – Mid-depth
- Percent of Time Data and Model Exceed Criterion (Using imaginary 30-day period)

Station	Class	Criterion	2016 Data	2016 Model	**diff**	2017 Data	2017 Model	**diff**
B24	FW2	235	33.1	47.8	**14.7**	73.8	59.6	**14.2**
2	FW2	235	46.5	59.0	**12.5**	NA	NA	
3	FW2	235	70.4	37.7	**32.7**	67.8	56.1	**11.7**
B22	FW2	235	53.0	38.0	**15.0**	NA	NA	
4	FW2	235	50.6	60.7	**10.1**	61.9	42.1	**19.8**
5	FW2	235	44.0	49.7	**5.7**	46.8	30.5	**16.3**
7	FW2-SE2	235	80.5	75.0	**5.5**	88.1	55.1	**33.0**
8	FW2-SE2	235	77.1	79.2	**2.1**	91.9	62.5	**29.4**

Model Calibration



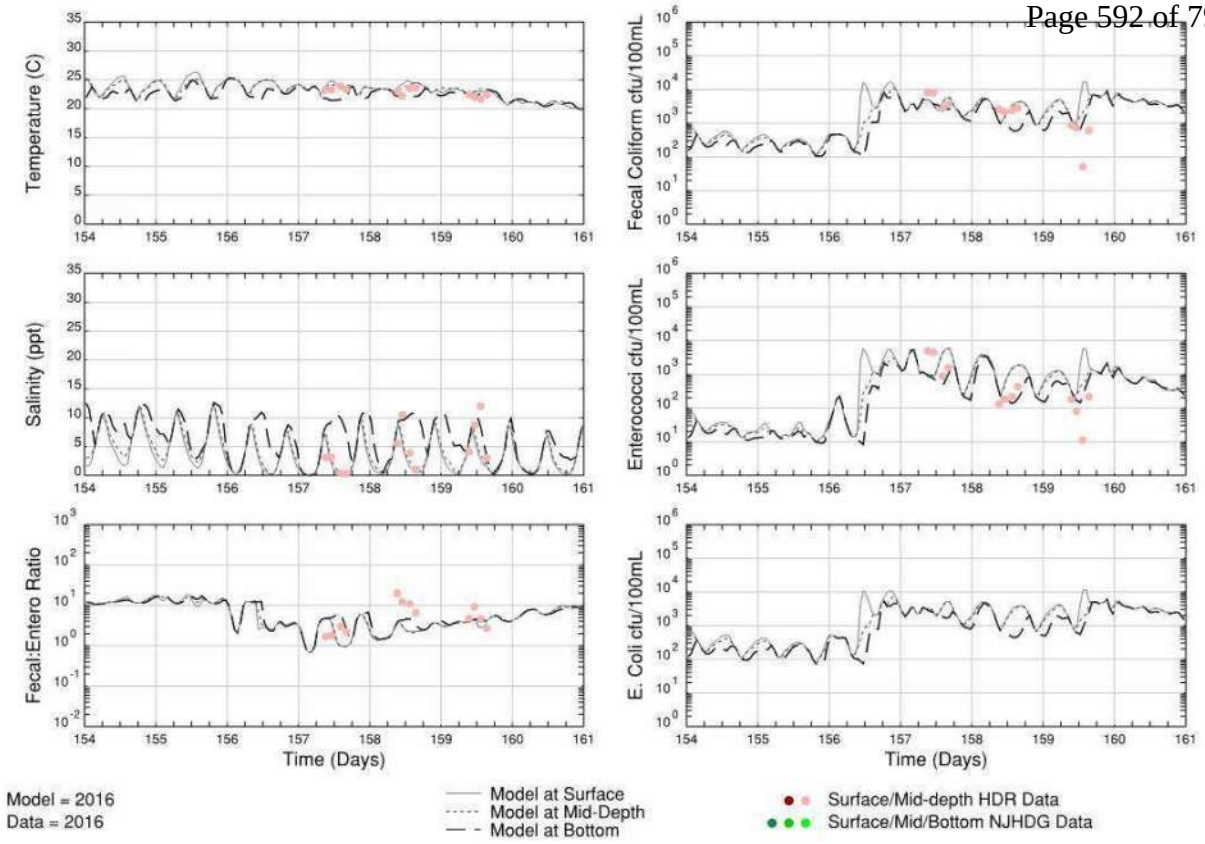
MATERIALS.



MATERIALS.
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Passaic River & Tributaries
Passaic River

Station: 10 Event 1 (June 3-9)

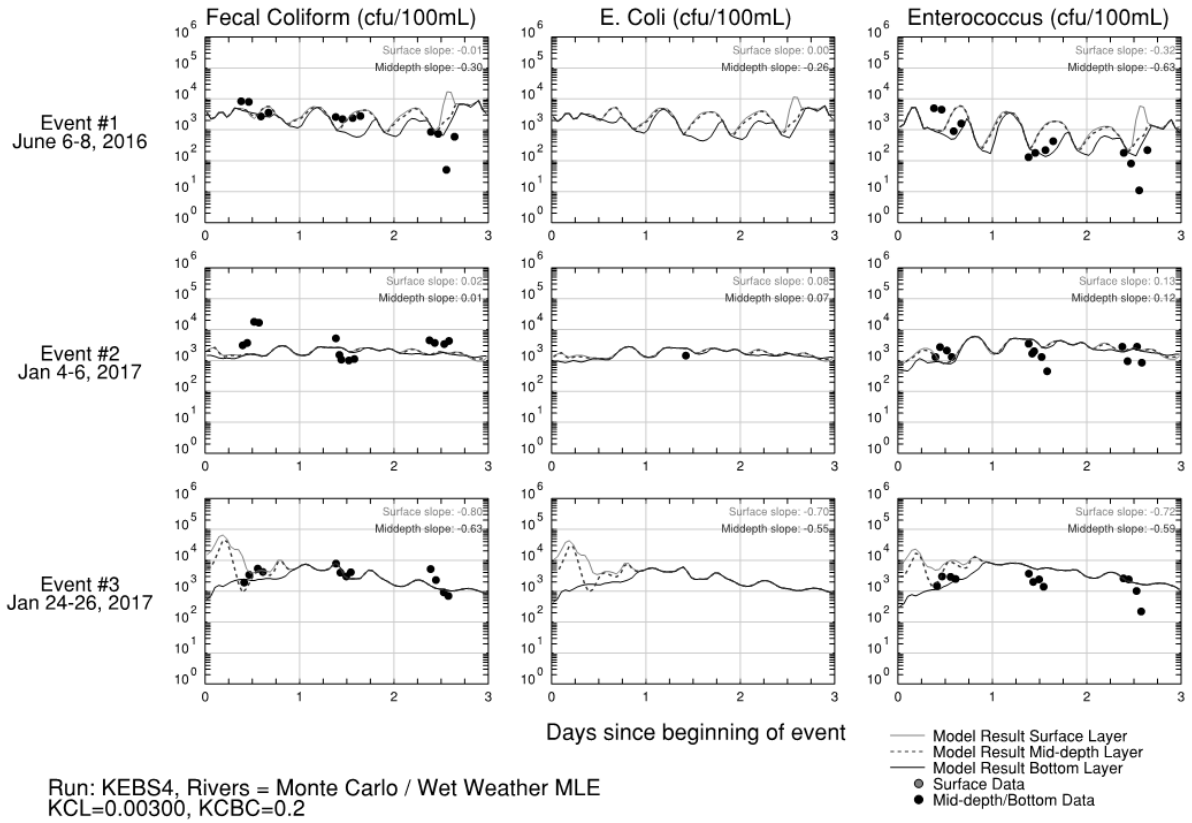


:RIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Passaic River & Tributaries
Passaic River

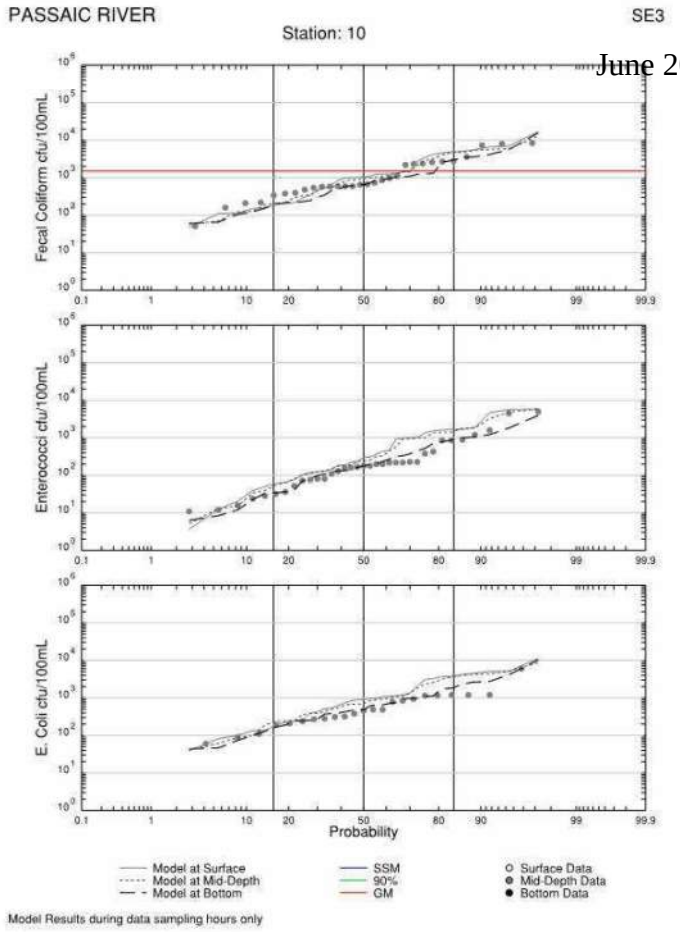
SE3

Station: 10



Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00300, KCBC=0.2

INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.



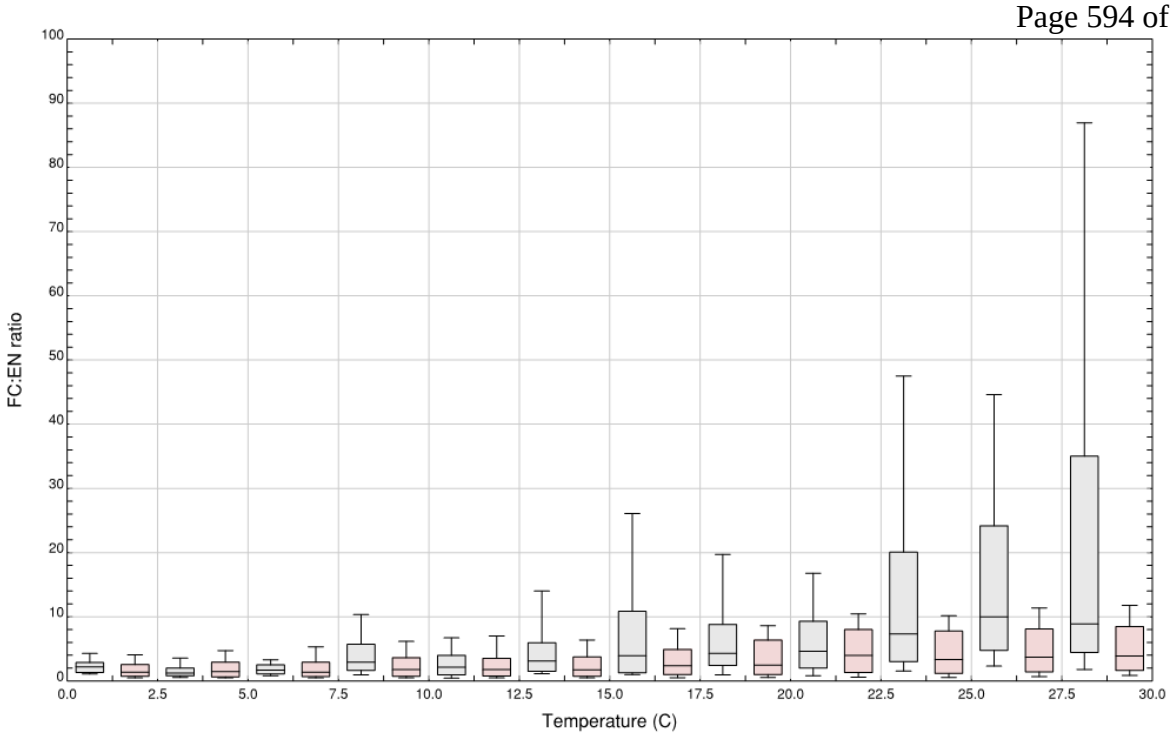
ONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Assessment of Model's Ability to Calculate Attainment

- Passaic River – GM Criterion – Mid-depth
- Do Data and Model Exceed Criterion (Using imaginary 30-day period)?

Station	Class	Criterion	2016 Data	2016 Model	2017 Data	2017 Model
7	FW2-SE2	770	Y	N (49)	N	N
8	FW2-SE2	770	N	Y	Y	Y
10	SE3	1500	N	N	Y	N (49)
11	SE3	1500	N	N	-	-
B6	SE3	1500	N	N	Y	Y
12	SE3	1500	-	-	-	-

Passaic River & Tributaries
2016 / 2017



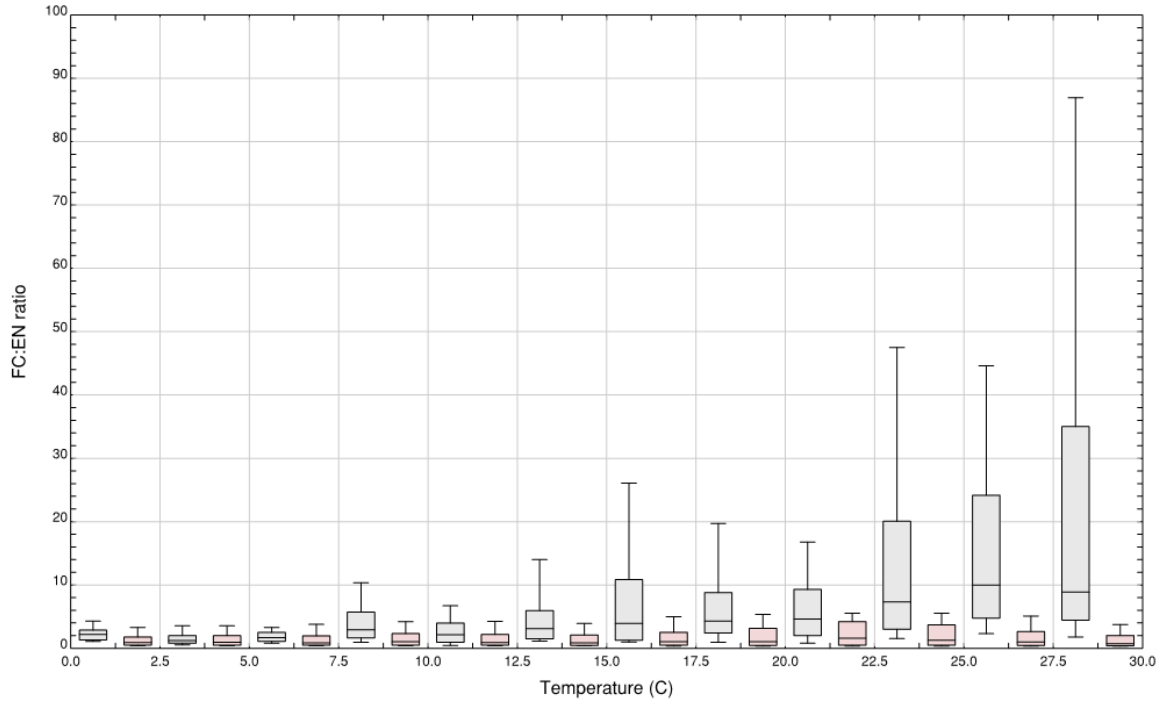
Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00300, KCBC=0.2

plots show 10, 25, 50, 75, 90 percentiles

Data, All Depths
Model, All Depths

INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Passaic River & Tributaries
2016 / 2017



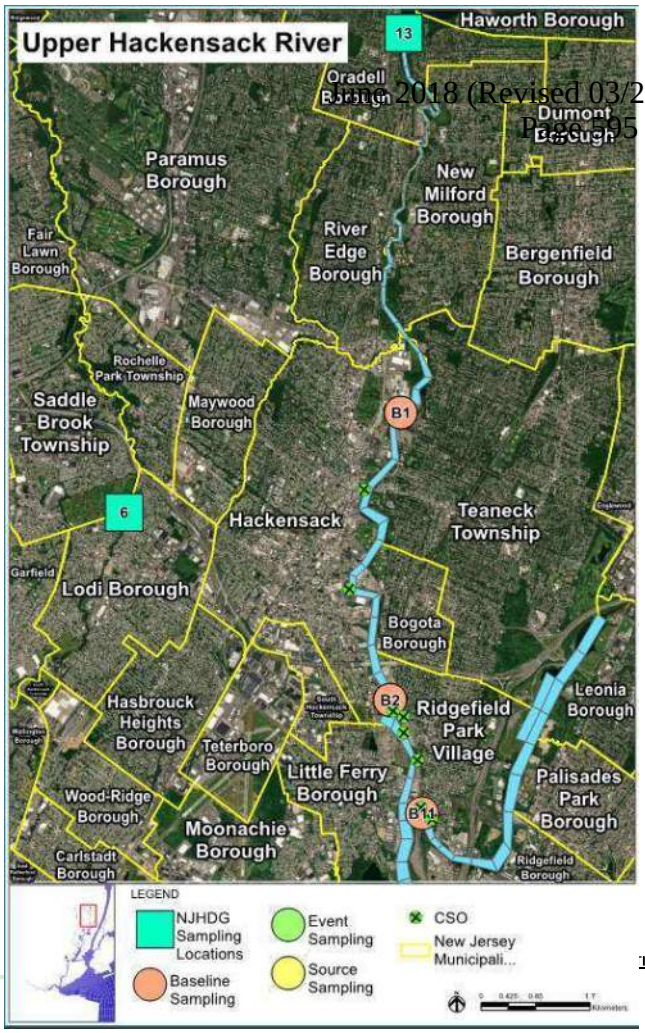
Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00824, KCBC=0.8

plots show 10, 25, 50, 75, 90 percentiles

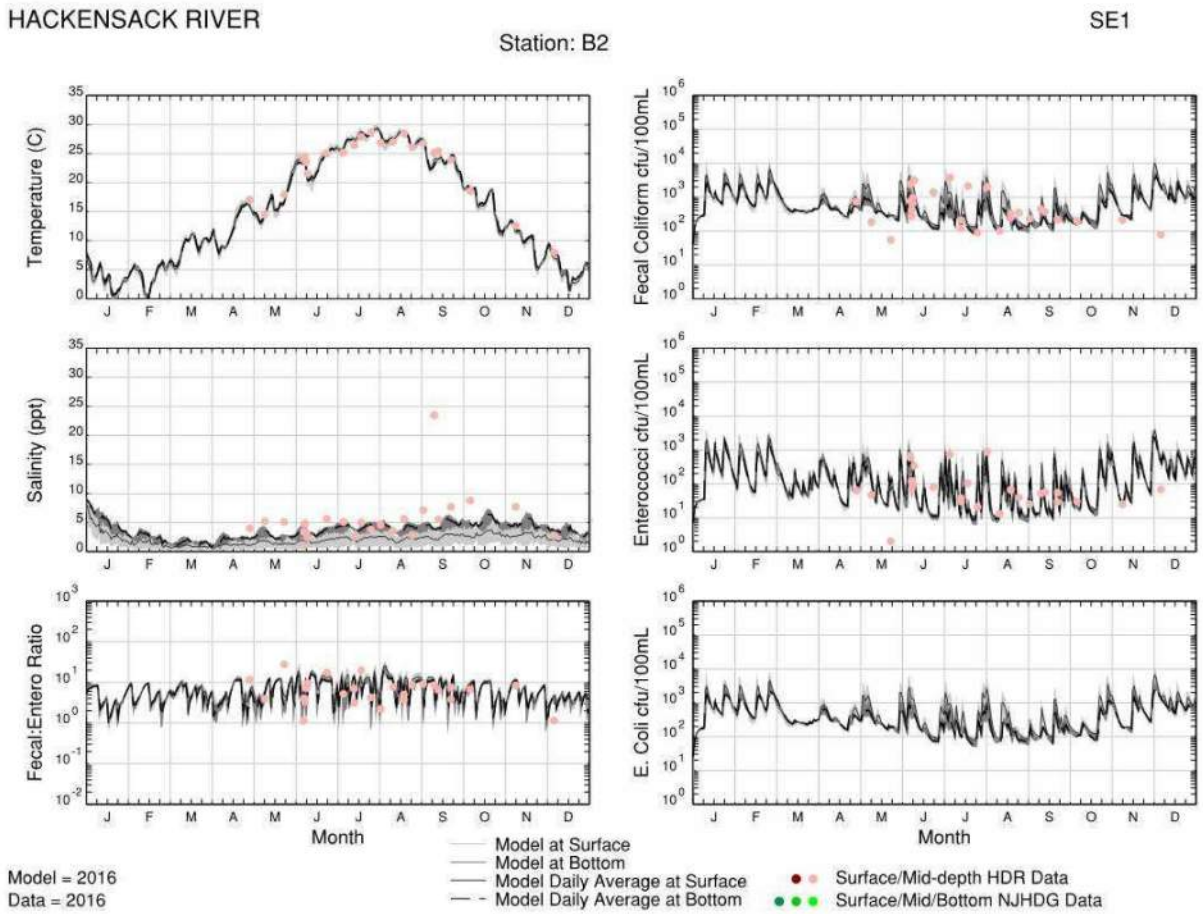
Data, All Depths
Model, All Depths

INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
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Model Calibration



IVE MATERIALS.

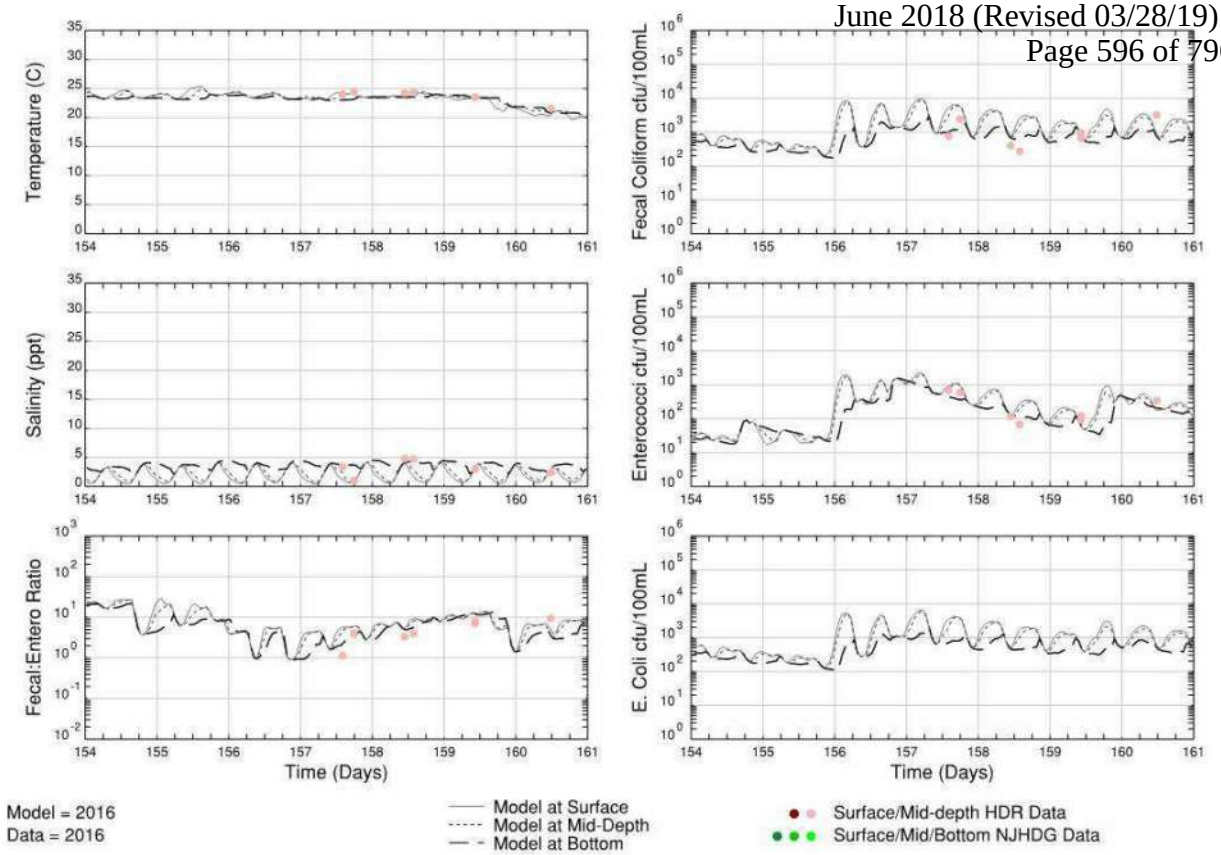


INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Hackensack River & Tributaries
Hackensack River

Station: B2 Event 1 (June 3-9)

SE1

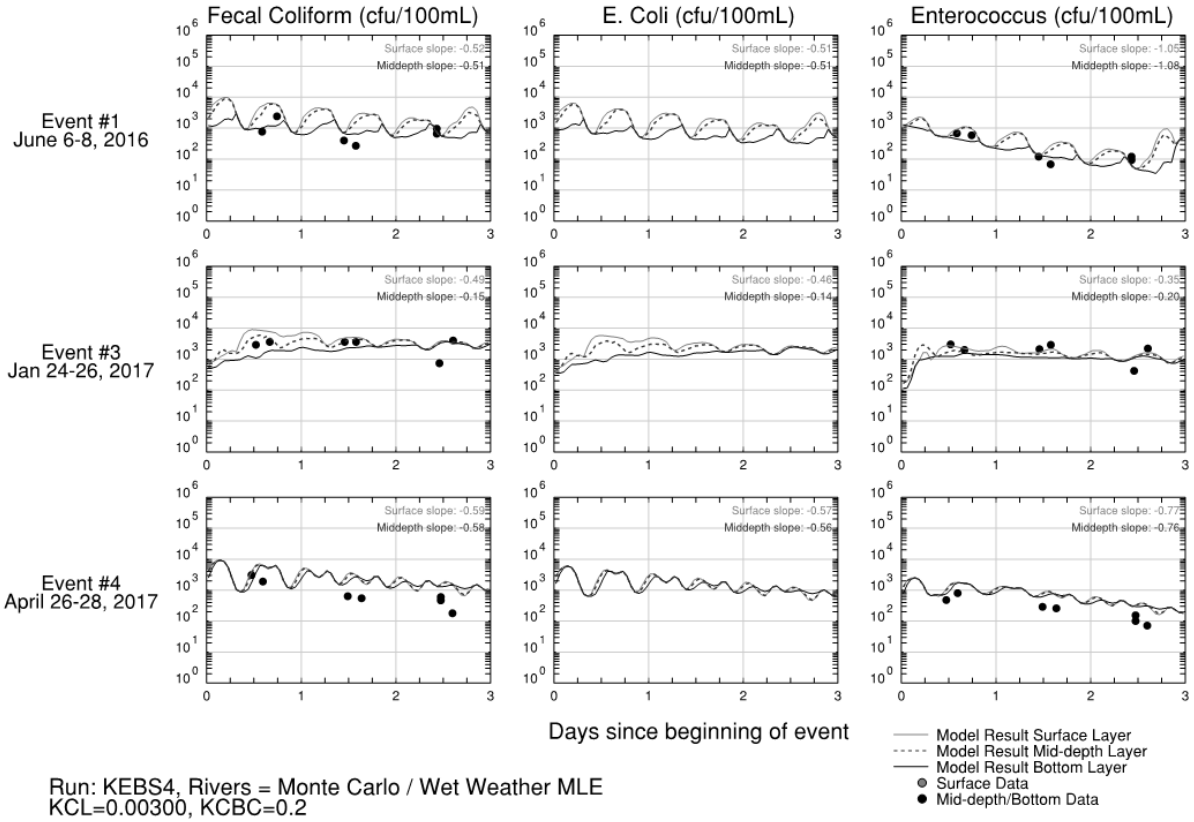


INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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Hackensack River & Tributaries
Hackensack River

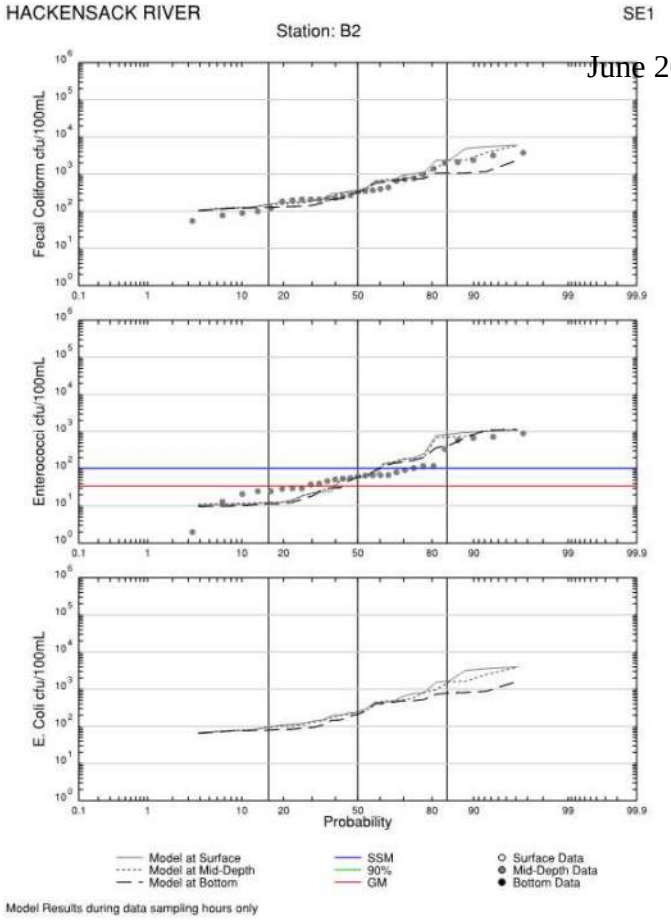
Station: B2

SE1



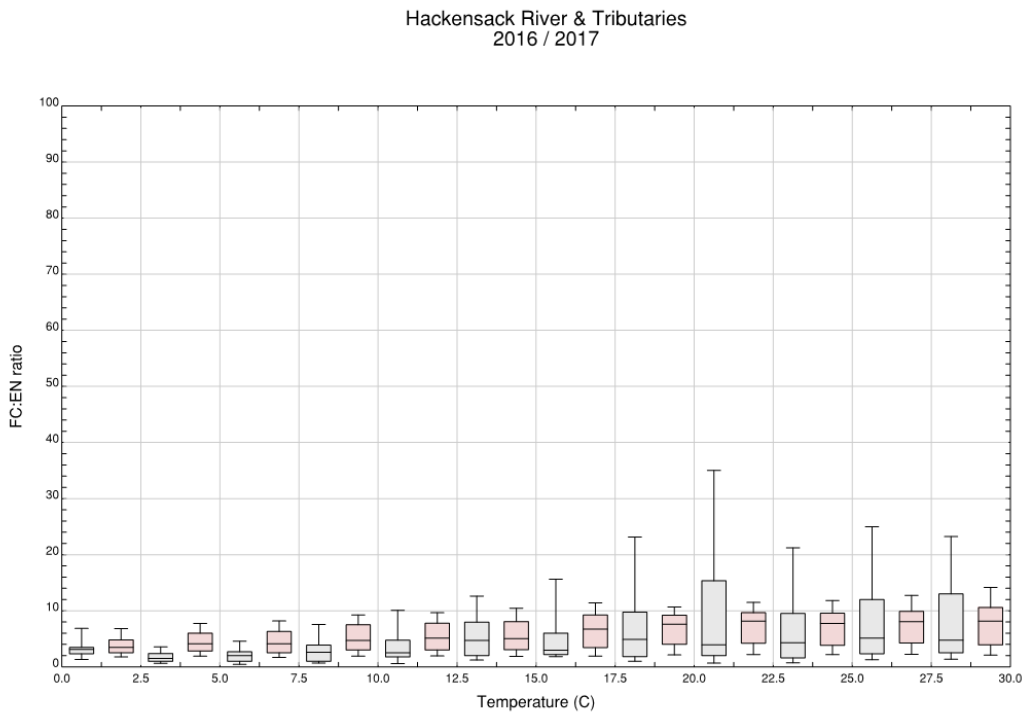
Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00300, KCBC=0.2

INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
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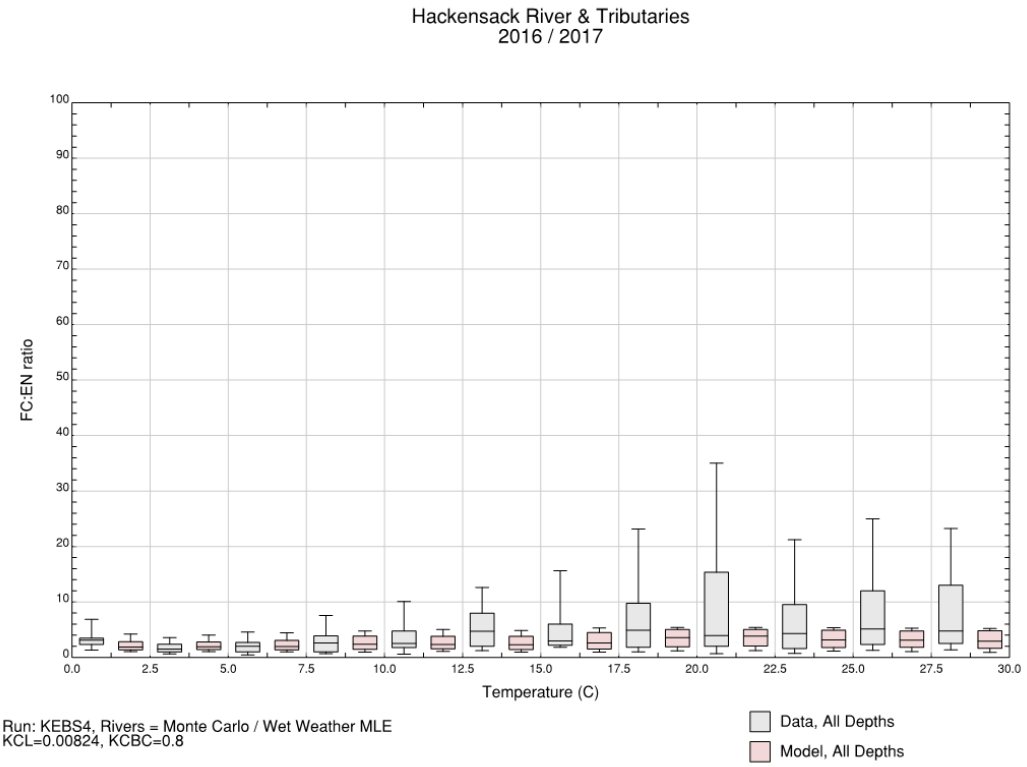
INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Model Calibration



TIVE MATERIALS.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Model Calibration



ATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Model Calibration

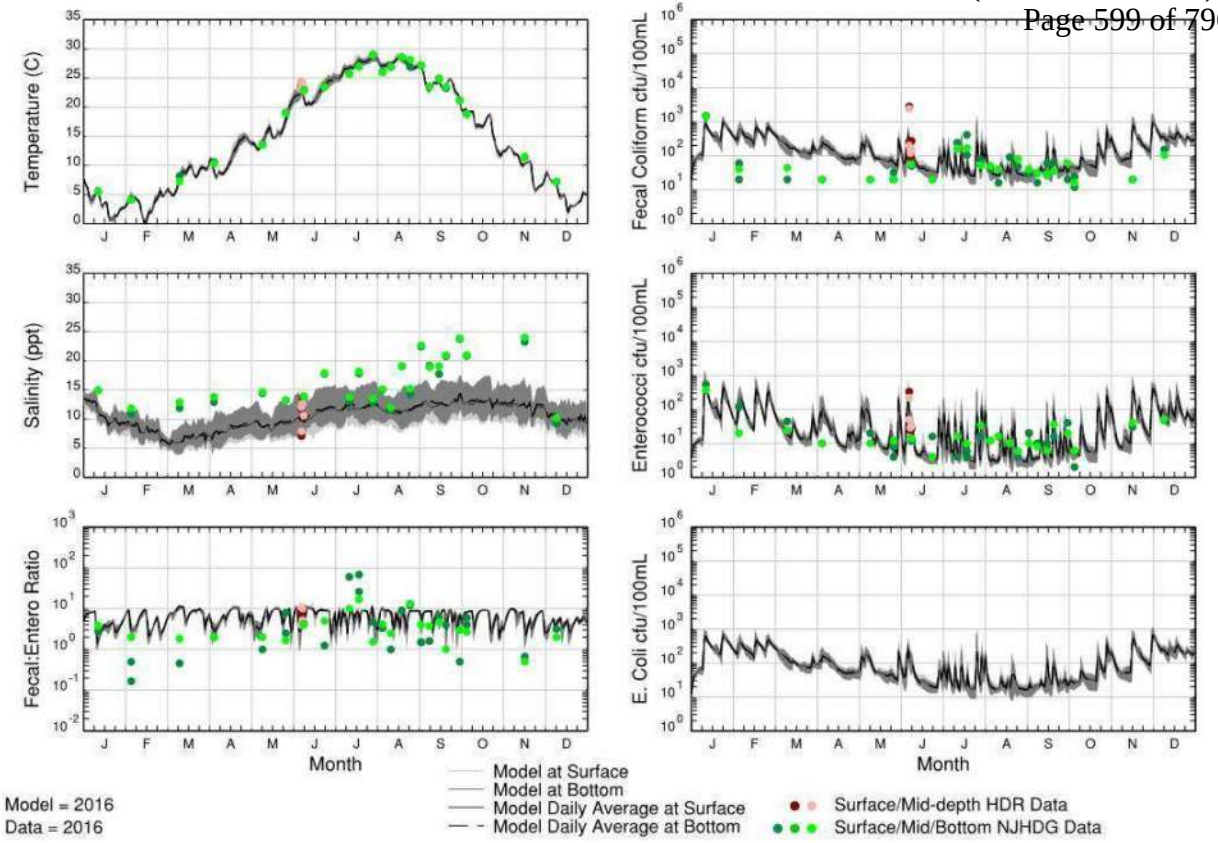


E MATERIALS.

HACKENSACK RIVER

Station: 14

SE2

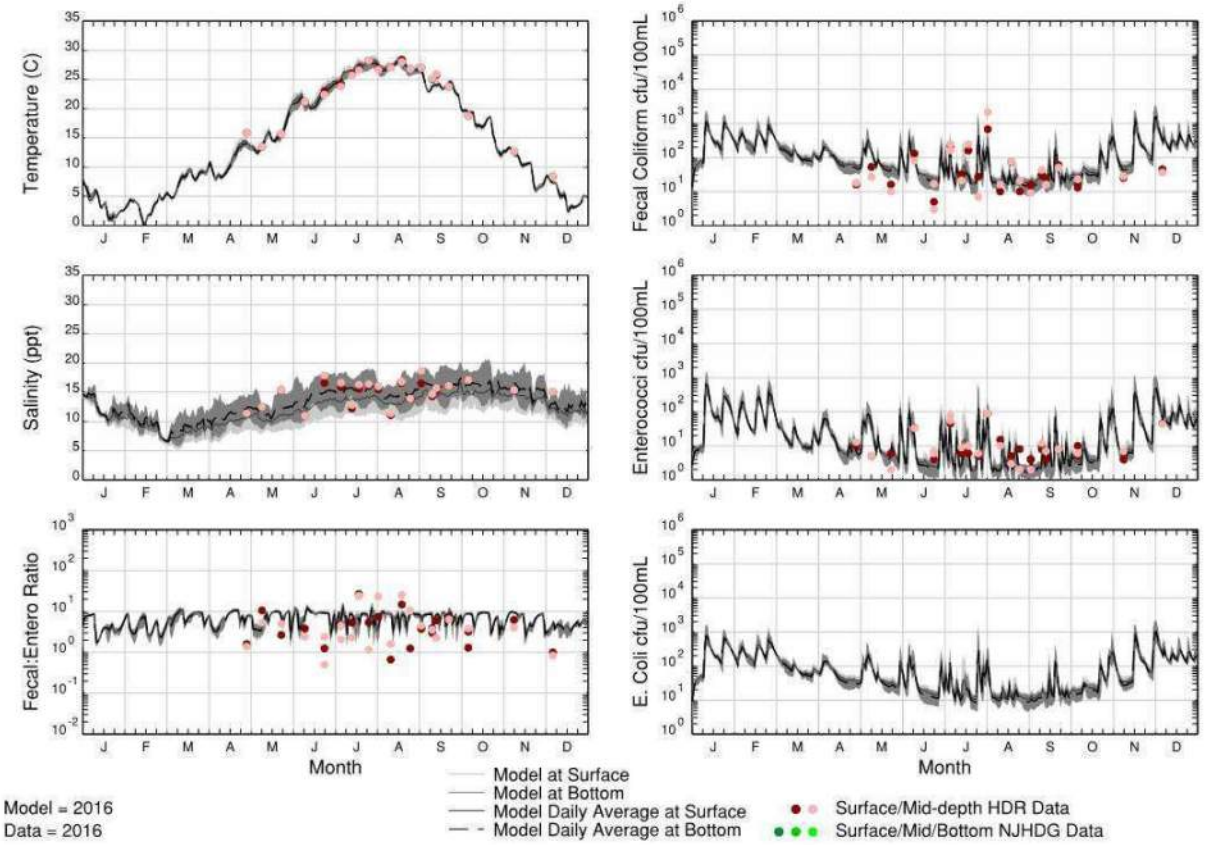


RIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

HACKENSACK RIVER

Station: B7

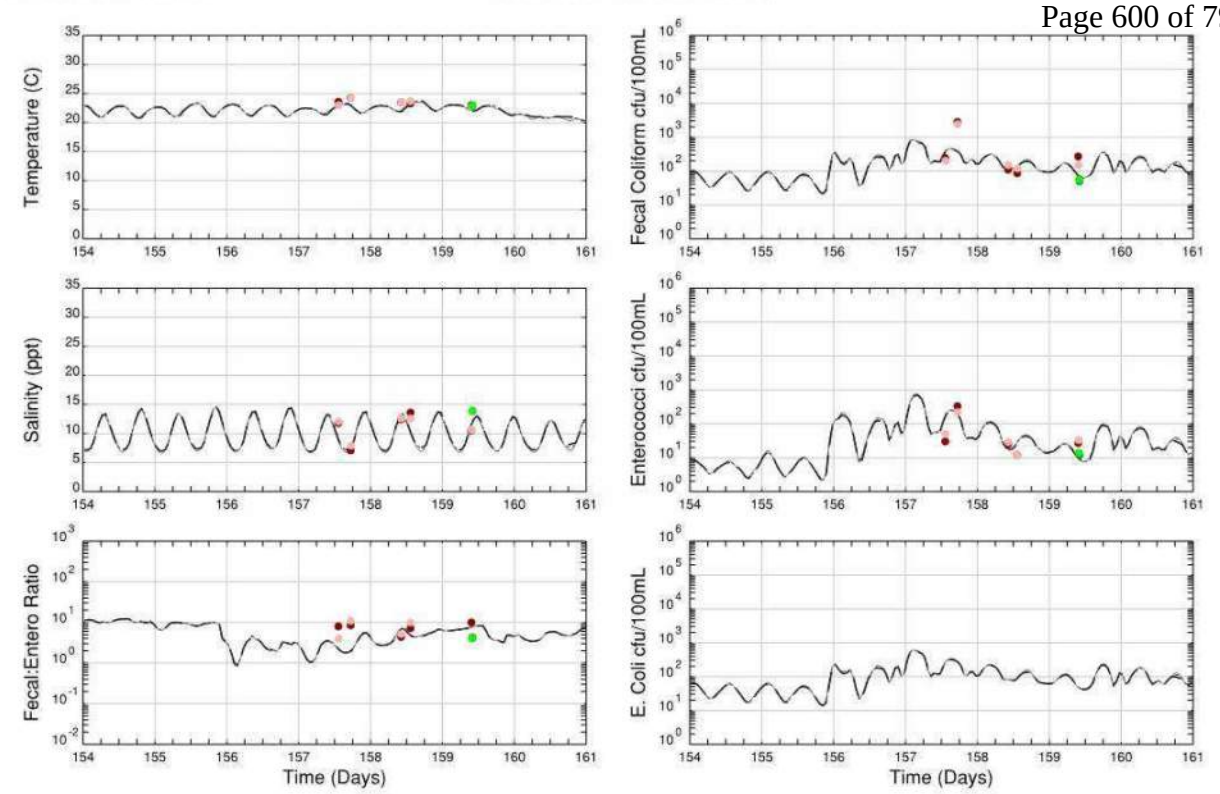
SE2



IALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Hackensack River & Tributaries
Hackensack River

Station: 14 Event 1 (June 3-9)



Model = 2016
Data = 2016

Model at Surface
Model at Mid-Depth
Model at Bottom

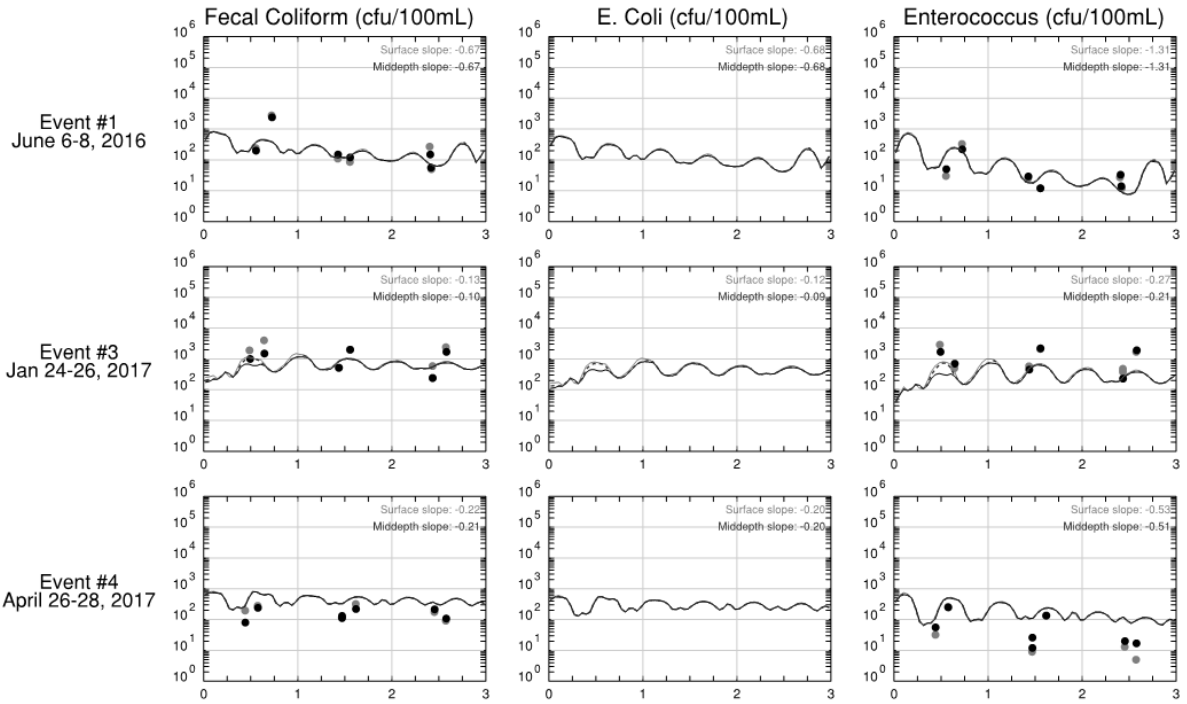
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

TERIALS.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Hackensack River & Tributaries
Hackensack River

SE2

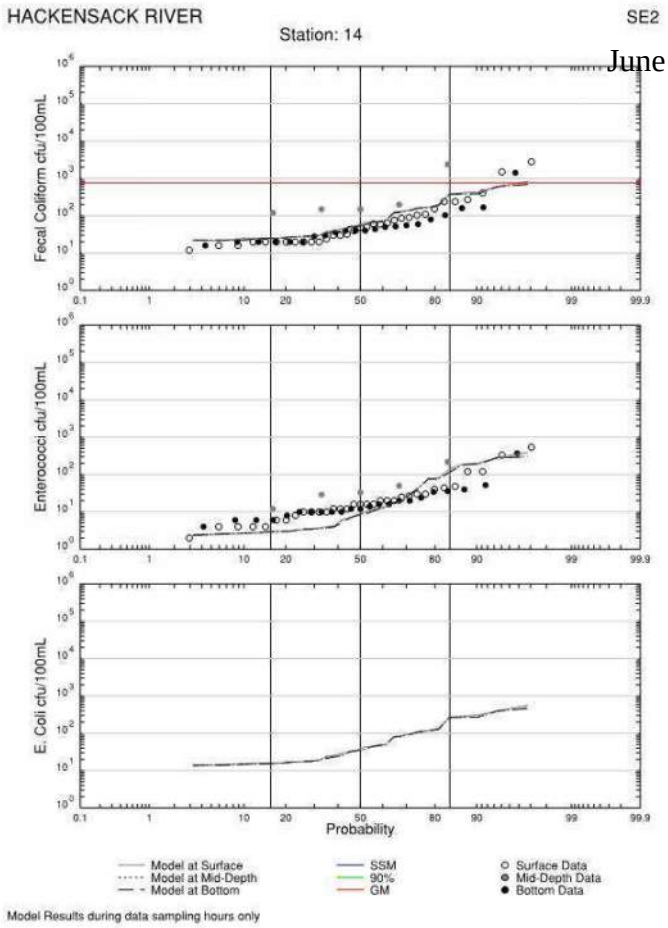
Station: 14



Model Result Surface Layer
Model Result Mid-depth Layer
Model Result Bottom Layer
Surface Data
Mid-depth/Bottom Data

Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00300, KCBC=0.2

RIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
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Y, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Assessment of Model's Ability to Calculate Attainment

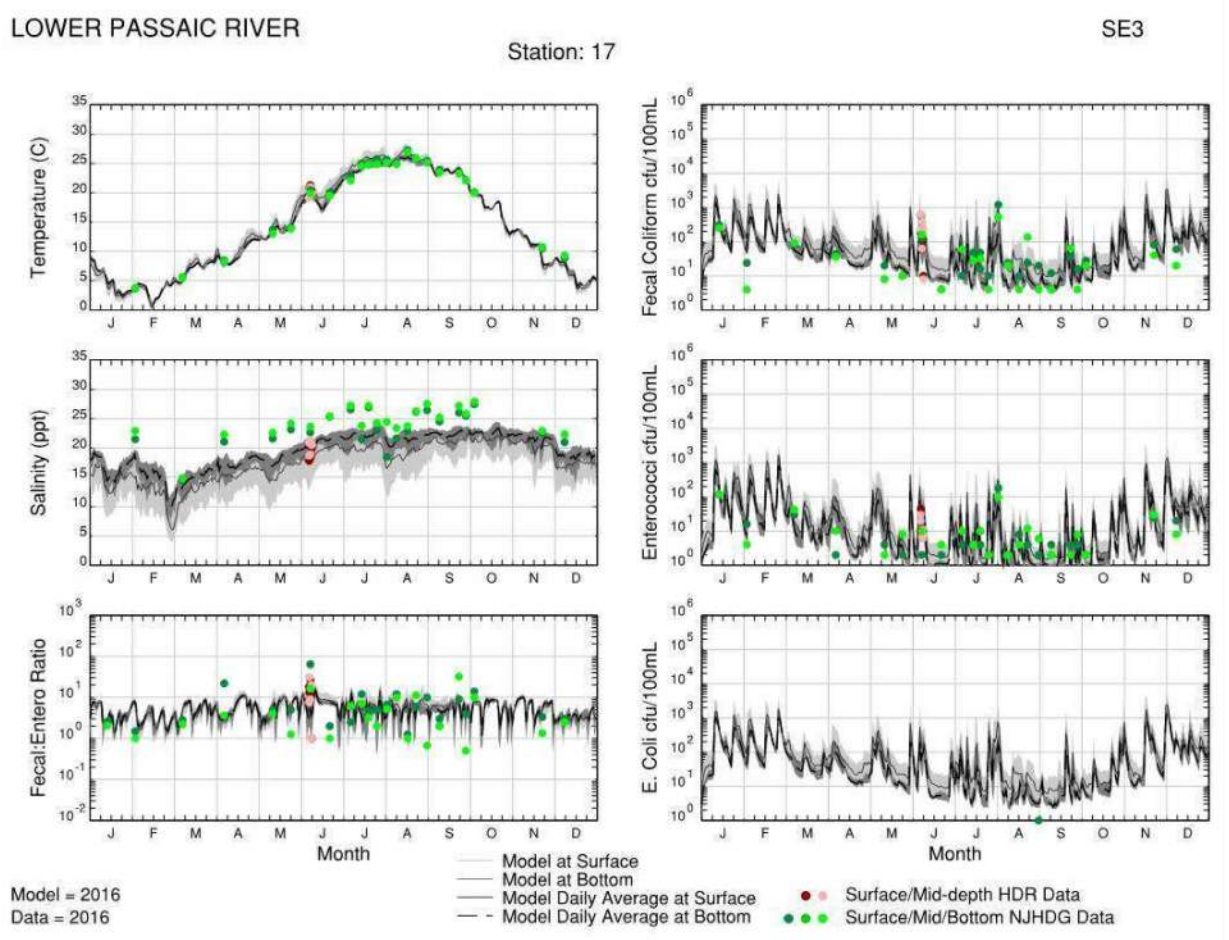
- Hackensack River – GM Criterion – Mid-depth
- Do Data and Model Exceed Criterion (Using imaginary 30-day period)?

Station	Class	Criterion	2016 Data	2016 Model	2017 Data	2017 Model
13	SE1	35	N	N	N	N
B1	SE1	35	Y	Y	Y	Y
B2	SE1	35	Y	Y	Y	Y
B11	SE2	770	N	N	-	-
B3	SE2	770	N	N	-	-
B4	SE2	770	N	N	-	-
14	SE2	770	-	-	N	N
B7	SE2	770	N	N	-	-
15	SE2	770	N	N	N	N
16	SE3	1500	-	-	-	-

Model Calibration



TIVE MATERIALS.

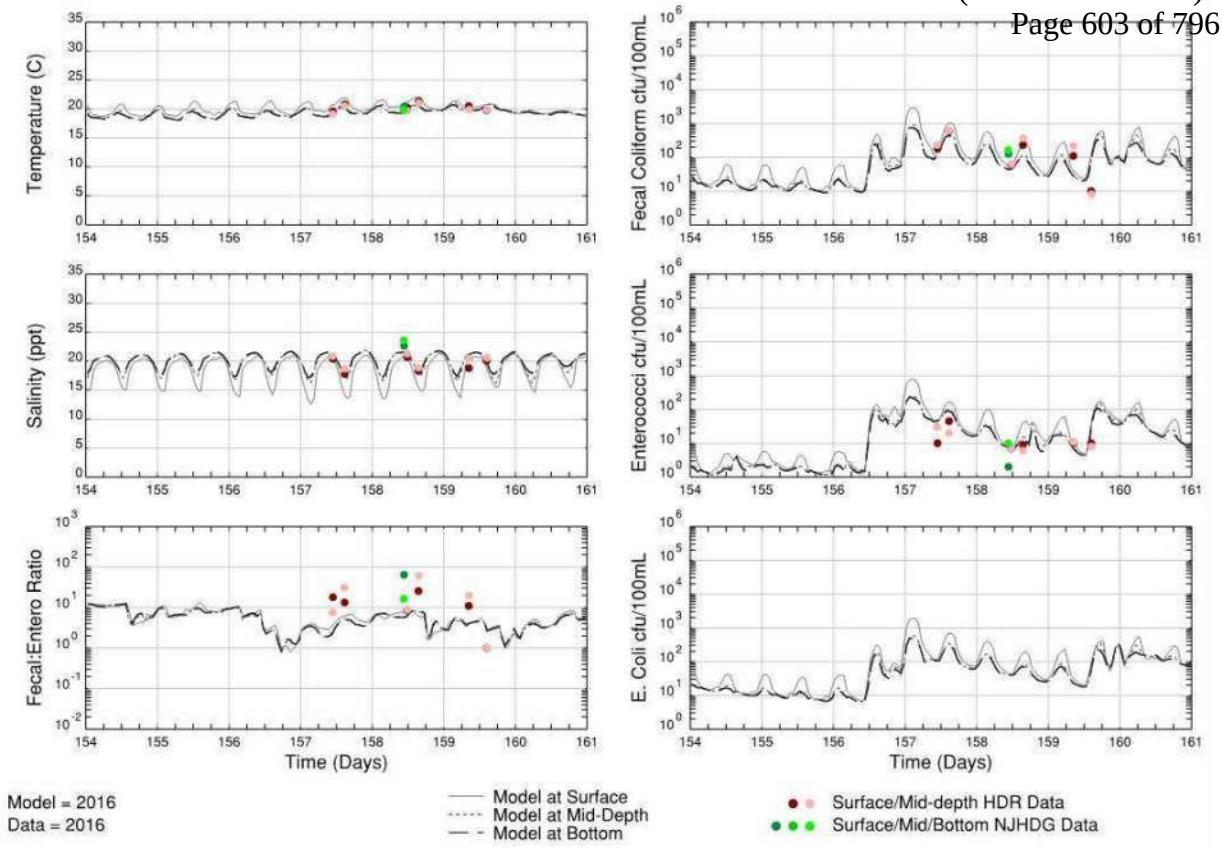


INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Newark Bay & Tributaries
Newark Bay

Station: 17 Event 1 (June 3-9)

SE3

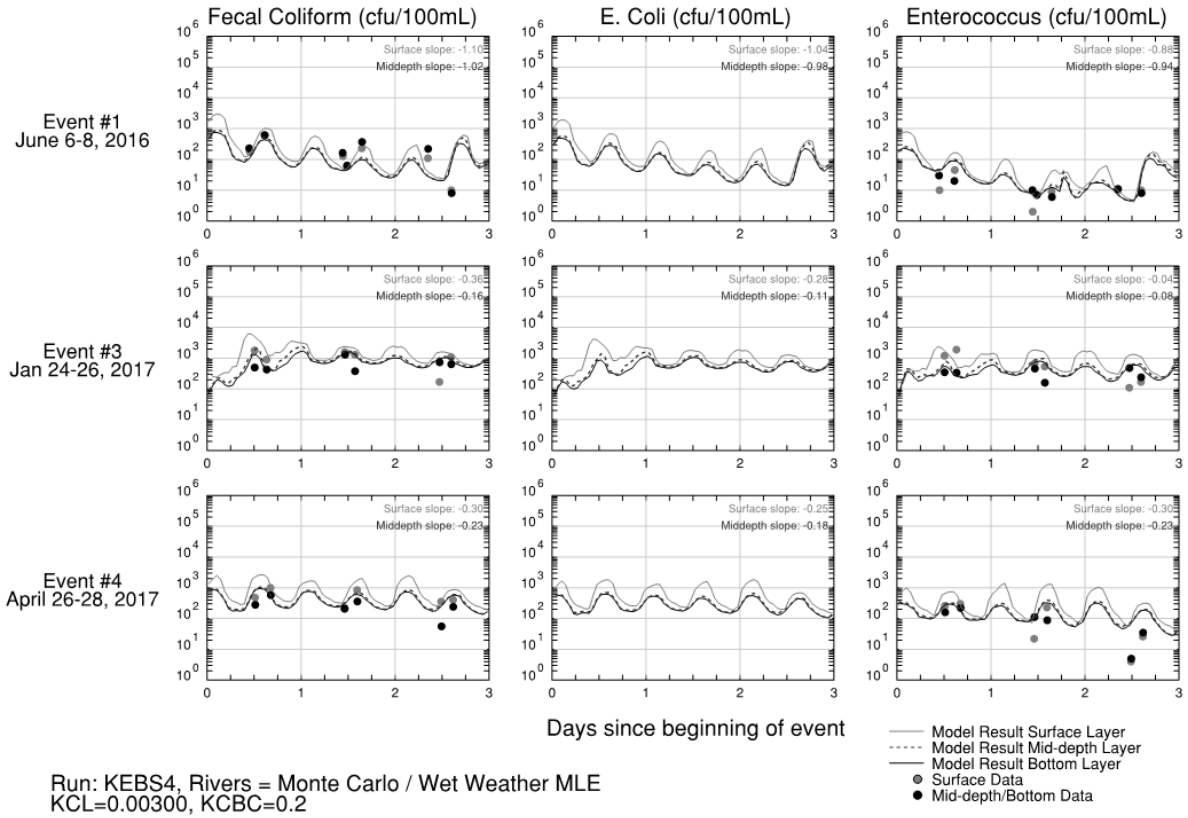


NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

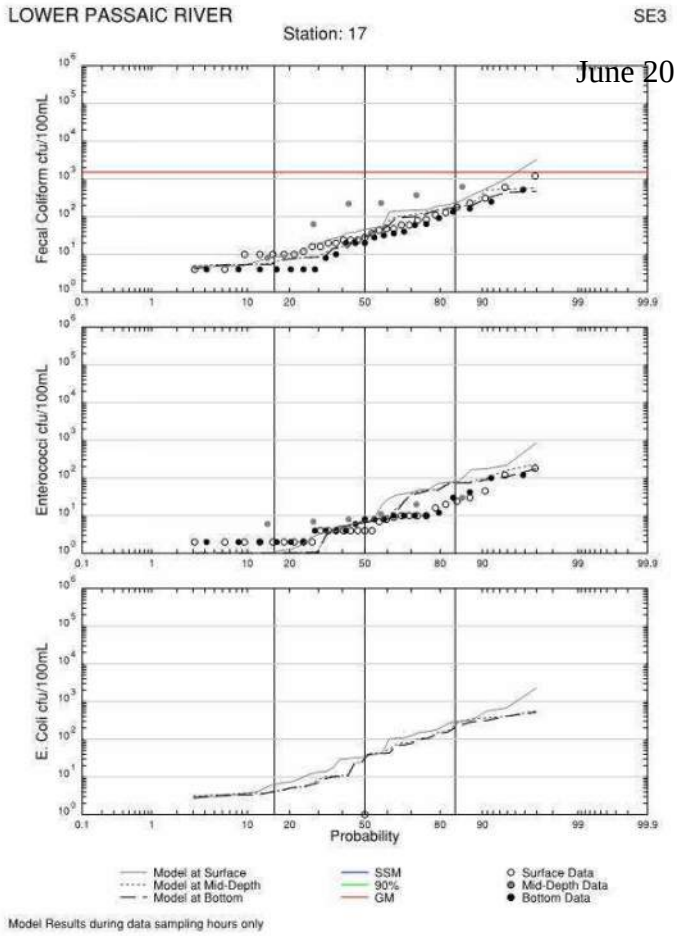
Newark Bay & Tributaries
Newark Bay

Station: 17

SE3

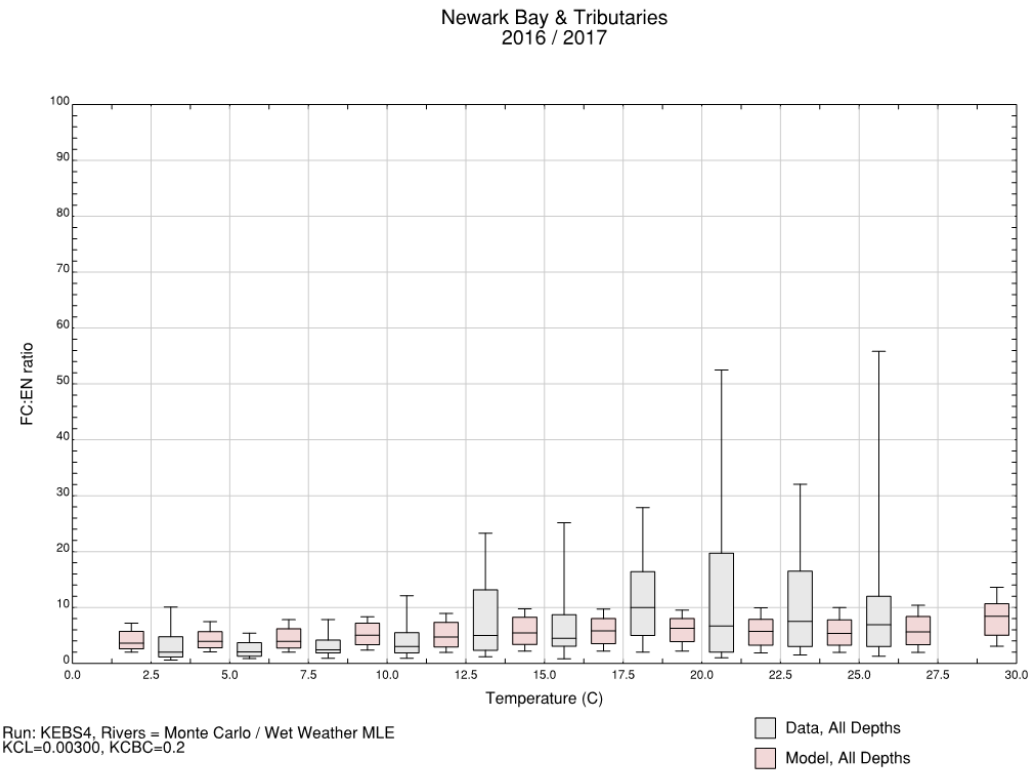


OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.



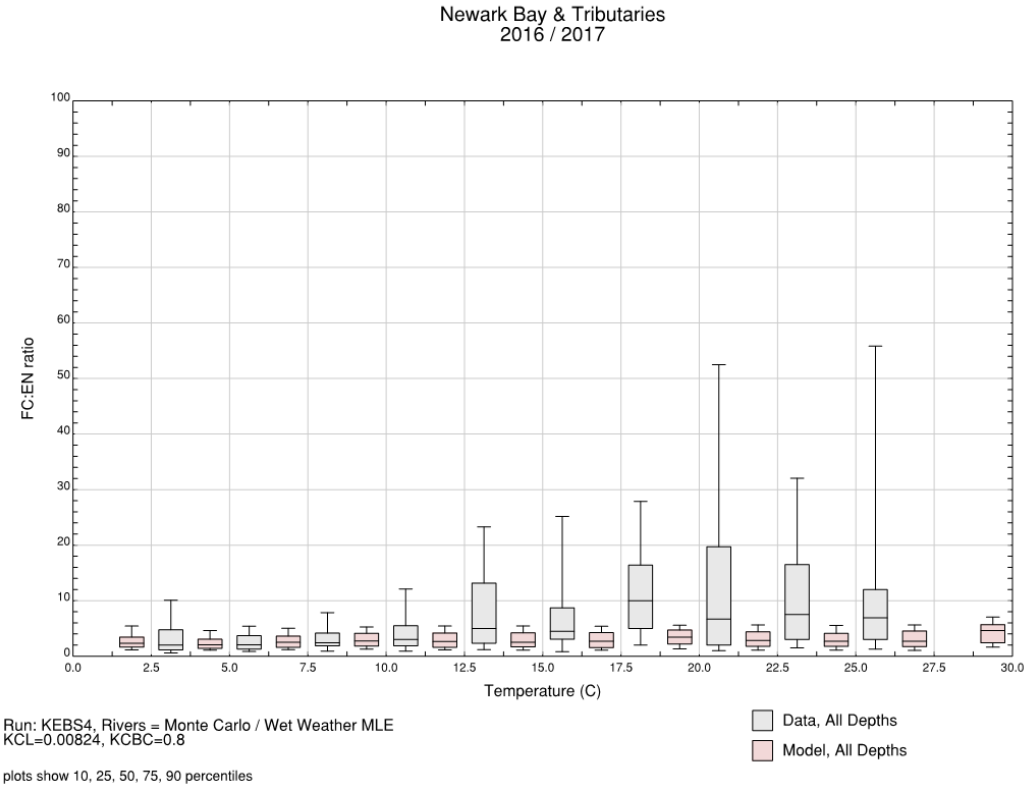
INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Model Calibration



INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
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Model Calibration



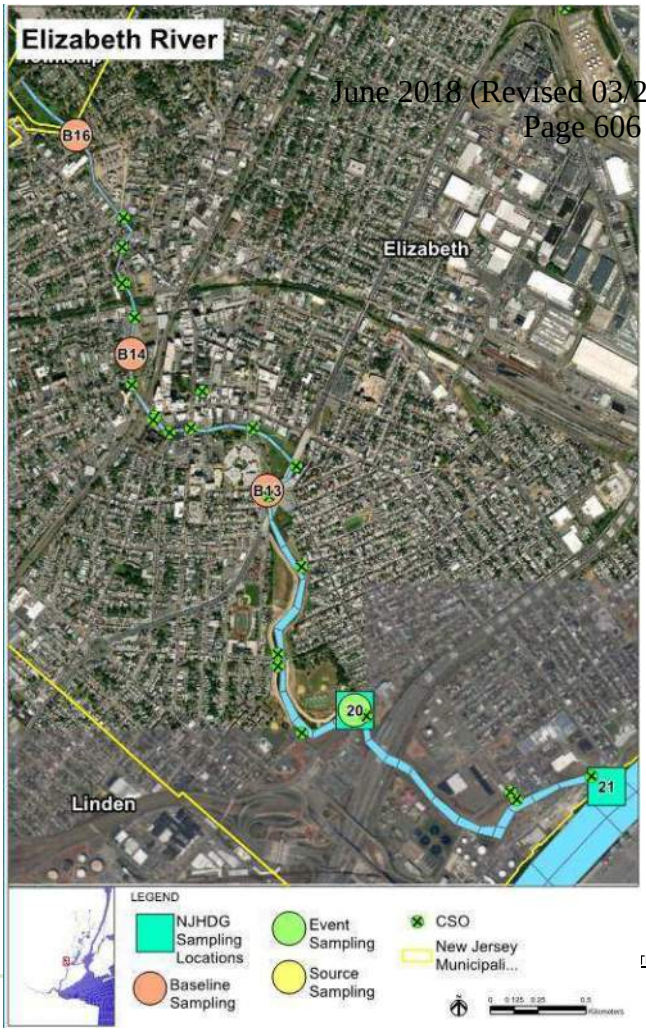
INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Assessment of Model's Ability to Calculate Attainment

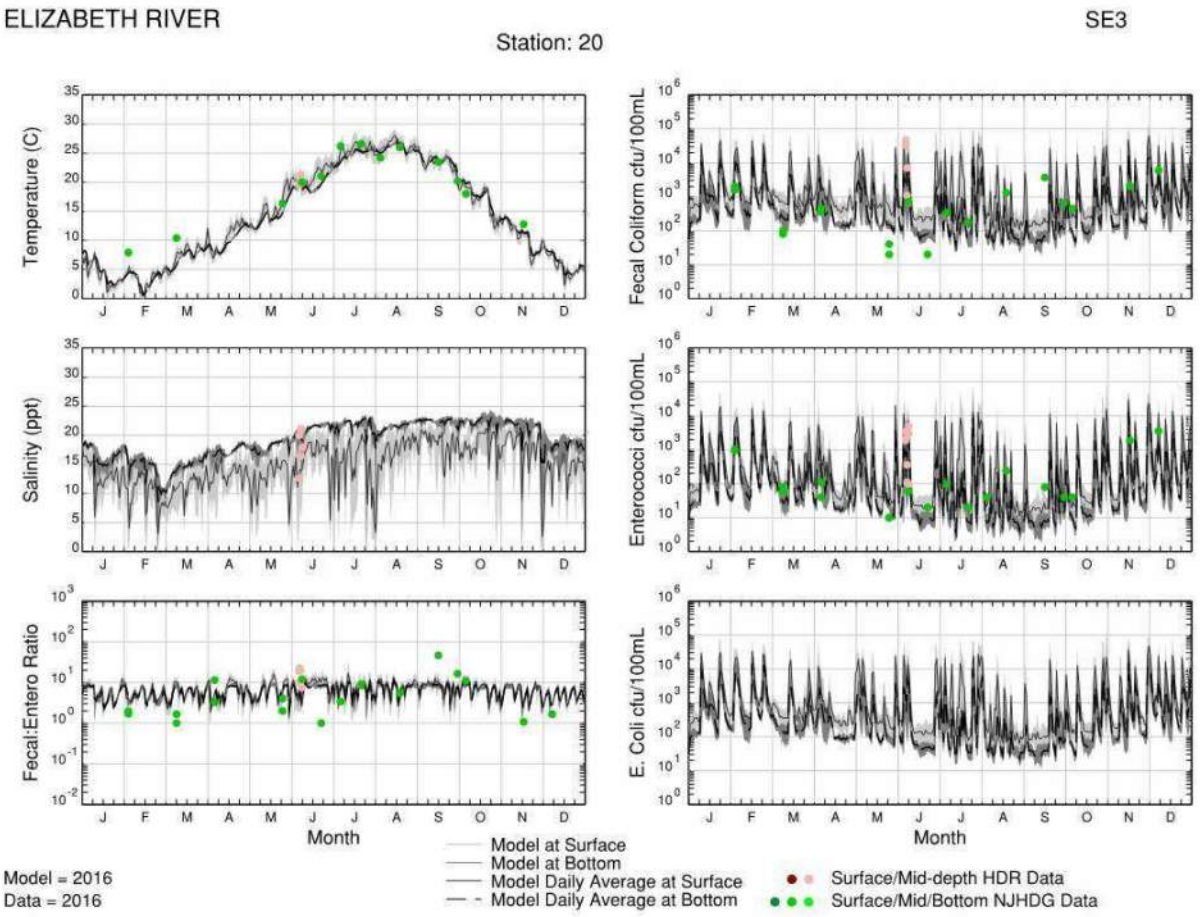
- Newark Bay – GM Criterion – Mid-depth
- Do Data and Model Exceed Criterion (Using imaginary 30-day period)?

Station	Class	Criterion	2016 Data	2016 Model	2017 Data	2017 Model
17	SE3	1500	N	N	N	N
B10	SE3	1500	N	N	-	-
18	SE3	1500	N	N	N	N
B17	SE3	1500	-	-	-	-
19	SE3	1500	N	N	N	N

Model Calibration



IVE MATERIALS.

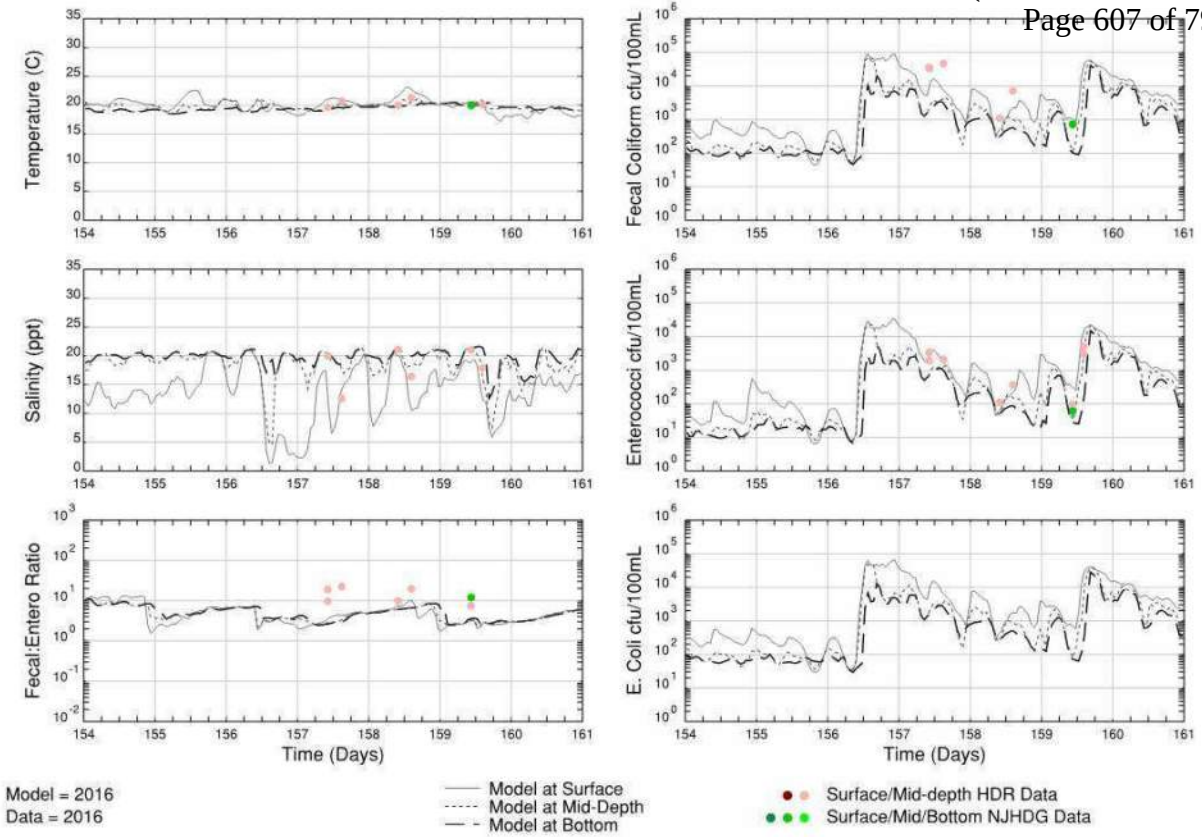


ILS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Newark Bay & Tributaries
Elizabeth River

Station: 20 Event 1 (June 3-9)

SE3

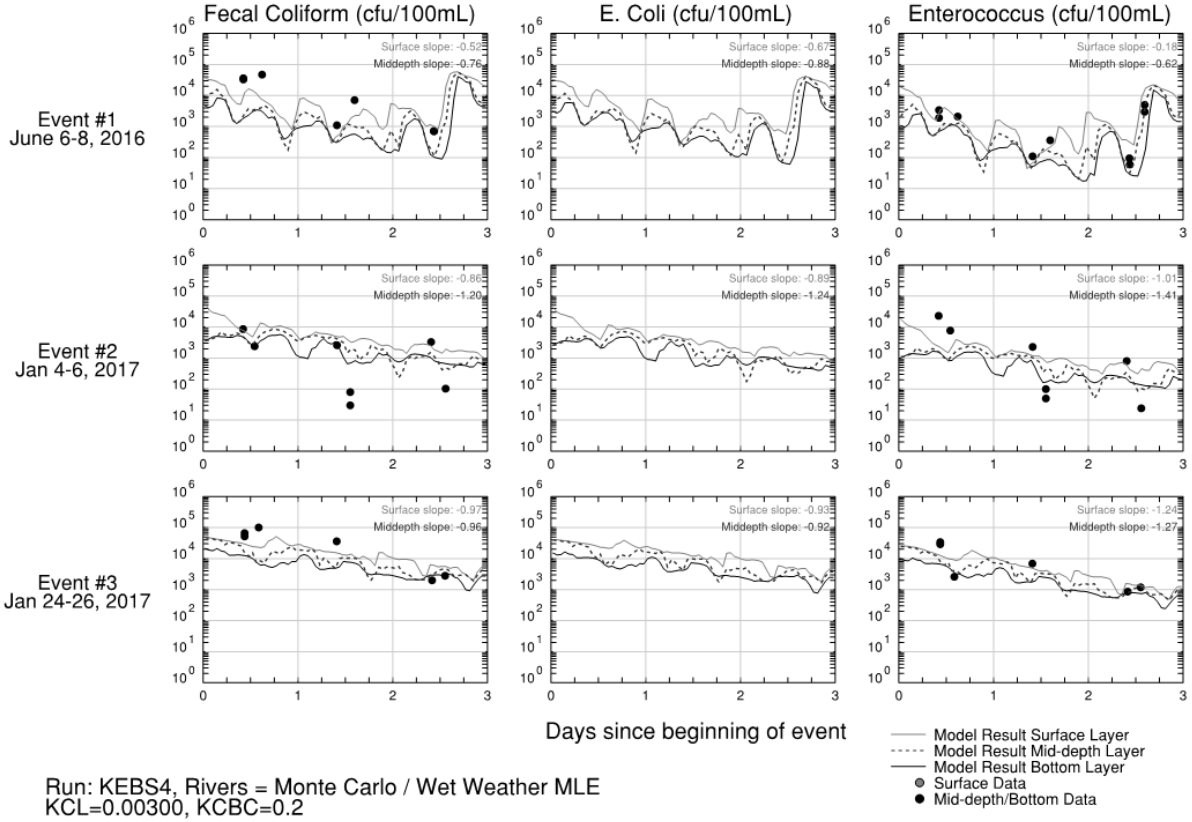


INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Newark Bay & Tributaries
Elizabeth River

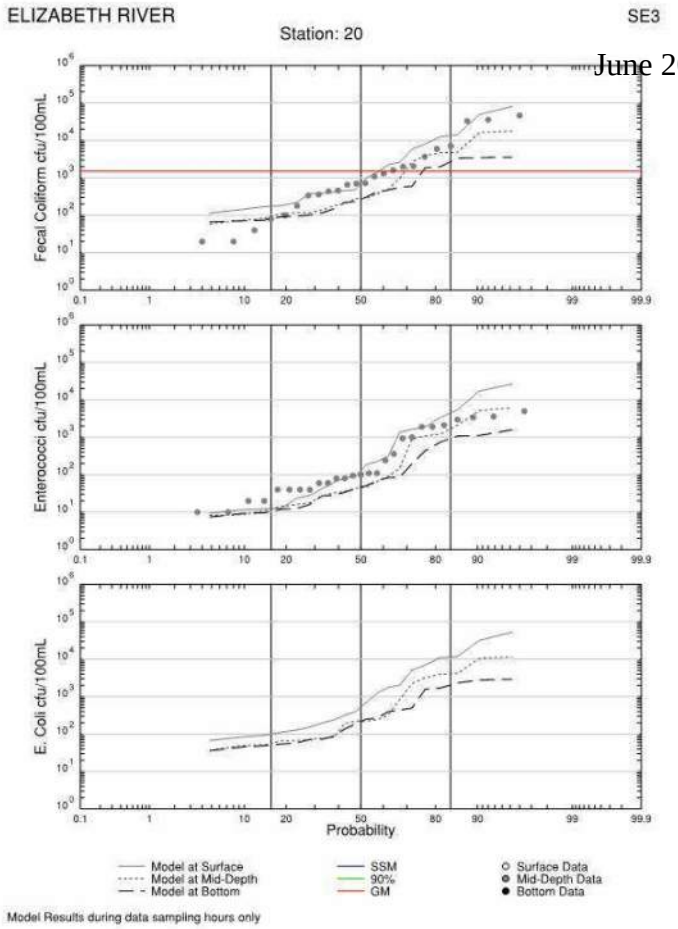
Station: 20

SE3



Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00300, KCBC=0.2

INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Assessment of Model's Ability to Calculate Attainment

- Elizabeth River – GM Criterion – Mid-depth
- Do Data and Model Exceed Criterion (Using imaginary 30-day period)?

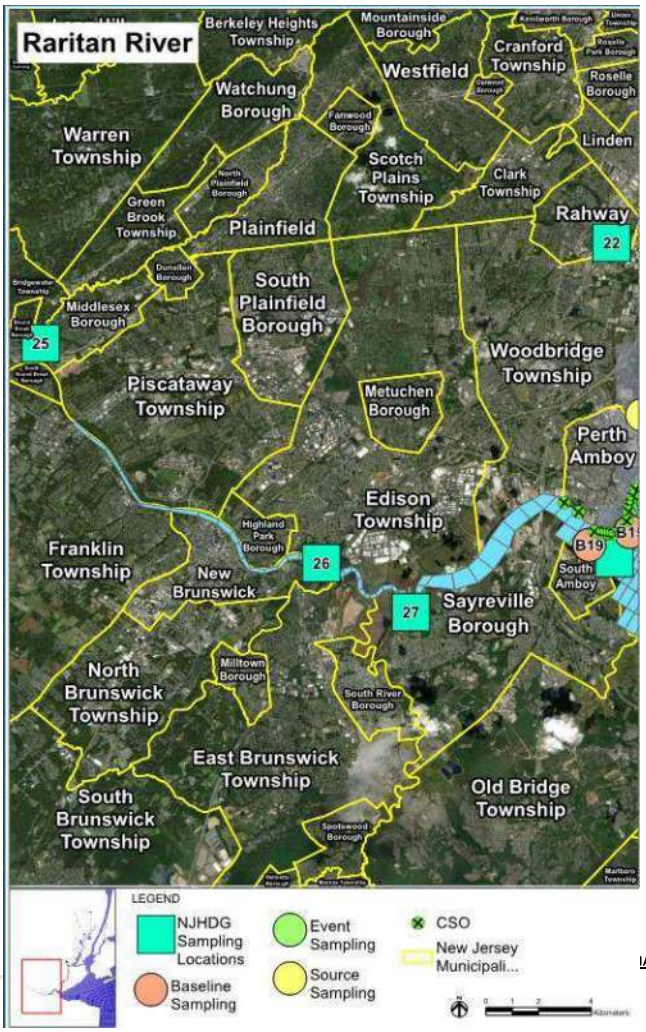
Station	Class	Criterion	2016 Data	2016 Model	2017 Data	2017 Model
B16	FW2	126	Y	Y	-	-
B14	FW2	126	Y	Y	-	-
B13	SE3	1500	Y	N	-	-
20	SE3	1500	N	N	Y	Y

Assessment of Model's Ability to Calculate Attainment

- Elizabeth River – SSM Criterion – Mid-depth
- Percent of Time Data and Model Exceed Criterion (Using imaginary 30-day period)

Station	Class	Criterion	2016 Data	2016 Model	**diff**
B16	FW2	235	91.1	80.8	**10.3**
B14	FW2	235	86.6	70.7	**15.9**

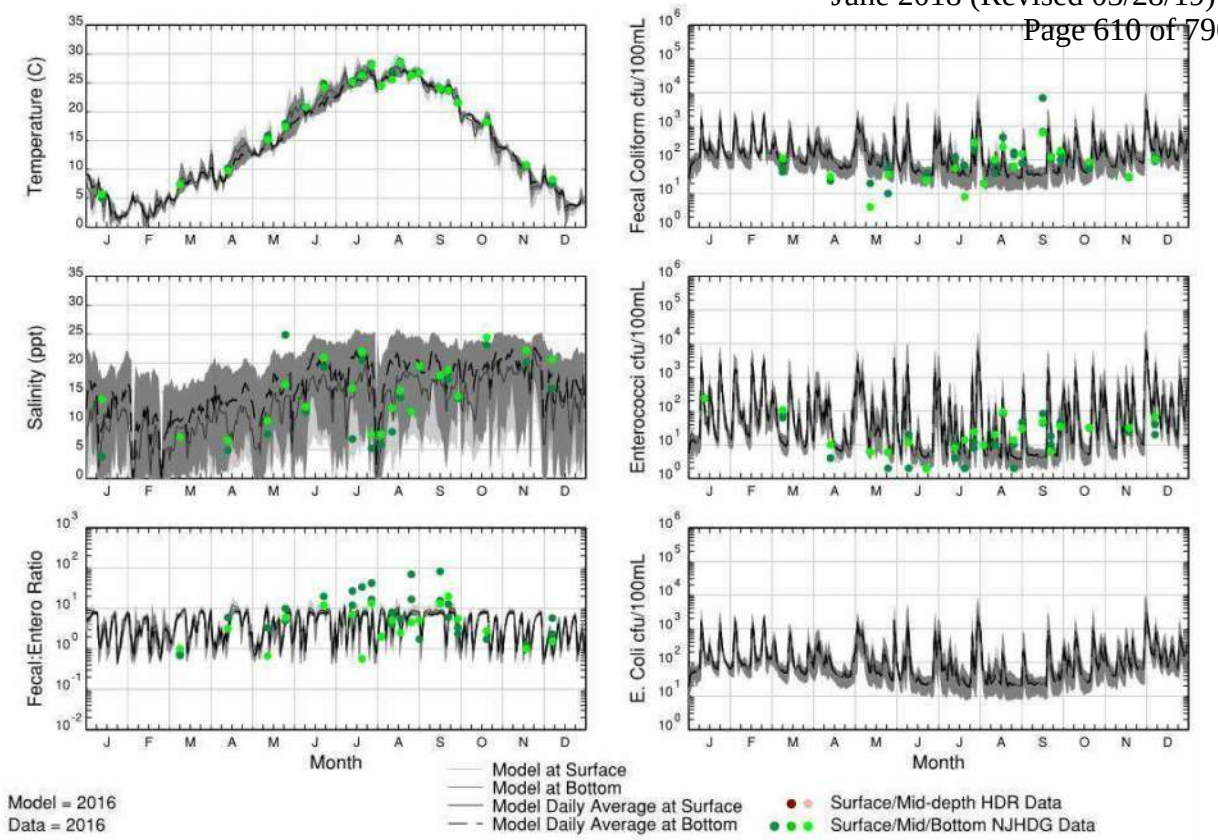
Model Calibration



RARITAN RIVER

Station: 27

SE1

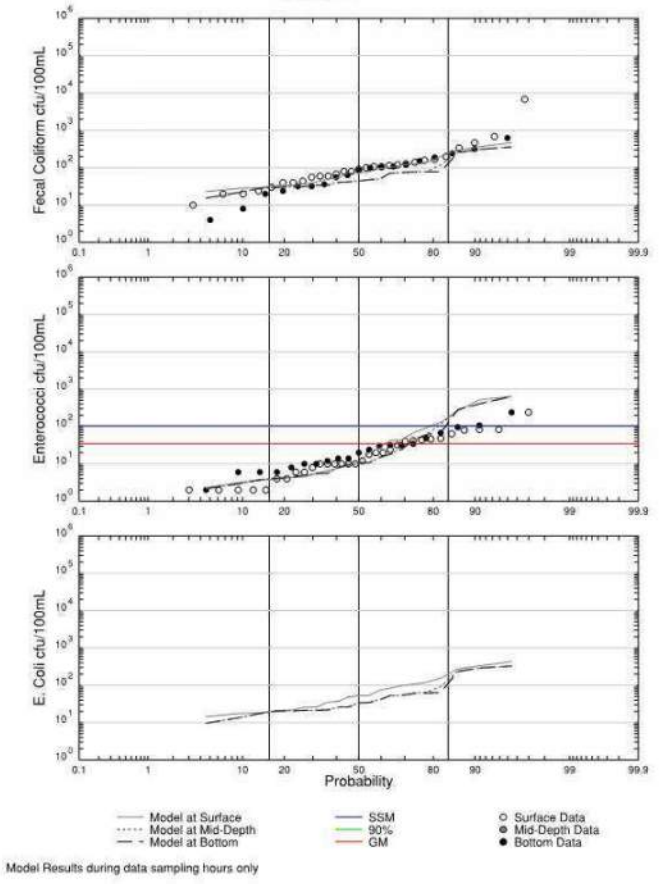


INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
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OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

RARITAN RIVER

Station: 27

SE1

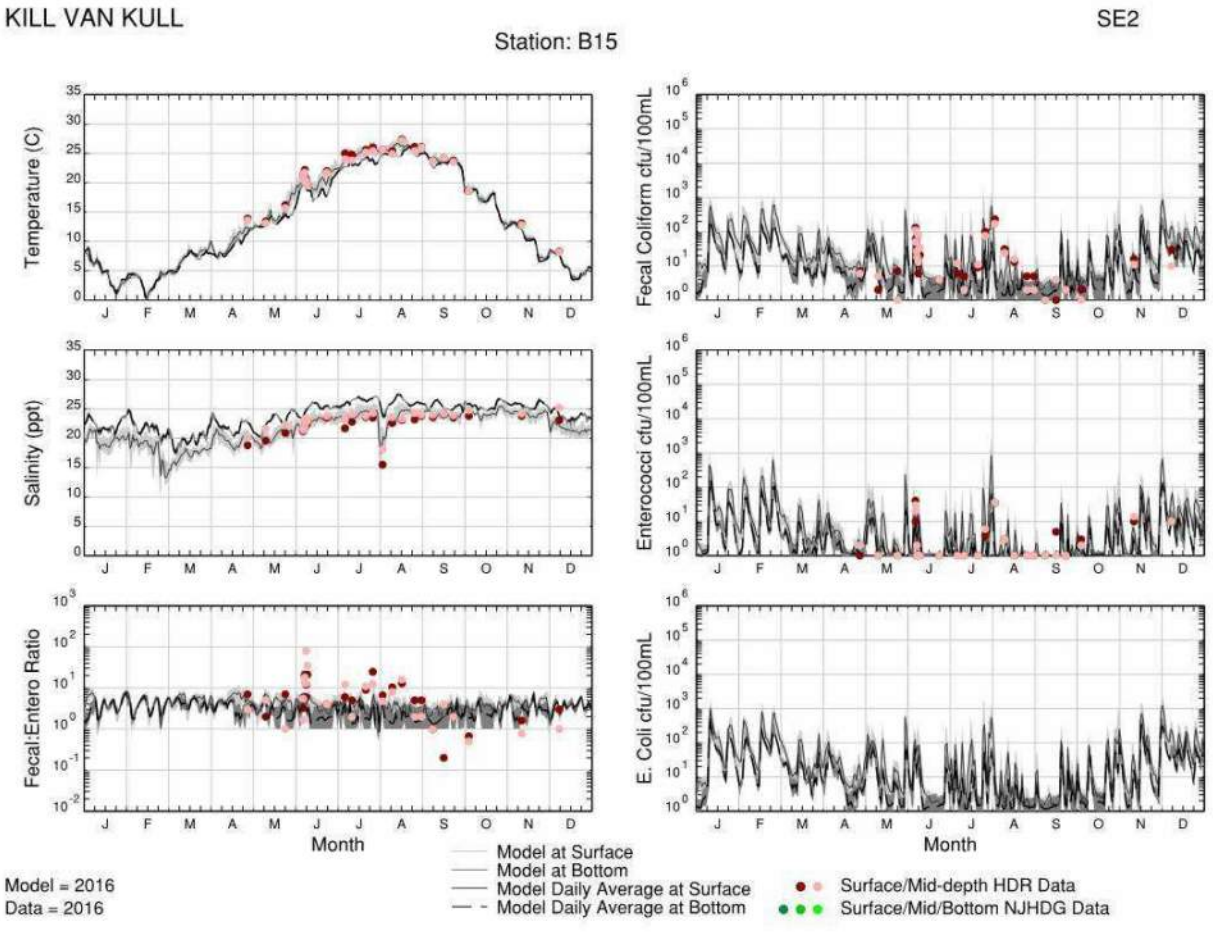


INTERAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Model Calibration



/E MATERIALS.

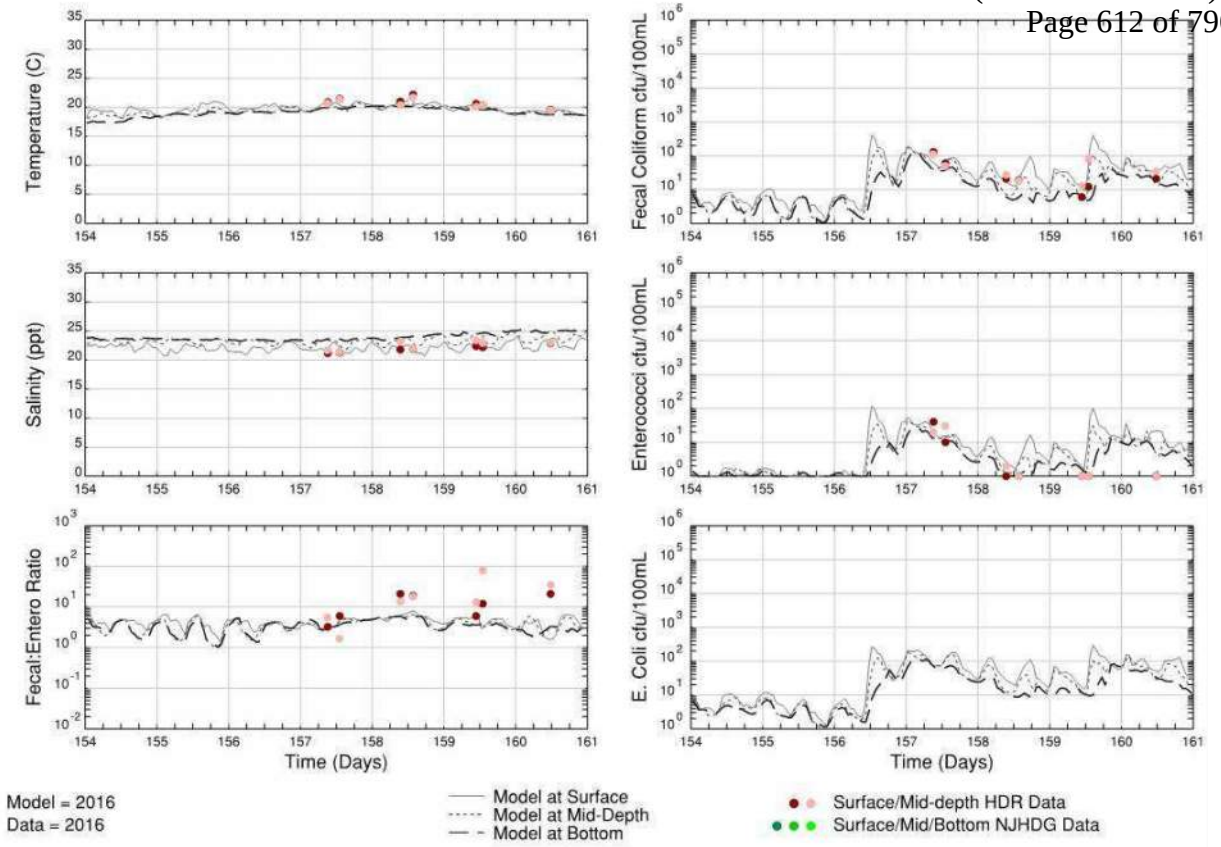


NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

Station: B15 Event 1 (June 3-9)

SE2

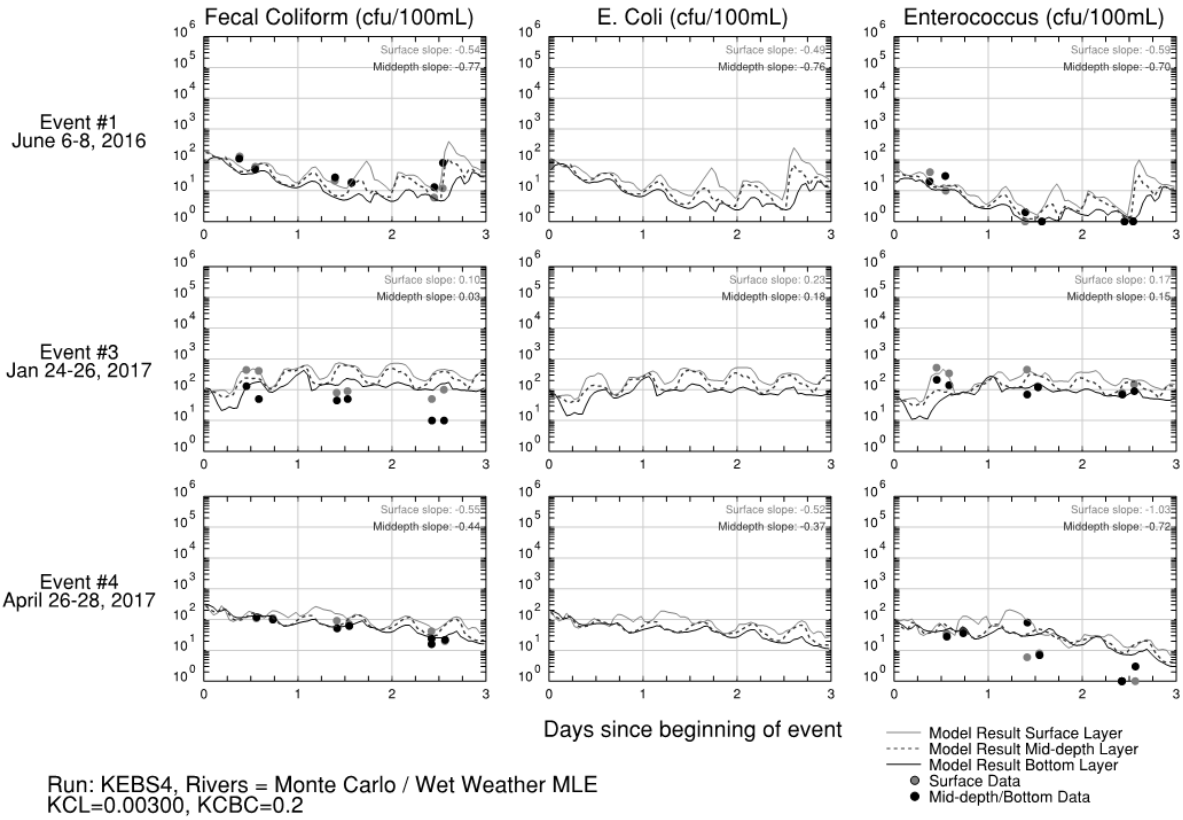


RIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.

Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

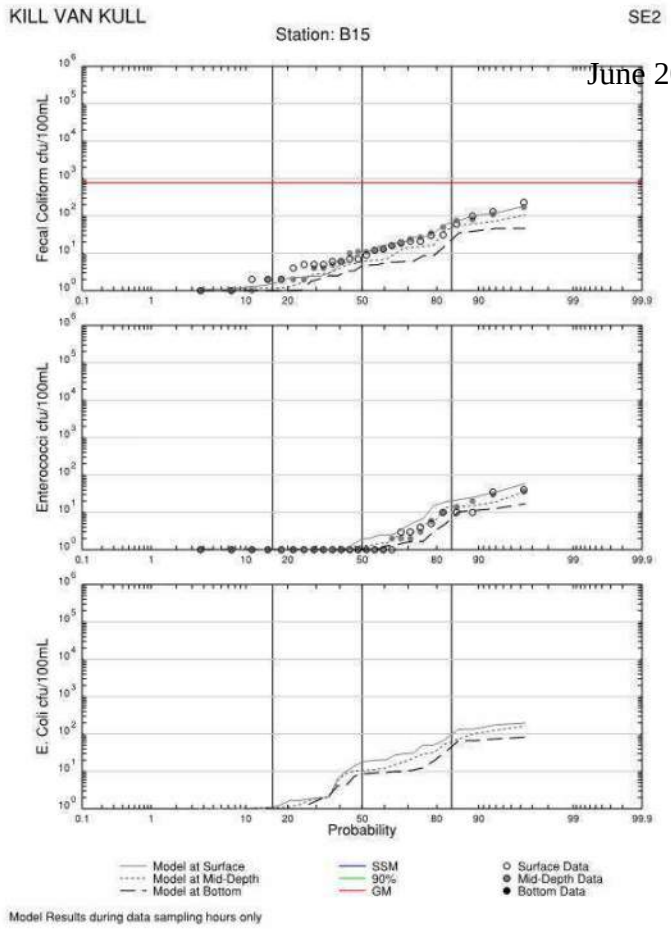
Station: B15

SE2



Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00300, KCBC=0.2

INTRAAGENCY ADVISORY, CONSULTATIVE AND/OR DELIBERATIVE MATERIALS.
NOT SUBJECT TO DISCLOSURE UNDER N.J.S.A 47:1A-1 ET SEQ.
OR THE COMMON LAW RIGHT TO INSPECT PUBLIC RECORDS.



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Assessment of Model's Ability to Calculate Attainment

- Arthur Kill– GM Criterion – Surface
- Do Data and Model Exceed Criterion (Using imaginary 30-day period)?

Station	Class	Criterion	2016 Data	2016 Model	2017 Data	2017 Model
21	SE3	1500	N	N	N	N
23	SE3	1500	N	N	N	N
24	SE3	1500	N	N	N	N
B15	SE2	770	N	N	N	N

Assessment of Model's Ability to Calculate Attainment

- Raritan Bay – GM Criterion – Surface
- Do Data and Model Exceed Criterion (Using imaginary 30-day period)?

Station	Class	Criterion	2016 Data	2016 Model	2017 Data	2017 Model
28	Shellfish	35	N	N	N	N
29	Shellfish	35	N	N	N	N
30	Shellfish	35	N	N	N	N

Model Calibration

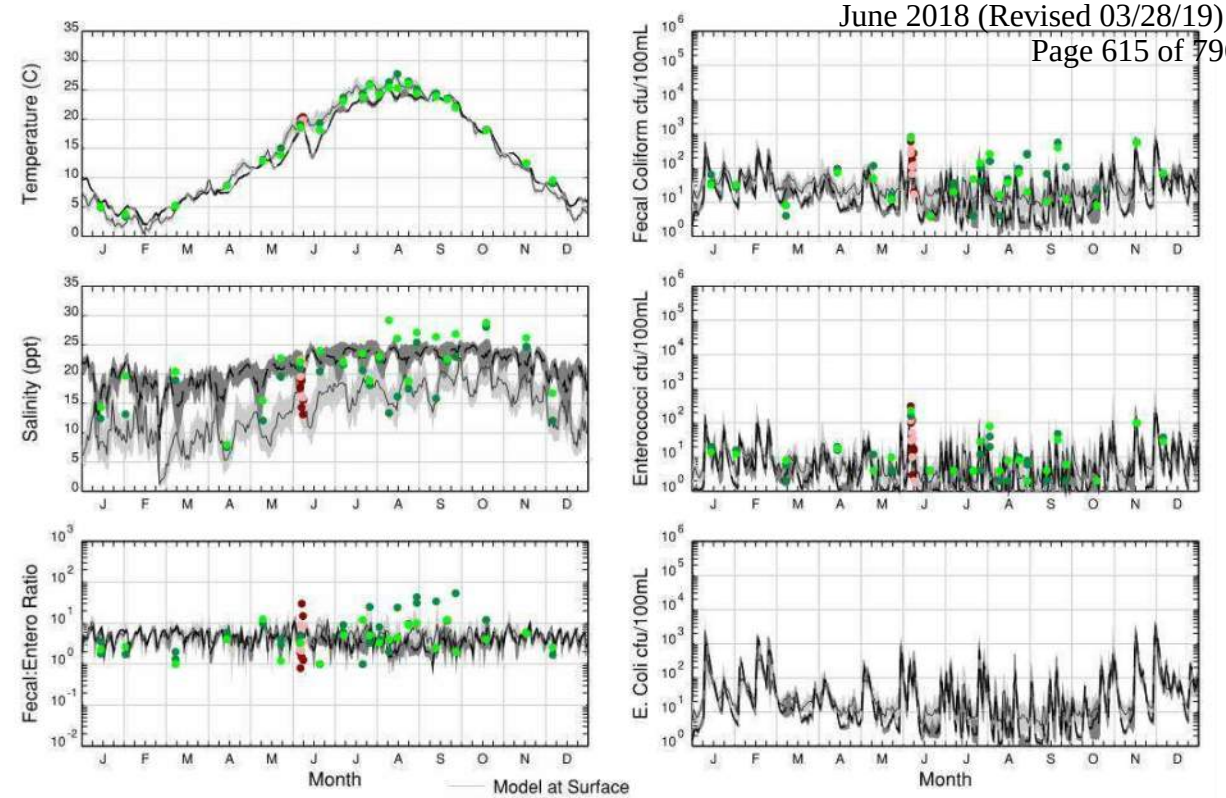


IVE MATERIALS.

HUDSON RIVER

SE2

Station: 32



Model = 2016
Data = 2016

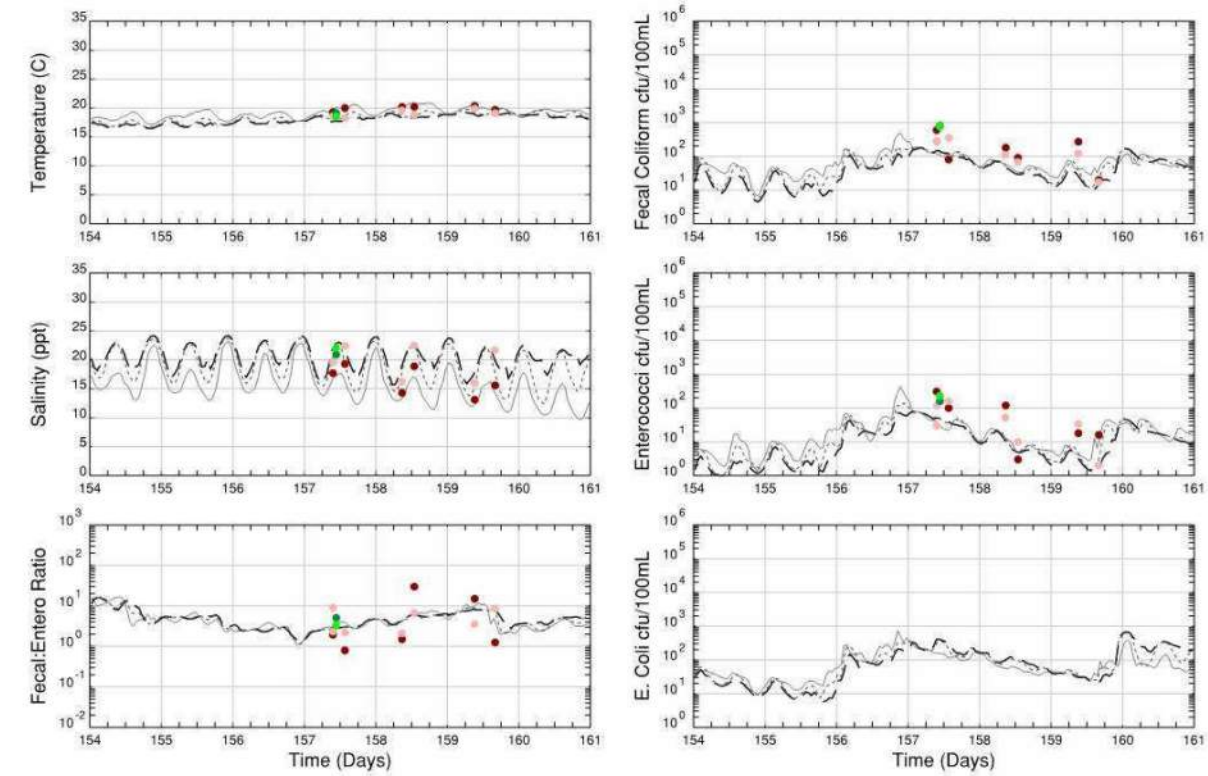
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

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Hudson River, Upper Bay
Hudson River

SE2

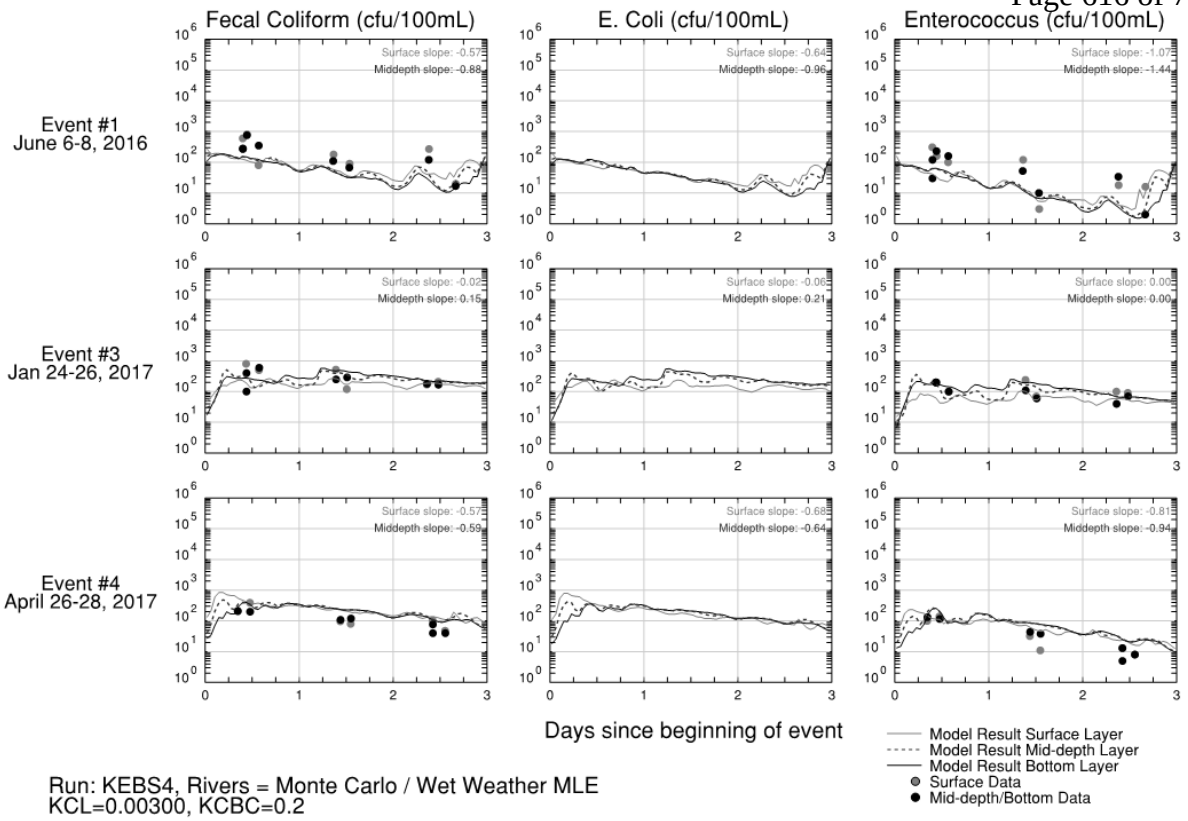
Station: 32 Event 1 (June 3-9)



Model = 2016
Data = 2016

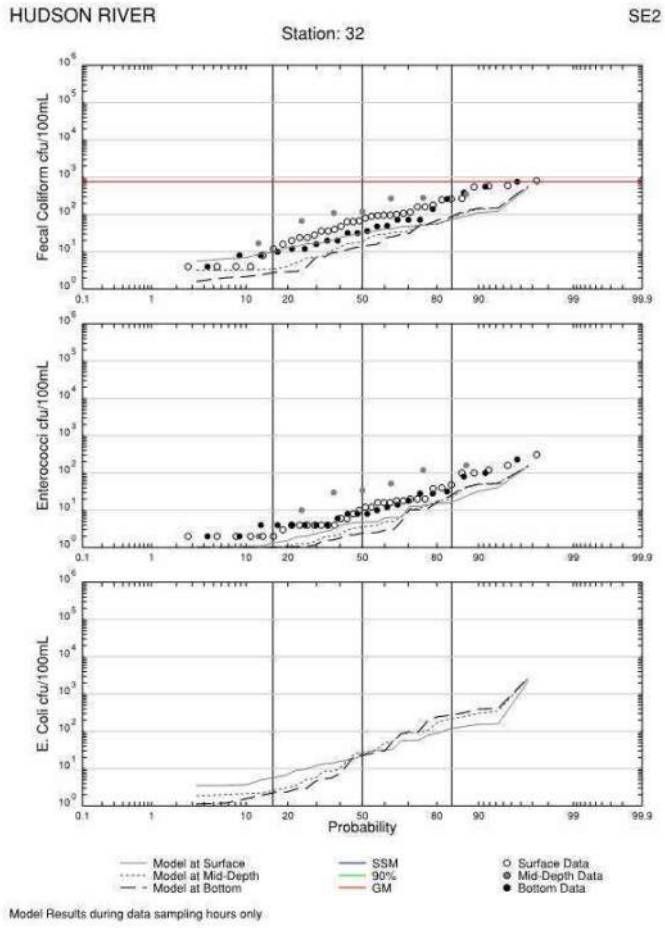
Model at Surface
Model at Mid-Depth
Model at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

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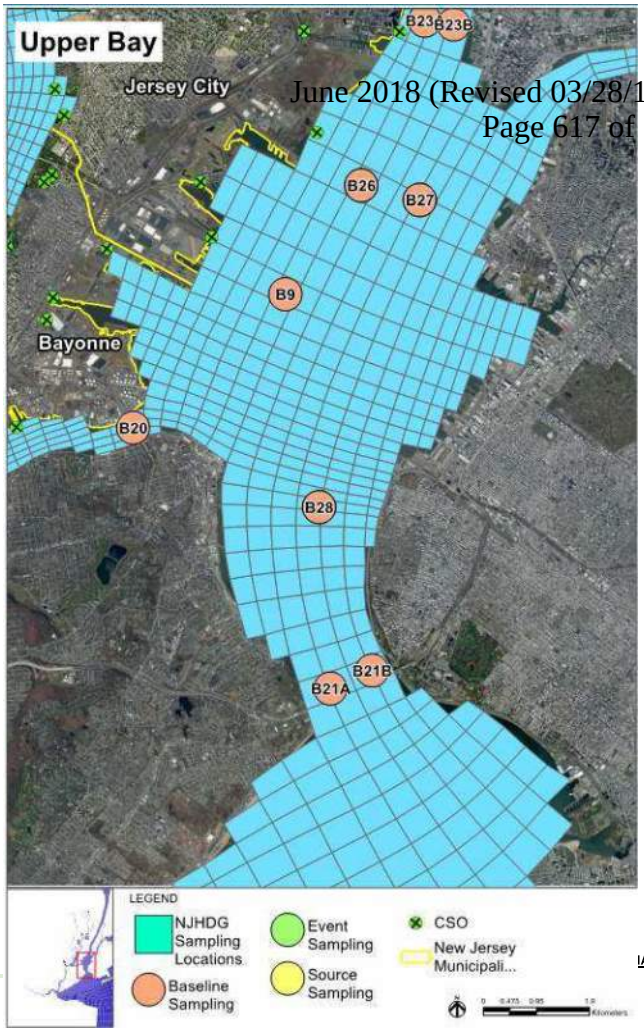
Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00300, KCBC=0.2

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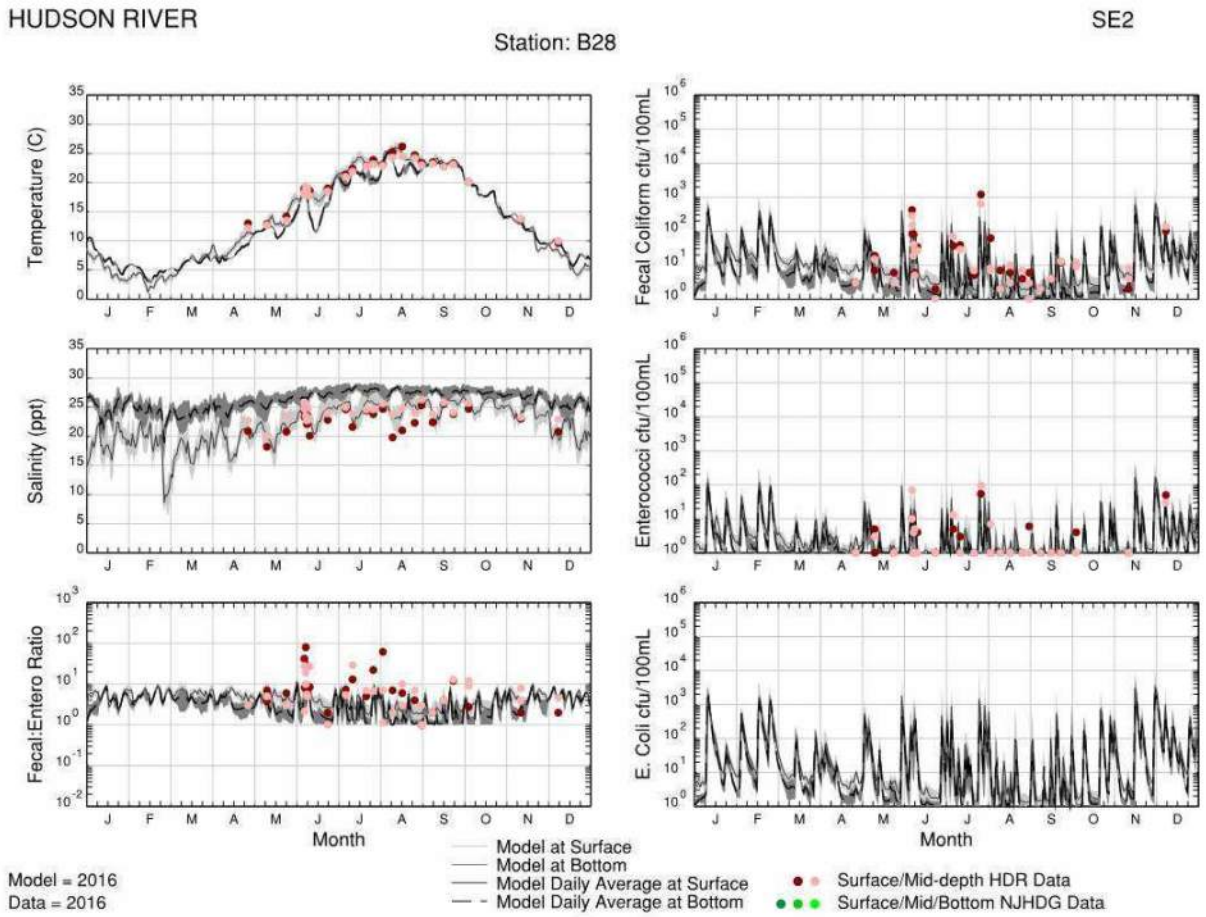


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Model Calibration



ATERIALS.

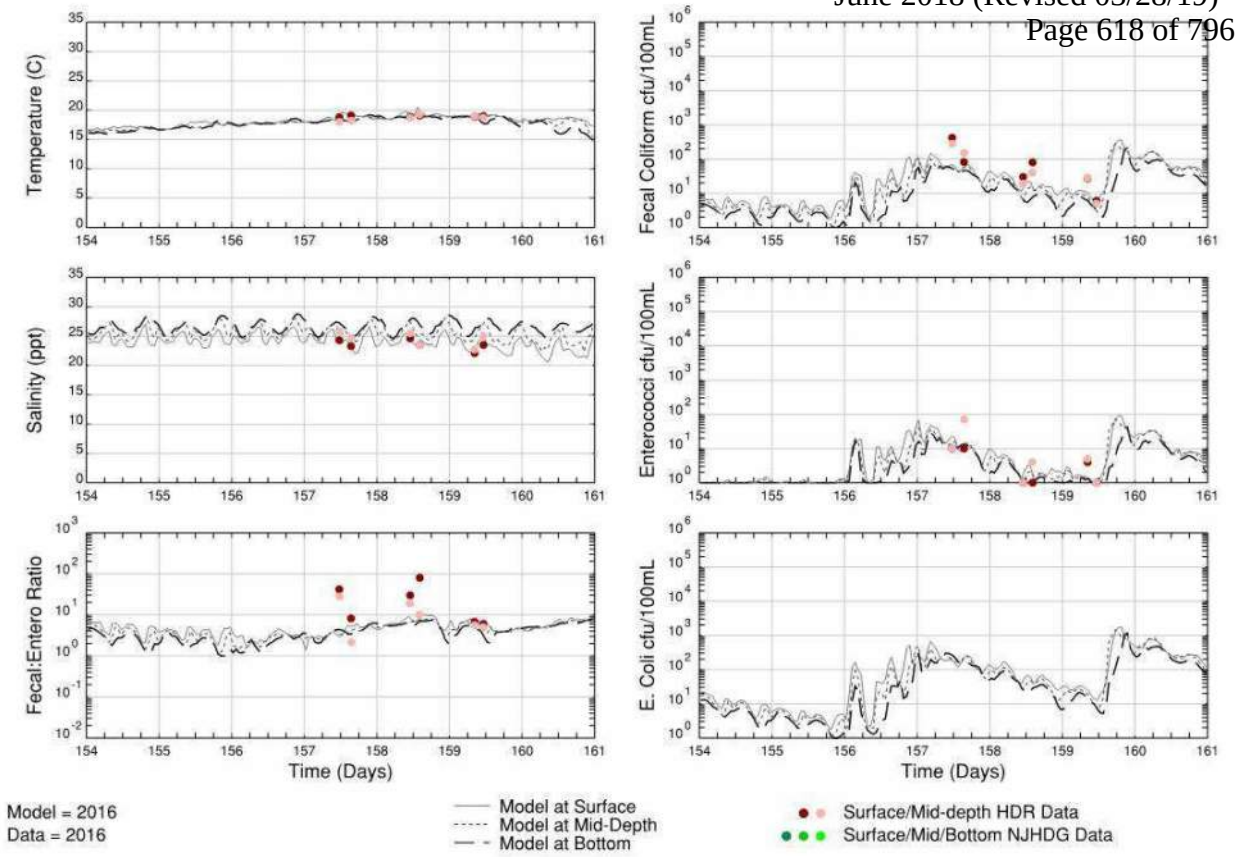


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Upper Bay

Station: B28 Event 1 (June 3-9)

SE2

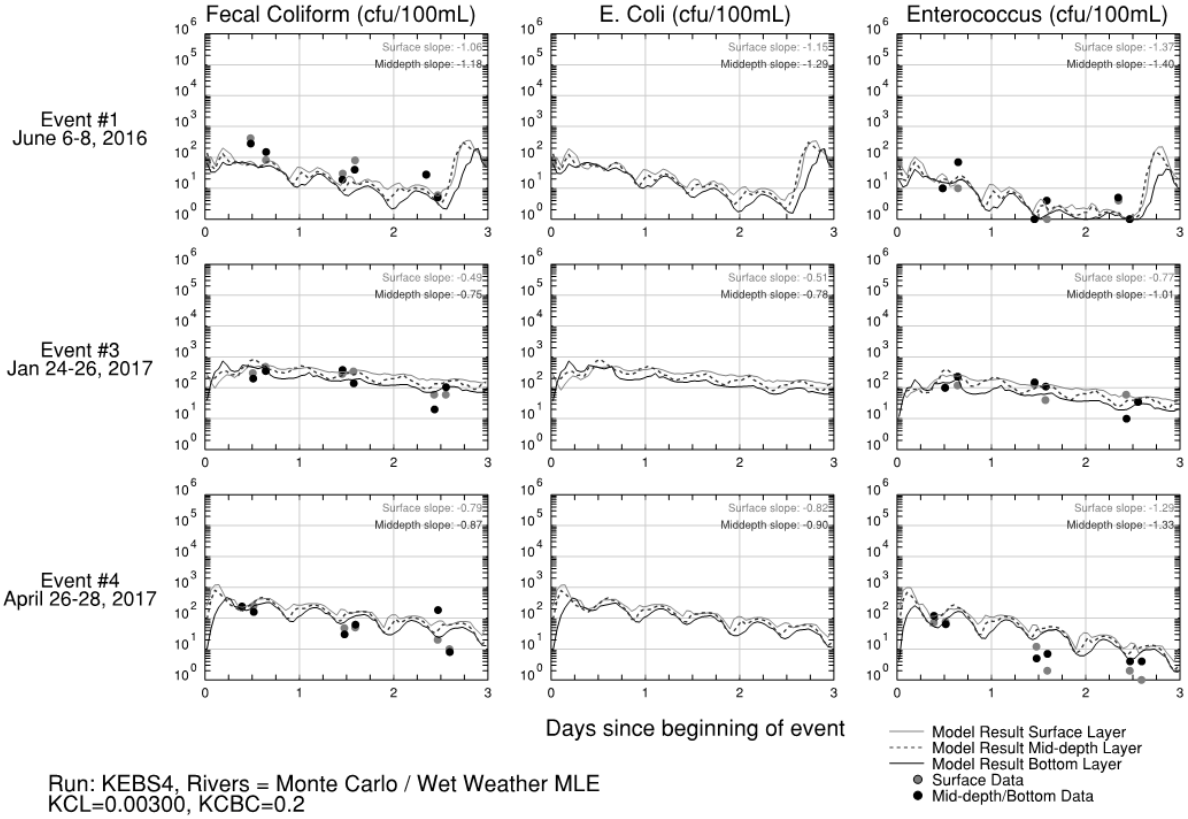


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Hudson River, Upper Bay
Upper Bay

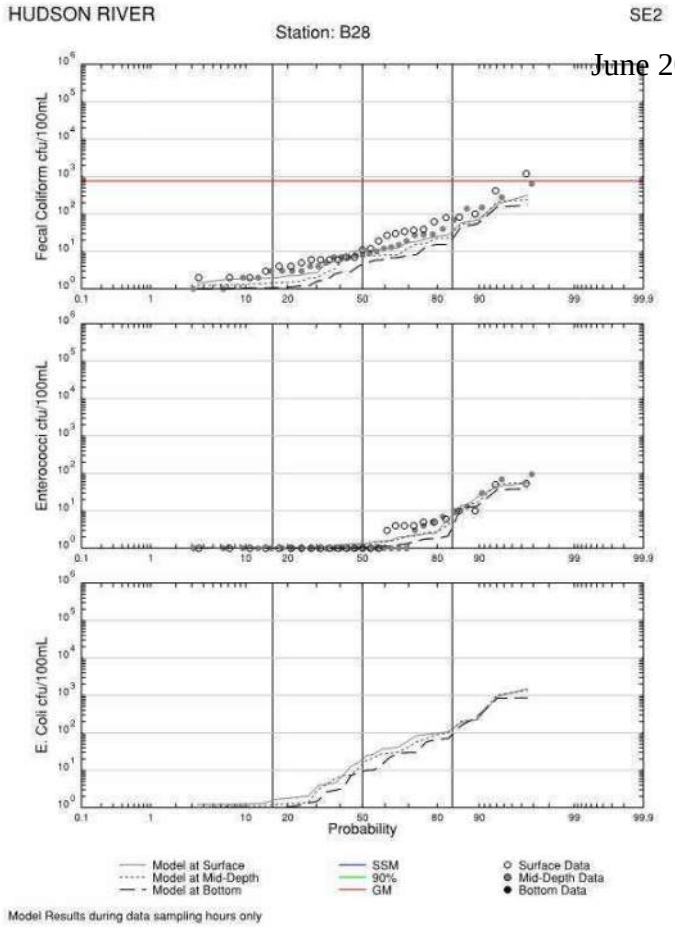
Station: B28

SE2



Run: KEBS4, Rivers = Monte Carlo / Wet Weather MLE
KCL=0.00300, KCBC=0.2

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Calibration/Validation Conclusions

- The hydrodynamic model successfully reproduces the observed temperature and salinity within the area of interest during the calibration/validation periods.
- The receiving water model generally reproduces the observed fecal coliform, enterococci and E. coli concentrations within the project area during the calibration/validation periods.
- The receiving water model, as developed, will be a useful tool for comparing water quality improvements associated with CSO control alternatives.
- The model can be used to assess attainment of water quality criteria, but is more suited to assess relative attainment of alternatives than absolute attainment.

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Projection Runs

- Baseline
- Gap Analysis (100% CSO Removal)
- Component Analysis
  - NYC Sources
  - NJ CSOs
  - NJ Non-CSOs
  - Upstream/Downstream Boundary Conditions
  - Dry-Weather Sources
- CSO Control Alternatives
  - Permittee Related (3)
  - Area-Wide
  - Final Selected Plan

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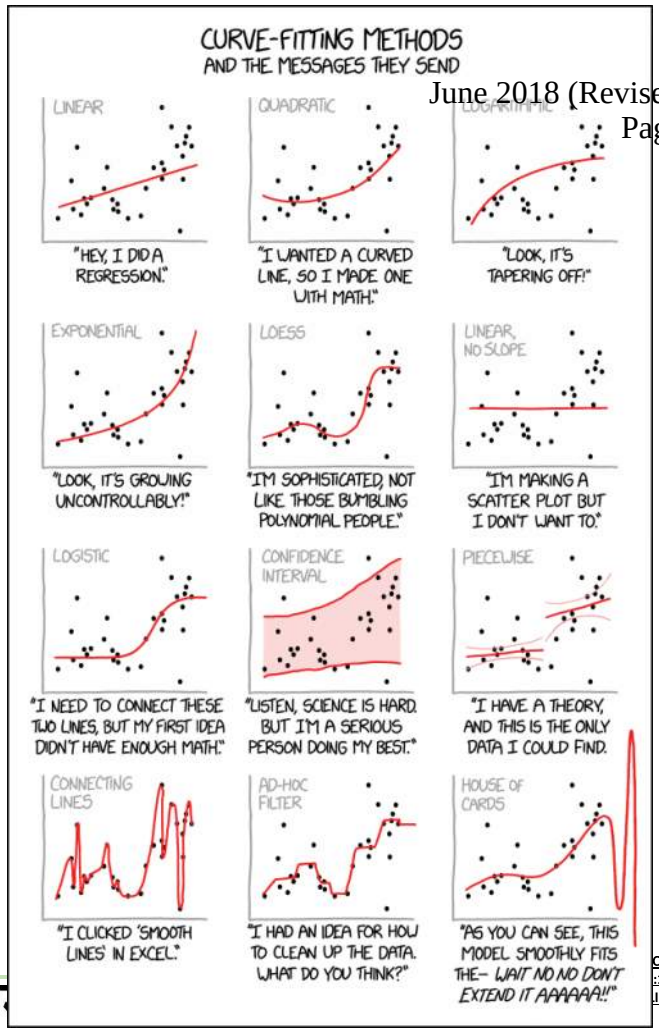
Baseline Conditions

- 2004 Meteorological Conditions
- 2015 Infrastructure
- River Concentrations at Existing Conditions
- Dry-weather loading as is

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Final Thoughts or Questions?



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APPENDIX C

Subcatchment Characteristics (Baseline Model)

Appendix C: Combined Subcatchment Characteristics (Baseline Model)

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
BA_10th_St_a	4.576	251.9	21.5%	6.5%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_27th_St_1	2.049	295.1	66.0%	66.0%	3.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_9th_St_1	4.53	244.6	21.5%	6.5%	0.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Ave_C_1	5.068	132.6	40.0%	12.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_AveA_026N1	19.632	3478	65.0%	65.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_AveA_026S1	2.751	1302	65.0%	65.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_AveA_027N1	1.332	543.6	66.0%	66.0%	1.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_AveA_027S1	0.269	244.4	66.0%	66.0%	1.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_AveB_1	6.042	1157.7	64.0%	64.0%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_AveB_2	14.93	1820.1	64.0%	64.0%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_AveB_6	10.711	1541.7	64.0%	64.0%	1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_AveB_new_1	13.956	1759.5	64.0%	64.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Broadway_1	0.429	51	21.5%	6.5%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Broadway_4	2.166	77.2	21.5%	6.5%	0.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Broadway_5	11.574	173.3	21.5%	6.5%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Bway_new_1	5.428	548.6	68.0%	68.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Bway_new_3	33.861	1370.4	68.0%	68.0%	1.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Cottage_St_1	0.968	400.6	21.5%	21.5%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Cottage_St_2	5.801	283.6	21.5%	6.5%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Cottage_St_3	3.526	221.1	21.5%	6.5%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_E_5th_4	3.233	220.8	21.5%	6.5%	0.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_E18th_2	7.371	639.4	68.0%	68.0%	1.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_E5th_St_5	14.522	265.3	21.5%	6.5%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO002-4B	4.783	515	68.0%	68.0%	1.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO002-5B_E1	23.91	1151.6	68.0%	68.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO004-1	11.799	1618.1	63.0%	63.0%	3.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO022-3	6.151	146	40.0%	12.0%	1.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO024-1	18.167	251	40.0%	40.0%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO024-2	14.692	152.5	40.0%	40.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO024-3	6.227	146.9	40.0%	12.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO027-1	5.42	1096.4	66.0%	66.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO028-1	4.415	989.7	64.0%	64.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO029-1	3.33	859.7	64.0%	64.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO031-1	5.02	1055.2	66.0%	66.0%	1.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_IO032-2	6.154	1168.4	66.0%	66.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_MH028_8	14.755	1808.5	64.0%	64.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_MHaIO006-2	0.884	774.8	66.0%	66.0%	0.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_MHb_IO006-2	1.759	1041.3	66.0%	66.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_MHcIO006-2	0.789	732.4	66.0%	66.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_MHdIO006-2	1.089	860.4	66.0%	66.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_MHh_IO006-2	1.87	281.8	66.0%	66.0%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_MHj_IO006-2	2.318	313.8	66.0%	66.0%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_MHl_IO006-2	1.187	898	66.0%	66.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_MHm_IO006-2	1.208	905.6	66.0%	66.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
BA_MHo_IO006-2	0.453	554.4	66.0%	66.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_N100	5.681	1122.8	66.0%	66.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_N108	5.921	1146	66.0%	66.0%	2.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_N109	2.121	662.8	66.0%	66.0%	1.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_N112	2.235	704	66.0%	66.0%	0.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_N123	29.852	743.4	68.0%	68.0%	0.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_N89	1.399	121.9	40.0%	12.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_NE002	35.52	701.8	68.0%	68.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_NE013	4.549	1757.6	66.0%	66.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_NE014	3.753	912.4	66.0%	66.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_NE021	8.016	666.8	67.0%	67.0%	1.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_NE022	25.688	1193.6	67.0%	67.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_NE025	10.426	760.4	67.0%	67.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_NE027	12.85	844.2	68.0%	68.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_NE028	11.818	809.6	68.0%	68.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Packard_3	1.432	140.9	66.0%	66.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Prospect_Ave4	3.678	1580.8	66.0%	66.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Prospect_Ave5	3.42	1524.8	66.0%	66.0%	3.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R002_a	0.132	85.4	68.0%	68.0%	1.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R003_mh01	1.964	660	66.0%	66.0%	0.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R015MH04	10.847	1550.4	66.0%	66.0%	1.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R01MH01	4.009	943.6	65.0%	65.0%	5.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02_new1	19.233	1032.8	68.0%	68.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02_new2	20.878	1076	68.0%	68.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02_new3	10.368	758.4	68.0%	68.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02_new4	6.495	600.2	68.0%	68.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02_new5	3.054	411.6	68.0%	68.0%	1.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02_new7	4.854	518.8	68.0%	68.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_11	2.248	353.2	68.0%	68.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_12	3.83	460.8	68.0%	68.0%	0.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_14	5.931	573.6	68.0%	68.0%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_16	4.753	513.4	68.0%	68.0%	1.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_20	0.965	231.4	68.0%	68.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_21	1.76	312.4	68.0%	68.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_24	9.969	743.6	68.0%	68.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_27	15.356	922.8	68.0%	68.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_33	5.443	549.4	68.0%	68.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_35	5.193	536.6	68.0%	68.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_36	10.192	751.8	68.0%	68.0%	1.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_37	13.834	876	68.0%	68.0%	0.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R02MH_5	3.238	208.2	21.5%	21.5%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R03MH01	3.834	1614.4	66.0%	66.0%	3.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R03MH02	7.047	2188.4	66.0%	66.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R03MH03	0.726	702.8	66.0%	66.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R03OF02	8.604	2418	66.0%	66.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
BA_R03OF03	7.653	2280.4	66.0%	66.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_junc	2.985	355.9	66.0%	66.0%	3.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new1	17.304	813.6	66.0%	66.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new10	15.135	1959.2	66.0%	66.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new11	3.384	1832.4	66.0%	66.0%	1.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new13	13.674	858	66.0%	66.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new16	13.944	1741.6	66.0%	66.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new17	7.285	1758.8	66.0%	66.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new18	5.68	1271.2	66.0%	66.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new19	21.089	1132.4	66.0%	66.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new21	3.786	2163.2	66.0%	66.0%	1.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new23	6.447	928.8	66.0%	66.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new24	6.045	1196	66.0%	66.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new25	9.288	1158	66.0%	66.0%	2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new3	18.151	1435.6	66.0%	66.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new4	9.2	2006.8	66.0%	66.0%	0.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new5	12.853	1428.8	66.0%	66.0%	0.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new8	13.948	1688.4	66.0%	66.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04_new9	10.313	1759.2	66.0%	66.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04n_MH02	6.748	1512.8	66.0%	66.0%	1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04nMH01	10.611	1223.6	66.0%	66.0%	1.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R04sMH01	20.728	1539.2	66.0%	66.0%	1.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new1	9.278	358.7	21.5%	6.5%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new10	11.243	394.8	21.5%	6.5%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new12	2.707	193.8	21.5%	6.5%	1.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new14	26.412	604.4	21.5%	6.5%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new15	2.764	194.3	21.5%	6.5%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new16	3.078	206.6	21.5%	6.5%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new17	6.92	310.1	21.5%	6.5%	1.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new18	7.485	322.2	21.5%	6.5%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new19	4.644	253.7	21.5%	6.5%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new22	13.96	440	21.5%	6.5%	1.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new23	5.54	277.2	21.5%	6.5%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new24	9.011	353.5	21.5%	6.5%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new25	7.481	322.1	21.5%	6.5%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new26	7.256	317.2	21.5%	6.5%	0.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new28	23.757	569.8	21.5%	6.5%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new29	6.621	313.5	21.5%	6.5%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new3	4.376	246.3	21.5%	6.5%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new30	5.525	276.8	21.5%	6.5%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new4	2.6	189.9	21.5%	6.5%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new5	3.54	221.6	21.5%	6.5%	1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new6	3.698	226.4	21.5%	6.5%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new7	3.519	220.9	21.5%	6.5%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R05_new8	4.031	236.4	21.5%	6.5%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2

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BA_R05_newjunc	19.111	514.8	21.5%	6.5%	1.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R06_middle	0.819	426.1	63.0%	63.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R06aMH03	13.322	1719.1	63.0%	63.0%	10.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R06bMH01	4.04	946.7	63.0%	63.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R07_mh03	8.097	167.6	40.0%	12.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R07MH04	6.118	145.6	40.0%	12.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R08aMH01	1.321	541.2	68.0%	68.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R08aMH04	7.127	1257.6	68.0%	68.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R08bMH02	9.903	1482	68.0%	68.0%	1.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R08MH01	2.791	786.8	68.0%	68.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R09bMH04	28.581	2517.9	61.0%	61.0%	1.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R09cMH03	3.59	892.4	68.0%	68.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R11_new1	11.452	398.5	82.0%	82.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R12_new1	11.092	686.4	67.0%	67.0%	0.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R12_new2	4.858	454.1	67.0%	67.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R12_new3	6.503	525.5	67.0%	67.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R12_new4	9.434	633	67.0%	67.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R12_new5	11.207	689.9	67.0%	67.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R12_new6	11.03	684.4	67.0%	67.0%	1.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R12_new7	17.286	856.8	67.0%	67.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R12MH01	10.917	680.9	67.0%	67.0%	1.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R14MH01	12.464	2771.3	65.0%	65.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R15MH02	7.117	1256.4	66.0%	66.0%	3.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R16_new2	4.282	974.9	64.0%	64.0%	2.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R16_new3	1.745	622.4	64.0%	64.0%	1.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R16_new4	12.951	1695.1	64.0%	64.0%	1.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R16_new5	7.803	1315.7	64.0%	64.0%	1.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R16_new6	2.391	728.5	64.0%	64.0%	1.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R16MH01	2.115	684.8	64.0%	64.0%	9.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R17_new1	12.141	1641.2	66.0%	66.0%	2.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R17_new2	2.877	798.8	66.0%	66.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new1	7.492	422.3	68.0%	68.0%	1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new12	5.024	363.9	68.0%	68.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new2	4.228	342.1	68.0%	68.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new3	10.848	487.8	68.0%	68.0%	1.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new4	6.099	390.8	68.0%	68.0%	1.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new5	8.282	438.9	68.0%	68.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new6	11.031	491.1	68.0%	68.0%	2.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new7	4.054	337.1	68.0%	68.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new8	9.553	464	68.0%	68.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18_new9	9.677	466.3	68.0%	68.0%	1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18aMH03	34.364	700	68.0%	68.0%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18bMH03	6.379	397.4	68.0%	68.0%	0.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_R18MH01	5.849	393.1	68.0%	68.0%	0.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_RH11MH01	16.451	477.6	82.0%	82.0%	3.3	0.02	0.05	0.1	0.05	0%	5	2	2

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BA_RH13MH03	20.317	928.9	68.0%	68.0%	1.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_E26th_1	0.371	71.7	66.0%	66.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_E26th_3	1.003	118	66.0%	66.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_E27th_1	0.411	75.4	66.0%	66.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_E27th_2	0.618	92.6	66.0%	66.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_E28th_1	0.449	78.9	66.0%	66.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_E28th_2	0.552	588	66.0%	66.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_MHaIO006-2	0.542	151.7	66.0%	66.0%	0.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_MHb_IO006-2	1.013	207.4	66.0%	66.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_MHdIO006-2	0.229	98.7	66.0%	66.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_MHflO006-2	1.149	235.6	66.0%	66.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_MHh_IO006-2	1.144	220.3	66.0%	66.0%	0.7	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_MHi_IO006-2	1.386	242.6	66.0%	66.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_MHk_IO006-2	1.462	249.2	66.0%	66.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_MHl_IO006-2	1.002	206.3	66.0%	66.0%	0.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_MHm_IO006-2	1.14	220	66.0%	66.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_S_NE013	28.436	1098.8	66.0%	66.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_SE004	3.294	854.8	68.0%	68.0%	0.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_SE009	6.639	1213.6	68.0%	68.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_SE011	4.117	119.5	40.0%	40.0%	0.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_SE015	4.916	130.6	40.0%	40.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_SE017	2.826	99	40.0%	40.0%	0.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_SE019	7.965	166.2	40.0%	40.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_SE023	5.363	136.4	40.0%	40.0%	0.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_SNew_St_1	0.398	74.3	66.0%	66.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_SNew_St_3	0.97	116	66.0%	66.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_Storm_1	2.125	1201.2	66.0%	66.0%	0.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_ToR007_1	11.742	201.5	40.0%	12.0%	1.2	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W25St_mh2	43.461	5175.3	65.0%	65.0%	1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W34th_St_4	8.597	1381.3	64.0%	64.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W42nd_St_2	4.311	978.1	64.0%	64.0%	1.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W43rd_St_1	8.036	1335.3	64.0%	64.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W43rd_St_2	4.362	983.5	64.0%	64.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W44th_St_2	4.872	1039.5	64.0%	64.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W45th_St_1	2.779	785.1	64.0%	64.0%	1.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W45th_St_2	4.609	1011.2	64.0%	64.0%	1.8	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W46th_St_1	14.828	1813.7	64.0%	64.0%	1.3	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W53rd_033	3.308	314.2	68.0%	68.0%	4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W5St_mh1	1.491	575.3	61.0%	61.0%	9.6	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W5St_mh2	1.498	576.5	61.0%	61.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BA_W5St_mh3	6.687	1218.1	61.0%	61.0%	2.9	0.02	0.05	0.1	0.05	0%	5	2	2
BA_WN002	1.85	640.5	64.0%	64.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_WN003	3.068	825.1	64.0%	64.0%	1.5	0.02	0.05	0.1	0.05	0%	5	2	2
BA_WN005	4.11	954.7	64.0%	64.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
BA_WN006	5.326	767.5	64.0%	64.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
BA_WN009	4.802	1032	64.0%	64.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_WN011	5.428	1097.1	64.0%	64.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_WN012	3.909	931.2	64.0%	64.0%	0.1	0.02	0.05	0.1	0.05	0%	5	2	2
BA_WN014	11.106	1569.6	64.0%	64.0%	0.4	0.02	0.05	0.1	0.05	0%	5	2	2
BranchBrookParkLake	237.162	1039	11.0%	6.3%	5.7	0.02	0.05	0.1	0.05	0%	5	2	2
EN_CS38#1	62.455	3584.8	62.9%	37.7%	3.4	0.02	0.05	0.1	0.05	25%	5	2	2
HR_CS39#1	6.068	885	58.2%	17.7%	5.6	0.02	0.05	0.1	0.05	25%	5	2	2
HR_CS40#1	26.133	2125.4	57.0%	30.8%	3.8	0.02	0.05	0.1	0.05	25%	5	2	2
HR_CS41#1	81.418	4202.9	60.8%	37.2%	3.1	0.02	0.05	0.1	0.05	25%	5	2	2
HR_CS42#1	3.161	598.4	62.1%	55.1%	1	0.02	0.05	0.1	0.05	25%	5	2	2
HR_CS43#1	76.531	4049.7	64.2%	46.8%	1.6	0.02	0.05	0.1	0.05	25%	5	2	2
HR_CS44#1	59.121	3468.7	63.9%	9.6%	2	0.02	0.05	0.1	0.05	25%	5	2	2
HR_CS45#1	174.307	6636.1	57.4%	15.0%	2	0.02	0.05	0.1	0.05	25%	5	2	2
HR_H-HSW3	9.456	1154.9	61.6%	50.5%	2	0.02	0.05	0.1	0.05	25%	5	2	2
JCE10C110#1	5.5	399	80.8%	80.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE10C274#1	6.714	600	66.5%	66.5%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE10C294#1	2.069	230	72.2%	72.2%	1.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE10C314#1	2	285	66.5%	66.5%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE10C32#1	3.4	263	78.9%	78.9%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE10C348#1	26.03	1080	61.8%	61.8%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE10C400#1	21.36	1180	47.5%	47.5%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE10C60#1	1.8	170	80.8%	80.8%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE10C76#1	2	289	80.8%	80.8%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE10C88#1	3.5	308	80.8%	80.8%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C140#1	1.21	220	80.8%	80.8%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C194#1	1.51	270	80.8%	80.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C224#1	1.4	250	80.8%	80.8%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C262#1	12.1	420	79.8%	79.8%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C336#1	10	727	80.8%	80.8%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C396#1	0.49	200	42.8%	42.8%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C464#1	1.67	150	80.8%	80.8%	5.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C490#1	1.12	200	80.8%	80.8%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C50#1	2.2	260	80.8%	80.8%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C50#2	4.098	170	85.5%	85.5%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C510#1	2.33	530	82.7%	82.7%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C568#1	4.602	335	74.1%	74.1%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C578#1	5.5	477	82.7%	82.7%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C600#1	10.12	470	82.7%	82.7%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C632#1	12	697	71.3%	71.3%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C691#1	20.2	1150	76.0%	76.0%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C72#1	3.46	258	82.7%	82.7%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C720#1	8.8	545	80.8%	80.8%	2.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C82#1	6.31	330	80.8%	80.8%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C870#1	1.2	150	82.7%	82.7%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11C894#1	1.42	135	82.7%	82.7%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2

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JCE11C94#1	10.79	360	80.8%	80.8%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE11CC11#1	15.9	771	78.9%	78.9%	2.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE13C206#1	12.6	643	76.0%	76.0%	1.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE14C218#1	13.6	1186	80.8%	80.8%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE14C242#1	1.37	300	80.8%	80.8%	1.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE14C270#1	1.33	200	80.8%	80.8%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE14C62#1	6.6	390	82.7%	82.7%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE14CM12#1	1.95	200	85.5%	85.5%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE14CM8#1	5.85	400	85.5%	85.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C136#1	1.3	150	80.8%	80.8%	1.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C154#1	0.53	140	61.8%	61.8%	1.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C192#1	1.2	150	80.8%	80.8%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C300#1	2	438	80.8%	80.8%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C308#1	6.74	340	82.7%	82.7%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C324#1	7.18	350	82.7%	82.7%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C342#1	4.581	465	66.5%	66.5%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C35#1	6.6	229	80.8%	80.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C354#1	1.52	260	66.5%	66.5%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C354#2	5.33	420	38.0%	38.0%	2.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C388#1	1.2	180	66.5%	66.5%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C463#1	0.54	160	82.7%	82.7%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C472#1	1.41	180	82.7%	82.7%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C486#1	0.63	175	82.7%	82.7%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C52#1	7.2	300	80.8%	80.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C520#1	1.77	225	82.7%	82.7%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C562#1	1.34	210	82.7%	82.7%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C580#1	2.534	265	66.5%	66.5%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C68#1	1.96	380	61.8%	61.8%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15C76#1	6.792	550	61.8%	61.8%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE15CBD#1	9.6	700	47.5%	47.5%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE16C118#1	0.65	180	66.5%	66.5%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE16C136#1	3.89	245	66.5%	66.5%	1.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE16C154#1	1.3	200	52.3%	52.3%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE16C192#1	0.555	115	47.5%	47.5%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE16C44#1	9.1	440	66.5%	66.5%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE16C60#1	6.9	300	47.5%	47.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE16C84#1	3.17	350	66.5%	66.5%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE16C94#1	6.38	420	66.5%	66.5%	0.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C114#1	1.25	200	80.8%	80.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C124#1	0.65	145	80.8%	80.8%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C136#1	1.68	180	80.8%	80.8%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C174#1	0.81	130	80.8%	80.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C202#1	0.34	75	52.3%	52.3%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C230#1	2.7	970	66.5%	66.5%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C276#1	5.57	450	57.0%	57.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2

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JCE17C304#1	4.96	354	57.0%	57.0%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C314#1	10.1	787	66.5%	66.5%	2.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C40#1	1.7	318	61.8%	61.8%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C438#1	0.66	100	57.0%	57.0%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C48#1	7.3	450	52.3%	52.3%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C64#1	5.5	330	80.8%	80.8%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE17C82#1	3.9	430	57.0%	57.0%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C1028#1	7.6	500	57.0%	57.0%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C1088#1	1.71	250	57.0%	57.0%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C110#1	5.75	500	47.5%	47.5%	3.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C1103#1	1.36	160	57.0%	57.0%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C1128#1	1.62	150	57.0%	57.0%	1.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C164#1	42.1	1357	68.4%	68.4%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C192#1	3.15	400	66.5%	66.5%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C232#1	31	965	33.3%	33.3%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C348#1	13.7	796	48.5%	48.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C4002#1	5.75	320	47.5%	47.5%	5.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C494#1	3.31	340	66.5%	66.5%	1.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C504#1	17.32	1300	66.5%	66.5%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C800#1	9.89	630	57.0%	57.0%	3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C830#1	9.03	500	66.5%	66.5%	1.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C850#1	2.76	340	66.5%	66.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C864#1	1.1	150	57.0%	57.0%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C870#1	2.29	600	57.0%	57.0%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C9010#1	5.53	450	57.0%	57.0%	1.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C9011#1	5.31	400	57.0%	57.0%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C942#1	10.12	625	57.0%	57.0%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C972#1	2.7	300	57.0%	57.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C9864#1	1.23	200	57.0%	57.0%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18C994#1	2.28	270	57.0%	57.0%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18G9010#2	3.31	300	57.0%	57.0%	1.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE18NH18#1	20.44	1187	61.8%	61.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C102#1	1.32	200	66.5%	66.5%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C1068#1	28.58	1350	54.2%	54.2%	3.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C1094#1	4.046	350	42.8%	42.8%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C1110#1	20.955	1573	57.0%	57.0%	0.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C1530#1	19.668	1080	40.9%	40.9%	3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C26#1	4	205	71.3%	71.3%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C510#1	36.426	1211	63.7%	63.7%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C520#1	10.933	476	60.8%	60.8%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C60S#1	17.05	1100	66.5%	66.5%	1.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C692#1	16.52	1360	61.8%	61.8%	3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C77#1	2	200	61.8%	61.8%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C828#1	29.25	763	63.7%	63.7%	3.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19C92#1	1.46	200	61.8%	61.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2

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JCE19C966#1	20.377	1105	66.5%	66.5%	2.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19N1122#1	7.39	1360	54.2%	54.2%	4.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19N172#1	0	512	63.7%	63.7%	4.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19N320#1	3.357	571	62.7%	62.7%	1.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19N602#1	15.328	602	61.8%	61.8%	2.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19N662#1	4.098	438	35.2%	35.2%	3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19N740#1	1.848	445	38.0%	38.0%	4.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19N84#1	48.432	700	58.0%	58.0%	1.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE19N94#1	4.134	310	45.6%	45.6%	1.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C104#1	13.4	1170	58.0%	58.0%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C130#1	4.728	273	70.3%	70.3%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C18#1	11.8	535	42.8%	42.8%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C32#1	7.2	500	68.4%	68.4%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C330#1	5	530	47.5%	47.5%	1.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C376#1	7.8	330	58.9%	58.9%	1.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C384#1	17.4	400	62.7%	62.7%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C400#1	8.1	615	61.8%	61.8%	1.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C406#1	29.842	1363	61.8%	61.8%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C418#1	4.742	302	67.5%	67.5%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C460#1	20.335	780	63.7%	63.7%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C580#1	38.74	521	58.9%	58.9%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C588#1	22.968	610	61.8%	61.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE1C97#1	17	1237	71.3%	71.3%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE21C320#1	32.8	1192	47.5%	47.5%	3.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE22G9098#1	17.023	450	48.5%	48.5%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE22G9098#2	6.745	230	47.5%	47.5%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE22G9098#3	2.169	209	42.8%	42.8%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE22N1320#1	6.169	650	42.8%	42.8%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE22N592#1	2.177	120	60.8%	60.8%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE22N608#1	16.662	1334	53.2%	53.2%	2.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C108#1	15.3	444	80.8%	80.8%	2.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C118#1	15.87	461	80.8%	80.8%	2.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C32#1	33.1	1500	47.5%	47.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C32#2	15.74	571	66.5%	66.5%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C370#1	16.71	607	82.7%	82.7%	2.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C472#1	14.48	573	80.8%	80.8%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C48#1	2.26	123	80.8%	80.8%	1.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C506#1	9.33	406	76.0%	76.0%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C54#1	1.42	139	67.5%	67.5%	1.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2C634#1	14.39	522	80.8%	80.8%	2.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2N60#1	0.5	60	67.5%	67.5%	1.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2N724#1	14.229	502	47.5%	47.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE2N782#1	8.918	502	47.5%	47.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE34N240#1	4.829	886	76.0%	76.0%	0.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C100#1	4.48	390	63.7%	63.7%	2	0.02	0.05	0.1	0.05	5%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
JCE3C108#1	1.9	296	63.7%	63.7%	2.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C1416#1	13.46	533	52.3%	52.3%	0	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C1420#1	27.58	924	42.8%	42.8%	0	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C1438#1	57.38	1785	47.5%	47.5%	0	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C146#1	2.6	234	68.4%	68.4%	2.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C1500#1	11.88	752	28.5%	28.5%	0	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C1508#1	30.66	1335	38.0%	38.0%	0	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C1522#1	11.88	493	38.0%	38.0%	0	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C181#1	10.24	686	68.4%	68.4%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C872#1	0.13	25	68.4%	68.4%	2.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C922#1	4.7	372	59.9%	59.9%	2.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C940#1	6.25	495	59.9%	59.9%	2.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3C960#1	6.62	501	59.9%	59.9%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE3N940#1	7.86	250	76.0%	76.0%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE4C1260#1	10.323	887	76.0%	76.0%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE4C174#1	4.62	447	61.8%	61.8%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE4C192#1	28.486	886	76.0%	76.0%	0.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE4C268#1	9.64	560	76.0%	76.0%	0.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE4C416#1	16.582	250	76.0%	76.0%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE4C659#1	29.55	613	66.5%	66.5%	1.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE4N426#1	7	250	76.0%	76.0%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56C1470#1	25.657	540	72.2%	72.2%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56C1602#1	23.43	1000	61.8%	61.8%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56C1630#1	14.235	400	71.3%	71.3%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56C268#1	25	350	74.1%	74.1%	1.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56C326#1	33.65	500	71.3%	71.3%	0	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56C5032#1	30.5	1050	71.3%	71.3%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56C814#1	3.025	200	71.3%	71.3%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56G10069#1	3.163	280	73.2%	73.2%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56G9925#1	3.89	600	66.5%	66.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56G9954#1	2.894	205	56.1%	56.1%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56G9954#2	1.387	189	76.0%	76.0%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56G9955#1	1.866	250	76.0%	76.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56G9958#1	3.717	339	74.1%	74.1%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1036#1	2.133	330	70.3%	70.3%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N104#1	2.274	194	70.3%	70.3%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1046#1	4.043	335	60.8%	60.8%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N106#1	7	250	64.6%	64.6%	1.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1098#1	4.278	210	56.1%	56.1%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1196#1	6.604	690	66.5%	66.5%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1232#1	28.413	700	50.4%	50.4%	2.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1326#1	6.983	390	50.4%	50.4%	2.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1378#1	3.454	242	66.5%	66.5%	1.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1396#1	5.437	260	69.4%	69.4%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1420#1	5.977	240	72.2%	72.2%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2

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JCE56N1506#1	9.951	690	65.6%	65.6%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N151#1	4.226	340	71.3%	71.3%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1676#1	4.741	314	59.9%	59.9%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1676#2	2.434	333	75.1%	75.1%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1776#1	3.297	500	58.9%	58.9%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1784#1	1.032	220	52.3%	52.3%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1806#1	5.268	368	66.5%	66.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1874#1	7.179	280	52.3%	52.3%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1874#2	1.967	186	52.3%	52.3%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1929#1	13.42	530	53.2%	53.2%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1960#1	5.164	600	71.3%	71.3%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N1971#1	2.837	250	68.4%	68.4%	0.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N2004#1	5.768	240	52.3%	52.3%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N2008#1	3.843	150	66.5%	66.5%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N2286#1	1.5	250	63.7%	63.7%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N2334#1	5.659	360	60.8%	60.8%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N2588#1	2.57	320	63.7%	63.7%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N2610#1	6.617	390	57.0%	57.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N2634#1	4.035	200	55.1%	55.1%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N2678#1	9.074	300	60.8%	60.8%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N2716	3.064	280	66.5%	66.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N3274#1	1.965	272	60.8%	60.8%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N3339#1	1.868	200	75.1%	75.1%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N360#1	4.699	400	74.1%	74.1%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N366#1	2.102	250	76.0%	76.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N374#1	3.292	370	72.2%	72.2%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N374#2	2.055	110	78.9%	78.9%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N444#1	2.948	300	52.3%	52.3%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N496#1	5.39	420	53.2%	53.2%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N550#1	4.403	271	53.2%	53.2%	1.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N564#1	5.28	460	64.6%	64.6%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N572#1	3.423	425	65.6%	65.6%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N70#1	7	460	64.6%	64.6%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N734#1	4.003	430	47.5%	47.5%	3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N824#1	6.004	440	72.2%	72.2%	2.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N882#1	5.746	315	58.0%	58.0%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N90#1	3.051	319	60.8%	60.8%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N916#1	2.204	300	54.2%	54.2%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N934#1	3.119	515	58.0%	58.0%	1.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N934#2	3.309	350	57.0%	57.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N934#3	3.844	400	57.0%	57.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N956#1	0.898	220	75.1%	75.1%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE56N988#1	3.375	260	56.1%	56.1%	3.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE5C1642#1	15.938	400	55.1%	55.1%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCE5C1650#1	10.801	350	70.3%	70.3%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2

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JCE5C2190#1	7.984	350	71.3%	71.3%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE5C2262#1	9	322	57.0%	57.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE5C2360#1	24	830	62.7%	62.7%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE5C2380#1	43	1500	57.0%	57.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE5C2532#1	4.666	370	62.7%	62.7%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE6C1004#1	11.806	350	67.5%	67.5%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE6C1004#2	3.717	200	67.5%	67.5%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE6C748#1	24.59	1150	70.3%	70.3%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCE6C8040#1	11	600	68.4%	68.4%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCE6N854#1	10.74	640	67.5%	67.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCRE10&9C#1	5.544	300	91.2%	91.2%	1.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCRE17C#1	1.9	559	57.0%	57.0%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCrE18OLD#1	11.46	998	19.0%	19.0%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCRE8(STORM)#1	3.28	357	82.7%	82.7%	1.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCRW10C#1	6	145.2	76.0%	76.0%	1.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCRW1C	2.98	709	47.5%	47.5%	2.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCRW7C	16	830	66.5%	66.5%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW10C234#1	16.287	861	66.5%	66.5%	2.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW10C32#1	28.43	619	71.3%	71.3%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW10C76#1	43.73	952	65.6%	65.6%	1.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW10CD10#1	20.262	937	71.3%	71.3%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW11C26#1_2	30	1131	67.5%	67.5%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCW11C328#1	16.72	1324	69.4%	69.4%	3.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW11C38#1	27.61	1604	75.1%	75.1%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW11C484#1	9.364	291	67.5%	67.5%	3.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW11C52#1	35.69	2073	71.3%	71.3%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW11N430#1	8.209	203	69.4%	69.4%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW11N496#1	2.103	341	78.9%	78.9%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW12C170#1	25.58	1486	73.2%	73.2%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCW12C180#1	12.972	1113	72.2%	72.2%	8	0.02	0.05	0.1	0.05	5%	5	2	2
JCW12C190#1	5.399	303	68.4%	68.4%	3.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW12C34#1	10.7	500	80.8%	80.8%	2.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCW12C52#1	12.123	850	71.3%	71.3%	1.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW12N204#1	9.29	500	76.0%	76.0%	5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C20#1	3.2	230	19.0%	19.0%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C204#1	37.96	781	74.1%	74.1%	1.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C226#1	39	1266	66.5%	66.5%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C26#1	1	250	65.6%	65.6%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C26_1#1	1.5	300	23.8%	23.8%	5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C32#1	0.6	185	65.6%	65.6%	5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C541#1	2.8	300	28.5%	28.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C550#1	4	400	28.5%	28.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C554#1	1.9	190	54.2%	54.2%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C560#1	1.32	233	28.5%	28.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C567#1	0.45	100	28.5%	28.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
JCW13C569#1	1.8	120	28.5%	28.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C572#1	2	200	28.5%	28.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C590#1	3.8	477	62.7%	62.7%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C600#1	2.4	240	62.7%	62.7%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C604#1	2.1	225	28.5%	28.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C618#1	1	200	59.9%	59.9%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C66#1	27.9	938	67.5%	67.5%	2.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C672#1	1.93	275	28.5%	28.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13C692#1	1.1	233	28.5%	28.5%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13N104#1	12.501	700	61.8%	61.8%	2.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCW13N290#1	8.928	335	50.4%	50.4%	0.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1C110#1	19.973	1000	40.9%	40.9%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1C110.1#1	85	1500	59.9%	59.9%	1.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1C110.2#1	9.11	661	67.5%	67.5%	4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1C218#1	2.93	319	76.0%	76.0%	8.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1C44#1	3.475	156	42.8%	42.8%	4.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1C628#1	3.97	433	82.7%	82.7%	1.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1C74#1	1.2	210	80.8%	80.8%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1C74.1#1	60	1000	64.6%	64.6%	2.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1C92#1	3.51	382	80.8%	80.8%	0.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N370#1	7.95	577	48.5%	48.5%	8.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N40#1	5.49	255	42.8%	42.8%	6.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N443#1	9.686	400	19.0%	19.0%	4.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N463#1	4.548	247	42.8%	42.8%	3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N468#1	5.078	285	61.8%	61.8%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N522#1	5.08	235	48.5%	48.5%	4.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N530#1	5.227	261	45.6%	45.6%	5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N540#1	4.602	256	42.8%	42.8%	4.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N561#1	4.22	247	60.8%	60.8%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW1N594#1	2.746	379	76.0%	76.0%	3.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCW2C204#1	10.07	439	77.9%	77.9%	2.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW2C224#1	8.24	598	68.4%	68.4%	5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW2C32#1	7.33	580	64.6%	64.6%	6	0.02	0.05	0.1	0.05	5%	5	2	2
JCW2C344#1	17.4	892	80.8%	80.8%	3.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCW2C52#1	13.74	855	78.9%	78.9%	2.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW2C546#1	20.15	878	80.8%	80.8%	4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW2C64#1	13.19	766	80.8%	80.8%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW2G9028#1	3.66	399	84.6%	84.6%	7.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW3C106#1	7.16	445	38.0%	38.0%	3.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW3C18#1	19.29	934	76.0%	76.0%	3.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCW3C218#1	1.547	480	71.3%	71.3%	3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW3C48#1	6.4	400	44.7%	44.7%	2.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCW3C58#1	5.04	250	53.2%	53.2%	1.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCW3C58#2	1.503	400	77.9%	77.9%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW3C64#1	9.389	440	77.0%	77.0%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2

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JCW3C64#2	2.204	175	77.9%	77.9%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW3C70#1	4.938	500	78.9%	78.9%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW3C76#1	14.5	870	71.3%	71.3%	1.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW4C110#1	2.554	200	82.7%	82.7%	0.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCW4C124#1	2.773	200	72.2%	72.2%	0.2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW4C174#1	40.32	878	80.8%	80.8%	3.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW4C206#1	0.75	200	63.7%	63.7%	1.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCW4C228#1	2.42	240	82.7%	82.7%	1.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCW4C228#2	2.36	520	77.0%	77.0%	0.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCW4C26#1	9.21	401	80.8%	80.8%	3.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW4C294#1	1.07	400	74.1%	74.1%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW4C50#1	2.78	500	82.7%	82.7%	2.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW5C20#1	48.256	1194	83.6%	83.6%	1.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW5NMH3#1	1.38	46.1	90.3%	90.3%	0.1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW6C#1	40	1000	57.0%	57.0%	0.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCW6C230#1	15.35	669	76.0%	76.0%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW6C434#1	21.67	993	71.3%	71.3%	1.6	0.02	0.05	0.1	0.05	5%	5	2	2
JCW6C48#1	18.82	745	65.6%	65.6%	1.8	0.02	0.05	0.1	0.05	5%	5	2	2
JCW6C50#1	20.84	648	74.1%	74.1%	1.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C166#1	6.986	350	28.5%	28.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C210#1	17.523	500	66.5%	66.5%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C254#1	10.614	200	66.5%	66.5%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C268#1	32.76	673	66.5%	66.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C308#1	7.335	200	66.5%	66.5%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C32#1	4.712	176	28.5%	28.5%	0.7	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C48#1	5.554	250	28.5%	28.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C50#1	7.451	300	28.5%	28.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C52#1	6.706	300	28.5%	28.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C54#1	6.095	250	28.5%	28.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C58#1	8.541	300	28.5%	28.5%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW7C60#1	47.5	1294	66.5%	66.5%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C20#1	19.761	1000	80.8%	80.8%	1.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C46#1	20.301	1225	80.8%	80.8%	2.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C46#2	11.13	1225	80.8%	80.8%	2.5	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C530#1	12.815	770	80.8%	80.8%	3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C540#1	36.903	670	28.5%	28.5%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C568#1	30.907	1150	47.5%	47.5%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C628#1	15.083	546	80.8%	80.8%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C66#1	83.36	2074.9	80.8%	80.8%	0.3	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C686#1	11.888	546	80.8%	80.8%	2	0.02	0.05	0.1	0.05	5%	5	2	2
JCW8C750#1	8.06	300	80.8%	80.8%	1	0.02	0.05	0.1	0.05	5%	5	2	2
JCW9C180#1	15.44	791	80.8%	80.8%	0.9	0.02	0.05	0.1	0.05	5%	5	2	2
JCW9C250#1	14.98	768	82.7%	82.7%	2.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW9C260#1	16.35	838	80.8%	80.8%	2.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW9C52#1	35.28	1336	80.8%	80.8%	1.7	0.02	0.05	0.1	0.05	5%	5	2	2

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JCW9C72#1	2.5	305	80.8%	80.8%	3.4	0.02	0.05	0.1	0.05	5%	5	2	2
JCW9G9003#1	12.77	695	78.9%	78.9%	1	0.02	0.05	0.1	0.05	5%	5	2	2
KE_CS28#1	73.374	3948.6	31.5%	13.2%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
KE_CS31#1	153.857	6157.3	35.7%	17.1%	8.4	0.02	0.05	0.1	0.05	25%	5	2	2
KE_CS33#1	258.72	8410.5	56.8%	43.2%	3.4	0.02	0.05	0.1	0.05	25%	5	2	2
KE_CS34#1	664.027	1481	46.9%	23.5%	2.7	0.02	0.05	0.1	0.05	25%	5	2	2
KE_CS37#1	92.534	4538.4	54.1%	39.0%	3.4	0.02	0.05	0.1	0.05	25%	5	2	2
NB_MH 6-11	55.014	332.2	48.3%	20.1%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NB_MH 6-8	25.683	210.3	60.1%	40.6%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Out 003	59.275	347.4	64.5%	49.9%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Out 005	13.11	140.5	60.8%	42.1%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Out 006	29.911	230.4	47.7%	4.8%	6.1	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Out 007	11.484	129.7	52.6%	27.0%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Out 008	3.99	68.8	49.1%	21.3%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Out 010	5.45	82.9	63.9%	48.4%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-1	2.461	51.5	56.3%	33.5%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-10	65.527	368.9	54.5%	30.7%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-2	16.907	163.6	60.1%	40.6%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-3	5.736	85.5	53.9%	29.5%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-4	4.554	74.5	53.4%	28.3%	3.7	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-5	5.204	80.7	51.9%	25.8%	4.5	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-6	7.475	100.3	57.2%	35.0%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-7	168.621	650.5	53.7%	29.3%	5.1	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-8	151.341	609.6	58.7%	37.8%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 3-9	13.166	140.8	51.0%	24.6%	5.3	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 4-1	84.981	431.2	57.7%	36.2%	7.6	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 4-2/3	2.986	57.8	57.6%	36.1%	7.5	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 4-4	16.162	159.3	43.9%	14.7%	9.8	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 4-5	10.806	125.1	36.8%	6.4%	4.4	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 5-1	8.004	104.5	41.0%	4.1%	5.3	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 5-2	178.124	672.2	41.5%	4.2%	4.7	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 6-1	25.432	209.1	40.4%	10.3%	6.1	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 6-2	15.013	152.4	56.8%	34.7%	5.5	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 6-2A	64.495	365.4	46.3%	17.8%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 6-2B	7.955	104.1	63.9%	48.4%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 6-5/6	88.502	441.8	54.4%	30.6%	5	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 6-7	12.64	137.4	39.1%	8.7%	6.5	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 7-1	6.154	89.2	59.1%	39.0%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 7-3	84.264	429	50.6%	23.5%	7.4	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 7-4,5	14.124	146.9	61.3%	43.4%	3.2	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 8-1	2.937	57.2	60.6%	41.9%	7.9	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 8-2	1.684	41	49.7%	22.3%	7.3	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 9-1	24.379	203.8	61.2%	48.0%	4.1	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 9-1A	14.72	150.6	58.7%	43.2%	4.1	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 9-2	5.366	82.2	63.0%	12.6%	3.5	0.02	0.05	0.1	0.05	25%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
NB_Reg 9-3	43.389	288.1	59.7%	11.9%	4.1	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 9-5	10.361	122	45.0%	9.0%	10.2	0.02	0.05	0.1	0.05	25%	5	2	2
NB_Reg 9-8	46.462	300.1	52.7%	33.7%	7.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_4A10#1	13.722	1444	58.0%	44.7%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_4A12#1	59.702	3489.1	42.6%	24.3%	4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_4A22#1	56.026	3358.6	44.9%	26.9%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_4A3#1	43.67	2892.2	50.4%	33.8%	5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_4A4#1	22.597	1947.8	50.3%	33.7%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_4A5#1	21.189	1874.1	46.1%	28.1%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_4A6#1	11.925	1327.4	52.4%	36.7%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_4A7#1	14.154	1471.1	54.4%	39.7%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_4A8#1	12.906	1391.9	54.3%	39.1%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A10#1	19.913	1805.5	65.4%	56.9%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A11#1	34.55	2513	56.5%	42.4%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A2#1	119.554	5292.5	64.7%	55.6%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A20#1	17.566	1674.7	64.6%	55.6%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A21#1	23.675	2003.1	58.1%	45.3%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A22#1	10.936	1260.2	63.4%	53.9%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A24#1	28.685	2247.6	65.2%	56.7%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A26#1	83.373	4263.2	62.4%	51.8%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A27#1	22.131	1923.6	65.0%	56.6%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A28#1	17.819	1689.1	64.9%	55.8%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A32#1	31.849	2393.2	64.6%	55.6%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A33#1	9.902	1187.3	64.5%	55.5%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A34#1	12.48	1364.1	64.8%	55.7%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A4#1	39.794	2735.3	65.1%	56.6%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_A8#1	18.305	1716.6	64.8%	55.7%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F12#1	25.355	2087.2	62.0%	51.5%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F14#1	21.772	1904.8	58.8%	45.9%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F16#1	17.272	1657.8	55.7%	41.2%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F17#1	22.035	1918.6	65.2%	56.7%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F18#1	22.967	1966.9	63.4%	53.9%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F19#1	20.045	1812.7	62.9%	52.8%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F5#1	4.982	786.3	65.7%	57.8%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F6#1	11.891	1325.1	63.1%	53.0%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F7#1	28.989	2261.8	58.6%	45.7%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F8#1	22.405	1937.9	57.9%	44.6%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_F9#1	21.685	1900.3	63.7%	54.1%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB12#1	58.193	3435.9	33.2%	14.6%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB13#1	38.641	537	51.5%	7.2%	10	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB14#1	21.85	382	48.2%	5.8%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB17#1	30.577	467	41.6%	3.7%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB18#1	5.558	168	45.5%	5.0%	4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB20#1	34.543	502	45.3%	5.0%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB21#1	7.113	195	39.4%	3.2%	5	0.02	0.05	0.1	0.05	25%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
NE_HB22#1	39.407	544	33.6%	2.0%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB3#1	31.74	2388.3	49.3%	32.5%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB4#1	66.353	3717.4	49.0%	31.9%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB5#1	24.621	2050.7	52.0%	35.9%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB8#1	5.604	169	50.0%	6.5%	0.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_HB9#1	8.015	209	51.5%	7.2%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR10#1	8.65	1094.8	60.3%	48.2%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR11#1	30.654	2338.9	62.7%	52.7%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR12#1	29.609	2290.7	51.7%	35.7%	0.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR13#1	5.815	862.7	56.1%	42.1%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR15#1	10.303	1215.9	51.8%	35.7%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR16#1	42.116	2830	57.4%	44.2%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR4#1	33.737	2477.3	54.0%	38.9%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR5#1	33.433	2463.9	52.9%	37.6%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR6#1	32.693	2431.1	58.9%	46.5%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR7#1	53.165	3254.6	61.9%	51.4%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_IR8#1	24.916	2065.4	60.0%	48.0%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_J10#1	24.684	2053.9	65.7%	57.8%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_J2FIX#1	15.151	1532.4	39.1%	20.3%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_J3#1	21.239	1876.7	62.0%	51.5%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_J5#1	10.476	1228.1	64.9%	56.5%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_J9#1	15.725	1567	66.3%	58.3%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M10#1	8.859	1665.9	61.5%	50.4%	2.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M100#1	56.528	5064.9	52.6%	36.8%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M101#1	27.238	3268.2	49.6%	32.7%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M103#1	7.653	1525.8	53.4%	37.9%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M104#1	24.659	3078.9	60.6%	49.1%	3.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M106#1	7.226	1474.2	65.2%	56.7%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M107#1	28.902	3386.7	58.4%	45.6%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M108#1	34.992	3798.3	57.6%	44.4%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M109#1	9.341	1719.8	53.4%	37.9%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M11#1	14.696	2257.1	58.5%	45.6%	1.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M110#1	10.17	1809.8	46.1%	28.6%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M111#1	6.719	1411.2	55.2%	40.8%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M112#1	15.52	2332.1	47.3%	29.8%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M114#1	1.268	518.8	61.6%	50.5%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M115#1	41.409	4202.1	50.8%	34.5%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M13#1	16.725	2439.2	56.9%	43.2%	3.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M14#1	27.537	3289.8	56.0%	42.0%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M15#1	9.31	1716.3	52.0%	35.9%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M16#1	65.8	5548.2	55.3%	40.9%	6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M18#1	15.555	2335.2	50.8%	34.5%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M19#1	12.258	2024.3	44.4%	26.2%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M23#1	21.884	2866.1	46.7%	29.0%	2.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M26#1	25.292	3126.2	47.9%	30.7%	3.2	0.02	0.05	0.1	0.05	25%	5	2	2

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NE_M27#1	29.359	3418.7	48.3%	30.9%	3.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M28#1	47.567	4566.6	52.8%	37.0%	3.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M29#1	35.557	3835	54.6%	39.9%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M3#1	10.767	1872.8	62.6%	52.0%	6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M31#1	11.804	1979	51.4%	35.5%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M32#1	8.322	1604.6	54.9%	40.1%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M35#1	36.18	3875.3	54.2%	39.0%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M36#1	30.914	3526.2	48.9%	31.8%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M37#1	138.618	8675.7	25.6%	8.7%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M39#1	20.729	2774.4	57.2%	43.5%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M40#1	18.653	2604.2	55.5%	41.1%	6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M41#1	33.146	3676.8	39.3%	20.4%	7.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M45#1	45.007	4417.5	36.0%	17.3%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M46#1	10.416	1835.9	29.5%	11.5%	10	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M48#1	39.009	4054.2	28.1%	10.4%	4.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M49#1	31.416	3560.4	59.7%	47.8%	0.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M5#1	16.95	2458.8	55.1%	40.2%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M50#1	16.137	2387.3	57.7%	44.4%	1.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M51#1	26.749	3233	60.3%	48.2%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M52#1	22.743	2933.1	55.3%	40.9%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M53#1	9.281	1713	39.4%	20.9%	1.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M54#1	27.97	3320.7	30.0%	12.0%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M60#1	35.84	3853.4	52.1%	35.9%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M68#1	2.835	840.9	61.9%	51.4%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M7#1	46.374	4497.6	61.8%	50.7%	3.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M71#1	36.962	3925.2	54.3%	39.1%	2.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M79#1	7.869	1551.6	48.3%	30.9%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M8#1	17.014	2464.4	40.9%	22.5%	5.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M80#1	10.043	1796.1	55.3%	40.9%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M82#1	12.109	2009.4	52.6%	36.8%	3.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M83#1	16.664	2433.8	56.6%	42.5%	3.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M87#1	26.736	3232.1	56.7%	43.1%	5.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M89#1	33.99	3732.8	49.0%	31.9%	5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M91#1	18.54	2594.7	59.1%	46.7%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M92#1	6.197	1344.5	60.5%	49.0%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M93#1	6.723	1411.8	58.3%	45.5%	3.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M94#1	11.101	1907.4	59.8%	47.8%	4.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M95#1	37.525	3961.1	51.2%	34.8%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_M98#1	26.424	3209.3	55.2%	40.8%	5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD1#1	2.497	104	30.0%	6.0%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD100#1	19.982	362	50.6%	17.2%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD102#1	16.692	325	49.1%	16.2%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD103#1	21.131	374	47.2%	14.6%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD104#1	24.686	411	48.8%	16.1%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD105#1	15.065	305	48.8%	16.1%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2

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NE_PD106#1	31.659	477	45.8%	14.2%	7.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD107#1	17.067	329	44.6%	13.4%	0.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD108#1	16.817	326	48.7%	15.6%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD109#1	13.078	281	50.4%	17.1%	0.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD11#1	12.149	268	53.0%	18.6%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD110#1	27.113	434	45.1%	13.5%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD111#1	9.128	226	39.7%	10.3%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD112#1	25.951	423	43.5%	12.6%	4.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD113#1	13.441	285	49.7%	16.4%	4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD115#1	54.083	658	48.7%	15.6%	2.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD117#1	36.403	519	55.7%	20.6%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD118#1	21.753	381	54.2%	19.5%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD12#1	23.088	395	52.1%	18.2%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD13#1	20.258	365	58.5%	22.8%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD14#1	11.028	253	55.8%	20.6%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD15#1	73.946	793	61.0%	25.0%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD19#1	9.615	233	62.9%	26.4%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD20#1	9.747	235	64.7%	27.8%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD23#1	36.207	517	46.0%	14.3%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD24#1	29.168	454	51.2%	17.4%	5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD26#1	15.96	316	49.4%	16.3%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD27#1	14.534	299	50.2%	16.6%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD28#1	11.827	264	52.7%	18.4%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD3#1	26.186	426	48.9%	16.1%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD30#1	28.111	444	52.7%	18.4%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD31#1	22.056	384	59.4%	23.8%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD32#1	4.483	148	57.8%	22.5%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD33#1	7.075	194	57.1%	21.7%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD34#1	5.913	174	49.9%	16.5%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD36#1	24.583	410	50.5%	17.2%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD38#1	17.603	335	56.3%	21.4%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD39#1	17.26	331	48.6%	15.6%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD40#1	15.807	314	49.3%	16.3%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD41#1	17.89	339	48.1%	15.4%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD43#1	32.871	488	51.1%	17.4%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD44#1	36.637	521	51.0%	17.3%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD45#1	11.569	261	50.1%	16.5%	4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD46#1	14.564	299	46.6%	14.4%	4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD47#1	17.365	333	55.5%	20.5%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD49#1	39.879	548	50.0%	16.5%	3.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD5#1	28.543	448	56.7%	21.5%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD51#1	20.426	367	45.2%	13.6%	5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD52#1	25.617	420	44.1%	12.8%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD56#1	25.066	414	55.5%	20.5%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD57#1	29.178	454	55.3%	20.5%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2

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NE_PD58#1	32.365	483	63.9%	27.5%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD6#1	23.718	401	49.3%	16.3%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD60#1	14.336	296	50.9%	17.3%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD61#1	12.464	273	49.4%	16.3%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD62#1	8.071	210	46.6%	14.4%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD64#1	15.433	310	49.5%	16.3%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD65#1	11.055	254	53.4%	19.2%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD66#1	26.16	425	51.8%	18.1%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD67#1	16.433	322	41.4%	11.6%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD69#1	7.806	206	50.3%	17.1%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD7#1	10.427	245	46.6%	14.4%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD70#1	13.524	286	49.9%	16.5%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD70#2	15.625	312	52.6%	18.4%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD72#1	18.496	345	51.1%	17.4%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD73#1	15.698	313	48.6%	15.6%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD75#1	21.082	374	51.1%	17.4%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD77#1	11.654	262	55.5%	20.5%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD78#1	20.924	372	53.2%	18.6%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD79#1	23.019	394	52.6%	18.4%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD80#1	35.313	509	23.1%	3.5%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD81#1	19.227	353	54.1%	19.5%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD82#1	29.081	453	45.0%	13.5%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD83#1	19.264	354	52.4%	18.3%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD87#1	15.593	312	53.2%	18.6%	3.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD89#1	66.632	745	25.3%	4.3%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD9#1	38.546	537	44.3%	13.3%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD91#1	17.606	335	52.4%	18.3%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD92#1	15.993	317	49.4%	16.3%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD93#1	13.052	280	55.6%	20.6%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD94#1	18.643	347	46.2%	14.3%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD95#1	30.557	467	46.1%	14.3%	3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD96#1	20.451	367	49.2%	16.2%	4.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD97#1	41.152	558	52.3%	18.3%	3.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD98#1	40.013	549	51.1%	17.4%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_PD99#1	21.008	373	49.0%	16.2%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_Q10#1	14.151	1470.9	34.9%	16.4%	5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_Q11#1	17.637	1678.7	21.8%	6.3%	4.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_Q13#1	63.369	3616.2	33.3%	14.7%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_Q14#1	32.221	2409.9	59.3%	46.8%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_Q15#1	14.901	1517.2	53.2%	37.8%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_Q3#1	30.712	2341.6	59.8%	47.8%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_Q5#1	24.844	2061.8	52.2%	36.5%	5.6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_Q7#1	80.616	4178.1	64.2%	55.2%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM10#1	20.822	185.4	66.4%	18.6%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM11#1	18.191	171	63.1%	16.4%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2

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NE_RM12#1	13.897	145.5	64.9%	17.5%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM14#1	39.23	271.2	66.9%	18.7%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM17#1	15.548	155.6	63.9%	16.6%	2.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM19#1	15.691	156.5	65.6%	18.4%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM21#1	16.486	161.2	62.1%	15.5%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM23#1	28.045	221.7	65.9%	18.5%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM24#1	29.066	226.5	64.1%	17.3%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM25#1	37.077	262.1	54.3%	10.9%	7.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM27#1	9.738	117.5	58.2%	13.4%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM27#2	34.463	250.9	58.6%	13.5%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM28#1	7.865	103.4	62.6%	15.7%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM32#1	11.101	127.1	62.2%	15.6%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM34#1	10.409	122.3	63.6%	16.5%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM36#1	14.223	147.5	64.6%	17.4%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM37#1	12.69	137.7	61.7%	15.4%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM4#1	24.685	205.3	53.5%	10.7%	2.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_RM5#1	21.645	189.8	56.0%	12.3%	2.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S11#1	10.846	1254	60.9%	49.3%	4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S14#1	29.895	2304	55.9%	41.9%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S16#1	40.672	2771.4	58.3%	45.5%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S18#1	17.732	1684.1	60.4%	48.3%	7.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S22#1	14.409	1487	50.3%	33.7%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S23#1	19.767	1797.6	65.6%	57.1%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S3#1	21.486	1889.8	57.0%	43.3%	5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S34#1	54.391	3299.4	54.9%	40.1%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S37#1	28.026	2216.4	56.1%	42.1%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S42#1	6.712	94	59.2%	14.2%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S43#1	41.327	279.8	58.6%	13.5%	3.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S45#1	38.286	267.2	45.1%	6.8%	3.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S47#1	26.497	214.3	55.1%	11.6%	3.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S5#1	8.937	1116.4	62.6%	52.0%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S55#1	13.901	145.5	51.0%	9.2%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S57#1	34.399	2506.4	56.2%	42.2%	1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S8#1	16.457	1610.4	54.7%	39.9%	6	0.02	0.05	0.1	0.05	25%	5	2	2
NE_S9#1	12.614	1372.9	56.0%	42.0%	4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V11#1	21.406	1885.6	48.8%	31.7%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V12#1	6.485	921	49.5%	32.7%	4.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V13#1	53.261	3258.1	44.1%	26.0%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V14#1	23.828	2010.8	43.1%	24.6%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V18#1	16.464	1610.8	44.2%	26.1%	1.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V22#1	26.647	2150.4	40.5%	21.9%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V26#1	23.607	1999.6	33.2%	14.6%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V27#1	154.667	6176.7	31.3%	13.1%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V28#1	43.629	2890.6	53.4%	37.9%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_V29#1	27.719	2201.9	49.7%	32.8%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
NE_V8#1	17.617	1677.6	51.3%	34.9%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH10#1	30.985	2354	59.9%	47.9%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH12#1	19.799	1799.3	53.8%	38.7%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH13#1	14.194	1473.6	56.9%	43.2%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH14#1	7.648	1016.8	43.5%	25.2%	4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH15#1	19.985	1809.4	50.9%	34.6%	4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH20#1	22.177	1926	56.6%	42.5%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH22#1	15.697	1565.3	44.6%	26.3%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH24#1	14.896	1516.9	51.2%	34.8%	6.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH25#1	32.247	2411.1	47.7%	30.5%	6.3	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH3#1	28.999	2262.3	61.5%	50.4%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH4#1	10.466	1227.4	65.8%	57.9%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH6#1	19.497	1782.8	63.6%	54.1%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WH9#1	10.729	1245.8	58.7%	45.8%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WV1#1	105.79	4918	36.7%	18.0%	2	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WV2#1	43.004	2865.7	55.7%	41.2%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WV4#1	56.007	3357.9	63.7%	54.1%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WV5#1	25.074	2073.3	43.3%	25.1%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
NE_WV6#1	75.262	4009.3	58.5%	45.6%	2	0.02	0.05	0.1	0.05	25%	5	2	2
PT_003A	14.14	1470.2	52.3%	25.4%	1.6	0.02	0.05	0.1	0.05	25%	5	2	2
PT_005A	14.444	1489.1	45.3%	18.7%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
PT_009A	19.047	1758	51.9%	7.7%	3.1	0.02	0.05	0.1	0.05	25%	5	2	2
PT_010A	99.484	4740	55.5%	6.2%	1.9	0.02	0.05	0.1	0.05	25%	5	2	2
PT_010A_US	7.39	996.1	38.0%	11.4%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
PT_012A_1	31.491	2377.1	65.1%	4.2%	0	0.02	0.05	0.1	0.05	25%	5	2	2
PT_012A_2	24.923	2065.8	62.1%	10.3%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
PT_013A	110.543	5049.4	55.0%	8.1%	2.8	0.02	0.05	0.1	0.05	25%	5	2	2
PT_014A	22.692	1952.7	54.0%	13.3%	2.6	0.02	0.05	0.1	0.05	25%	5	2	2
PT_015A	35.705	2563.1	47.5%	6.2%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
PT_017A	30.028	2310.2	47.1%	16.1%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
PT_021A	7.44	1000.1	44.3%	9.2%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2
PT_021A_US	10.127	1203.4	36.8%	15.0%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
PT_023A	29.831	2301.1	59.3%	19.0%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
PT_024A	90.563	4480.1	54.0%	17.9%	3.4	0.02	0.05	0.1	0.05	25%	5	2	2
PT_025A_US1	41.682	2812.5	45.5%	19.3%	1.9	0.02	0.05	0.1	0.05	25%	5	2	2
PT_025A_US2	37.717	2648.8	39.2%	24.6%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
PT_025A_US3	25.674	2102.9	40.5%	23.9%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
PT_026A	53.548	3268.6	40.1%	12.7%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2
PT_026A_US1	111.123	5134.7	21.9%	1.4%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
PT_026A_US2	21.657	1898.9	19.8%	1.3%	4.2	0.02	0.05	0.1	0.05	25%	5	2	2
PT_032A	31.639	2383.8	49.3%	17.0%	3.1	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_028A_A1-1	179.089	6744.7	40.8%	4.9%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_028A_A1-3	214.013	7505.6	40.3%	2.6%	2.7	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_028A_A1-5	94.821	4605.4	31.3%	2.0%	5.2	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_028A_A1-6	7.28	987.2	44.7%	2.9%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2

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PT_I_028A_A1-9	9.426	1152.7	53.6%	3.5%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_030A_V2-1b	453.207	11773.4	52.8%	5.8%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-1	31.995	2399.8	47.5%	8.4%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-4	14.507	1493	33.9%	12.7%	4	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-6a	8.666	1096	54.6%	4.0%	1	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-6b	3.21	604	44.2%	7.1%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-7a	8.201	1060.3	48.5%	7.1%	1	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-7b	17.191	1653.1	39.0%	11.7%	3	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-8a	98.83	4721.3	57.4%	3.7%	2.3	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-8b	77.16	4069.7	41.7%	9.3%	2	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-8c	15.123	1530.7	54.1%	3.5%	1	0.02	0.05	0.1	0.05	25%	5	2	2
PT_I_031A_V1-9	191.81	7028.2	51.8%	3.4%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
{022d7196-d998-4033-8558-fcb3cd6432ad}	3.242	212	67.1%	38.5%	2.7	0.02	0.05	0.1	0.05	25%	5	2	2
{02ba9454-285e-4250-8c28-e87dc75f8915}	5.345	272.2	42.3%	4.7%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
{03533f01-b4ce-4a22-8438-fdf698344e26}	9.342	359.9	48.5%	8.0%	6.5	0.02	0.05	0.1	0.05	25%	5	2	2
{03be8ec3-71d2-483f-9e87-2ea3e756c36b}	2.9	200.5	64.0%	19.1%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
{06b89f93-26c8-48dd-ba90-e8dccc53cb3f}	0.405	74.9	54.0%	45.1%	4.4	0.02	0.05	0.1	0.05	25%	5	2	2
{072c7985-b21f-4f05-ad41-1f618dfdd102}	1.115	124.4	51.3%	15.0%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{07fb050f-8b40-4154-8184-860310db3e9c}	85.11	1086.3	54.4%	16.2%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{08cc1c62-469b-419b-906b-a380377def00}	14.562	449.3	56.1%	16.7%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2
{0a0daee0-48eb-4af3-a06b-0b5255f2d03b}	1.804	158.2	54.1%	39.8%	5.2	0.02	0.05	0.1	0.05	25%	5	2	2
{0a873310-4d87-4f83-8abe-8fec4d60630e}	0.327	67.3	63.8%	45.5%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{0af64b8c-28ef-467a-9e7c-d6332a5da63d}	2.099	170.6	48.2%	27.7%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
{0e6e0503-a848-4a5f-a6f1-1a0ed3d91ee4}	6.54	301.1	63.1%	36.2%	2.3	0.02	0.05	0.1	0.05	25%	5	2	2
{0ec9cb7d-a234-46ad-8ee7-c396f313c08a}	23.916	575.9	41.9%	12.3%	3.4	0.02	0.05	0.1	0.05	25%	5	2	2
{122f6717-dc7f-4837-a02f-4ad23594fdc6}	0.821	106.7	57.4%	13.1%	1	0.02	0.05	0.1	0.05	25%	5	2	2
{141d2160-e275-4791-a38e-69bba571cdd4}	0.627	93.3	40.3%	20.1%	3.5	0.02	0.05	0.1	0.05	25%	5	2	2
{14939660-5f9e-49bb-8762-a6256c8e9d50}	0.795	105	58.6%	9.7%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{197dfd02-021b-4a0a-878f-cd5d63f65886}	1.232	130.7	62.1%	45.7%	1	0.02	0.05	0.1	0.05	25%	5	2	2
{1b2e86c6-c622-46a0-a621-96a0e89db433}	1.528	145.5	65.0%	37.4%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{1dcc2367-31d0-482d-a068-cceb5a29aaef}	1.441	141.4	57.4%	33.0%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{217f103b-603a-4f43-b80c-5ccd2bfac3ea}	4.442	248.2	60.7%	30.3%	2.3	0.02	0.05	0.1	0.05	25%	5	2	2
{21da9e9d-1356-4b4b-b135-9202db2c8dce}	22.732	561.4	48.8%	14.6%	1.9	0.02	0.05	0.1	0.05	25%	5	2	2
{230cffbe-38e0-4913-9dc4-abe9bc18168e}	1.063	121.4	55.5%	40.2%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2
{233260db-85dd-4a02-b067-8cbe152d50ff}	87.837	1103.6	56.0%	12.1%	3.1	0.02	0.05	0.1	0.05	25%	5	2	2

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{235dc662-af33-4245-a0a5-0770ec517348}	1.609	149.4	61.1%	13.9%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
{245fcdaf-e12b-40f0-9dc3-fa0846ebae90}	2.89	200.2	52.0%	15.2%	3.4	0.02	0.05	0.1	0.05	25%	5	2	2
{265b9ce0-f691-4bf7-bda7-7f3bc75b0ea4}	1.106	123.8	68.7%	50.6%	0.5	0.02	0.05	0.1	0.05	25%	5	2	2
{26dd38b8-a28c-4ac1-bef5-d7216d3bd547}	0.834	107.5	66.6%	33.2%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2
{29cc6252-d413-4a2a-a99d-9f55ed6a8696}	37.055	716.8	49.6%	14.8%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{2acf3fe8-ab61-4294-9341-ec21991c859d}	2.837	198.3	50.5%	25.2%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
{2c5df7b7-41a4-434a-9018-a7444838cbe4}	0.59	90.5	63.6%	45.4%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
{2d0ed345-ac4b-4ab0-8a6b-9403a85283dd}	3.6	223.4	43.6%	31.6%	1.3	0.02	0.05	0.1	0.05	25%	5	2	2
{2e0aba76-d69a-4e14-9642-1705b40c2f61}	8.156	336.3	65.8%	55.0%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
{2e3170fc-5cd3-4a67-add5-b5ee527190ad}	15.766	467.6	61.6%	31.5%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
{31450336-880b-4ab9-b283-00a62c4144cd}	2.279	177.8	58.8%	43.3%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
{32a6ff7a-62fe-4393-a8d8-6c5b959a72d3}	2.326	179.6	60.8%	44.8%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
{32c84cd4-7067-4f1d-8b9a-7aa93f80da1a}	0.318	66.4	64.5%	53.9%	4.2	0.02	0.05	0.1	0.05	25%	5	2	2
{35df1a51-fbc3-49c0-a42f-1934b097bde6}	5.332	271.9	44.1%	32.4%	4.1	0.02	0.05	0.1	0.05	25%	5	2	2
{37227722-265c-4814-bd73-96959934a7f9}	6.415	298.2	39.3%	8.5%	0.6	0.02	0.05	0.1	0.05	25%	5	2	2
{3c161c73-bc52-4398-826c-250fe5aae41c}	2.64	191.3	68.1%	50.1%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{3e7e2a80-e682-4469-9b85-9a837a283b81}	2.647	191.6	61.8%	18.4%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{3fb85c1f-2c28-41f3-b260-a9ca06334b07}	121.784	1299.5	49.9%	26.6%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{40181e28-01e1-45c3-9b22-413be97d8669}	1.879	161.4	51.4%	36.1%	1	0.02	0.05	0.1	0.05	25%	5	2	2
{402ee7f1-f73a-490e-a844-9ae8a7f7db63}	0.818	106.5	57.5%	6.3%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{407dfbf3-4655-40e7-92a5-9ace36b0b018}	1.523	145.3	64.0%	13.8%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
{40c9a62d-abb9-4b97-ae0c-69fad9ce0ce9}	76.326	970.7	32.3%	17.2%	3.2	0.02	0.05	0.1	0.05	25%	5	2	2
{4100a136-b68c-4321-8322-c67588a9671c}	0.579	89.6	50.6%	14.8%	4.5	0.02	0.05	0.1	0.05	25%	5	2	2
{42063e92-fa59-49e8-922e-7ced1c964ef4}	76.674	1064.5	45.1%	24.0%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
{42184cb7-0884-4ad7-a7ca-7717f443562f}	1.185	128.2	59.0%	31.4%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
{44675404-65e1-4285-a879-41e92d572321}	35.894	705.5	55.7%	29.7%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
{45e8daa7-a1cb-4c4e-b571-3cc696e64ad0}	0.523	85.1	47.1%	13.8%	4.5	0.02	0.05	0.1	0.05	25%	5	2	2
{47838e8c-72fd-4b5e-801c-4993b871e18d}	11.094	392.2	65.4%	7.2%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
{48660930-969f-4e40-9fd9-c6b4e4a0af65}	6.59	302.3	62.4%	35.9%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
{48f890a1-1795-4f46-b350-594dd39b2d87}	40.046	745.2	53.0%	12.1%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{4a6bca9c-8f06-4ce0-9693-2e4d0f0587ef}	74.602	1017.1	46.7%	10.6%	3.1	0.02	0.05	0.1	0.05	25%	5	2	2
{4bd99177-1665-427c-a67b-0991e848cc5a}	6.824	307.6	61.6%	43.3%	1.9	0.02	0.05	0.1	0.05	25%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
{4e254db7-fa52-4fce-97f3-c9daee7ea1d8}	0.761	102.7	68.3%	36.0%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{4f9b4631-57e7-4785-9b4f-a4aaa9967c12}	0.701	98.6	57.0%	9.4%	6.3	0.02	0.05	0.1	0.05	25%	5	2	2
{4fc1b3b3-70c0-43a6-ae6a-27ff8f24e005}	0.77	103.4	55.9%	16.7%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{5050028f-ac4e-4944-b57c-e8422a92f5eb}	2.078	169.7	60.0%	42.8%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
{50d40316-95bb-4b78-8684-f3dfa729b3f0}	56.335	883.8	100.0%	23.0%	1	0.02	0.05	0.1	0.05	0%	5	2	2
{51892345-7ca9-4af9-a05a-d336fab14cf1}	2.399	182.4	50.9%	25.4%	0.3	0.02	0.05	0.1	0.05	25%	5	2	2
{53eb1778-ac36-41b8-900c-2203547974ce}	2.075	169.6	52.3%	15.6%	0.6	0.02	0.05	0.1	0.05	25%	5	2	2
{53fe7fa4-39a1-43a9-8459-80e45818fe63}	0.585	90.1	62.3%	33.1%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{55aa31d3-9613-4559-86c1-c7ee61a85f3a}	2.889	200.1	65.5%	14.1%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
{56728f77-2ab2-421a-bd9e-70e7edd8c6b3}	4.741	256.4	49.4%	36.4%	2.7	0.02	0.05	0.1	0.05	25%	5	2	2
{5855b344-ba16-44ac-b224-25894221bfdb}	1.942	164.1	45.4%	13.3%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{5c0544ec-0a03-4d42-8591-a4791950a7b7}	7.937	331.7	49.3%	8.1%	1	0.02	0.05	0.1	0.05	25%	5	2	2
{5dafc15d-27cc-4a4c-b9cc-855f7eed1316}	2.899	200.5	23.9%	11.9%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{601de21b-9976-4033-b90f-7b22e8552128}	2.713	194	40.2%	8.7%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{6122f895-7a89-435c-af8d-1b649ad008f0}	3.817	230.1	31.2%	16.6%	0.6	0.02	0.05	0.1	0.05	25%	5	2	2
{62994278-d3fd-4319-9393-6214810e2077}	3.647	268.1	34.8%	18.5%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2
{64fc2055-935e-4997-90b8-08932ce5e3a4}	1.723	154.6	48.9%	14.3%	2.8	0.02	0.05	0.1	0.05	25%	5	2	2
{6899eb3d-a4fa-4241-bc77-7871cb4ed74a}	0.563	88.4	62.3%	35.8%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{68e6efcd-6ba8-46a9-a849-e51c74d8c6d7}	2.171	173.5	43.9%	9.5%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
{6b991c51-7aa7-4cc8-b5fd-c1692cdec045}	2.696	193.4	62.2%	51.9%	2.3	0.02	0.05	0.1	0.05	25%	5	2	2
{6e19b036-715f-42fa-896f-137407dff20b}	7.281	317.7	43.2%	31.8%	2.7	0.02	0.05	0.1	0.05	25%	5	2	2
{6e6907c9-04b3-42fe-9724-a5510bb27940}	331.736	2144.7	56.2%	6.2%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2
{7109da36-feac-457f-b8de-61bac527a454}	3.318	214.5	58.2%	48.6%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
{71e93b23-1207-4e50-bcd2-1c3243ec1d04}	3.218	211.2	59.6%	31.5%	3.2	0.02	0.05	0.1	0.05	25%	5	2	2
{7233df0e-9bce-4dd5-8598-0701f89bb563}	9.802	368.7	65.8%	14.2%	1.7	0.02	0.05	0.1	0.05	25%	5	2	2
{75c3a74c-fc34-48ba-9d17-19d8ac5a2a9b}	1.103	123.7	55.2%	16.2%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{766c0833-1bd1-4be1-82d5-df04482e06ca}	7.073	313.2	52.0%	38.2%	2.7	0.02	0.05	0.1	0.05	25%	5	2	2
{771bf7a2-0c94-4aa9-b82b-eb8d73c54f4c}	2.952	202.3	29.7%	8.9%	3.7	0.02	0.05	0.1	0.05	25%	5	2	2
{77c2dfef-a5fc-4f5c-8c76-4818627f8585}	8.06	334.3	62.2%	43.7%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
{77ec1b6b-61eb-4a96-8288-7b4ee42fbf4a}	0.669	96.3	60.0%	43.5%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{77f20508-47eb-4d76-bffa-90eb2adf10a1}	1.942	164.1	67.4%	34.4%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
{77f9c1e0-2ad0-4211-942f-bf31a1ccd8e6}	0.462	80	51.0%	8.4%	5	0.02	0.05	0.1	0.05	25%	5	2	2

Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
{788d4217-5a71-47cd-bffe-0de3512ef840}	67.244	965.6	47.5%	10.8%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2
{7fc897bc-fc16-4f2b-b8cd-9b251e481fb4}	0.773	103.5	65.6%	47.6%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{812f1ca7-87bf-4ec7-a7c1-915e3aa16a3e}	10.032	373	53.9%	15.8%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
{812fb8b7-0dc7-4e7e-b916-9f19bd402ee0}	4.077	237.8	24.3%	2.3%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
{814d152b-087b-4867-ae61-c96f13ad1675}	0.676	1064.5	53.0%	28.2%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
{814f0c64-403c-42c4-8ce7-b7bc98941b75}	1.695	153.3	61.0%	35.0%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
{8420cb77-d2bf-4447-a8c3-135e39fbbab2}	21.721	548.8	52.4%	15.6%	2.1	0.02	0.05	0.1	0.05	25%	5	2	2
{8460c431-4e07-4200-97ff-366c5e2eb3a6}	43.856	779.8	54.1%	38.6%	1.8	0.02	0.05	0.1	0.05	25%	5	2	2
{84ccdb2c-555e-4416-a92b-2102d8810549}	0.44	78.1	55.9%	41.1%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{864061b2-f343-46e0-8dde-56e8614088b0}	1.927	163.5	55.2%	11.9%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
{874ec50f-a2e0-446b-8ecc-059c11e2807e}	2.59	189.5	40.5%	9.2%	2.9	0.02	0.05	0.1	0.05	25%	5	2	2
{88780532-47cc-4236-bba5-e94cda659ab1}	1.392	138.9	48.0%	14.3%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{8c4c8f34-6966-43d2-a97b-58b1e680b365}	2.548	188	44.9%	2.9%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{8caba47e-bd9b-4bb4-9137-2029024c3f22}	51.919	848.5	50.1%	25.0%	2.3	0.02	0.05	0.1	0.05	25%	5	2	2
{8d09eaff-1a07-4d67-95f1-ee291d96d92b}	1.661	151.8	61.5%	45.3%	2	0.02	0.05	0.1	0.05	25%	5	2	2
{902ae9d4-0639-4822-8274-68193c8ca77e}	4.688	255	65.3%	45.9%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{91b4aa15-8c1b-4e6a-9c43-5458ed071dcc}	2.922	201.3	54.6%	16.0%	5.4	0.02	0.05	0.1	0.05	25%	5	2	2
{91f7174f-b8ee-4ad4-8ed5-7a25f4aee76c}	0.135	43.2	0.0%	0.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
{932fe77d-45eb-4188-9275-7609420af1cb}	3.277	213.1	36.7%	4.0%	5.5	0.02	0.05	0.1	0.05	25%	5	2	2
{94c09d88-a4c9-4ea4-b486-d48011805d5d}	1.284	133.4	57.8%	30.8%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{9528247b-16b1-4f91-92fe-f2b24693b2bb}	1.659	151.7	64.4%	47.4%	3.5	0.02	0.05	0.1	0.05	25%	5	2	2
{9911c0d1-cbed-46c4-9cf4-410b5aeab701}	2.412	182.9	59.4%	43.7%	2.6	0.02	0.05	0.1	0.05	25%	5	2	2
{9ba11db2-4202-4c42-9296-cbe4b5101762}	46.346	801.6	56.1%	12.8%	2	0.02	0.05	0.1	0.05	25%	5	2	2
{9c3abcad-45f2-4b7d-b249-005fb925b141}	33.584	682.4	56.0%	6.2%	2.6	0.02	0.05	0.1	0.05	25%	5	2	2
{9ec6b10c-43e0-40b5-a04c-296f39105f14}	0.278	62.1	0.0%	0.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
{9f05728c-2fc2-40d7-96c7-9d435028d197}	0.694	98.1	67.7%	56.5%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{a1d747c9-68e9-4265-aadb-f25380ab64ce}	1.205	129.3	40.9%	21.8%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{a4ca6120-6064-42ee-ae88-5de915da57db}	6.102	290.9	45.4%	13.5%	3	0.02	0.05	0.1	0.05	25%	5	2	2
{a6cd0422-8642-44ed-b3f9-d83494af24bb}	1.176	127.7	36.2%	7.8%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
{ad4a7d5d-b4ac-4687-b030-51bf264cd4e0}	1.324	135.5	32.9%	17.5%	1	0.02	0.05	0.1	0.05	25%	5	2	2
{ad638dd8-6ac0-4312-affe-fc4f1938dc8b}	9.867	369.9	36.6%	18.3%	5.6	0.02	0.05	0.1	0.05	25%	5	2	2
{ae9cff20-0b69-4c22-8e46-1312f5d1e202}	1.124	124.8	58.7%	41.9%	0.6	0.02	0.05	0.1	0.05	25%	5	2	2

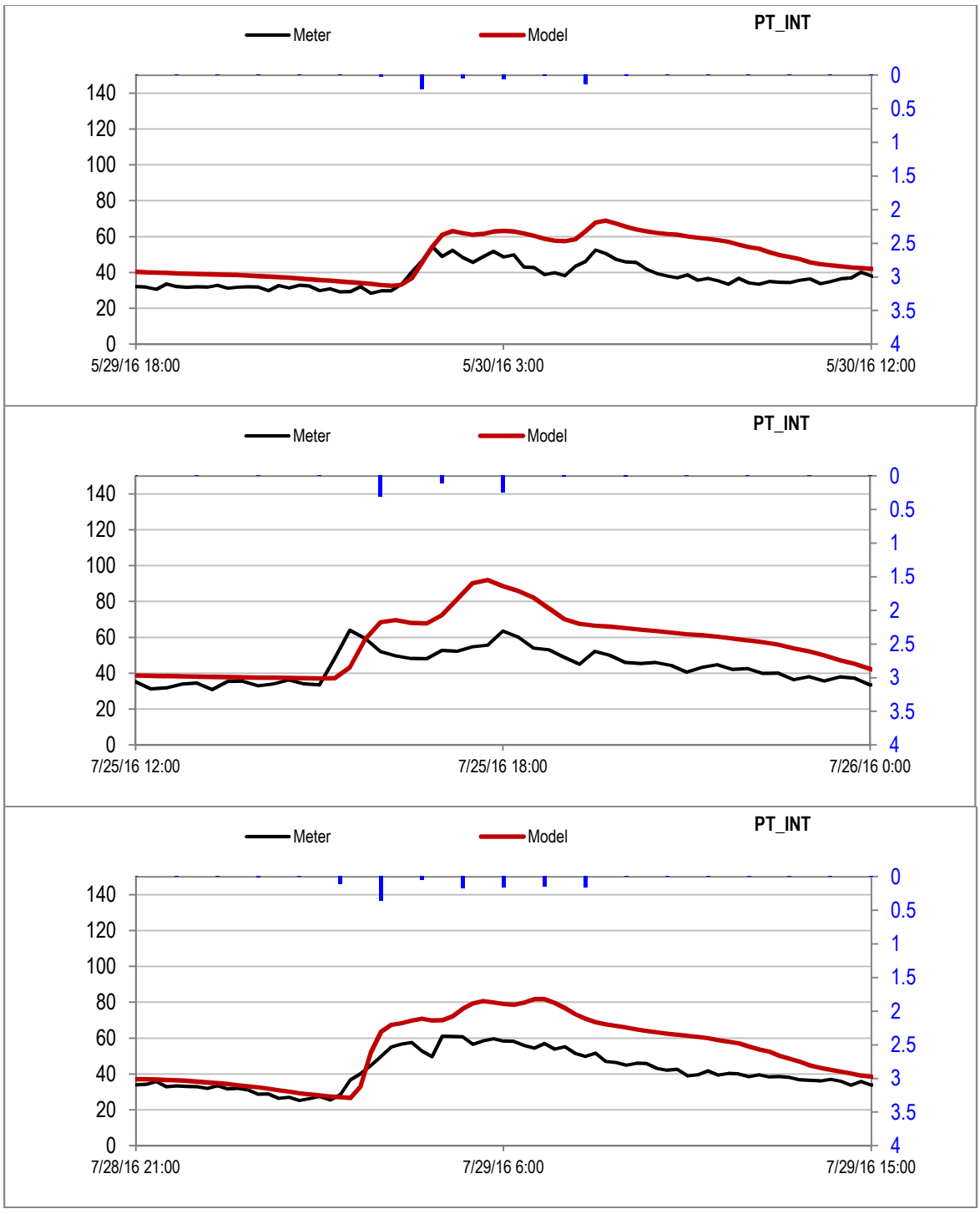
Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
{b128fd5f-71ae-4b15-8739-da060d8ad338}	1.615	149.6	45.4%	10.3%	3.7	0.02	0.05	0.1	0.05	25%	5	2	2
{b44e1335-c55d-46f8-8f72-856fddf35b11}	3.051	205.7	55.6%	29.6%	1.9	0.02	0.05	0.1	0.05	25%	5	2	2
{b45efd80-3293-4b78-a37f-7449093948af}	19.364	518.2	54.5%	38.3%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{b463ea69-b463-48df-b8a8-d10e772848b0}	67.809	969.6	53.4%	28.4%	1	0.02	0.05	0.1	0.05	25%	5	2	2
{b5cf924b-39f0-48ce-9069-d9a5d9d4b53f}	129.262	1338.8	42.5%	4.1%	3.3	0.02	0.05	0.1	0.05	25%	5	2	2
{b6b33c9a-8a22-47c3-8d51-8c3f9104d92c}	39.837	743.2	40.1%	9.1%	4.8	0.02	0.05	0.1	0.05	25%	5	2	2
{b7026465-57f8-460c-9bd3-d10888a11ae8}	17.012	485.7	30.6%	6.6%	2.5	0.02	0.05	0.1	0.05	25%	5	2	2
{b7adbc18-a2b5-4958-9373-6cbc492ec075}	38.572	731.3	49.1%	24.5%	2.6	0.02	0.05	0.1	0.05	25%	5	2	2
{bc5bfa08-5165-4732-8264-3a6f25199921}	0.455	79.5	48.0%	24.0%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{beb7bdc3-aea5-43df-9702-359097df8822}	2.984	203.4	53.3%	11.5%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
{beef1350-0ecb-4bac-afba-faa619918725}	1.802	158.1	60.8%	34.9%	1.9	0.02	0.05	0.1	0.05	25%	5	2	2
{c0d33f42-355a-4240-a2db-ec14bfac587d}	0.574	89.2	53.3%	37.4%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{c0e6c754-56ad-49b3-a893-466da624049f}	1.086	122.7	62.1%	31.0%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{c5abd834-714c-4293-85e7-8a541e894561}	34.066	687.3	51.0%	26.9%	2	0.02	0.05	0.1	0.05	25%	5	2	2
{c8370e38-ac69-4500-bec6-220a93dcf6a9}	2.025	167.6	65.1%	47.9%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2
{cbb5f9ba-bd8a-493f-9b43-fb915667c1a0}	1.017	118.7	55.3%	11.9%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{cc4dca10-1a7b-49fe-a293-ac8a3e7d87c6}	0.323	66.9	0.0%	0.0%	0	0.02	0.05	0.1	0.05	0%	5	2	2
{cc9aca9a-60ec-4cf0-aa0e-856a3d06cff2}	1.528	145.6	1.4%	0.1%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{cd60b6d1-dba0-4fab-82b6-ea176ff27f9f}	1.278	133.1	47.9%	25.5%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
{cd7ff27e-c0e6-4602-ab67-9b72c6627732}	1.537	146	47.9%	7.9%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{cda91ad0-a9aa-4f48-9232-ddcb846ac598}	10.072	373.7	54.2%	16.2%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
{cdcea2a8-a3d1-42ba-8241-7a1e2665a9f8}	11.617	401.3	51.9%	15.5%	0.4	0.02	0.05	0.1	0.05	25%	5	2	2
{ce1c0c5f-e968-4146-999f-a82a301752e9}	0.848	108.4	49.8%	11.3%	5.1	0.02	0.05	0.1	0.05	25%	5	2	2
{ce9da6fc-256c-4992-b384-aeb54728bcc8}	0.257	59.7	45.8%	3.0%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{cefb6757-5553-45b6-8014-603cdc94f29b}	2.214	175.2	28.0%	14.9%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
{cf960007-f1ef-47ad-96d4-c80b03c44ba1}	0.883	110.7	63.3%	45.9%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
{d2497c99-31c6-4291-860b-3315f21d2d49}	1.14	125.7	61.1%	13.9%	2.7	0.02	0.05	0.1	0.05	25%	5	2	2
{db681d0b-981b-42ea-bf93-151cab5035c1}	17.187	488.2	53.2%	15.6%	3.7	0.02	0.05	0.1	0.05	25%	5	2	2
{dc6fe25a-f503-45f4-9a50-c6aa0043862c}	0.838	107.8	69.5%	35.5%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{dd20e886-d072-4e3d-bee2-1523a6c8d8ec}	8.095	335	23.4%	17.2%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{de422b2a-6ca5-46f9-b66b-cade305614bc}	1.453	142	61.4%	32.7%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
{deeb0643-63e7-4412-a3ab-80be4d8dd993}	3.69	226.2	54.8%	6.0%	2.4	0.02	0.05	0.1	0.05	25%	5	2	2

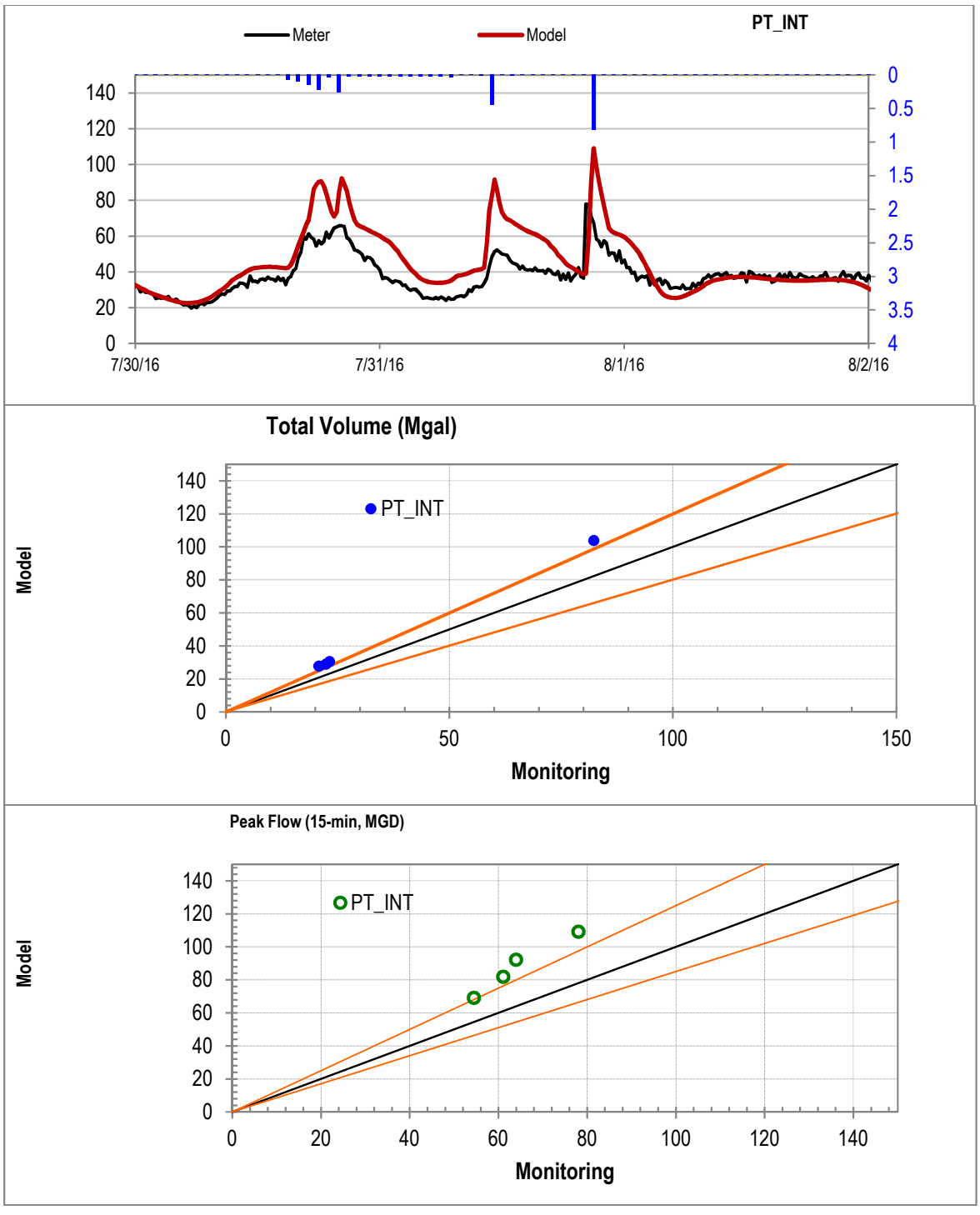
Subcatchment ID	Total area (acre)	Width (ft)	% imperv.	Effective % Imperv.	Slope (%)	Manning's N_ pervious	Manning's N_ impervious	Depression Storage_ Pervious (in)	Depression Storage_ impervious (in)	% of Impervious without Depression Storage	Horton initial (in/hr)	Horton limiting (in/hr)	Horton decay (1/hour)
{e147699b-8cd0-4c68-af1d-8fca70900cfb}	24.712	585.4	47.4%	14.1%	2	0.02	0.05	0.1	0.05	25%	5	2	2
{e2135597-687b-4d94-93c2-034632d8d8d0}	1.076	122.1	43.9%	25.2%	2.6	0.02	0.05	0.1	0.05	25%	5	2	2
{e266efd5-a26d-4769-8e6a-ae66970d8b37}	8.306	339.4	53.3%	28.4%	1.2	0.02	0.05	0.1	0.05	25%	5	2	2
{e2bdcb6a-6917-4e63-9008-ab1741739883}	0.778	103.9	55.5%	12.0%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
{e3b75612-a6a9-4c5d-9351-4e822b3f7c6b}	2.057	168.9	48.8%	14.6%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
{e4248cf4-fecd-4f07-9456-eeb2c66e5729}	47.181	808.8	61.3%	45.1%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{e49b25c2-4ad3-46d3-8875-5d04f21a89d9}	2.054	168.8	20.3%	1.9%	2.6	0.02	0.05	0.1	0.05	25%	5	2	2
{e6354b82-0a46-4609-86f6-68be6c6e3931}	64.657	946.8	55.1%	40.5%	2.3	0.02	0.05	0.1	0.05	25%	5	2	2
{e6e4ec23-799e-4bdc-a20b-28eebd8b0093}	19.836	524.4	51.5%	15.4%	0.6	0.02	0.05	0.1	0.05	25%	5	2	2
{e713c73b-5449-488e-9c5d-1cf6e6bdc6c2}	0.519	84.8	45.0%	31.6%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{e7a44f3a-308a-4130-9427-8ea80f34818e}	0.97	116	58.1%	13.2%	0.2	0.02	0.05	0.1	0.05	25%	5	2	2
{eabf784f-f4c1-4fd8-8459-72ccb8b55277}	16.312	475.6	46.2%	13.5%	2.3	0.02	0.05	0.1	0.05	25%	5	2	2
{ed324ed2-0dc4-459c-aecc-f04e5838e618}	2.382	181.7	46.4%	10.6%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{ed997efb-dada-44af-aa27-b67b68f665de}	0.666	96.1	59.3%	43.6%	3.4	0.02	0.05	0.1	0.05	25%	5	2	2
{ee45e3f9-7cd2-4eb2-8cc7-9e374c8d7b6a}	4.439	352.9	12.3%	6.6%	4.2	0.02	0.05	0.1	0.05	25%	5	2	2
{eeae12a8-0a7d-4d40-8aad-aee9fa5394e2}	3.565	222.3	37.6%	21.6%	1.6	0.02	0.05	0.1	0.05	25%	5	2	2
{f0519079-2372-427e-aec8-b1e5b656361f}	1.66	151.7	52.1%	29.9%	3.5	0.02	0.05	0.1	0.05	25%	5	2	2
{f0be5f9d-e8c7-4a4c-865c-d40b48067164}	4.142	239.7	53.8%	16.0%	0.7	0.02	0.05	0.1	0.05	25%	5	2	2
{f381a02c-48f7-48dc-8cea-b64b52000fd2}	1.141	125.8	39.8%	4.4%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{f3b930c7-86c3-4416-9ad7-ec0025aa3b76}	1.741	155.4	63.4%	45.2%	0.9	0.02	0.05	0.1	0.05	25%	5	2	2
{f56951cb-9c12-4192-8e0a-1cadfd74b0bb}	74.376	1015.5	59.8%	44.0%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2
{f60b7ea9-3cf4-4d79-9d47-cbd7ac2f7795}	0.968	115.9	66.0%	48.6%	0	0.02	0.05	0.1	0.05	25%	5	2	2
{f8de6ed5-ca93-4506-ad88-34be21be58ae}	0.979	116.5	64.5%	46.1%	1.1	0.02	0.05	0.1	0.05	25%	5	2	2
{f9391633-df99-46d6-ac9f-cc68297c43eb}	1.782	157.2	58.2%	29.1%	1.4	0.02	0.05	0.1	0.05	25%	5	2	2
{fcde0ea1-8c19-4d75-9e24-0152cde8330f}	1.424	140.5	63.5%	46.0%	0.8	0.02	0.05	0.1	0.05	25%	5	2	2
{ff31184a-5c61-4f35-9ffe-19a854cc7cf8}	0.969	115.9	62.5%	35.9%	1.5	0.02	0.05	0.1	0.05	25%	5	2	2

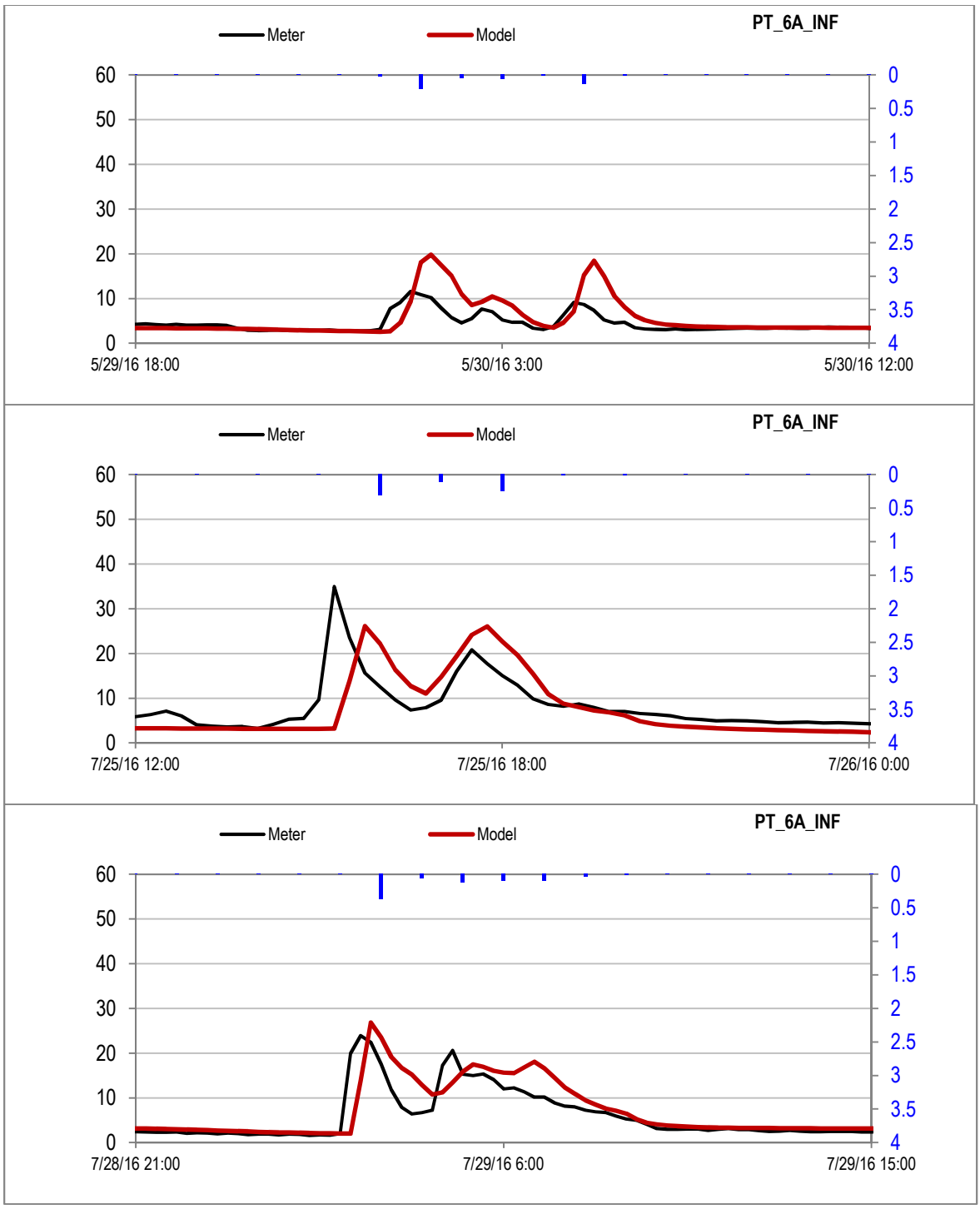
Note: JCMUA Subcatchments included in table are reflective of current PVSC Sewer District Hydrologic and Hydraulic model. Refer to separate JCMUA System Characterization Report for additional details of JCMUA Hydrologic and Hydraulic model.

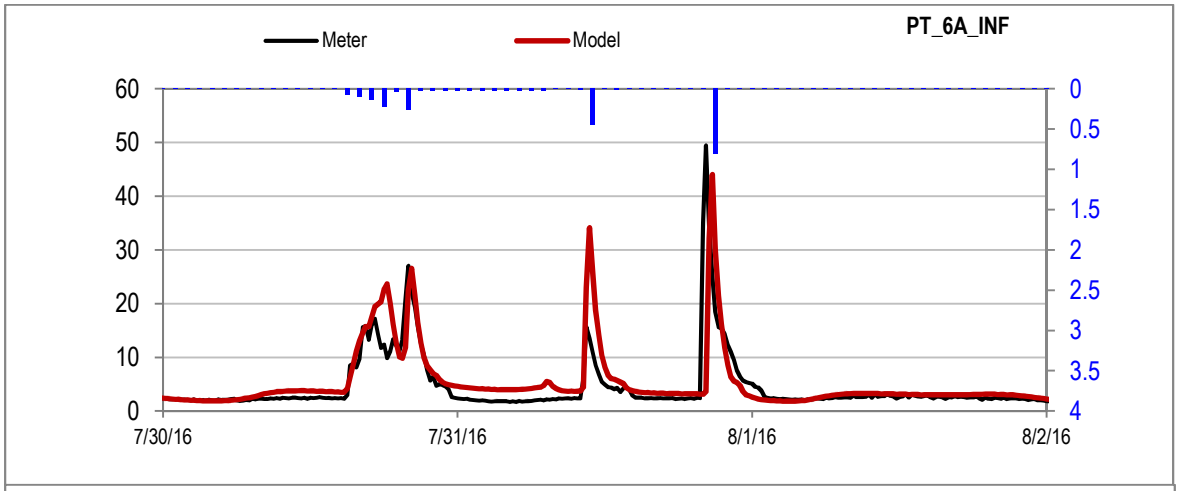
APPENDIX D

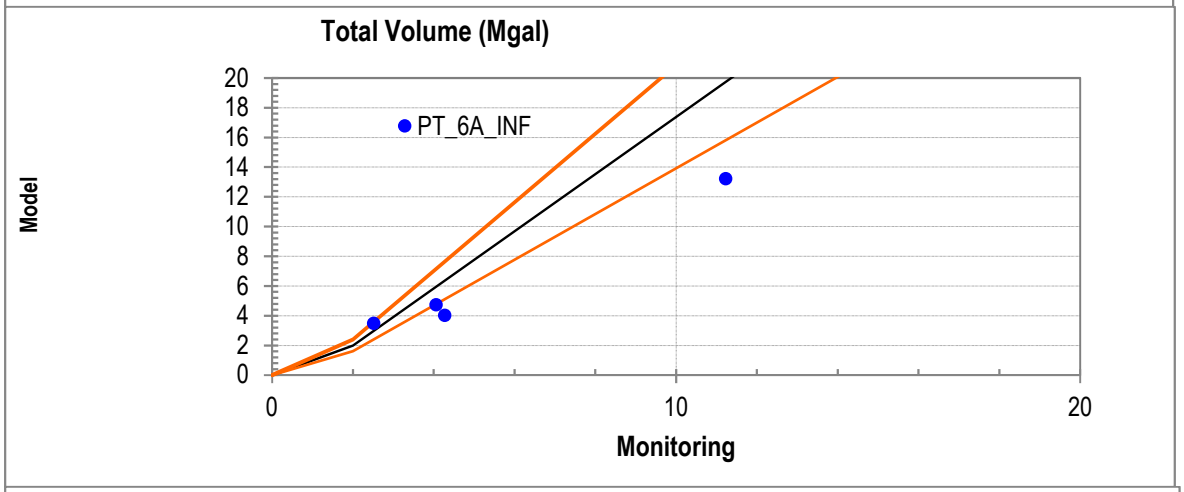
H&H Modeling Calibration Plots

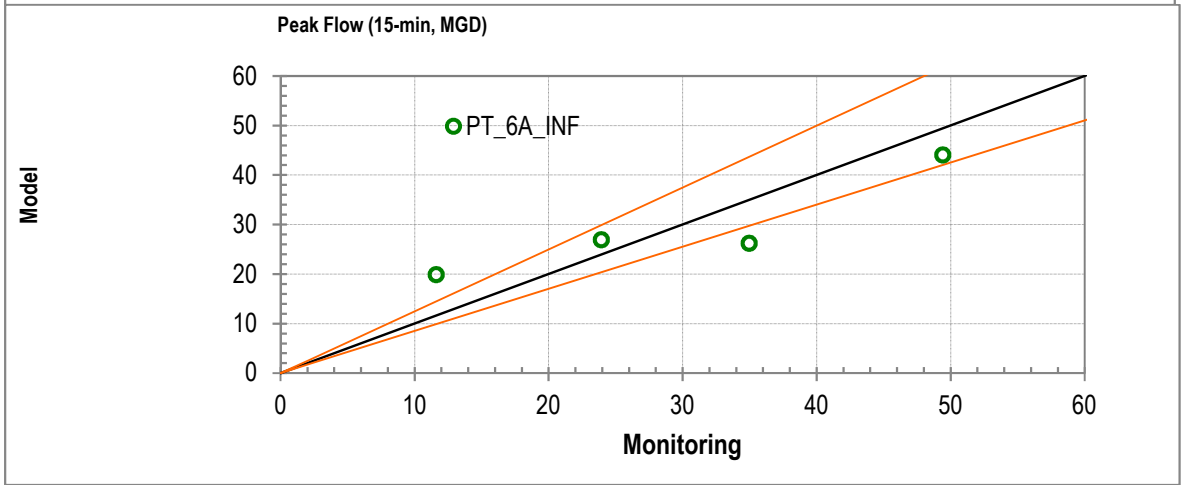

PT_INT
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
PT_INT
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
PT_INT
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

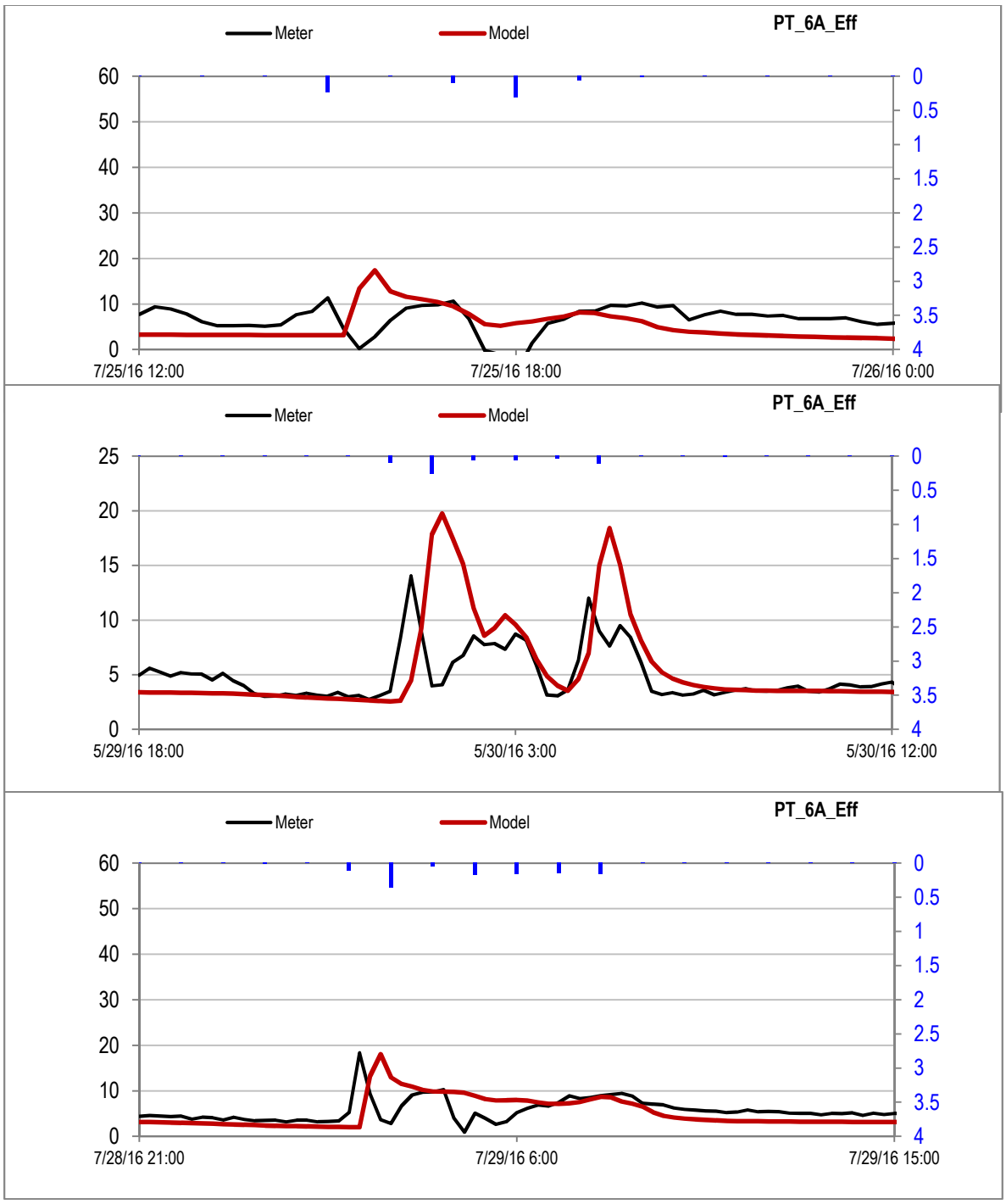

Meter
Model
PT_INT
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
PT_INT
0
50
100
150
Monitoring
Peak Flow (15-min, MGD)
Model
PT_INT
0
20
40
60
80
100
120
140
Monitoring

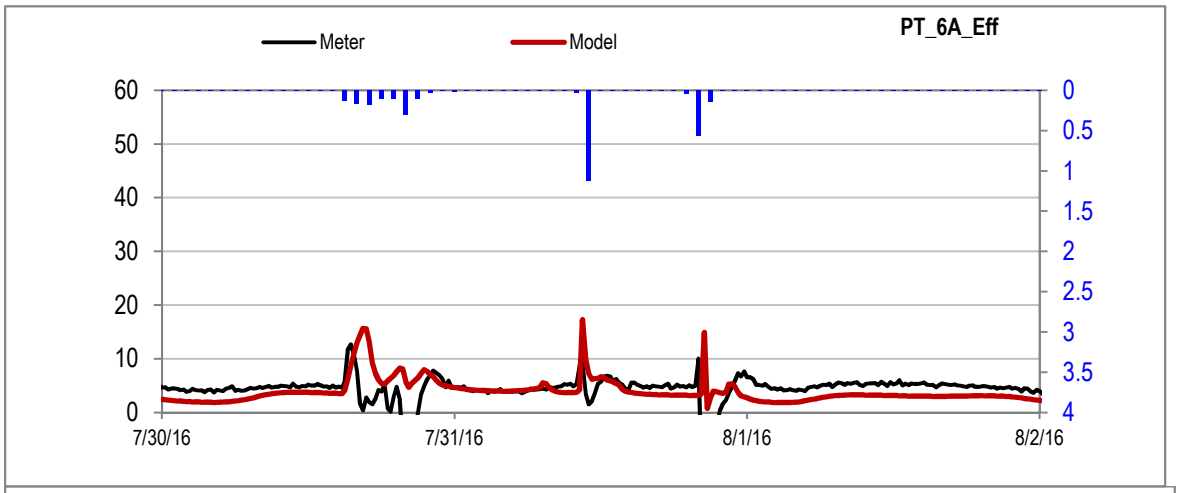

PT_6A_INF
Meter
Model
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
PT_6A_INF
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
PT_6A_INF
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

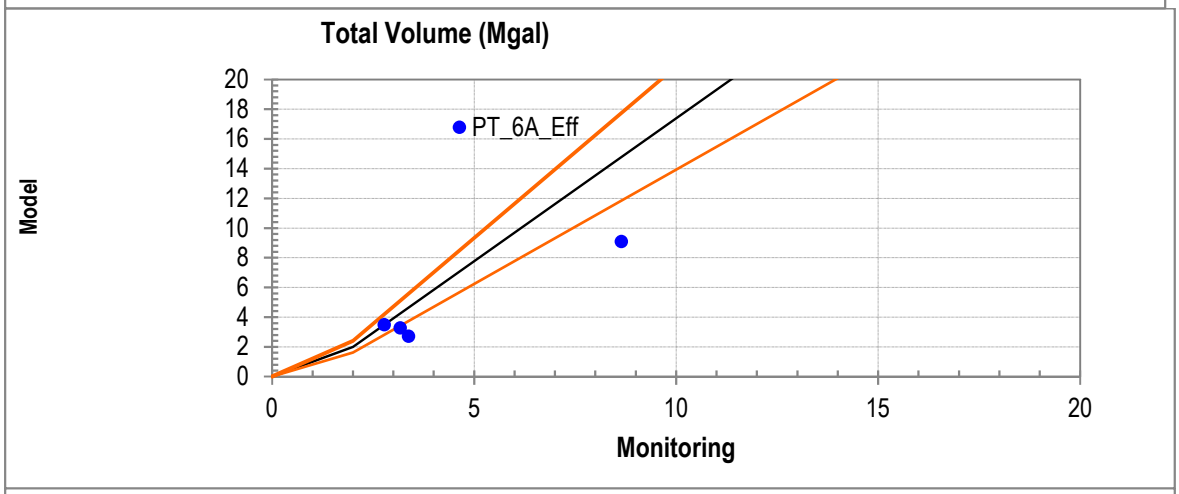

PT_6A_INF
Meter
Model
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

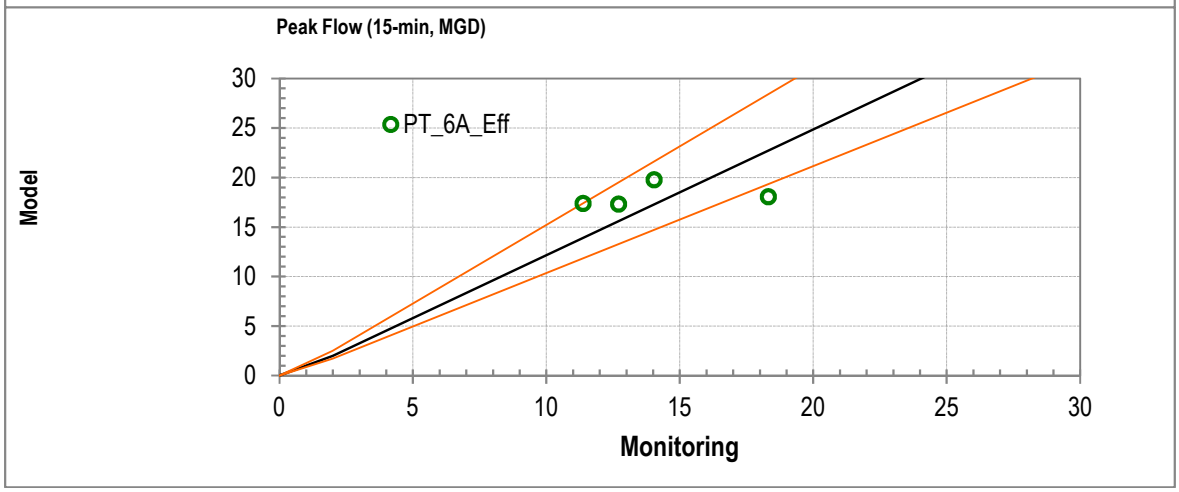

Total Volume (Mgal)
PT_6A_INF
Model
Monitoring
20
18
16
14
12
10
8
6
4
2
0
0
10
20

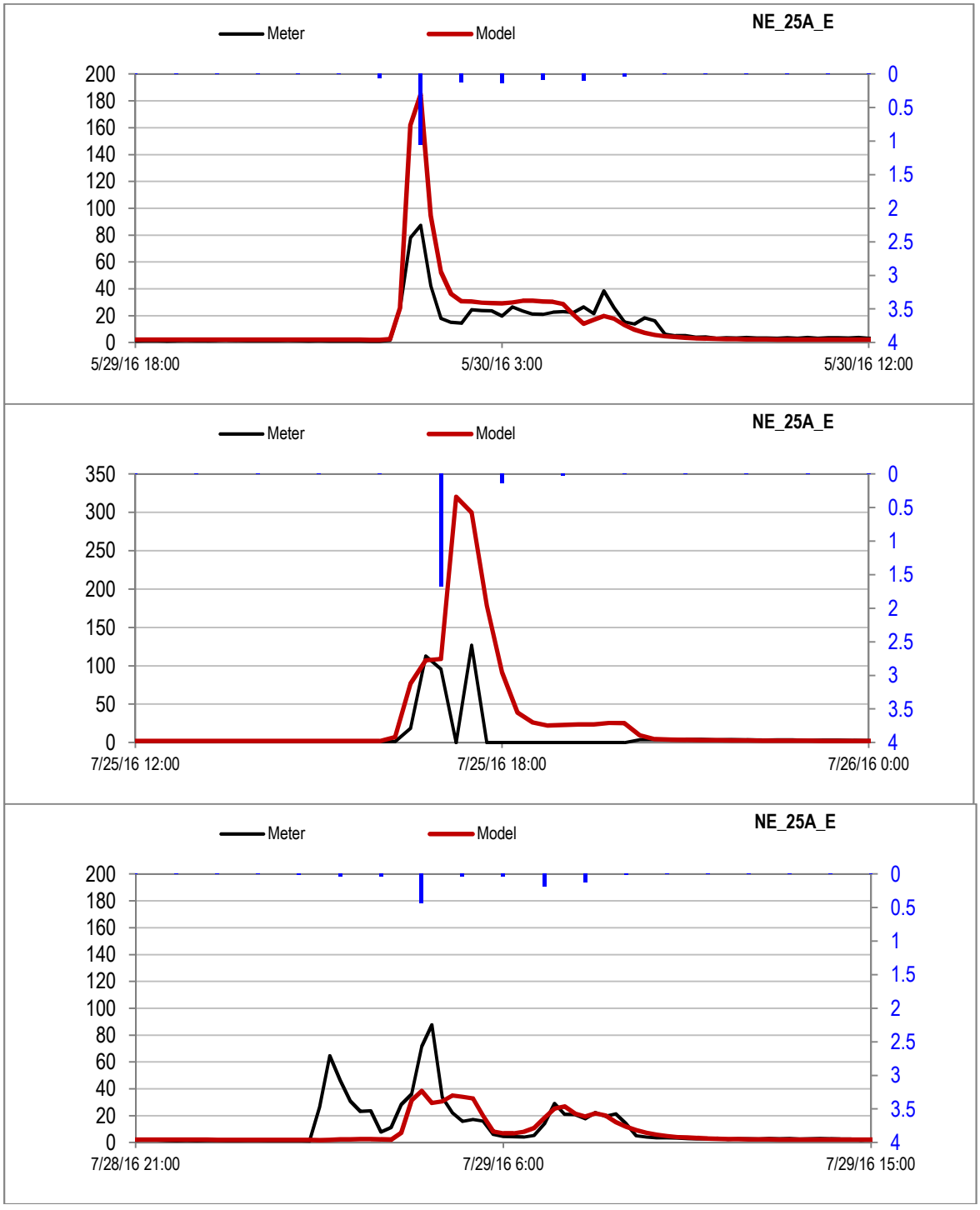

Peak Flow (15-min, MGD)
PT_6A_INF
Model
Monitoring
60
50
40
30
20
10
0
0
10
20
30
40
50
60

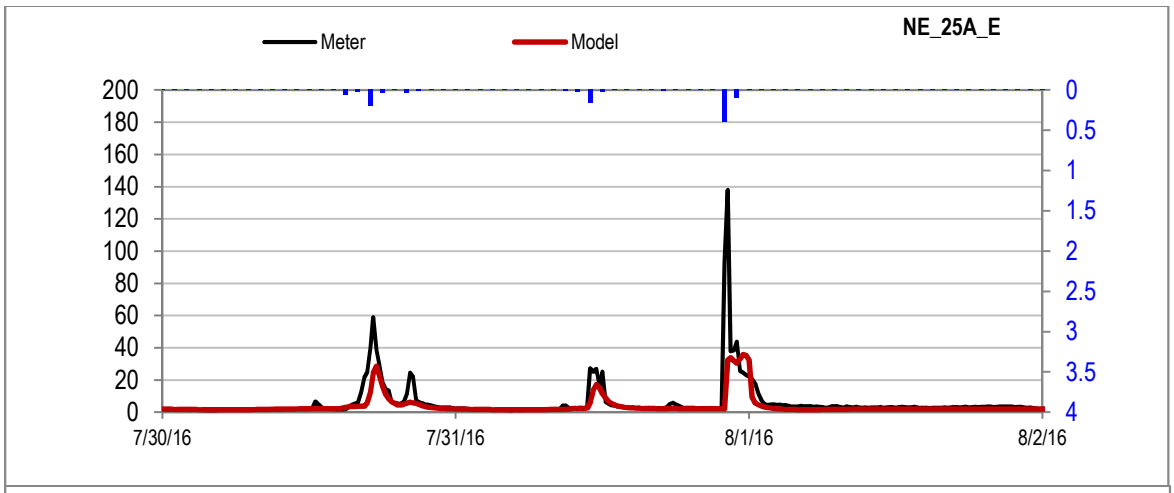

Meter
Model
PT_6A_Eff
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
Meter
Model
PT_6A_Eff
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Meter
Model
PT_6A_Eff
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

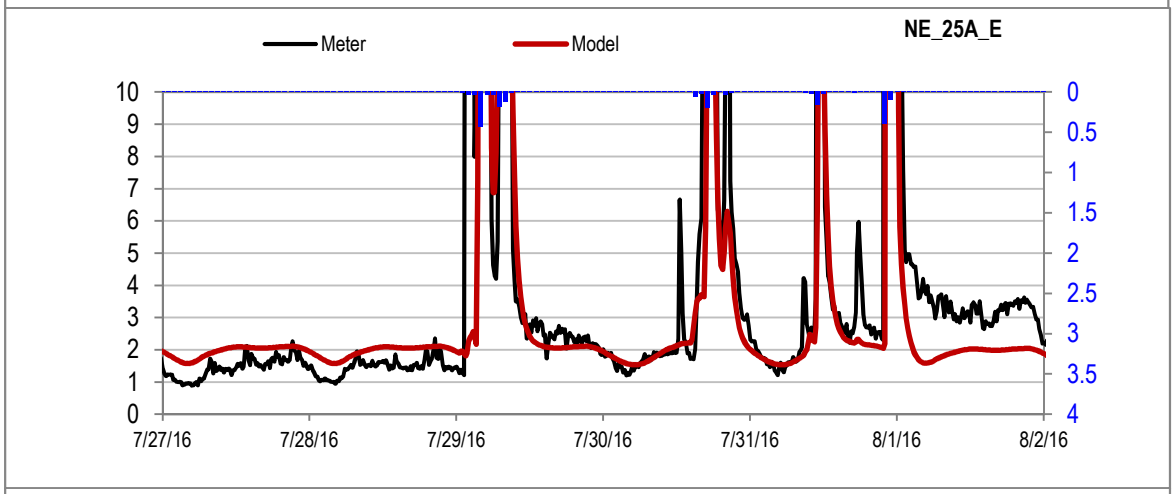

PT_6A_Eff
Meter
Model
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

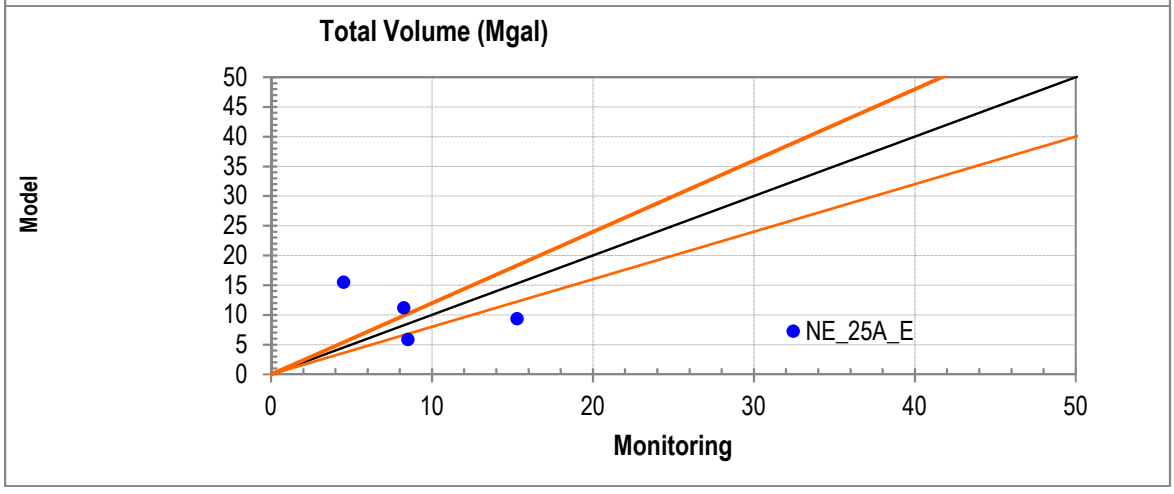

Total Volume (Mgal)
Model
PT_6A_Eff
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
Monitoring

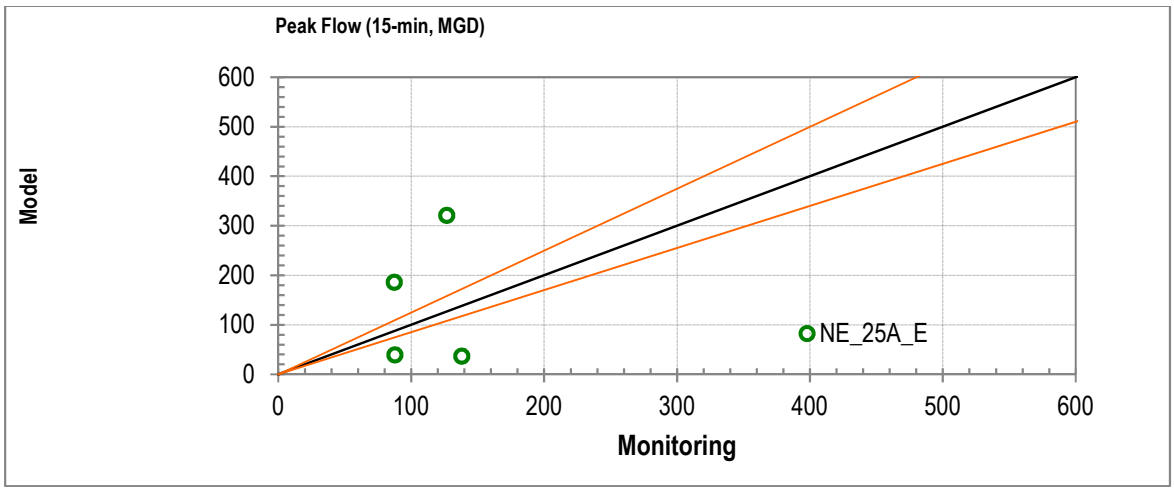

Peak Flow (15-min, MGD)
Model
PT_6A_Eff
30
25
20
15
10
5
0
0
5
10
15
20
25
30
Monitoring

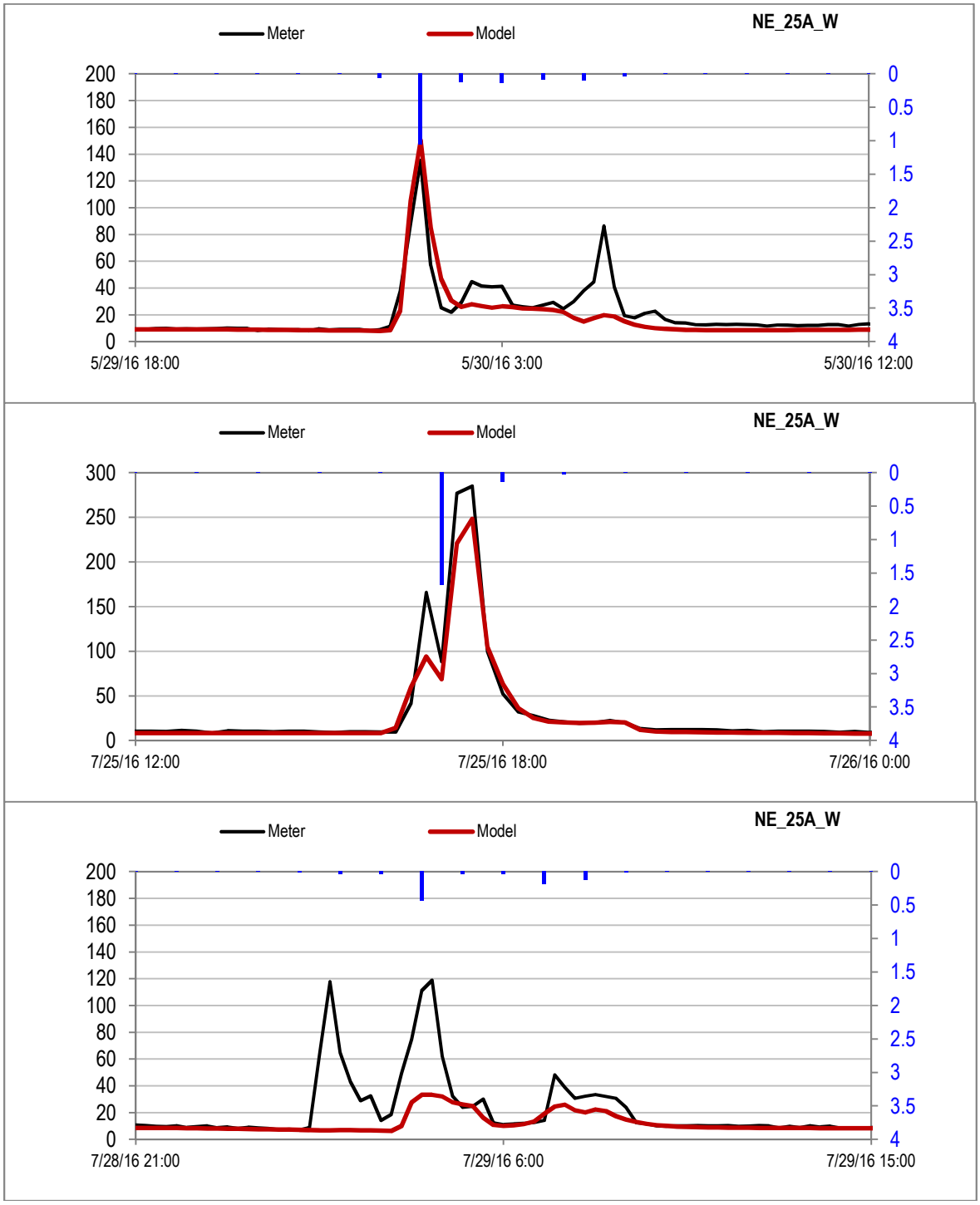

NE_25A_E
Meter
Model
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NE_25A_E
Meter
Model
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
NE_25A_E
Meter
Model
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

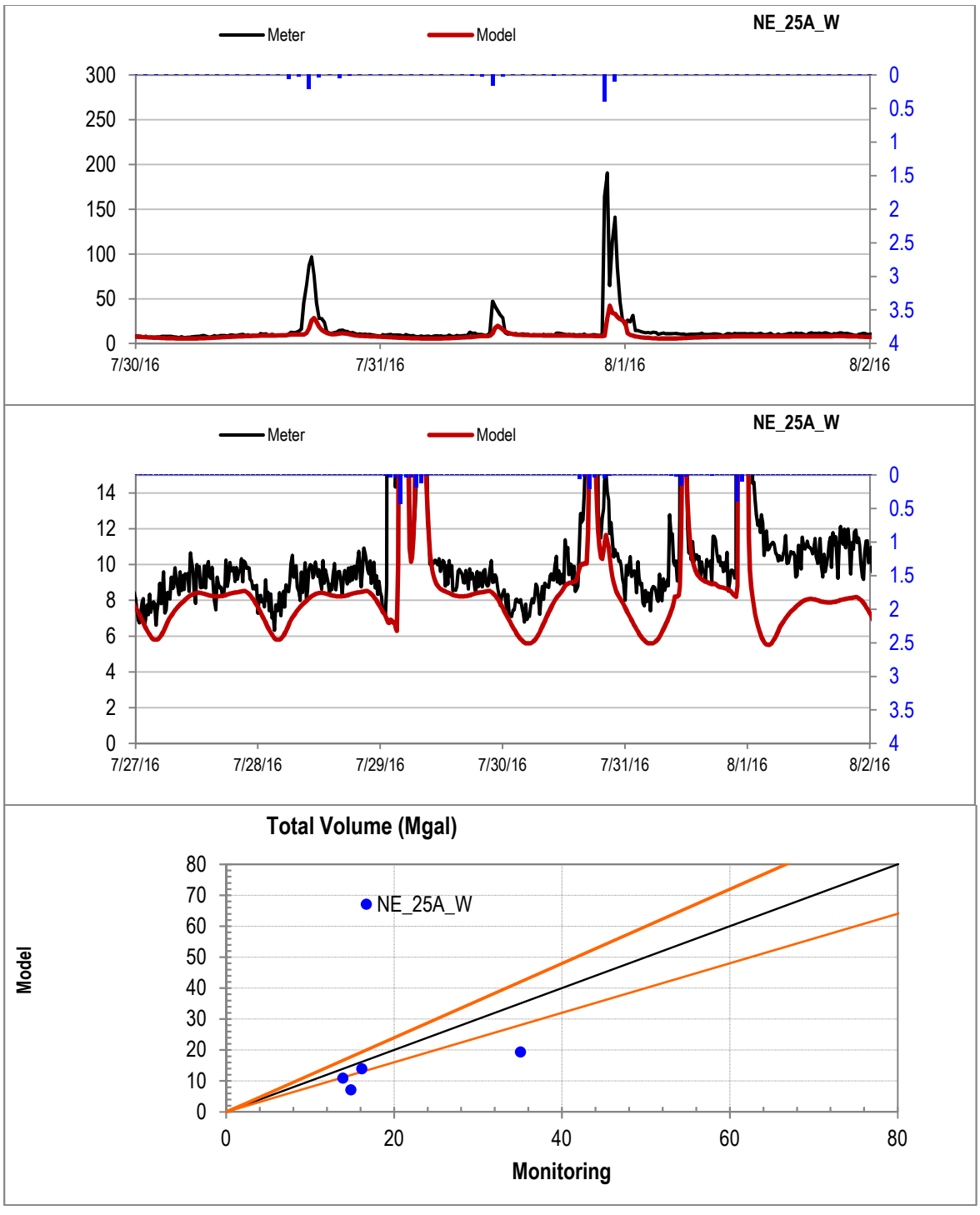

NE_25A_E
Meter
Model
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

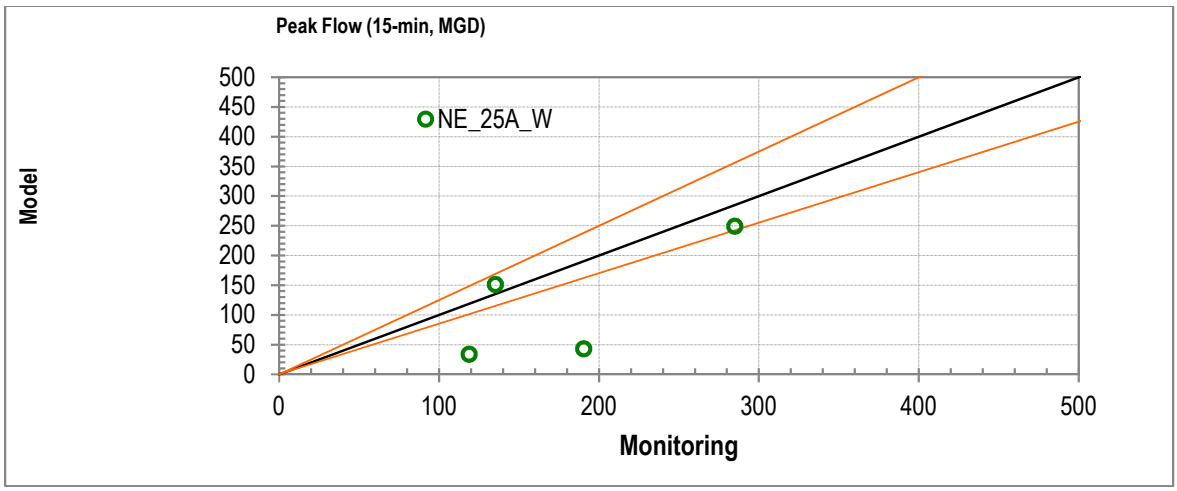

NE_25A_E
Meter
Model
10
9
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/27/16
7/28/16
7/29/16
7/30/16
7/31/16
8/1/16
8/2/16

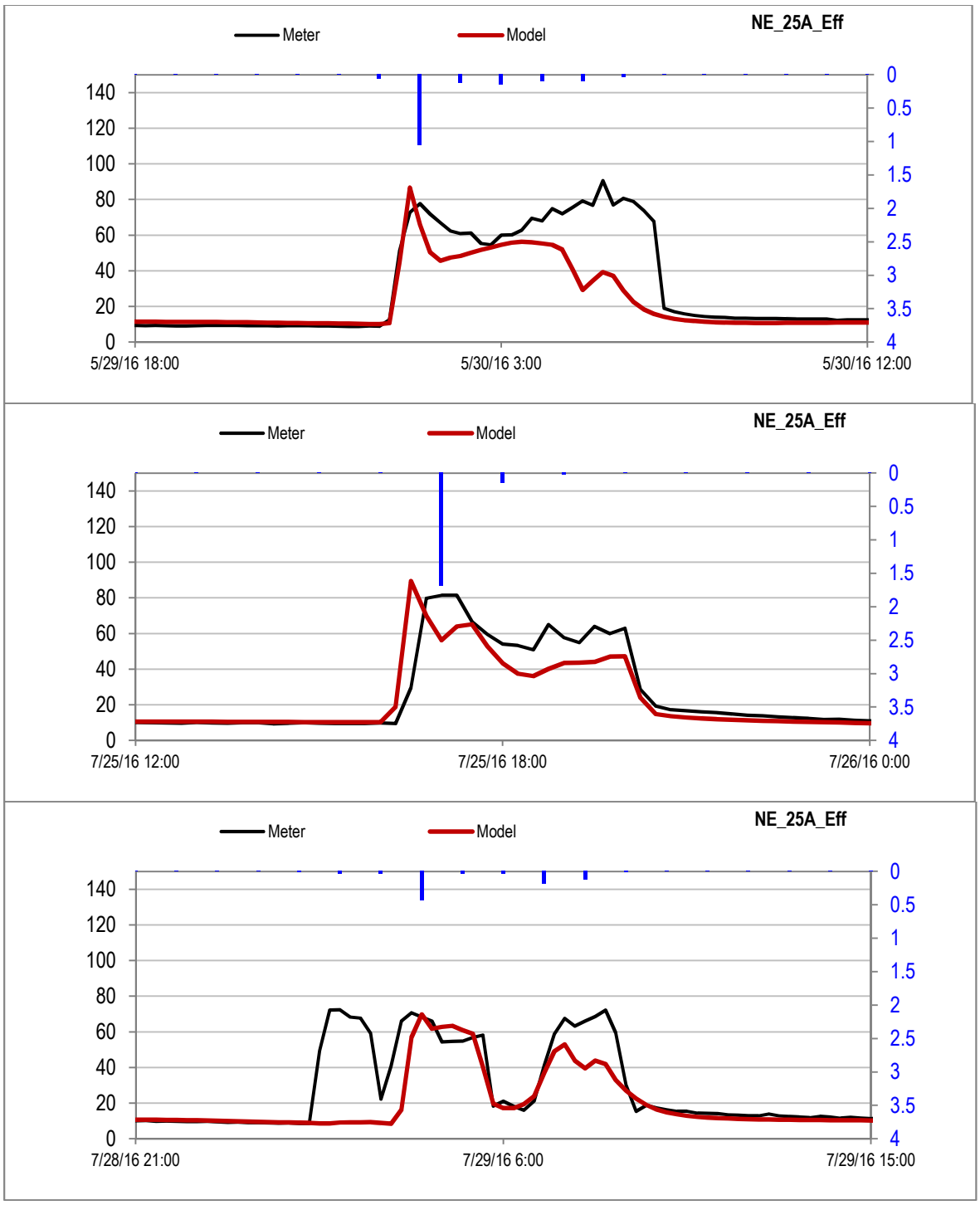

Total Volume (Mgal)
Model
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
Monitoring
NE_25A_E

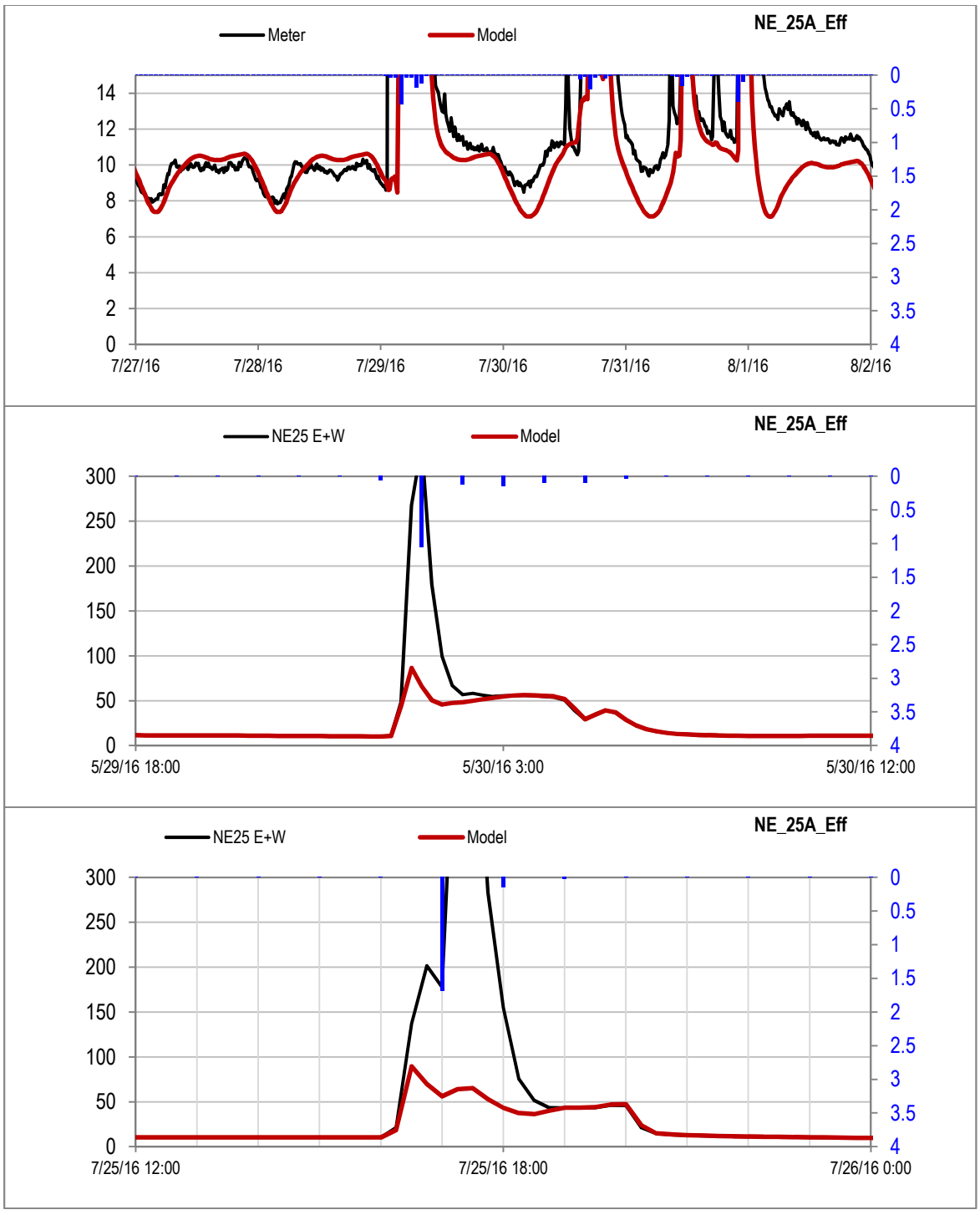

Peak Flow (15-min, MGD)
Model
Monitoring
0
100
200
300
400
500
600
NE_25A_E

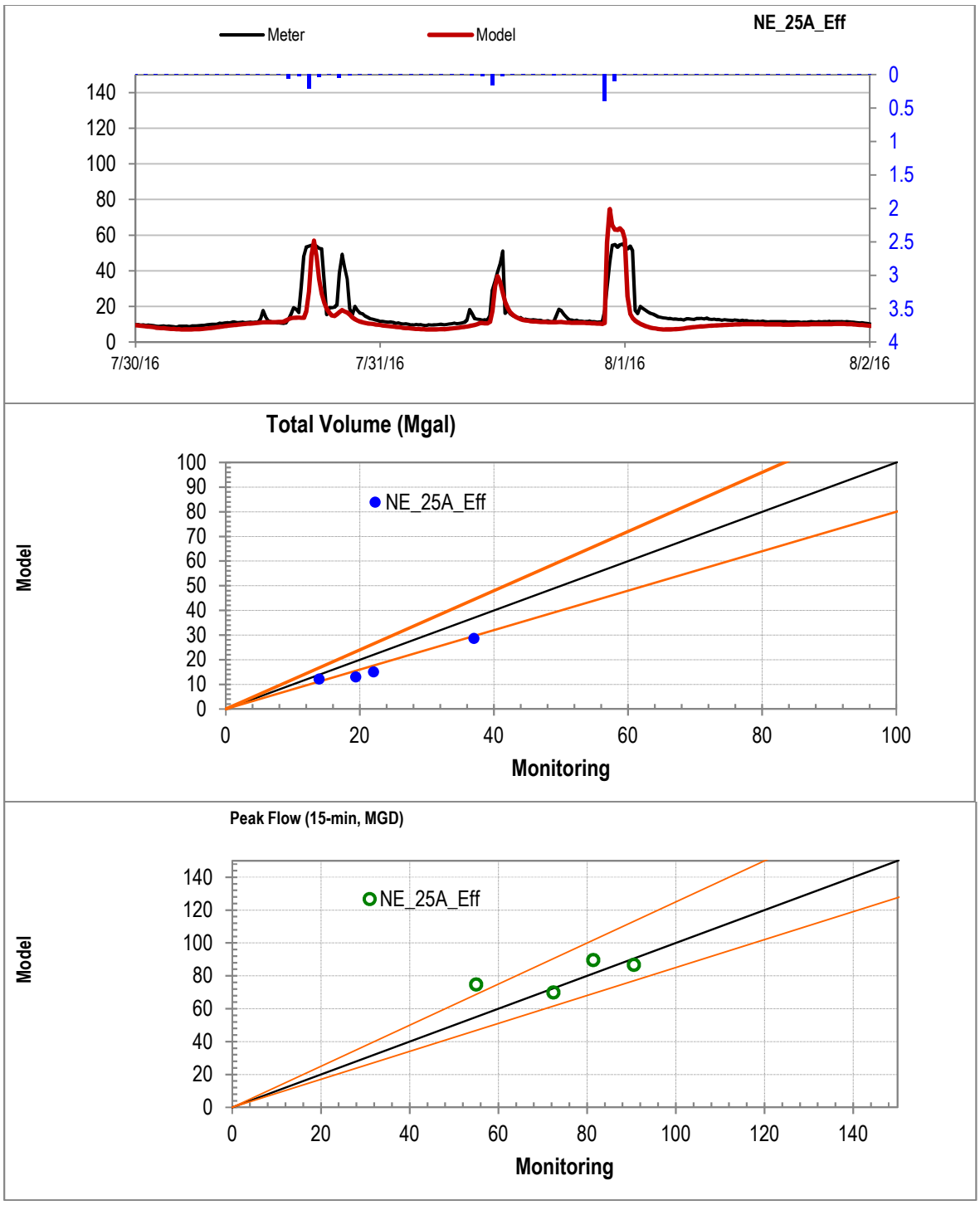

NE_25A_W
Meter
Model
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NE_25A_W
Meter
Model
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
NE_25A_W
Meter
Model
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

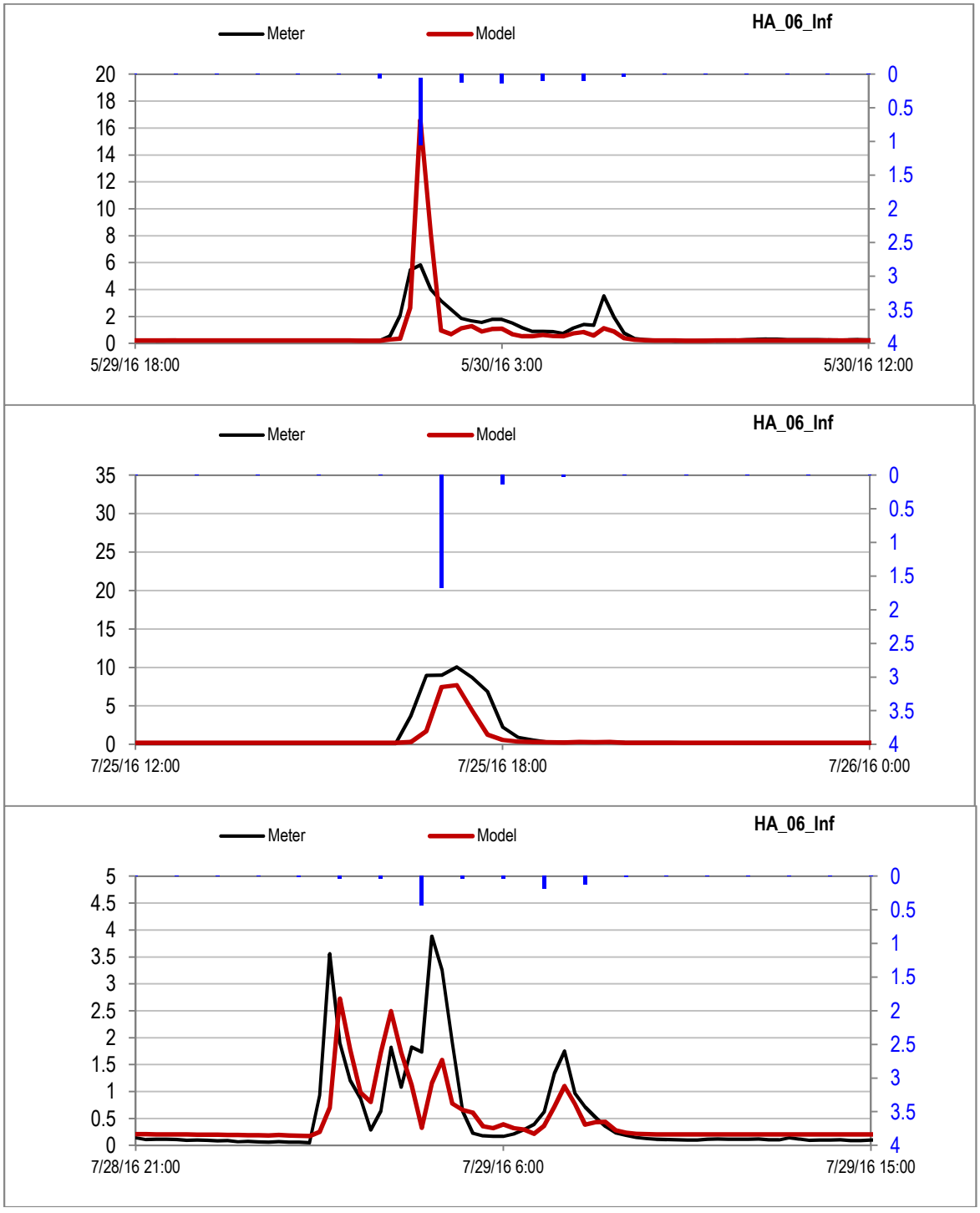

NE_25A_W
Meter
Model
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
NE_25A_W
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/27/16
7/28/16
7/29/16
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
NE_25A_W
80
70
60
50
40
30
20
10
0
0
20
40
60
80
Monitoring

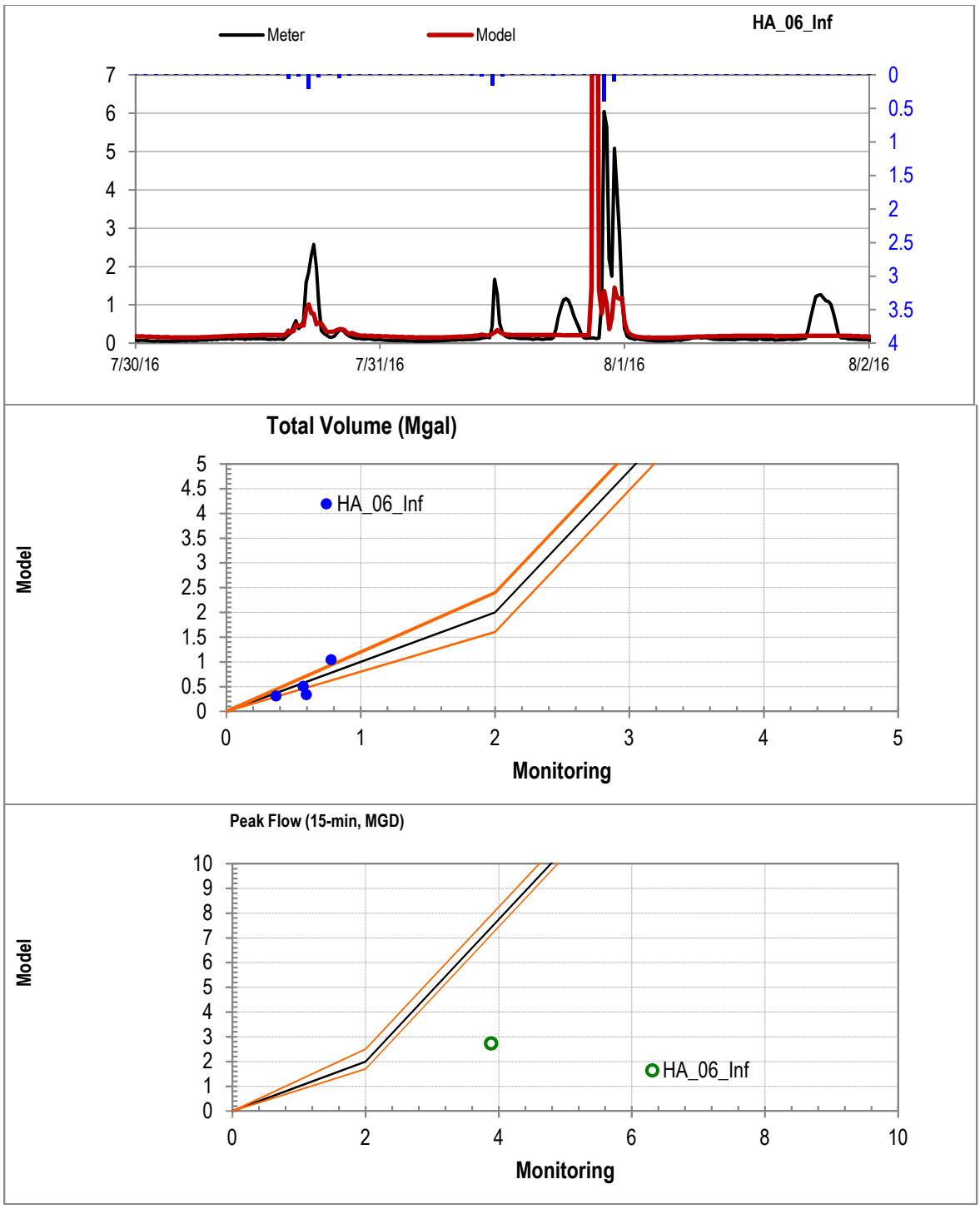

Peak Flow (15-min, MGD)
Model
Monitoring
NE_25A_W
0
50
100
150
200
250
300
350
400
450
500

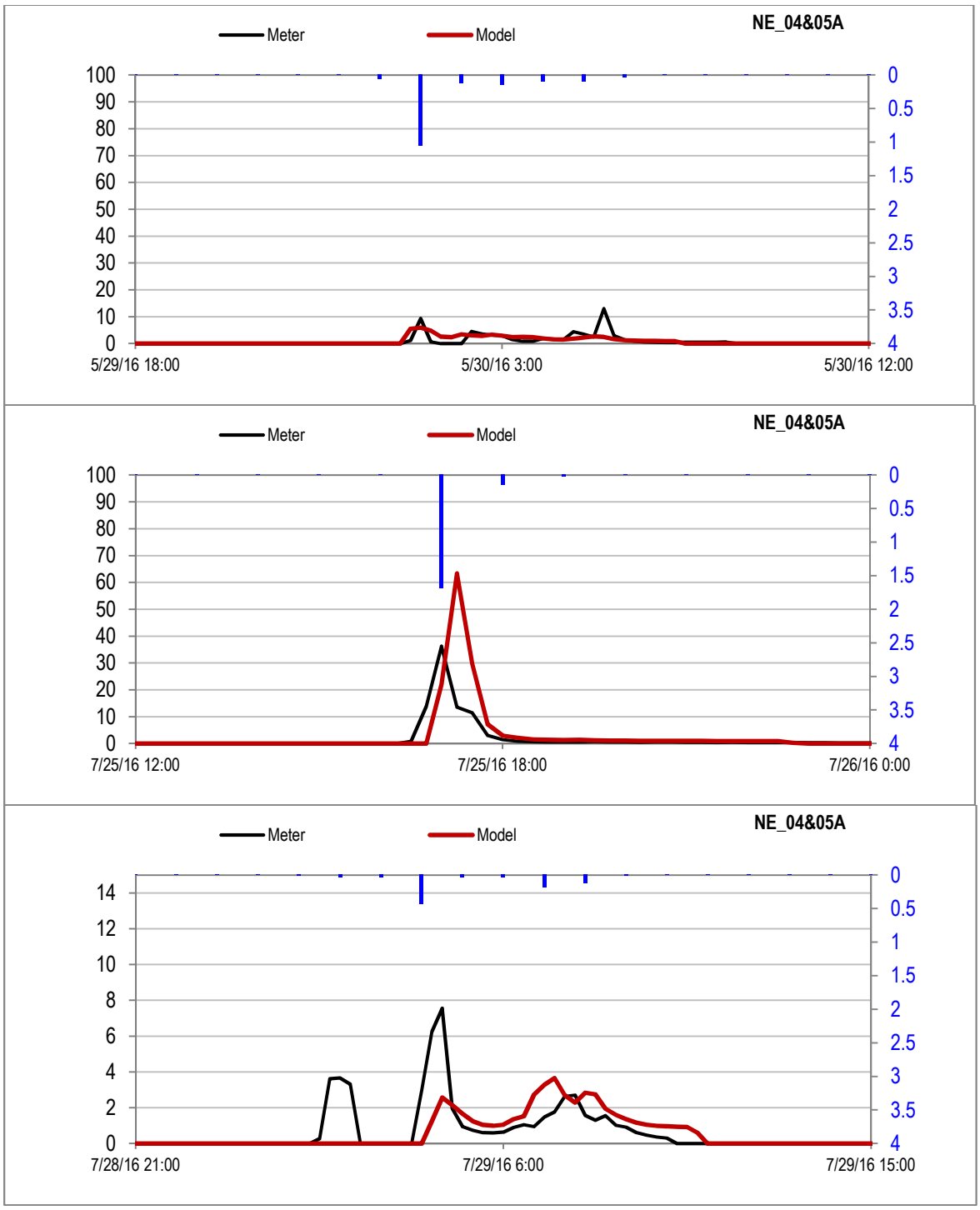

NE_25A_Eff
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NE_25A_Eff
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
NE_25A_Eff
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

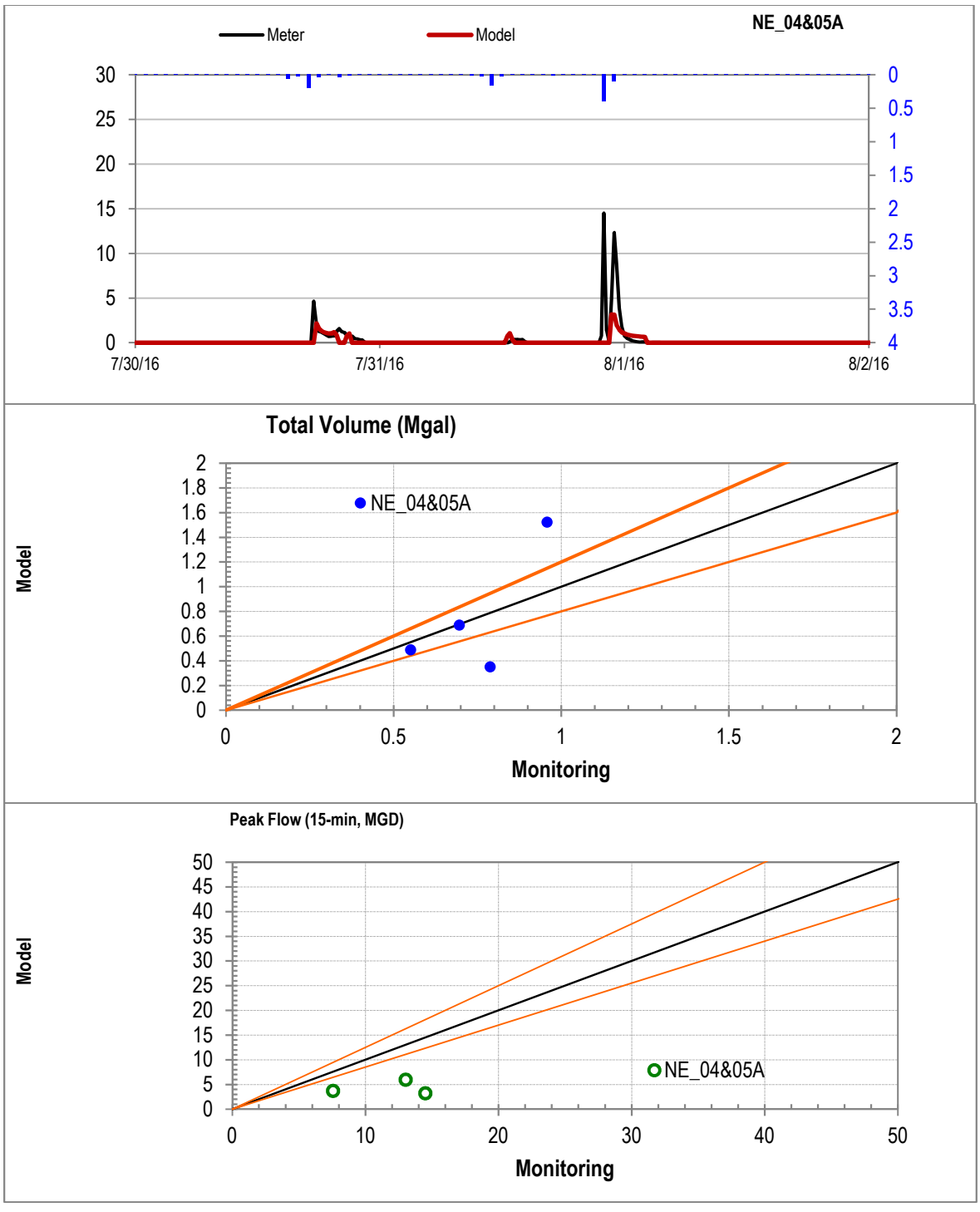

NE_25A_Eff
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/27/16
7/28/16
7/29/16
7/30/16
7/31/16
8/1/16
8/2/16
NE_25A_Eff
NE25 E+W
Model
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NE_25A_Eff
NE25 E+W
Model
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00

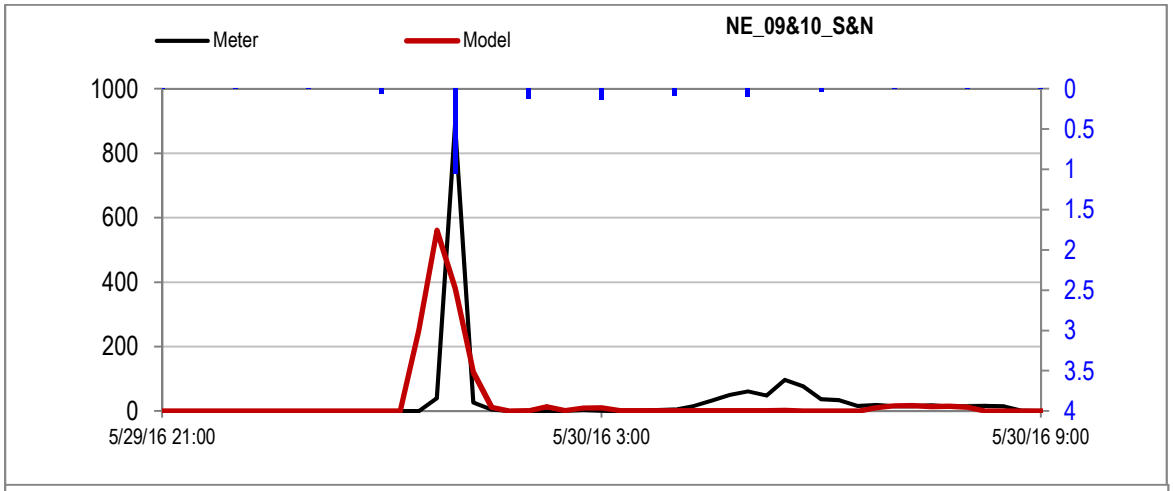

NE_25A_Eff
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
NE_25A_Eff
Monitoring
Peak Flow (15-min, MGD)
Model
NE_25A_Eff
Monitoring

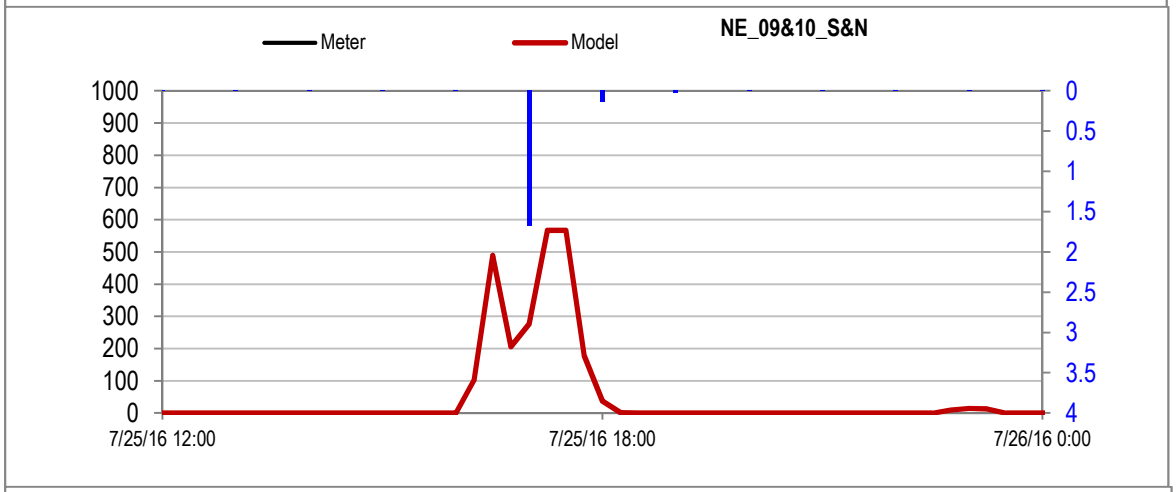

HA_06_Inf
Meter
Model
20
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
HA_06_Inf
Meter
Model
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
HA_06_Inf
Meter
Model
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

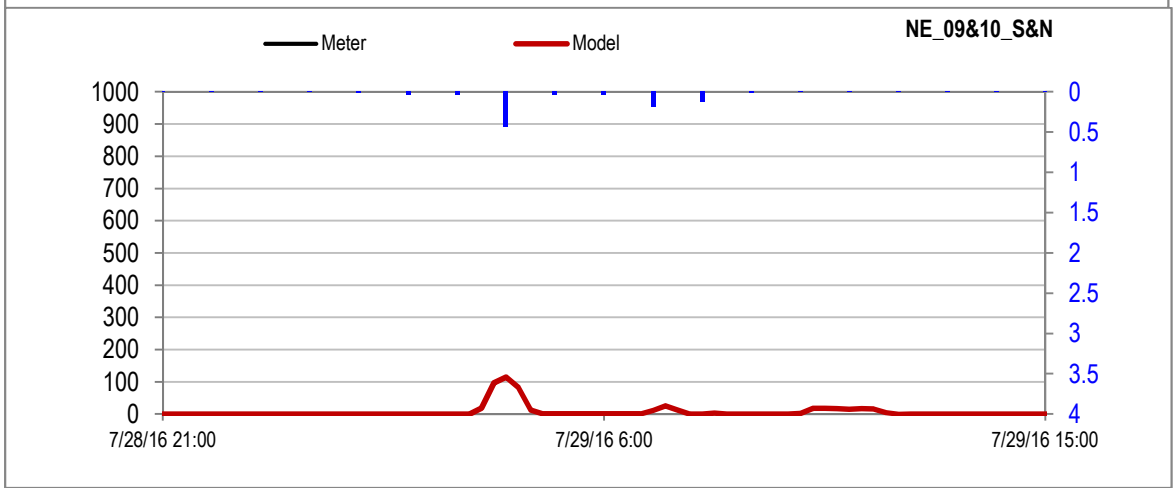

HA_06_Inf
Meter
Model
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
HA_06_Inf
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
Monitoring
Peak Flow (15-min, MGD)
Model
10
9
8
7
6
5
4
3
2
1
0
HA_06_Inf
0
2
4
6
8
10
Monitoring

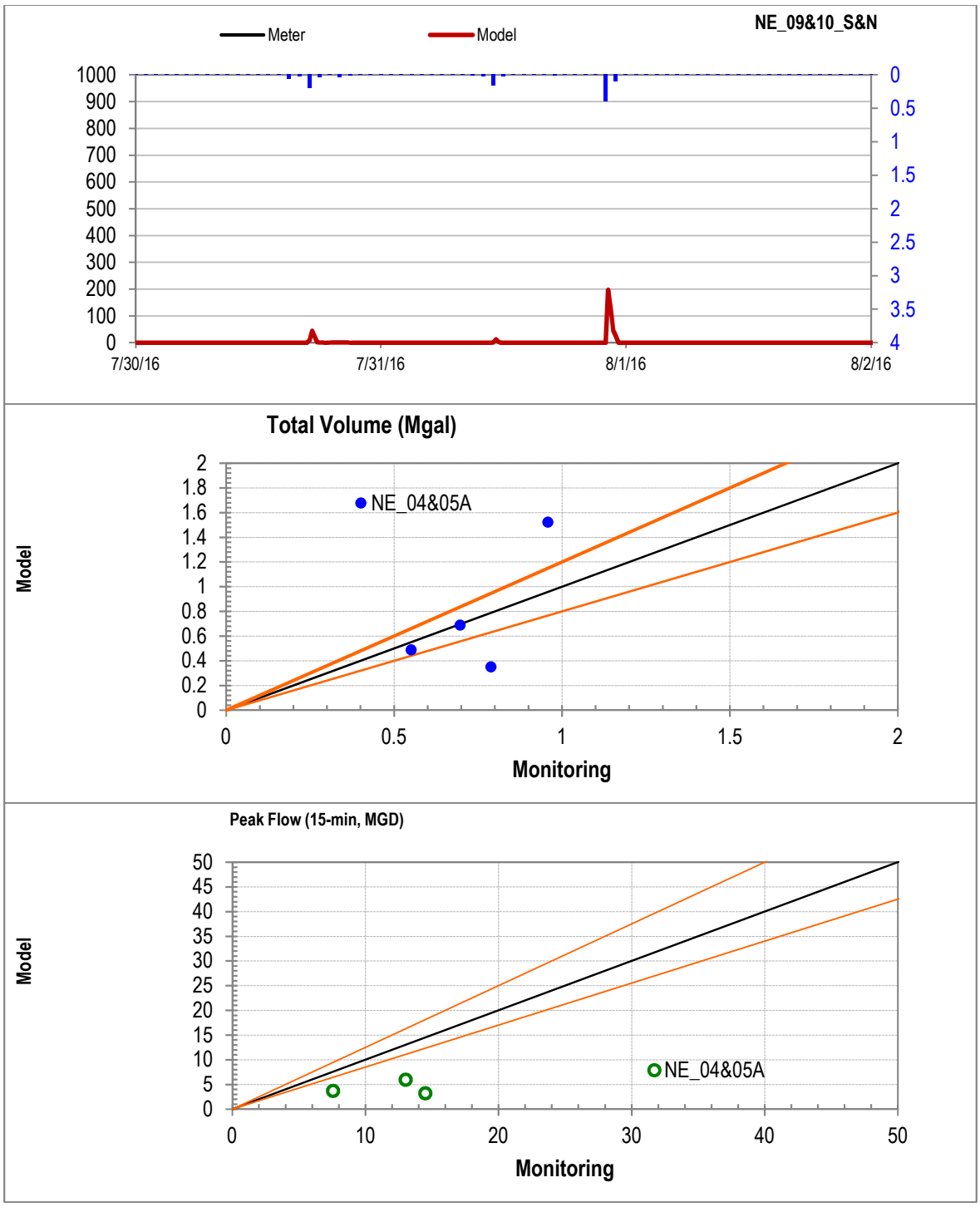

NE_04&05A
Meter
Model
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NE_04&05A
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
NE_04&05A
Meter
Model
14
12
10
8
6
4
2
0
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

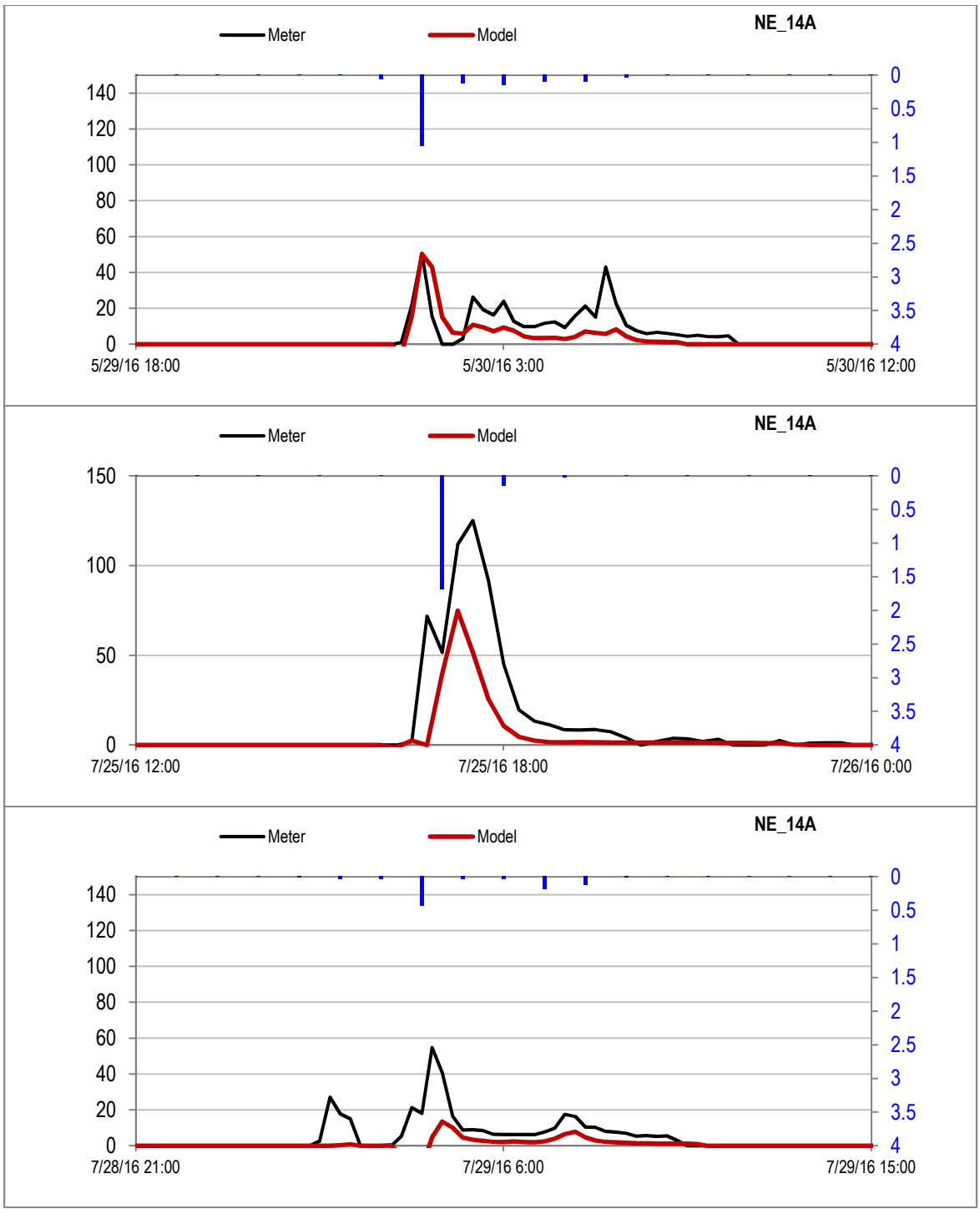

NE_04&05A
Meter
Model
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
NE_04&05A
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
Monitoring
Peak Flow (15-min, MGD)
Model
NE_04&05A
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
Monitoring

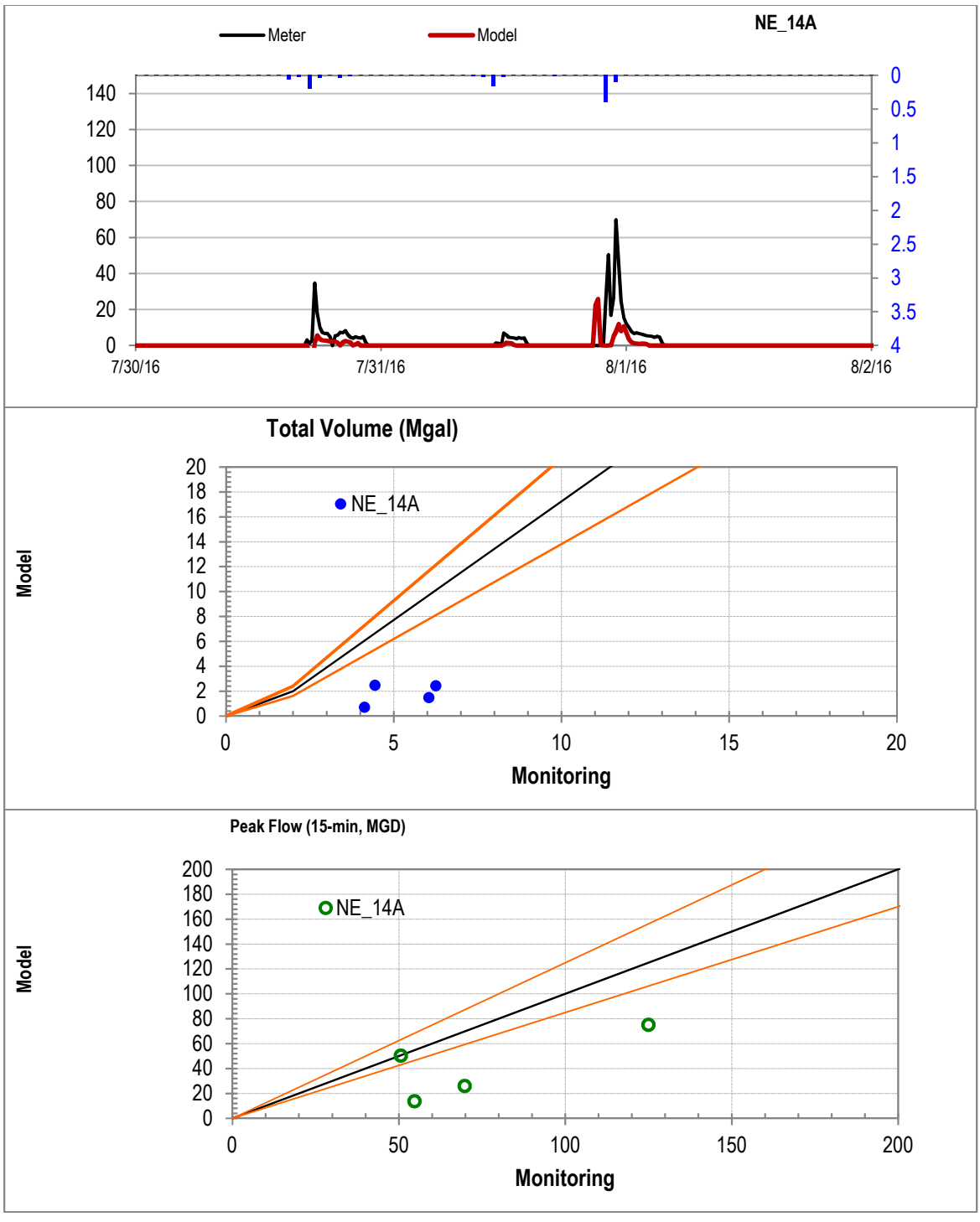

NE_09&10_S&N
Meter
Model
1000
800
600
400
200
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 21:00
5/30/16 3:00
5/30/16 9:00

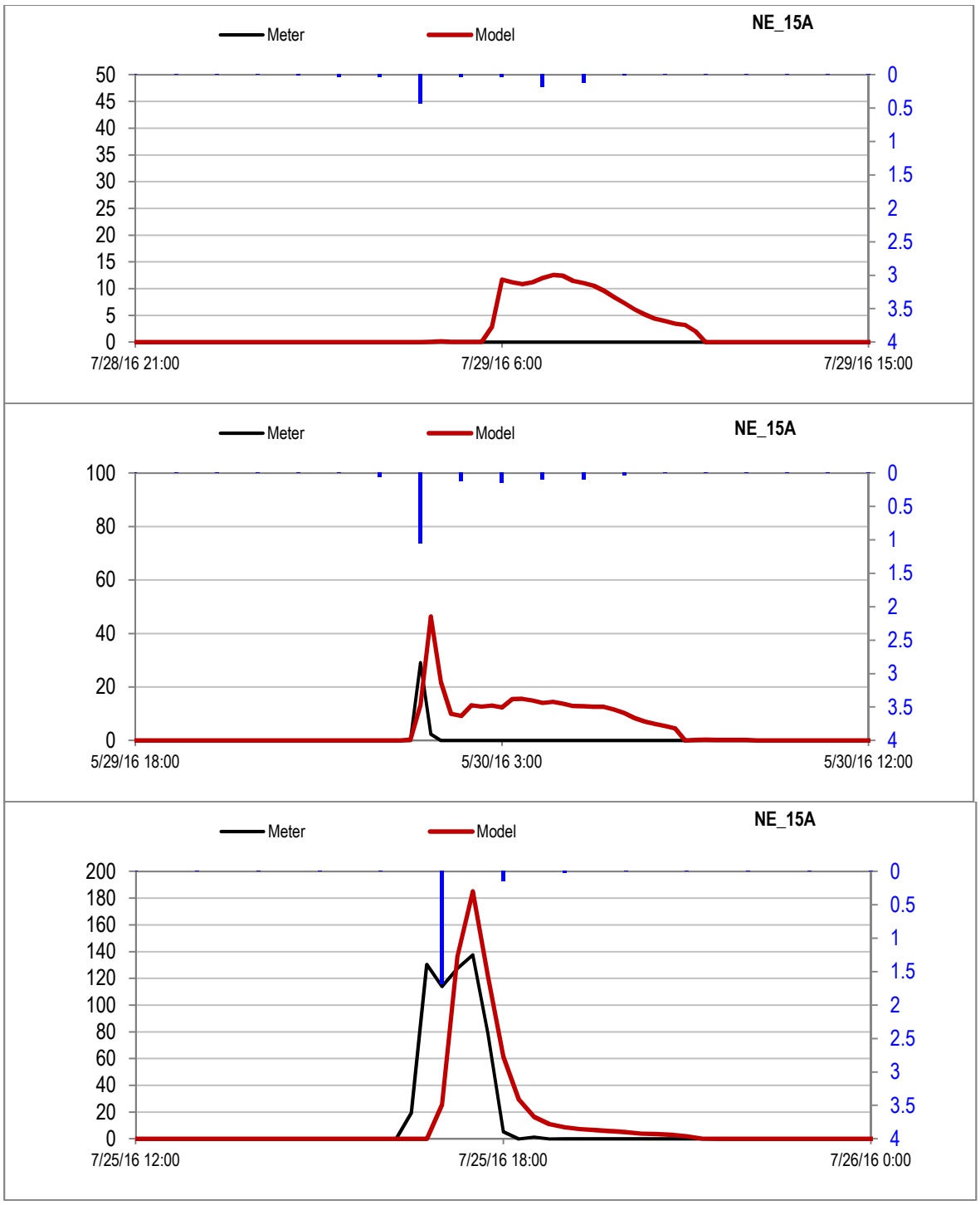

NE_09&10_S&N
Meter
Model
1000
900
800
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00

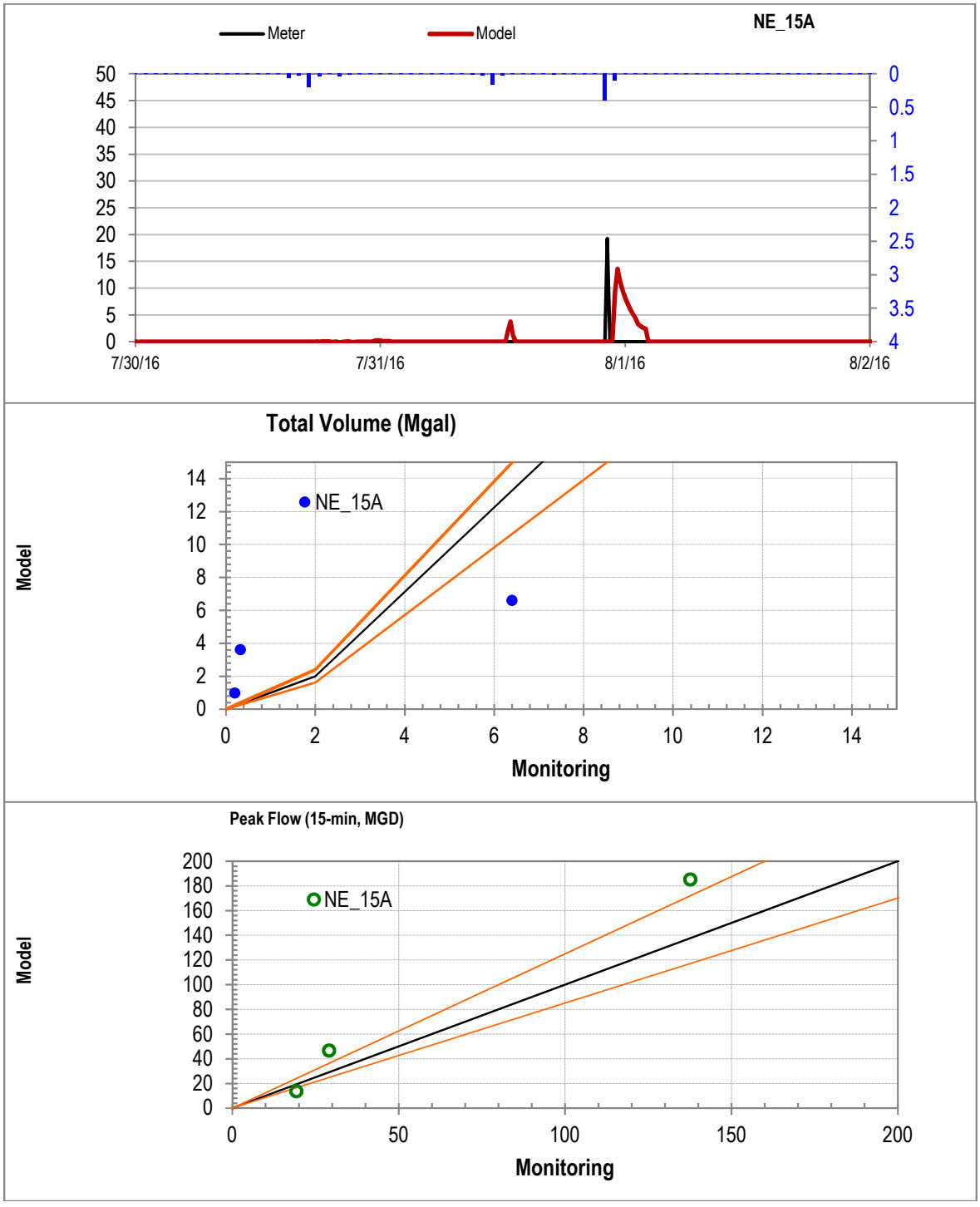

NE_09&10_S&N
Meter
Model
1000
900
800
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

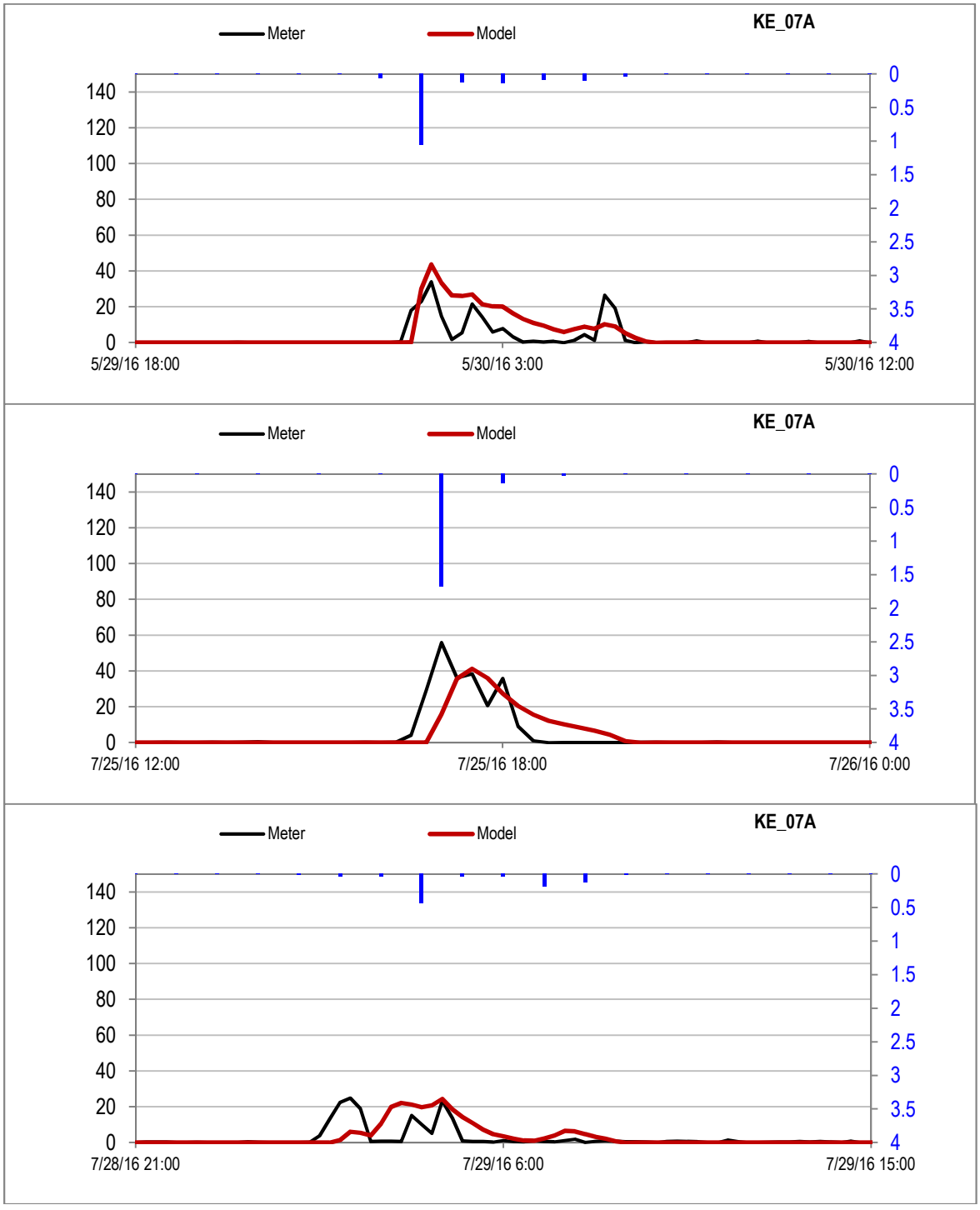

NE_09&10_S&N
Meter
Model
1000
900
800
700
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
NE_04&05A
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
Monitoring
Peak Flow (15-min, MGD)
Model
NE_04&05A
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
Monitoring

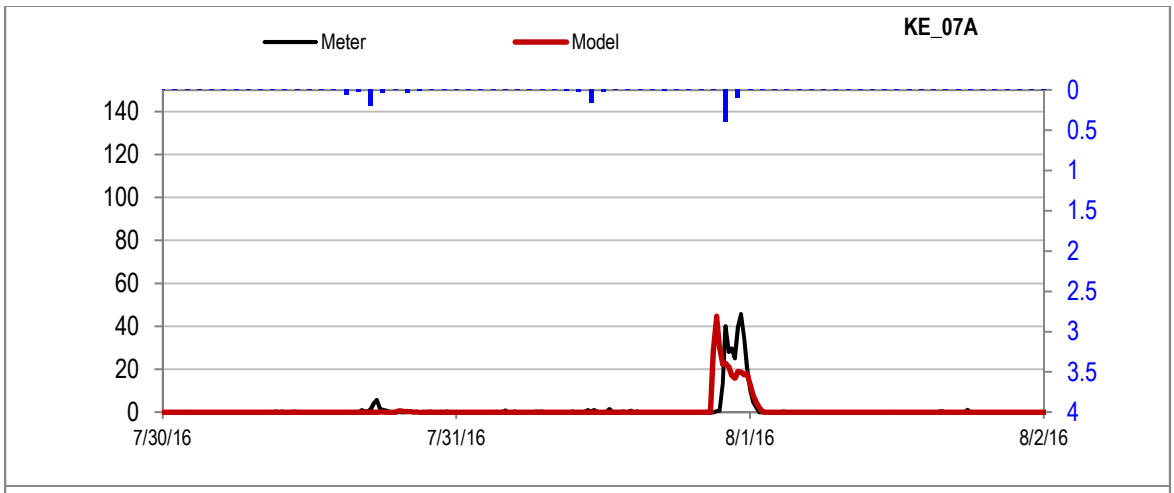

NE_14A
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NE_14A
Meter
Model
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
NE_14A
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

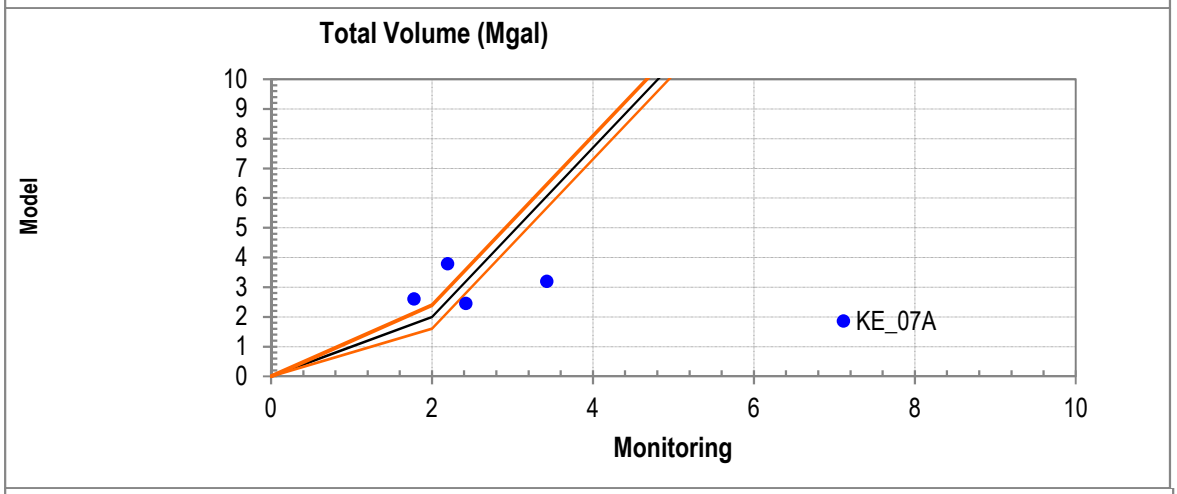

NE_14A
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
NE_14A
Monitoring
Peak Flow (15-min, MGD)
Model
NE_14A
Monitoring

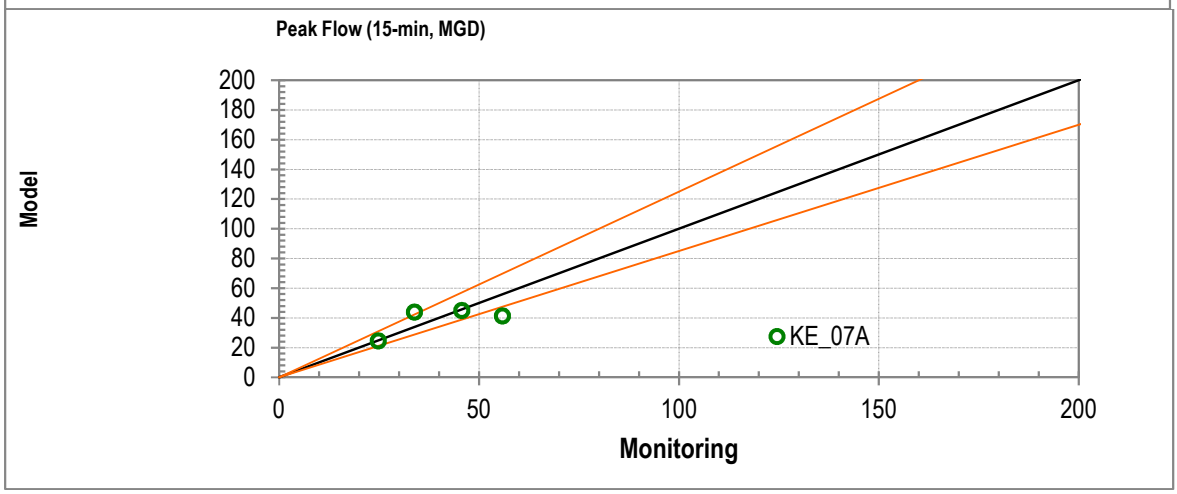

NE_15A
Meter
Model
50
45
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00
NE_15A
Meter
Model
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NE_15A
Meter
Model
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00

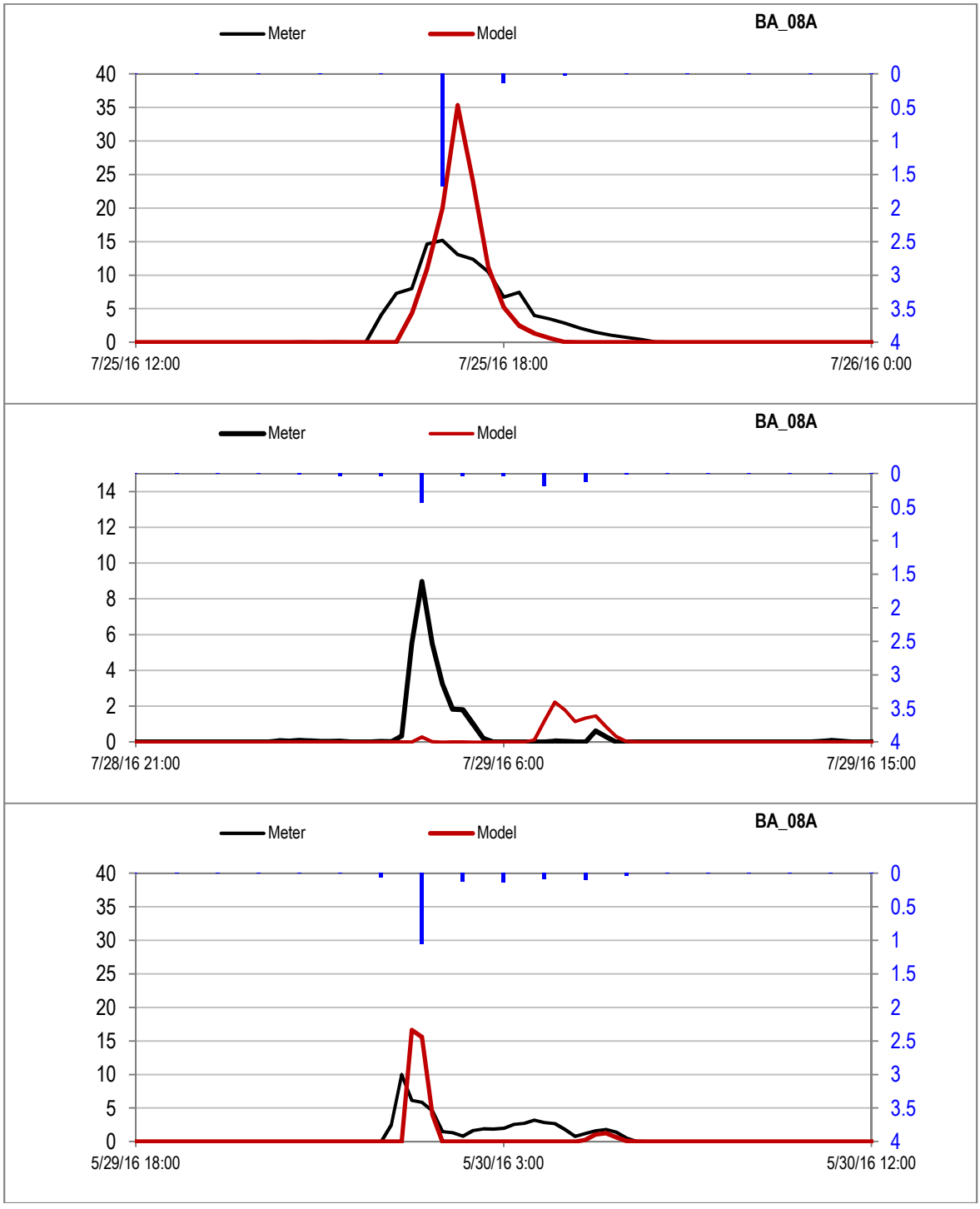

NE_15A
Meter
Model
50
45
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
NE_15A
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Monitoring
Peak Flow (15-min, MGD)
Model
NE_15A
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Monitoring

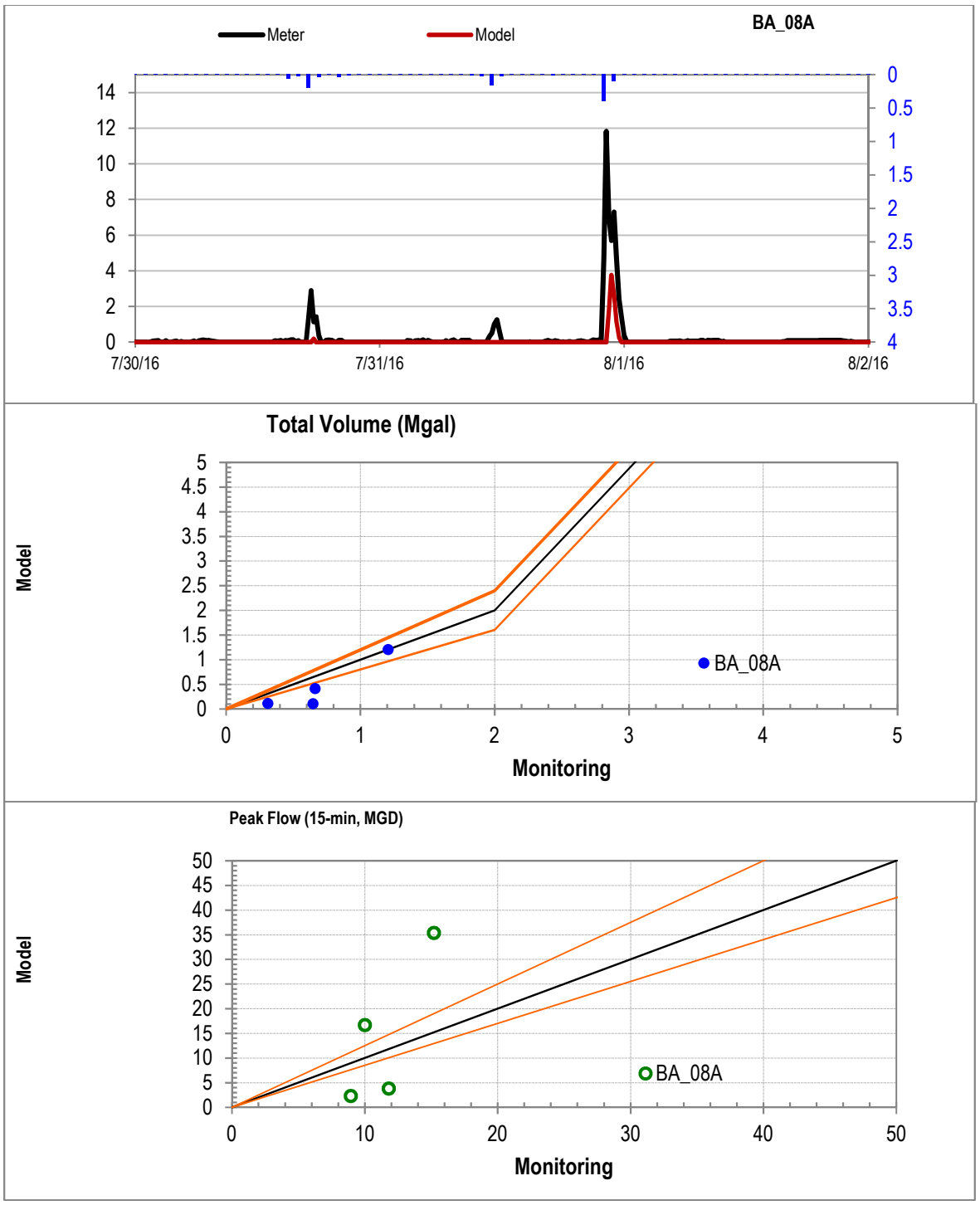

KE_07A
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
KE_07A
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
KE_07A
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

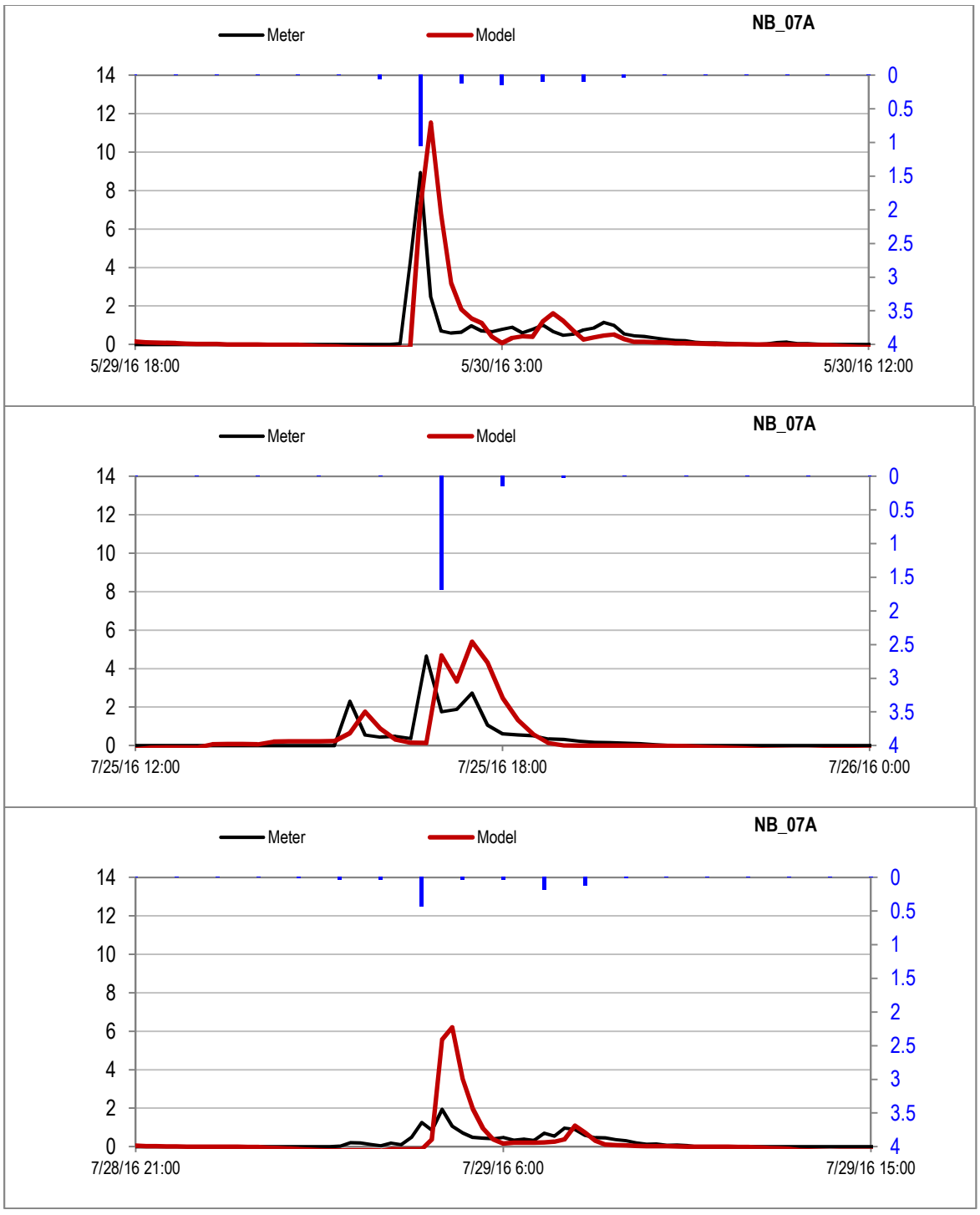

KE_07A
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

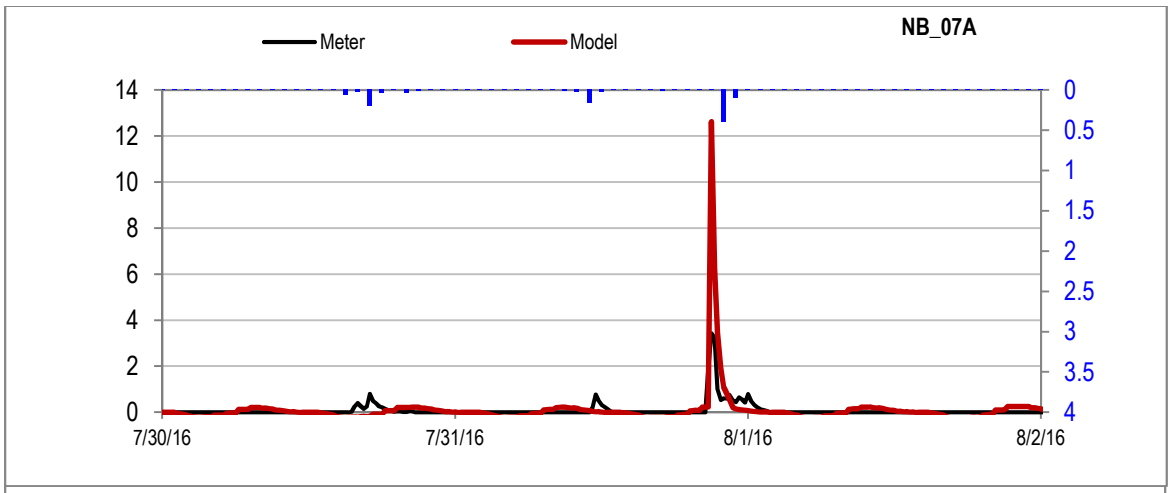

Total Volume (Mgal)
Model
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring
KE_07A

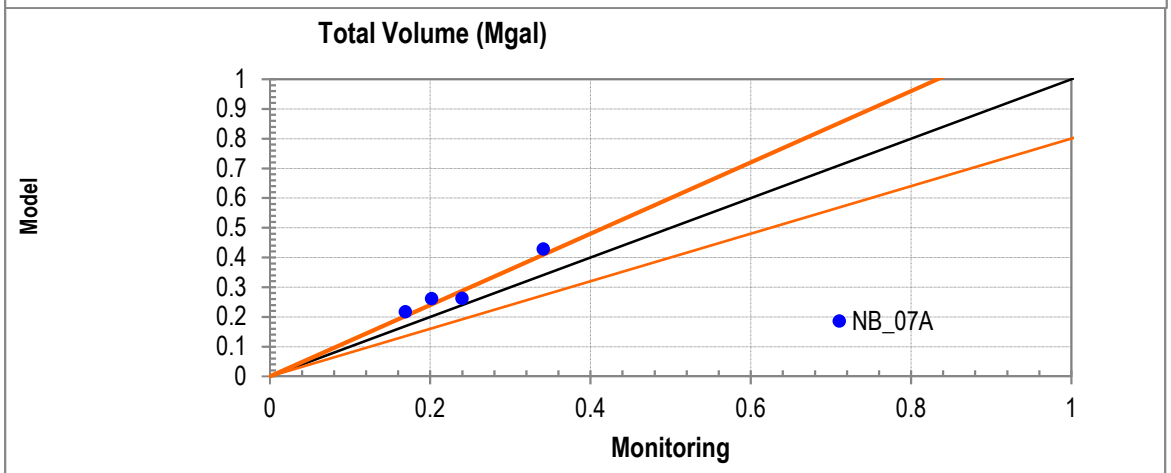

Peak Flow (15-min, MGD)
Model
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Monitoring
KE_07A

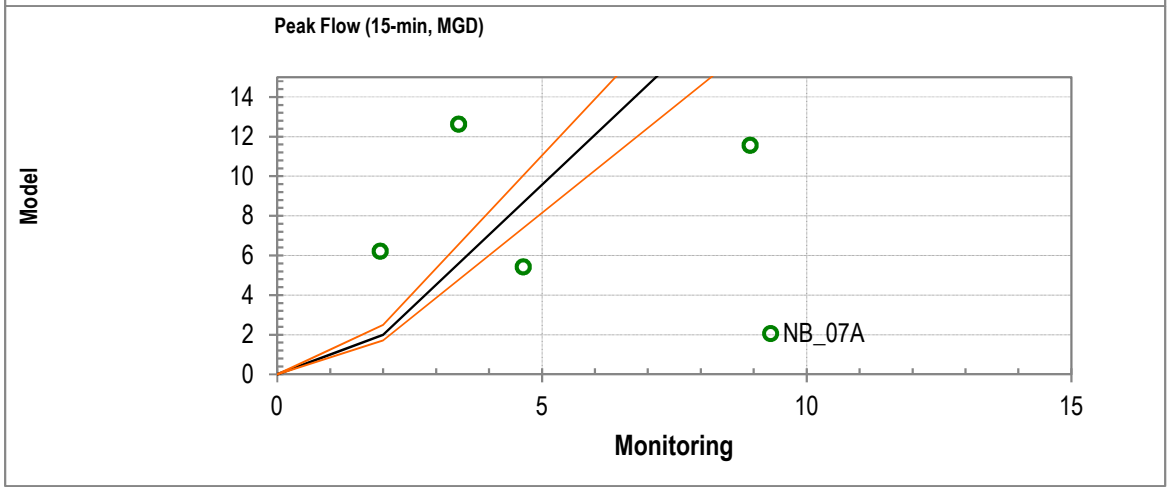

BA_08A
Meter
Model
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
BA_08A
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00
BA_08A
Meter
Model
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00

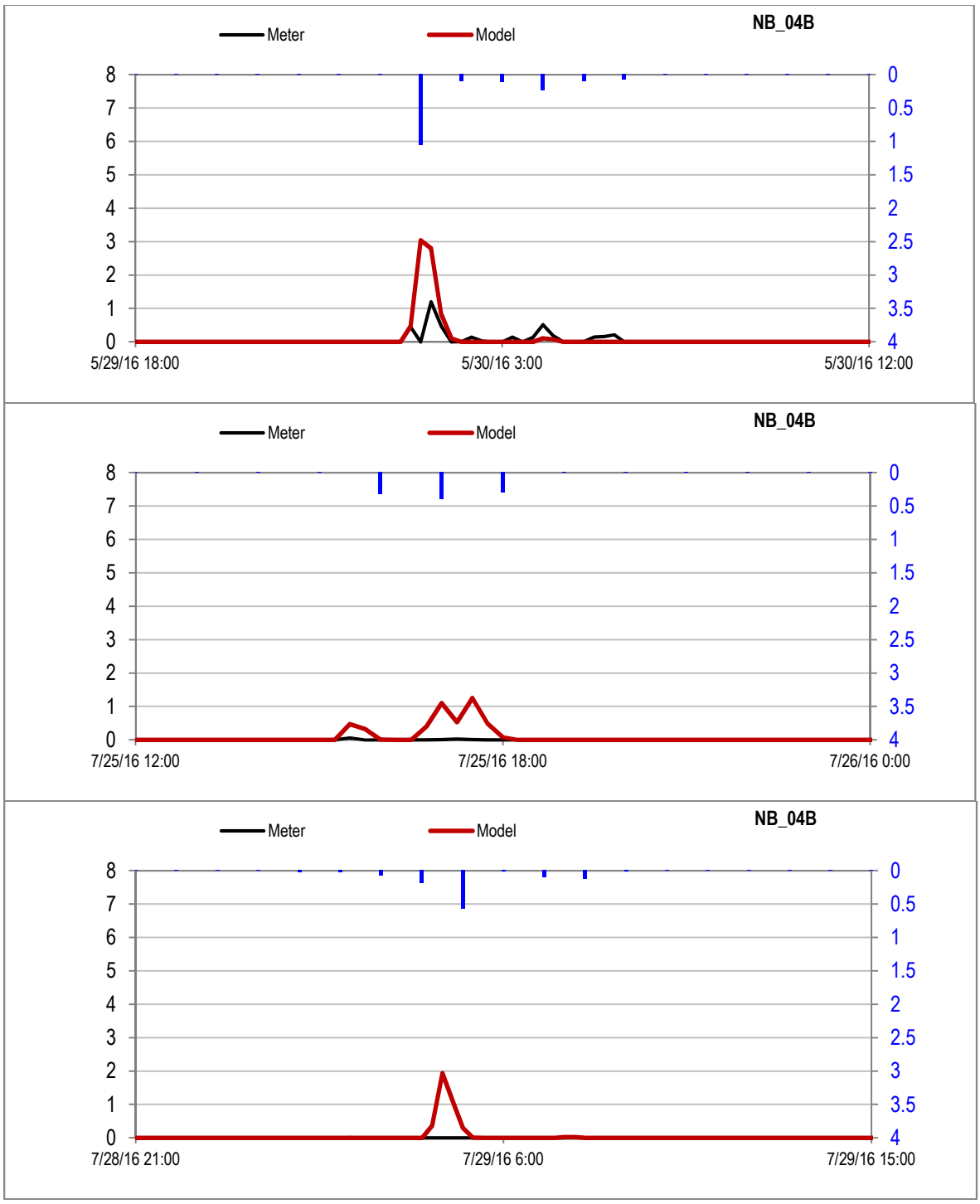

BA_08A
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
BA_08A
Monitoring
Peak Flow (15-min, MGD)
Model
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
BA_08A
Monitoring

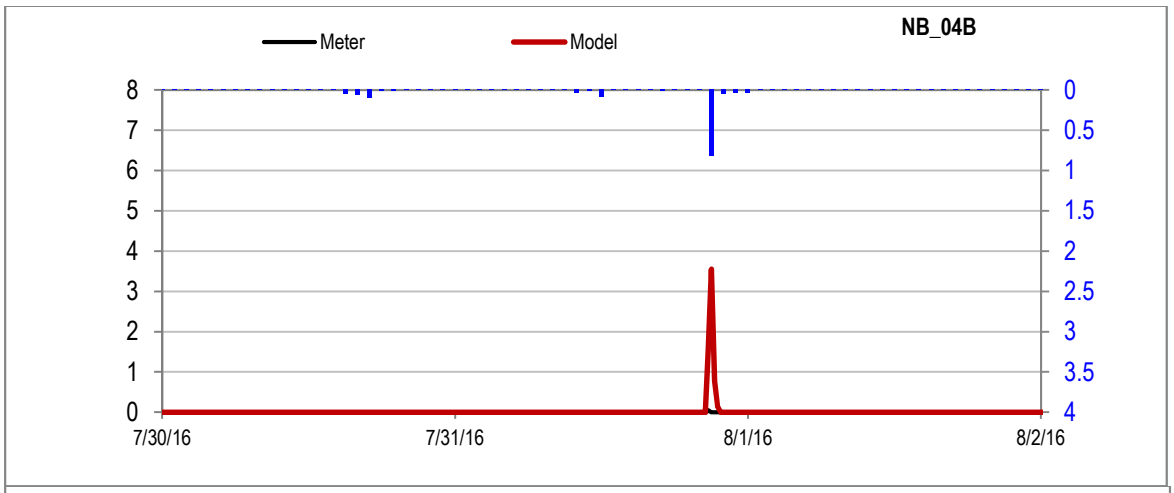

NB_07A
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NB_07A
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
NB_07A
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

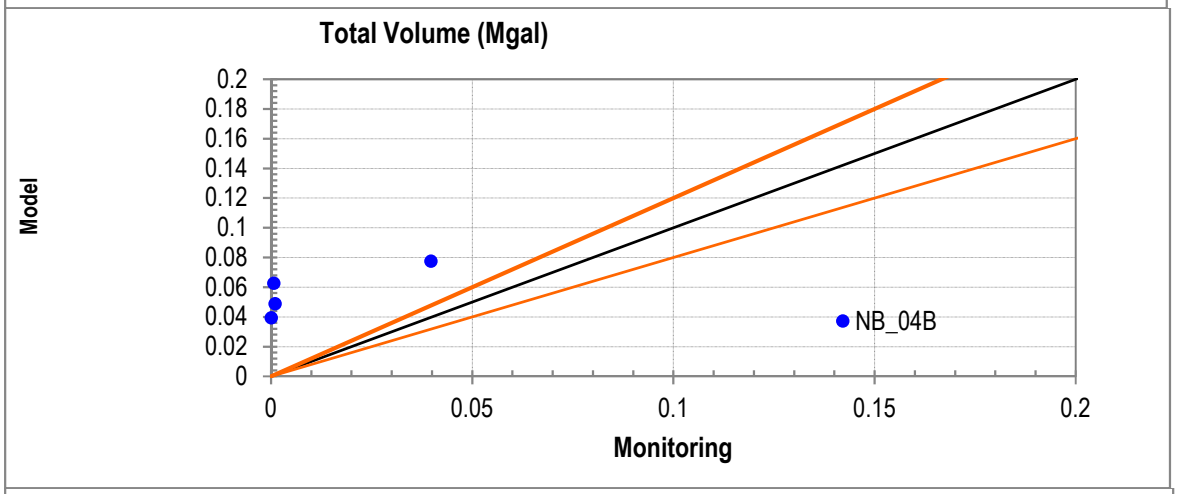

NB_07A
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

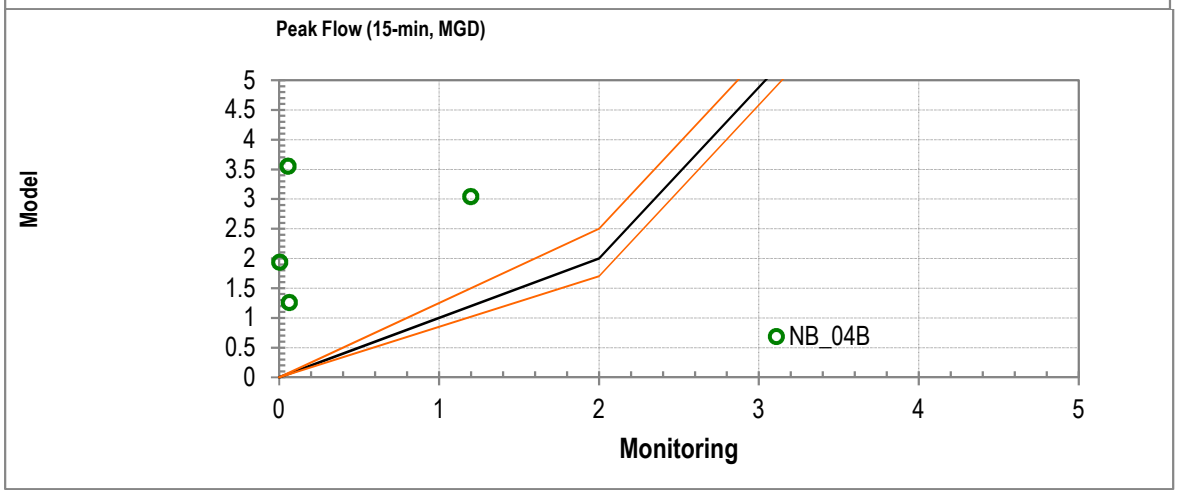

Total Volume (Mgal)
Model
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
NB_07A
Monitoring

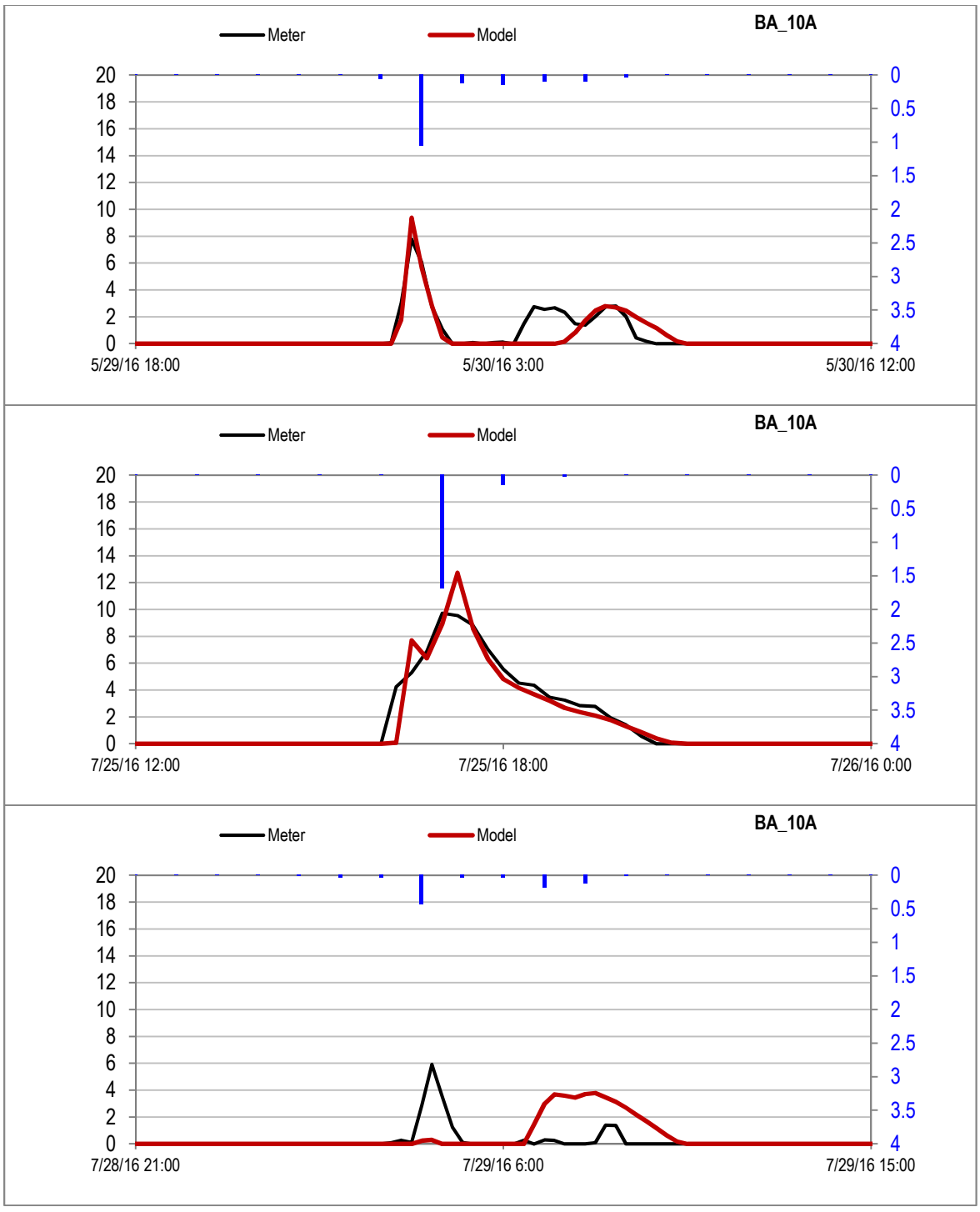

Peak Flow (15-min, MGD)
Model
14
12
10
8
6
4
2
0
0
5
10
15
NB_07A
Monitoring

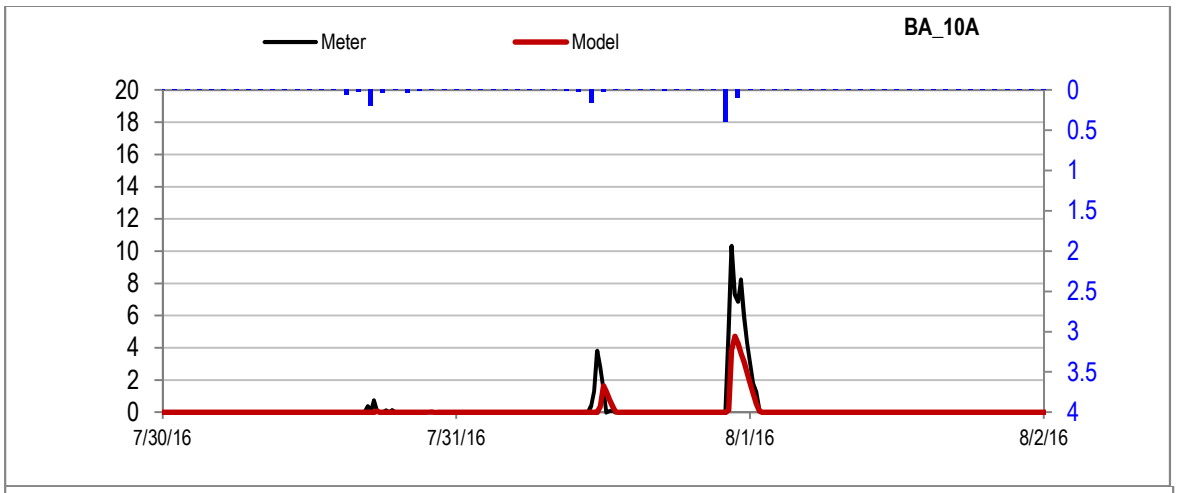

NB_04B
Meter
Model
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NB_04B
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
NB_04B
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

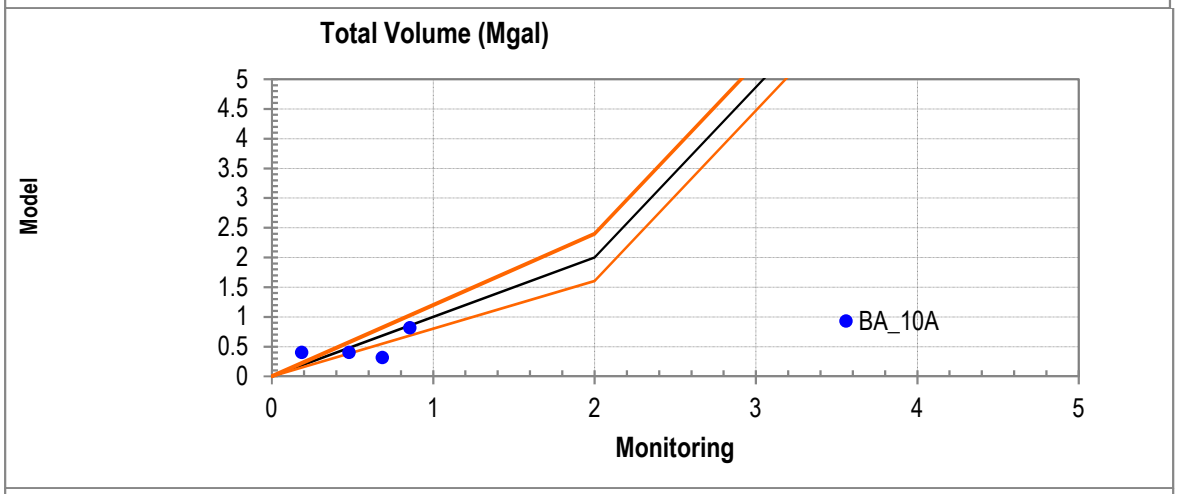

NB_04B
Meter
Model
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

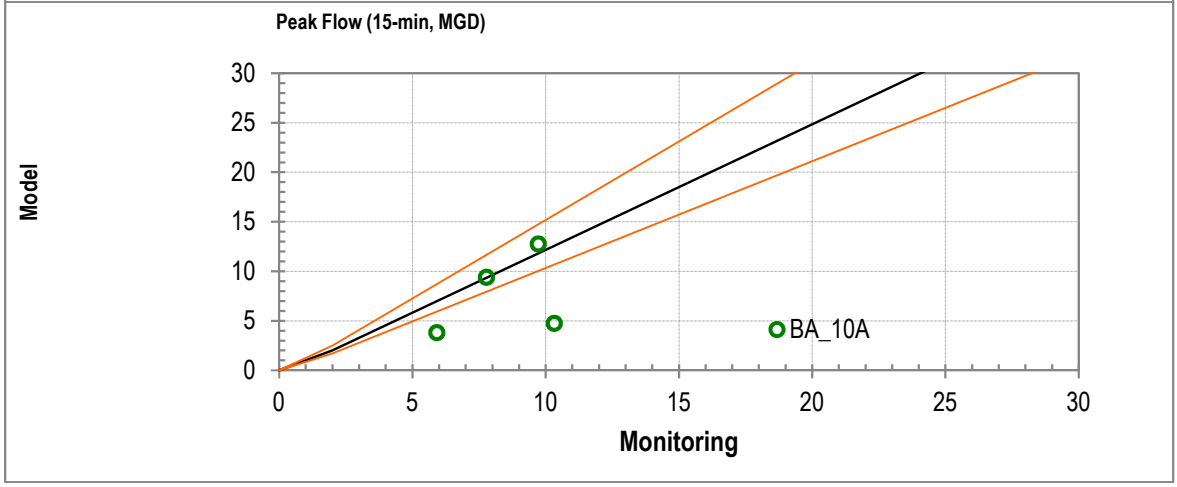

Total Volume (Mgal)
Model
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.05
0.1
0.15
0.2
NB_04B
Monitoring

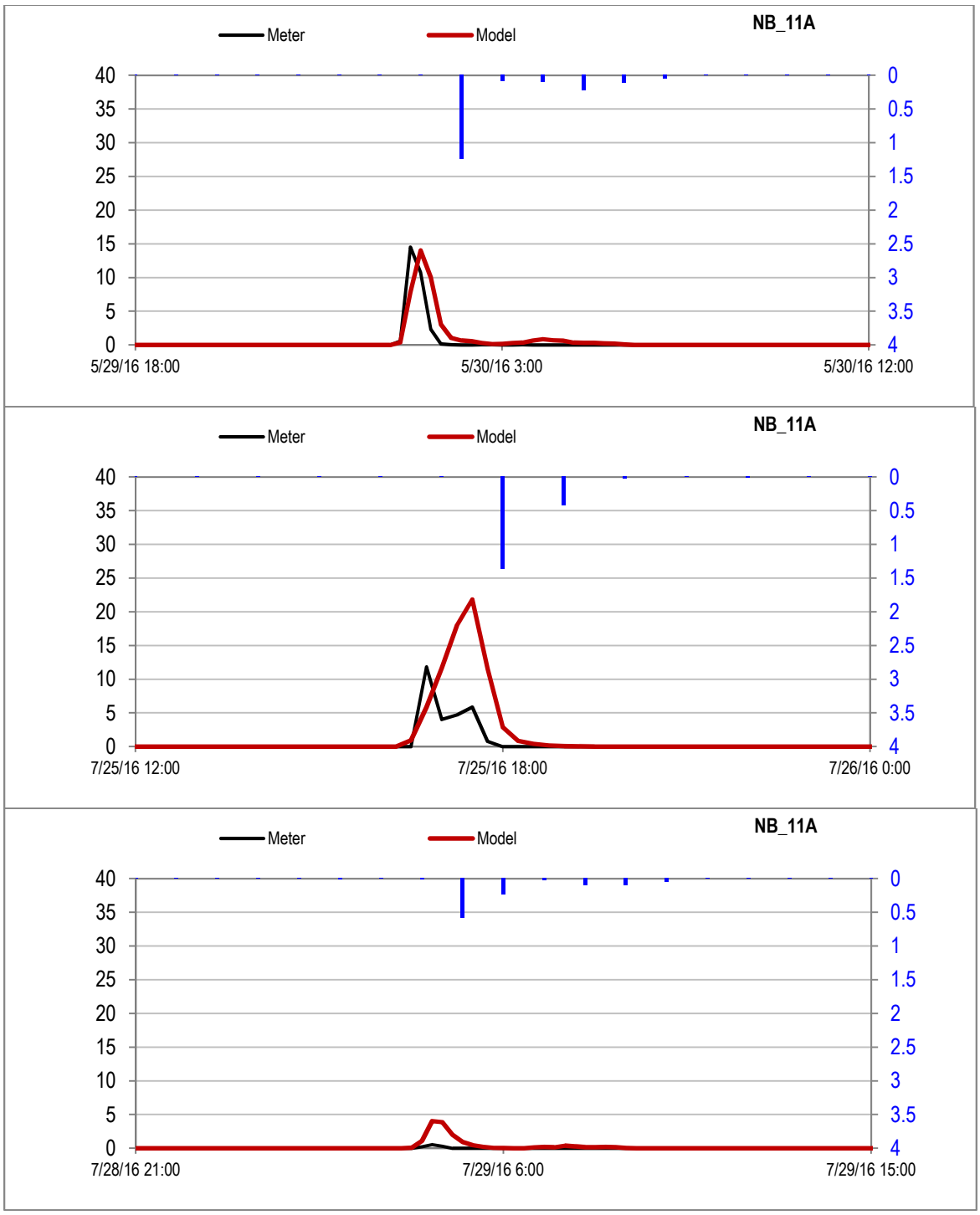

Peak Flow (15-min, MGD)
Model
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
NB_04B
Monitoring

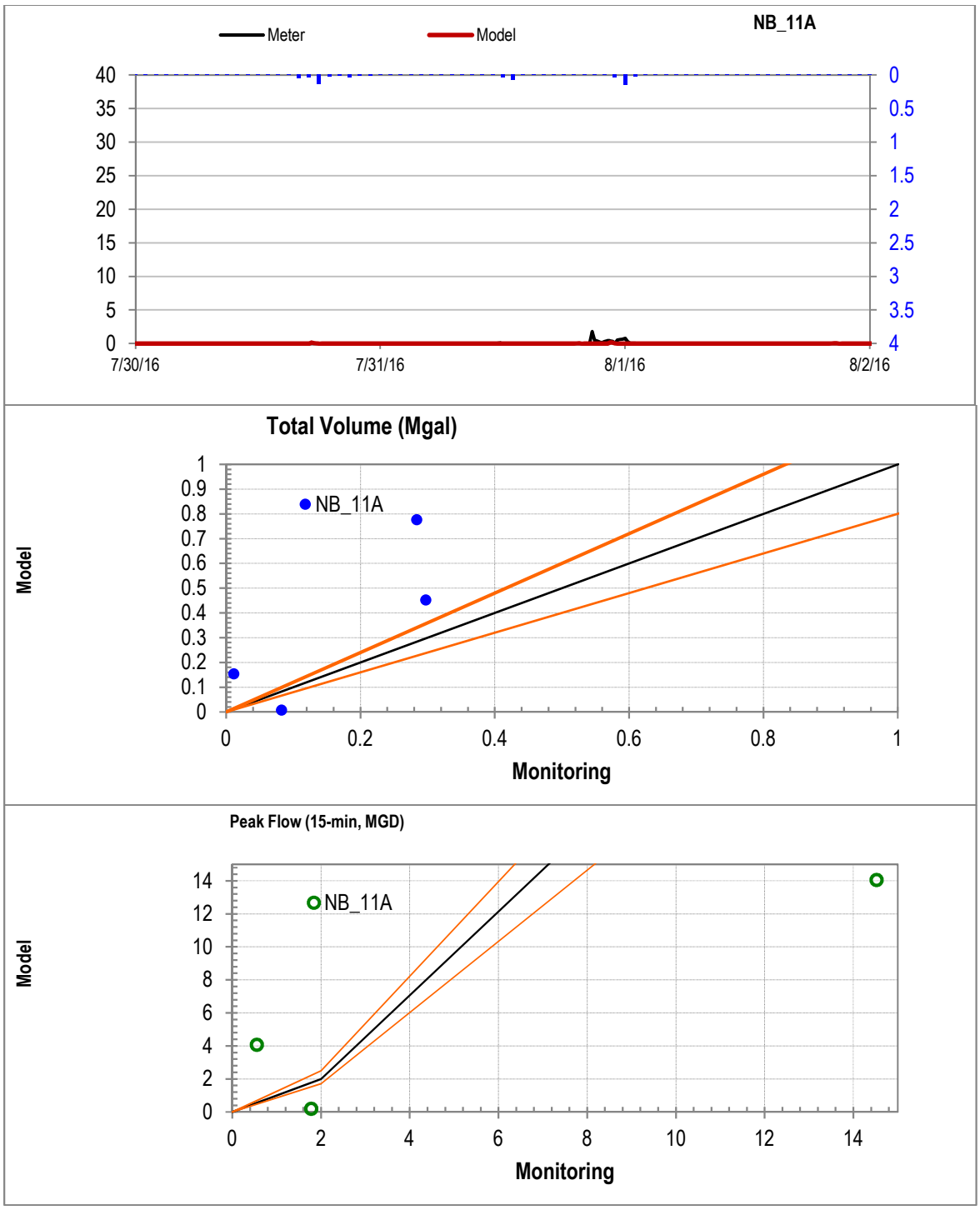

BA_10A
Meter
Model
20
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
BA_10A
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
BA_10A
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

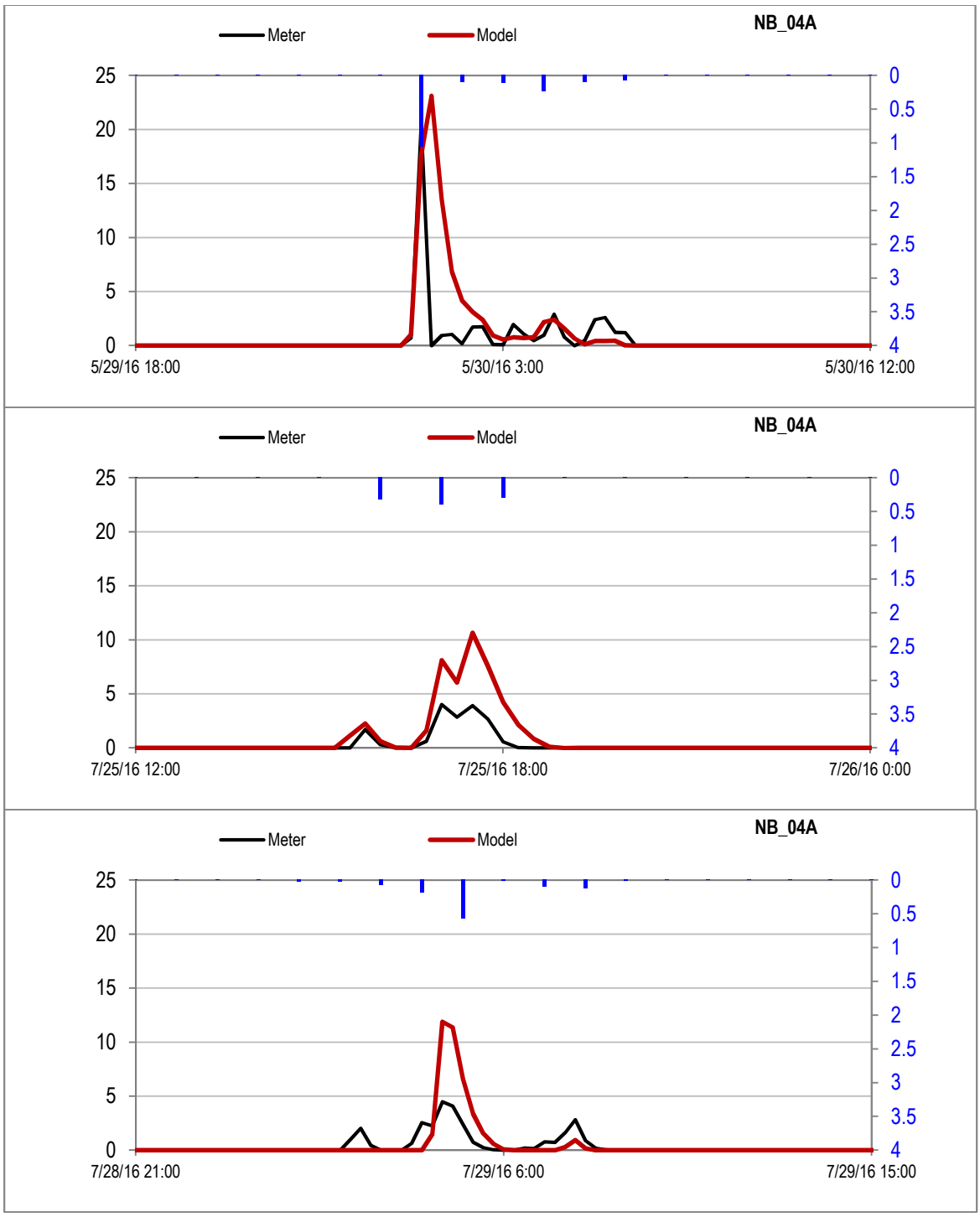

BA_10A
Meter
Model
20
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

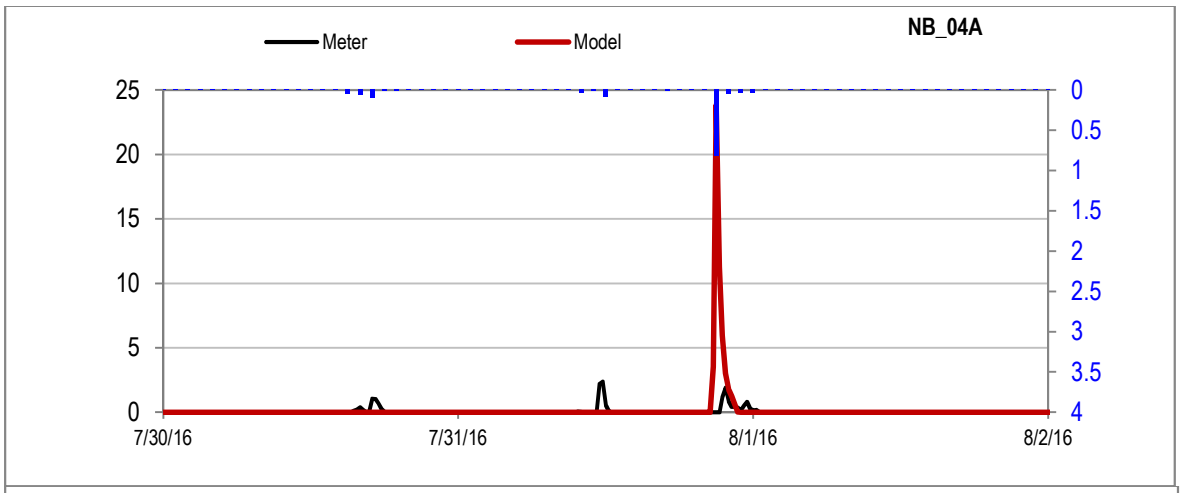

Total Volume (Mgal)
Model
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
BA_10A
Monitoring

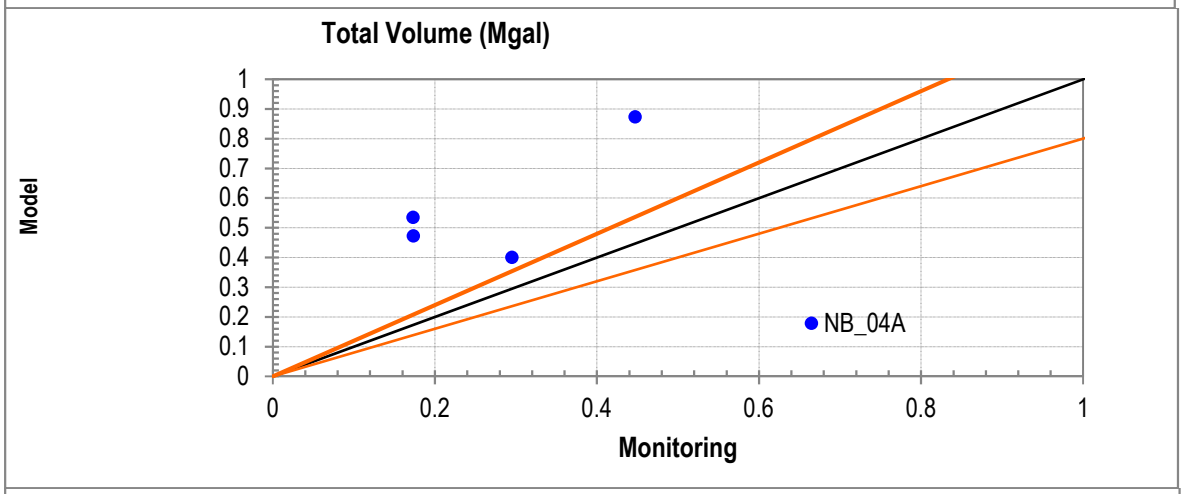

Peak Flow (15-min, MGD)
Model
30
25
20
15
10
5
0
0
5
10
15
20
25
30
BA_10A
Monitoring

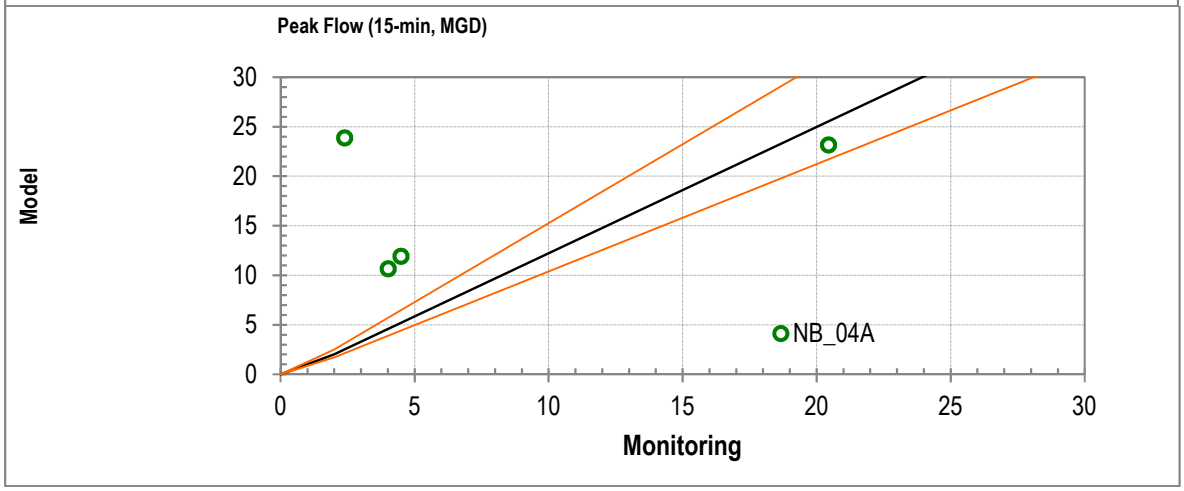

NB_11A
Meter
Model
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NB_11A
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
NB_11A
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

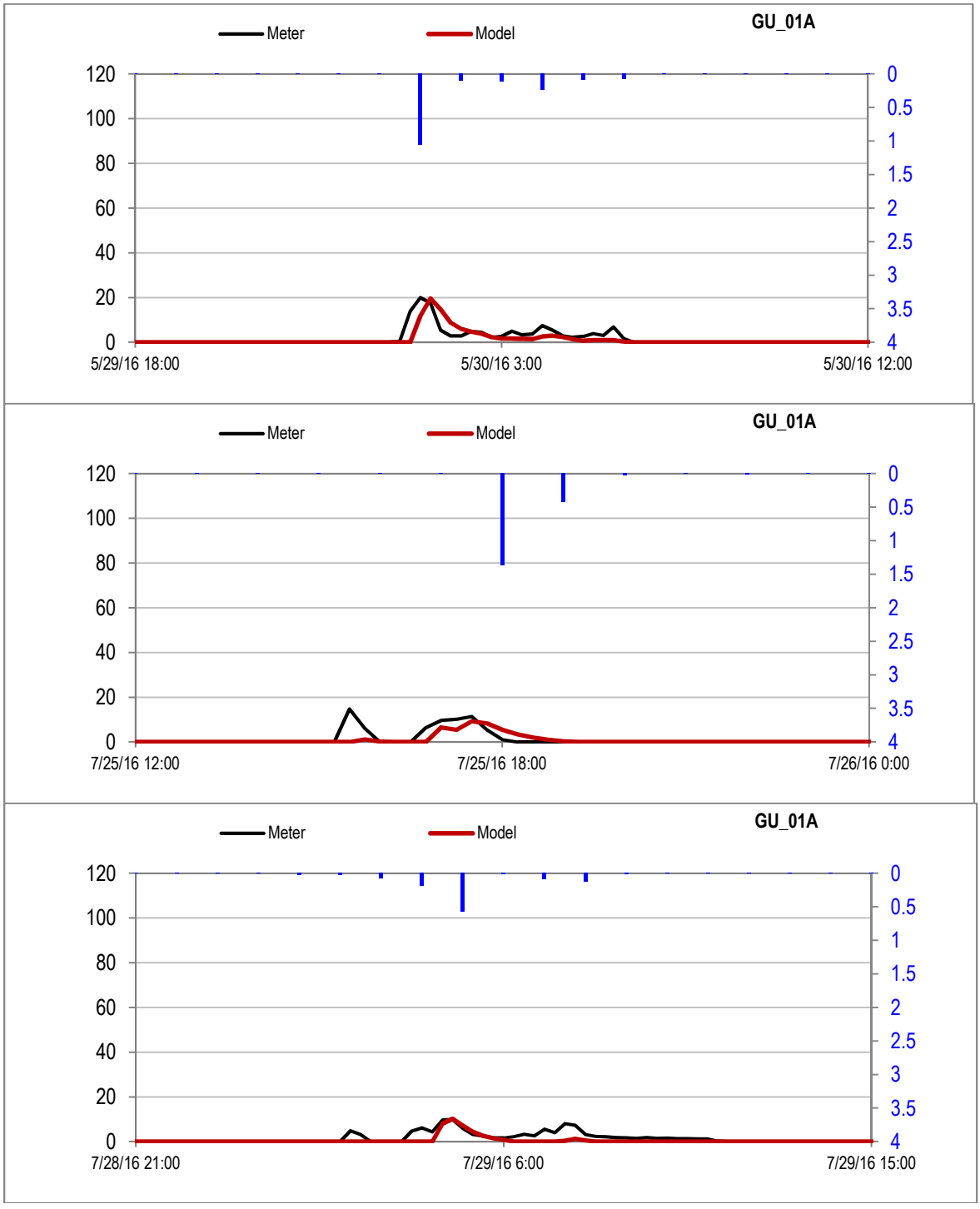

NB_11A
Meter
Model
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
NB_11A
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
Monitoring
Peak Flow (15-min, MGD)
Model
NB_11A
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
Monitoring

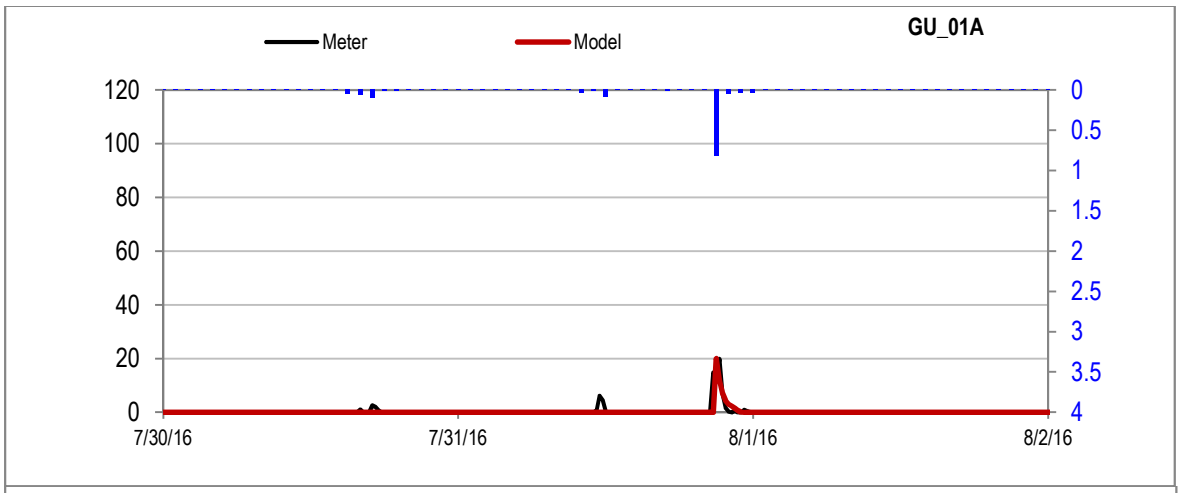

NB_04A
Meter
Model
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NB_04A
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
NB_04A
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

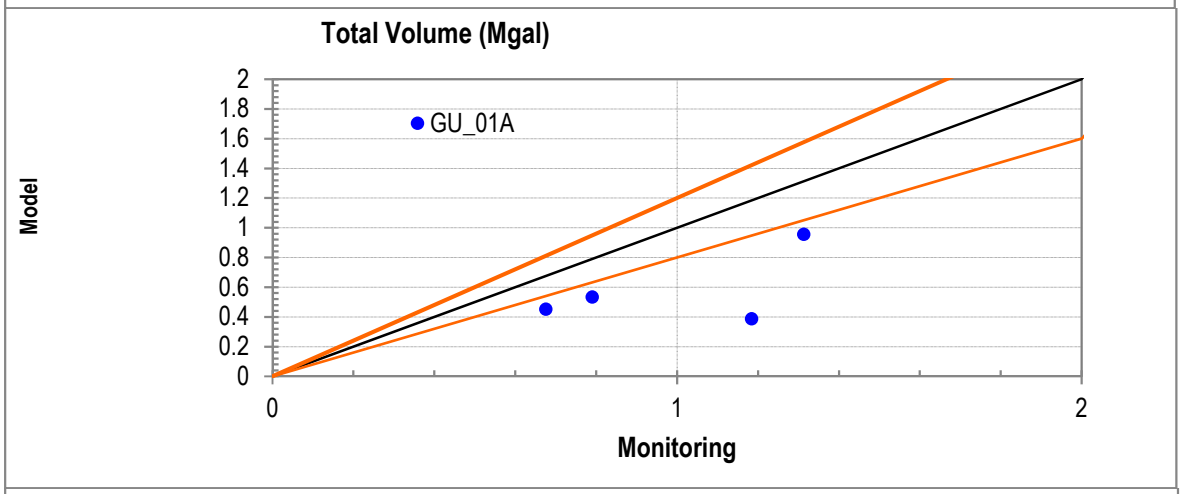

NB_04A
Meter
Model
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

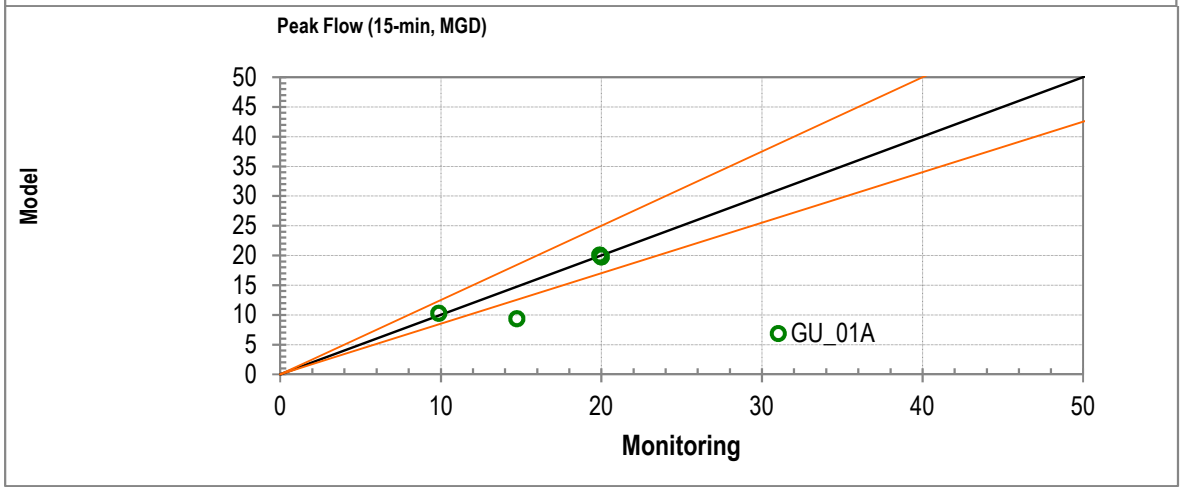

Total Volume (Mgal)
Model
Monitoring
NB_04A
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1

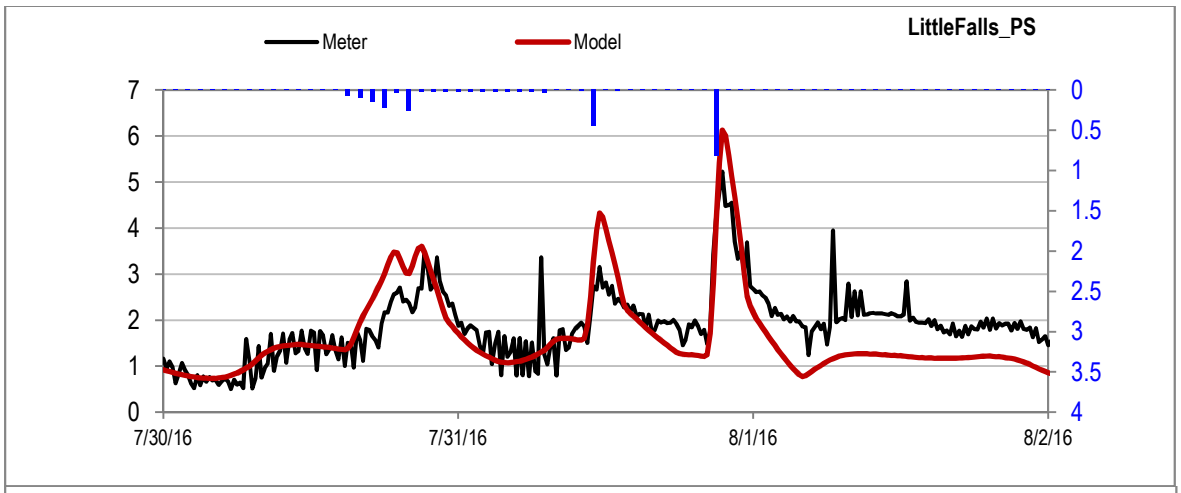

Peak Flow (15-min, MGD)
Model
Monitoring
NB_04A
0
5
10
15
20
25
30
0
5
10
15
20
25
30

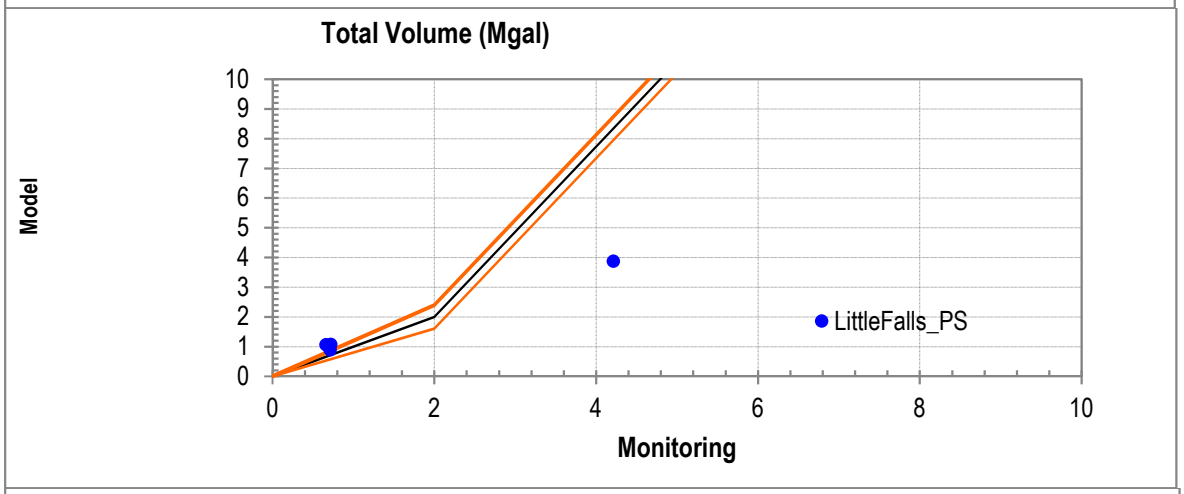

GU_01A
Meter
Model
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
GU_01A
Meter
Model
7/25/16 12:00
7/25/16 18:00
7/26/16 0:00
GU_01A
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

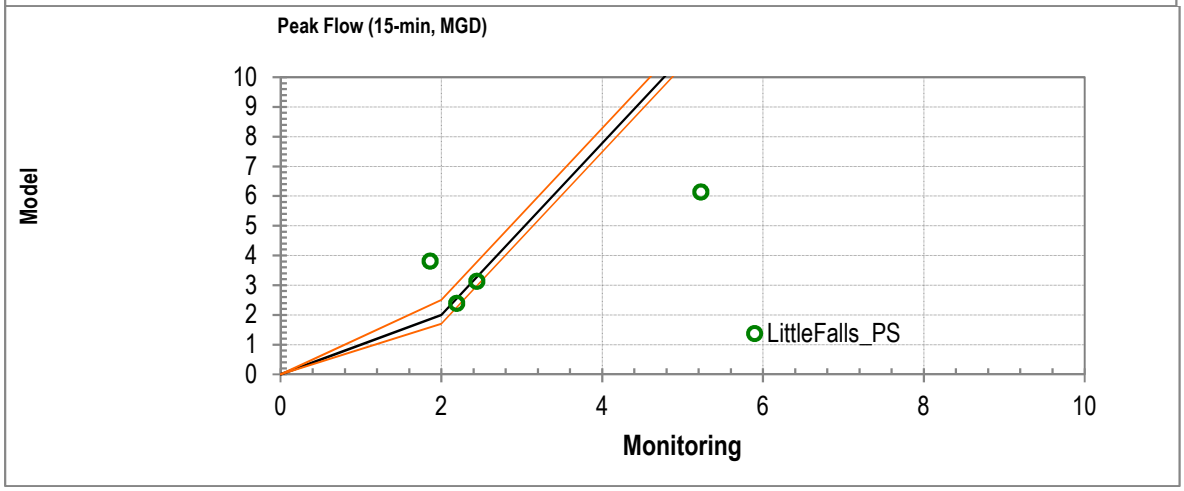

GU_01A
Meter
Model
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

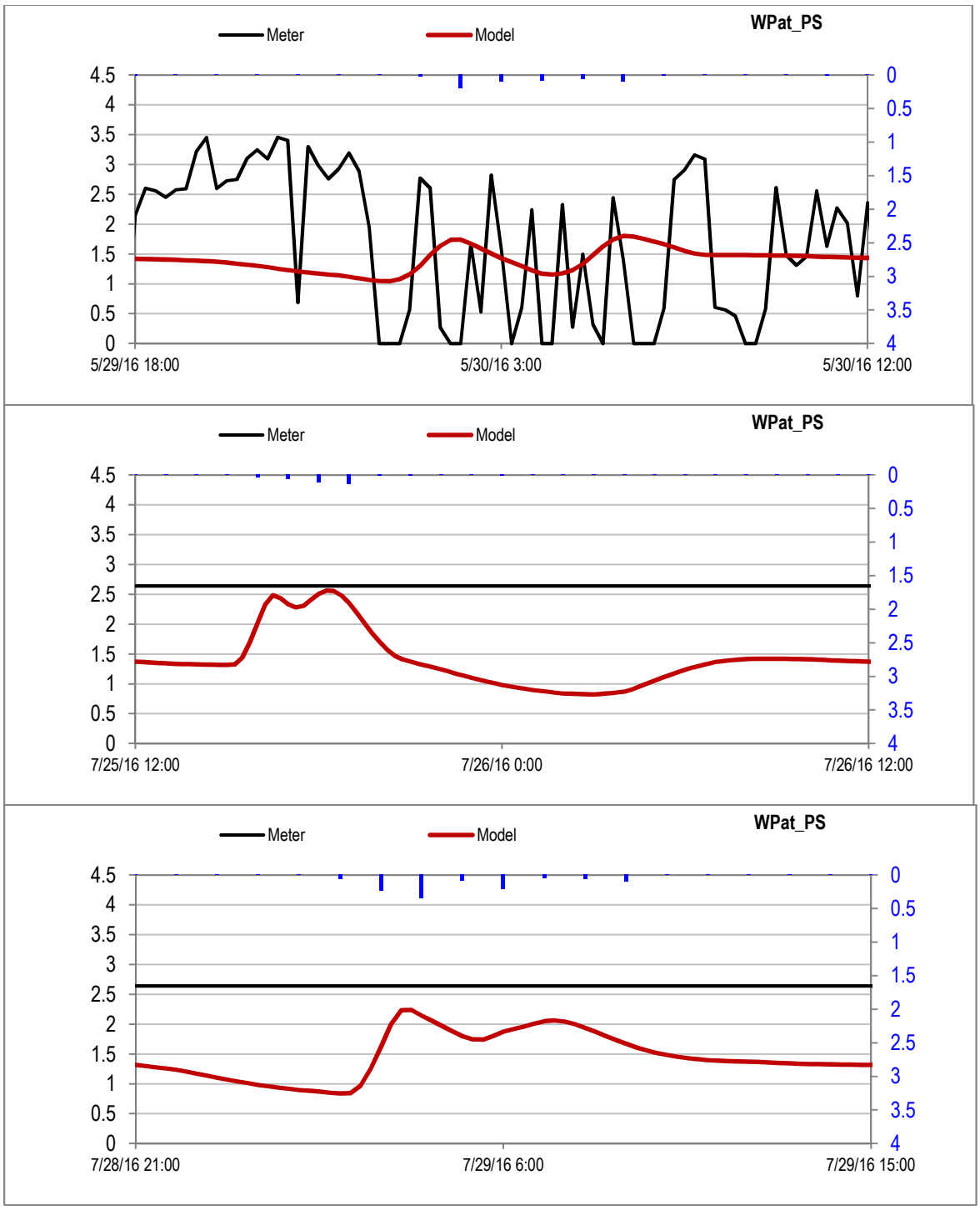

Total Volume (Mgal)
Model
GU_01A
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
Monitoring

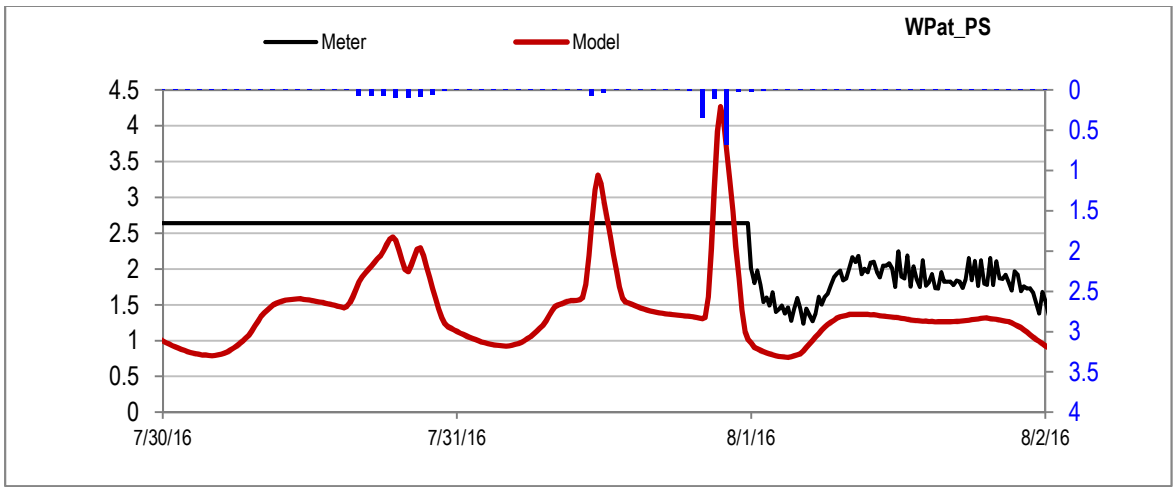

Peak Flow (15-min, MGD)
Model
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
GU_01A
Monitoring

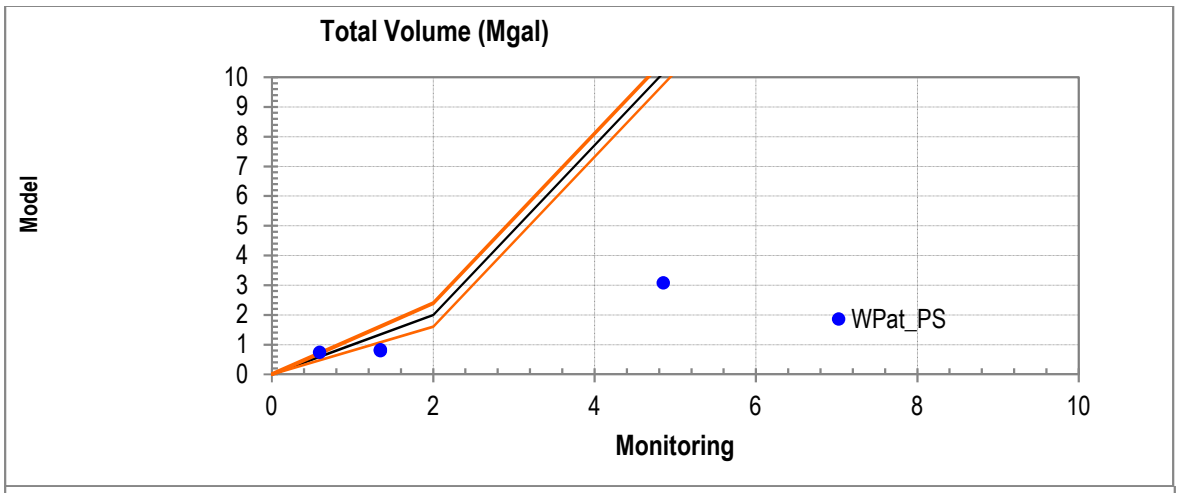

LittleFalls_PS
Meter
Model
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

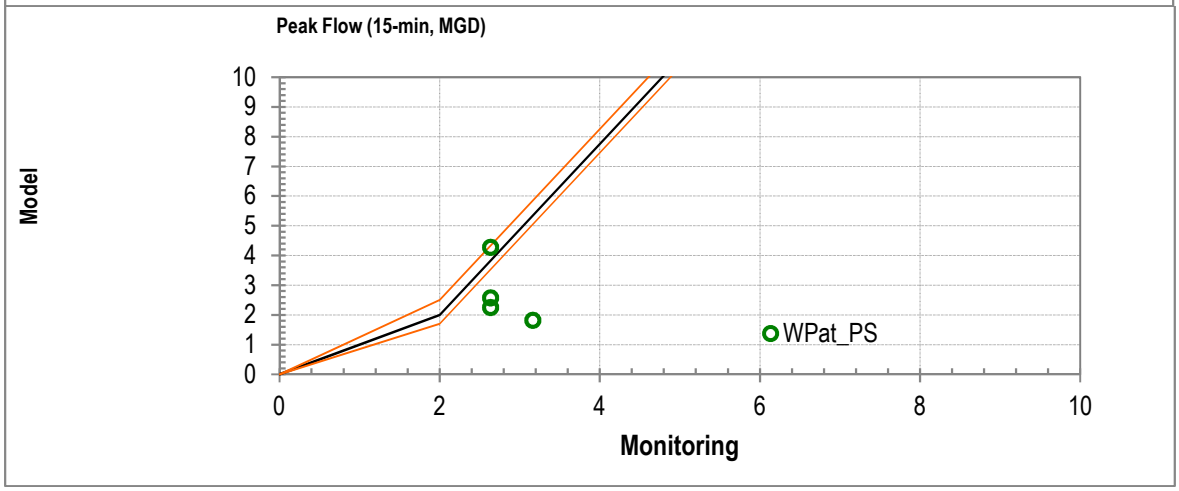

Total Volume (Mgal)
Model
Monitoring
LittleFalls_PS
0
2
4
6
8
10

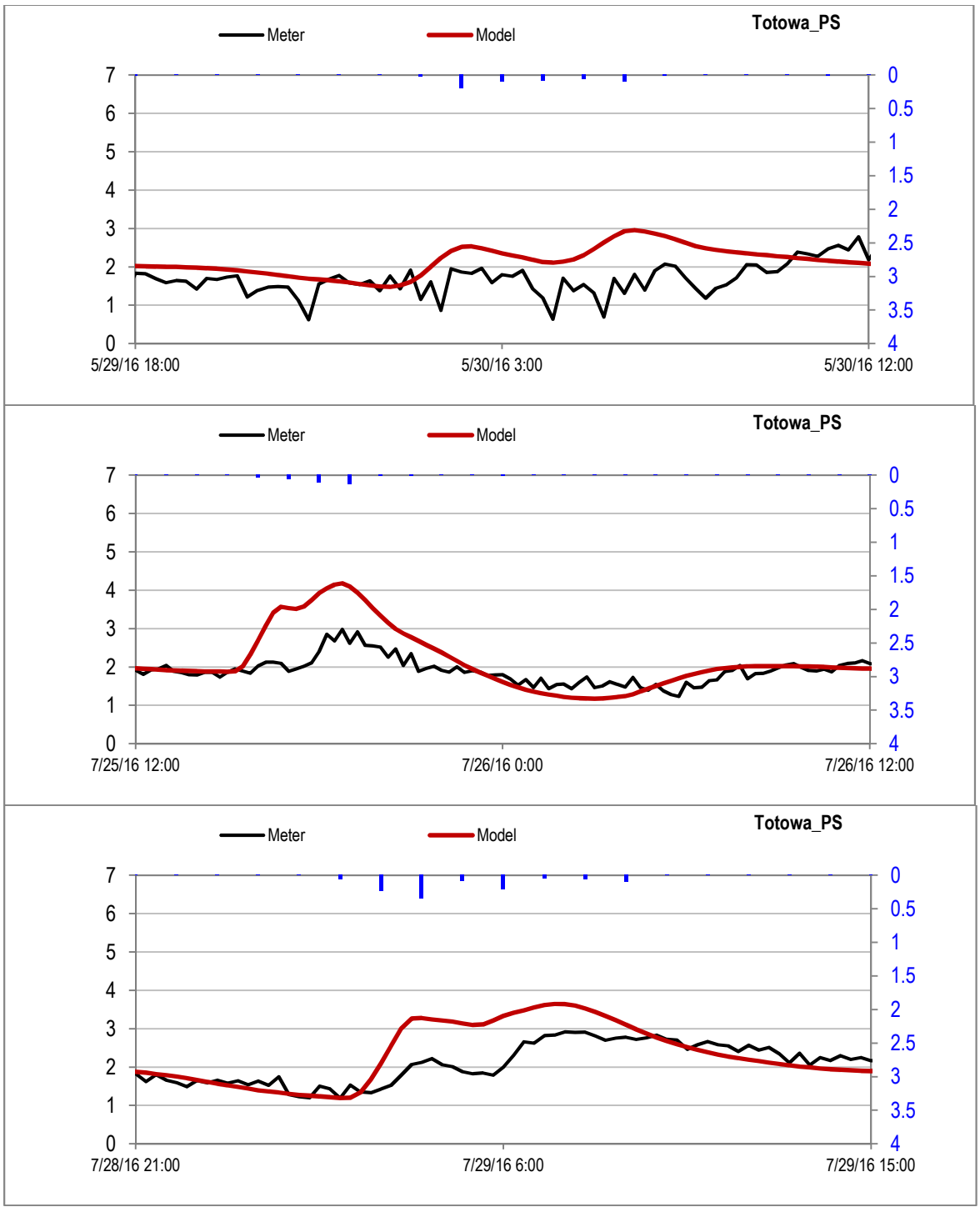

Peak Flow (15-min, MGD)
Model
Monitoring
LittleFalls_PS
0
2
4
6
8
10

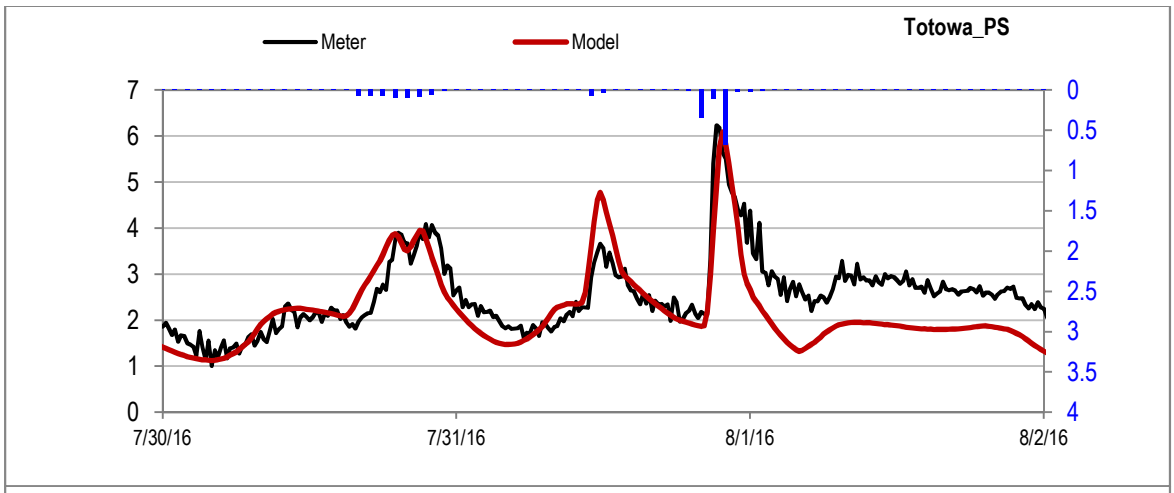

WPat_PS
Meter
Model
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
WPat_PS
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
WPat_PS
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

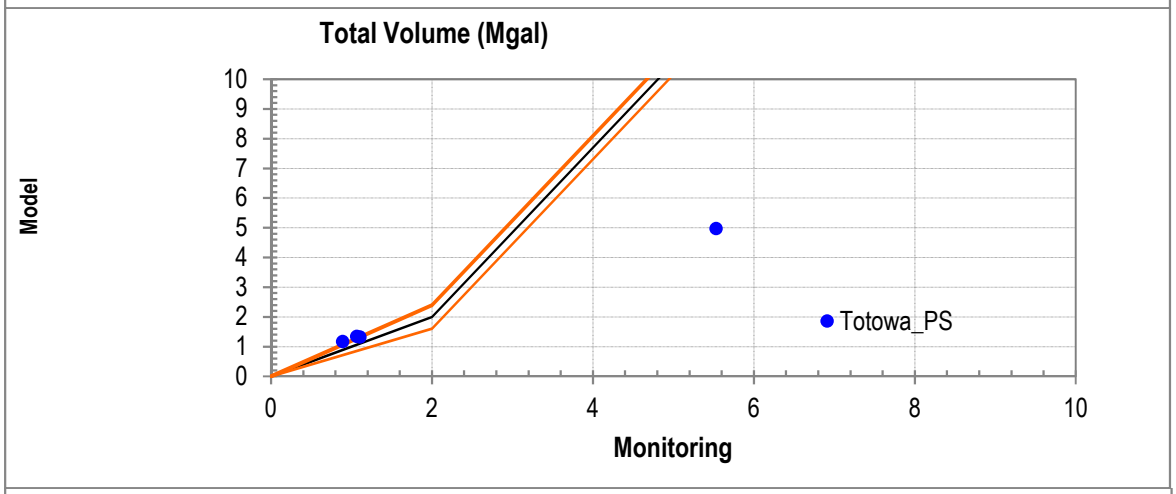

WPat_PS
Meter
Model
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

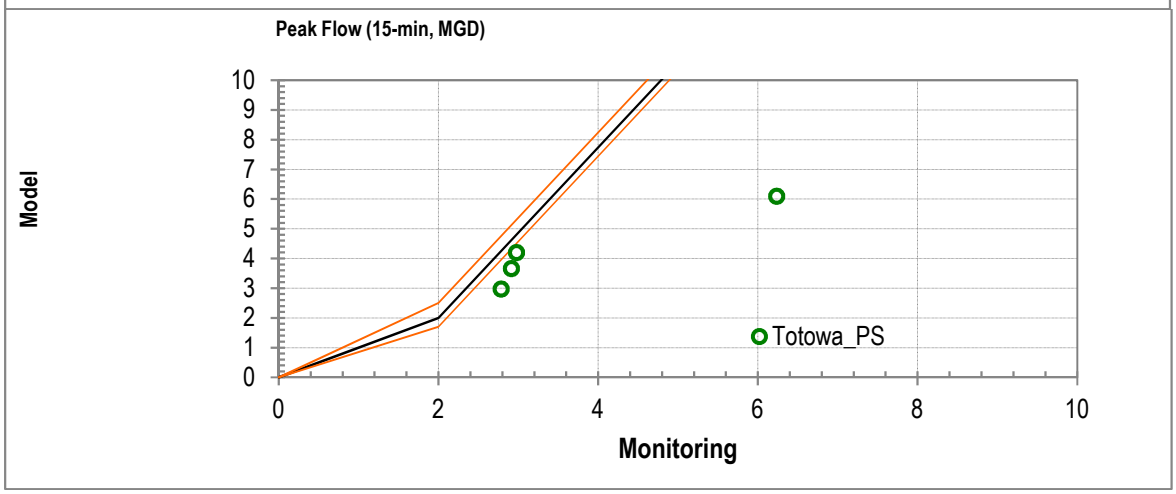

Total Volume (Mgal)
Model
Monitoring
WPat_PS
0
2
4
6
8
10

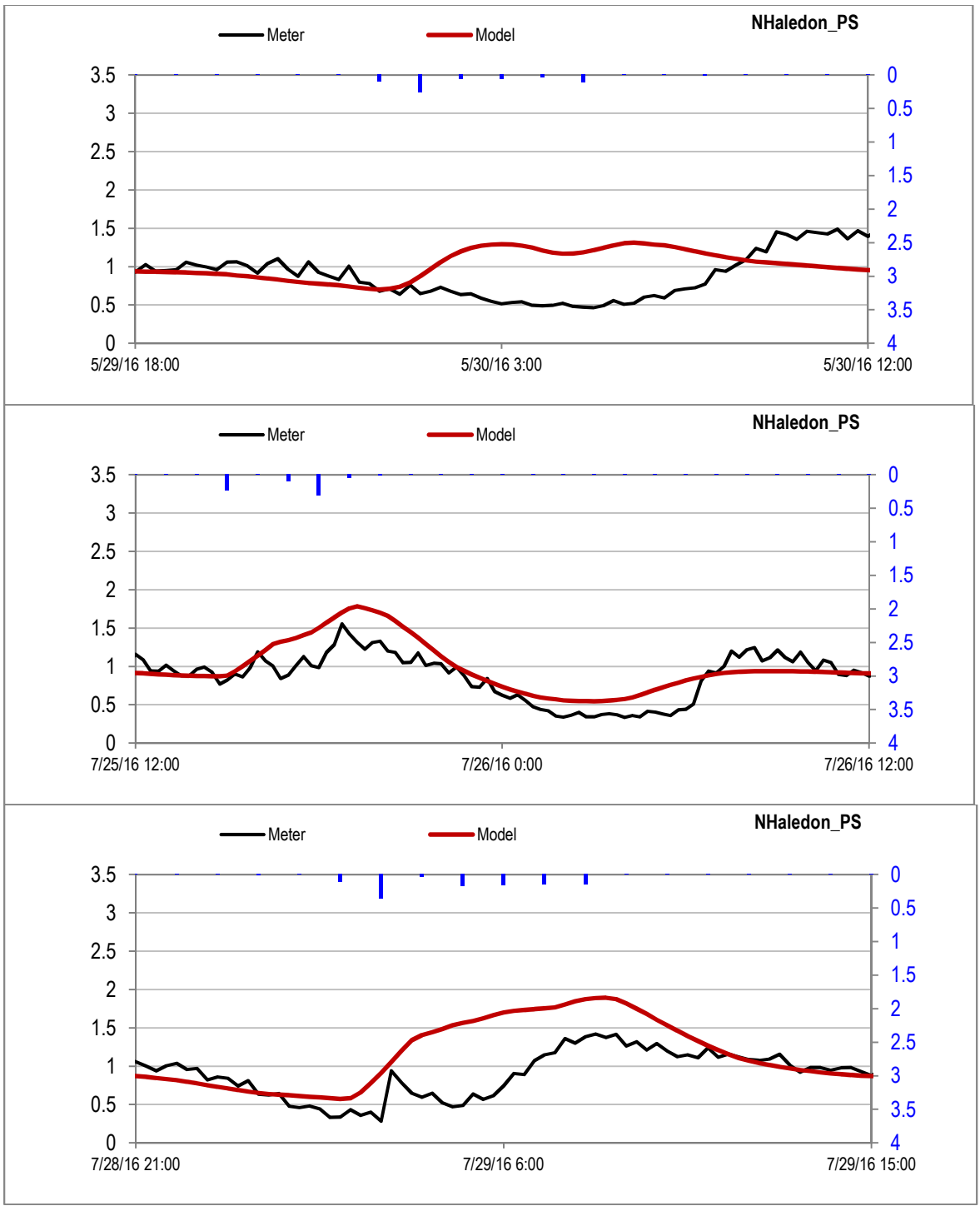

Peak Flow (15-min, MGD)
Model
Monitoring
WPat_PS
0
2
4
6
8
10

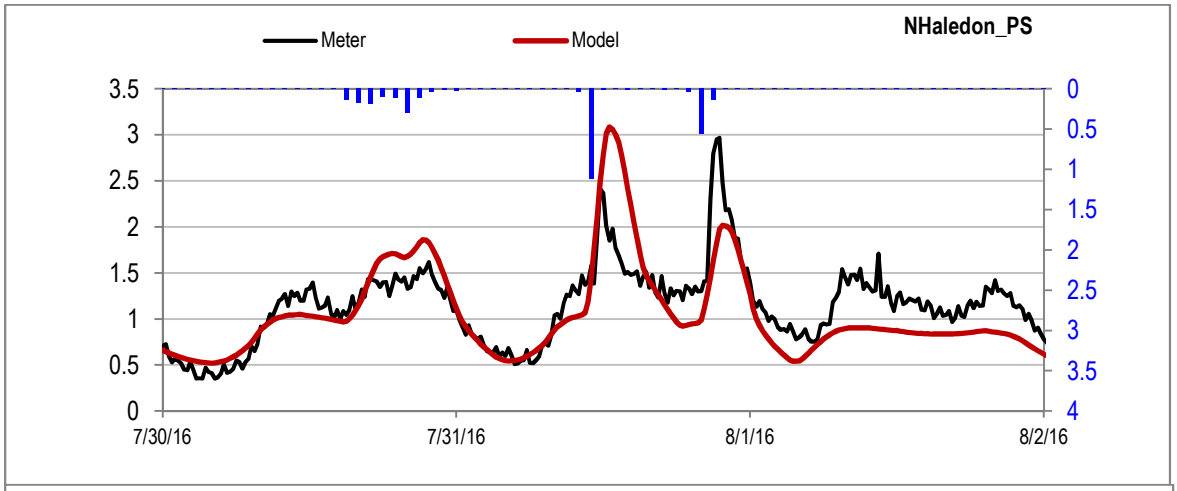

Totowa_PS
Meter
Model
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Totowa_PS
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Totowa_PS
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

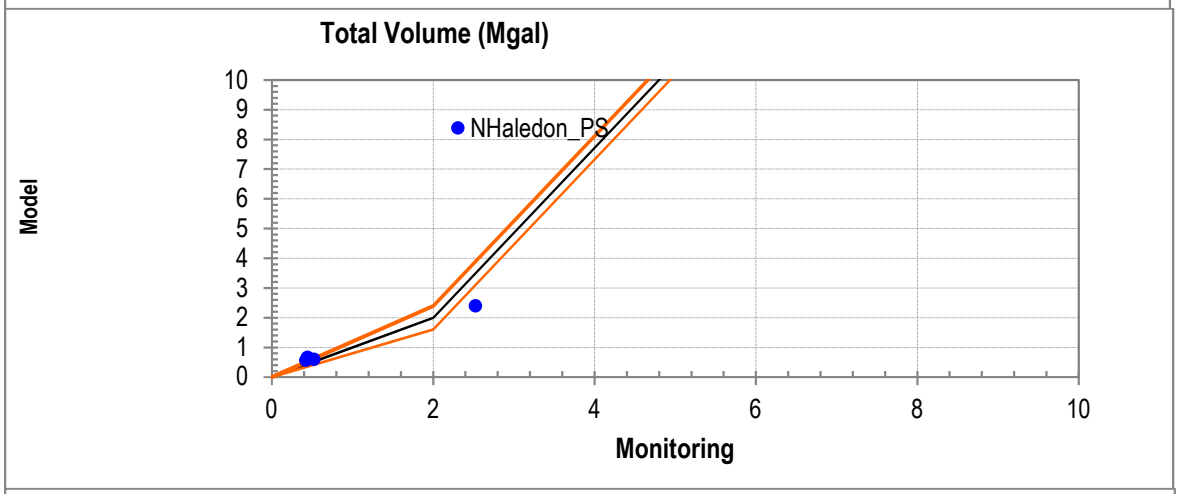

Totowa_PS
Meter
Model
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

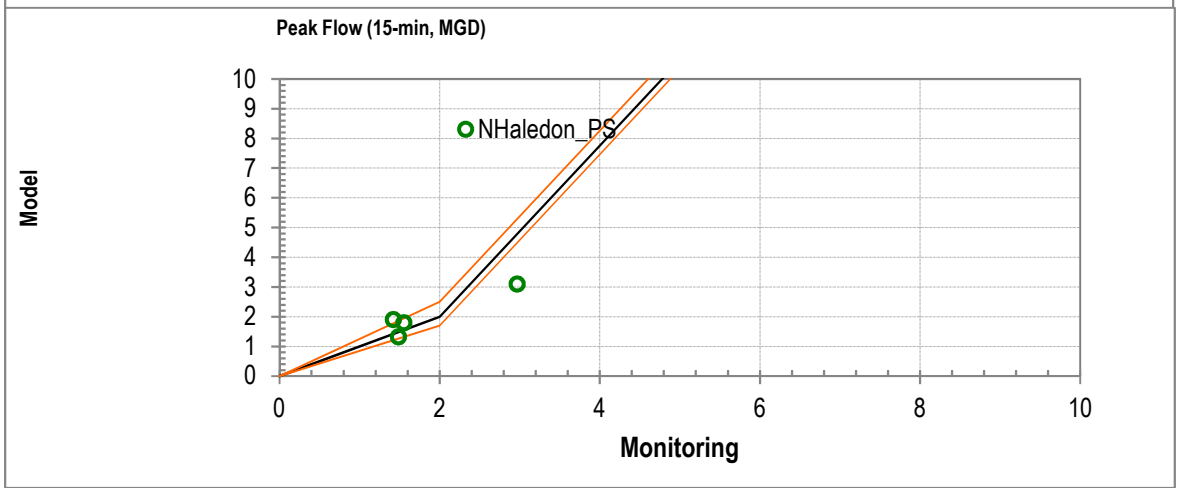

Total Volume (Mgal)
Model
Monitoring
Totowa_PS
0
2
4
6
8
10

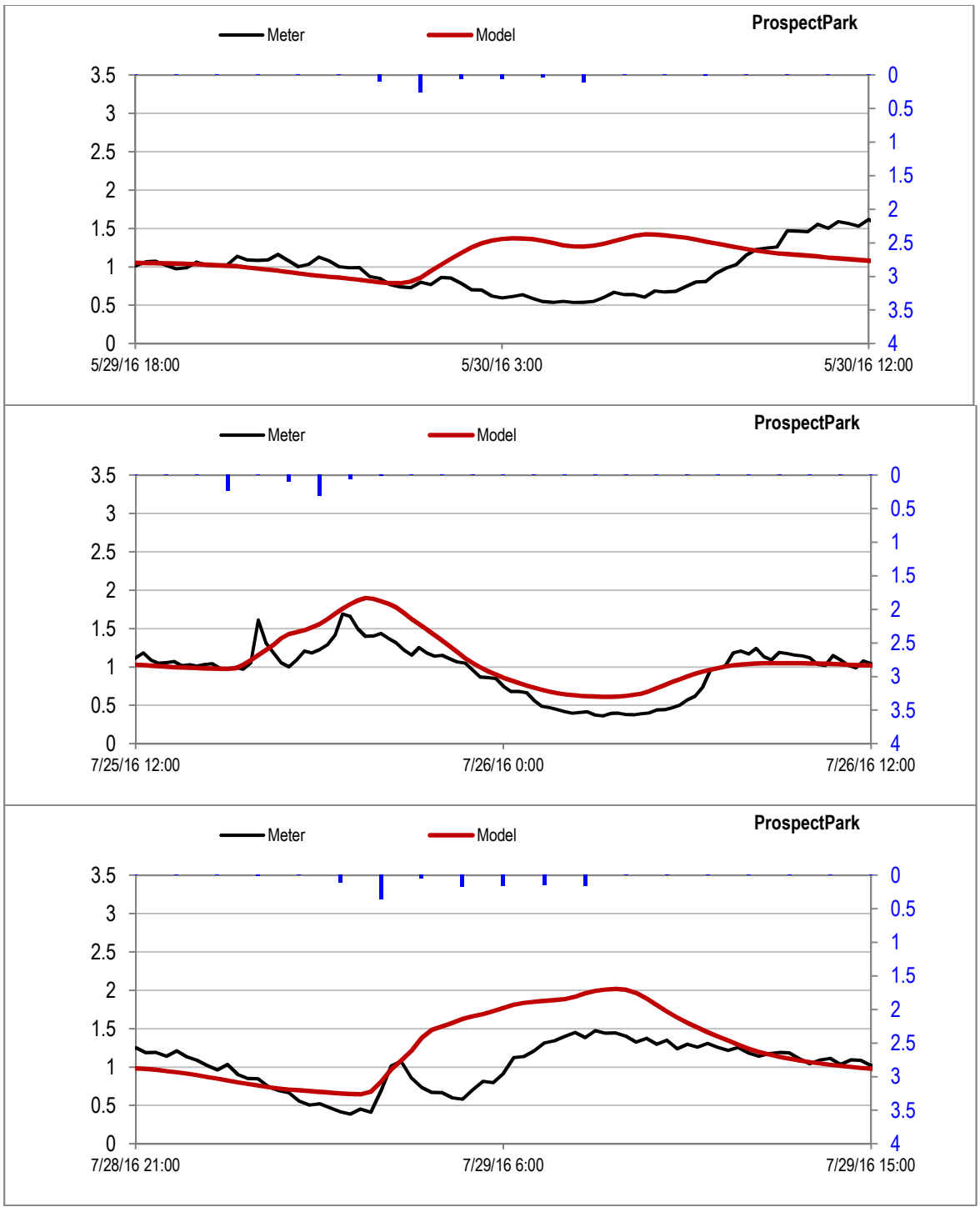

Peak Flow (15-min, MGD)
Model
Monitoring
Totowa_PS
0
2
4
6
8
10

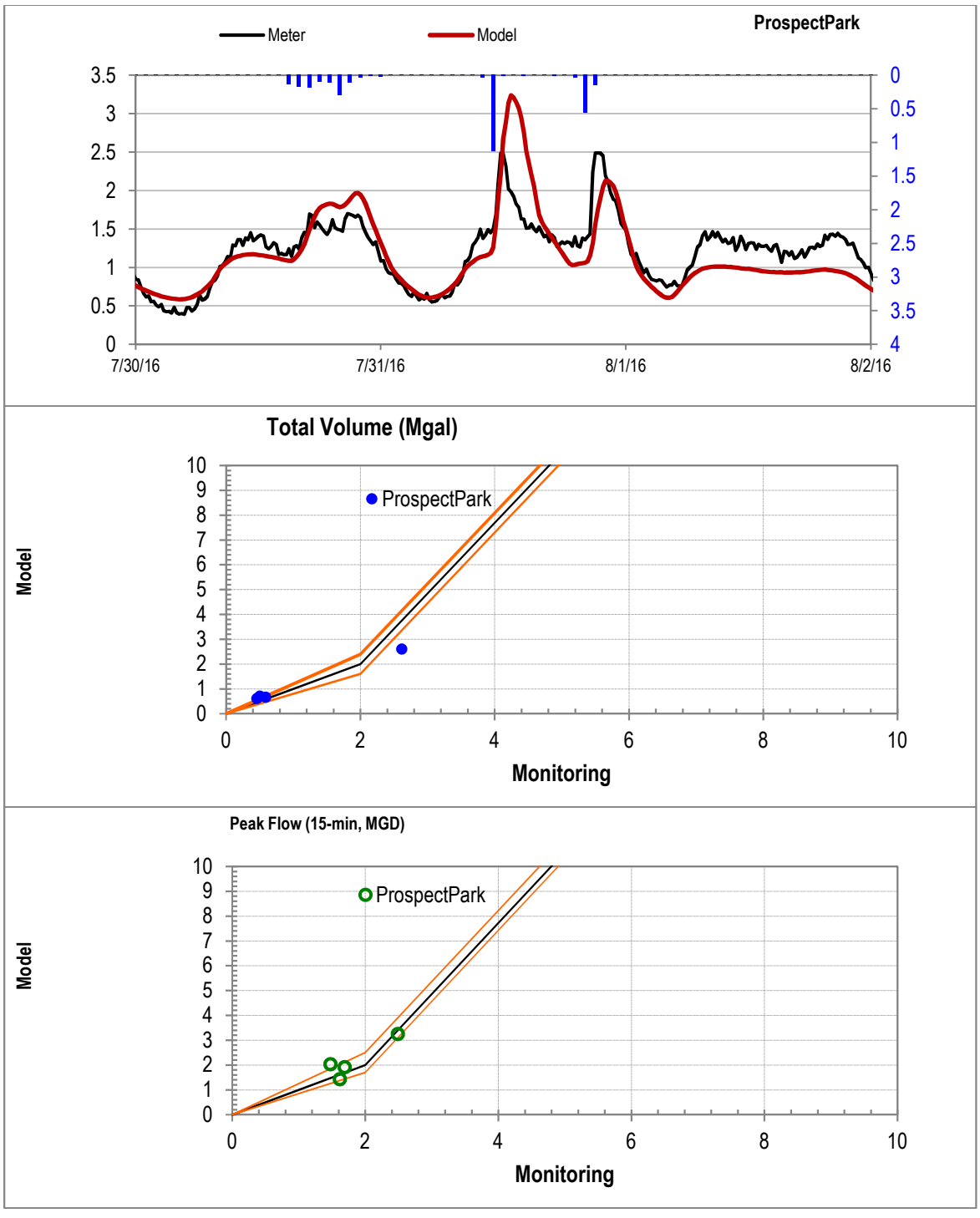

NHaledon_PS
Meter
Model
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NHaledon_PS
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
NHaledon_PS
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

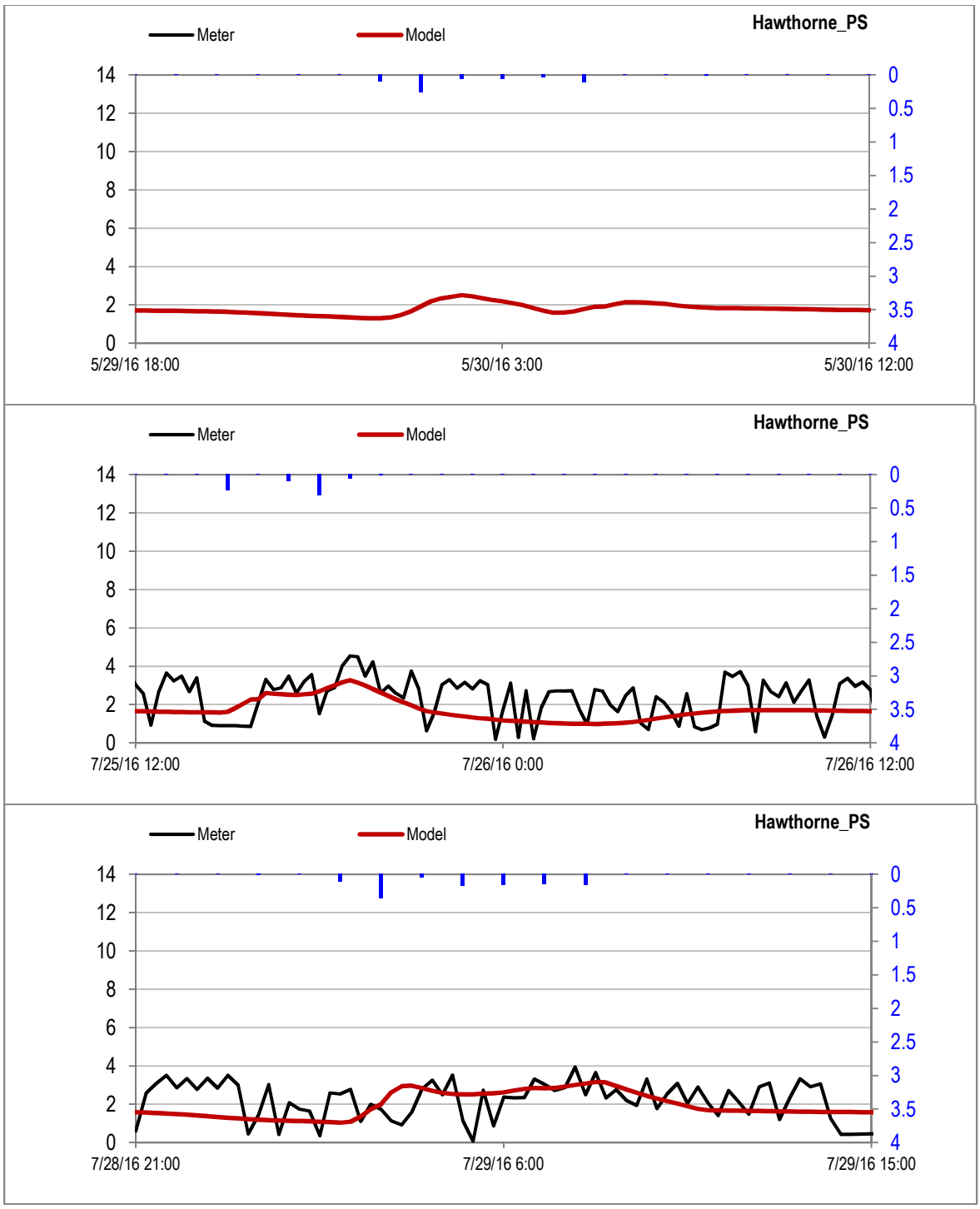

Meter
Model
NHaledon_PS
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

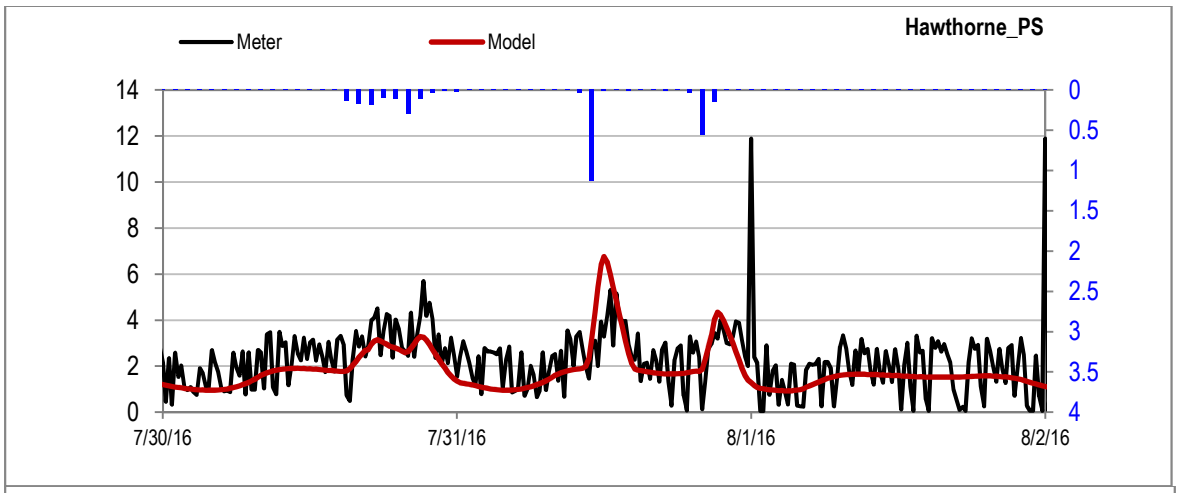

Total Volume (Mgal)
Model
NHaledon_PS
0
2
4
6
8
10
Monitoring

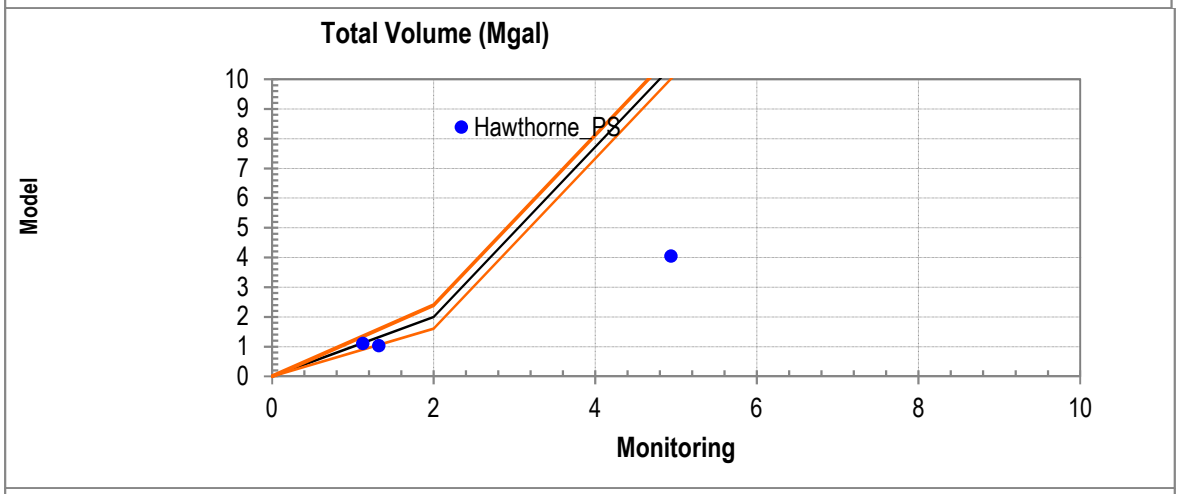

Peak Flow (15-min, MGD)
Model
NHaledon_PS
0
2
4
6
8
10
Monitoring

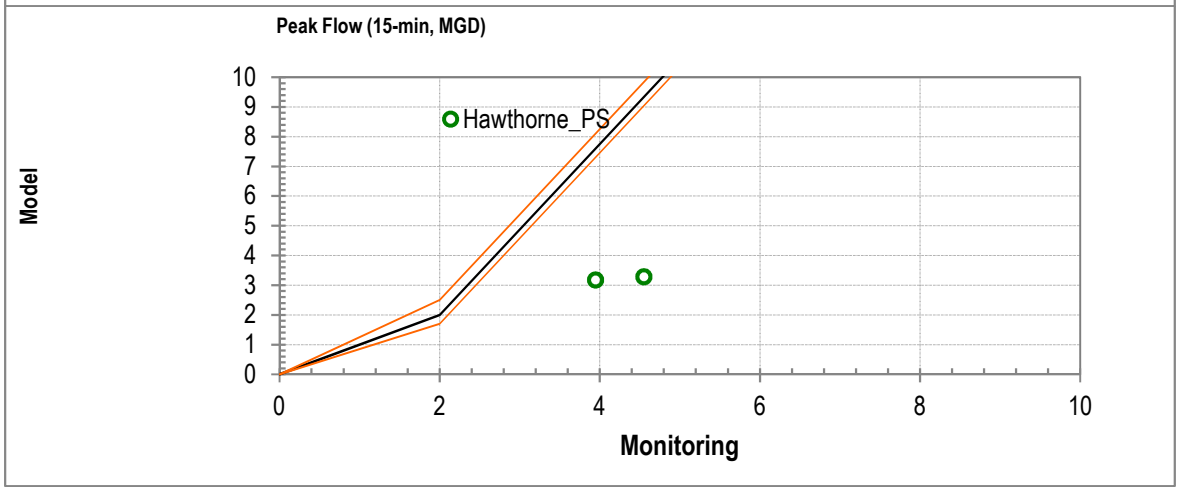

Meter
Model
ProspectPark
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Meter
Model
ProspectPark
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Meter
Model
ProspectPark
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

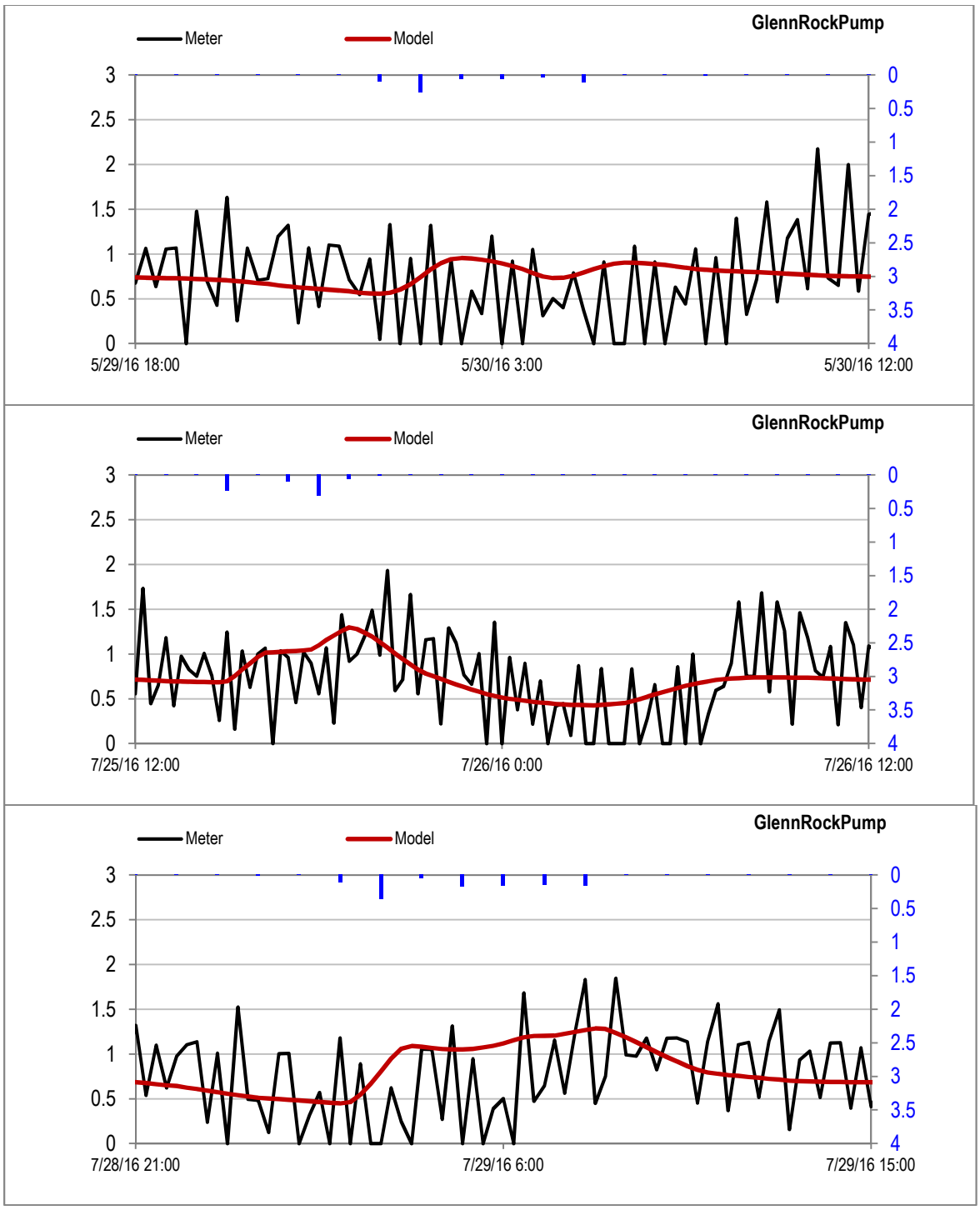

Meter
Model
ProspectPark
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
ProspectPark
Monitoring
Peak Flow (15-min, MGD)
Model
ProspectPark
Monitoring

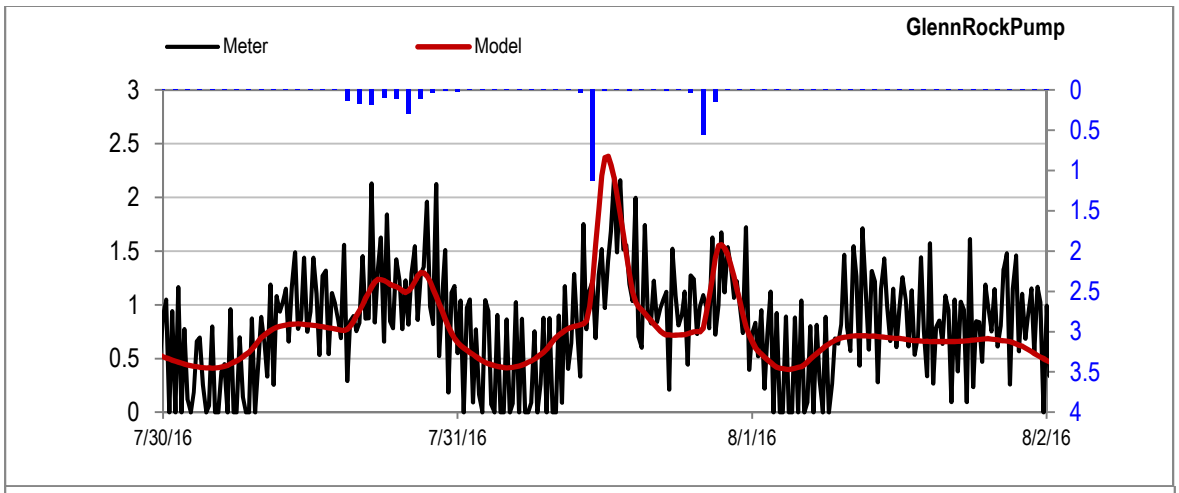

Hawthorne_PS
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Hawthorne_PS
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Hawthorne_PS
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

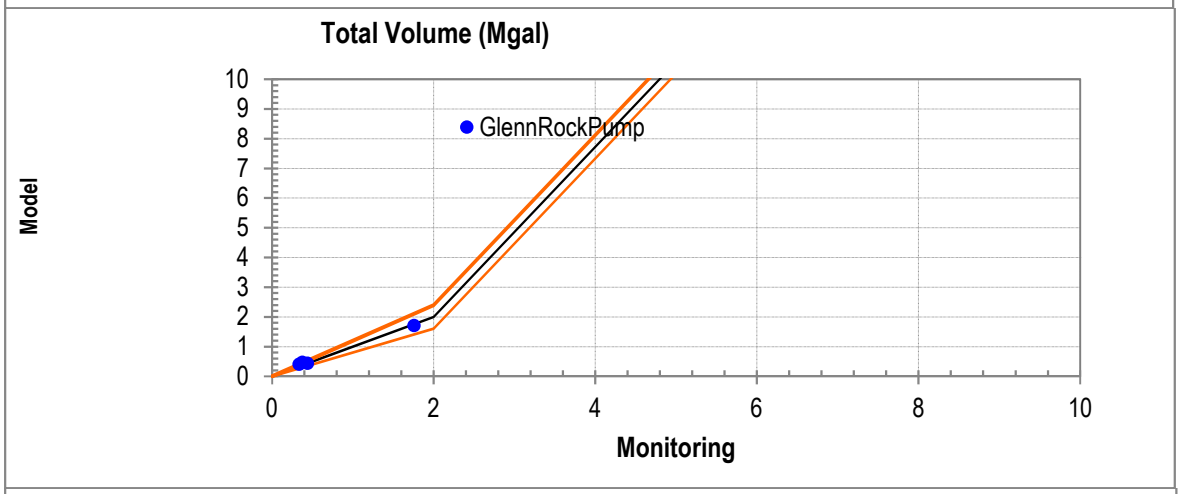

Hawthorne_PS
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

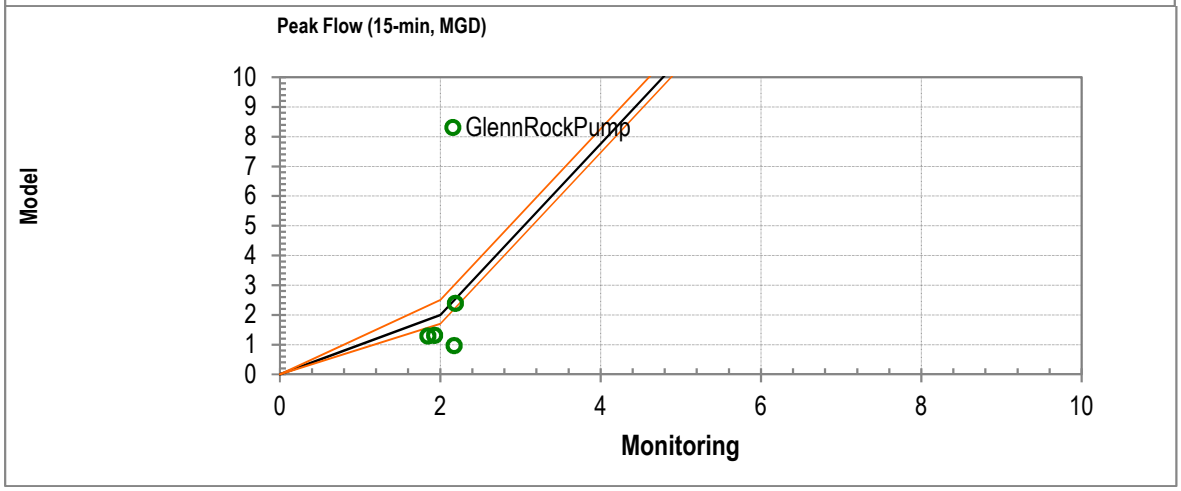

Total Volume (Mgal)
Model
Hawthorne_PS
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

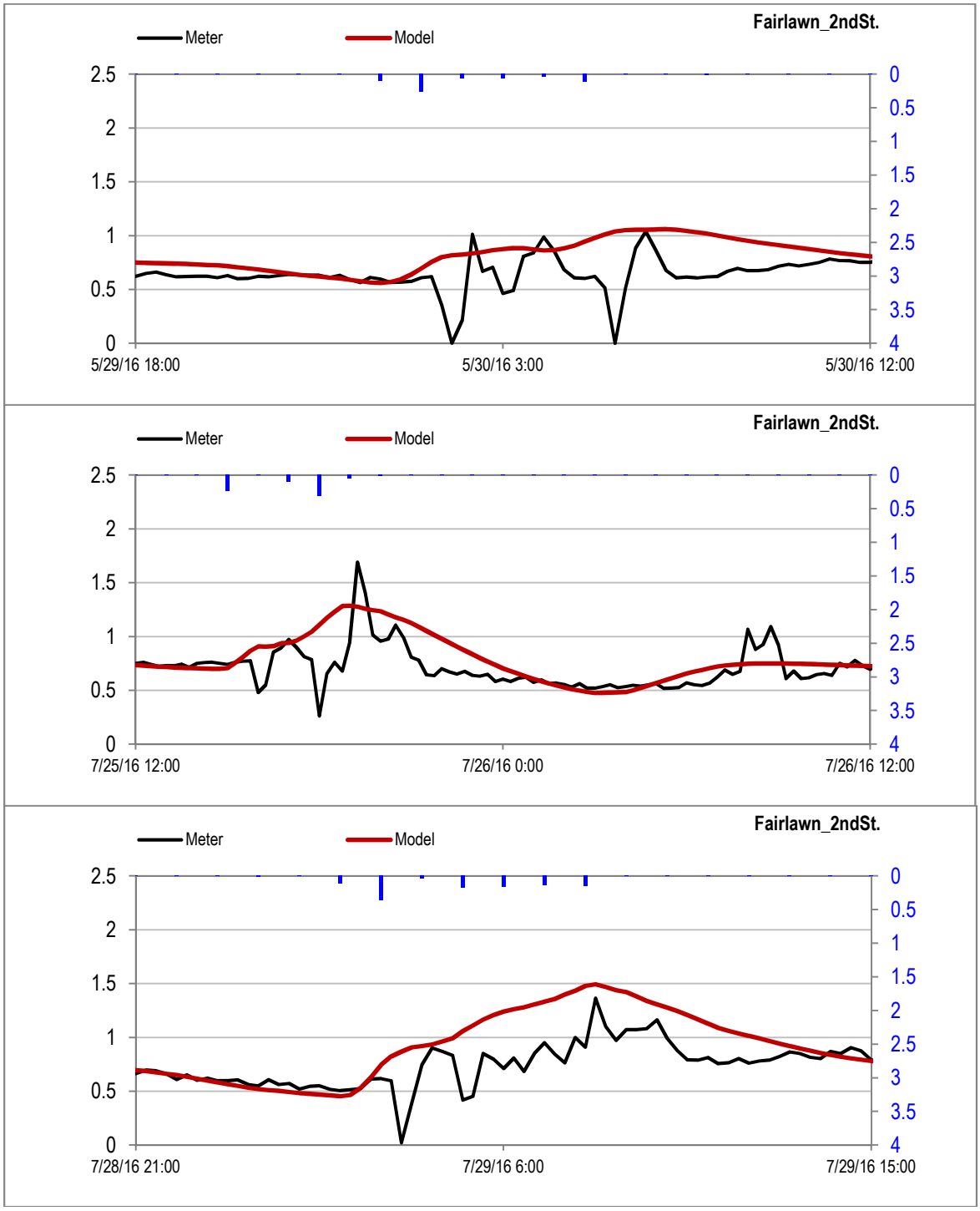

Peak Flow (15-min, MGD)
Model
Hawthorne_PS
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

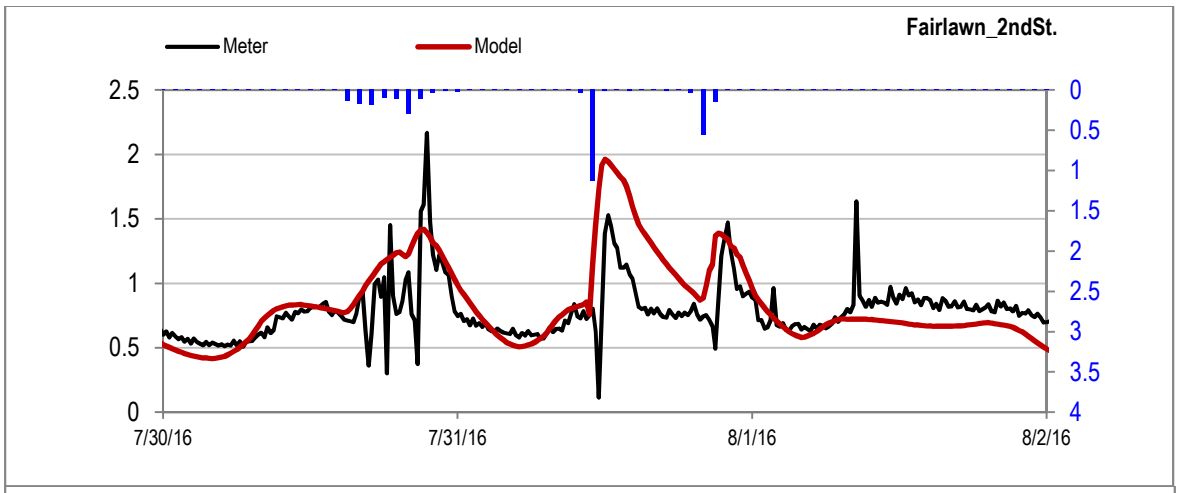

GlennRockPump
Meter
Model
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
GlennRockPump
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
GlennRockPump
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

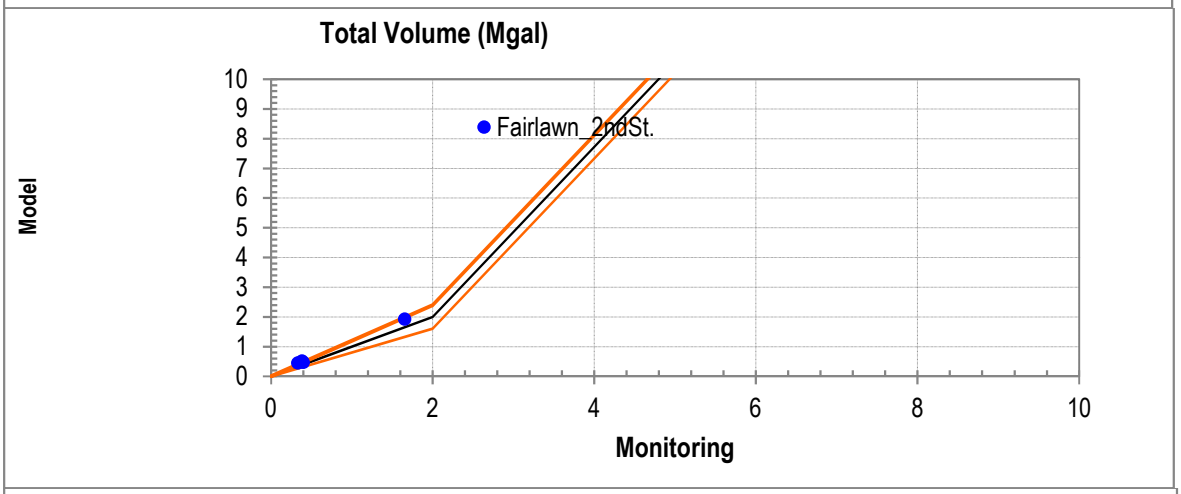

GlennRockPump
Meter
Model
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

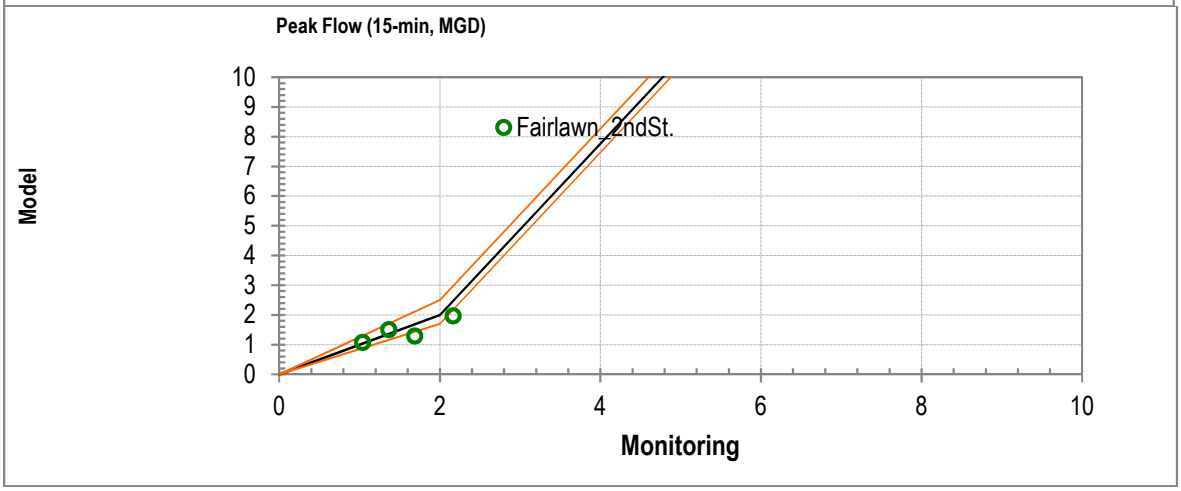

Total Volume (Mgal)
Model
GlennRockPump
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

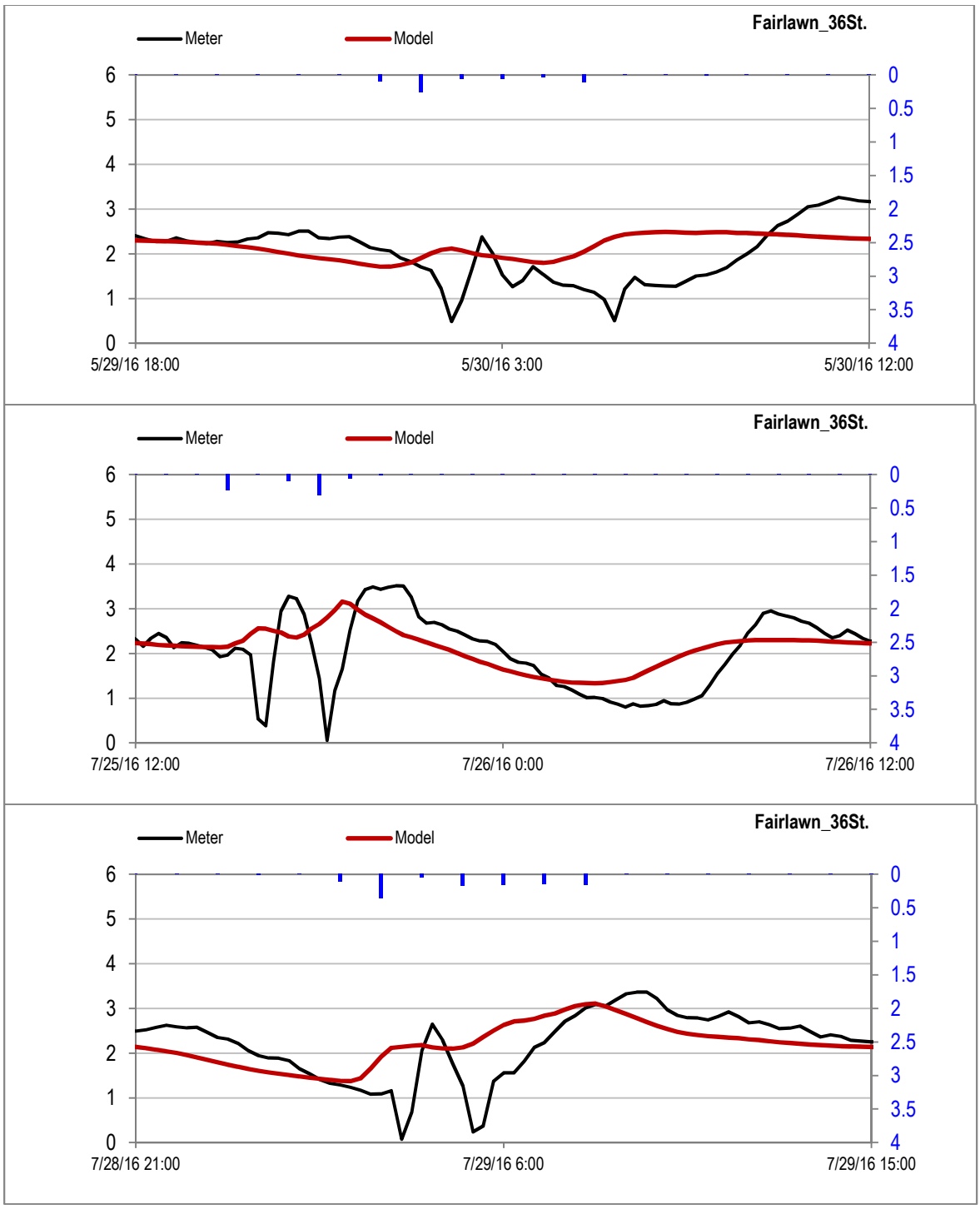

Peak Flow (15-min, MGD)
Model
GlennRockPump
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

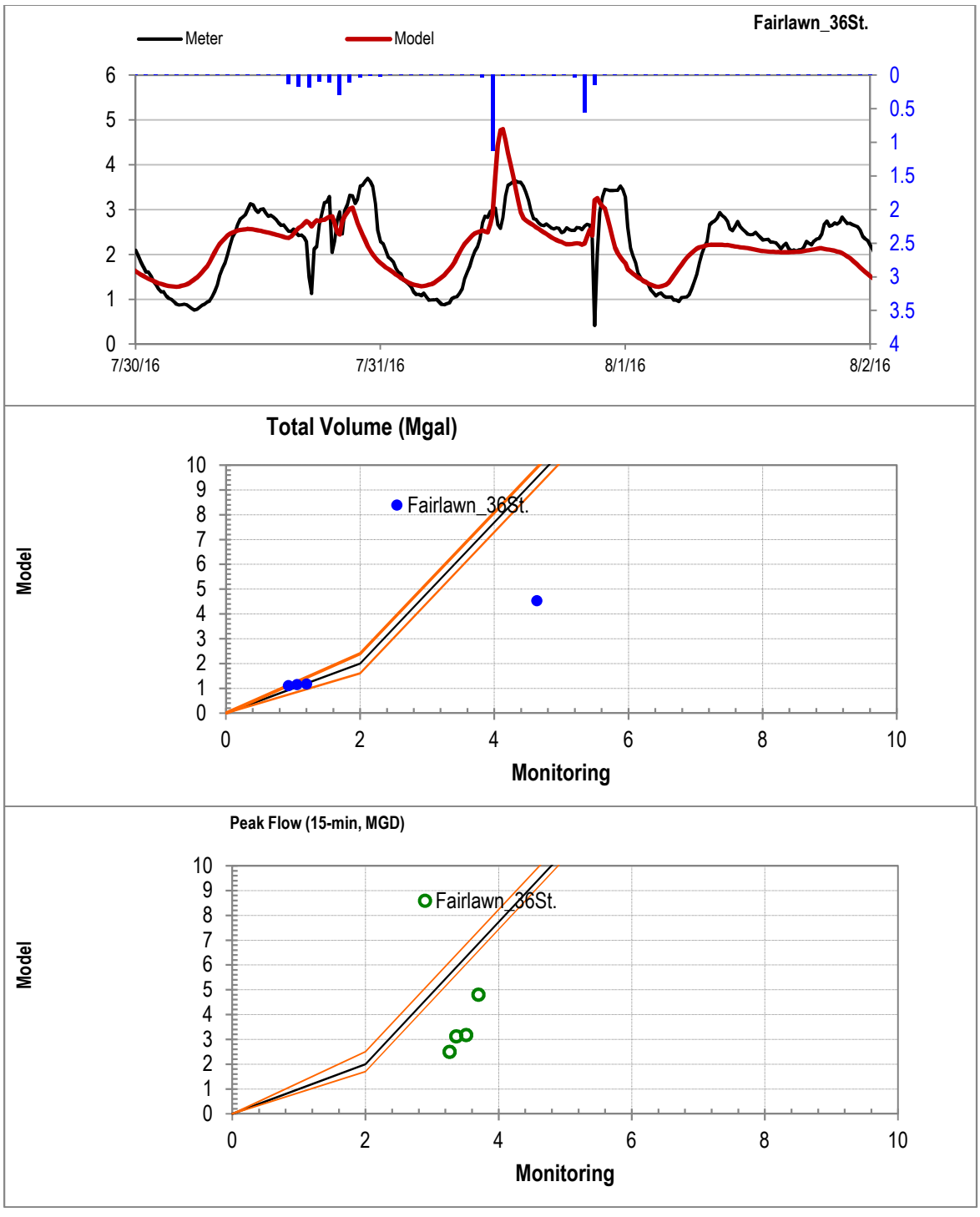

Fairlawn_2ndSt.
Meter
Model
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Fairlawn_2ndSt.
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Fairlawn_2ndSt.
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

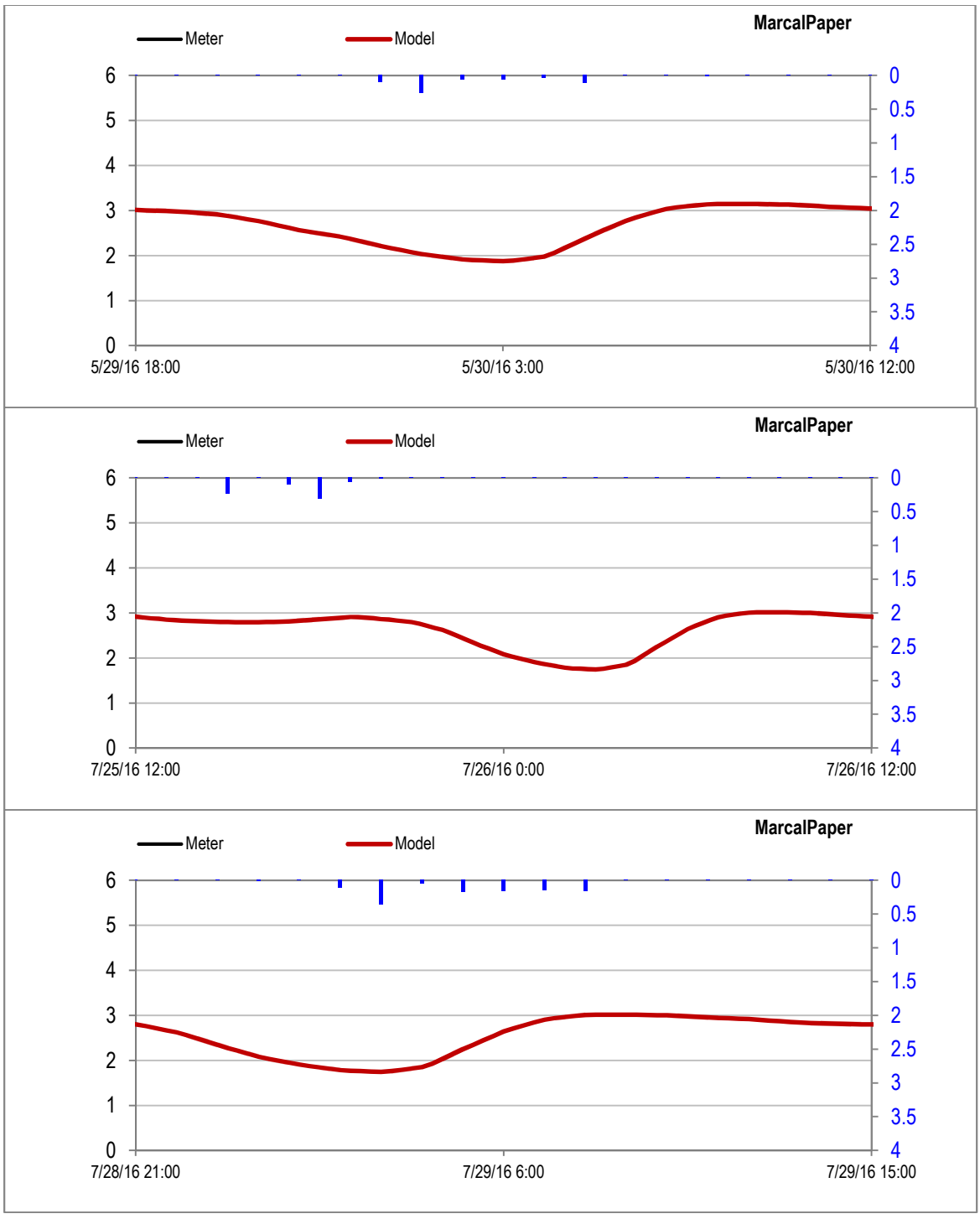

Fairlawn_2ndSt.
Meter
Model
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

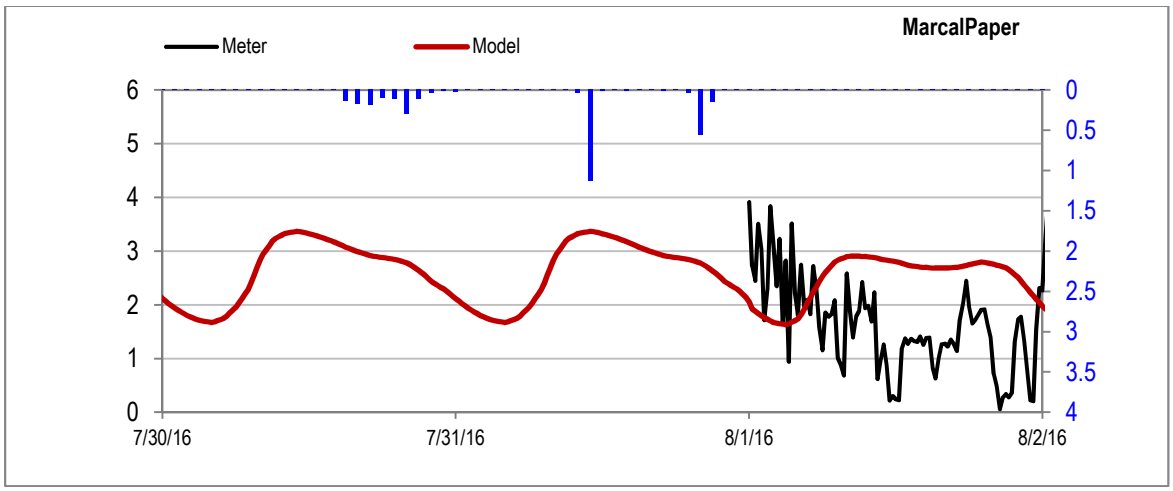

Total Volume (Mgal)
Model
Fairlawn_2ndSt.
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

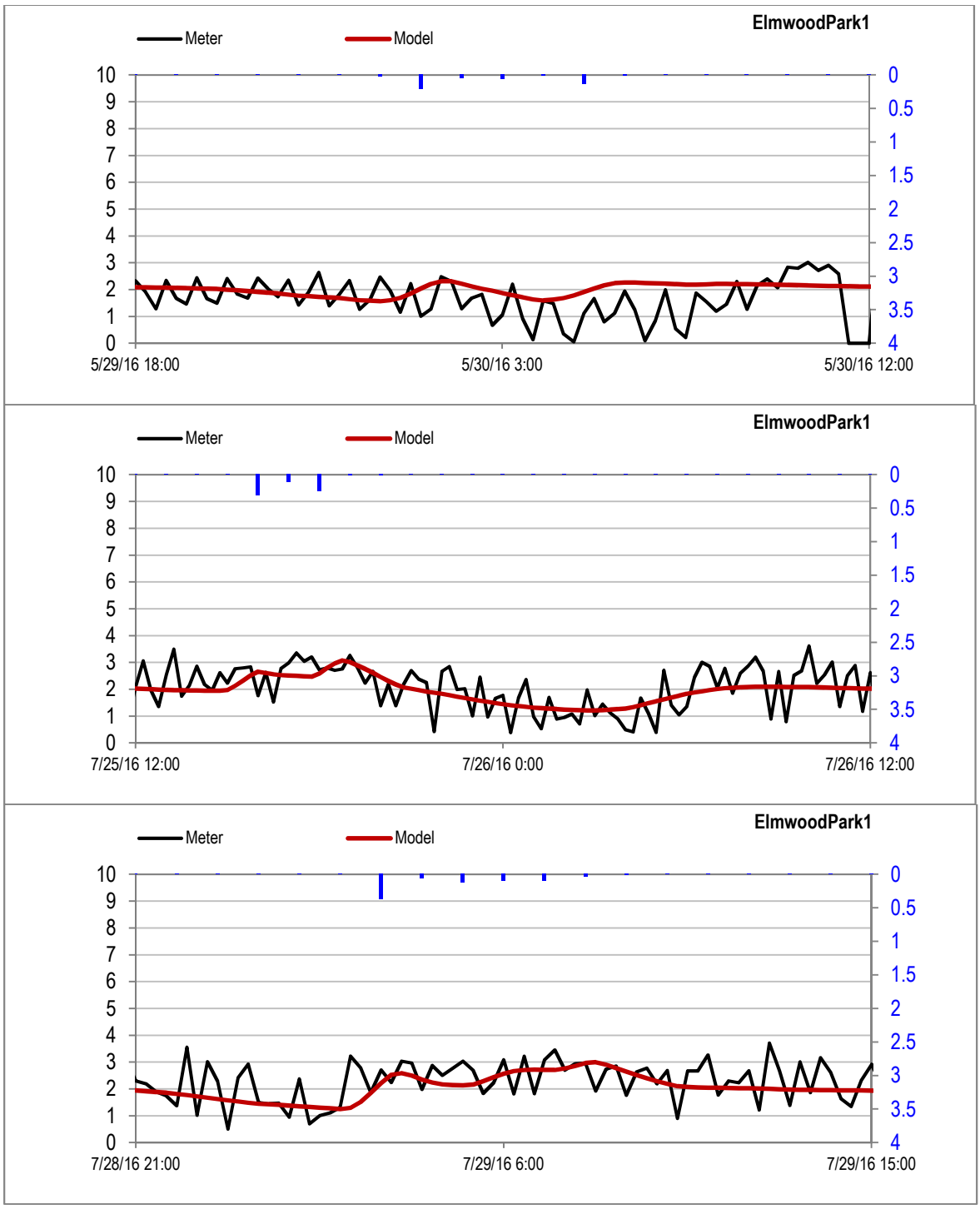

Peak Flow (15-min, MGD)
Model
Fairlawn_2ndSt.
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

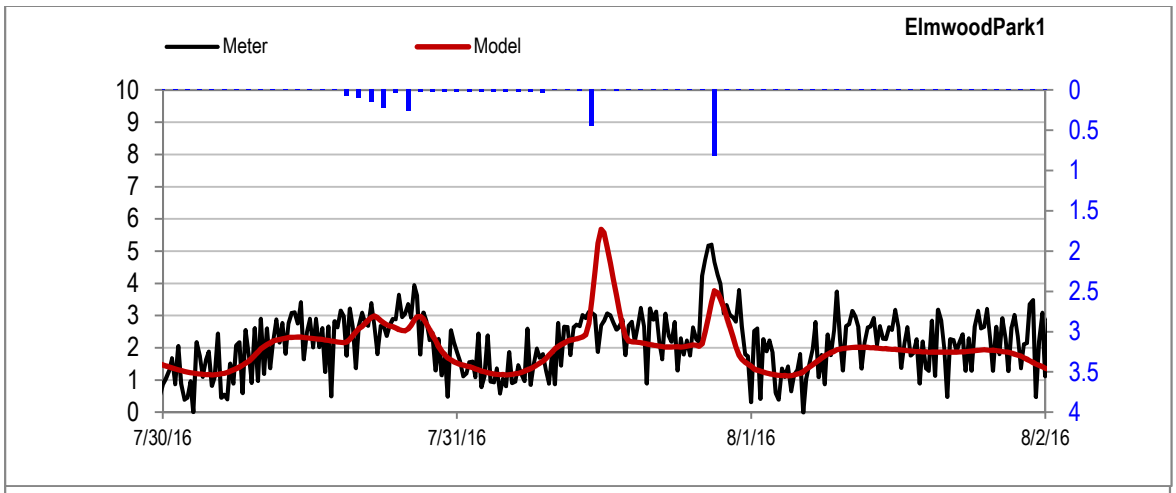

Fairlawn_36St.
Meter
Model
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Fairlawn_36St.
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Fairlawn_36St.
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

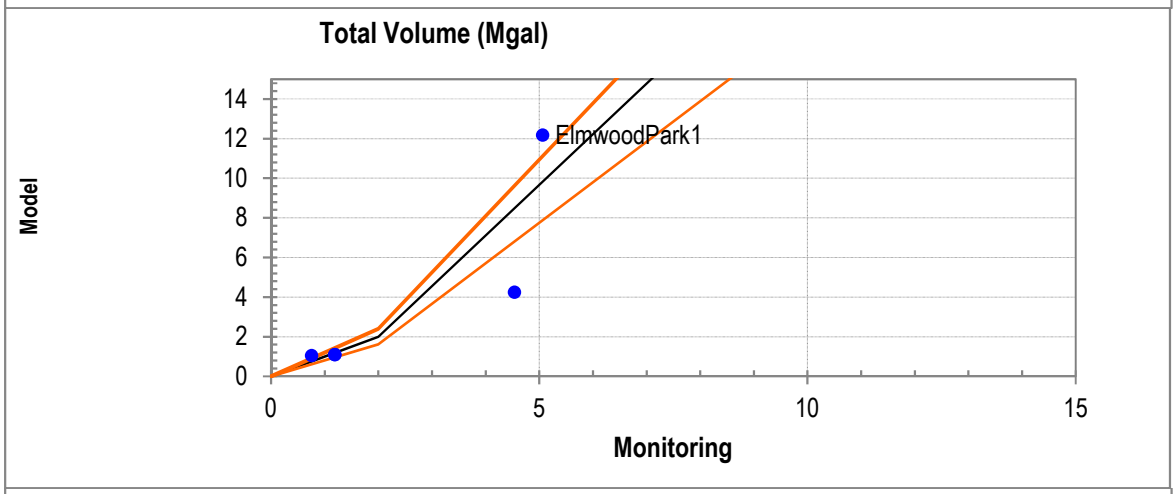

Fairlawn_36St.
Meter
Model
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
Fairlawn_36St.
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring
Peak Flow (15-min, MGD)
Model
Fairlawn_36St.
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

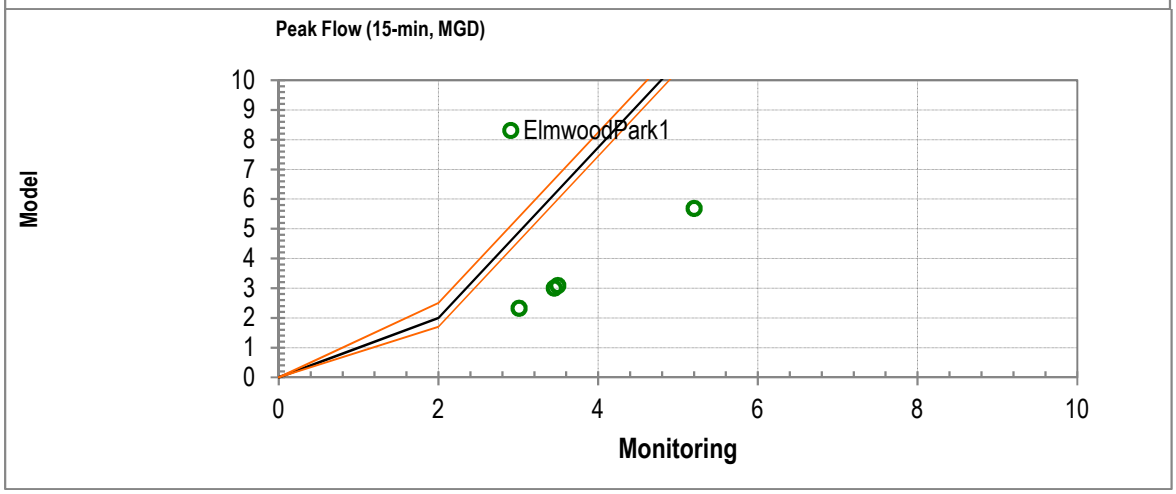

MarcalPaper
Meter
Model
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
MarcalPaper
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
MarcalPaper
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

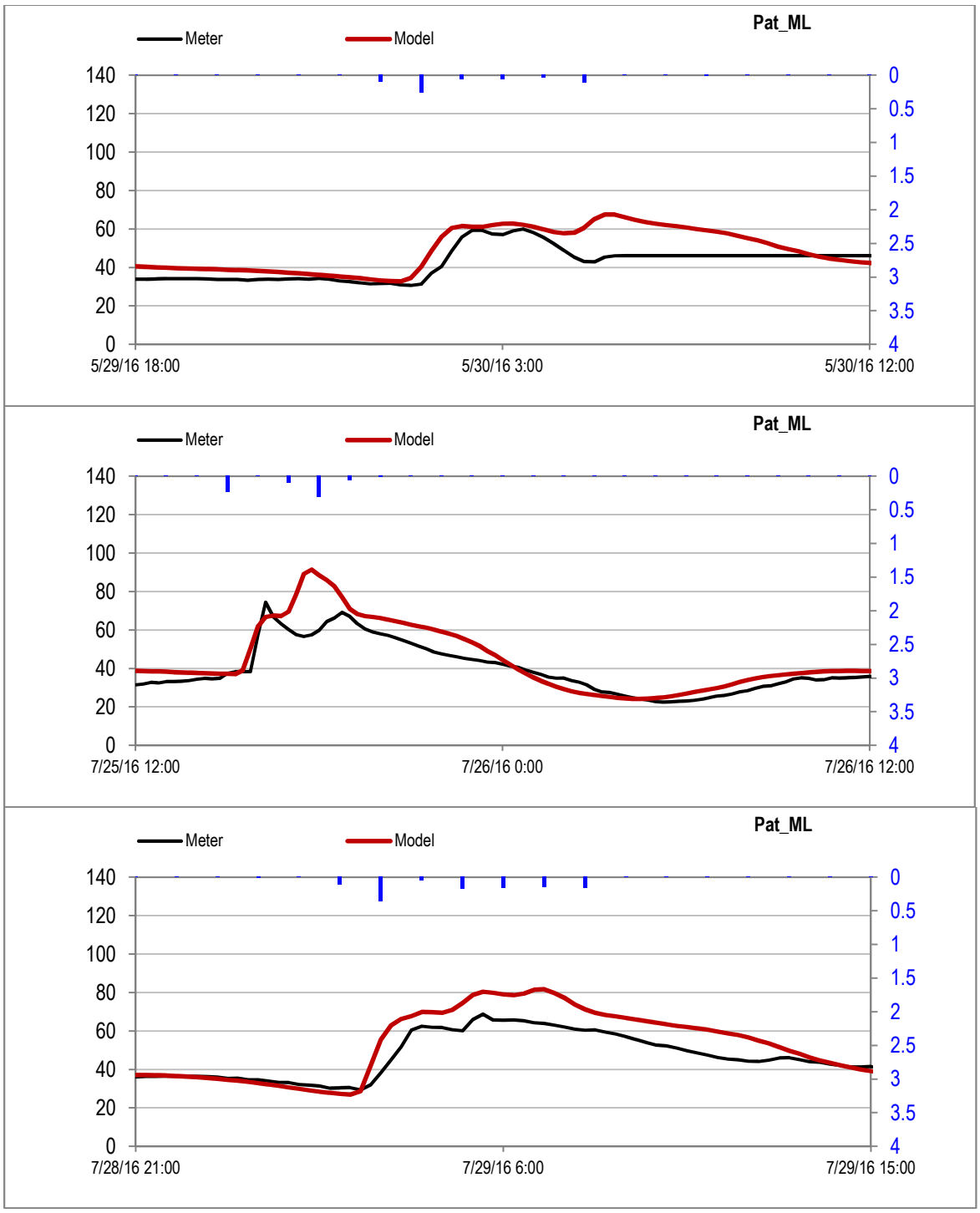

MarcalPaper
Meter
Model
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

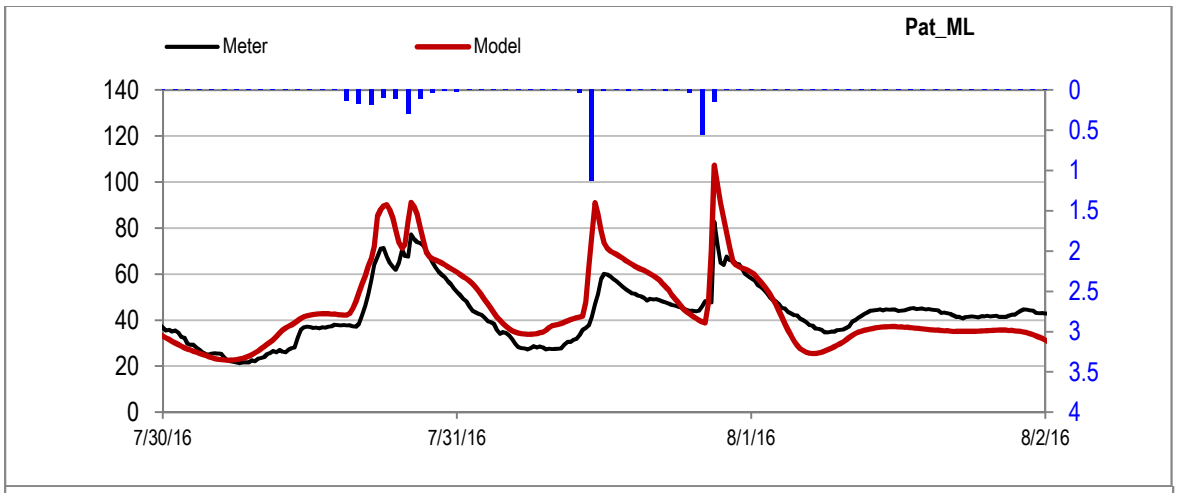

ElmwoodPark1
Meter
Model
10
9
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
ElmwoodPark1
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
ElmwoodPark1
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

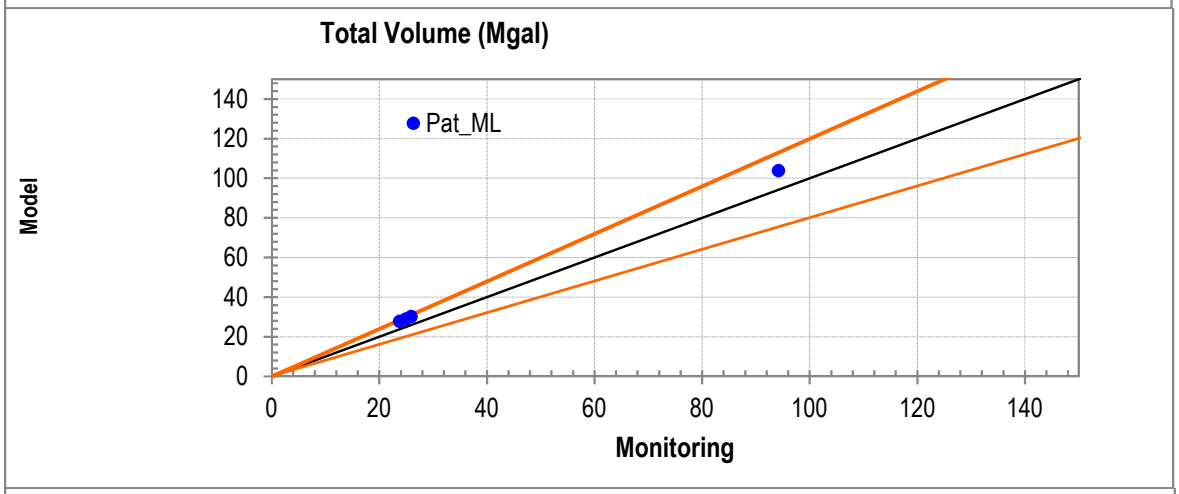

ElmwoodPark1
Meter
Model
10
9
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

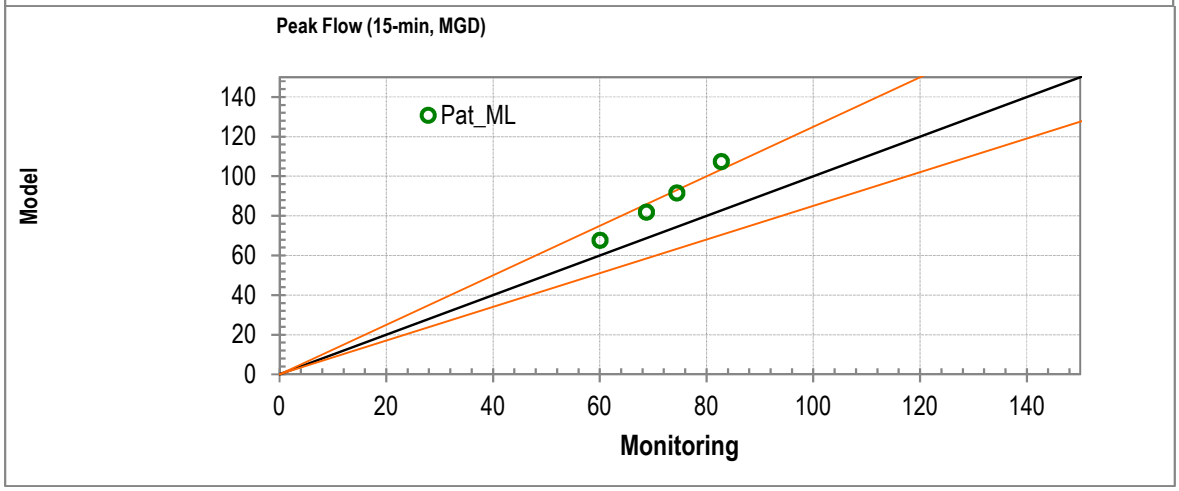

Total Volume (Mgal)
Model
ElmwoodPark1
14
12
10
8
6
4
2
0
0
5
10
15
Monitoring

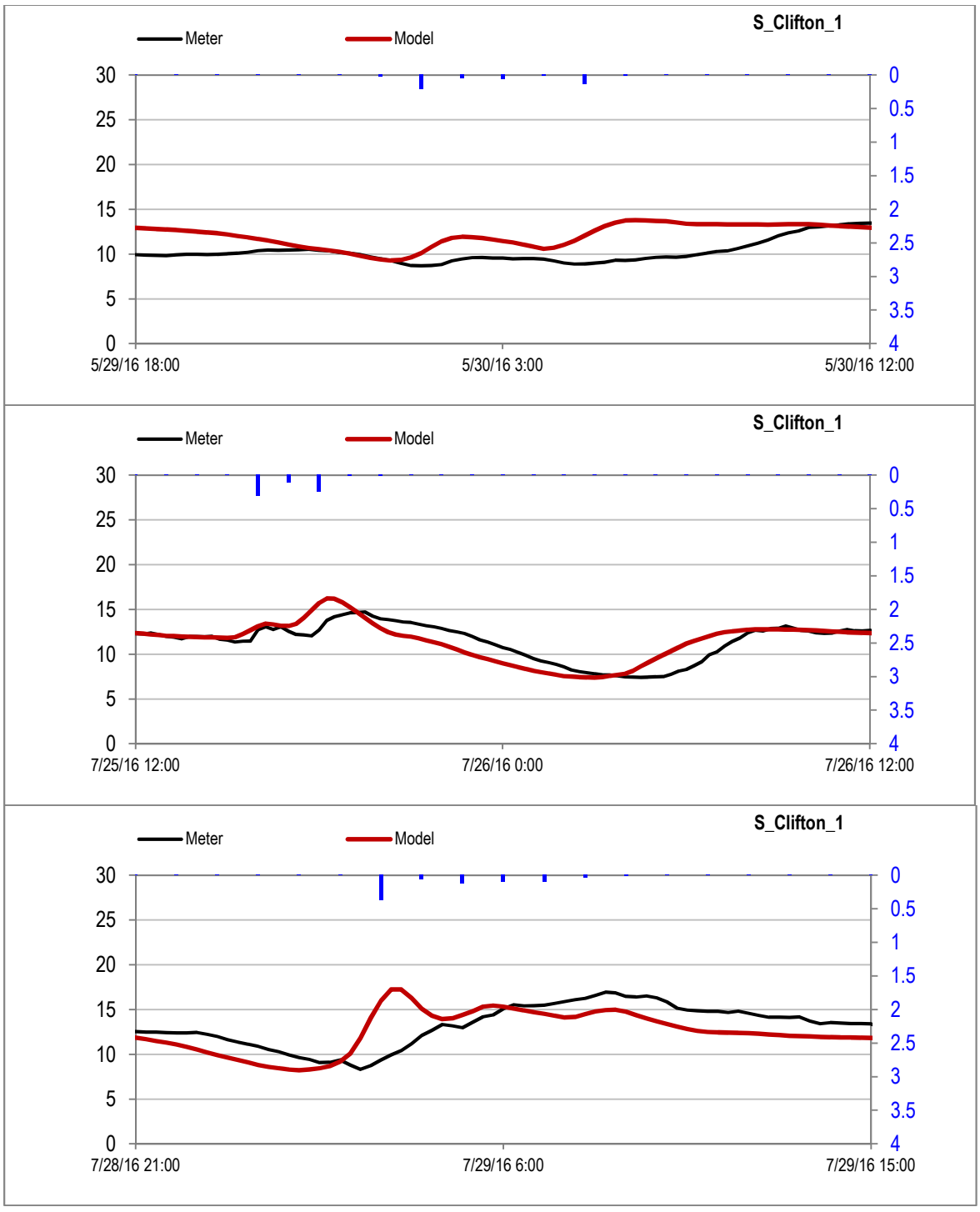

Peak Flow (15-min, MGD)
Model
ElmwoodPark1
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

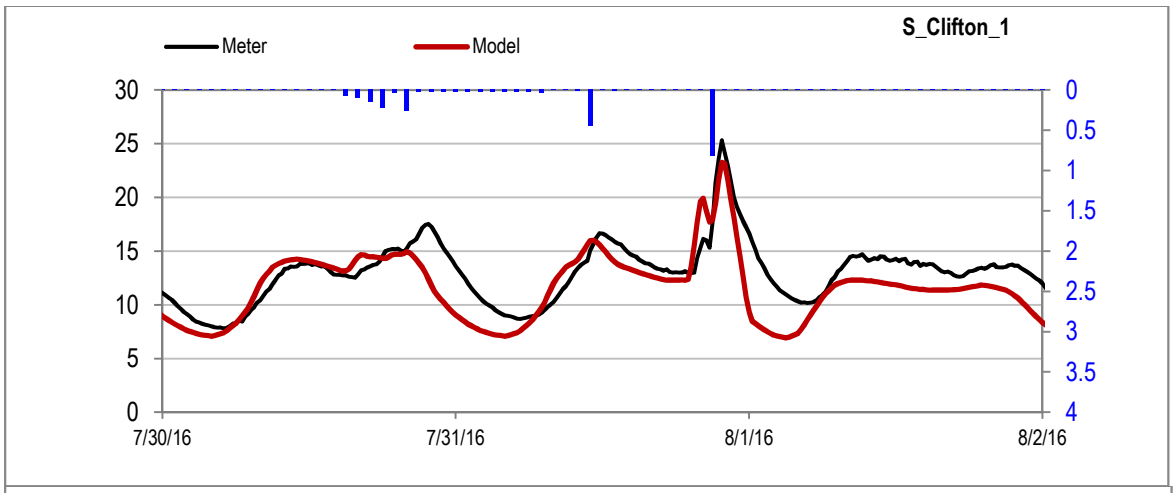

Pat_ML
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Pat_ML
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Pat_ML
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

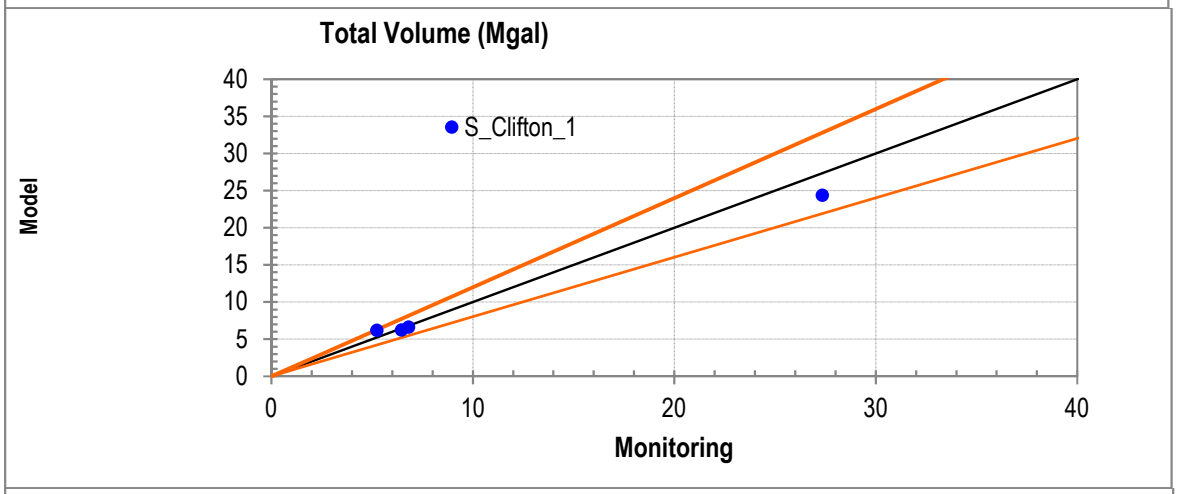

Pat_ML
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

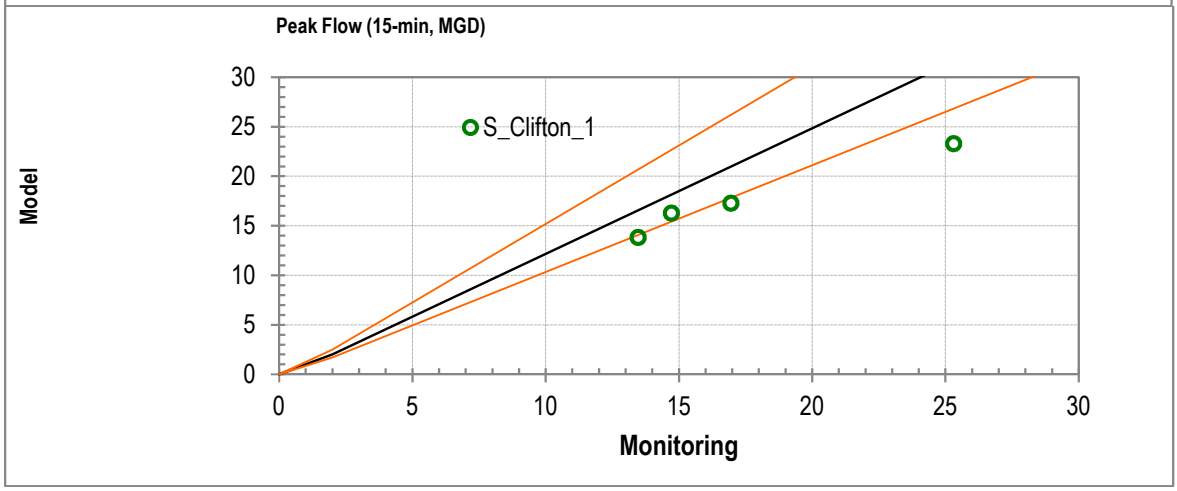

Total Volume (Mgal)
Model
Pat_ML
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
Monitoring

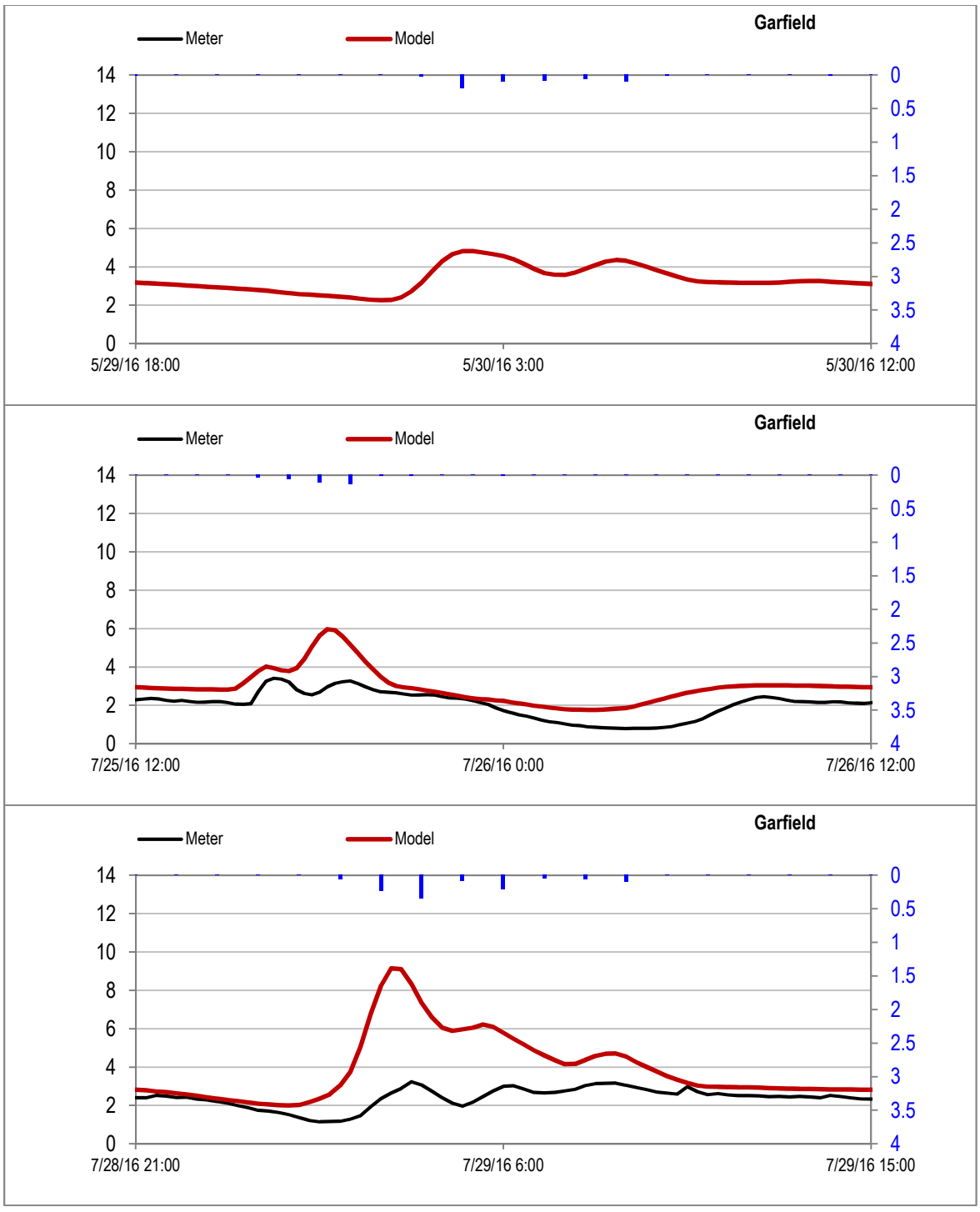

Peak Flow (15-min, MGD)
Model
Pat_ML
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
Monitoring

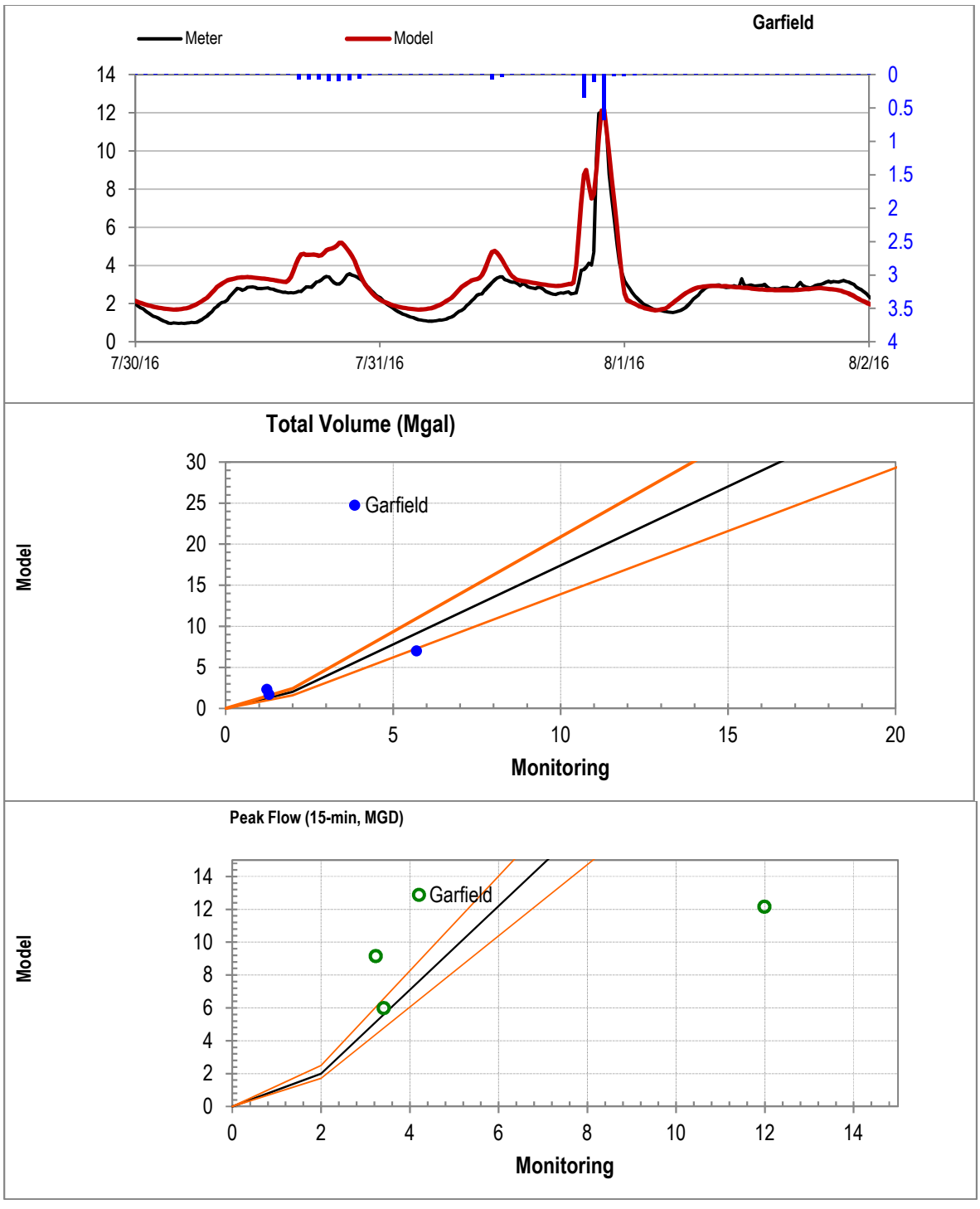

S_Clifton_1
Meter
Model
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
S_Clifton_1
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
S_Clifton_1
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

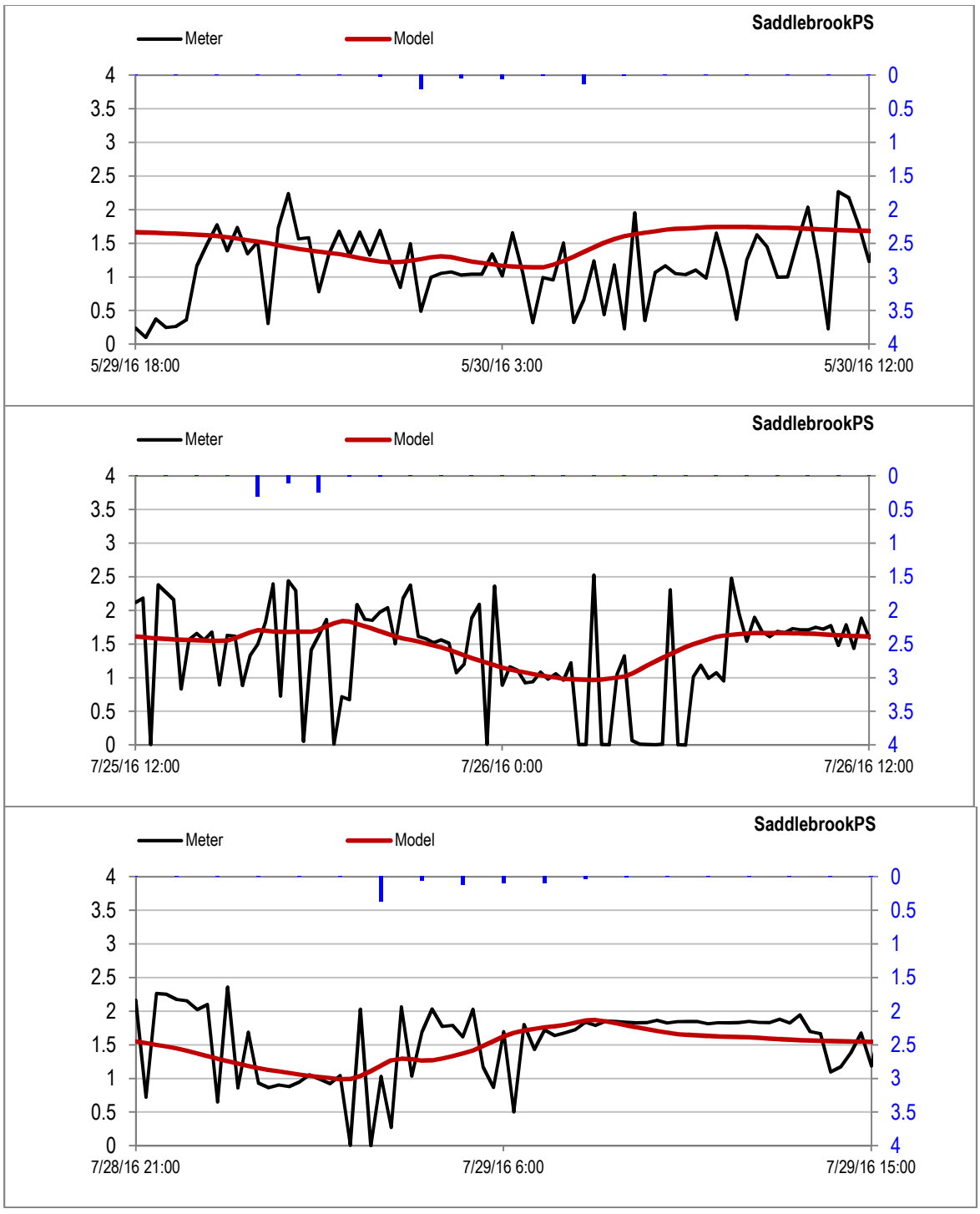

S_Clifton_1
Meter
Model
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

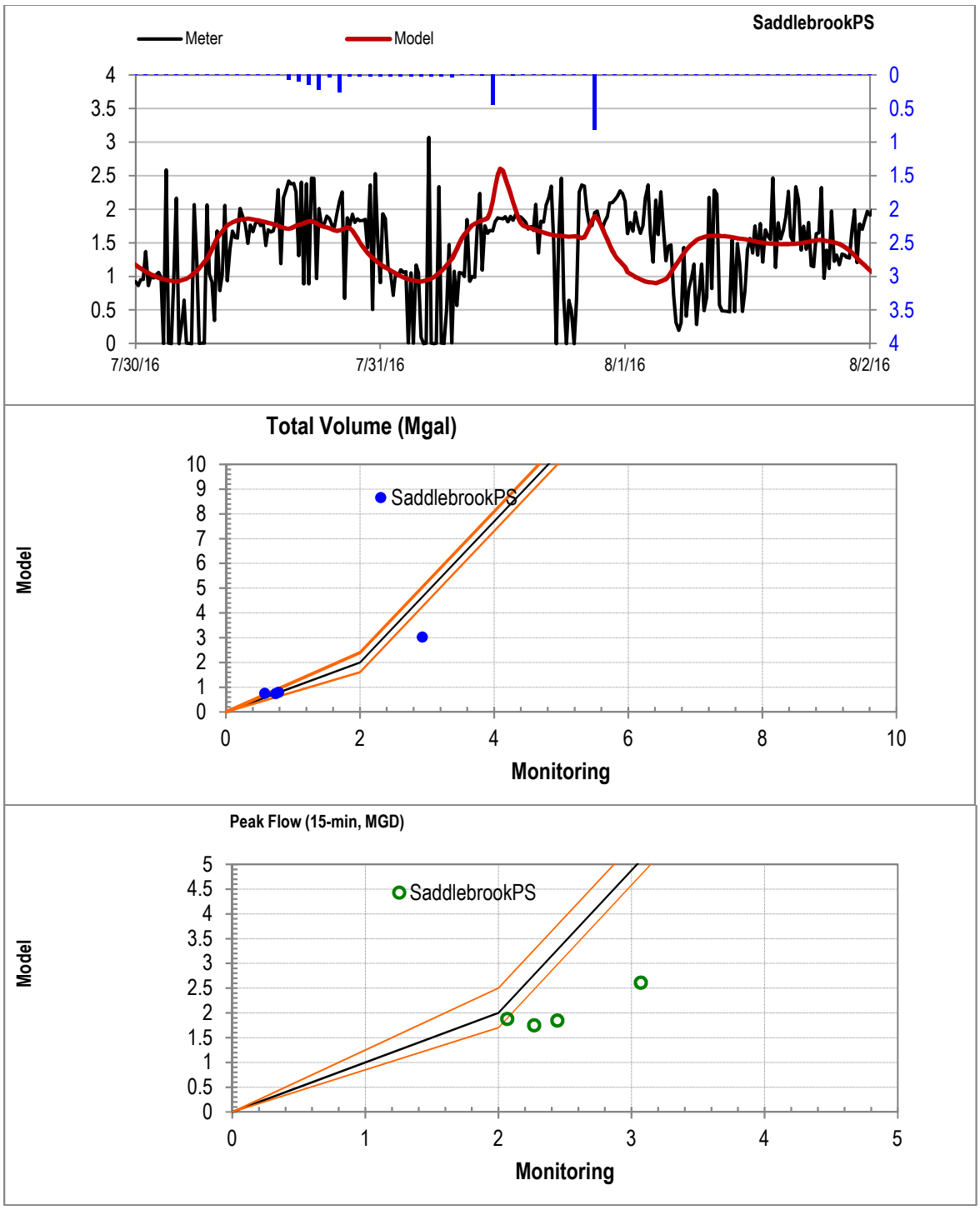

Total Volume (Mgal)
Model
S_Clifton_1
40
35
30
25
20
15
10
5
0
0
10
20
30
40
Monitoring

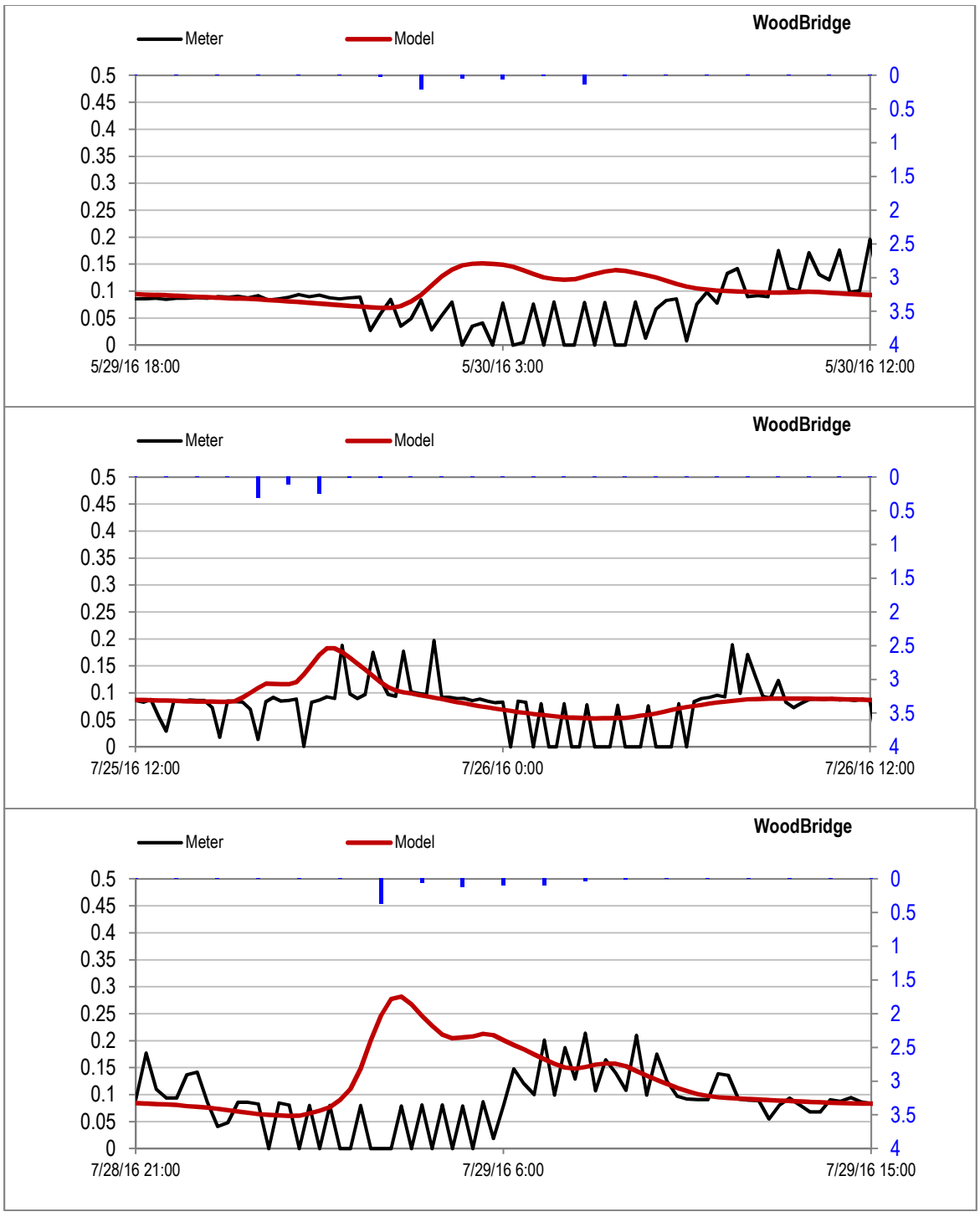

Peak Flow (15-min, MGD)
Model
S_Clifton_1
30
25
20
15
10
5
0
0
5
10
15
20
25
30
Monitoring

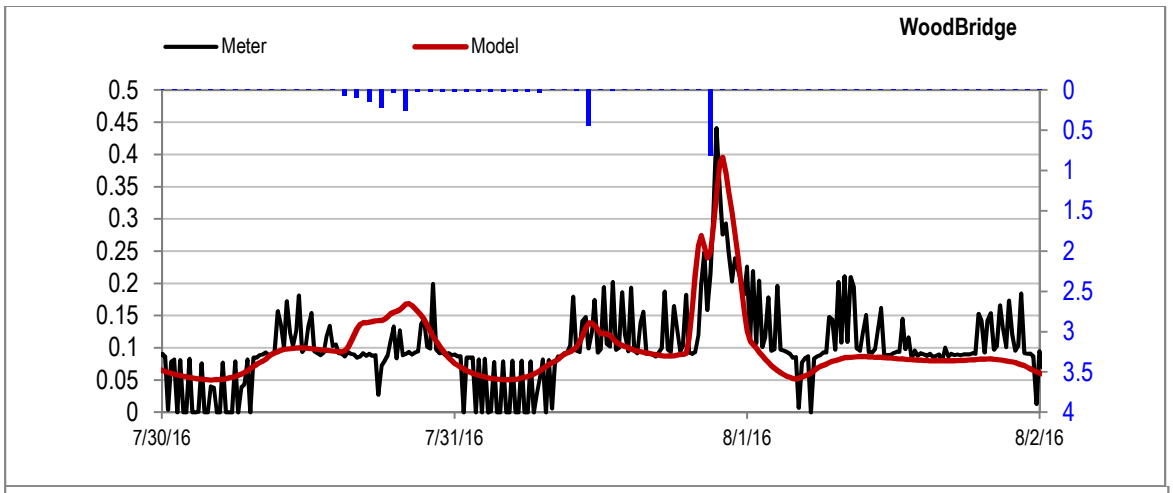

Garfield
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Garfield
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Garfield
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

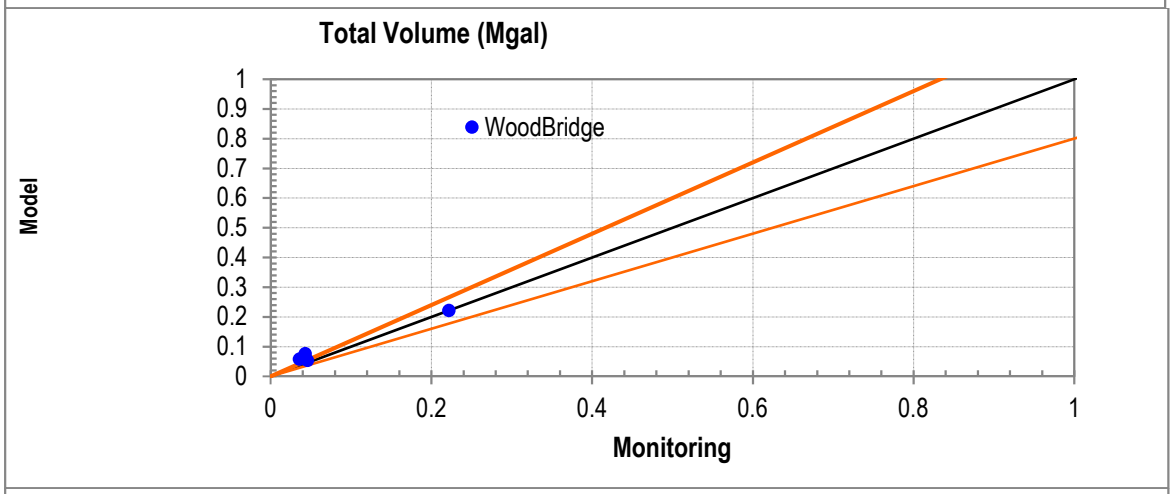

Garfield
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
30
25
20
15
10
5
0
Garfield
0
5
10
15
20
Monitoring
Peak Flow (15-min, MGD)
Model
14
12
10
8
6
4
2
0
Garfield
0
2
4
6
8
10
12
14
Monitoring

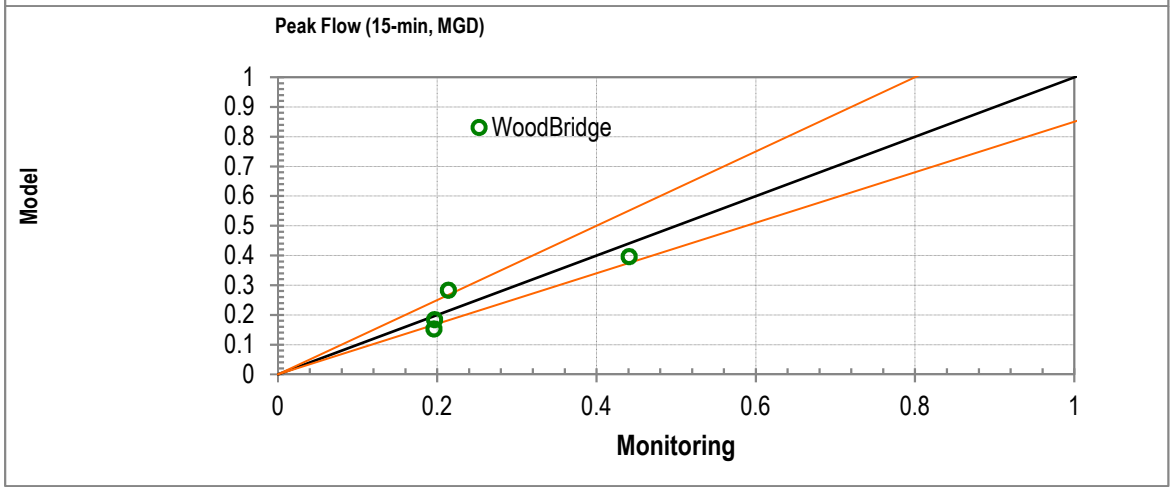

SaddlebrookPS
Meter
Model
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
SaddlebrookPS
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
SaddlebrookPS
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

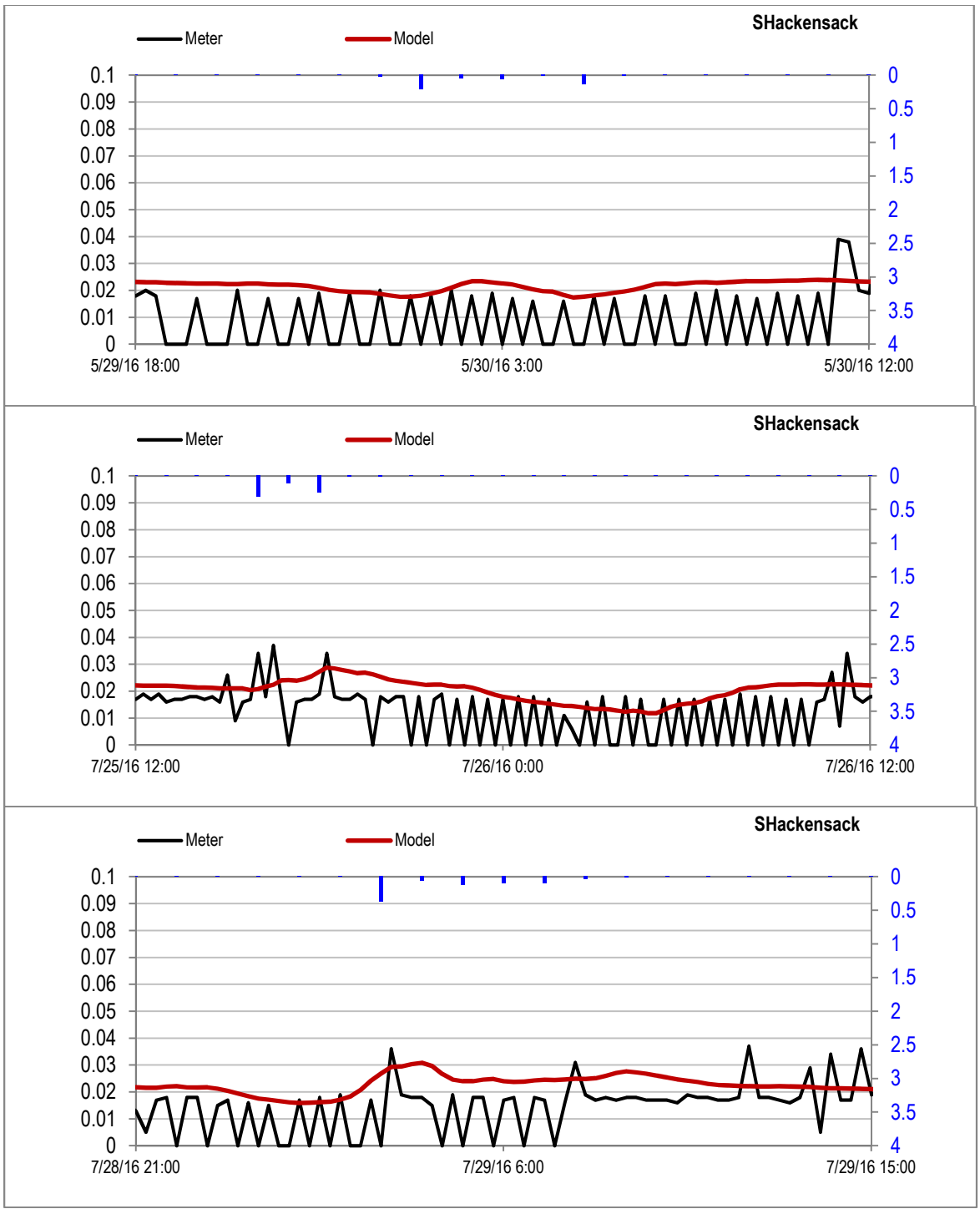

SaddlebrookPS
Meter
Model
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
SaddlebrookPS
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring
Peak Flow (15-min, MGD)
Model
SaddlebrookPS
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
Monitoring

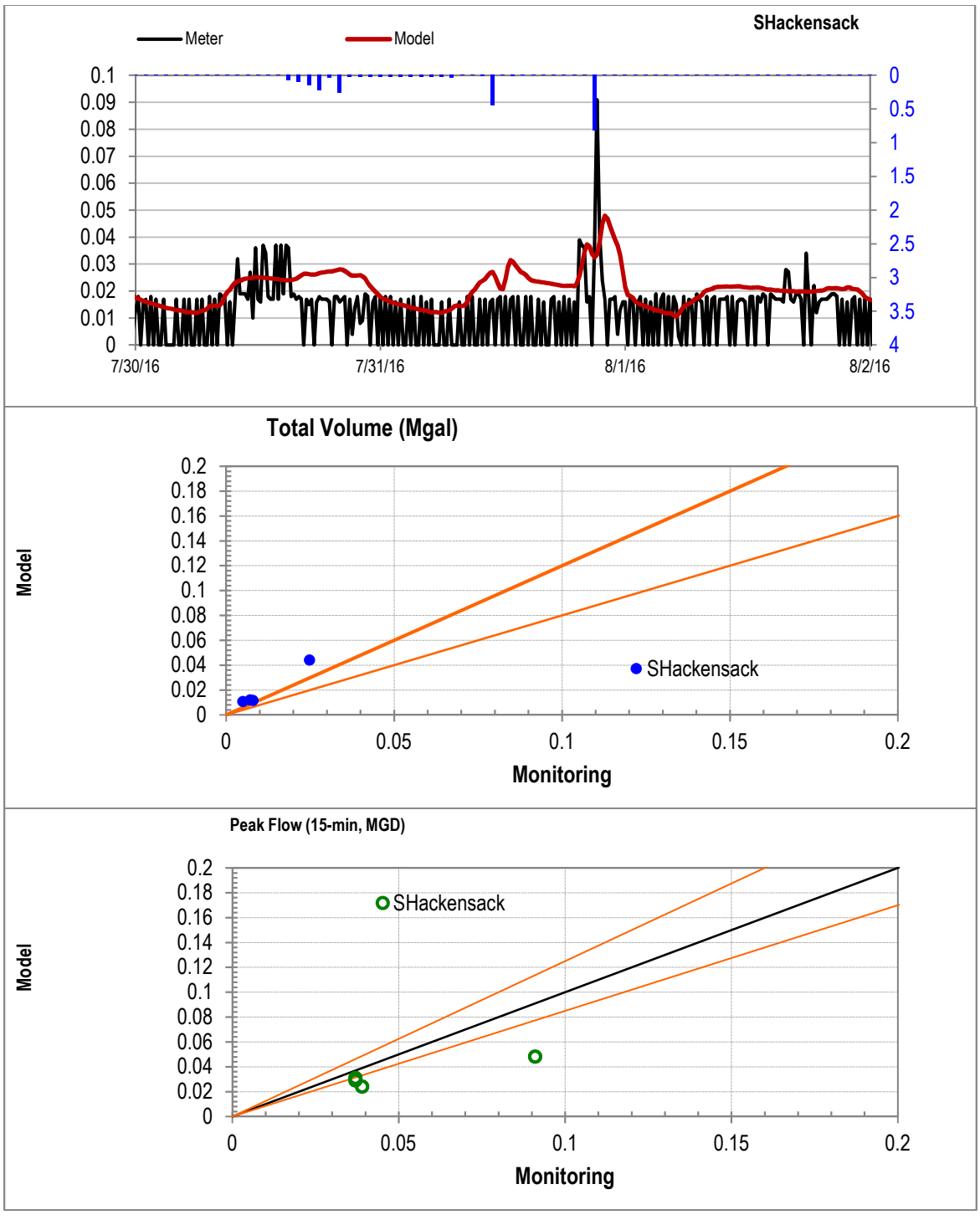

WoodBridge
Meter
Model
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
WoodBridge
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
WoodBridge
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

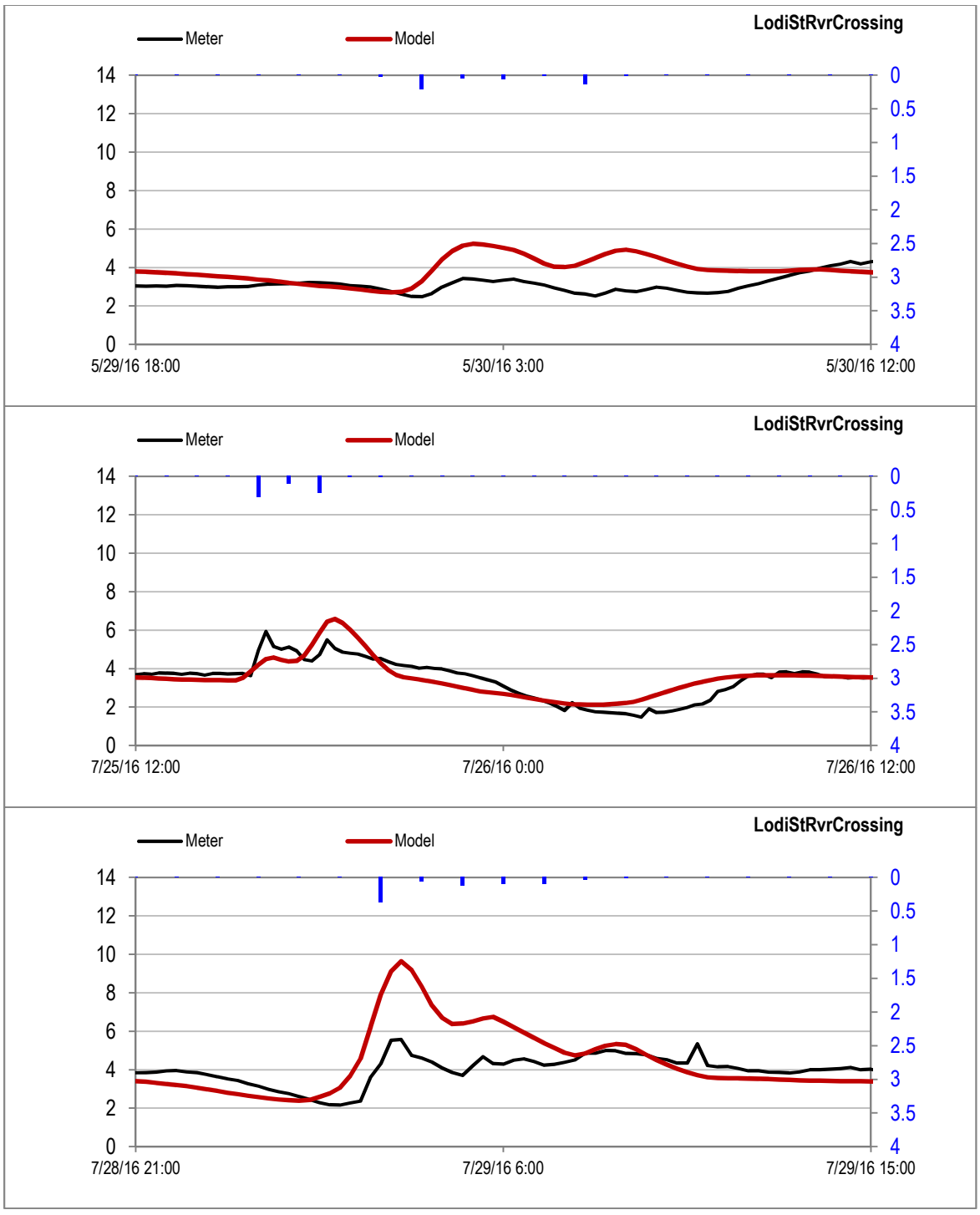

WoodBridge
Meter
Model
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

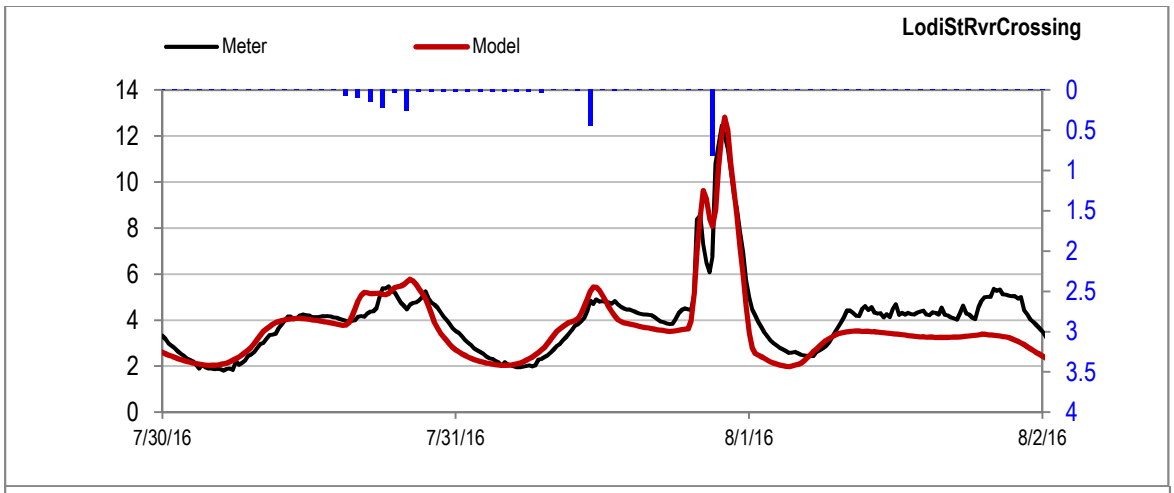

Total Volume (Mgal)
Model
WoodBridge
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
Monitoring

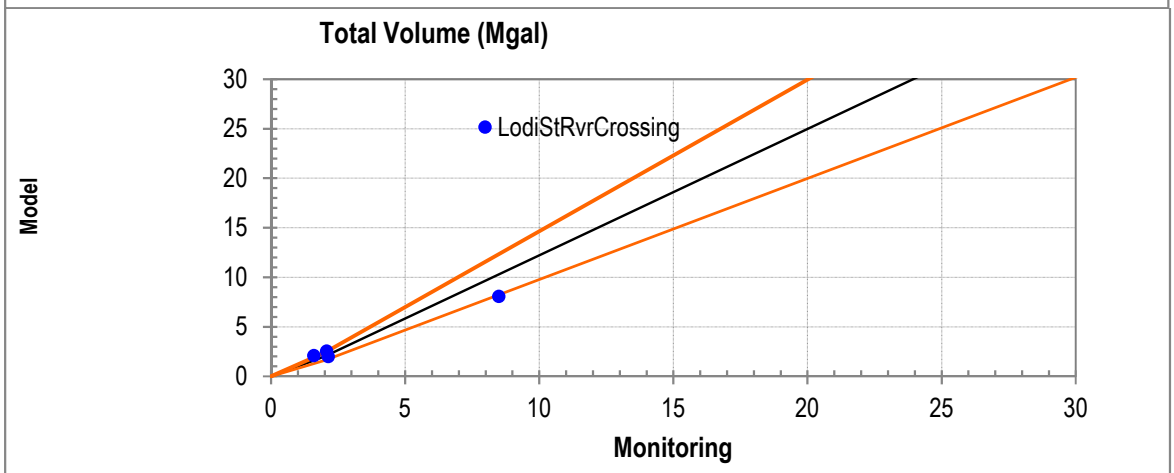

Peak Flow (15-min, MGD)
Model
WoodBridge
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
Monitoring

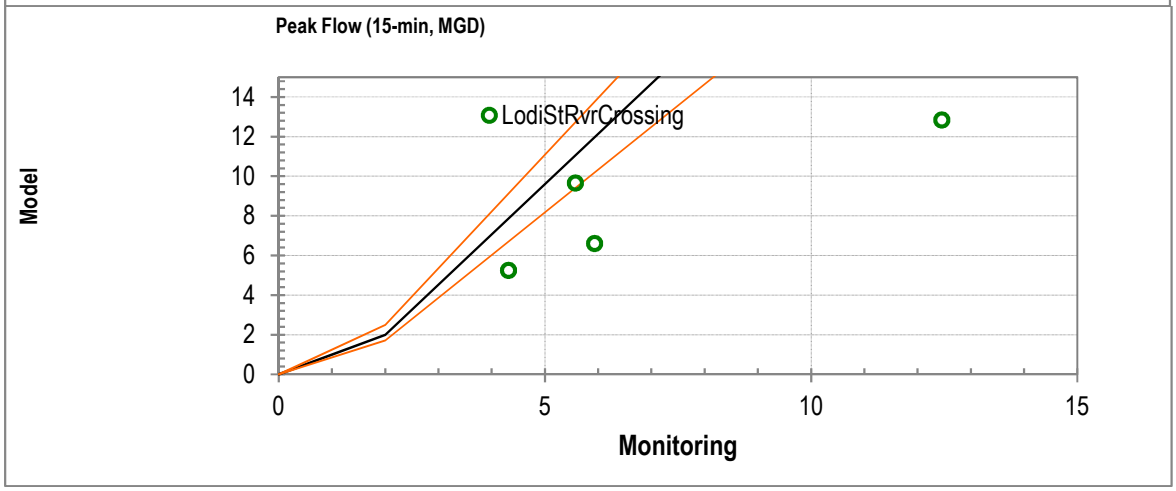

SHackensack
Meter
Model
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
SHackensack
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
SHackensack
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

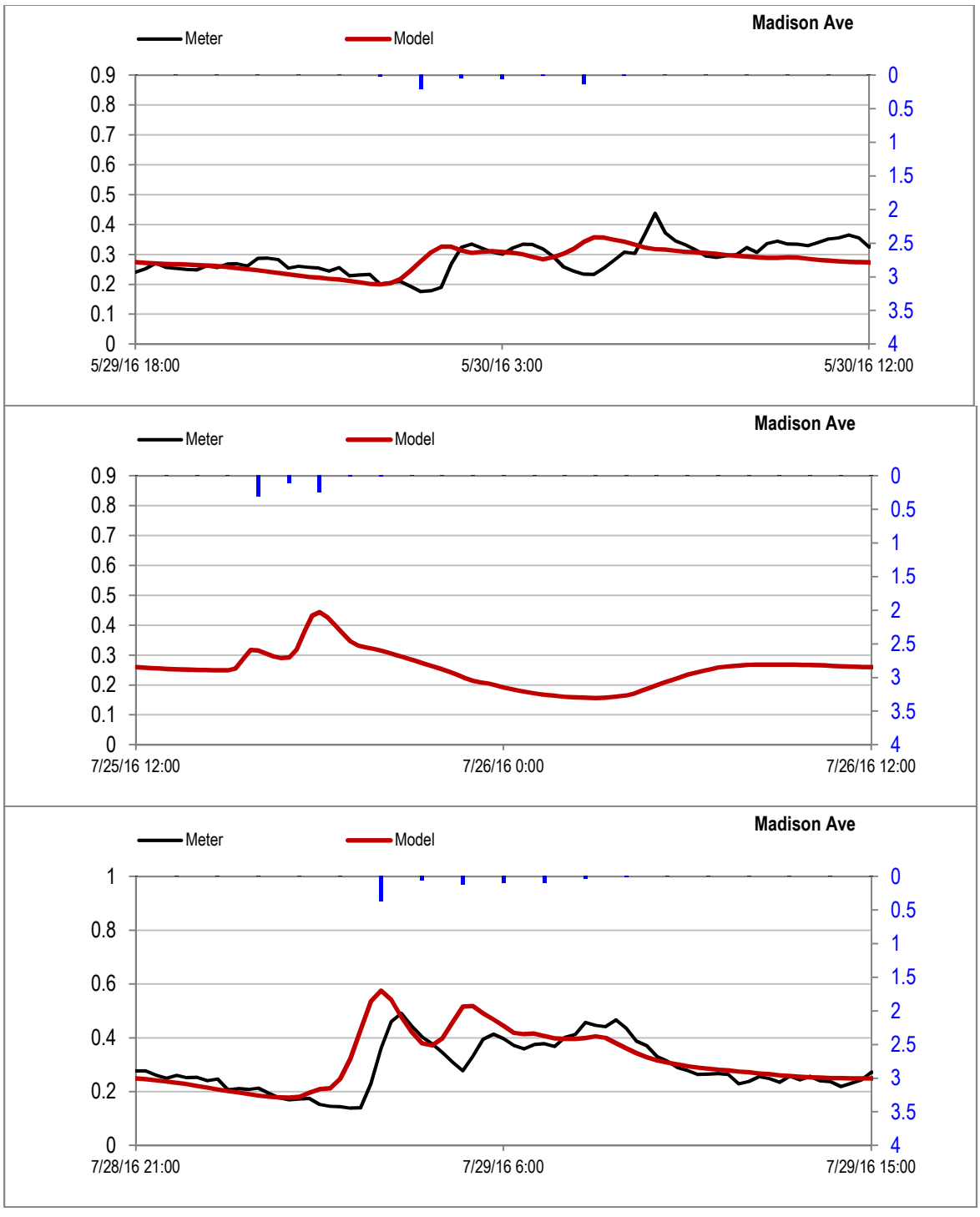

SHackensack
Meter
Model
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.05
0.1
0.15
0.2
SHackensack
Monitoring
Peak Flow (15-min, MGD)
Model
SHackensack
Monitoring

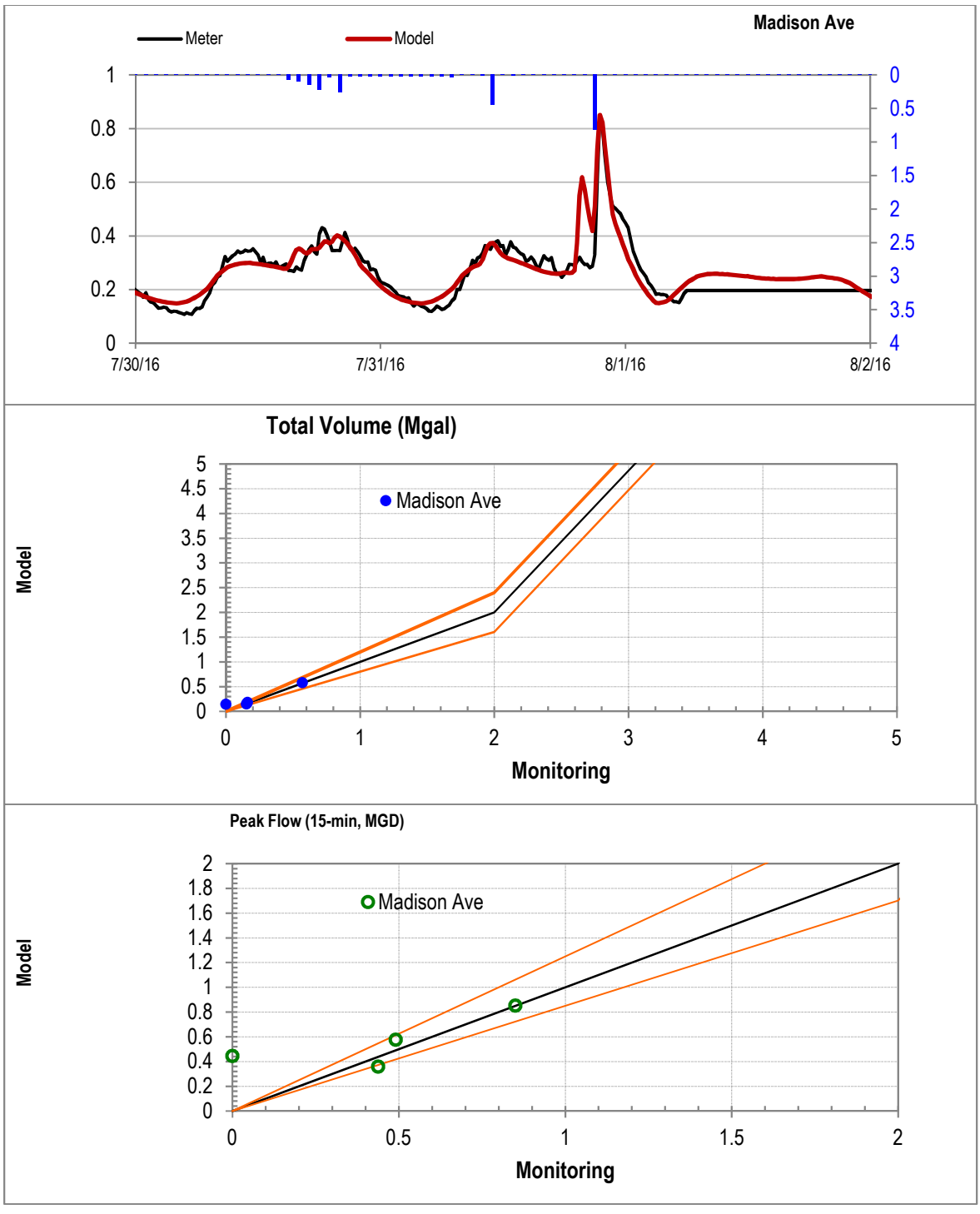

LodiStRvrCrossing
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
LodiStRvrCrossing
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
LodiStRvrCrossing
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

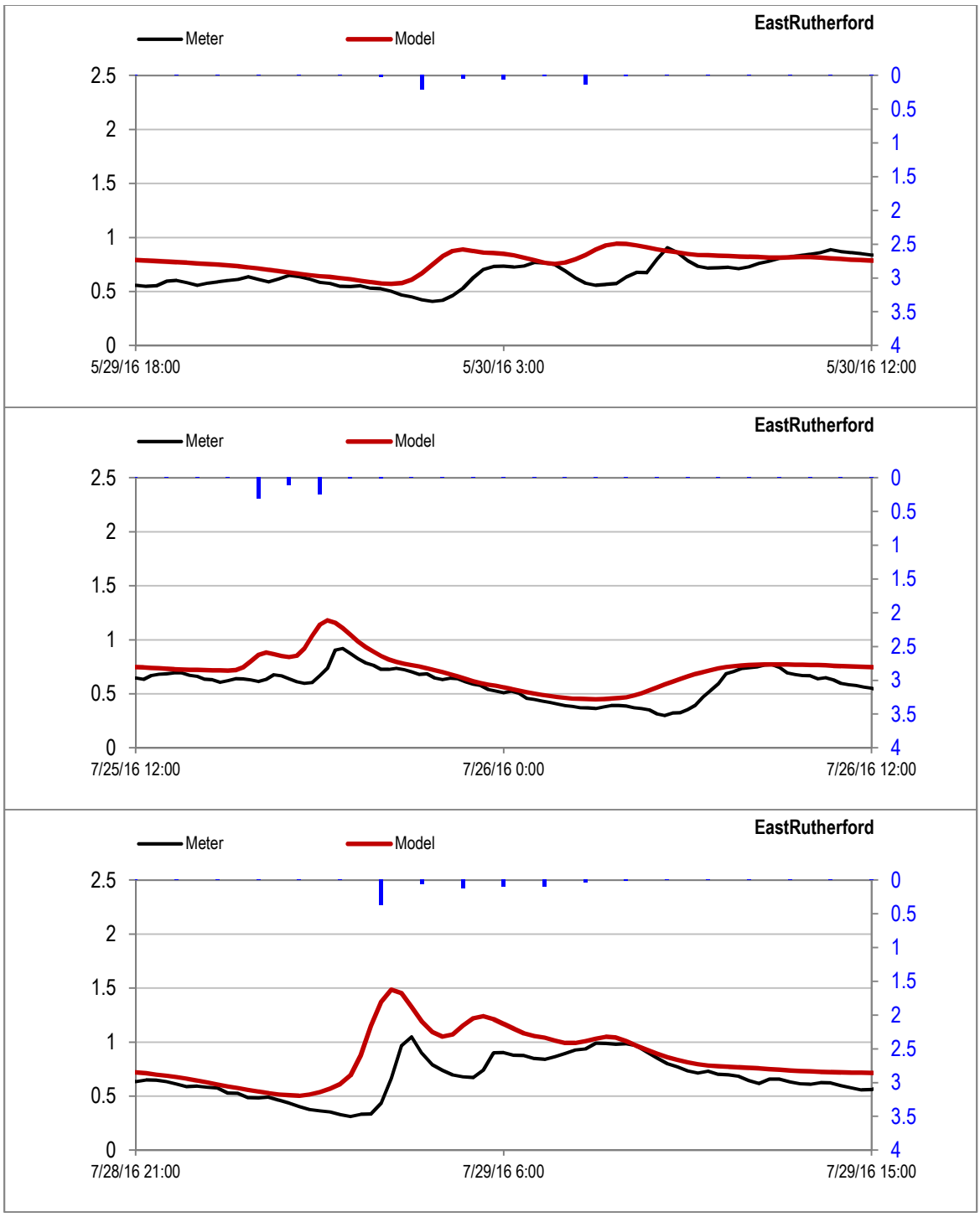

LodiStRvrCrossing
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

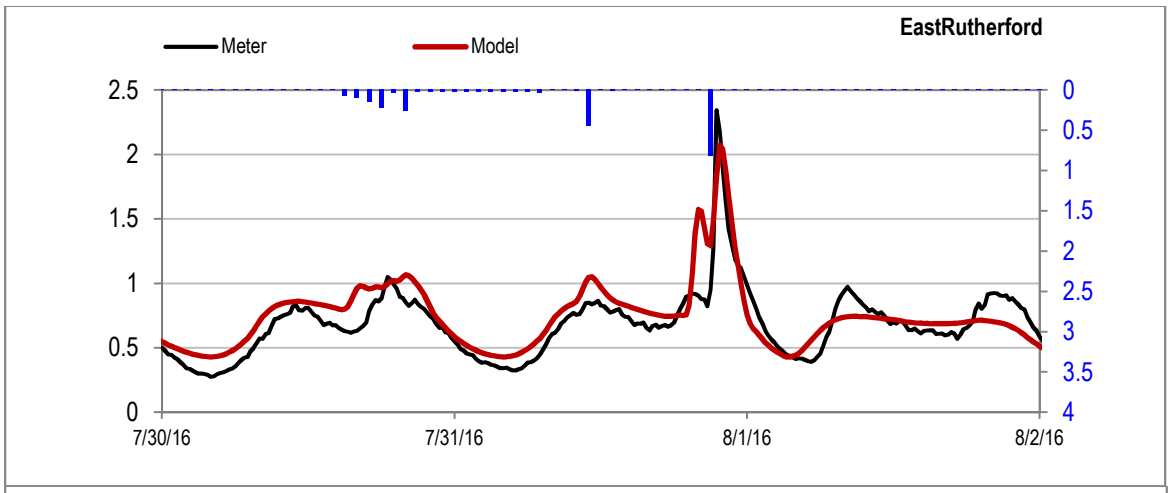

Total Volume (Mgal)
Model
LodiStRvrCrossing
30
25
20
15
10
5
0
0
5
10
15
20
25
30
Monitoring

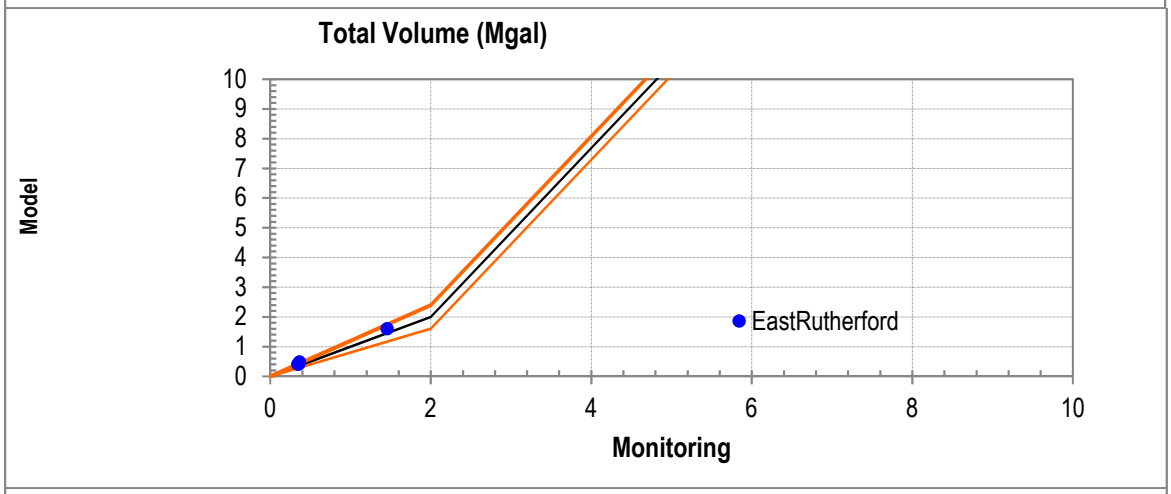

Peak Flow (15-min, MGD)
Model
LodiStRvrCrossing
14
12
10
8
6
4
2
0
0
5
10
15
Monitoring

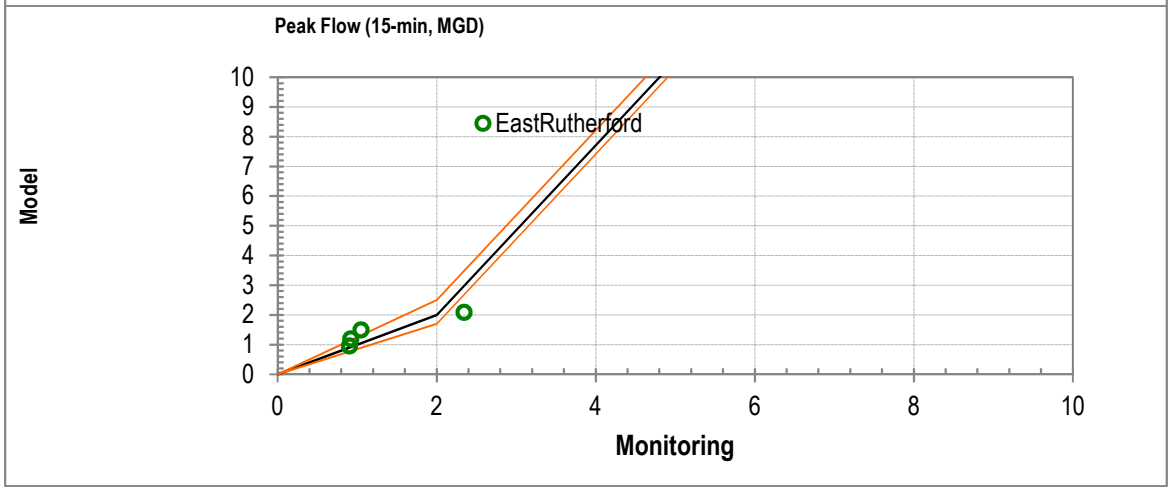

Madison Ave
Meter
Model
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Madison Ave
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Madison Ave
Meter
Model
1
0.8
0.6
0.4
0.2
0
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

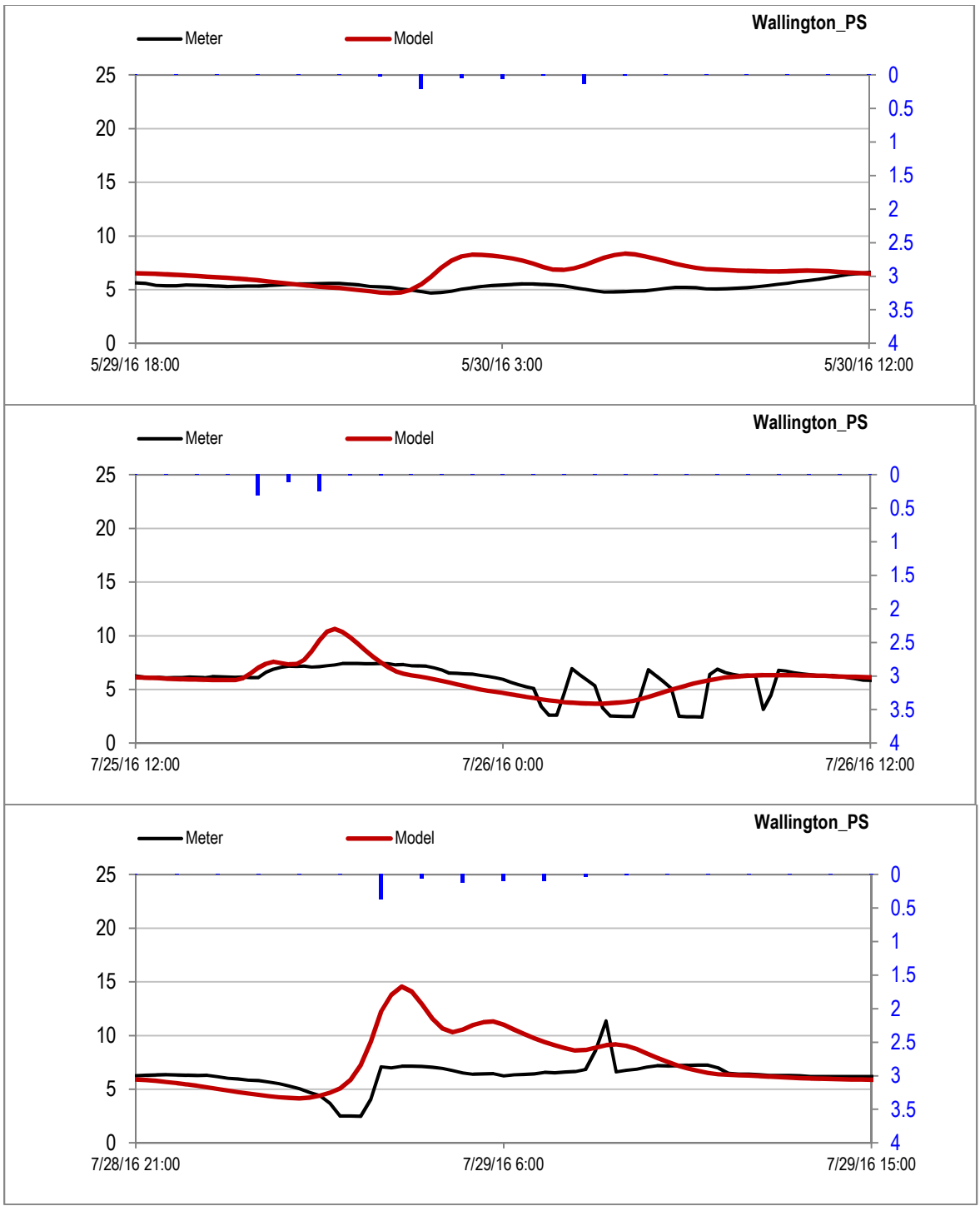

Madison Ave
Meter
Model
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
Madison Ave
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
Monitoring
Peak Flow (15-min, MGD)
Model
Madison Ave
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
Monitoring

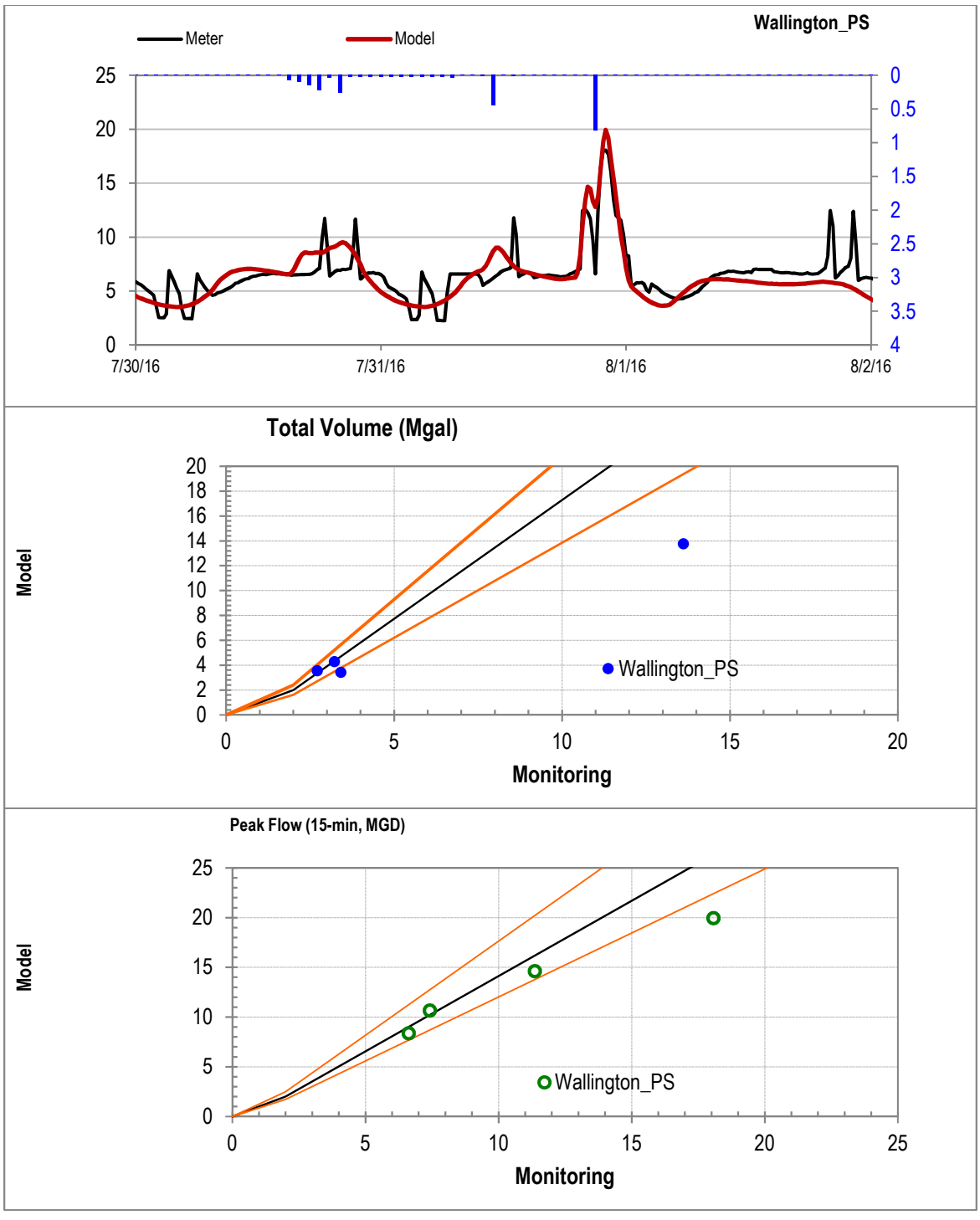

EastRutherford
Meter
Model
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
EastRutherford
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
EastRutherford
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

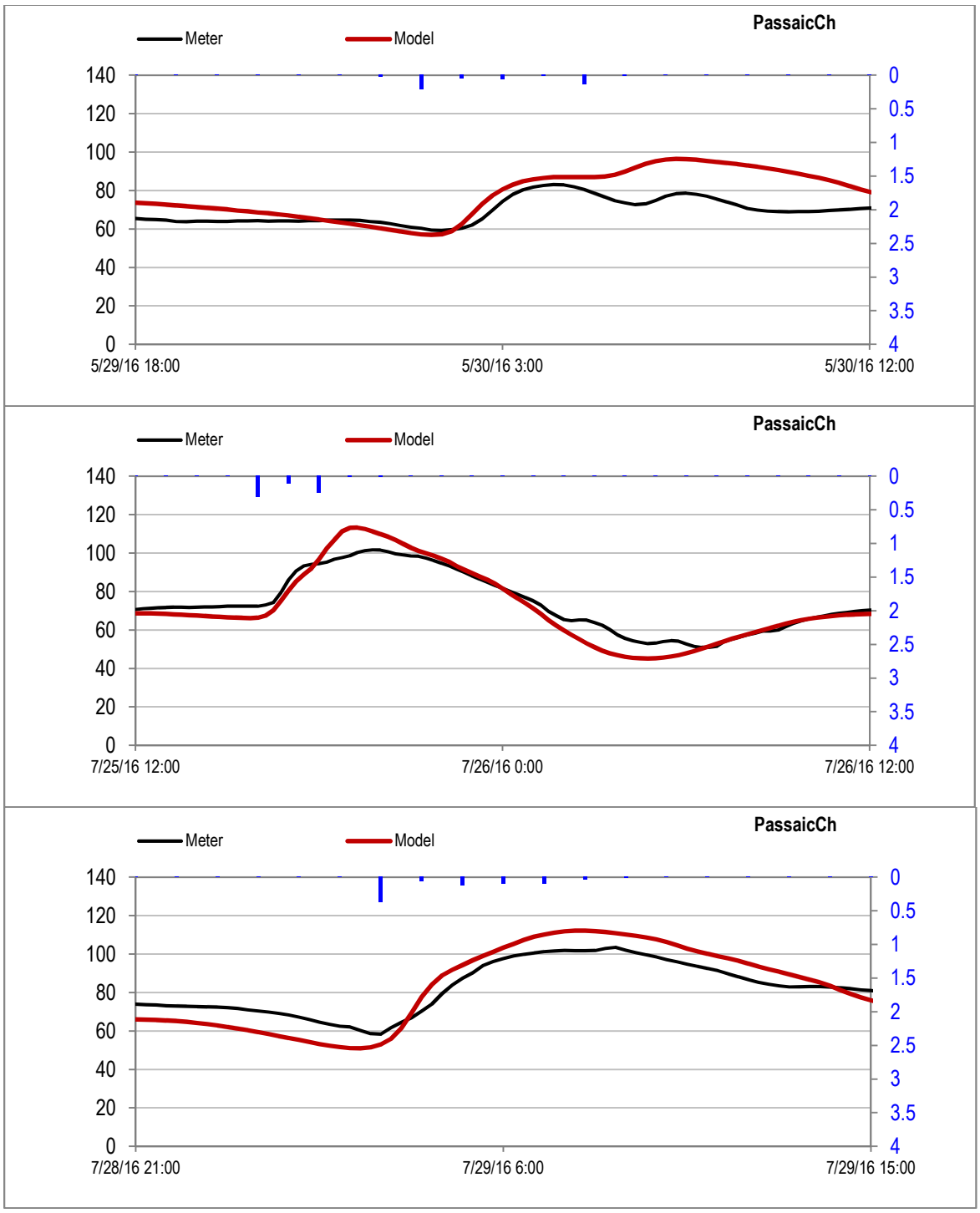

EastRutherford
Meter
Model
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

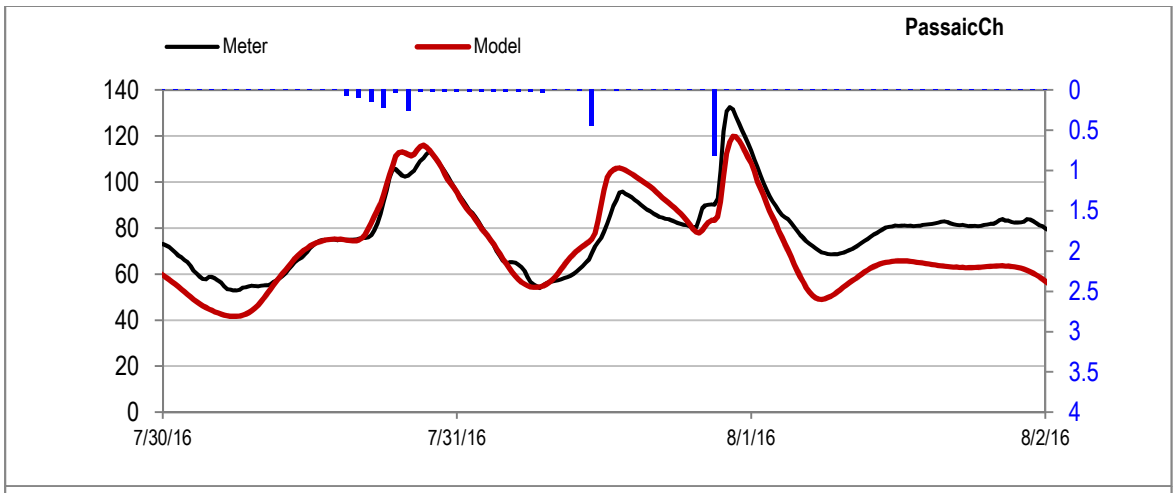

Total Volume (Mgal)
Model
Monitoring
EastRutherford
0
1
2
3
4
5
6
7
8
9
10

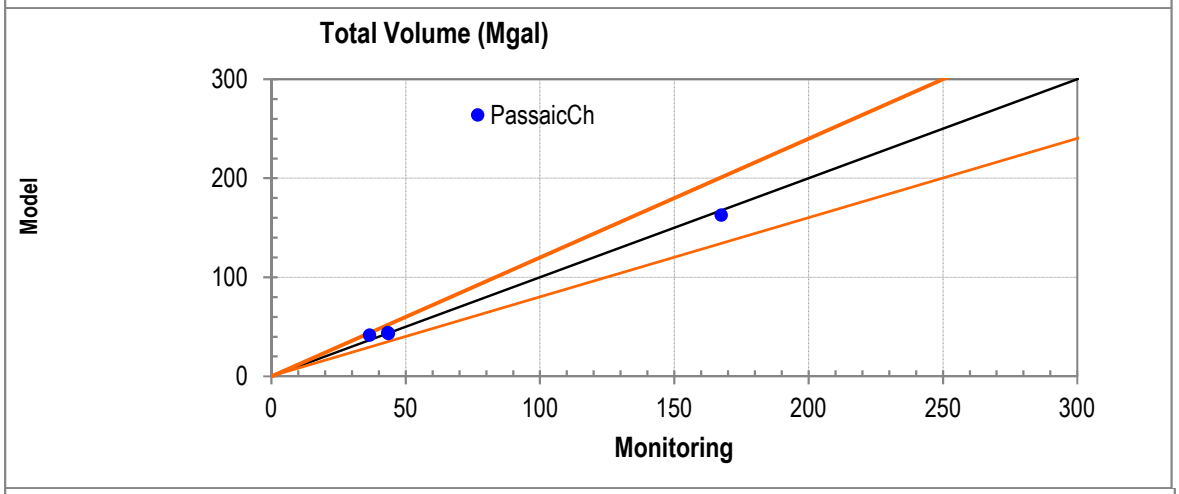

Peak Flow (15-min, MGD)
Model
Monitoring
EastRutherford
0
1
2
3
4
5
6
7
8
9
10

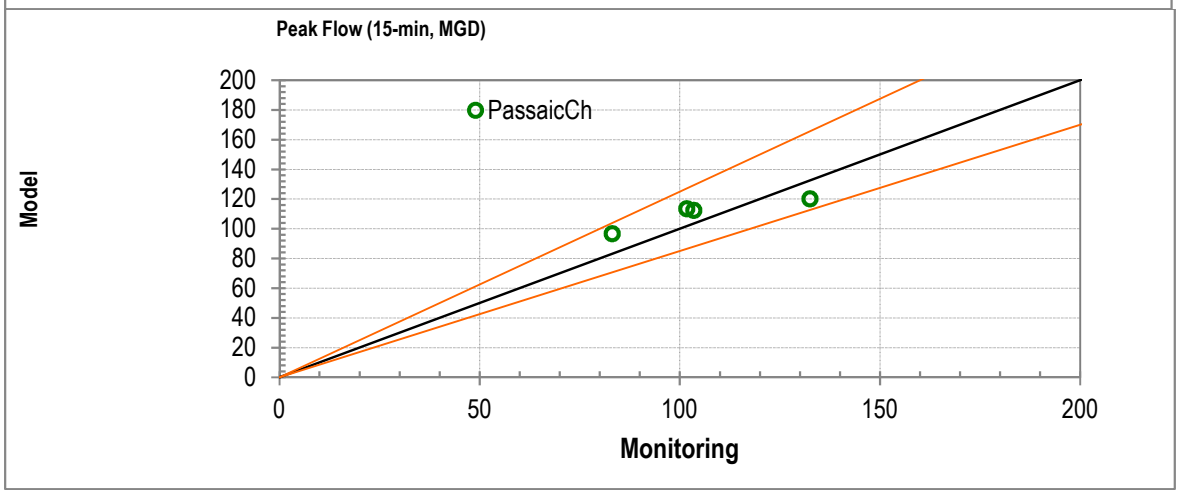

Wallington_PS
Meter
Model
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Wallington_PS
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Wallington_PS
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

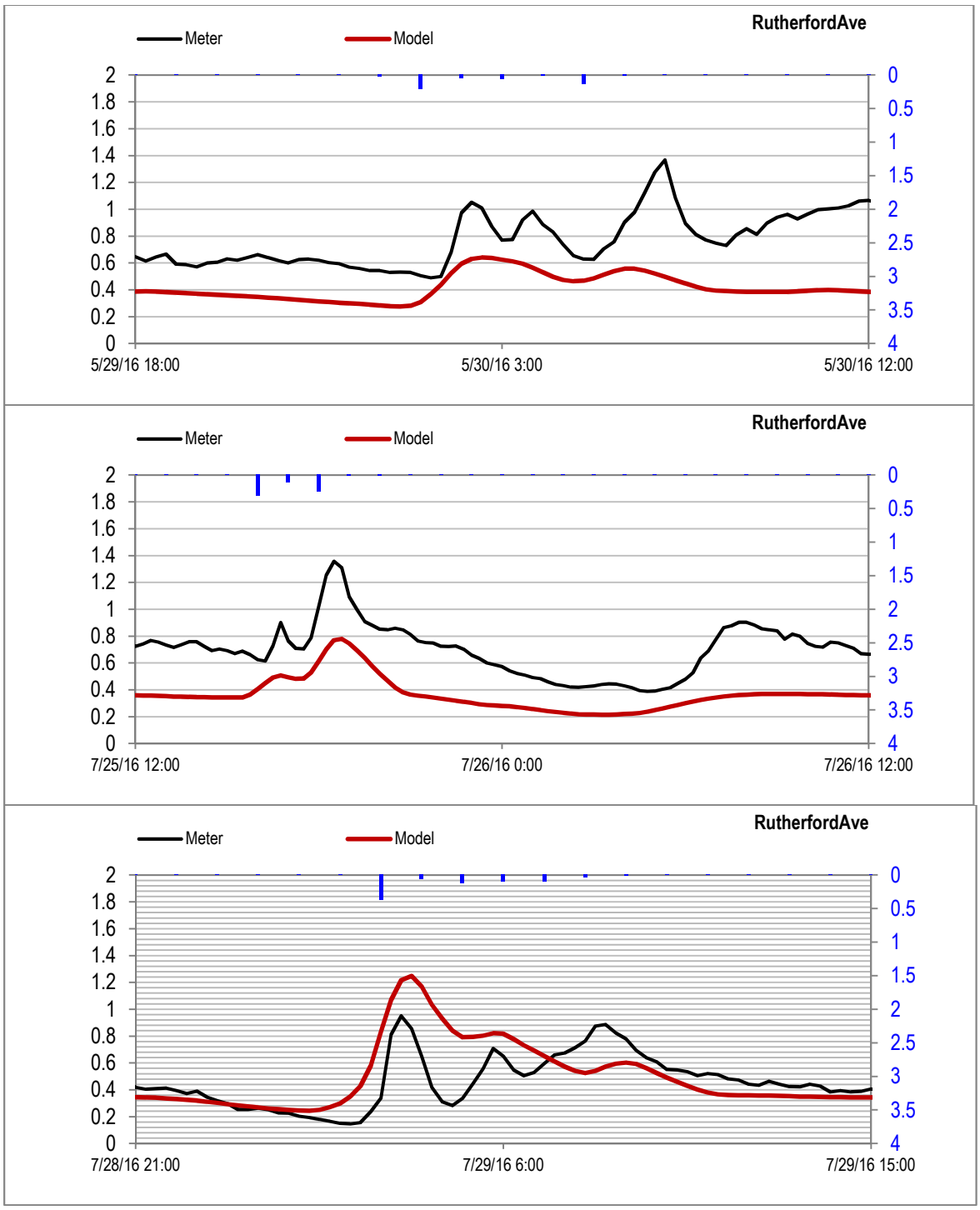

Wallington_PS
Meter
Model
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
Wallington_PS
Monitoring
Peak Flow (15-min, MGD)
Model
25
20
15
10
5
0
0
5
10
15
20
25
Wallington_PS
Monitoring

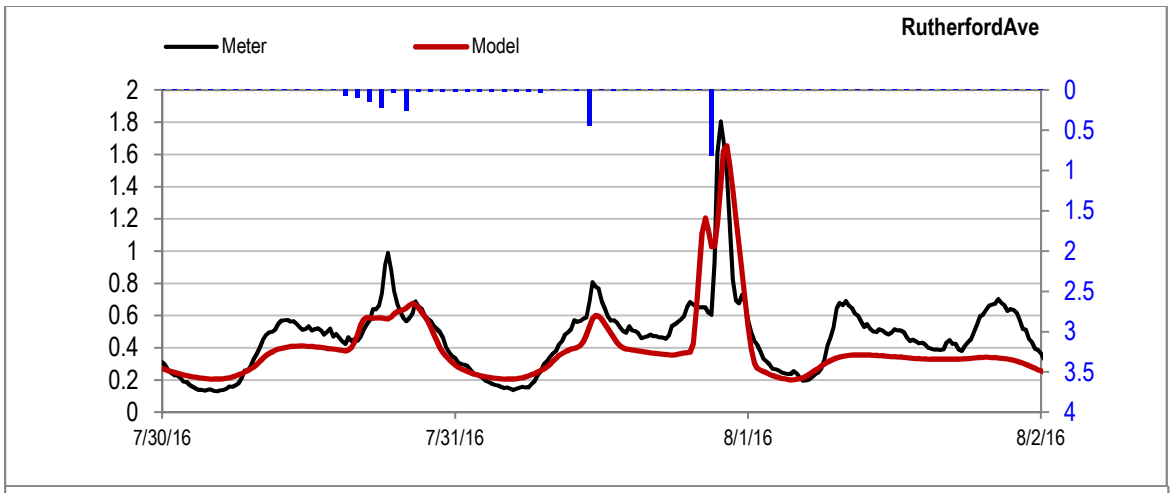

PassaicCh
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
PassaicCh
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
PassaicCh
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

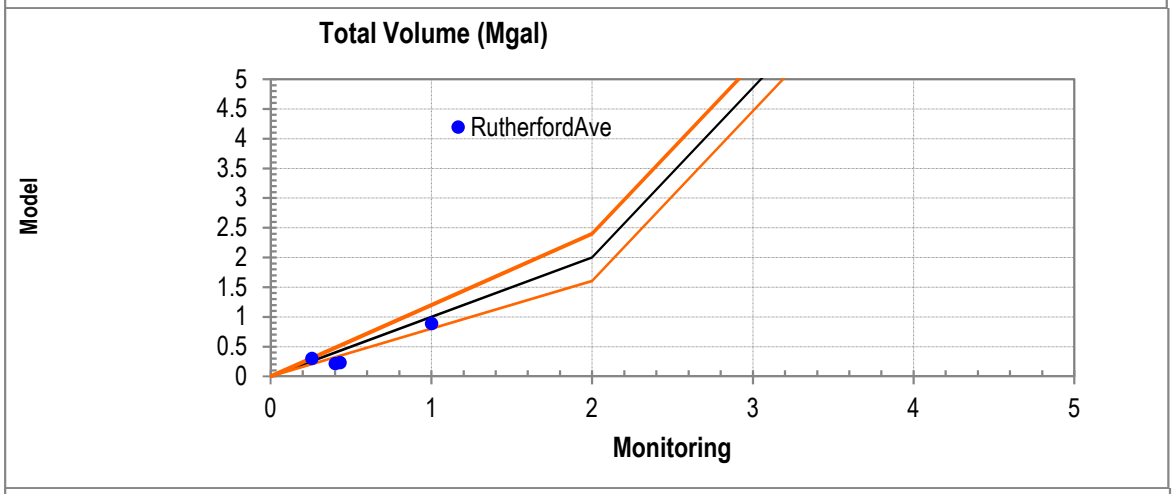

PassaicCh
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

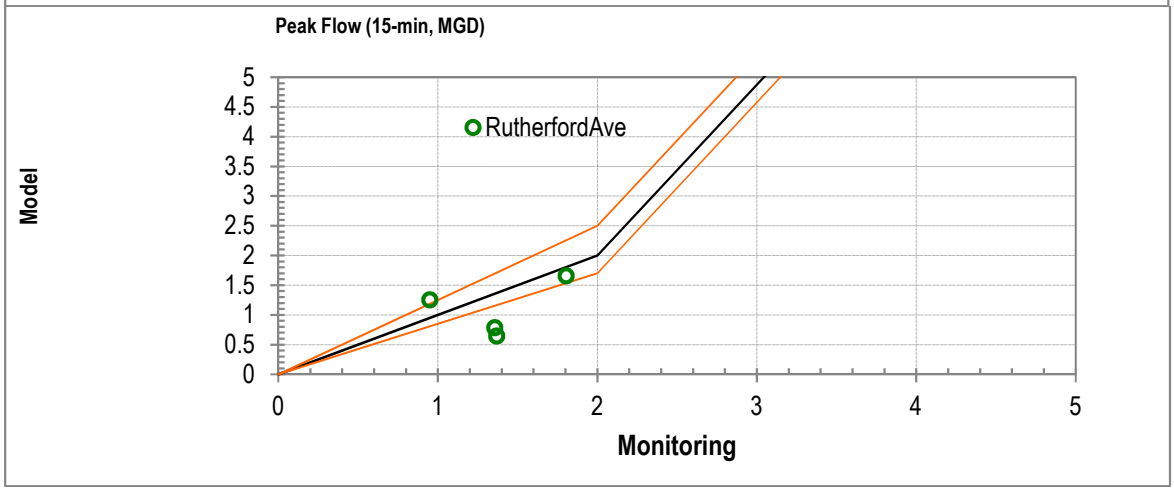

Total Volume (Mgal)
Model
PassaicCh
300
200
100
0
0
50
100
150
200
250
300
Monitoring

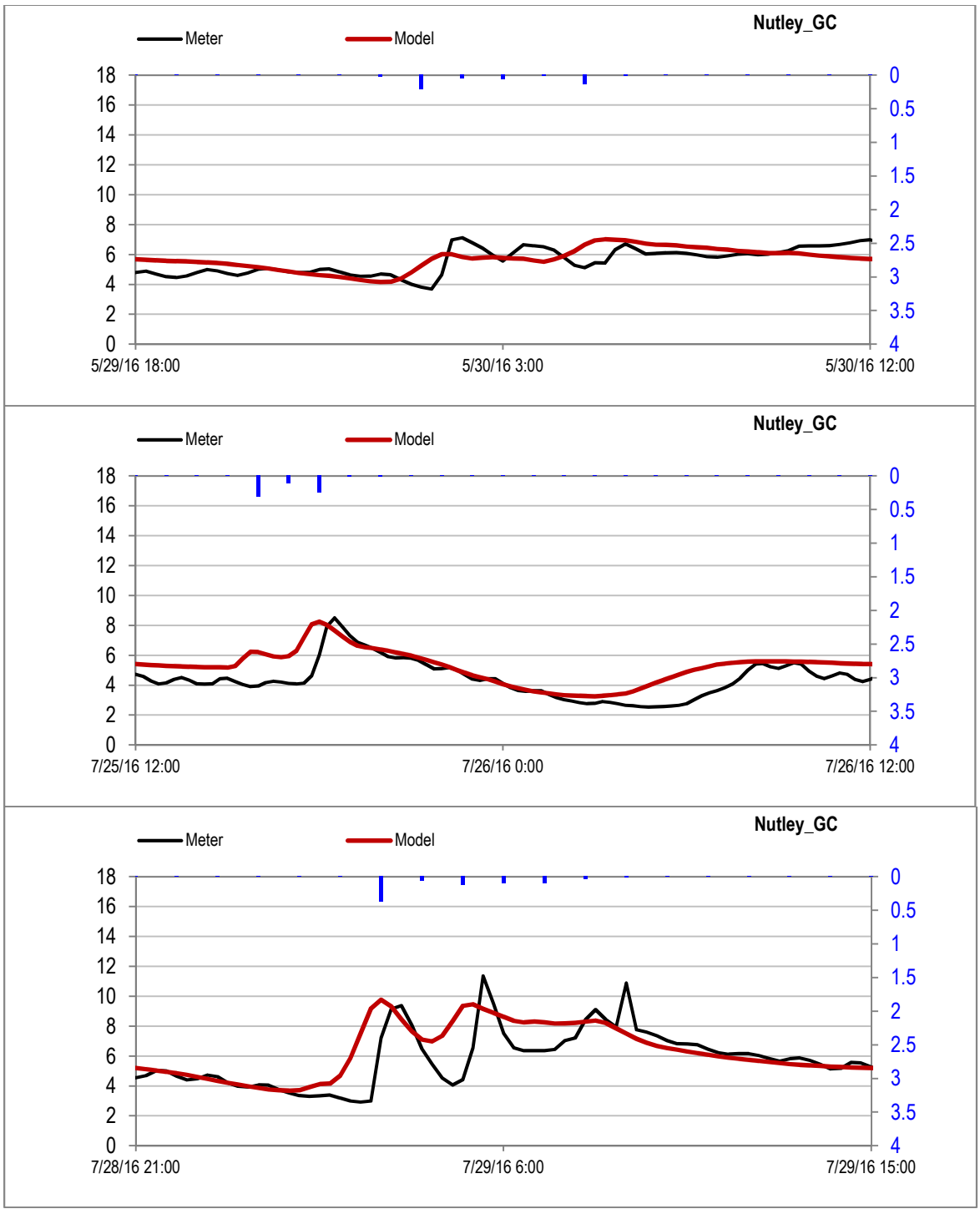

Peak Flow (15-min, MGD)
Model
PassaicCh
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Monitoring

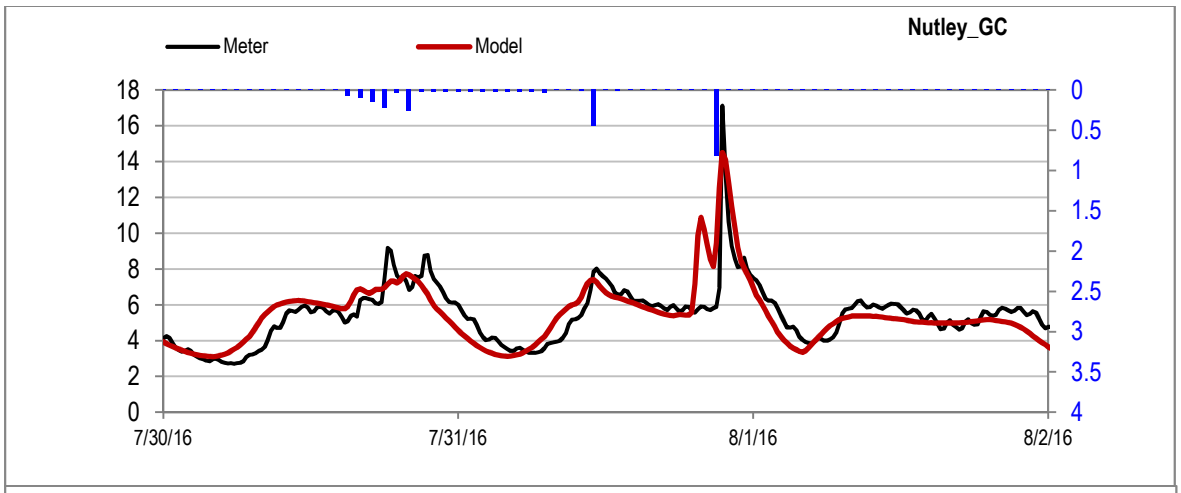

RutherfordAve
Meter
Model
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
RutherfordAve
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
RutherfordAve
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

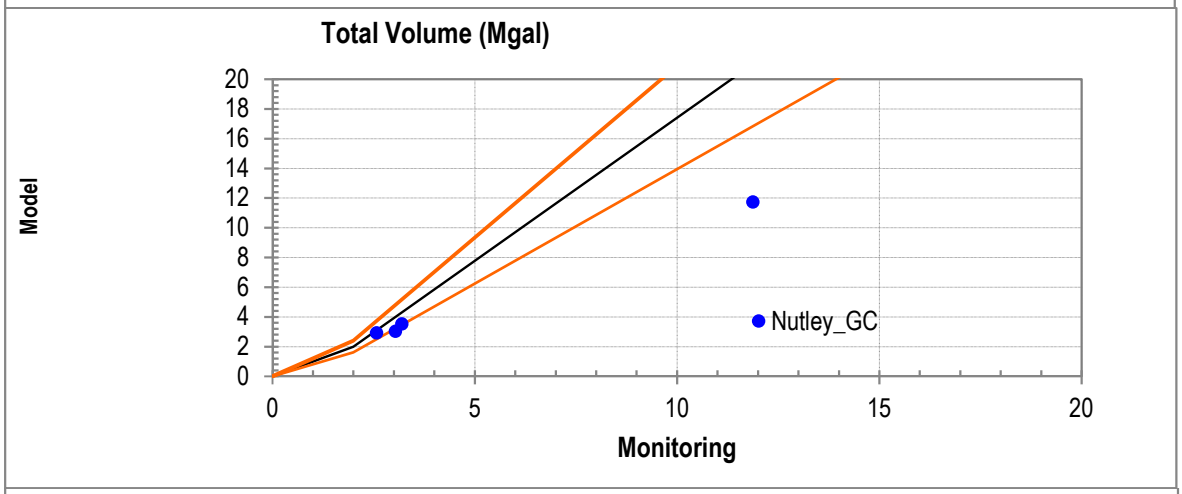

RutherfordAve
Meter
Model
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

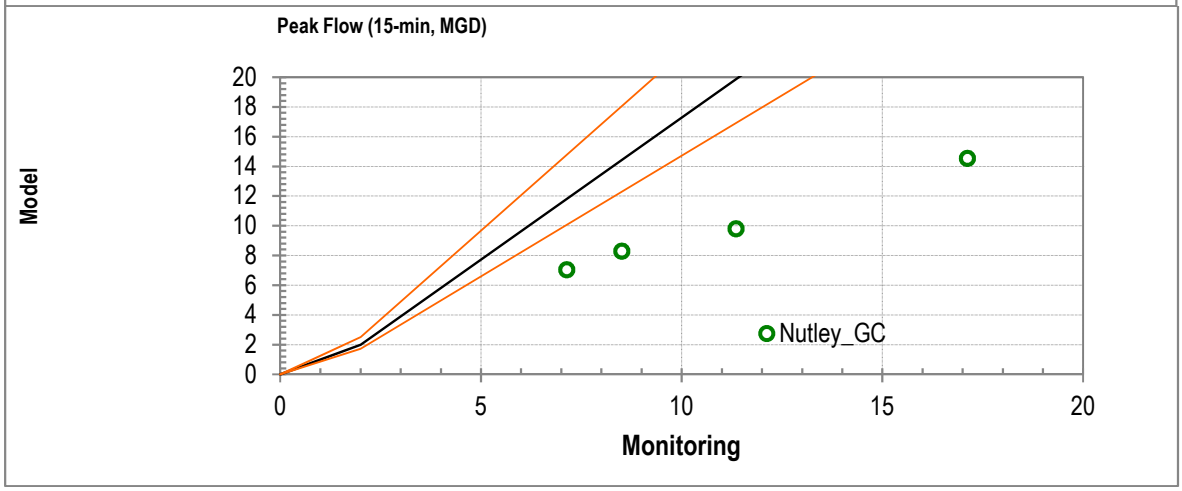

Total Volume (Mgal)
Model
RutherfordAve
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
Monitoring

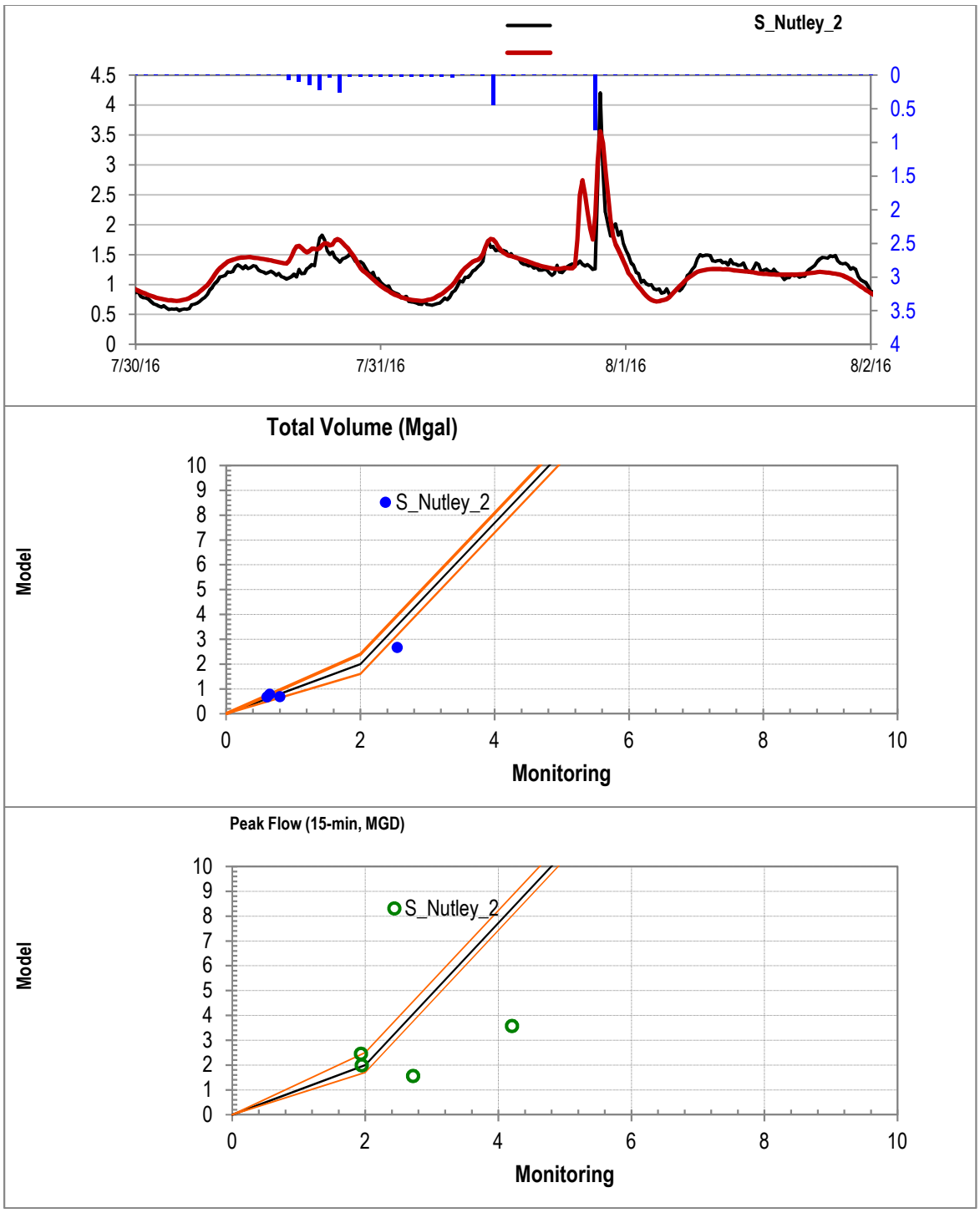

Peak Flow (15-min, MGD)
Model
RutherfordAve
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
Monitoring

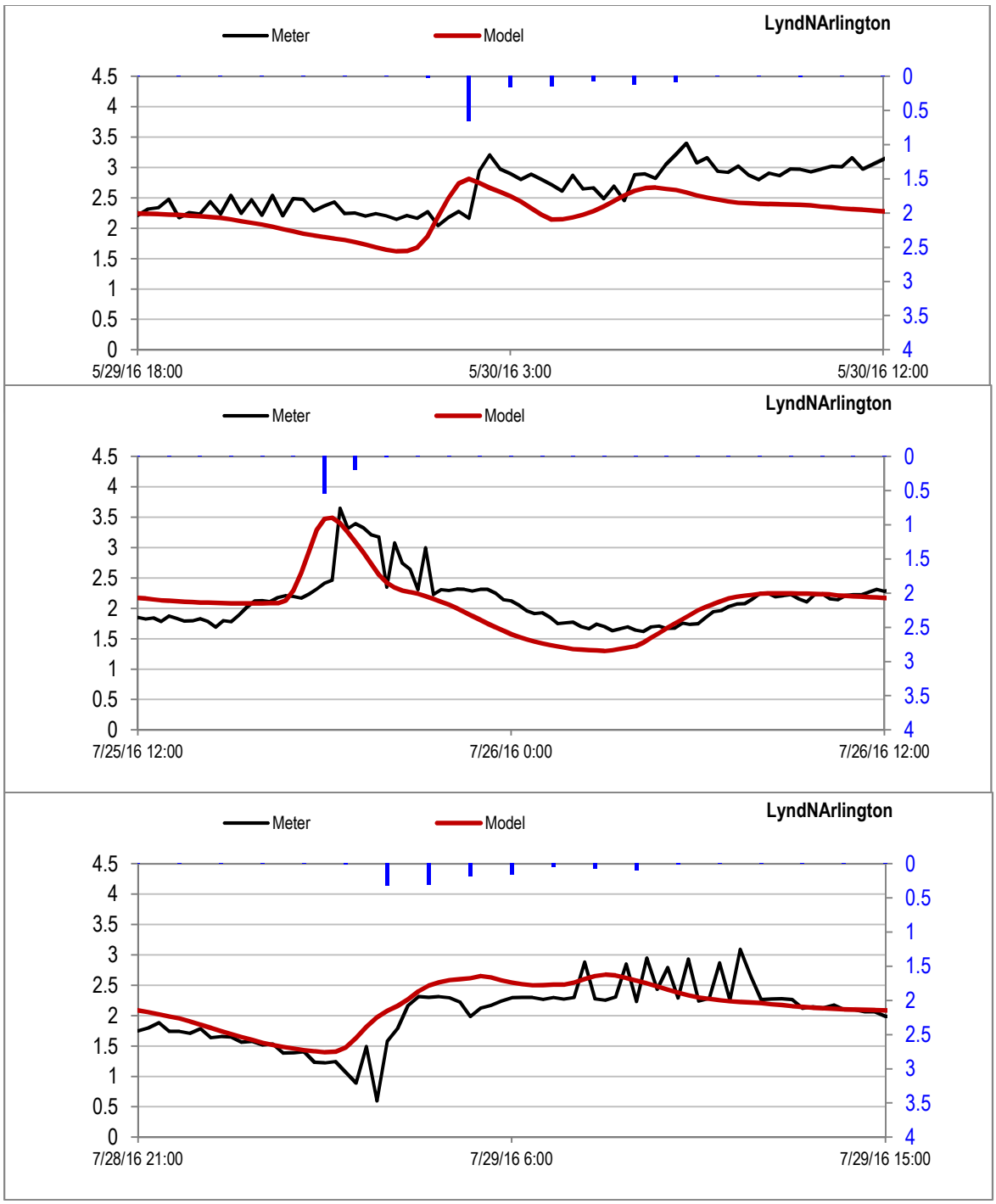

Nutley_GC
Meter
Model
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Nutley_GC
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Nutley_GC
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

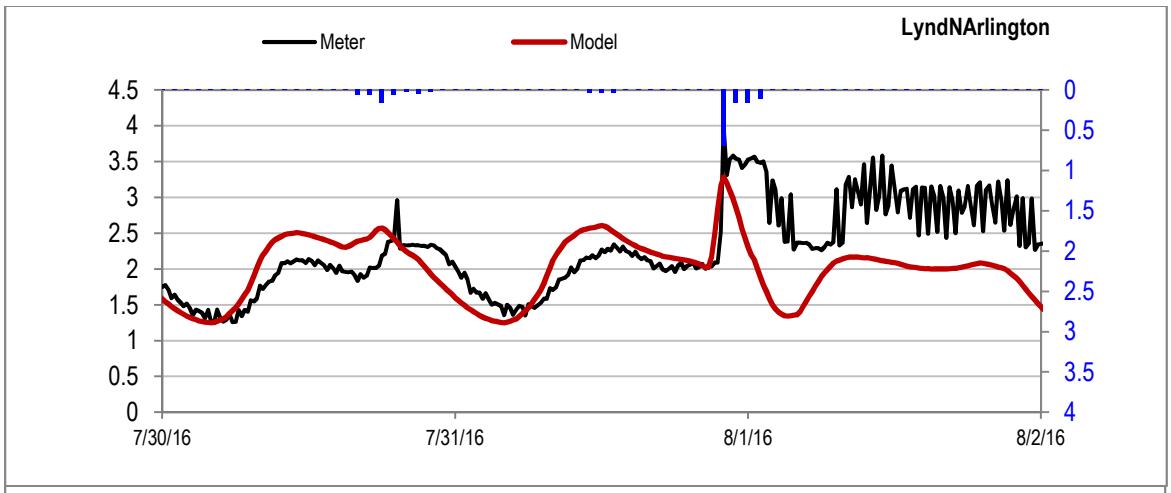

Nutley_GC
Meter
Model
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

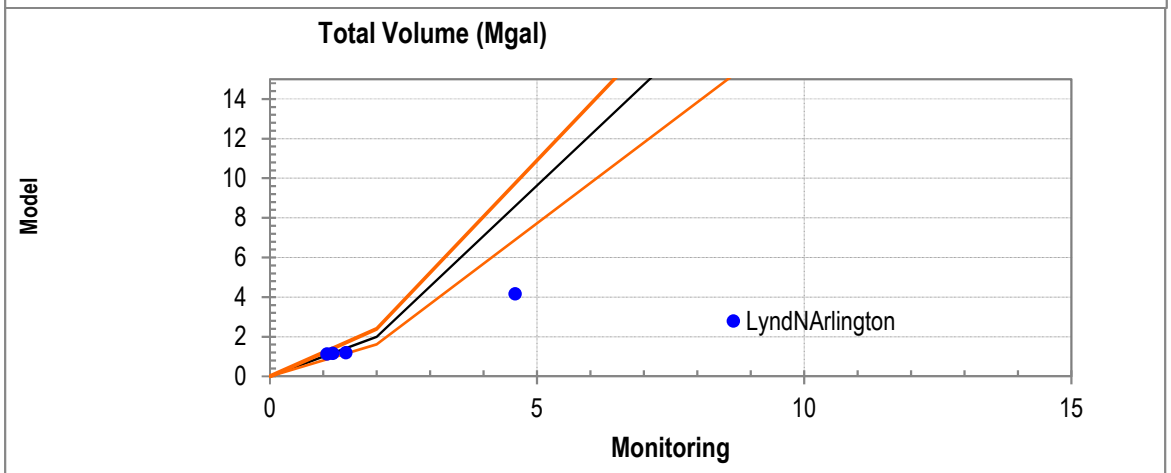

Total Volume (Mgal)
Model
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
Monitoring
Nutley_GC

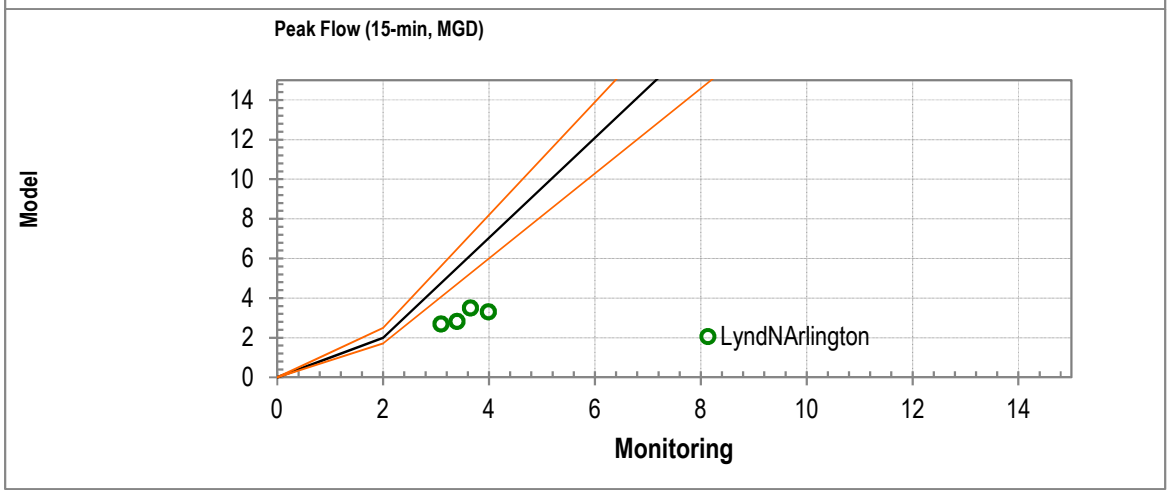

Peak Flow (15-min, MGD)
Model
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
Monitoring
Nutley_GC

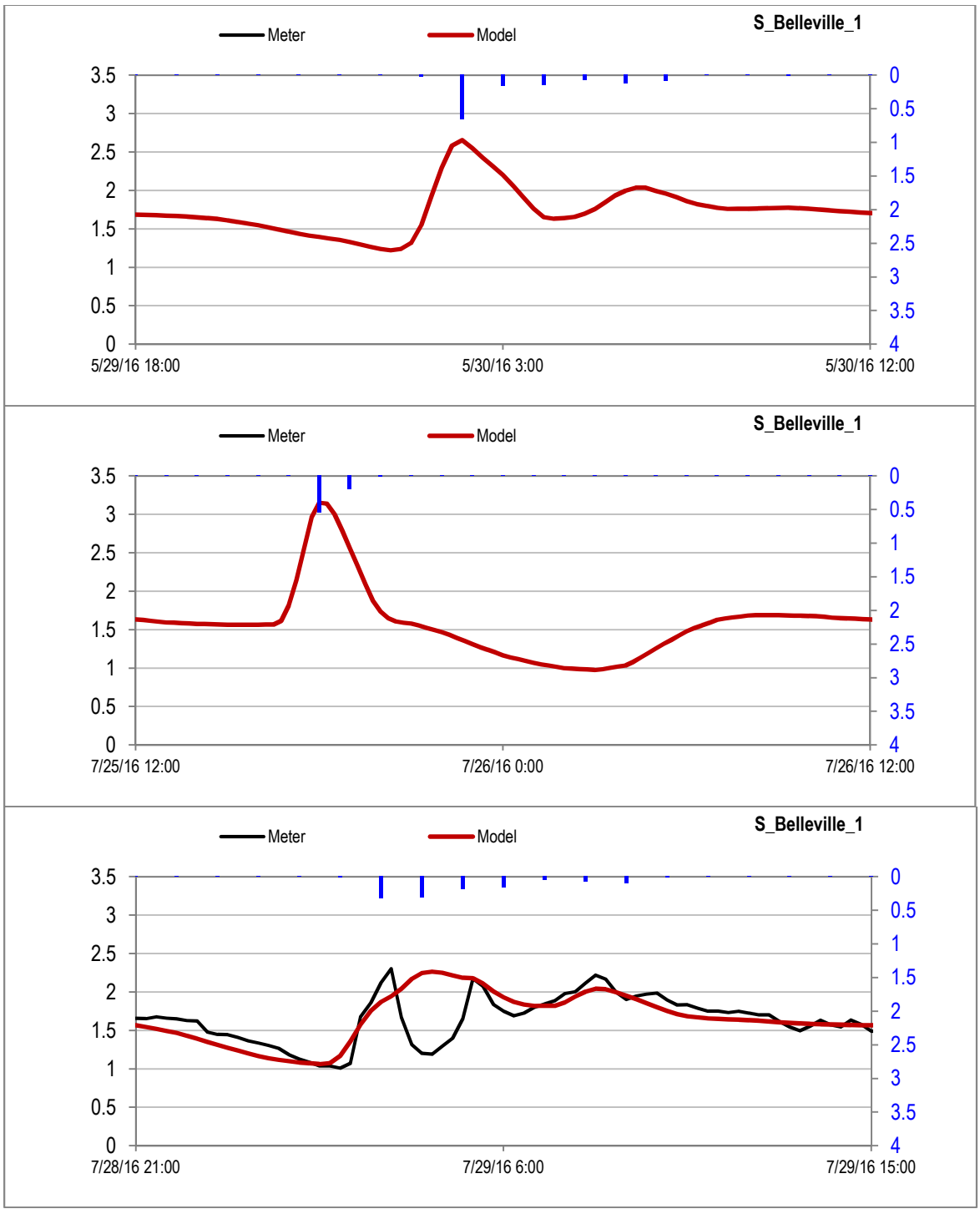

S_Nutley_2
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
S_Nutley_2
Monitoring
Peak Flow (15-min, MGD)
Model
S_Nutley_2
Monitoring

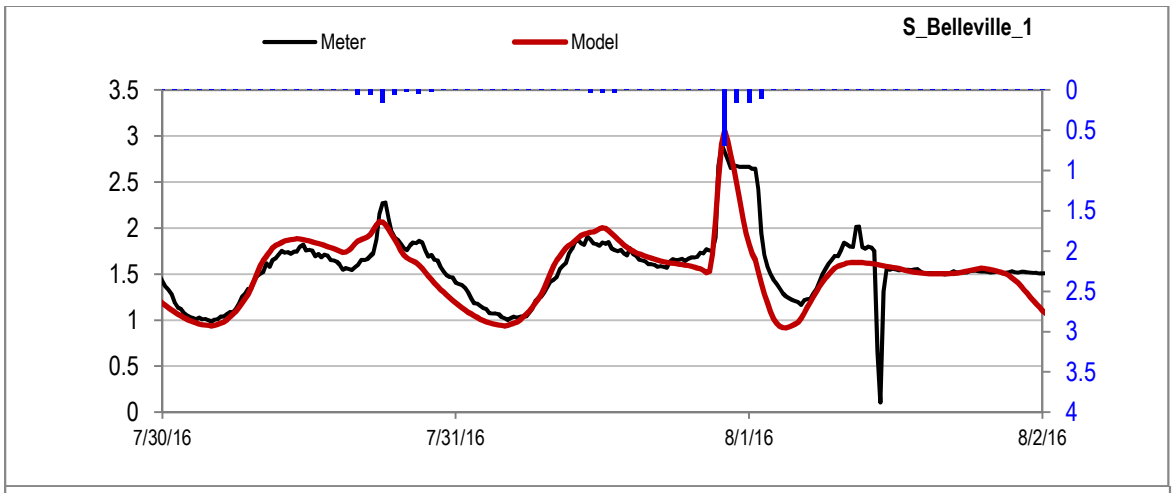

LyndNArlington
Meter
Model
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
LyndNArlington
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
LyndNArlington
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

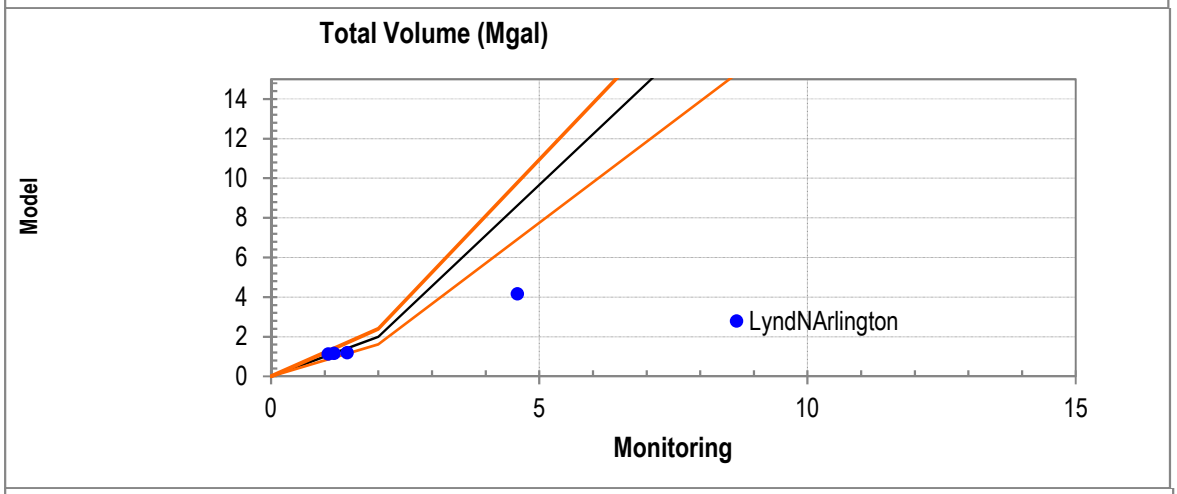

LyndNArlington
Meter
Model
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

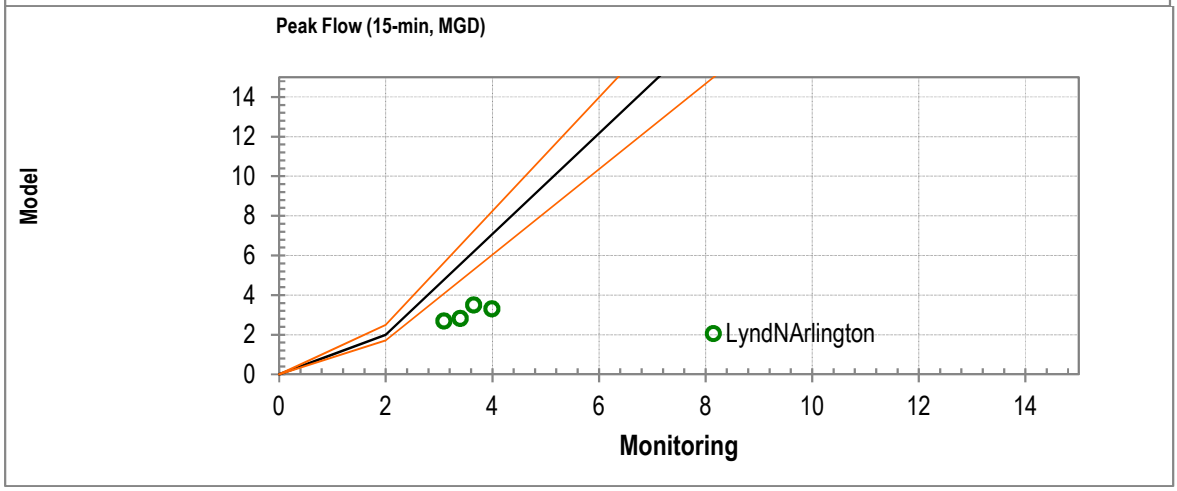

Total Volume (Mgal)
Model
14
12
10
8
6
4
2
0
0
5
10
15
LyndNArlington
Monitoring

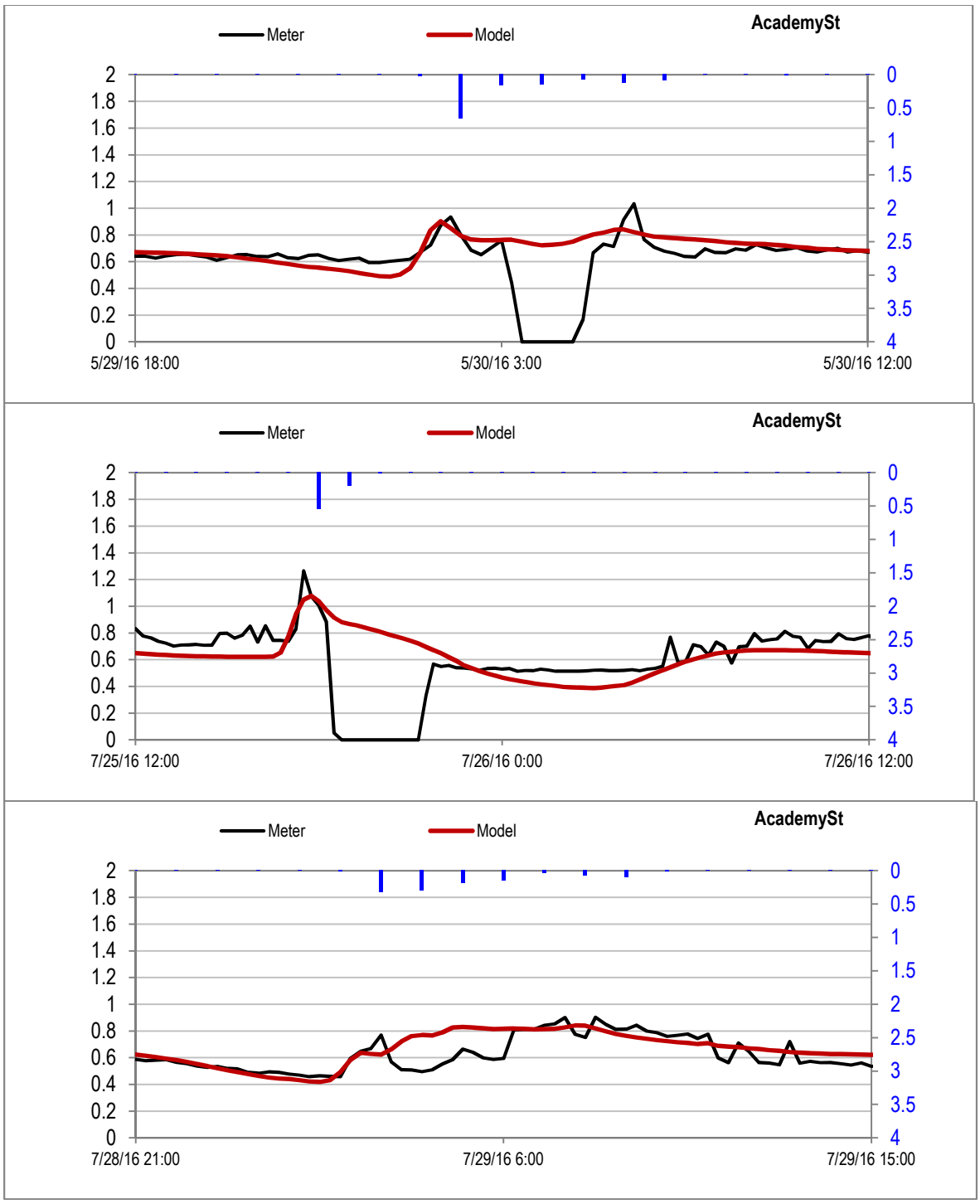

Peak Flow (15-min, MGD)
Model
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
LyndNArlington
Monitoring

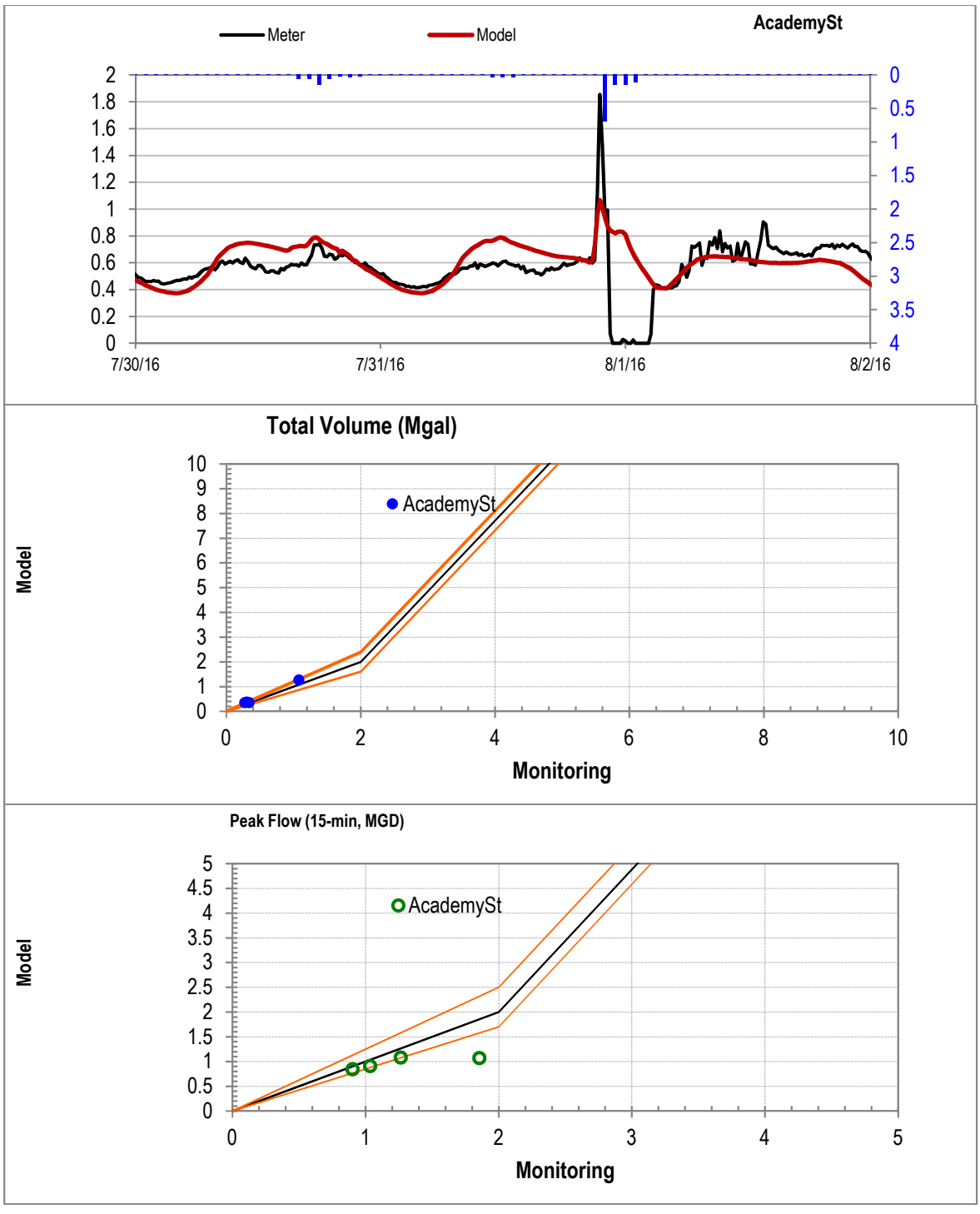

Meter
Model
S_Belleville_1
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Meter
Model
S_Belleville_1
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Meter
Model
S_Belleville_1
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

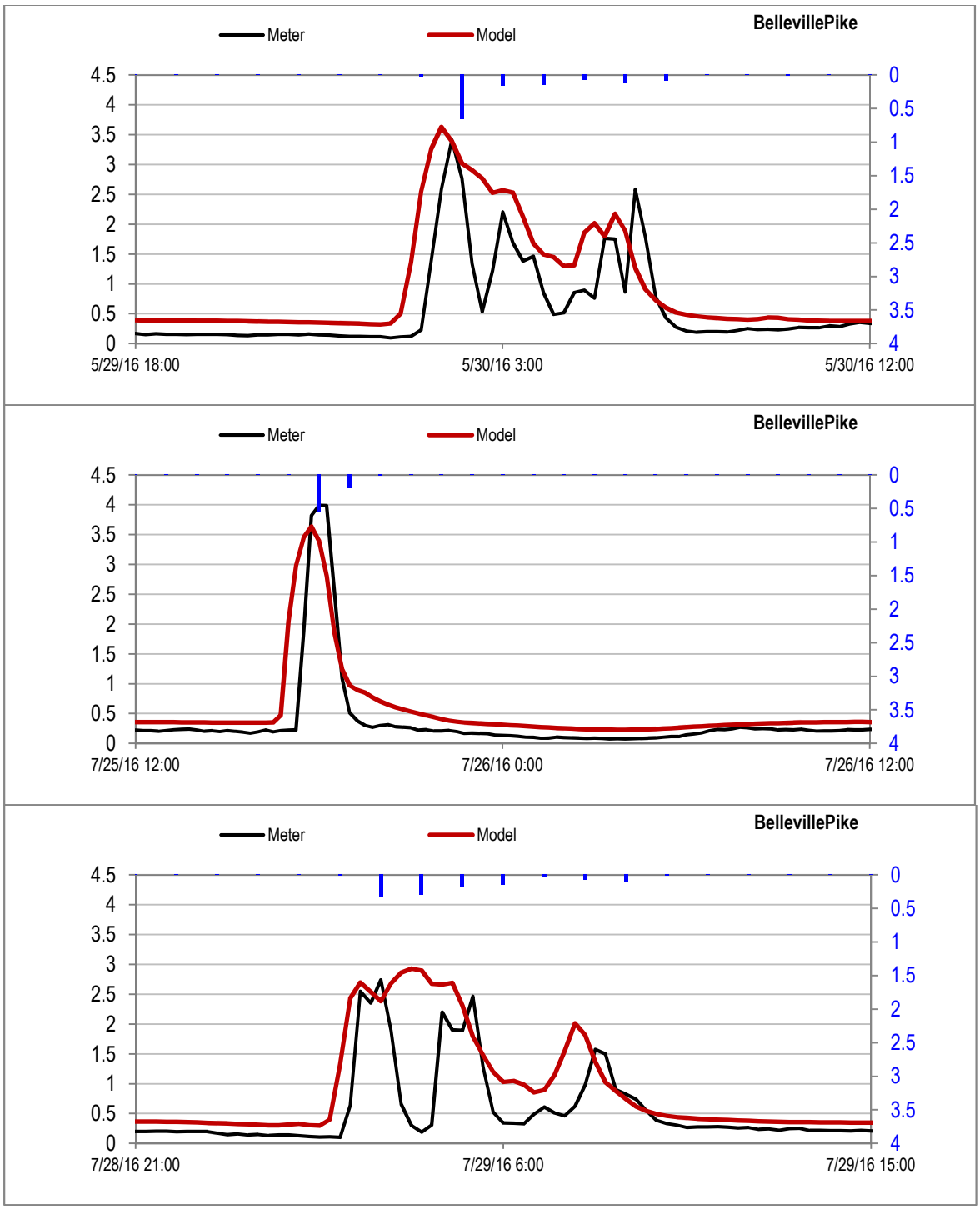

S_Belleville_1
Meter
Model
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

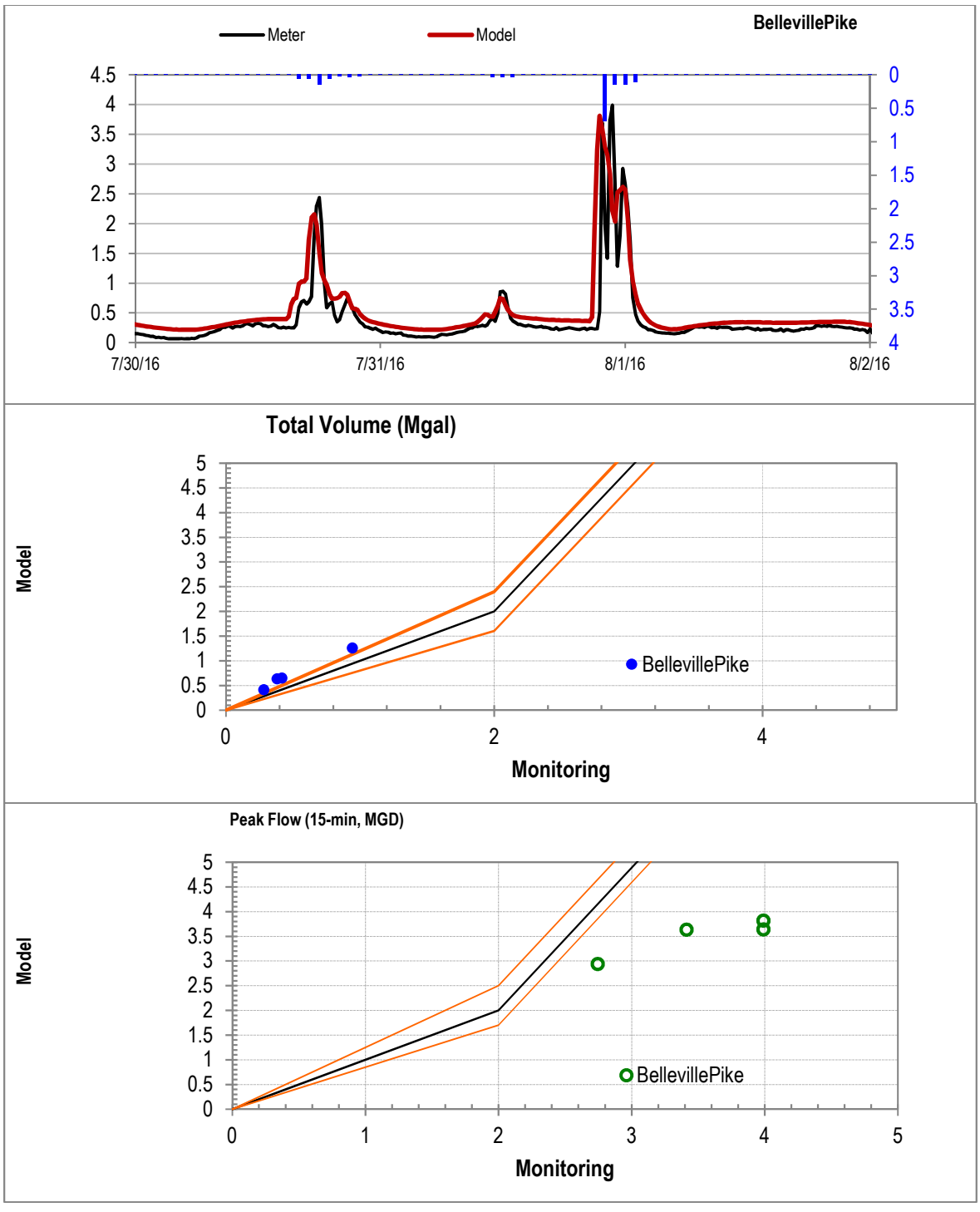

Total Volume (Mgal)
Model
14
12
10
8
6
4
2
0
0
5
10
15
LyndNArlington
Monitoring

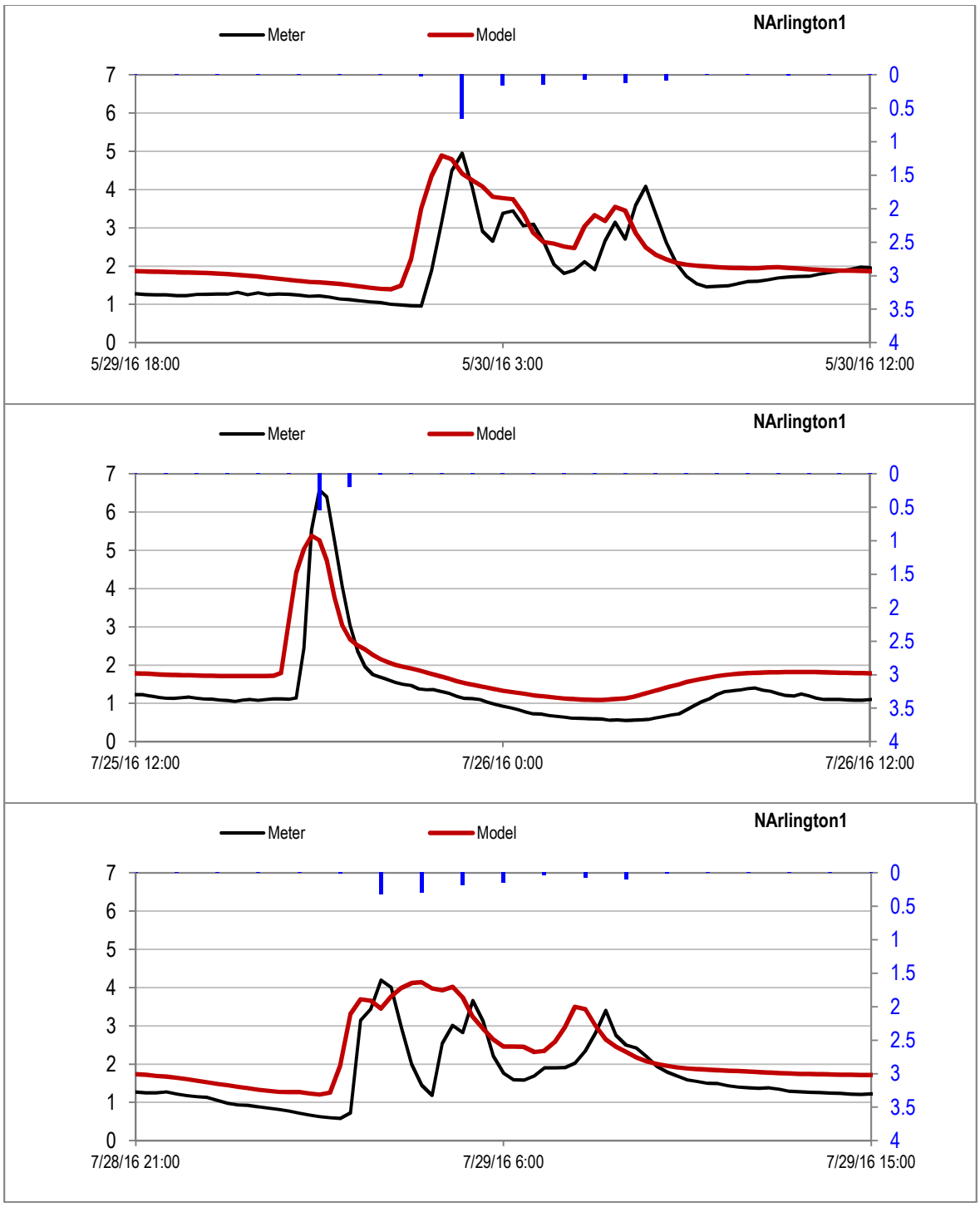

Peak Flow (15-min, MGD)
Model
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
LyndNArlington
Monitoring

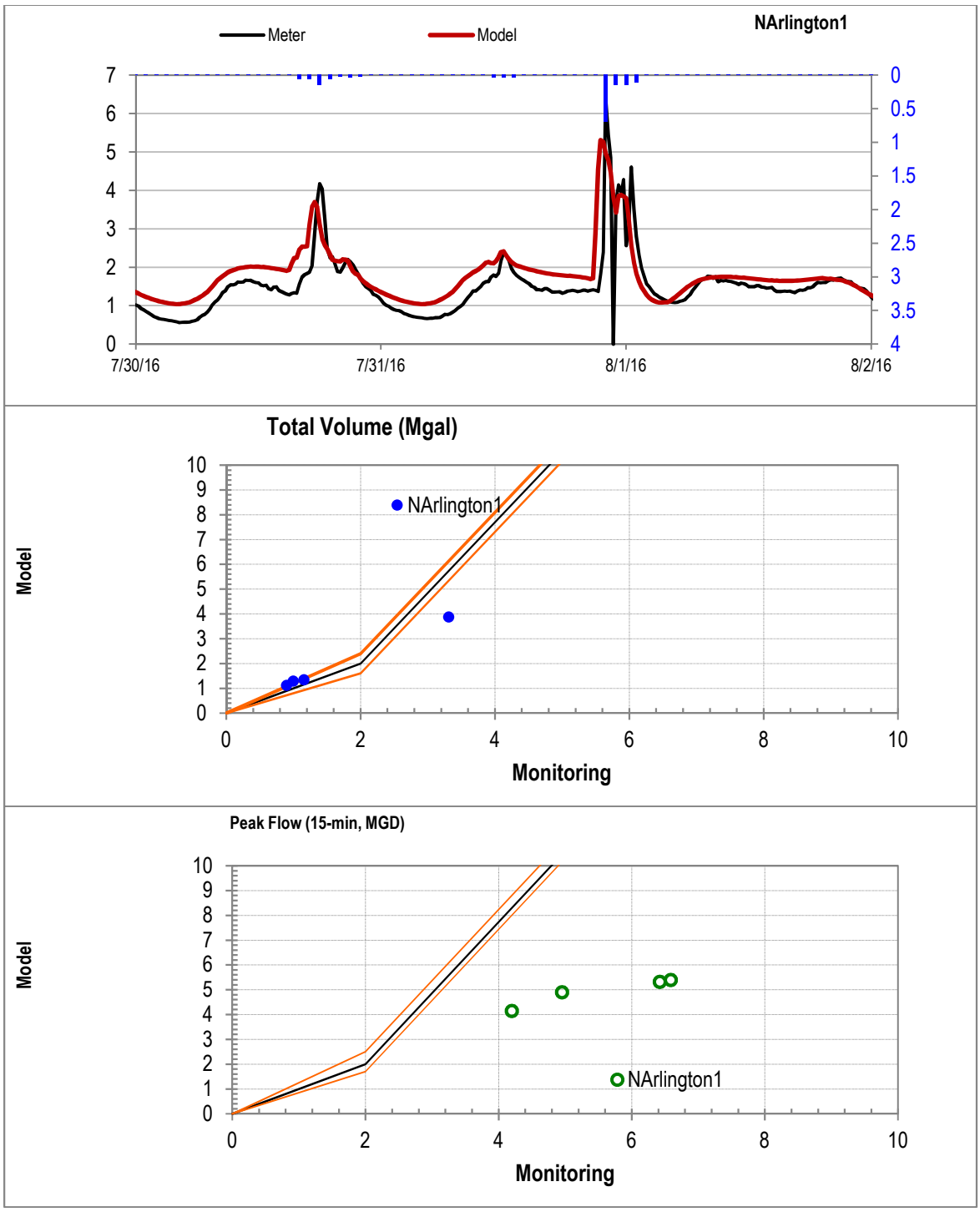

AcademySt
Meter
Model
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
AcademySt
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
AcademySt
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

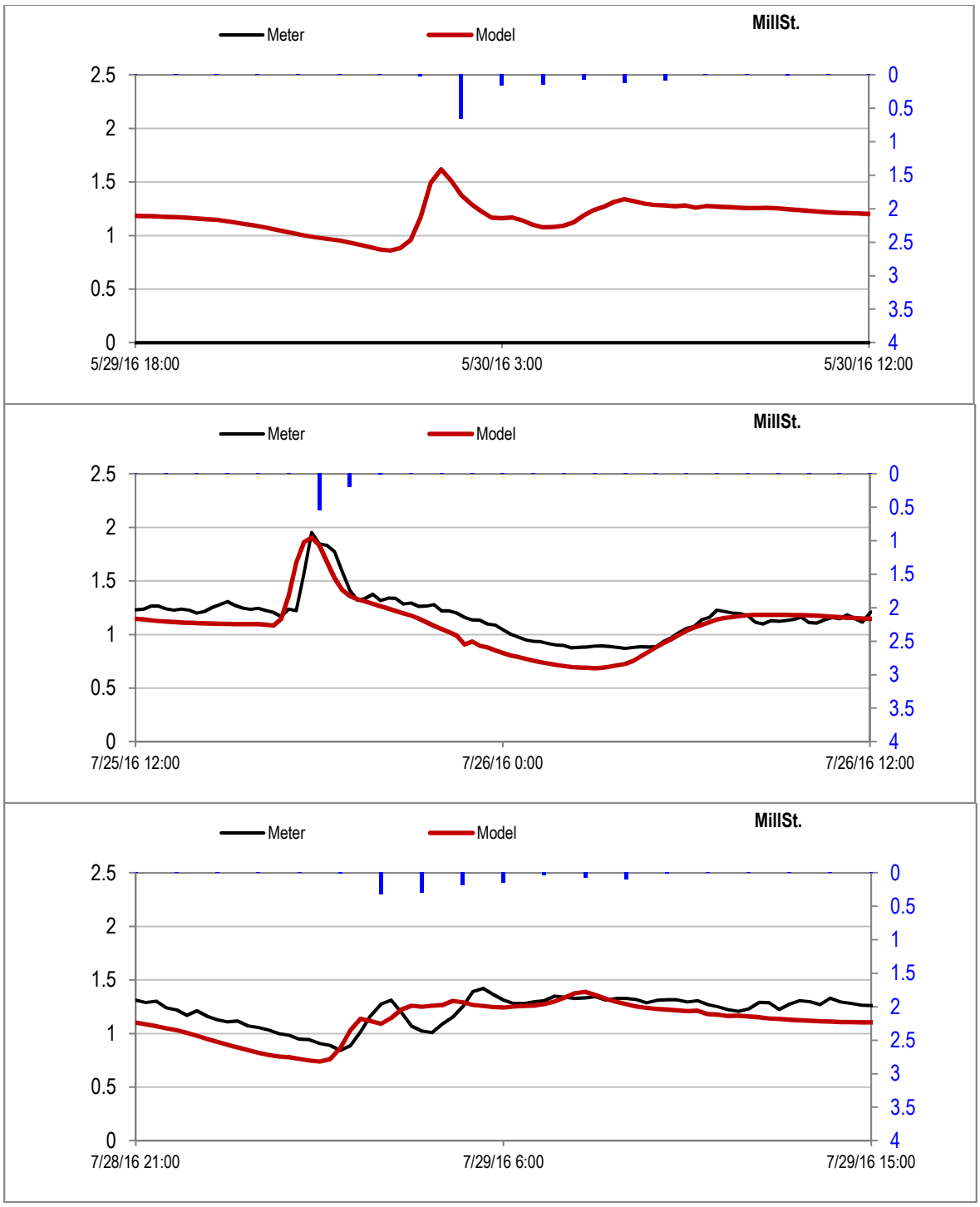

Meter
Model
AcademySt
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
AcademySt
Monitoring
Peak Flow (15-min, MGD)
Model
AcademySt
Monitoring

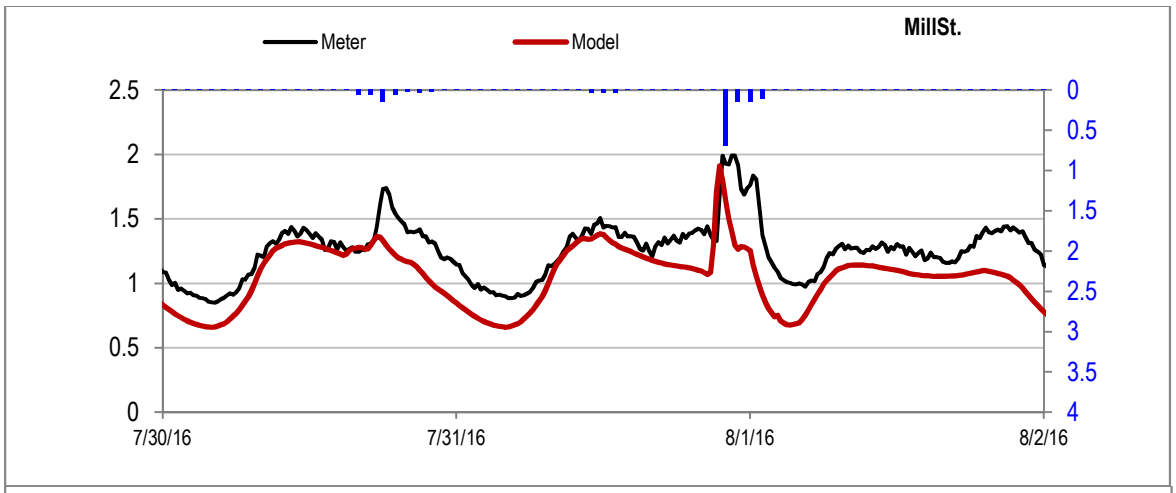

BellevillePike
Meter
Model
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
BellevillePike
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
BellevillePike
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

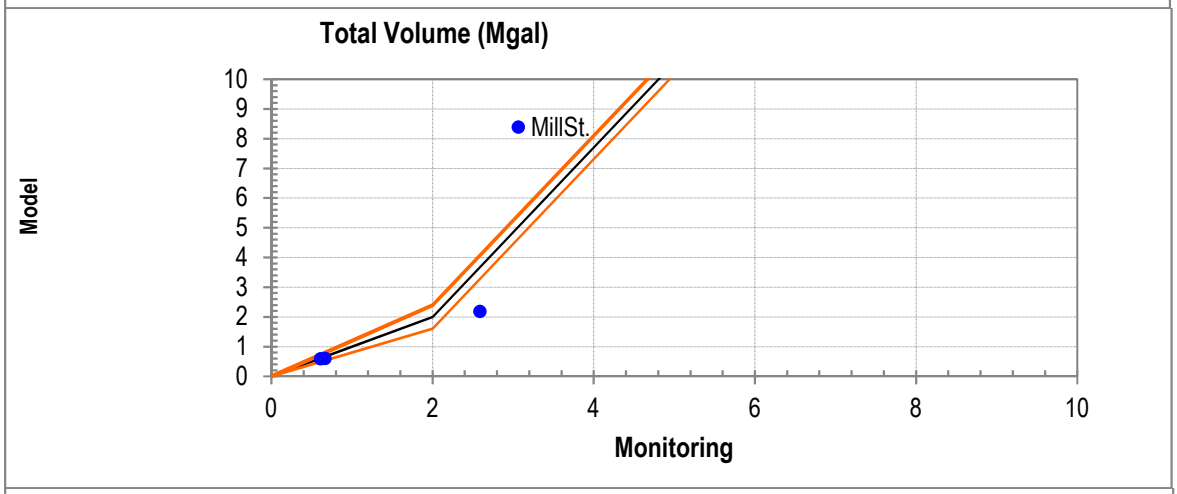

BellevillePike
Meter
Model
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
Monitoring
BellevillePike
Peak Flow (15-min, MGD)
Model
Monitoring
BellevillePike

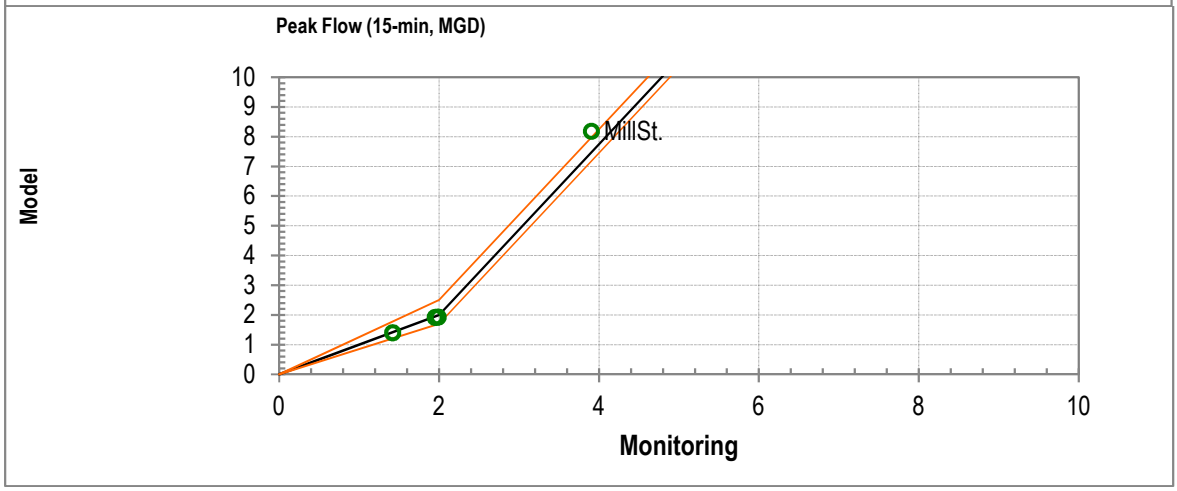

NArlington1
Meter
Model
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NArlington1
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
NArlington1
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

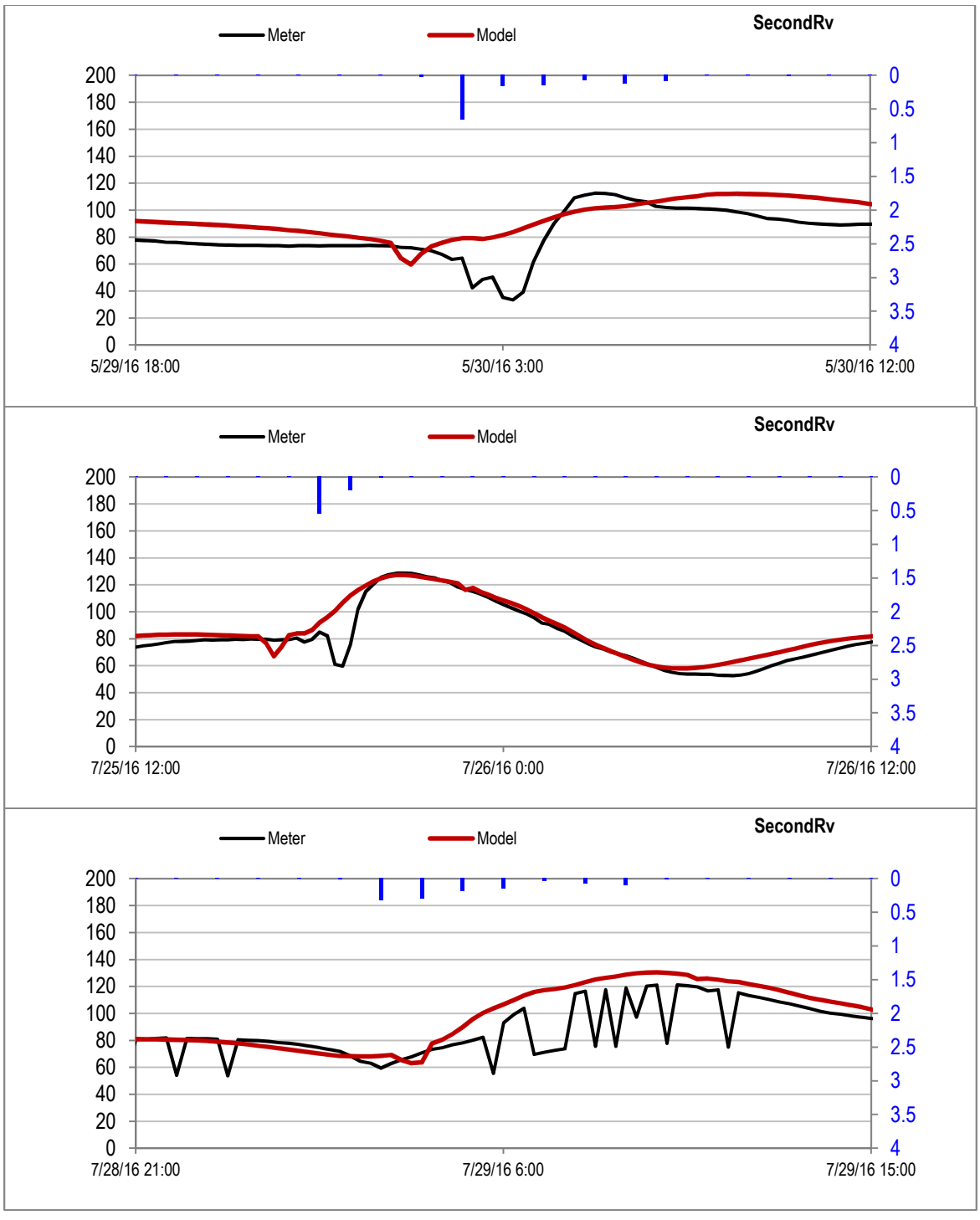

NArlington1
Meter
Model
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
NArlington1
Monitoring
Peak Flow (15-min, MGD)
Model
NArlington1
Monitoring

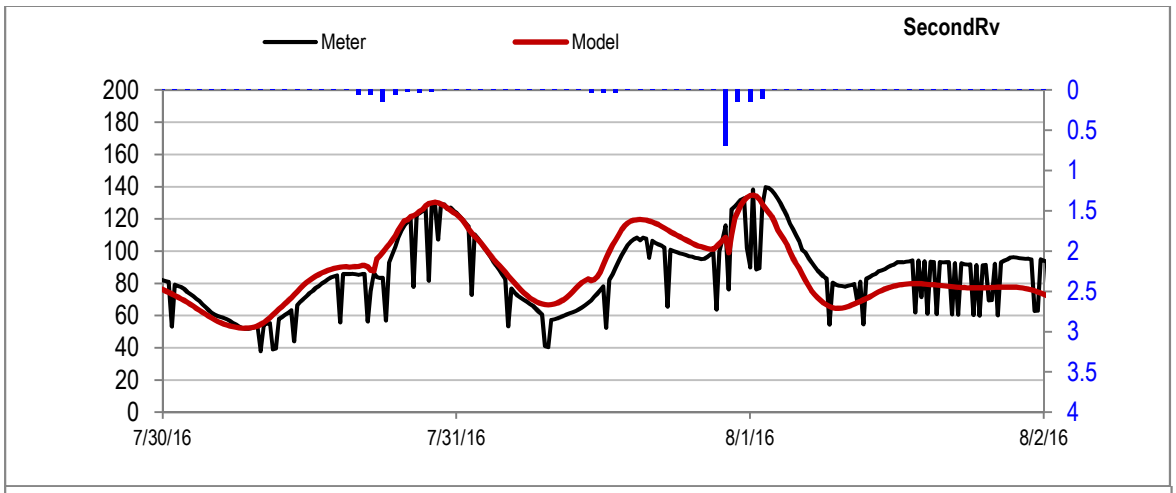

MillSt.
Meter
Model
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
MillSt.
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
MillSt.
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

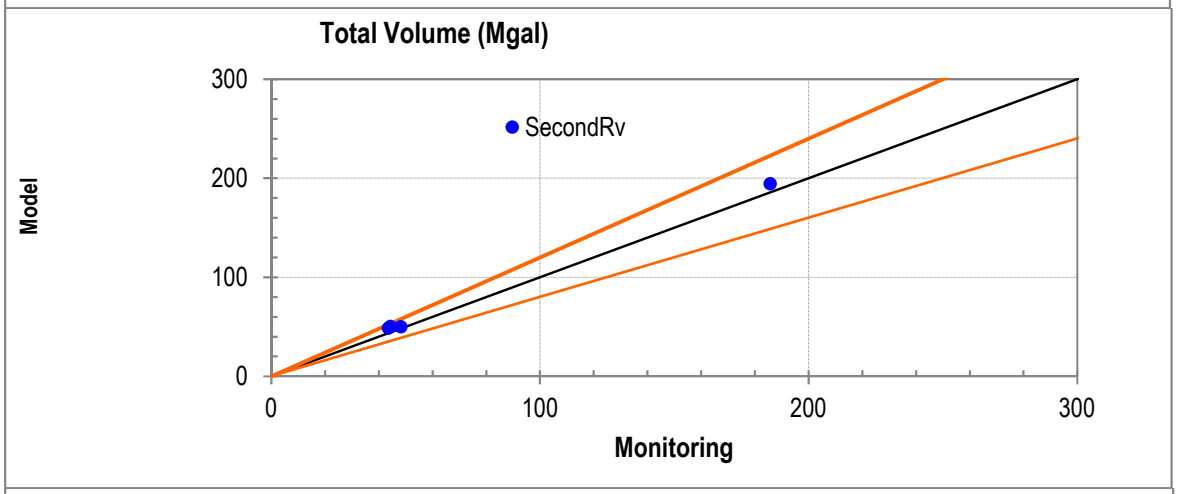

Meter
Model
MillSt.
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

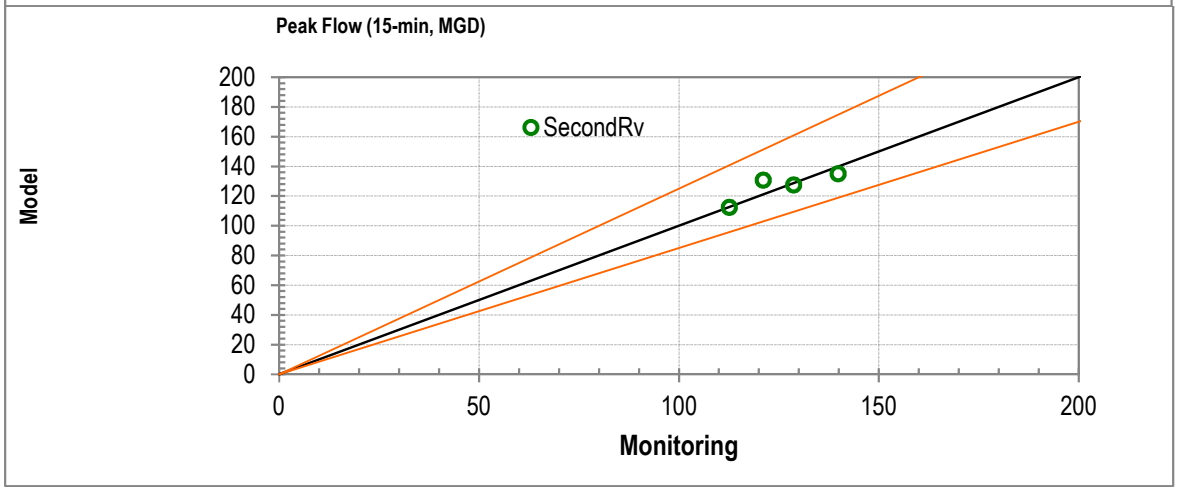

Total Volume (Mgal)
Model
MillSt.
Monitoring
0
2
4
6
8
10

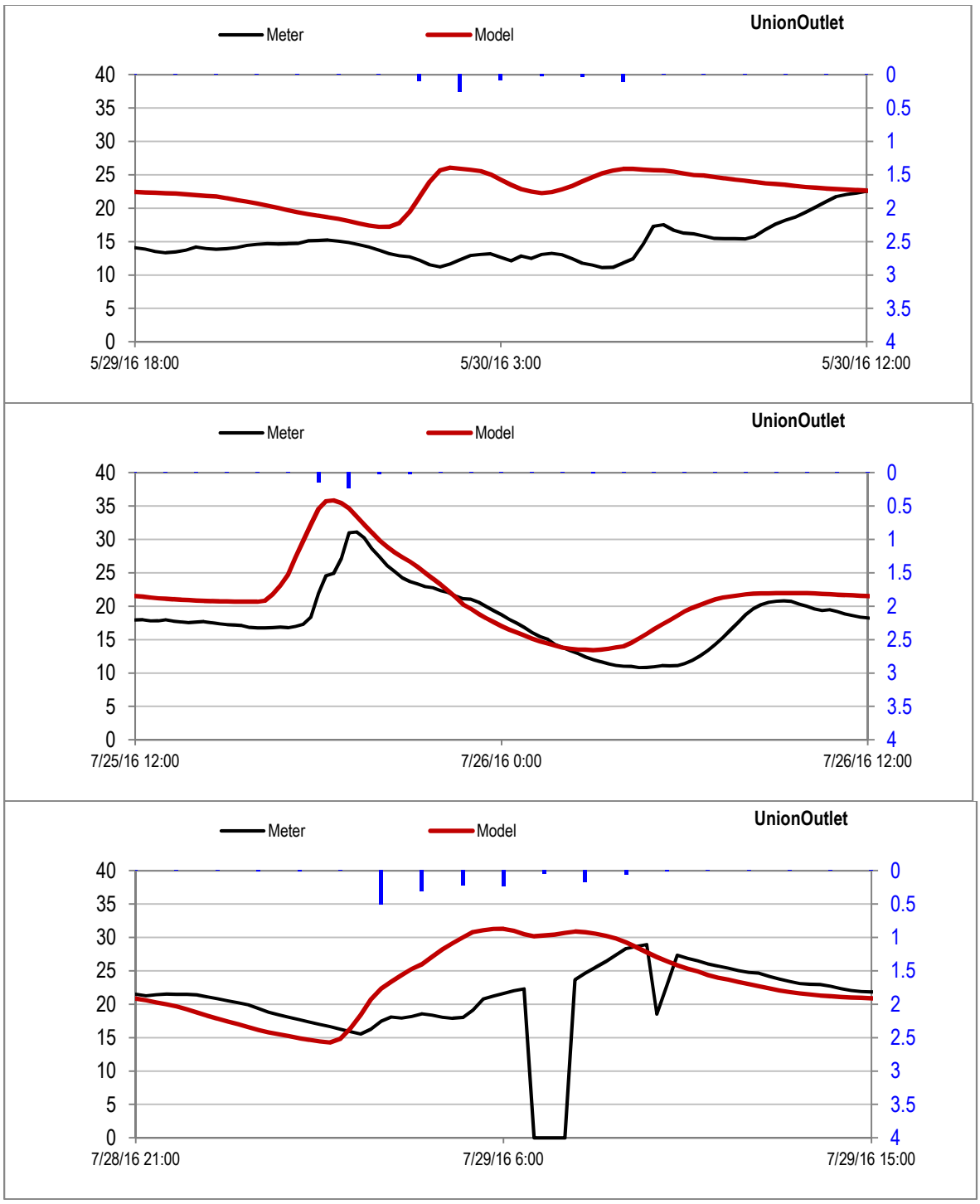

Peak Flow (15-min, MGD)
Model
MillSt.
Monitoring
0
2
4
6
8
10

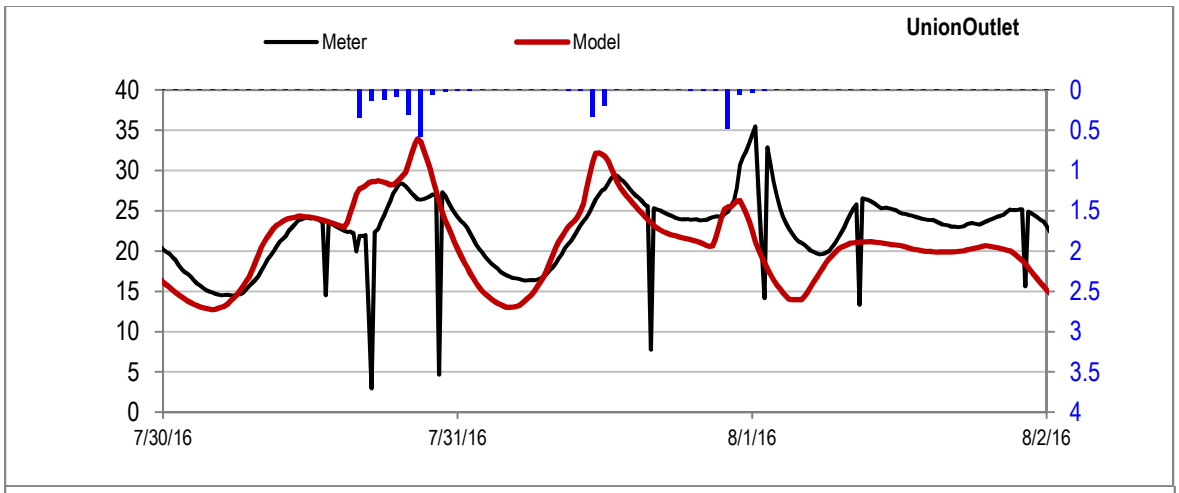

Meter
Model
SecondRv
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Meter
Model
SecondRv
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Meter
Model
SecondRv
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

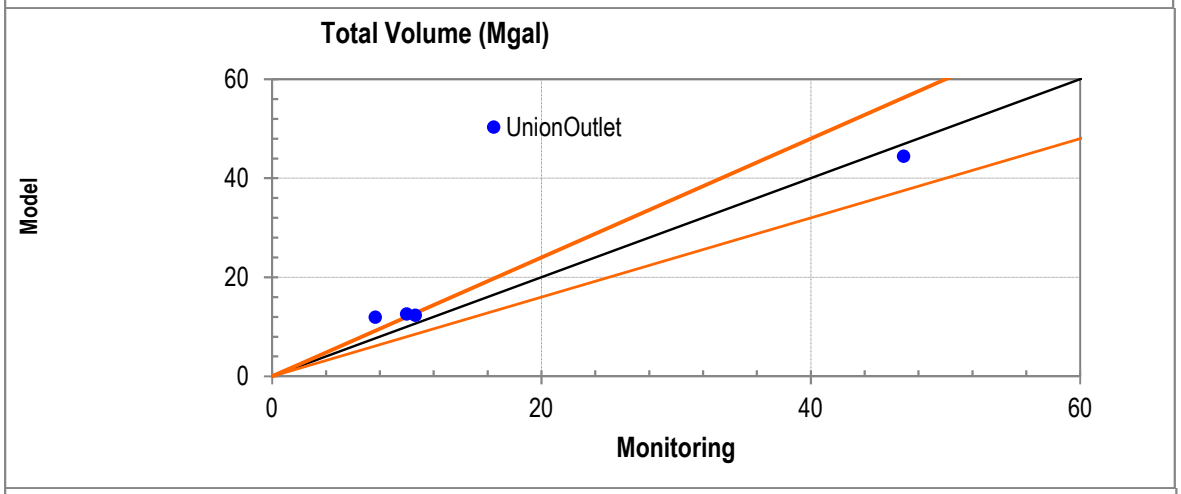

Meter
Model
SecondRv
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

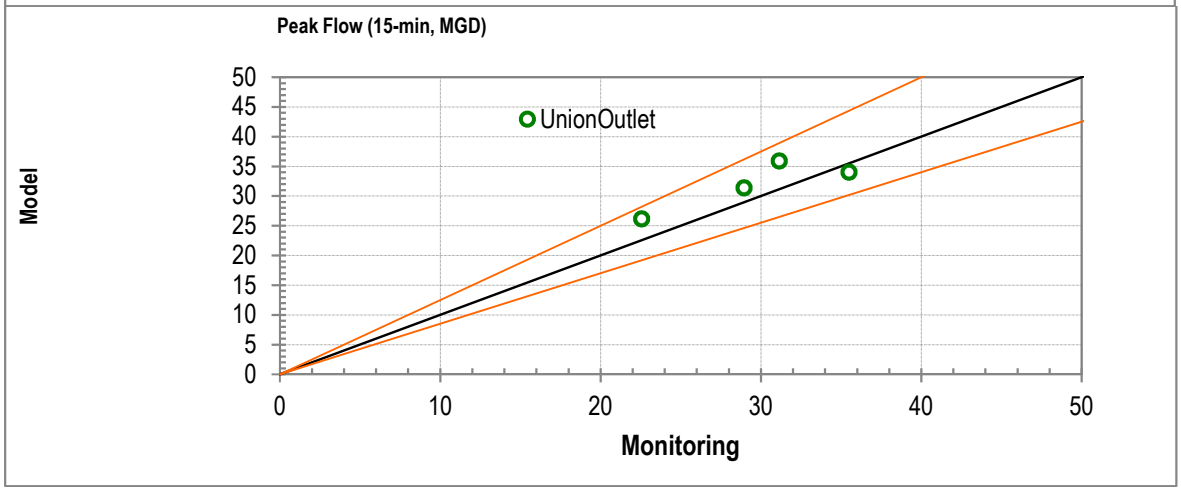

Total Volume (Mgal)
Model
SecondRv
300
200
100
0
0
100
200
300
Monitoring

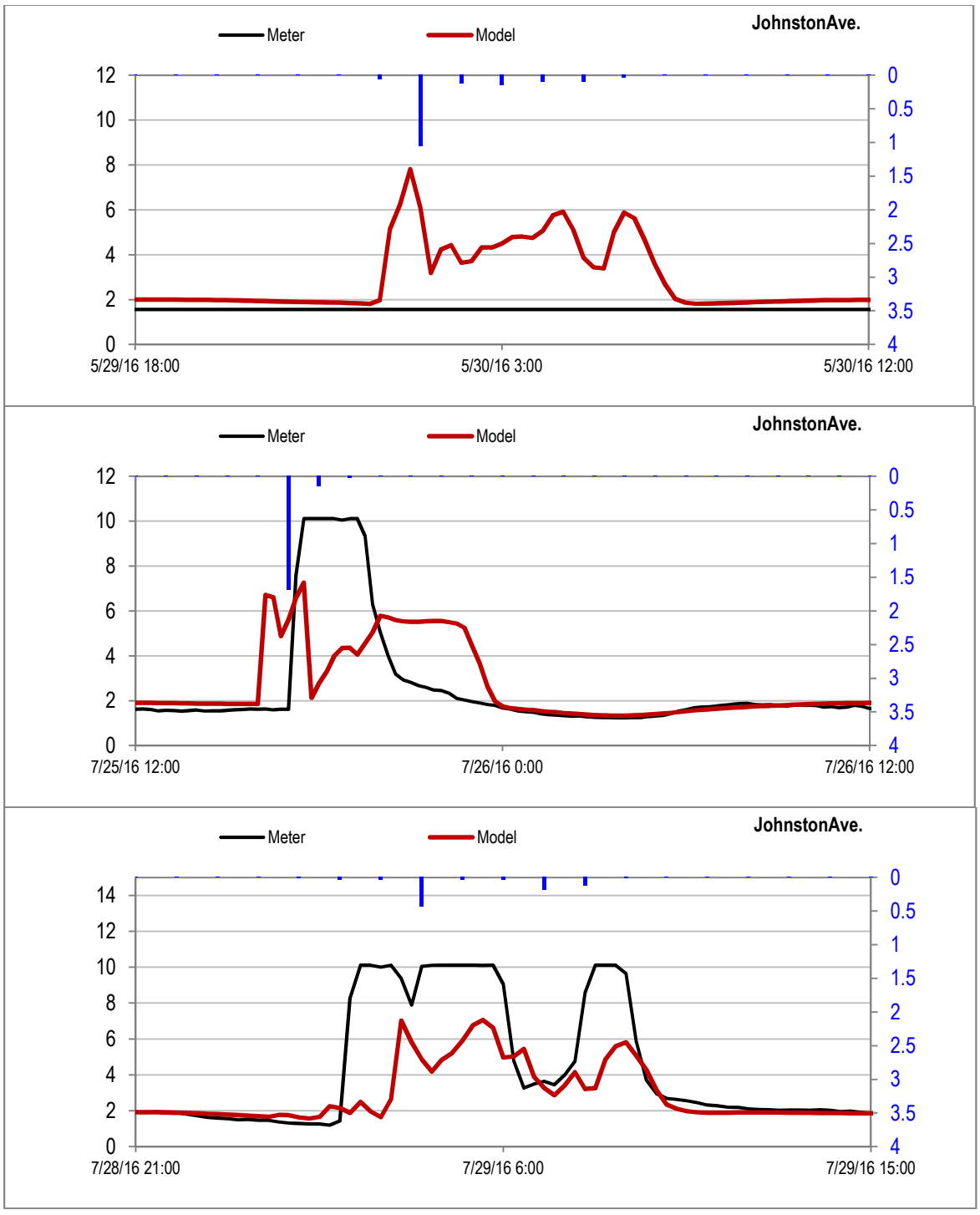

Peak Flow (15-min, MGD)
Model
SecondRv
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Monitoring

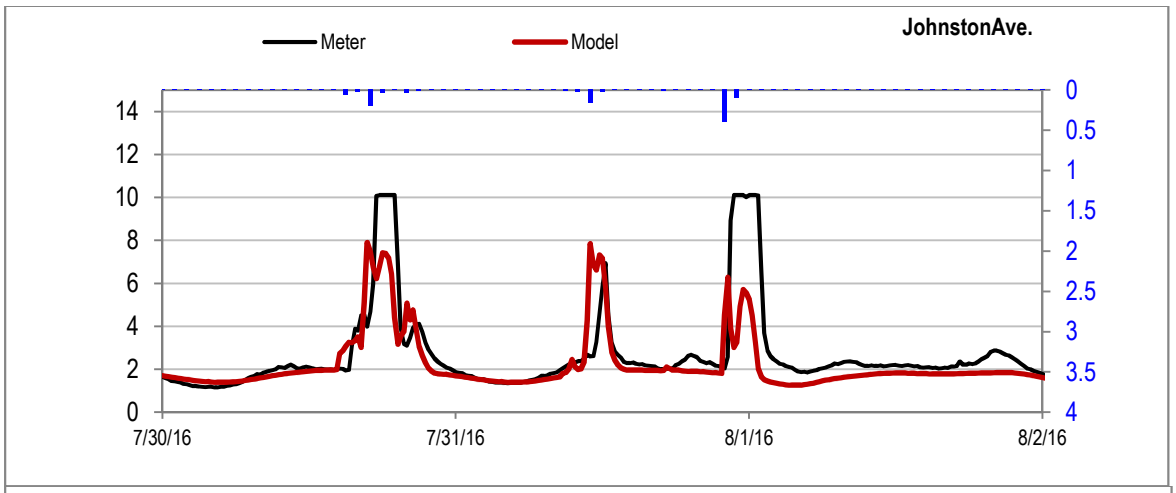

UnionOutlet
Meter
Model
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
UnionOutlet
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
UnionOutlet
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

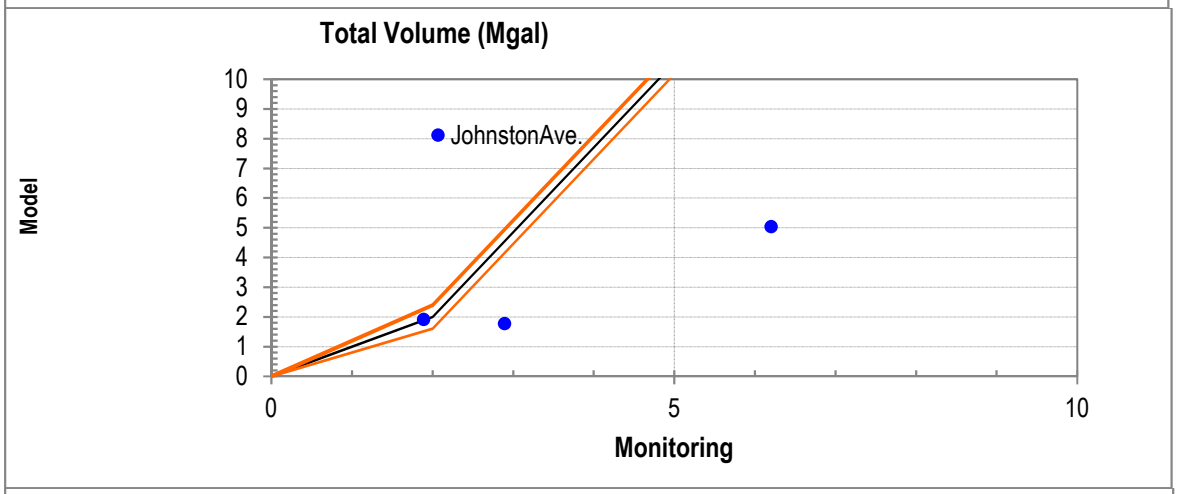

UnionOutlet
Meter
Model
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

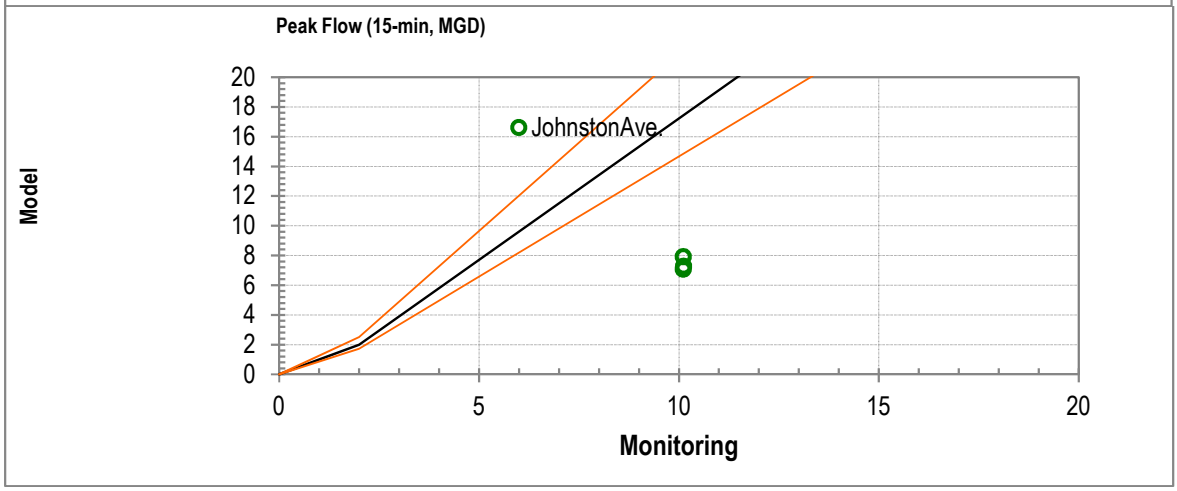

Total Volume (Mgal)
Model
UnionOutlet
60
40
20
0
0
20
40
60
Monitoring

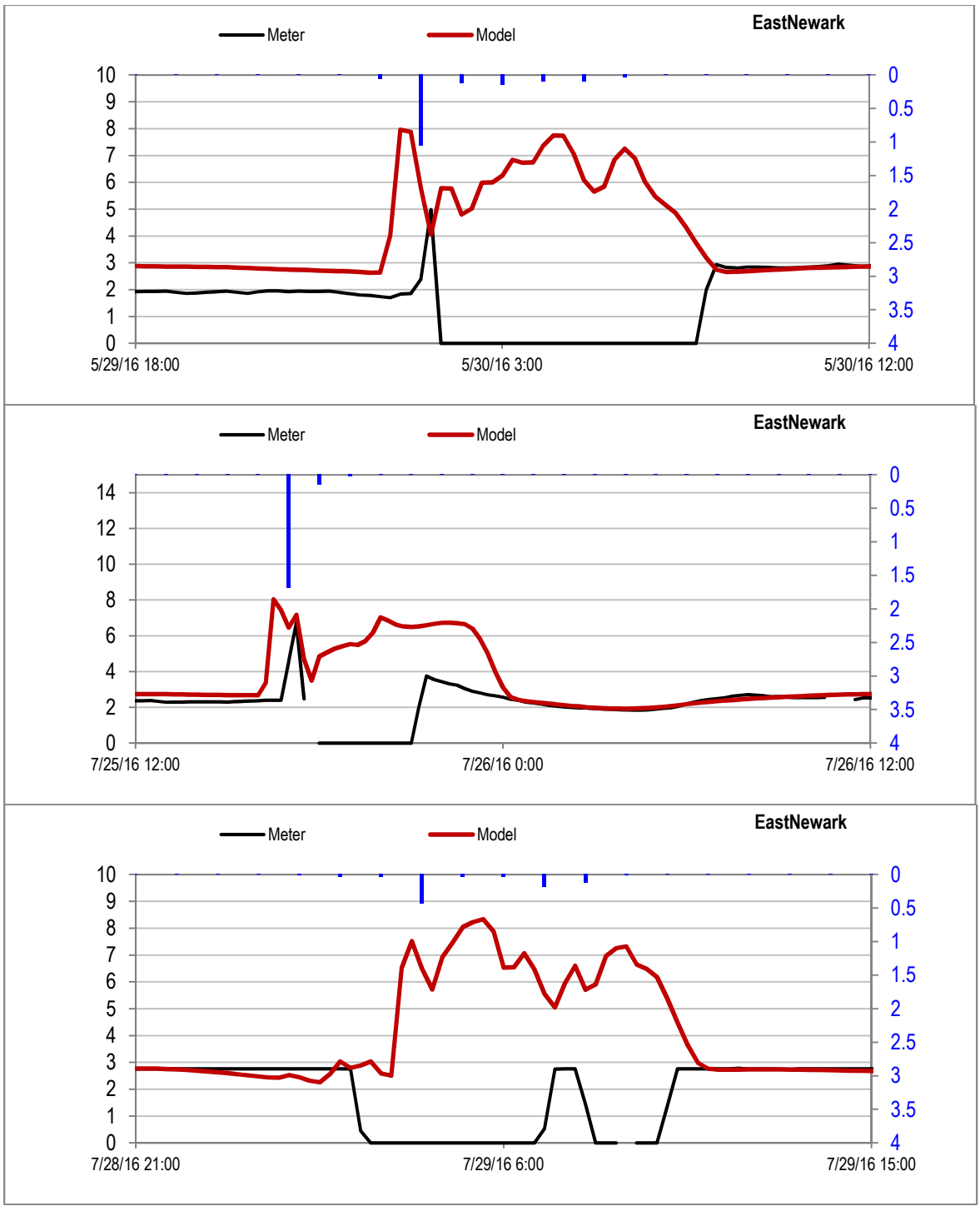

Peak Flow (15-min, MGD)
Model
UnionOutlet
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
Monitoring

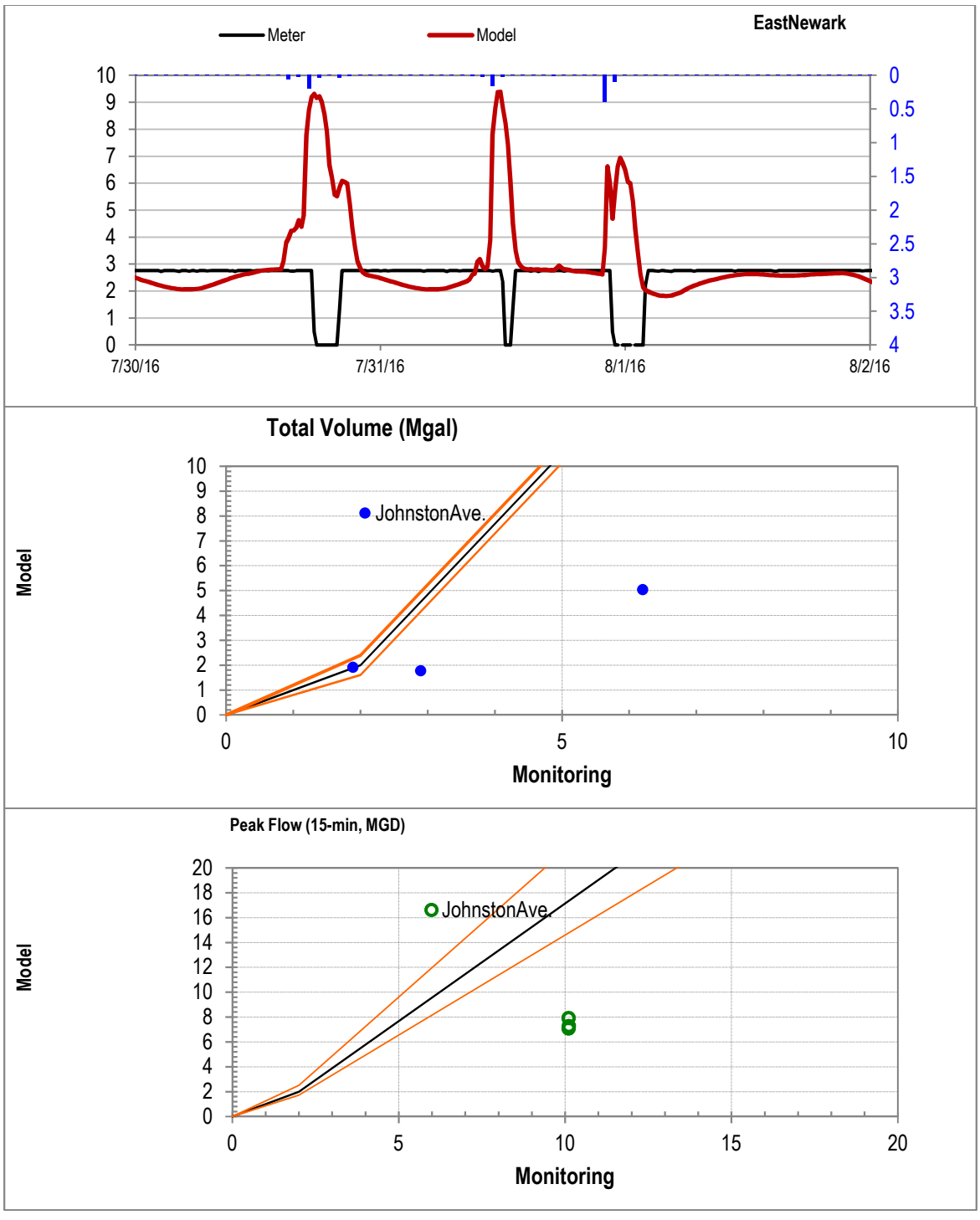

JohnstonAve.
Meter
Model
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
JohnstonAve.
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
JohnstonAve.
Meter
Model
14
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

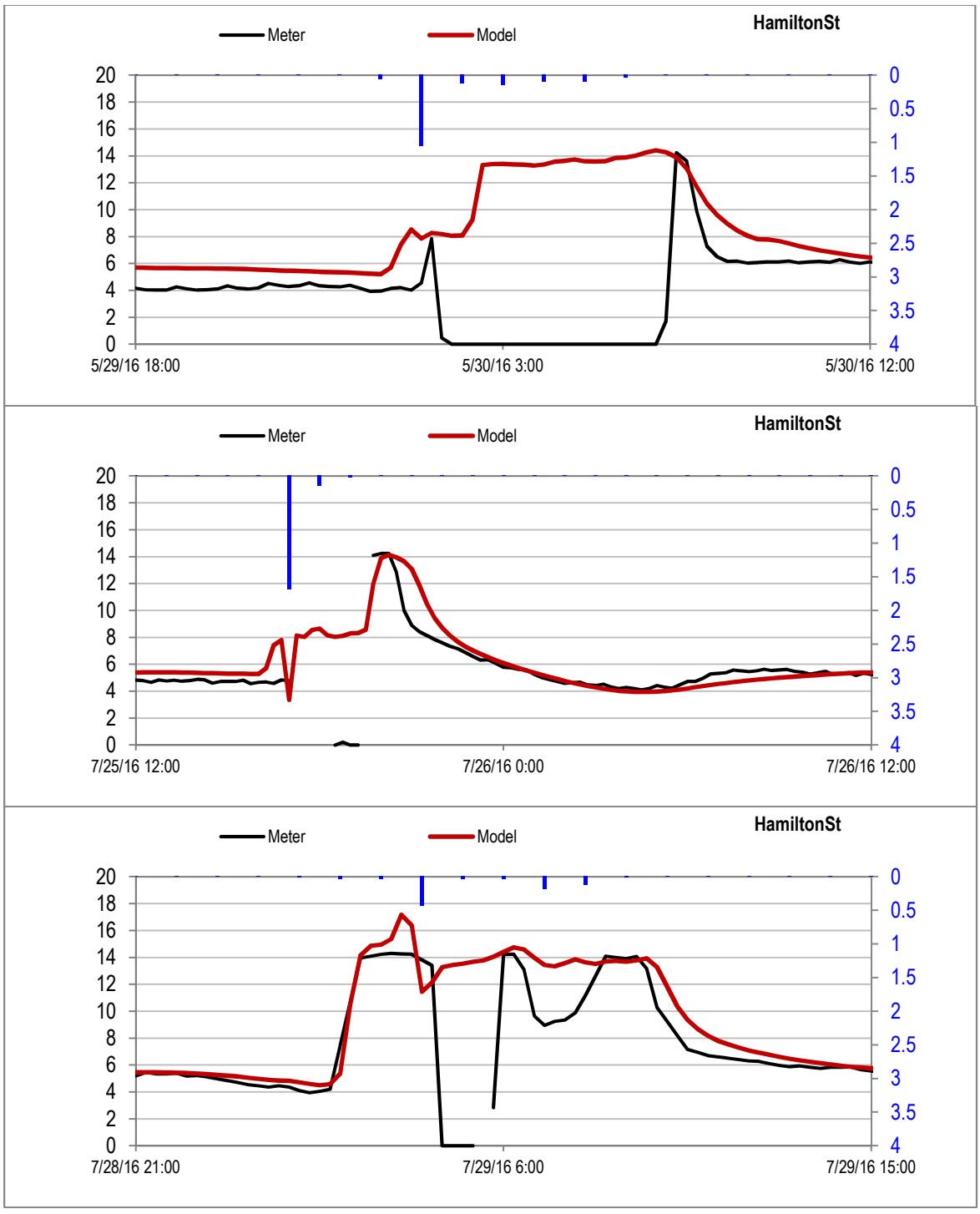

Meter
Model
JohnstonAve.
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

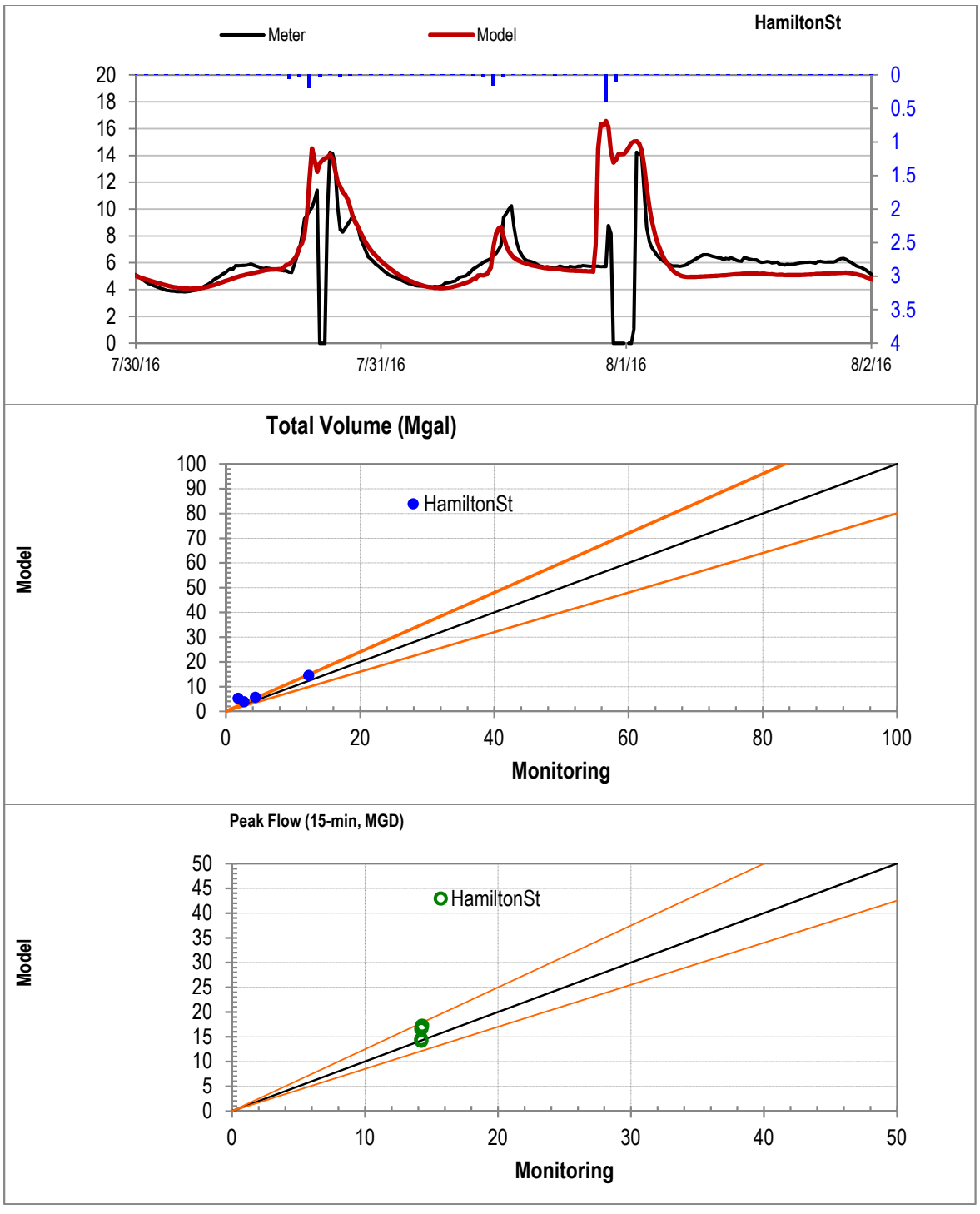

Total Volume (Mgal)
Model
JohnstonAve.
10
9
8
7
6
5
4
3
2
1
0
0
5
10
Monitoring

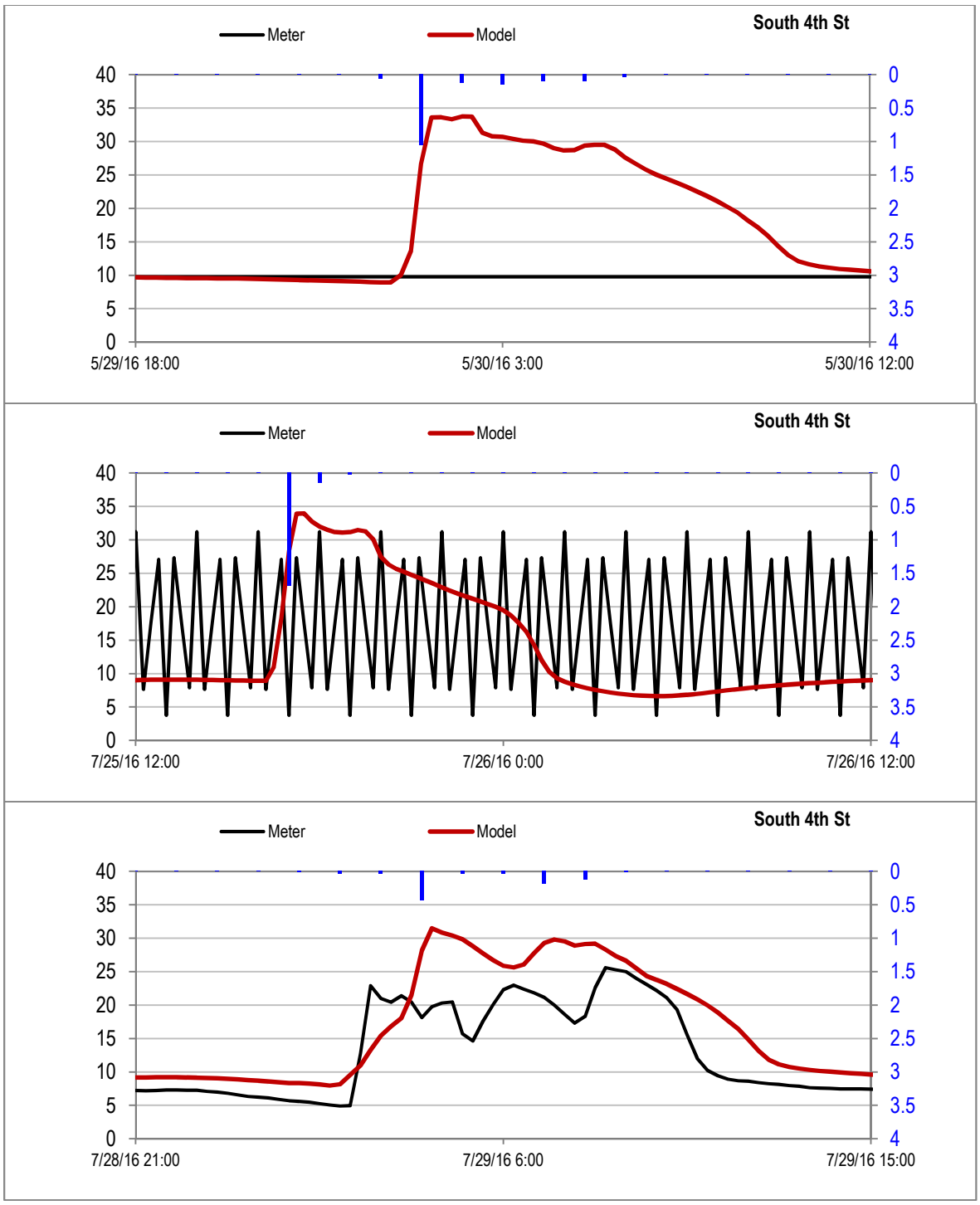

Peak Flow (15-min, MGD)
Model
JohnstonAve.
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
Monitoring

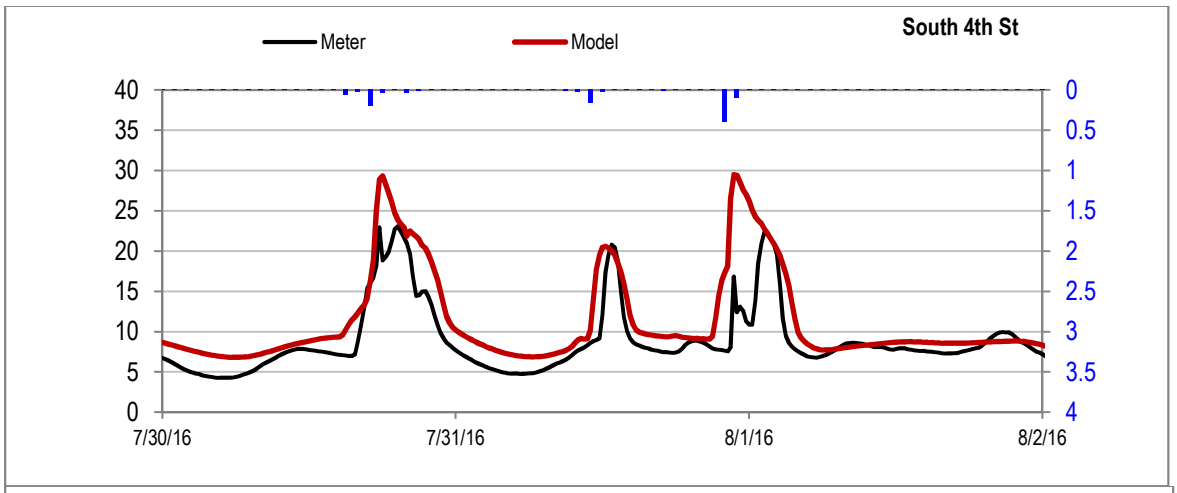

EastNewark
Meter
Model
10
9
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
EastNewark
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
EastNewark
Meter
Model
10
9
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

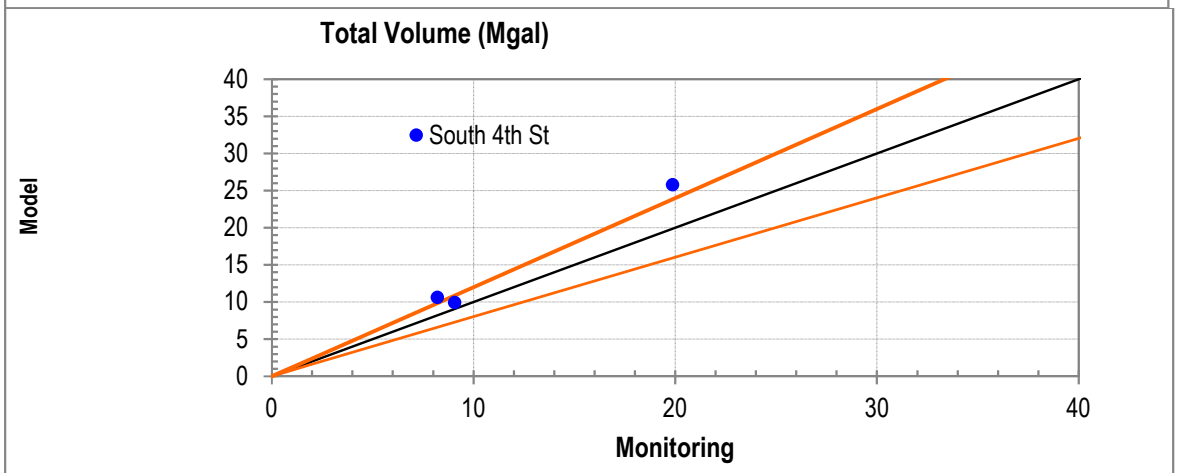

EastNewark
Meter
Model
10
9
8
7
6
5
4
3
2
1
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
JohnstonAve.
Monitoring
Peak Flow (15-min, MGD)
Model
JohnstonAve.
Monitoring

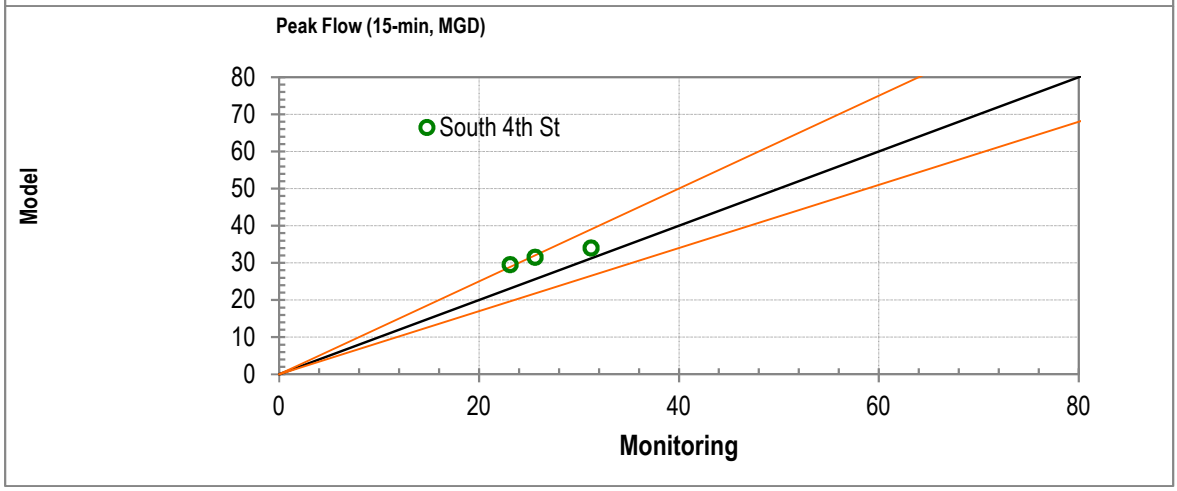

HamiltonSt
Meter
Model
20
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
HamiltonSt
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
HamiltonSt
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

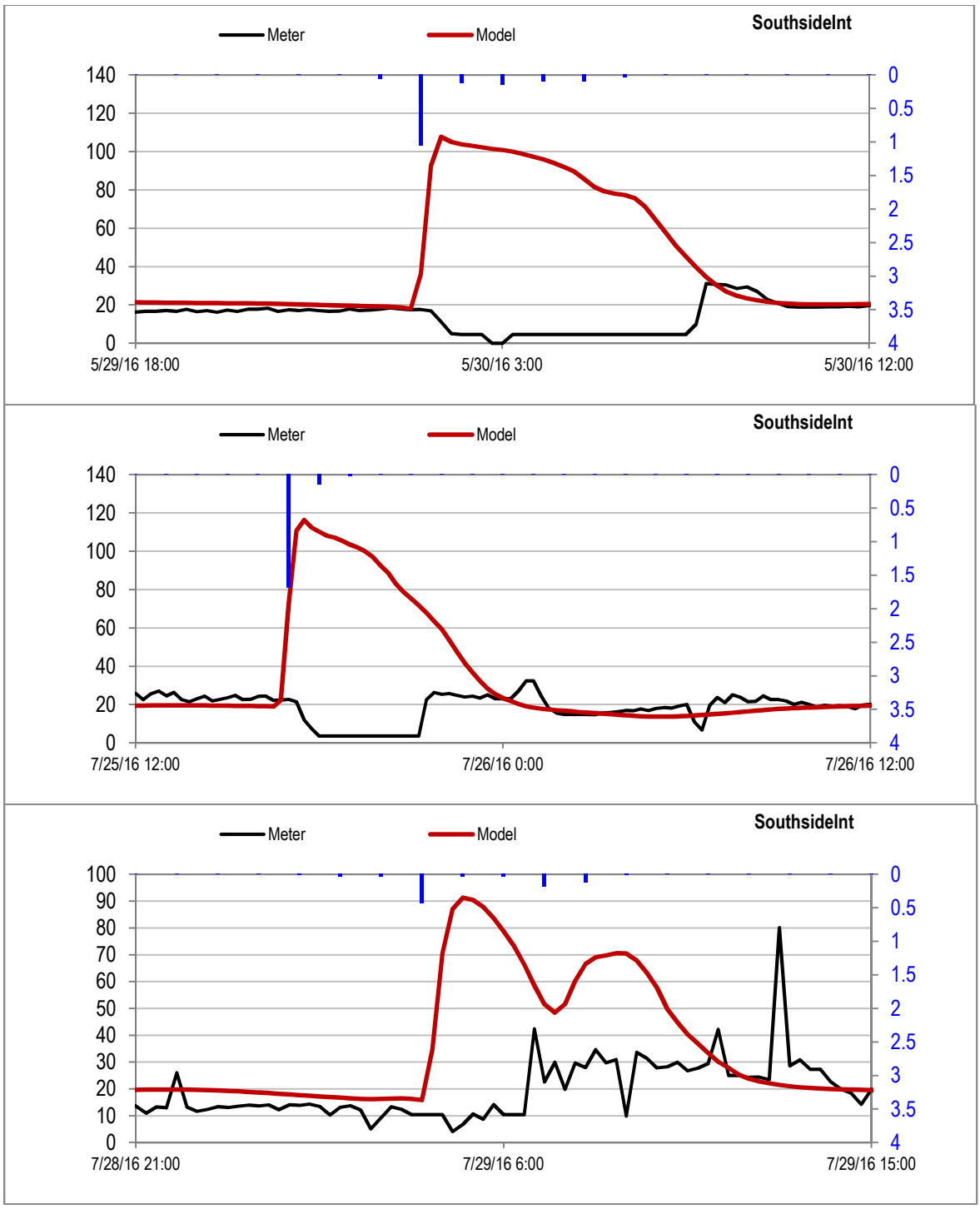

HamiltonSt
Meter
Model
20
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
HamiltonSt
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
Monitoring
Peak Flow (15-min, MGD)
Model
HamiltonSt
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
Monitoring

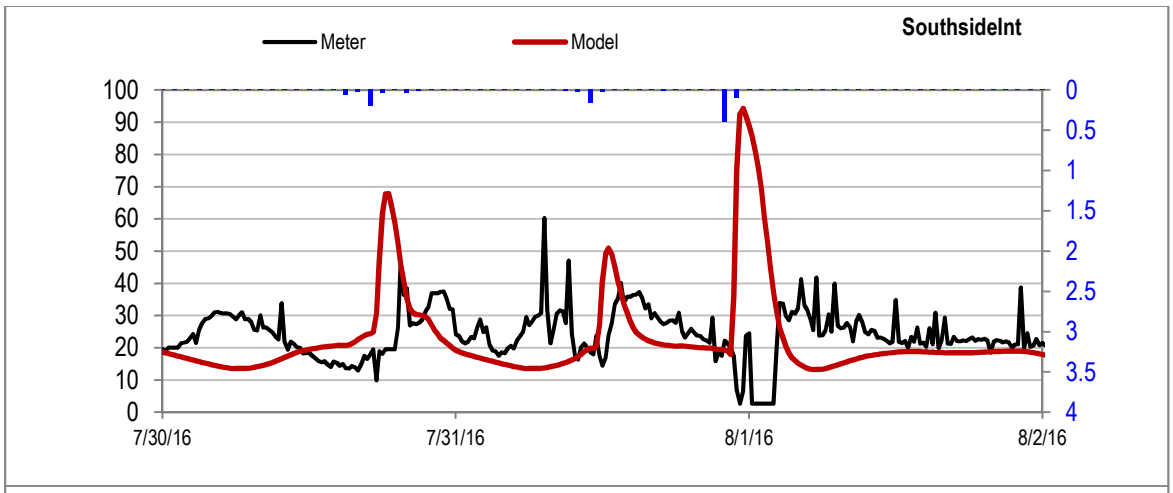

South 4th St
Meter
Model
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
South 4th St
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
South 4th St
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

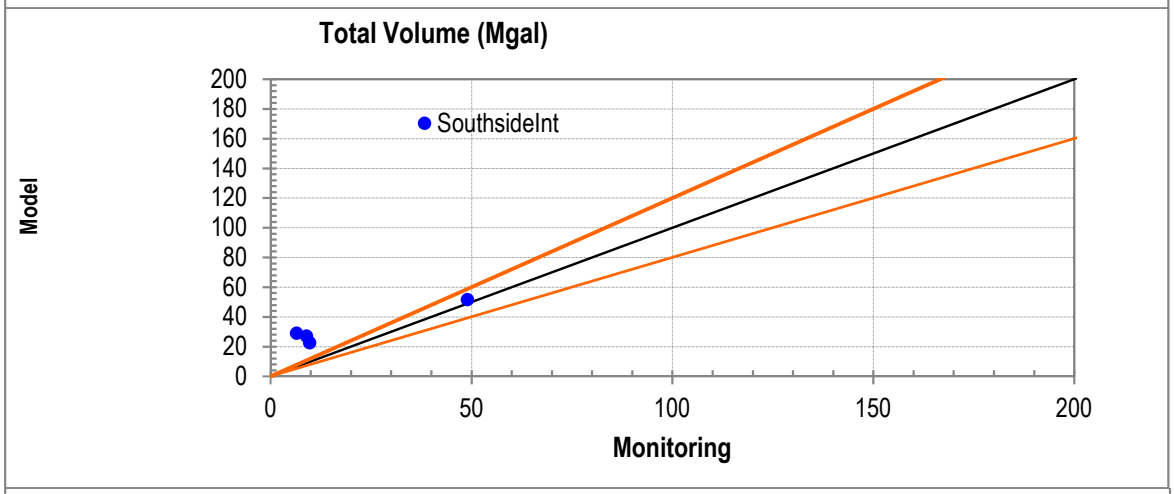

South 4th St
Meter
Model
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

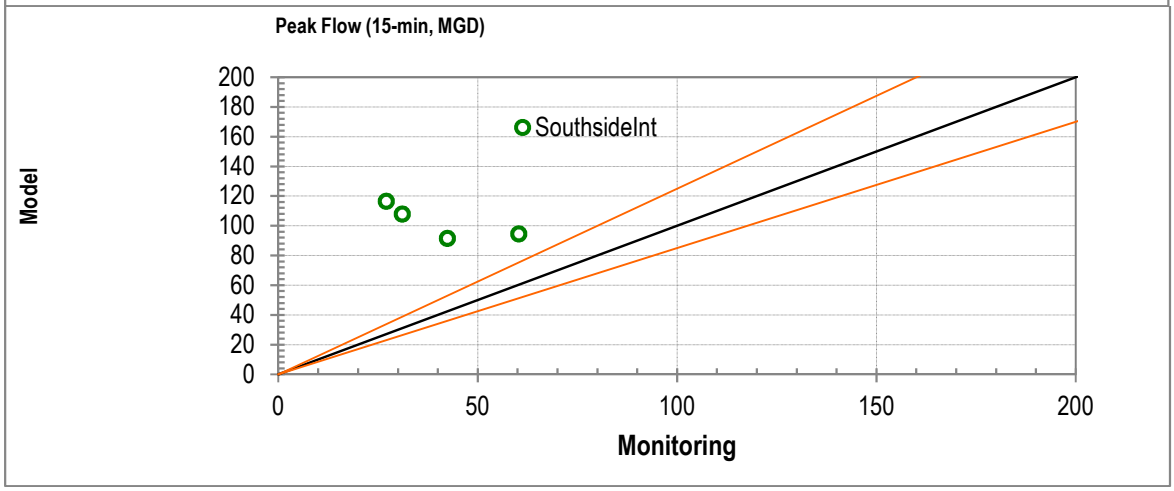

Total Volume (Mgal)
Model
South 4th St
40
35
30
25
20
15
10
5
0
0
10
20
30
40
Monitoring

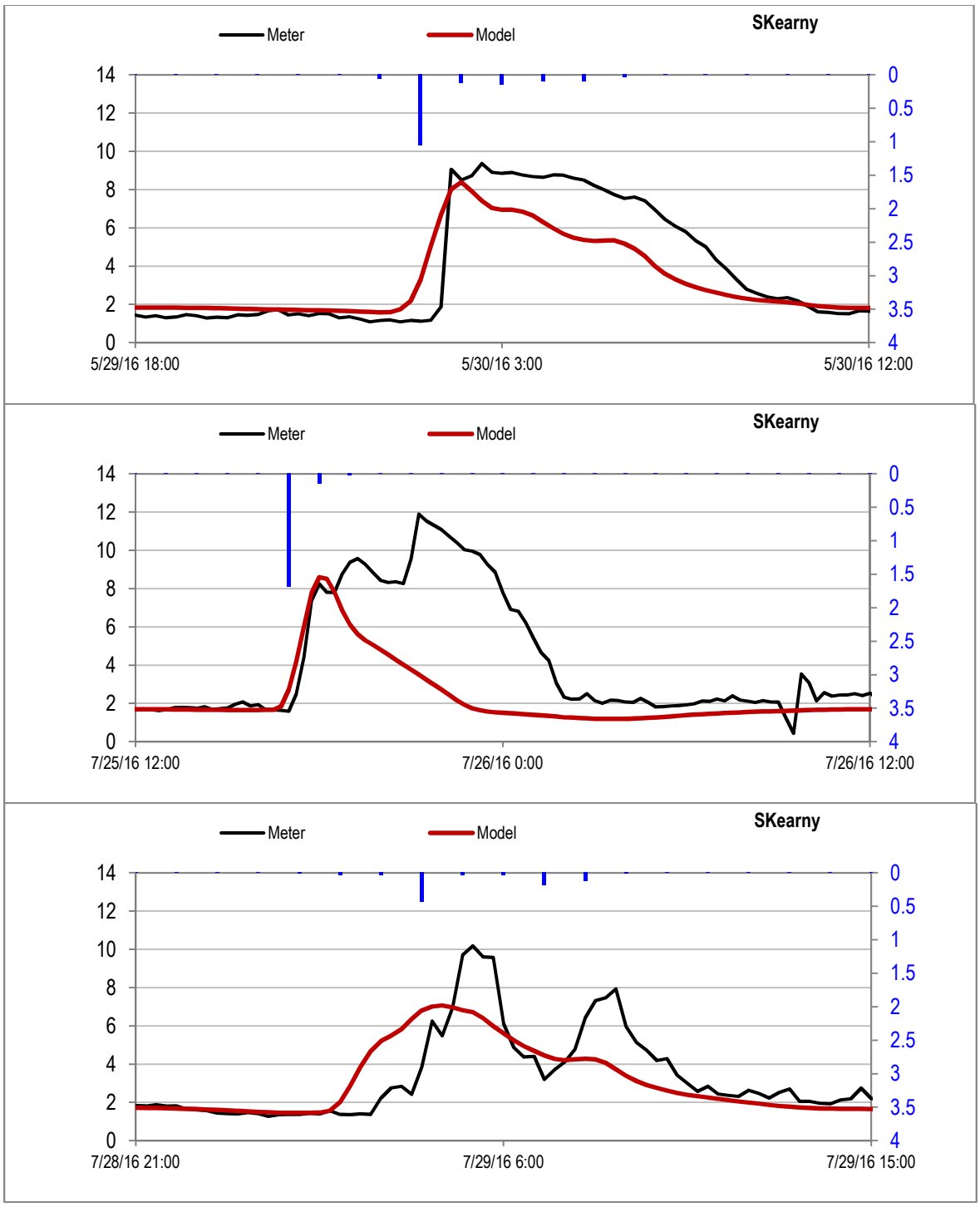

Peak Flow (15-min, MGD)
Model
South 4th St
80
70
60
50
40
30
20
10
0
0
20
40
60
80
Monitoring

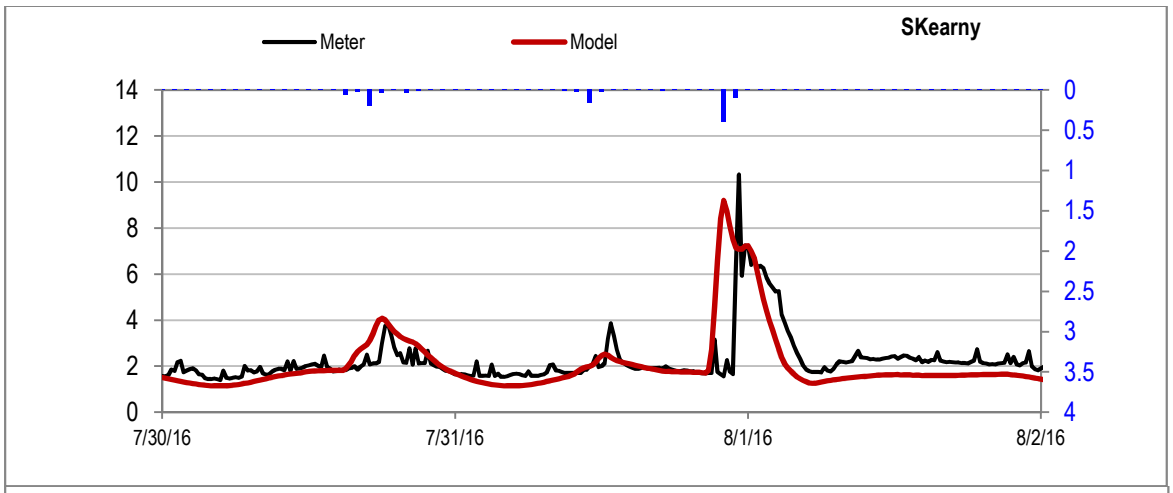

SouthsideInt
Meter
Model
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
SouthsideInt
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
SouthsideInt
Meter
Model
100
90
80
70
60
50
40
30
20
10
0
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

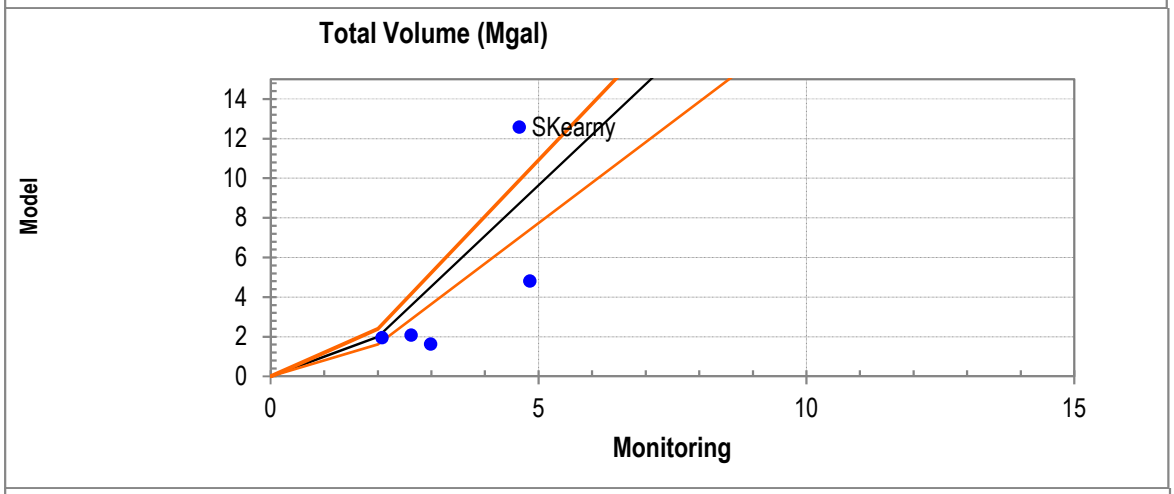

SouthsideInt
Meter
Model
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

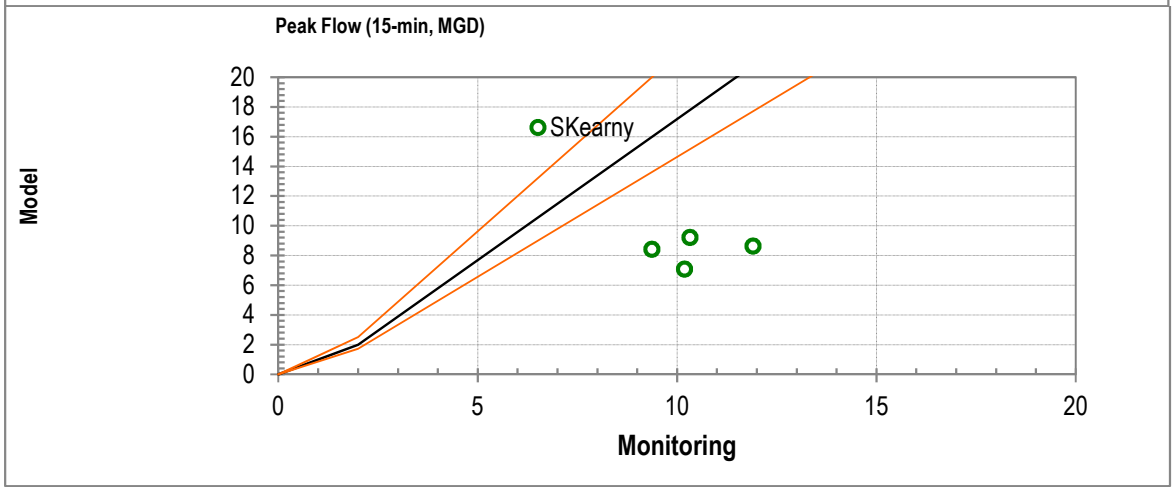

Total Volume (Mgal)
Model
SouthsideInt
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Monitoring

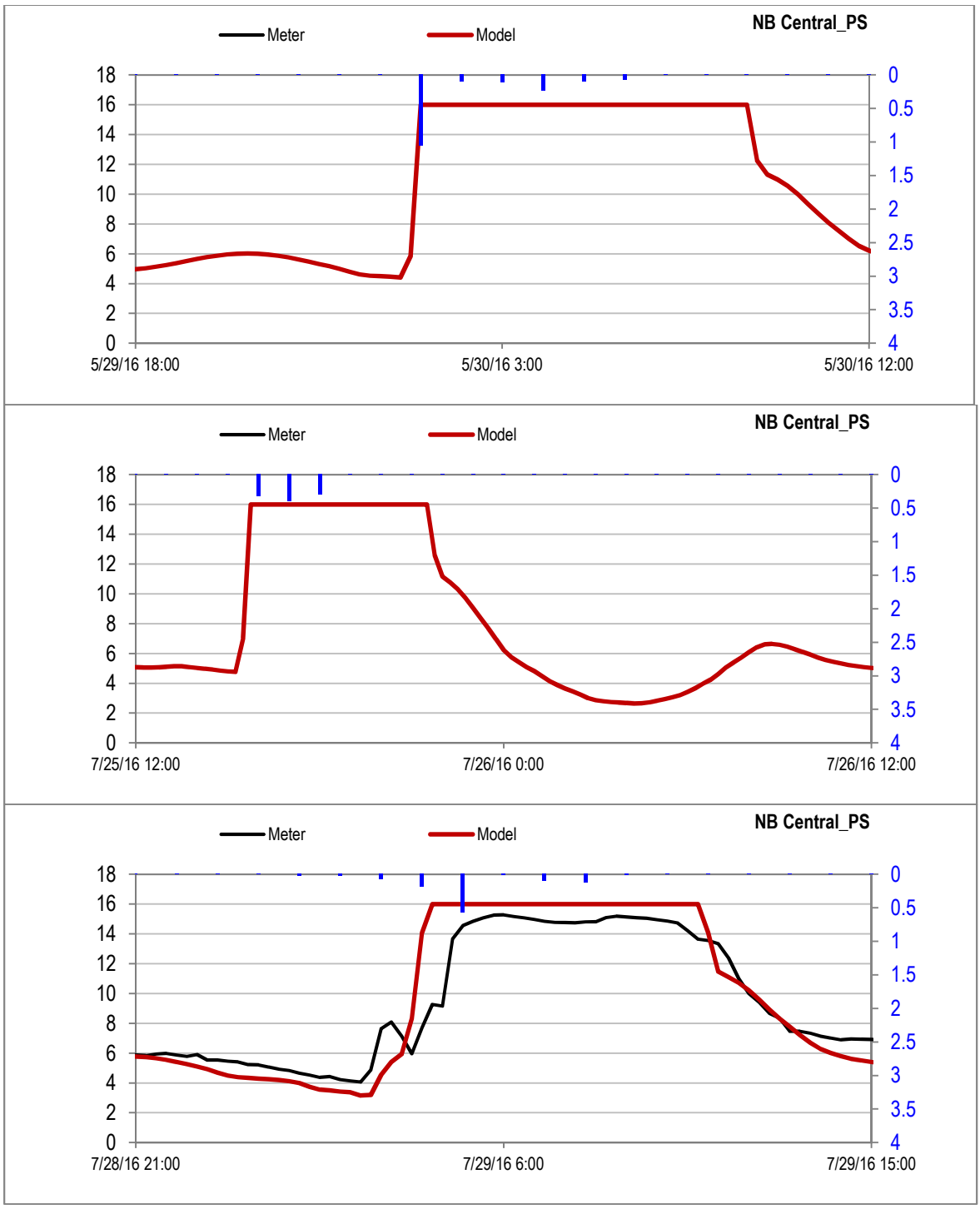

Peak Flow (15-min, MGD)
Model
SouthsideInt
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Monitoring

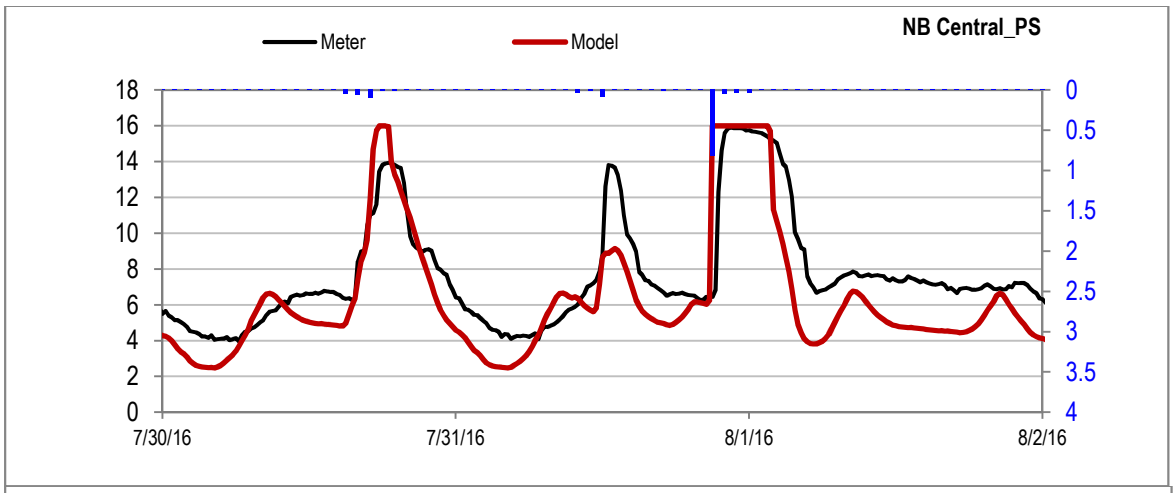

SKearny
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
SKearny
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
SKearny
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

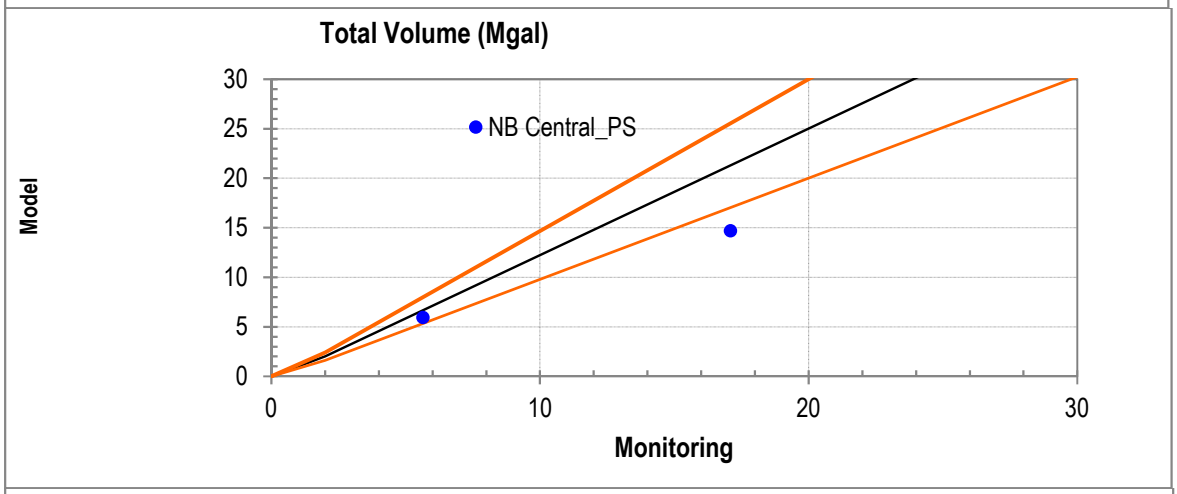

SKearny
Meter
Model
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

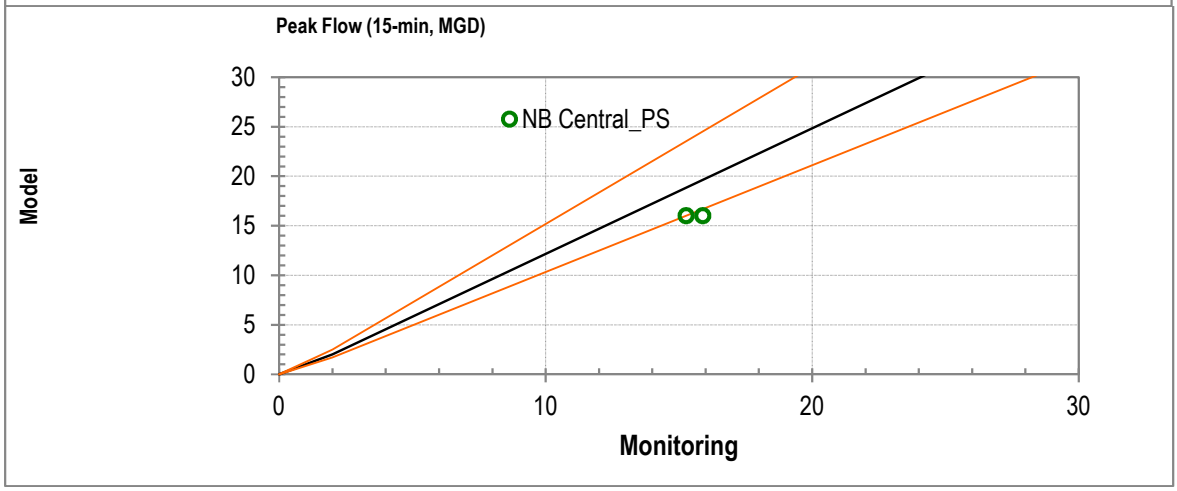

Total Volume (Mgal)
Model
SKearny
14
12
10
8
6
4
2
0
0
5
10
15
Monitoring

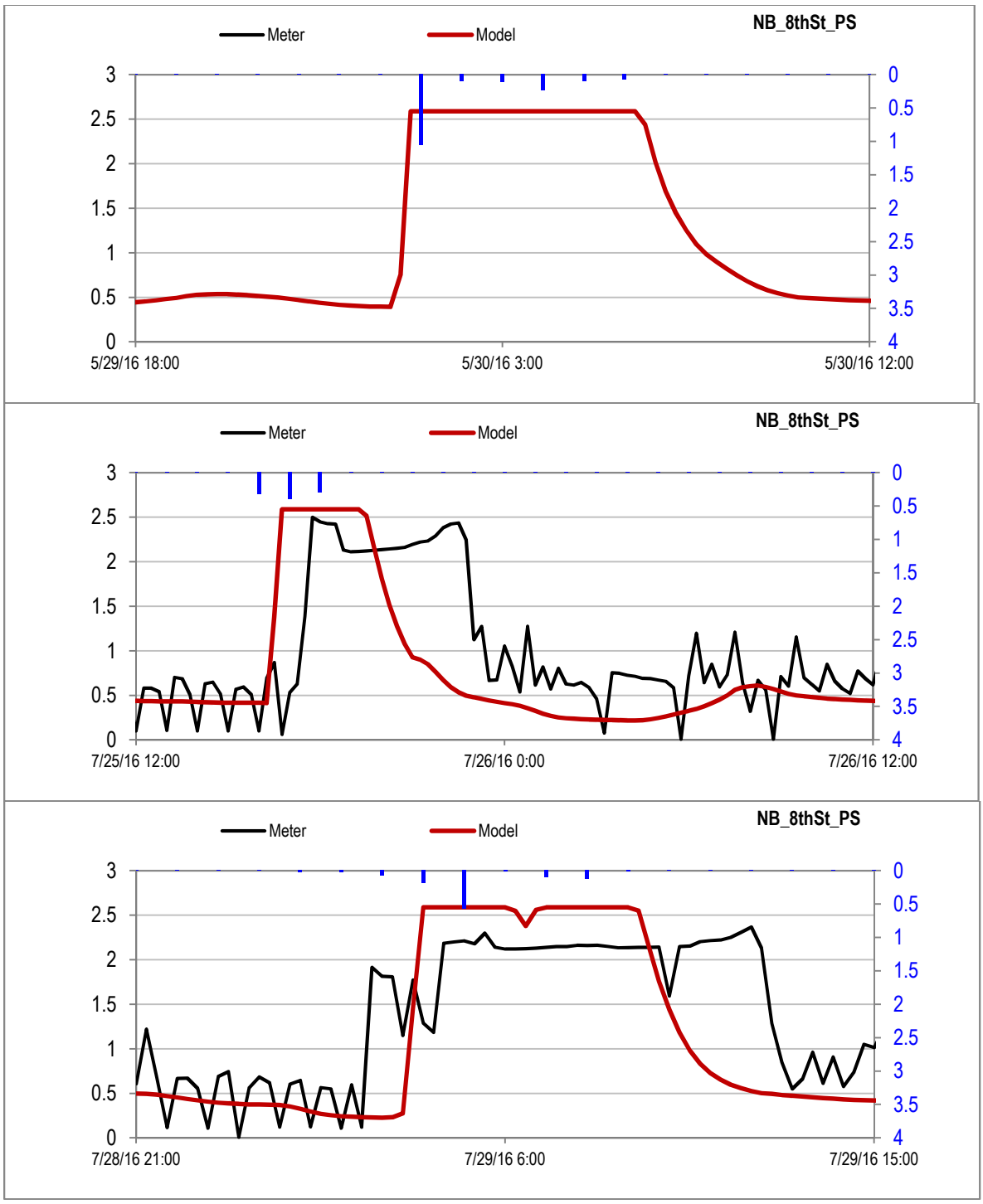

Peak Flow (15-min, MGD)
Model
SKearny
20
18
16
14
12
10
8
6
4
2
0
0
5
10
15
20
Monitoring

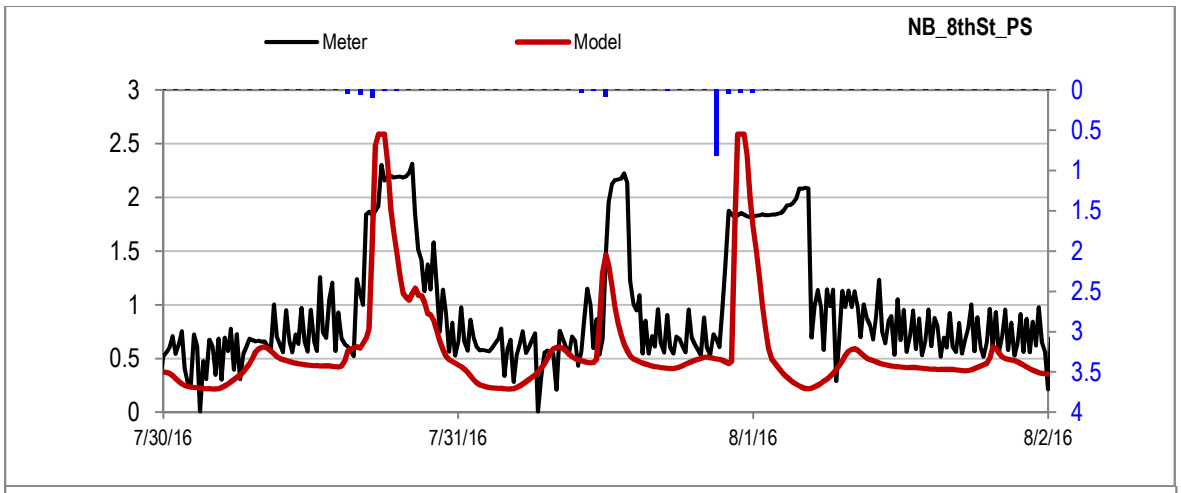

NB Central_PS
Meter
Model
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NB Central_PS
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
NB Central_PS
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

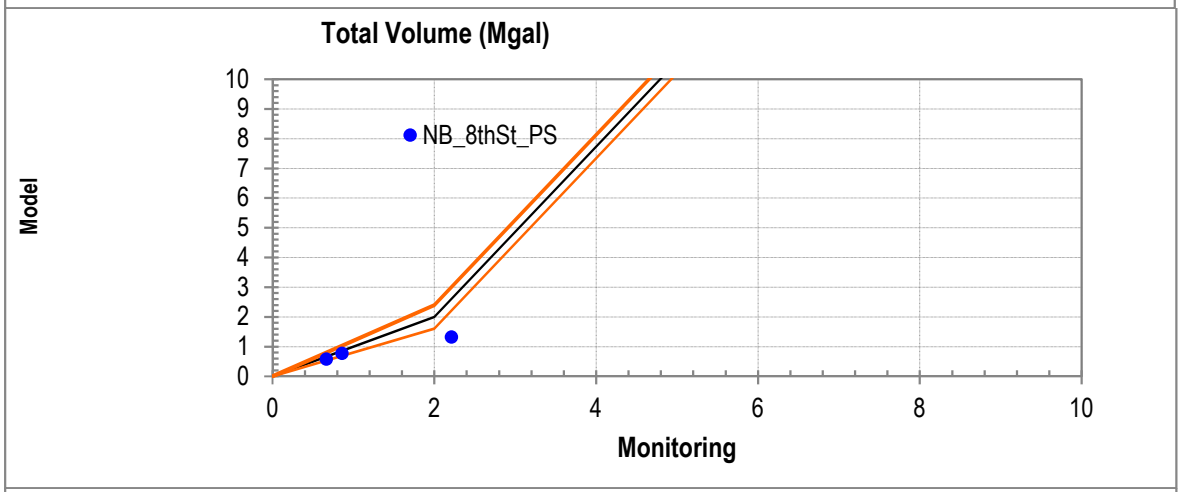

NB Central_PS
Meter
Model
18
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

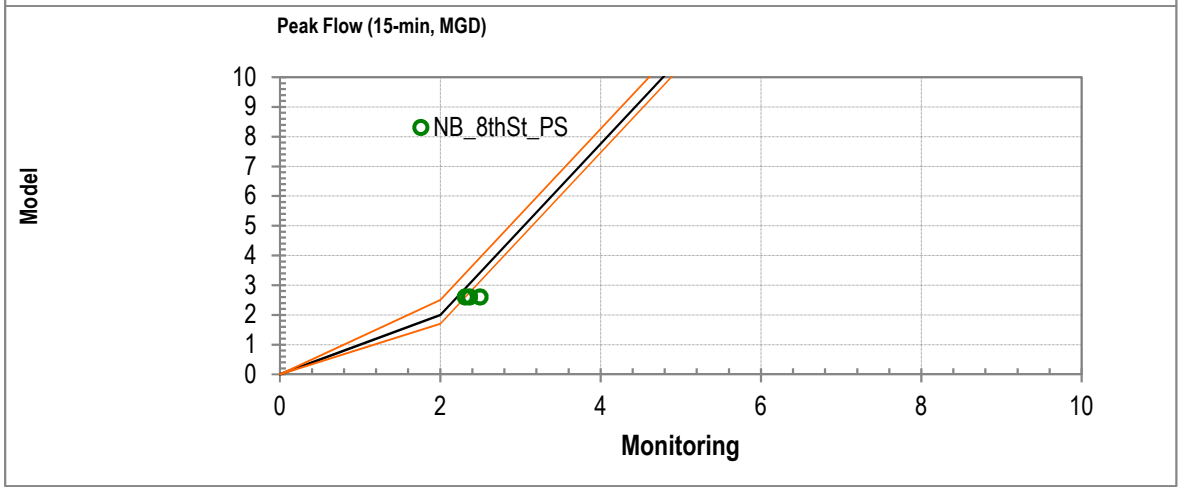

Total Volume (Mgal)
Model
NB Central_PS
30
25
20
15
10
5
0
0
10
20
30
Monitoring

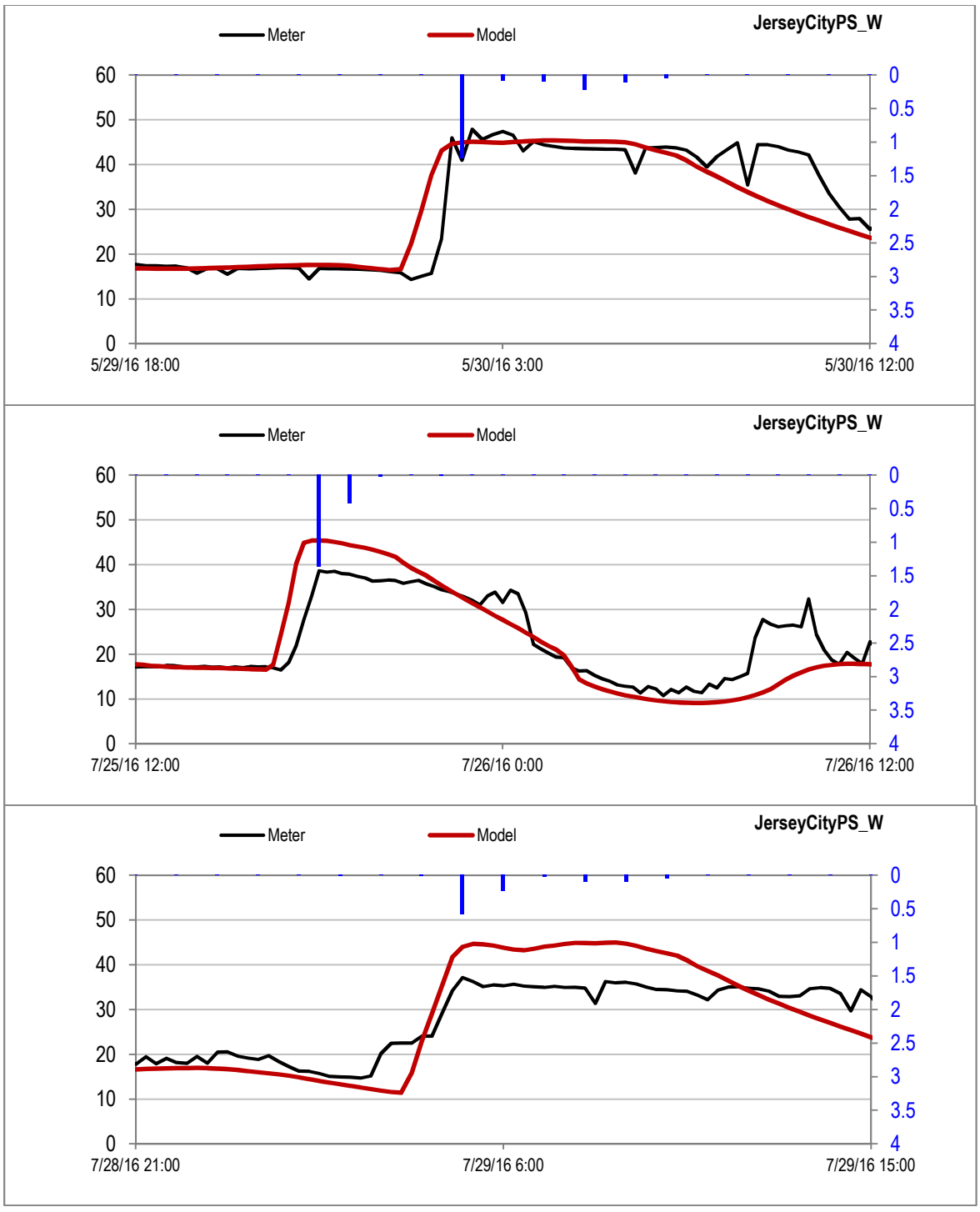

Peak Flow (15-min, MGD)
Model
NB Central_PS
30
25
20
15
10
5
0
0
10
20
30
Monitoring

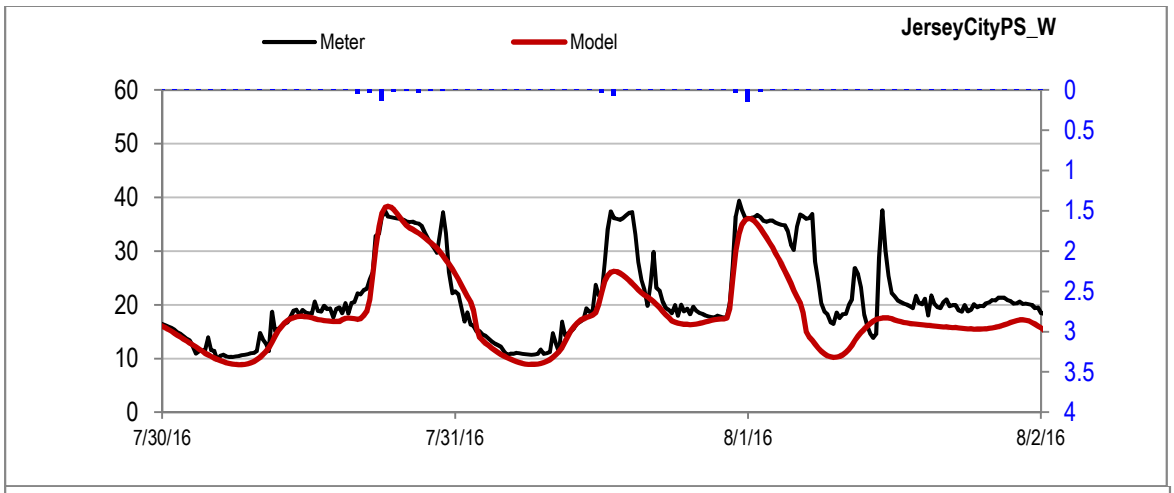

NB_8thSt_PS
Meter
Model
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
NB_8thSt_PS
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
NB_8thSt_PS
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

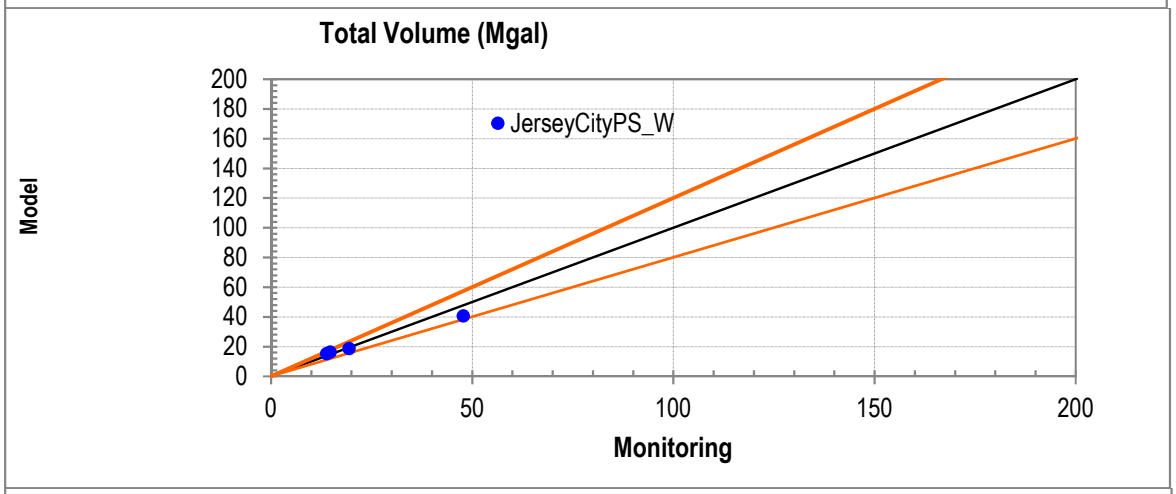

NB_8thSt_PS
Meter
Model
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

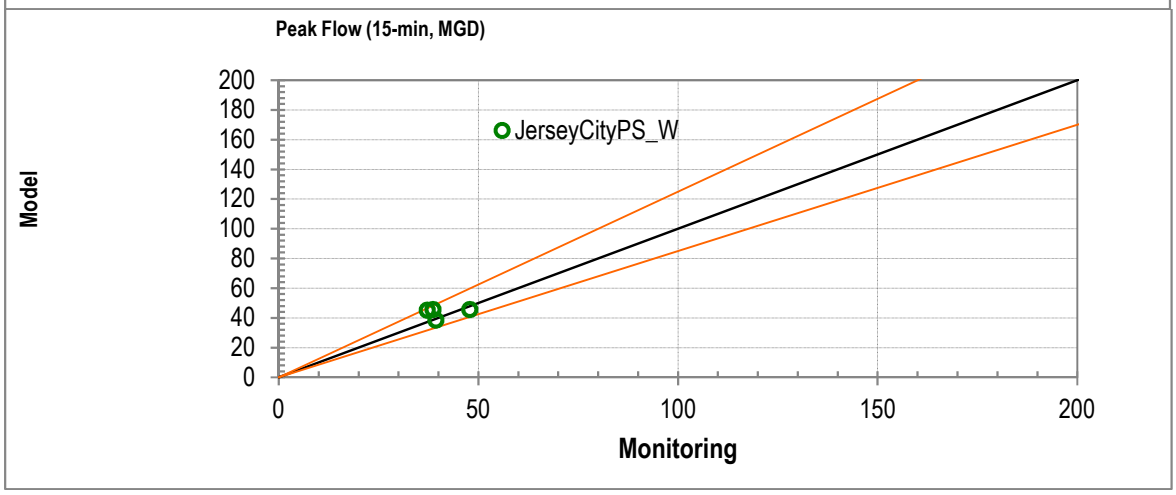

Total Volume (Mgal)
Model
NB_8thSt_PS
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

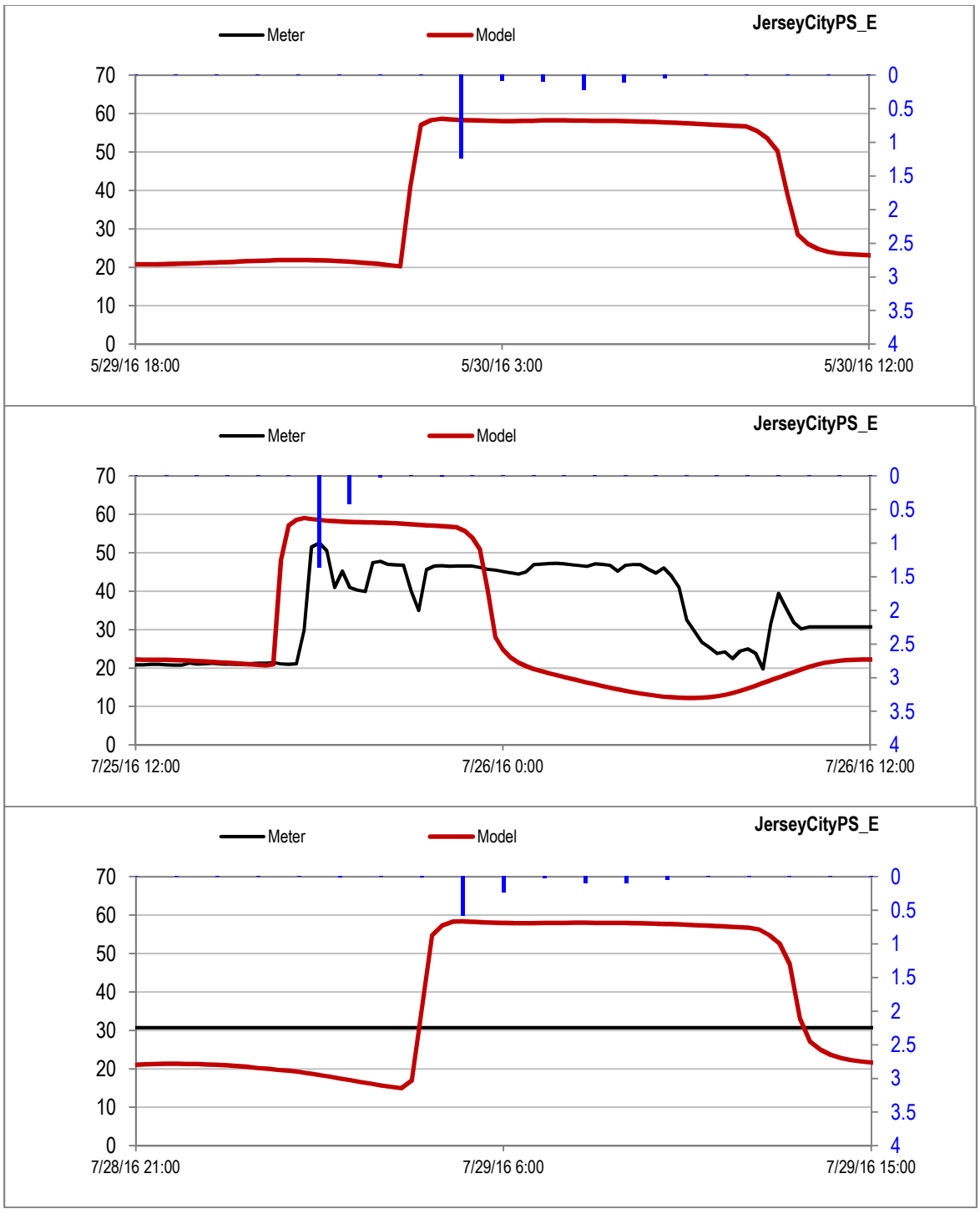

Peak Flow (15-min, MGD)
Model
NB_8thSt_PS
10
9
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
Monitoring

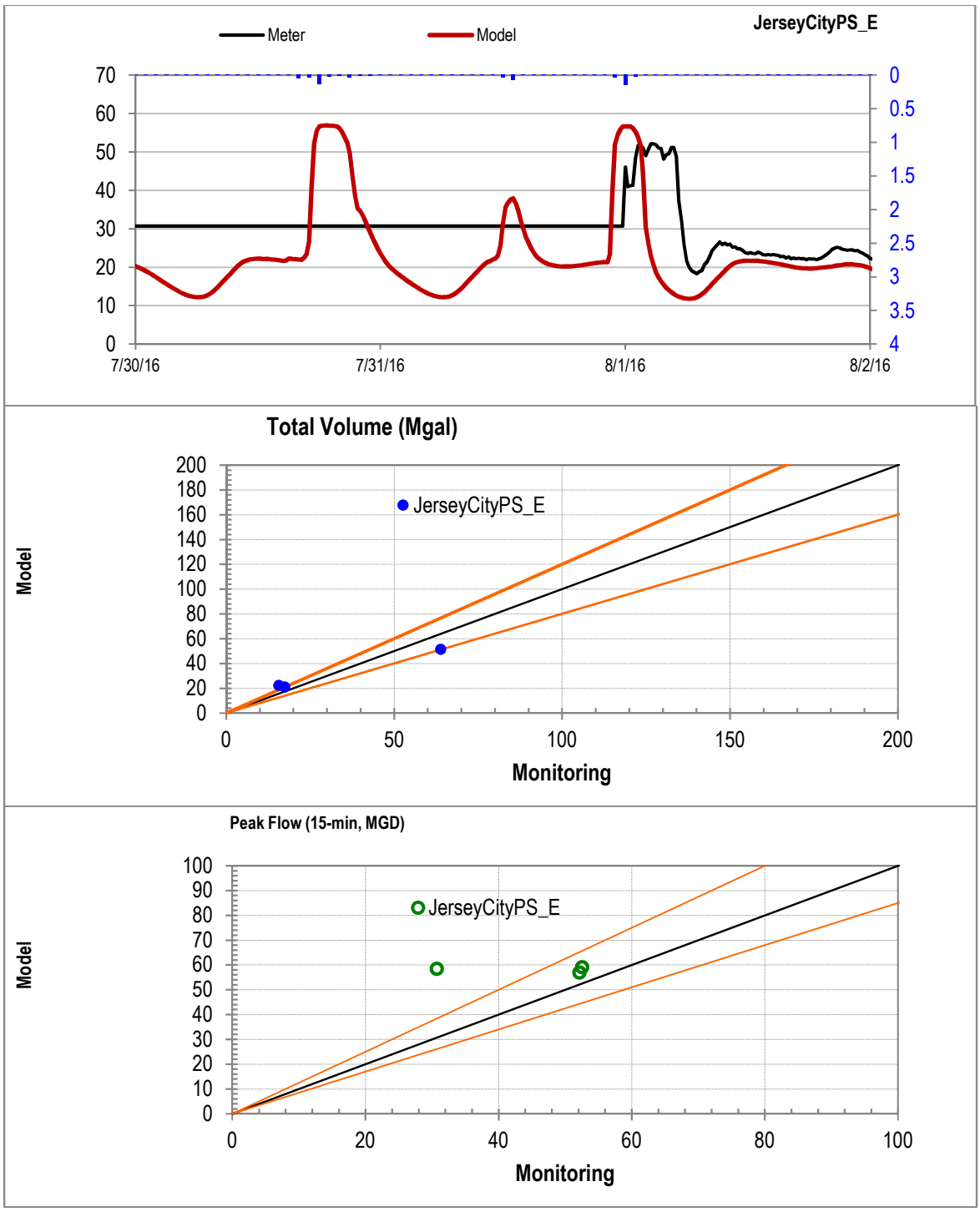

Meter
Model
JerseyCityPS_W
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Meter
Model
JerseyCityPS_W
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Meter
Model
JerseyCityPS_W
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

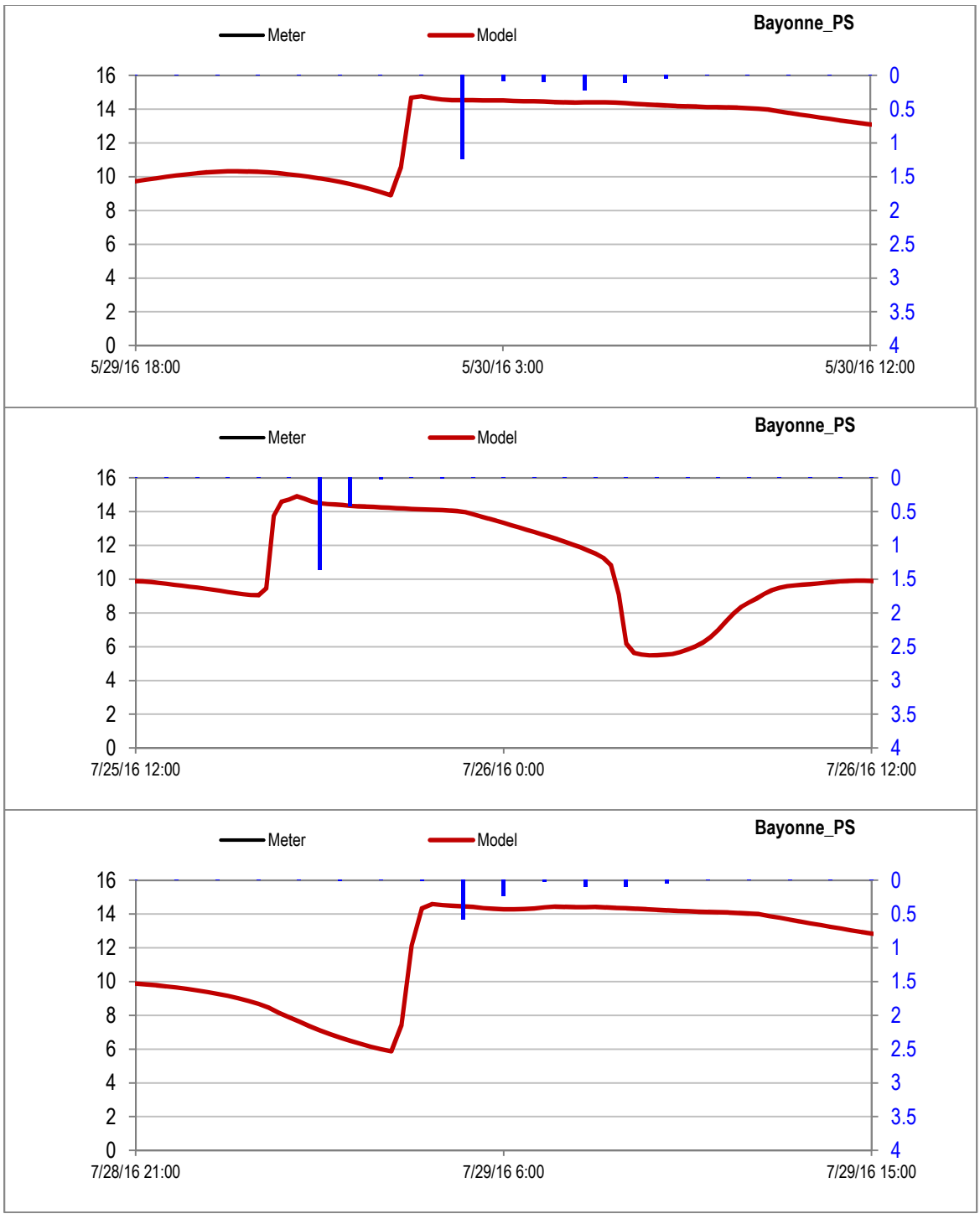

JerseyCityPS_W
Meter
Model
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16

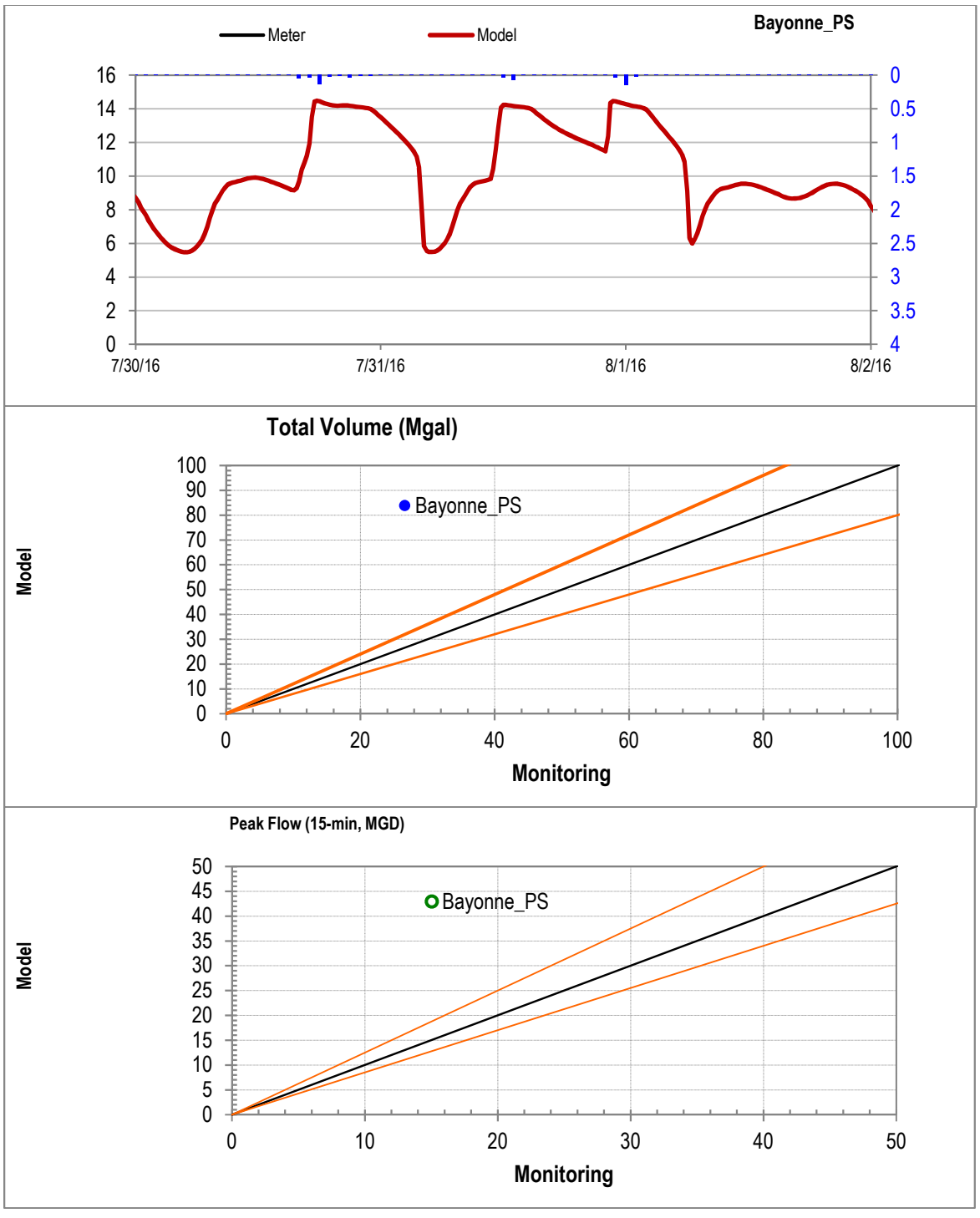

Total Volume (Mgal)
Model
JerseyCityPS_W
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Monitoring

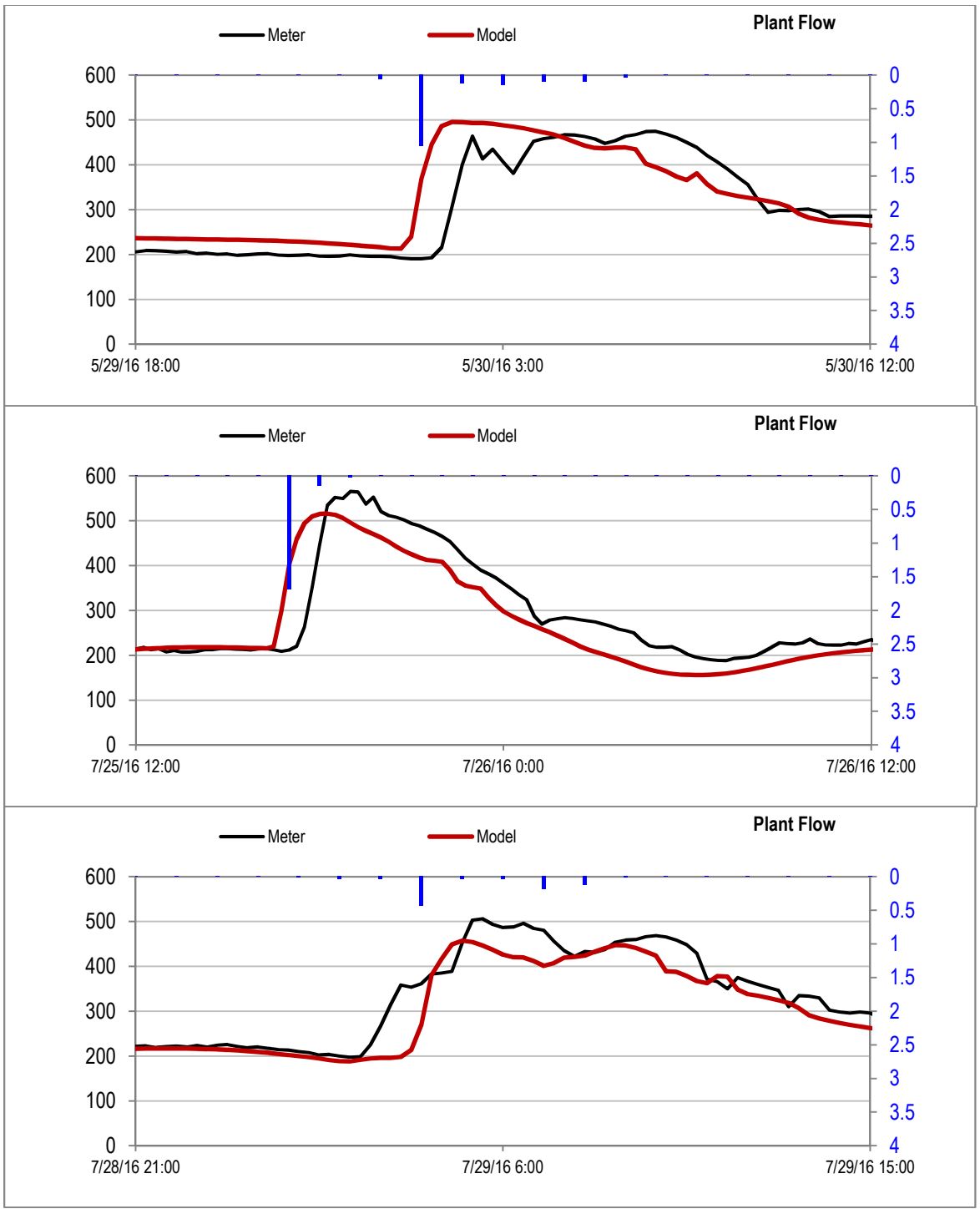

Peak Flow (15-min, MGD)
Model
JerseyCityPS_W
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Monitoring

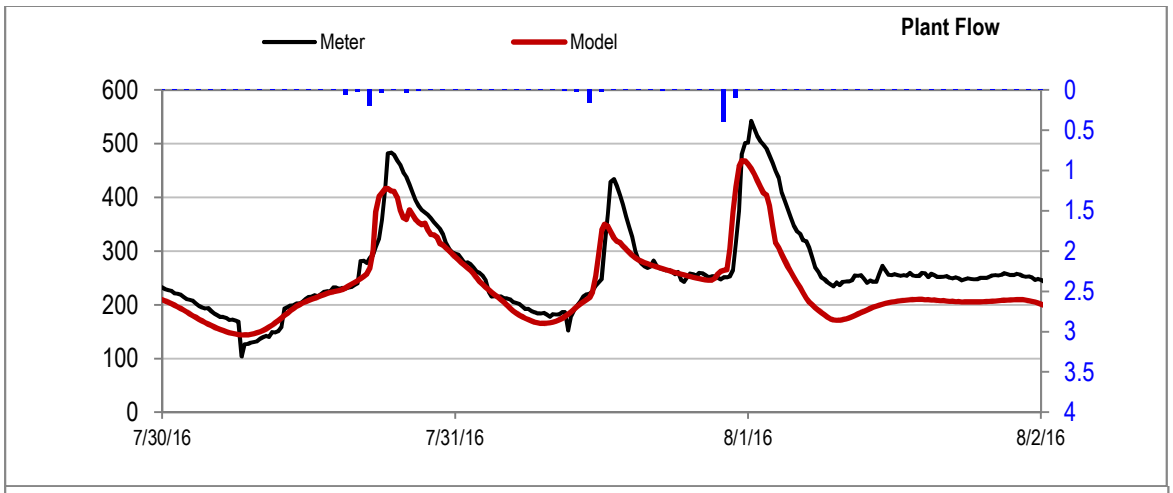

JerseyCityPS_E
Meter
Model
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
JerseyCityPS_E
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
JerseyCityPS_E
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00

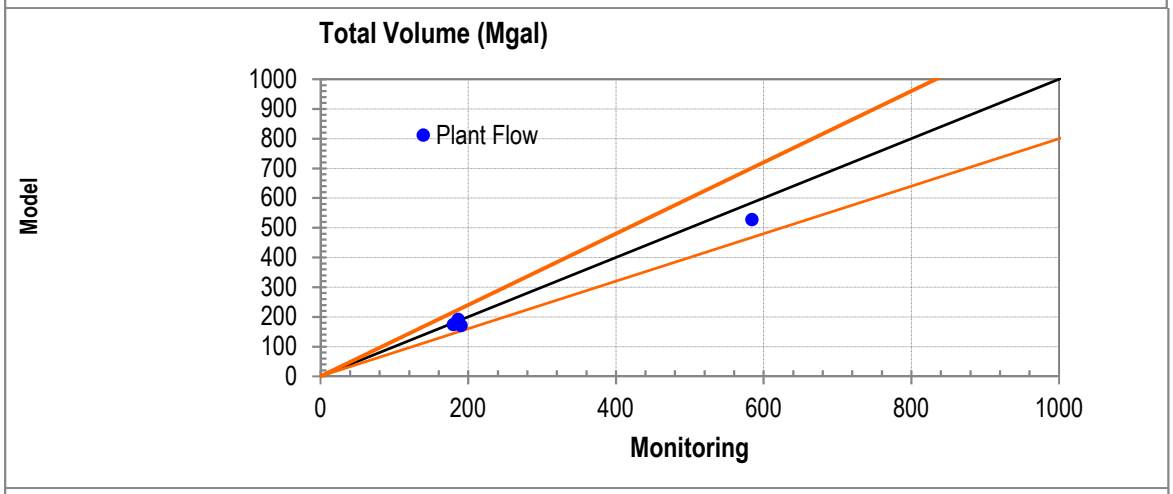

Meter
Model
JerseyCityPS_E
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
JerseyCityPS_E
200
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
Monitoring
Peak Flow (15-min, MGD)
Model
JerseyCityPS_E
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
Monitoring

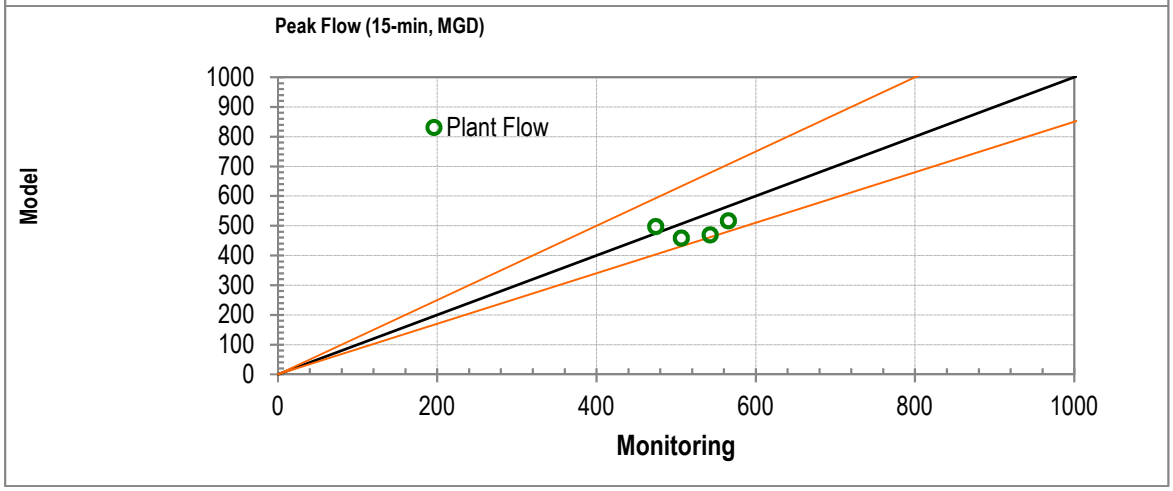

Bayonne_PS
Meter
Model
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Bayonne_PS
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Bayonne_PS
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00


Meter
Model
Bayonne_PS
16
14
12
10
8
6
4
2
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16
Total Volume (Mgal)
Model
Bayonne_PS
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
Monitoring
Peak Flow (15-min, MGD)
Model
Bayonne_PS
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
Monitoring


Plant Flow
Meter
Model
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
4
5/29/16 18:00
5/30/16 3:00
5/30/16 12:00
Plant Flow
Meter
Model
7/25/16 12:00
7/26/16 0:00
7/26/16 12:00
Plant Flow
Meter
Model
7/28/16 21:00
7/29/16 6:00
7/29/16 15:00


Plant Flow
Meter
Model
600
500
400
300
200
100
0
0
0.5
1
1.5
2
2.5
3
3.5
4
7/30/16
7/31/16
8/1/16
8/2/16


Total Volume (Mgal)
Model
Plant Flow
1000
900
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
Monitoring


Peak Flow (15-min, MGD)
Model
Plant Flow
1000
900
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
Monitoring

APPENDIX E

NJDEP Comment Letter
Dated October 9, 2018

State of New Jersey

PHIL MURPHY
Governor

SHEILA OLIVER
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Mail Code – 401-02B
Water Pollution Management Element
Bureau of Surface Water Permitting
P.O. Box 420 – 401 E State St
Trenton, NJ 08625-0420
Phone: (609) 292-4860 / Fax: (609) 984-7938

CATHERINE R. McCABE
Commissioner

October 9, 2018

To: Distribution List

Re: Technical Comments on "Service Area System Characterization Report"

Passaic Valley Sewage Commission, NJPDES Permit No. NJ0021016
Bayonne City Municipal Utilities Authority, NJPDES Permit No. NJ0109240
Borough of East Newark, NJPDES Permit No. NJ0117846
Town of Harrison, NJPDES Permit No. NJ0108871
Town of Kearny, NJPDES Permit No. NJ0111244
City of Newark, NJPDES Permit No. NJ0108758
North Bergen Municipal Utilities Authority, NJPDES Permit No. NJ0108898
City of Paterson, NJPDES Permit No. NJ0108880

Dear Permittees:

Thank you for your submission dated June 2018 as submitted cooperatively by Passaic Valley Sewage Commission with the above referenced permittees. The New Jersey Department of Environmental Protection (the Department or NJDEP) acknowledges that all the above permittees have committed to a single, coordinated Long Term Control Plan where this report represents all the above permittees for the purposes of permit compliance.

The New Jersey Pollutant Discharge Elimination System (NJPDES) Combined Sewer Overflow (CSO) permit, at Part IV.D.1.b, requires submission of a certification by the CSO permittees indicating concurrence with the System Characterization Report. This issue is discussed in the Department's letter of August 16, 2018 as submitted to your attention. The Department notes that the June 2018 report does not include signed certifications for all the above referenced permittees and for Jersey City MUA. Please note that this permit requirement is not considered fulfilled until this issue is addressed.

A work plan was submitted for the System Characterization Report on December 29, 2015 for the Borough of East Newark, the Town of Harrison, the Town of Kearny, the City of Newark, the City of Paterson and PVSC for which the Department provided comments on February 16, 2016. A revised work plan submission was dated March 16, 2016 and was approved by the Department on March 30, 2016. A separate work plan was submitted for the System Characterization Report on December 28, 2015 for the Bayonne Municipal Utilities Authority, North Bergen MUA and PVSC for which the Department provided comments on April 11, 2016. Revised submissions were dated March 17, 2016, April 21, 2016 and May 4, 2016. The work plan was approved by the Department on August 1, 2016.

This letter serves to provide technical comments on your submission.

Overall Objectives of the Sewer System Characterization

The required information for the Sewer System Characterization is included in the NJPDES CSO permit at Combined Sewer Management (CSM) Part IV.G.1. In order to provide a backdrop to some of the technical issues identified in this letter, the Department would like to note the objectives of modeling in relation to the Sewer System Characterization as contained in EPA's Guidance for Long-Term Control Plans (EPA 832-B-95-002). Specifically, once the model is calibrated and verified, the primary objectives of Combined Sewer System (CSS) modeling applications include:

- To predict overflow occurrence, volume, and, in some cases, quality for rain events other than those which occurred during the monitoring phase. These can include a storm event of large magnitude (long recurrence period) or numerous storm events over an extended period of time.

- To predict the performance of portions of the CSS that have not been extensively monitored.

- To develop CSO statistics, such as annual number of overflows and percent of combined sewerage captured as described in the CSO Control Policy.

- To optimize CSS performance as part of Nine Minimum Control (NMC) implementation. In particular, modeling can assist in locating storage opportunities and hydraulic bottlenecks and demonstrate that system storage and flow to the POTW are maximized.

- To evaluate and optimize control alternatives, from simple controls described under the NMC to more complex controls proposed in a municipality's LTCP. An example of a simple control would be to raise weir heights to increase in-line storage. The model can be used to evaluate the resulting reductions in CSO volume and frequency.

NJDEP Technical Review

In light of the above objectives, the Department's comments are as follows:

General Comments

Comment 1: Section G.4, Page 100, Sewer System Quality Results. The report states:

> "An analysis of the data indicated that the measured stormwater concentrations were similar in the various land-use areas, so the data were combined to represent stormwater in general."

Was this true for all sampled locations? Was there any further adjustment? Was there any further evaluation of the representativeness of the stormwater data? Was there an attempt to use literature values and see how they compare with measured data? Please provide all raw stormwater data in tabular format that formed the basis for Table G-4. Also, Enterococci results are significantly higher as compared to Fecal Coliform and/or E. coli. Please provide some discussion as how these values compare to literature values.

Comment 2: Section I, Page 115, Hydrologic and Hydraulic Modeling. This section discusses models' integration. However, no detailed model calibration/validation information was provided for the individual systems. For example, the discussion focused on the PVSC Interceptor Model and assumes all individual landsides models developed for the collection system are successfully calibrated and

validated. Please provide a detailed discussion with supporting model calibration and validations for all CSO affected PVSC Municipalities.

Comment 3: Section I.2.6, Page 136, Model Evaluation Group (MEG) Review. Please provide a copy of the MEG's comments in the appendix and how these comments were addressed. Also, did the MEG review the final modeling results?

Comment 4: Section I.3.2, Page 143, Subcatchment. Please expand upon Table I-6 with all sub-catchments input parameters for the modeled areas. The table should include the following parameters: Surface Area, Basin Width, Percent Impervious and Directly Connected Impervious Area (Effective Impervious), Land Slope, Manning's Roughness Coefficients, Infiltration Coefficients and Depression Storage.

Comment 5: Figure I-39, Page 175, Correlation between Rainfall Depth and CSO Overflow Volume. Some of the correlations presented exhibit large variation, (e.g., Paterson and Harrison). Was this due to correlating all CSO outfalls within a Municipality in one graph? Please provide a graph depicting site specific correlation between Rainfall Depth and CSO Overflow for each CSO outfall. Also, please provide discussion and justification for assuming accepted model performance.

Comment 6: Table I-12, Page 176. The table does not provide the duration of overflows. The main objective of running the H&H model is to quantify volume, frequency and duration of discharge, please refer to the permit requirement at Part IV.G.1.d.iii. Also, in the last sentence below the table, it is stated that the duration for each discharge can be found in the monthly discharge monitoring reports (DMRs) report. This statement is confusing and should be deleted since these results are for the typical year which predated any DMR data.

Comment 7: CSO overflow volume as estimated for the typical year 2004, with an average rainfall depth of 48.37 inches, is significantly less than the previously estimated CSO volume in historic studies for the typical year 1988 with a significantly less rainfall depth. Please provide clarification on how and why there is such a discrepancy in the estimated CSO volumes. It is suggested that you re-run the model using the 1988 rainfall with the updated model, provide the results, and provide a comparison analysis.

Comment 8: Part IV.G.1.b of the permit requires a thorough review of the entire collection system that conveys flows to the PVSC System, including areas of sewage overflows. Therefore, the report must include a discussion of areas that are prone to flooding based on observed and reported incidents, including dates of occurrence, type of storm events that caused the flooding, and antecedent conditions, if known.

Comment 9: Please provide a pie chart depicting the total runoff generated from the PVSC combined sewer area and assumed water loss, i.e., water budget. For example, please provide estimated quantities of the total runoff, volume diverted to the combined sewer, direct runoff to nearby receiving waterbodies, evaporation, infiltration, etc.

Specific Comments

Comment 10: Section E.3, Page 67, Dry Weather Flow (DWF) Analysis. Figure E-2 shows a graphical representation of the DWF for just the Paterson Interceptor. However, the report cites that the overall and monthly DWFs for all monitoring sites were analyzed. Please include the results of these analysis in tabular format for all the monitoring sites in the final report.

Comment 11: Section E.4, Page 69, Wet Weather Flow Analysis. While the methodology used to quantify the wet weather flow is acceptable, the report does not provide a sufficient detailed analysis of the wet weather flow at all monitoring stations. Please include in the appendix all monitoring stations where wet weather flow analyses were conducted.

Comment 12: Section E.5, Page 70, Wet Weather Event Selection for Model Calibration and Validation Flow Analysis. Table E-2, outlines the rainfall events used in the model calibration/validation. First, specify the location of the rain gauges of these rainfall events as to whether they were based on Newark Airport or on other gage stations. Secondly, please clarify how these rainfall events compare to rainfall captured at other stations within the system.

Comment 13: Section E.5, Page 70, Wet Weather Event Selection for Model Calibration and Validation Flow Analysis. Further justification is needed for selecting the July 31, 2016 rainfall event. This event has the longest duration, 14 hours; however, both rainfall depth and average intensity are extremely low compare to other shorter events - in fact, this event resulted in zero flow at certain locations. It is recommended that the July 29, 2016 rainfall event be used as the long duration event and add one of the events listed in Table E-4, for short duration, i.e., July 16, 2016 or July 9, 2016. In addition, can any of the rainfall events, e.g., June 6, 2016, listed in the Baseline Compliance Monitoring Program (BCMP) report on Page 32, Table 12 be used for the landside model calibration/validation?

Comment 14: Section E.9, Page 73, Collection of PVSC Water Resources Recovery Facility Operational Data Regarding the PVSC flow data during the period of model calibration/validation, please present the data in tabular format, if possible.

Comment 15: Section E.10, Page 73 Summary. The summary states that "The Newark Airport rain gauge was analyzed to determine which wet weather events would be used for model calibration." Please provide an example or further justification on how these analyses were performed as the report does not provide such information.

Comment 16: Section F.2, Page 76, Pollutants of Concern in the Receiving Waters. Please add "fresh water tributaries" next to the E. coli indicator for Newark and Upper New York Bay.

Comment 17: Section F.4.6, Page 80 Designated Uses and Water Quality Criteria from NJ Code. Please specify which part of the Passaic River these impairments are listed for. For example, list impairments by specific waterbody, i.e., Upper Passaic River near Paterson, Lower Passaic River and so on.

Comment 18: Table F-6, Page 92. Under the column entitled "Designated Uses", please be advised that an SE1 classification does not always mean the waterbody is designated for shellfishing. Even if an SE1 waterbody is specifically designated for shellfishing, the pathogen criteria will be much more stringent than primary contact criteria.

Comment 19: Section G.3.3, Page 97, Sewer System Quality Sampling. The report states that:

> "The original Quality Assurance Project Plan (QAPP) targeted 18 CSO and 8 stormwater locations, distributed throughout the PVSC region by municipality and land use. See **Figure G-1** for an overview of the sampling locations. The goal of the sampling protocol was to obtain three wet-weather events of sufficient depth, intensity, and duration for valid model calibration at each targeted location…"

And then, states that:

> "…only one of the 18 CSO locations was successfully sampled three times, and four of the targeted CSO locations were not sampled at all due to access or other logistical issues."

Please add a short discussion, or reference to other sections of the report as to how the lack of such data been addressed and the model was successfully calibrated and validated.

Comment 20: Section G.3.6, Page 99-100, System Characterization and Landslide Modeling QAPP Goals. Please ensure that the listed objectives of the system characterization and modeling agrees with these objectives outlined in the Work Plan and as stated above.

Comment 21: Section G.4, Page 100, Sewer System Quality Results. The report states:

> "The CSO data will be used to verify the CSO concentrations calculated by using a combination of sewer system model output and estimated sanitary and stormwater pathogen concentrations. This "Mass Balance Approach" will be used to estimate pathogen loading from CSOs in the receiving water model."

Does the above statement suggest that final estimates of CSO loadings will not be provided until after successfully calibrating and validating the receiving water model? If so, comparison analysis of the derived loadings against literature values must be performed to ensure accurateness and/or representativeness of the final loading estimates.

Comment 22: Section G.4.1, Page 100-101, Plant Influent Sampling and Results. The report states that fecal coliform and E. coli showed seasonal variation. How was this addressed in the model development?

Comment 23: Section I.1.1, Page 117-118, PVSC Interceptor Model. On page 117, the report states that the model did not include the Hudson County Force Main. However, on page 118, it states that:

> "Sewers collected from its collection system are conveyed to the wet well at the Bayonne Pump Station at the Oak Street and pumped to the Hudson County Force Main, which conveys the combined flows from the Jersey City, the North Bergen and Bayonne to the PVSC WRRF for treatment…"

Please provide more clarification.

Comment 24: Section I.3.2, Page 148, Manning's "n" Roughness Coefficients. The report states initial values were set to 0.02 for impervious surfaces and 0.05 for pervious surfaces. Please provide the final values used after successful model calibration and a comparison to the range of acceptable literature values.

Comment 25: Section I.5.2, Page 158, Wet Weather Calibration. The report states that the acceptable range for simulated wet weather flow volume is within -20% to +20%. Please justify your selection of this range. Dry weather simulated flow will be within 10% of observed flow which is consistent with the value outlined in the report.

Comment 26: Section I.5.2, Page 160-182, Wet Weather Calibration. The report states that not all wet weather events selected for model calibration were eventually used. For example, on page 169, it states:

"1. Monitored data was not available for an extended portion of the May 29th, 2016 event. Therefore, this event was not considered during model calibration.
2. The monitored data for the July 29th, 2016 and July 30th, 2016 events also has some missing or periods of zero flow. The calibration effort for this site focused on matching peak flows and the hydrograph pattern."

Was there an attempt to use other rainfall events that may result in a better calibration? This question also pertains to the calibration plots on pages 170, 171, and 172. Also, some of the simulated total volume and peak flow (specifically page 163 – calibration plot for PVSC Interceptor WRRF) are mostly underpredicting. Please provide additional discussion as to how this was addressed in calculating the final total volume.

Comment 27: Table I-13, Page 180, Percent Capture. This section should be omitted from this report as it is more applicable in the Development and Evaluation of Alternatives Report, which is to be submitted on July 1, 2019.

Comment 28: Appendix A, Combined Sewer Overflow and Stormwater Sampling Results. Please provide the data in excel format as well.

Please incorporate these changes to the report and submit a revised version to the Department no later than 60 days from the date of this letter.

Thank you for your continued cooperation.

Sincerely,

Dwayne Kobesky
CSO Team Leader
Bureau of Surface Water Permitting

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Teresa Guloy, Bureau of Surface Water Permitting
Susan Rosenwinkel, Bureau of Surface Water Permitting
Joe Mannick, Bureau of Surface Water Permitting
Tim Ebersberger, Bureau of Nonpoint Pollution Control

Finizio, Marlene

From: Kobesky, Dwayne <Dwayne.Kobesky@dep.nj.gov>
Sent: Thursday, December 06, 2018 2:59 PM
To: McKenna, Bridget; Hope, Michael; Rosenwinkel, Susan; Mannick, Joe; Kempel, Nancy
Cc: Eley, Marques; Sheldon S. Lipke (slipke@SJLConsultants.com); mwitt; Finizio, Marlene; Fang, Yuan; Gibby, Eloise; Dupuis, Timothy J.; David Ksyniak (ksyniakda@cdmsmith.com)
Subject: RE: [EXTERNAL] RE: [EXTERNAL] Technical Comments on the Service Area System Characterization Report

Hi Bridget,

In response to your request for an extension of time, the Department is granting you your request of a 45 day extension to resubmit the System Characterization Reports for the PVSC District and the North Bergen MUA/Guttenberg District Reports to address the comments received from the MEG.

Please let me know if you have any questions.

Dwayne

From: McKenna, Bridget <BMcKenna@PVSC.COM>
Sent: Thursday, December 6, 2018 8:14 AM
To: Kobesky, Dwayne <Dwayne.Kobesky@dep.nj.gov>; Hope, Michael <mhope@greeley-hansen.com>; Rosenwinkel, Susan <Susan.Rosenwinkel@dep.nj.gov>; Mannick, Joe <Joe.Mannick@dep.nj.gov>; Kempel, Nancy <Nancy.Kempel@dep.nj.gov>
Cc: Eley, Marques <MEley@PVSC.COM>; Sheldon S. Lipke (slipke@SJLConsultants.com) <slipke@SJLConsultants.com>; mwitt <mwitt@chasanlaw.com>; Finizio, Marlene <mfinizio@greeley-hansen.com>; Fang, Yuan <yfang@greeley-hansen.com>; Gibby, Eloise <egibby@greeley-hansen.com>; Dupuis, Timothy J. <dupuistj@cdmsmith.com>; David Ksyniak (ksyniakda@cdmsmith.com) <ksyniakda@cdmsmith.com>
Subject: RE: [EXTERNAL] RE: [EXTERNAL] Technical Comments on the Service Area System Characterization Report

Good morning,
PVSC held its 4th MEG meeting yesterday. As a result of comments received from the MEG members, PVSC is respectfully requesting a 45 day extension to resubmit the System Characterization Reports for the PVSC District and the North Bergen MUA/Guttenberg District Reports to address the comments received yesterday.
Should you have any questions regarding this request or require additional information please call or email me.
Thanks very much,
Bridget

Bridget M. McKenna | Chief Operating Officer
Passaic Valley Sewerage Commission | 600 Wilson Avenue | Newark, New Jersey 07105
(P) 973-817-5976 | (F) 973-817-5709 | email: bmckenna@pvsc.com

---

From: Kobesky, Dwayne [mailto:Dwayne.Kobesky@dep.nj.gov]
Sent: Wednesday, December 05, 2018 9:15 AM

To: Hope, Michael <mhope@greeley-hansen.com>; Rosenwinkel, Susan <Susan.Rosenwinkel@dep.nj.gov>; Mannick, Joe <Joe.Mannick@dep.nj.gov>; Kempel, Nancy <Nancy.Kempel@dep.nj.gov>
Cc: McKenna, Bridget <BMcKenna@PVSC.COM>; Eley, Marques <MEley@PVSC.COM>; Sheldon S. Lipke (slipke@SJLConsultants.com) <slipke@SJLConsultants.com>; mwitt <mwitt@chasanlaw.com>; Finizio, Marlene <mfinizio@greeley-hansen.com>; Fang, Yuan <yfang@greeley-hansen.com>; Gibby, Eloise <egibby@greeley-hansen.com>; Dupuis, Timothy J. <dupuistj@cdmsmith.com>; David Ksyniak (ksyniakda@cdmsmith.com) <ksyniakda@cdmsmith.com>
Subject: [EXTERNAL] RE: [EXTERNAL] Technical Comments on the Service Area System Characterization Report

Hi Mike,

Thank you. Receipt confirmed.

Dwayne

From: Hope, Michael <mhope@greeley-hansen.com>
Sent: Tuesday, December 4, 2018 5:09 PM
To: Rosenwinkel, Susan <Susan.Rosenwinkel@dep.nj.gov>; Kobesky, Dwayne <Dwayne.Kobesky@dep.nj.gov>; Mannick, Joe <Joe.Mannick@dep.nj.gov>; Kempel, Nancy <Nancy.Kempel@dep.nj.gov>; DEP NJCSOProgram <NJCSOProgram@dep.nj.gov>
Cc: McKenna, Bridget <BMcKenna@PVSC.COM>; Eley, Marques <MEley@PVSC.COM>; Sheldon S. Lipke (slipke@SJLConsultants.com) <slipke@SJLConsultants.com>; mwitt <mwitt@chasanlaw.com>; Finizio, Marlene <mfinizio@greeley-hansen.com>; Fang, Yuan <yfang@greeley-hansen.com>; Gibby, Eloise <egibby@greeley-hansen.com>; Dupuis, Timothy J. <dupuistj@cdmsmith.com>; David Ksyniak (ksyniakda@cdmsmith.com) <ksyniakda@cdmsmith.com>
Subject: RE: [EXTERNAL] Technical Comments on the Service Area System Characterization Report

Good afternoon.

We are in receipt of the New Jersey Department of Environmental Protection's (NJDEP's) letter, dated October 9, 2018, which transmitted technical comments on the Service Area System Characterization (Report) for the Passaic Valley Sewerage Commission (PVSC) and the Permittees within the PVSC Sewer District. Comment No. 1 and Comment No. 28 have requested the combined sewer overflow and stormwater sampling data to be provided in Microsoft Excel format.

Attached and in response to these comments, on behalf of PVSC and the Permittees within the PVSC Sewer District, please find the requested combined sewer overflow and stormwater data in Microsoft Excel format.

Please note that the revised Report in order to address the remaining NJDEP's comments as transmitted in the above referenced letter will be sent under a separate email.

Thank you,

GREELEY AND HANSEN
Michael J. Hope, P.E.
Managing Director
1700 Market Street, Suite 2130
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P: 215.553.7917
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From: Kobesky, Dwayne [mailto:Dwayne.Kobesky@dep.nj.gov]
Sent: Tuesday, October 09, 2018 2:52 PM
To: McKenna, Bridget <BMcKenna@PVSC.COM>; boroughofeastnewark@verizon.net; Newark - Adebowale, Andrea <Adebowalea@ci.newark.nj.us>; 'fmargron@patersonnj.gov' <fmargron@patersonnj.gov>; 'tboyle@baynj.org' <tboyle@baynj.org>; rrussomanno@townofharrison.com; 'Smith, Robert J.' <rsmith@kearnynj.org>; Fpnbmua <fpnbmua@aol.com>
Cc: Rosenwinkel, Susan <Susan.Rosenwinkel@dep.nj.gov>; Alebus, Marzooq <Marzooq.Alebus@dep.nj.gov>; Guloy, Teresa <Teresa.Guloy@dep.nj.gov>; Mannick, Joe <Joe.Mannick@dep.nj.gov>; Ebersberger, Timothy <timothy.ebersberger@dep.nj.gov>
Subject: [EXTERNAL] Technical Comments on the Service Area System Characterization Report

Good Afternoon,

Please find the attached Technical Comments on the Service Area System Characterization Report.

Thank you,

Dwayne Kobesky
New Jersey Department of Environmental Protection
Division of Water Quality
Bureau of Surface Water Permitting
401 East State Street, P.O. Box 420
Mail Code 401-02B
Trenton, NJ 08625-0420
(609) 292-4860
Dwayne.Kobesky@dep.nj.gov

APPENDIX F

NJDEP Comment Letter
Dated February 26, 2019

State of New Jersey

PHIL MURPHY
Governor

SHEILA OLIVER
Lt. Governor

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Mail Code – 401-02B
Water Pollution Management Element
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P.O. Box 420 – 401 E State St
Trenton, NJ 08625-0420
Phone: (609) 292-4860 / Fax: (609) 984-7938

CATHERINE R. McCABE
Commissioner

February 26, 2019

To: Distribution List

Re: Review of Revised "Service Area System Characterization Report"

Passaic Valley Sewage Commission, NJPDES Permit No. NJ0021016
Bayonne City Municipal Utilities Authority, NJPDES Permit No. NJ0109240
Borough of East Newark, NJPDES Permit No. NJ0117846
Town of Harrison, NJPDES Permit No. NJ0108871
Town of Kearny, NJPDES Permit No. NJ0111244
City of Newark, NJPDES Permit No. NJ0108758
North Bergen Municipal Utilities Authority, NJPDES Permit No. NJ0108898
City of Paterson, NJPDES Permit No. NJ0108880

Dear Permittees:

Thank you for your submission dated January 21, 2019 which contains a revised version of the "Service Area System Characterization Report" as well as a "Summary of Changes" document. The original submission was dated June 2018 and was in response to Part IV.D.3.b.ii of the above referenced NJPDES permit. The New Jersey Department of Environmental Protection (the Department or NJDEP) provided technical comments on your original submission on October 9, 2018 where this revised submission is in response to those comments. The Department acknowledges that both the original and revised submissions were made in a timely manner. This letter is written to provide a determination on your most recent submission.

The Department has conducted a technical review of your report and has the following remaining technical comments. Any comments that pertain to the October 9, 2018 document are identified as "Former NJDEP Comment" with the relevant number.

Comment 1: Section E.3, Dry Weather Flow (DWF) Analysis. The Department acknowledges that the Dry Weather Flow values for individual flow meters were included in the revised report as Figure E-4 as an average. Please acknowledge whether or not the time period for Figure E-4 corresponds with July 23, 2016 to July 31, 2016. (Former NJDEP Comment 10).

Comment 2: Section E.7, Rainfall Event Analysis; Section E.8, Wet Weather Event Selection for Model Calibration and Validation; and Section I.5.2, Wet Weather Flow Calibration/Validation. In Former NJDEP Comment 13 in the Department's October 9, 2018 letter, the selection of the July 31, 2016 rainfall event was questioned with a suggestion that the July 29, 2016 rainfall event be considered. It is unclear if the July 31, 2016 rainfall event was replaced with the July 29, 2016 and the July 30, 2016 rainfall events. Specifically, "Table E-5- Calibration and Validation Rainfall Events" in the revised version lists events from July 29, 2016 and July 30, 2016 (without July 31, 2016) as does "Table

E-2: Event Wet Weather Volume and Peak for Temporary Metering Locations" and "Table E-3: Top 10 Rainfall Events (Volume Based), 5/20/16-8/10/16". Please clarify.

Comment 3: Section I.2.7, Model Evaluation Group. The Department is aware that this subject "Service Area System Characterization Report" is one of the reports that is being reviewed by the Model Evaluation Group and acknowledges that there is a new section in the revised report (Section I.2.7) describing this review. In addition, Appendix B contains summaries and meeting minutes as well as an e-mail from the Model Evaluation Group dated March 6, 2016 regarding Session 1 as held on February 5, 2016. Please provide additional information as to whether or not any other input or formal concurrence or approval has transpired with the Model Evaluation Group regarding Session 2 (March 17, 2017), Session 3 (September 15, 2017), Session 4 (December 5, 2018), or regarding the final "Service Area System Characterization Report." (Former NJDEP Comment 3)

Comment 4: Section I.3.2, Subcatchment; Section I.3.3, Trunk sewer and Main Interceptor. On page 185 of the revised report, the following is stated:

> "A typical range of Manning's "n" suggested by the SWMM is 0.011-0.024 for impervious area and 0.05-0.80 for pervious area. The initial values were set to 0.02 for impervious surfaces and 0.05 for pervious surfaces."

The Manning's N values were included in Appendix C of the revised report as a standard value of 0.05 for pervious surfaces and 0.02 for impervious surfaces. As per Former NJDEP Comment 24, please confirm if there were any adjustments to the Manning's N values as part of the calibration/validation process. Other sections of the report suggest that adjustments were made. For example, on page 185 of the revised report, the following is stated:

> "Most of the gravity sewer mains and PVSC Interceptor in the final PVSC model were imported from the previous models during model integration. Sewer size, shape, invert, and Manning's "n" value were inherited from the previous models as well."

Whereas page 180 of the revised report states:

> "Manning's "n" and subcatchment slope are usually held constant during calibration, as adjusting these values has the same effect as adjusting W (the differing exponents mean that the response may be inverted or less pronounced, but the overall effect on the hydrograph is the same)."

Please clarify. (NJDEP Comment 24)

Comment 5: Please provide a pie chart depicting the total runoff generated for 2004 from the combined sewer areas and assumed water loss, i.e., water budget (Former Comment 9). To provide further detail on an acceptable option, this chart can be generated for the total runoff generated from the modeled combined sewer area using data exported from the existing conditions hydraulic model simulation for the 2004 representative year precipitation record. The volume of precipitation falling upon the overall combined sewer area can be partitioned into 3 broad components, which is consistent with data available through the modeling software. The total annual surface runoff volume calculated to enter the modeled collection system can be divided into a treated runoff volume and an overflow runoff volume, while the balance of the water budget outflows (i.e. losses), such as evaporation, interception, infiltration, and direct runoff to water bodies, can be classified as overall water losses. In summary, a simple pie chart showing the approximate percentage of treated runoff volume, overflow runoff volume, and water losses within the combined sewer areas would suffice.

Comment 6: Section I.6.3, Table I-13 of the revised report depicts percent capture for the 2004 Typical Year and shows 83.8% capture for PVSC Interceptor Communities; 67.2% capture for North Bergen;

and 43.64% for Bayonne. As described in Former NJDEP Comment 27, the Department objected to inclusion of this information in the July 2018 submission based on the rationale that it is more appropriate for the Development and Evaluation of Alternatives Report, which is to be submitted on July 1, 2019.

However, because this table is still included in the revised report the Department is hereby expressing its objections. The Department acknowledges that percent capture is a component of the CSO Control Policy where this section is referenced within the Presumption Approach as follows:

"ii. The elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis."

Similar language is included in the NJPDES permit at Part IV.G.4.f.ii also as one of the criteria for the Presumption Approach:

"ii. The elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a hydraulically connected system-wide annual average basis."

While an equation was not provided within Section I.6.3 of the revised report, it appears that the resultant calculation of 83.8% for the PVSC Interceptor Communities is not limited to combined sewer communities and includes separately sewered communities in the overall average. Please note the above permit language specifically references the "CSS"; therefore, any percent capture calculation that includes separately sewered communities is in direct conflict with the NJPDES permit.

Please incorporate these changes to the report and submit a revised version to the Department no later than 30 days from the date of this letter.

Thank you for your continued cooperation.

Sincerely,



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CSO Team Leader
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