East Bay Dischargers Authority

2017 Hydraulic Study

HYDRAULIC MODEL RECALIBRATION AND CAPACITY ANALYSIS

FINAL May 2018

carollo®

East Bay Dischargers Authority
2017 Hydraulic Study

TECHNICAL MEMORANDUM 1

HYDRAULIC MODEL RECALIBRATION AND CAPACITY ANALYSIS

05/02/2018

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Abbreviations

AEPS	Alvarado Effluent Pump Station
Carollo	Carollo Engineers, Inc.
CVSD	Castro Valley Sanitation District
DWF	dry weather flow
EBDA	East Bay Dischargers Authority
ft.	feet
Hayward	City of Hayward
HEPS	Hayward Effluent Pump Station
I/I	infiltration and inflow
LAVWMA	Livermore-Amador Valley Water Management Authority
MDF	Marina Dechlorination Facility
OLEPS	Oro Loma Effluent Pump Station
OLSD	Oro Loma Sanitary District
RDII	Rainfall Derived Infiltration and Inflow
SWMM	Storm Water Management Model
USD	Union Sanitary District
WPCF	Water Pollution Control Facility

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Technical Memorandum 1

HYDRAULIC MODEL RECALIBRATION AND CAPACITY ANALYSIS

1.1 Introduction

The purpose of this technical memorandum is to document the key findings of the 2017 Hydraulic Study (Project), which was conducted by Carollo Engineers, Inc. (Carollo) under the Professional Services Agreement between Carollo and the East Bay Dischargers Authority (EBDA), dated July 14, 2017.

1.2 Background

EBDA operates a system of effluent pump stations and associated force mains which collects flow from multiple wastewater agencies in the East San Francisco Bay area and discharges the treated effluent to the San Francisco Bay via a deep water diffuser. The southern portion of the transport system includes the collection of wastewater from Union Sanitary District (USD) and the City of Hayward (Hayward). USD treats its collected wastewater and discharges it to the EBDA system via the Alvarado Effluent Pump Station (AEPS) and the associated 60-inch diameter force main. The force main conveys flow from both AEPS and the Hayward Effluent Pump Station (HEPS) to the Oro Loma Effluent Pump Station (OLEPS). A portion of the flow from AEPS to OLEPS can be diverted from the force main to the Hayward Marsh. The EBDA transport system is dependent on a number of operational parameters, such as the discharge to the Hayward Marsh, operation of HEPS, and wet well levels at OLEPS. These varying operational scenarios of the system affect AEPS and HEPS conveyance capacity.

This Project's objective was to update and recalibrate EBDA's hydraulic model and to determine the capacity of certain components of the EBDA system under varying agency flow rates and operational conditions. As part of this task, available record drawings, reports, and studies were reviewed. Carollo also reviewed any recent changes to the transport system such as pump station modifications to HEPS, AEPS, or OLEPS; operational characteristics; and any other relevant modifications that have occurred since the hydraulic model of the EBDA transport system was developed as part of the 2011 System Flow Master Plan. The calibration of the model was updated to include the discharge by Hayward to the Hayward Ponds during peak wet weather events. No other significant changes to the physical or operational characteristics were noted since the completion of the 2011 System Flow Master Plan.

1.2.1 Existing System

The EBDA pipeline and outfall system discharges effluent from five agencies including USD, City of San Leandro (San Leandro), Hayward, Oro Loma Sanitary District (OLSD), and Castro Valley Sanitation District (CVSD). Livermore-Amador Valley Water Management Authority (LAVWMA) is not an EBDA member but leases system capacity from EBDA. Disinfected secondary effluent is pumped north from AEPS, located at USD's Alvarado Wastewater Treatment Plant, through the Alvarado Valve Box to the Hayward Valve Box via a 6-mile, 60-inch diameter force main. The Hayward Effluent Pump Station adds disinfected secondary effluent from the Hayward Water Pollution Control Facility (WPCF) immediately downstream of the Hayward Valve Box. The combined effluent flows to OLEPS via a 2-mile, 60-inch diameter force main. OLEPS then pumps the combined effluent from USD, Hayward, and OLSD through a 2-mile, 96-inch diameter force main to the Marina Valve Box. LAVWMA effluent is added to the EBDA system in this 96-inch diameter reach. Final effluent from San Leandro is conveyed via a 48-inch diameter force main south to the Marina Valve Box where it combines with the flow from USD, Hayward, OLSD, and LAVWMA. The combined effluent is discharged through a 7.5 mile long, 96-inch diameter outfall on the bottom of San Francisco Bay. A schematic of the system is shown in Figure 1.1.

1.3 Hydraulic Model Recalibration

1.3.1 Hydraulic Model Development

The EBDA hydraulic model, originally built as part of the 2011 System Flow Master Plan project, combines information on the physical and operational characteristics of the EDBA system and performs calculations to solve a series of mathematical equations to simulate flows and pressures in pipes. The EBDA hydraulic model was constructed using Innovyze's H_2O MAP SWMM hydraulic modeling software. The Storm Water Management Model (SWMM) is a hydraulic engine that was developed by the United States Environmental Protection Agency (USEPA) in the 1970. The SWMM engine utilizes the fully dynamic 1-Dimensional Saint Venant equation to simultaneously solve for flow, pressure, and velocity in system conduits, pumps, and storage facilities. The SWMM engine has become the industry standard in urban wastewater and storm drainage collection system modeling applications and is utilized by thousands of municipal agencies around the world.

Carollo reviewed the H_2O MAP SWMM model and converted the model to the ESRI ArcMap based InfoSWMM model. The two modeling platforms have identical operations and usability, the only difference is the software platform for which they operate. After conversion to the InfoSWMM platform, Carollo updated the hydraulic model to include relevant changes that have been implemented since the 2011 System Flow Master Plan was completed. The update included the system model based on the operation of the Hayward Ponds as a wet weather diversion facility. Refer to the 2011 System Flow Master Plan for full details on how the EBDA hydraulic model was built.

1.3.2 Wet Weather Flow Development and Model Recalibration

EBDA provided measured flow, pressure, and surge tower level data in 15-minute intervals for all components of the EBDA system from July 1, 2016 through June 30, 2017. This section describes how this data was used to recalibrate the EBDA hydraulic model.

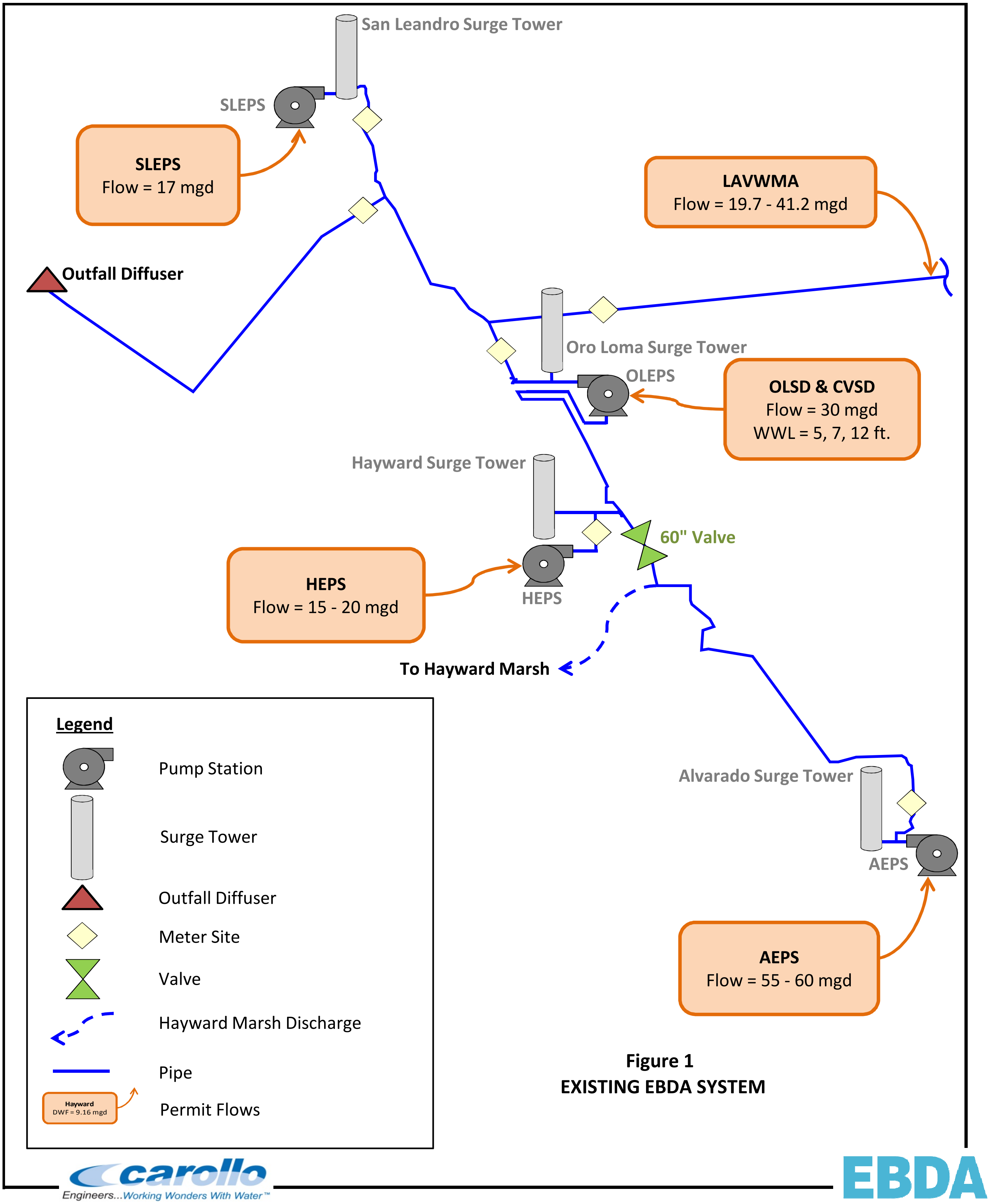


Figure 1
EXISTING EBDA SYSTEM

1.3.2.1 Dry Weather Calibration

Model calibration consisted of two phases: dry weather calibration and wet weather calibration. Dry weather flow (DWF) calibration ensures an accurate depiction of base wastewater flow discharged into the EBDA system, and also ensures that the model accurately simulates the pressure conditions observed in the field. From the data received from EBDA, Carollo identified a 2-week period of dry weather to use for the DWF calibration (November 4-17, 2016). DWFs were allocated into the model based on the data provided by EBDA for this period. Diurnal patterns were also developed for each agency based on the DWF data.

The DWF calibration process consisted of comparing the field measured flows and pressures to the model predicted flows and pressures during the same time period. The primary varied parameters for the dry weather calibration include operational controls and pipe roughness coefficients. Carollo found that the original DWF calibration which was completed as part of the 2011 System Flow Master Plan predicted the new DWF data well, and only minor adjustments were necessary. The adjustments made to the model included updating the Hayward Marsh flow diversion curve and minor adjustments to Hazen-Williams roughness coefficients.

An example of the dry weather calibration for HEPS is shown in Figure 1.2. Comparisons of the model results to observed field conditions for the DWF calibration for all the member agencies is provided in Appendix A. Overall, the trends seen in the field data are predicted by the model. As shown in Table 1.1, the majority of modeled flows and pressures fell within industry standards (10 percent) of the field measured data. Two variables could not be calibrated within acceptable margins of error – Marina Dechlorination Facility (MDF) flow and OLEPS surge tower level. After further investigation and discussion with EBDA, it was determined that these variations are likely due to flow meter errors. EBDA plans to investigate these issues and the calibration will be updated in the future as necessary.

Table 1.1 DWF Calibration Summary

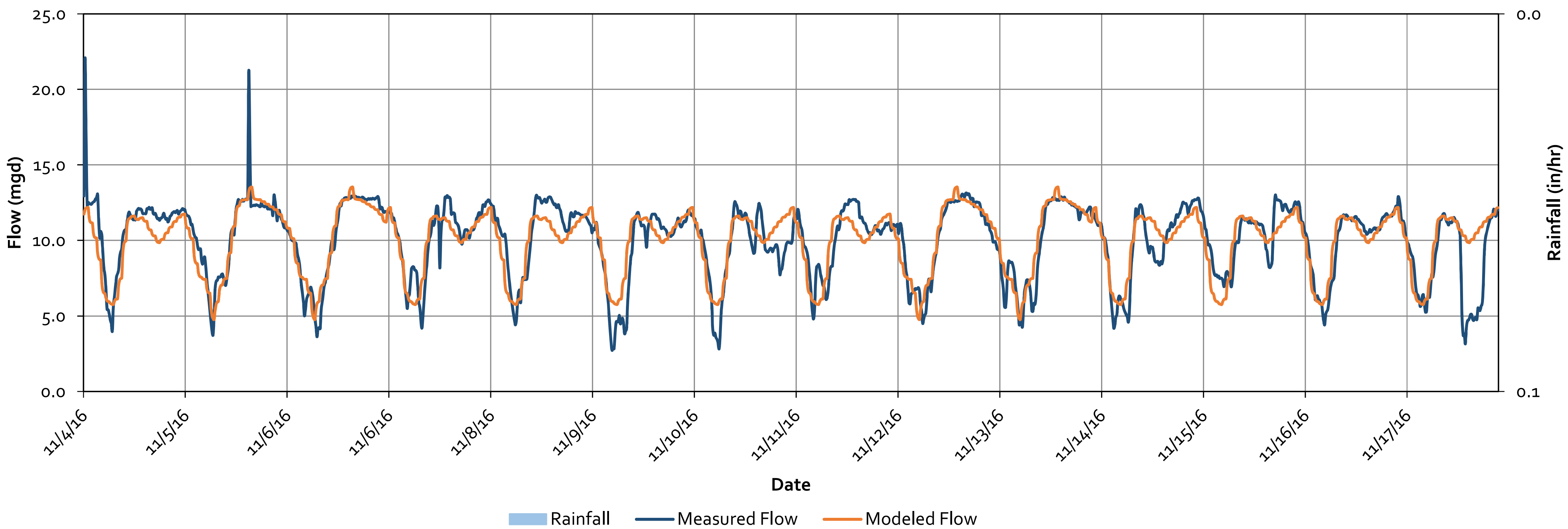
Calibration Site	Variable	Avg. % Diff.	Max. % Diff.
AEPS	Flow	1.1%	-4.0%
	Surge Level	-9.8%	-10.5%
Hayward Marsh	Flow	-7.6%	-1.1%
HEPS	Flow	0.3%	3.0%
	Surge Level	-2.1%	-16.4%
OLEPS	Flow	-6.5%	-16.8%
	Surge Level	-18.2%	-21.8%
SLEPS	Flow	0.1%	-16.6%
	Pressure	3.6%	5.8%
MDF	Flow	-14.9%	-21.5%
	Pressure	-1.3%	-9.3%

EBDA DRY WEATHER HYDRAULIC MODEL CALIBRATION

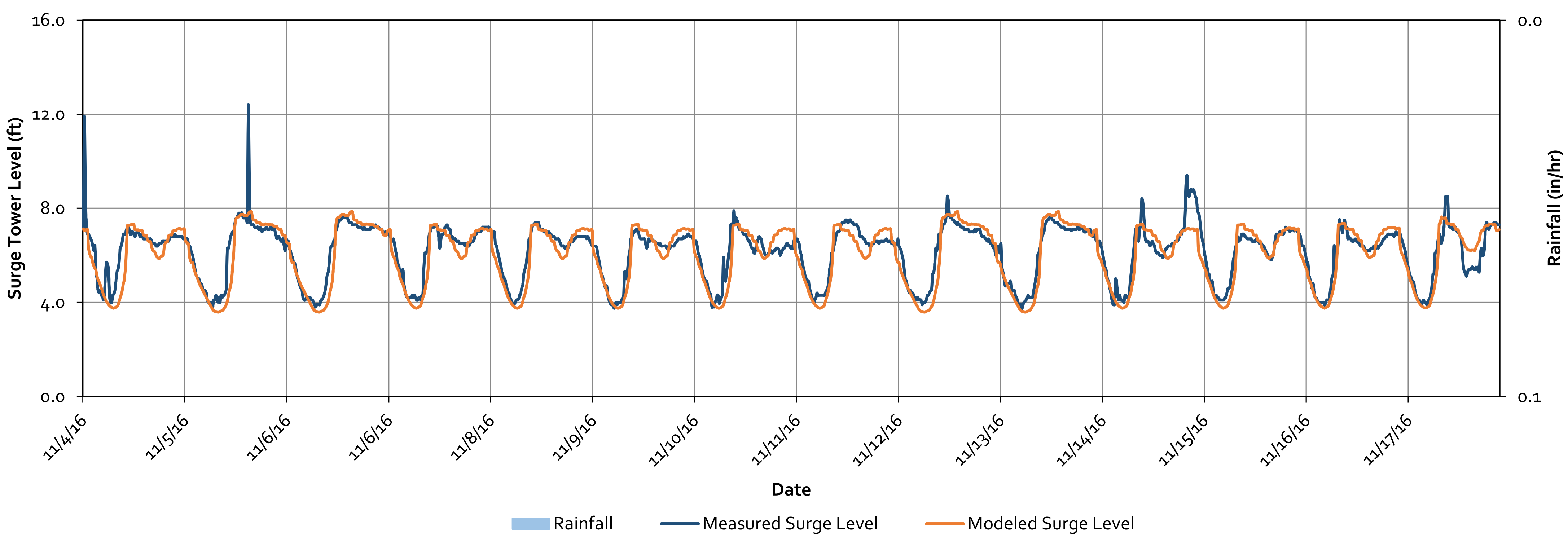
HAYWARD EFFLUENT PUMP STATION

FIGURE 2

Flow Calibration



Surge Level Calibration



DWF Calibration Summary

	Measured[1]			Modeled			Percent Diff.[2]	
Variable	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	10.0	13.1	2.7	10.0	13.5	4.8	0.3%	3.0%
Surge Level	6.1	9.4	3.7	6.0	7.9	3.6	-2.1%	-16.4%

Notes:

(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

1.3.2.2 Wet Weather Calibration

For many wastewater collection systems in the San Francisco Bay Area, there are significant increases in collection system flows following rainfall events. These peak flows are caused by storm water that enters the system through direct storm drain connections, offset joints in sewer pipes, and cracks in aging sewer pipelines. This extraneous flow, or Rainfall Derived Infiltration and Inflow (RDII), has the largest impact on system capacity.

Modeling RDII requires developing system parameters that simulate how the system responds to varying storm events and groundwater conditions. This section describes the development of the RDII parameters used in the model and the collection of precipitation data used to evaluate the system capacity.

Carollo used the data provided by EBDA from July 2016 to June 2017 (Winter 2016/2017) to recalibrate the InfoSWMM model to measured wet weather flow data. Carollo used the wet weather data from the large storm events in the winter of 2017 to calibrate the wet weather parameters in the model. Carollo also collected precipitation data from several rain gauges in the area. This precipitation data was input into the model to simulate the actual rain events experienced during the 2016-2017 winter season.

Carollo identified three storm events to represent the capacity of the transport system. These three storm events took place on January 7-16, 2017; February 3-13, 2017; and February 16 – March 4, 2017. While the model calibration was actually run from December 31, 2016 through March 17, 2017, only the data from the storm events was compared to the measured data.

For the wet weather calibration runs, the average flow for the dry weather days (November 4-17, 2016) were allocated into the model to represent the dry weather, or base flow experienced during each storm event. Rainfall derived infiltration and inflow (RDII) was then added on top of the base flows. An exception to this was for LAVWMA. LAVWMA flows were simply input into the model as point loads. The reason for this is that LAVWMA utilizes various discharges and diversions that are not practical to include in the hydraulic model, and LAVWMA's flow data displayed highly variable patterns that are difficult to simulate. Furthermore, because EBDA can limit the amount of flow that can be discharged by LAVWMA to 19.7 mgd, it is unnecessary to develop rainfall infiltration parameters for LAVWMA for the purposes of this study.

Carollo used industry-accepted calibration standards to compare the model simulated flows to the measured flows from EBDA's SCADA system. Model calibration was performed for all three storm events by developing RDII unit hydrographs for each member agency. RDII unit hydrographs are the main component of the model that simulates wet weather infiltration and inflow into the agency's collection system. Each unit hydrograph is a combination of three separate triangular hydrographs (short term, medium term, and long term), which are defined by the parameters R, T, and K. R represents the percentage of rainfall that is converted into infiltration and inflow (I/I), T represents the time from the onset of the rainfall to the peak of the triangular hydrograph in hours, and K represents the ratio of the time to recession of the triangular hydrograph to the time to peak. Since each RTK unit hydrograph combines three separate triangular hydrographs, the hydrographs for each discharger include nine (9) separate variables. Many model runs were made while adjusting the RTK parameters for each agency until the calibration for all three storm events fell within an acceptable margin of error from the measured data.

A comparison of the model results to observed field conditions for HEPS is shown in Figure 1.3, and calibration plots for the other agencies are provided in Appendix A. Overall, the trends seen in the field data are well predicted by the model. As shown in Table 1.2, Table 1.3, and Table 1.4, the majority of modeled flows and pressures fell within industry standards (+15/-10 percent for average data and +25/-15 percent for peak hour flow data) of the field measured data. The only exceptions to this are the San Leandro flows and force main pressure. However, because of questions regarding San Leandro's flow meter that EBDA and San Leandro staff are evaluating, , the model was considered calibrated for the purposes of this study.

Table 1.2 WWF Calibration Summary - Storm 1 (1/7/17 - 1/16/17)

Calibration Site	Variable	Avg. % Diff.	Max. % Diff.
AEPS	Flow	6.3%	7.4%
	Surge Level	-0.7%	10.4%
Hayward Marsh	Flow	20.3%	-1.0%
HEPS	Flow	-7.8%	-11.3%
	Surge Level	-4.9%	-15.7%
OLEPS	Flow	2.4%	-15.0%
	Surge Level	-0.5%	-12.2%
SLEPS	Flow	9.6%	7.7%
	Pressure	29.5%	20.7%
MDF	Flow	2.9%	-15.7%
	Pressure	7.8%	-13.7%

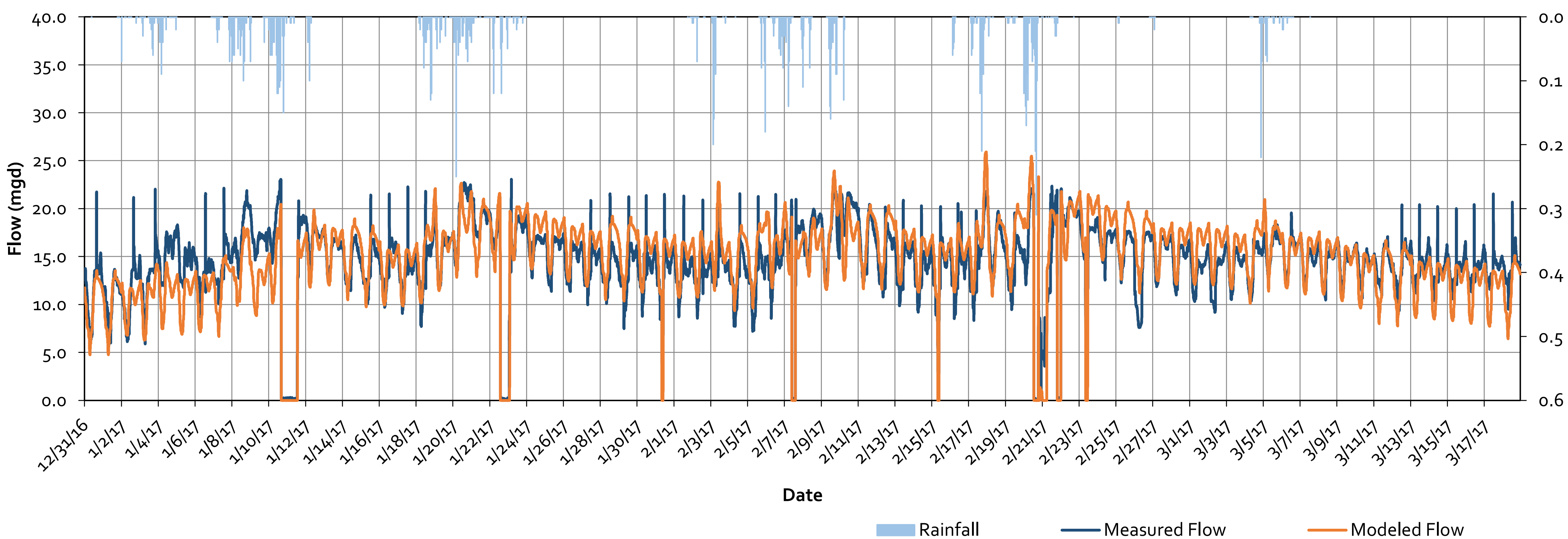
EBDA

HYDRAULIC MODEL CALIBRATION

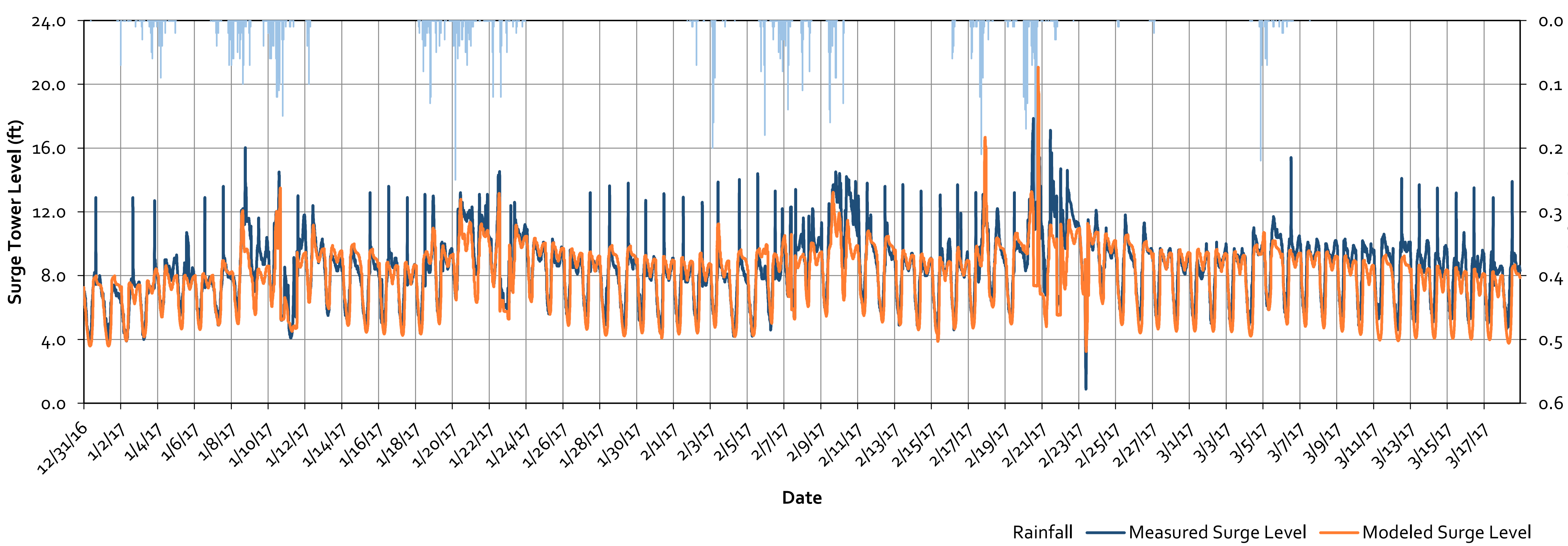
HAYWARD EFFLUENT PUMP STATION

FIGURE 3

Flow Calibration



Surge Level Calibration



WWF Calibration Summary - Storm 1 - 1/7/17 - 1/16/17

	Measured[1]			Modeled			Percent Diff.[2]	
Variable	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	14.4	23.0	0.0	13.3	20.4	0.0	-7.8%	-11.3%
Surge Level	8.3	16.0	4.1	7.9	13.5	4.3	-4.9%	-15.7%

WWF Calibration Summary - Storm 2 - 2/3/17 - 2/13/17

	Measured[1]			Modeled			Percent Diff.[2]	
Variable	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	15.4	22.0	0.0	16.2	23.9	0.0	5.4%	9.0%
Surge Level	8.8	14.5	4.2	8.4	13.2	4.2	-4.2%	-8.8%

WWF Calibration Summary - Storm 3 - 2/16/17 - 3/4/17

	Measured[1]			Modeled			Percent Diff.[2]	
Variable	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	14.7	22.3	0.0	16.0	25.9	0.0	9.5%	16.2%
Surge Level	8.9	17.8	0.9	8.5	21.0	3.2	-5.1%	18.1%

Notes:

(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

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Table 1.3 WWF Calibration Summary - Storm 2 (2/3/17 - 2/13/17)

Calibration Site	Variable	Avg. % Diff.	Max. % Diff.
AEPS	Flow	-1.3%	2.0%
	Surge Level	-5.9%	3.5%
Hayward Marsh	Flow	15.7%	12.7%
HEPS	Flow	5.4%	9.0%
	Surge Level	-4.2%	-8.8%
OLEPS	Flow	4.5%	-6.0%
	Surge Level	2.8%	-10.7%
SLEPS	Flow	5.2%	8.0%
	Pressure	33.4%	22.2%
MDF	Flow	5.1%	-14.9%
	Pressure	9.9%	-10.2%

Table 1.4 WWF Calibration Summary - Storm 3 (2/16/17 - 3/4/17)

Calibration Site	Variable	Avg. % Diff.	Max. % Diff.
AEPS	Flow	-8.7%	-7.1%
	Surge Level	-10.7%	11.2%
Hayward Marsh	Flow	10.8%	3.7%
HEPS	Flow	9.5%	16.2%
	Surge Level	-5.1%	18.1%
OLEPS	Flow	3.4%	6.2%
	Surge Level	6.4%	3.6%
SLEPS	Flow	6.7%	38.3%
	Pressure	37.0%	23.8%
MDF	Flow	3.2%	-13.8%
	Pressure	15.1%	0.5%

1.4 Capacity Analysis

1.4.1 Methodology

The intent of this Hydraulic Study is to determine the capacity of various elements of the EBDA system. With the model recalibrated to the data from the 2016-2017 winter season, the capacity analysis scenarios identified in the Scope of Work were conducted. EBDA requested that Carollo use the hydraulic model to evaluate the capacity of AEPS, HEPS, and the transport system between AEPS and OLEPS. The following flows and operational conditions were identified by EBDA for analysis in the Scope of Work:

- AEPS – 60/55 mgd
- HEPS – 20/15 mgd

- OLSD & CVSD – 30 mgd
- SLEPS – 17 mgd
- LAVWMA – 19.7/41.2 mgd
- With/without discharge to the Hayward Marsh
- OLEPS wet well level at 5 ft./7 ft./12 ft.
- King tide/high tide

Based on the above parameters, Carollo evaluated the capacity of the transport system for the following model scenarios:

1. Using the flows and conditions above, determine the capacity of the transport system between AEPS and OLEPS as a function of the different AEPS and HEPS flows and OLEPS wet well levels.
2. Using the flows and conditions above, determine the capacity of AEPS.
3. Using the flows and conditions above, determine the capacity of HEPS.
4. Determine the impact of OLEPS flows and different tides on the MDF capacity.

After the model was calibrated for both DWF and WWF conditions, a steady state scenario was built to analyze each of the four scenarios identified in the Scope of Work. A steady state scenario means that the model is only analyzing a singular moment of time, rather than assessing the response of the model over the course of a storm event. Steady state scenarios were used for the capacity analysis so that inflows to each EBDA facility could be manually controlled to view the specific response of the EBDA system to specific hydraulic conditions. The evaluation scenarios were run by manually inputting flows at each facility, and running the steady state scenario to assess the hydraulic conditions throughout the system at that moment of time. With this approach, Carollo ran a multitude of flow scenarios to develop system flow relationships between AEPS, HEPS, and OLEPS. These results allowed us to determine the controlling factors, flow rates, and how each agency's flows affect the others for varying operating conditions.

As detailed above, EBDA asked Carollo to analyze the EBDA hydraulic model under AEPS flows of either 60 or 55 mgd; HEPS flows of either 20 or 15 mgd; and OLEPS wet well levels of 5, 7, and 12 ft. Carollo decided to expand the AEPS and HEPS flows which were used to provide a better picture of what the system response would be to a wide range of hydraulic conditions.

Each scenario and its results are detailed in the following sections.

1.4.2 Scenario 1

The purpose of this scenario was to determine the capacity of the EBDA transport system between AEPS and OLEPS. For this analysis, the transport system capacity was defined as the combined flow of AEPS and HEPS which can be pumped to OLEPS. Flows discharged to Hayward Marsh, when applicable, were also included in the total transport system capacity.

The following variables were considered in this analysis: AEPS flows, HEPS flows, OLEPS wet well levels, and discharge to the Hayward Marsh. Because all effluent from AEPS and HEPS discharges into the OLEPS wet well, variables downstream of OLEPS such as tide levels and LAVWMA discharge do not affect the AEPS to OLEPS transport system capacity.

The results of the analysis of Scenario 1 are summarized in Table 1.5. The full results for this scenario are included in Appendix B.

Table 1.5 AEPS-OLEPS Transport System Capacity

Hayward Marsh Status	OLEPS Wet Well Level (ft.)	AEPS – OLEPS Transport System Capacity (mgd)
Without Hayward Marsh Discharge	5	84.8
	7	83.7
	12	80.1
With Hayward Marsh Discharge*	5	95.0
	7	93.5
	12	90.2

(1)* Note: Includes 19.5 mgd discharge to Hayward Marsh.

As shown in Table 1.5, the capacity of the AEPS to OLEPS transport system falls as the OLEPS wet well level rises. Capacity drops by approximately 1 mgd when the wet well level rises from 5 to 7 ft., and approximately 3 mgd when the wet well level rises from 7 to 12 ft. The capacity of the transport system is about 10 mgd higher with Hayward Marsh discharge included. Under these conditions, AEPS discharges 19.5 mgd to the Hayward Marsh.

1.4.3 Scenario 2

The purpose of this scenario was to determine the capacity of AEPS using the varying flow conditions at HEPS. As mentioned previously, tidal variations and LAVWMA discharge do not impact the AEPS capacity.

The results for Scenario 2 are shown in Figure 1.4, Figure 1.5, and Figure 1.6 for OLEPS wet well levels of 5-ft., 7-ft., and 12-ft. respectively. Each figure includes results with and without Hayward Marsh discharge.

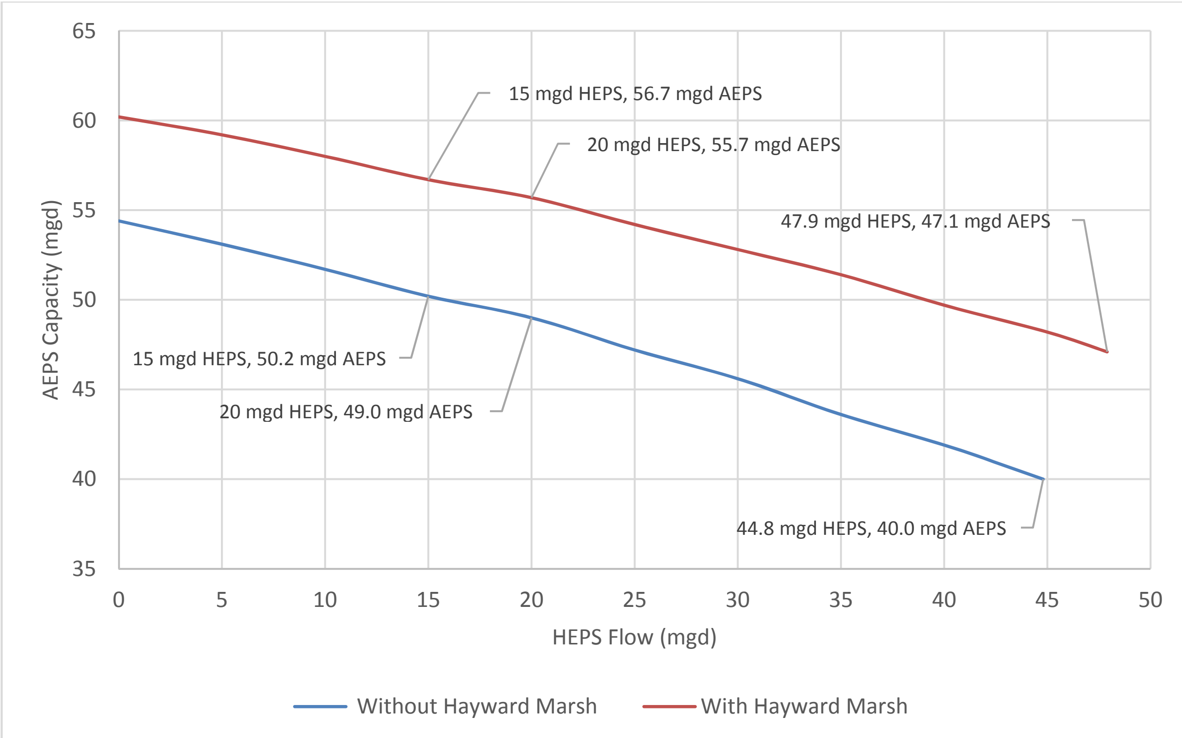


Figure 1.4 AEPS Capacity vs. HEPS Flow, OLEPS WWL = 5 ft.

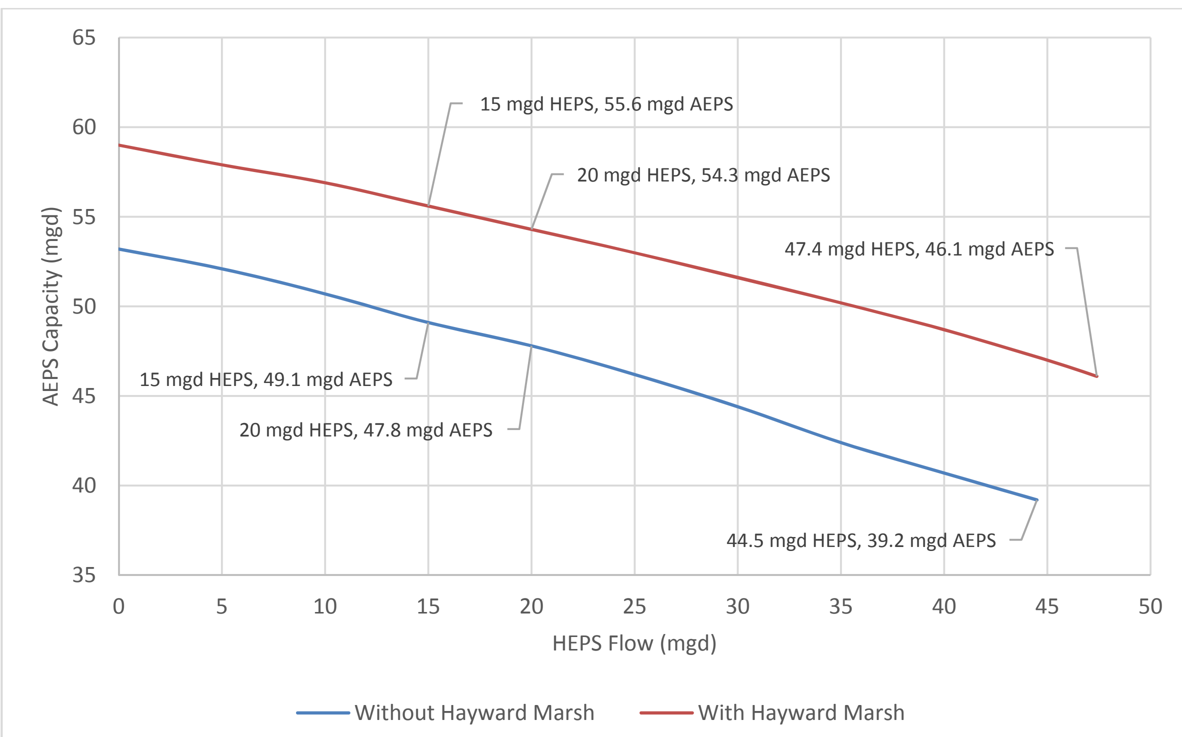


Figure 1.5 AEPS Capacity vs. HEPS Flow, OLEPS WWL = 7 ft.

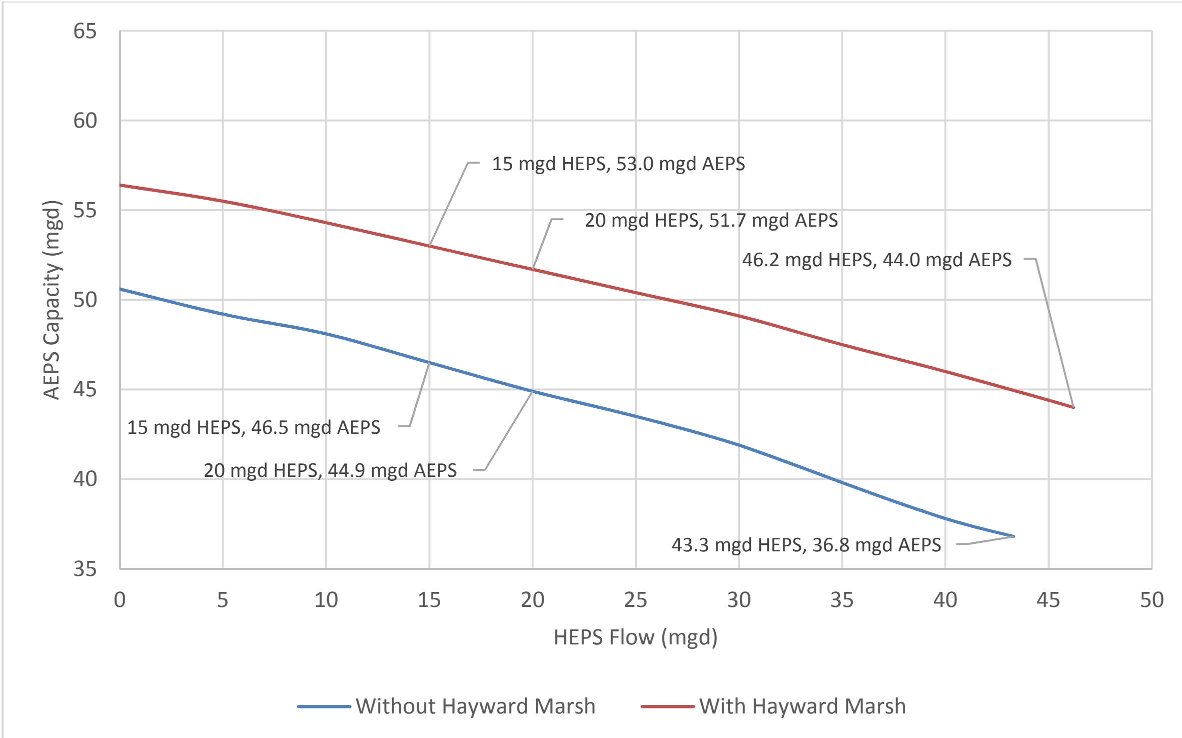


Figure 1.6 AEPS Capacity vs. HEPS Flow, OLEPS WWL = 12 ft.

As shown, the capacity of AEPS with no discharge from HEPS ranges from approximately 60 mgd to 57 mgd with Hayward Marsh discharge included, depending on the OLEPS wet well level. Without Hayward Marsh discharge, the AEPS capacity ranges from approximately 54 mgd to 51 mgd. At a HEPS discharge of 15 mgd, AEPS capacity ranges from approximately 57 mgd to 53 mgd including Hayward Marsh discharge, and from approximately 50 mgd to 47 mgd without Hayward Marsh discharge. At a HEPS discharge of 20 mgd, AEPS capacity ranges from approximately 56 mgd to 52 mgd including Hayward Marsh discharge, and from approximately 49 mgd to 45 mgd without Hayward Marsh discharge.

The endpoints of these graphs represent the points at which the interaction of AEPS and HEPS flows reaches its equilibrium. The HEPS flow cannot increase beyond these points unless the AEPS flow is reduced.

1.4.4 Scenario 3

The purpose of this scenario was to determine the capacity of HEPS using the varying flow conditions at AEPS. As mentioned previously, tidal variations and LAVWMA discharge do not impact the HEPS capacity.

The results for Scenario 3 are shown in Figure 1.7, Figure 1.8, and Figure 1.9 for OLEPS wet well levels of 5-ft., 7-ft., and 12-ft. respectively. Each figure includes results with and without Hayward Marsh discharge.

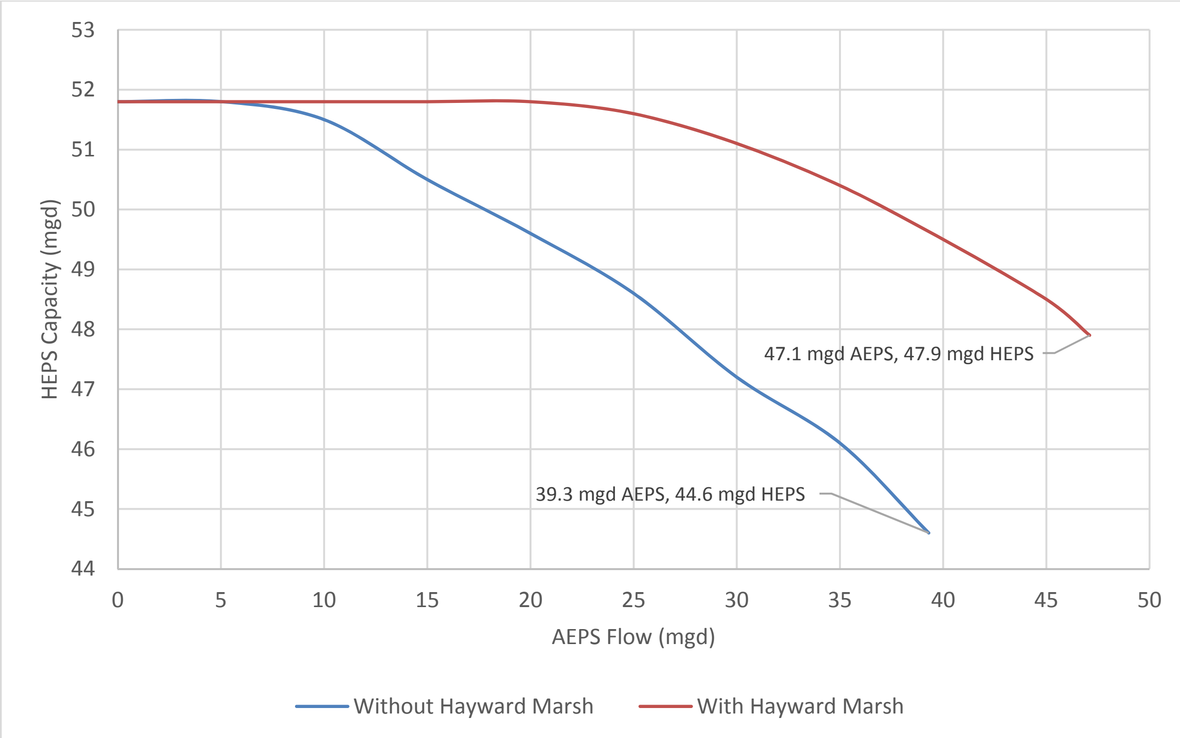


Figure 1.7 HEPS Capacity vs. AEPS Flow, OLEPS WWL = 5 ft.

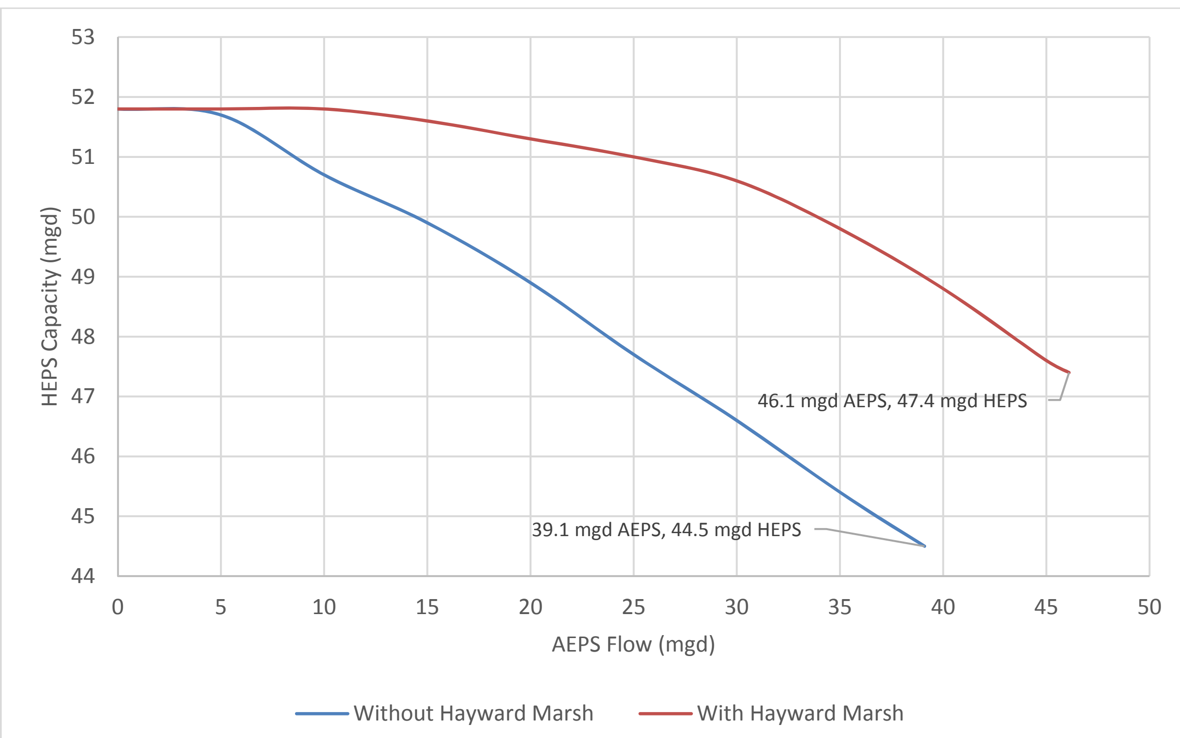


Figure 1.8 HEPS Capacity vs. AEPS Flow, OLEPS WWL = 7 ft.

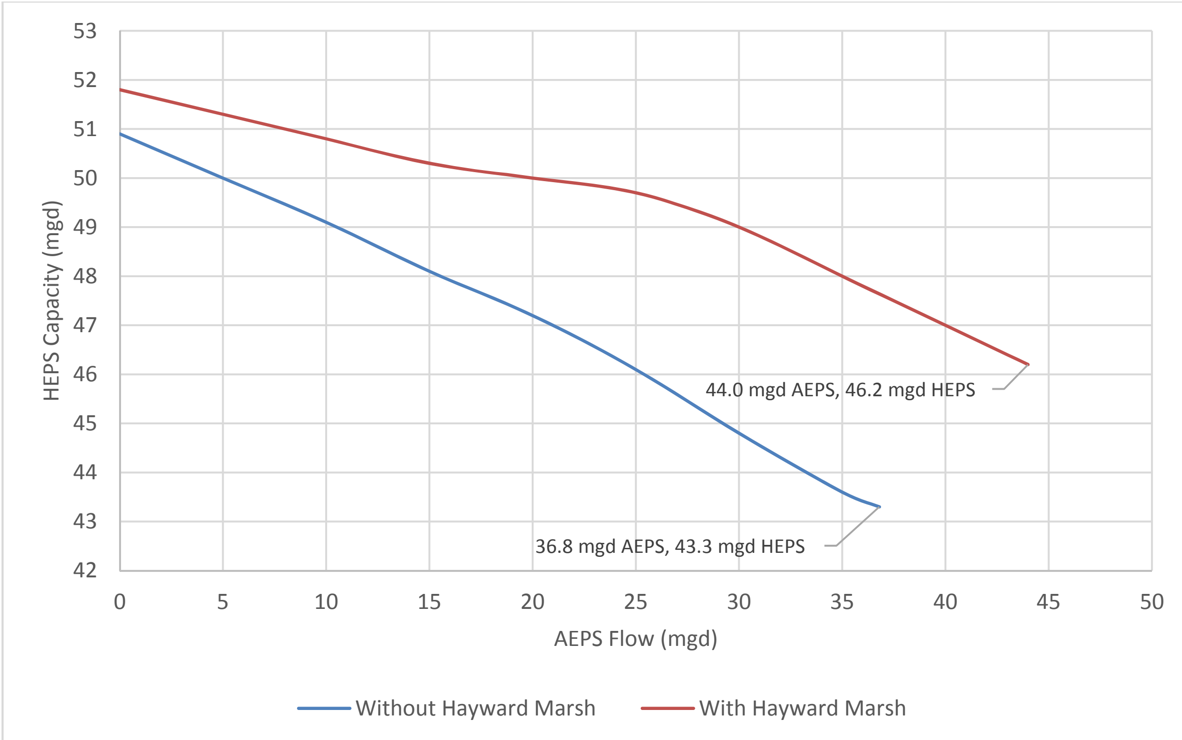


Figure 1.9 HEPS Capacity vs. AEPS Flow, OLEPS WWL = 12 ft.

As shown, the capacity of HEPS with no discharge from AEPS is approximately 51.8 mgd for OLEPS wet well levels of 5-ft. or 7-ft., regardless of whether Hayward Marsh discharge is included. At an OLEPS wet well level of 12-ft., HEPS capacity is approximately 51.8 mgd including Hayward Marsh discharge, and approximately 50.9 mgd without Hayward Marsh discharge. AEPS flows do not begin to impact HEPS capacity until they reach approximately 10 mgd at an OLEPS wet well level of 5-ft., or 5 mgd at an OLEPS wet well level of 7-ft.

The endpoints of these graphs represent the points at which the interaction of AEPS and HEPS flows reaches its equilibrium. The AEPS flow cannot increase beyond these points unless the HEPS flow is reduced. These points correspond to the endpoints of the Scenario 2 figures.

1.4.5 Scenario 4

The purpose of this scenario is to determine the flows at MDF based on varying OLEPS flows and tidal levels. Three different tidal levels were modeled – low tide, high tide, and King tide. For reference, King tide represents a level of 4.95 ft. above average sea level (as measured on January 12, 2017), high tide was modeled as 3.5 ft. above average sea level, and low tide was modeled as 5 ft. below average sea level.

The EBDA variables upstream of OLEPS (AEPS flow, HEPS flow, Hayward Marsh discharge) do not affect OLEPS capacity. It was also determined by Carollo that the OLEPS wet well level being fixed at either 5 or 7 ft. was negligible (less than 1 mgd difference) in the context of the capacity of OLEPS. The variables considered in this scenario are the tidal levels and LAVWMA discharge of either 19.7 mgd or

41.2 mgd. The results of this scenario are shown below in Figure 1.10 and Figure 1.11 is a close-up view of the upper portion of Table 1.5. It should be noted that these figures are not meant to show MDF capacity, but rather OLEPS capacity and the corresponding flows seen at MDF with SLEPS discharge fixed at 17 mgd.

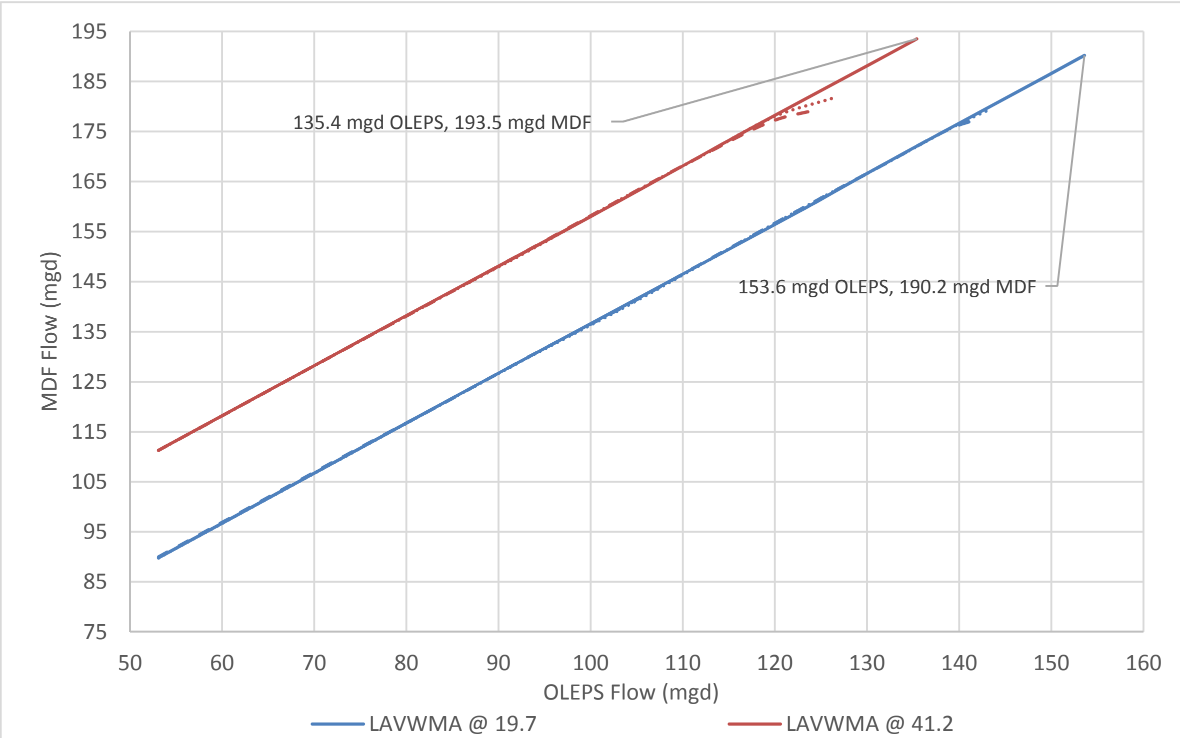


Figure 1.10 MDF Flow vs. OLEPS Flow

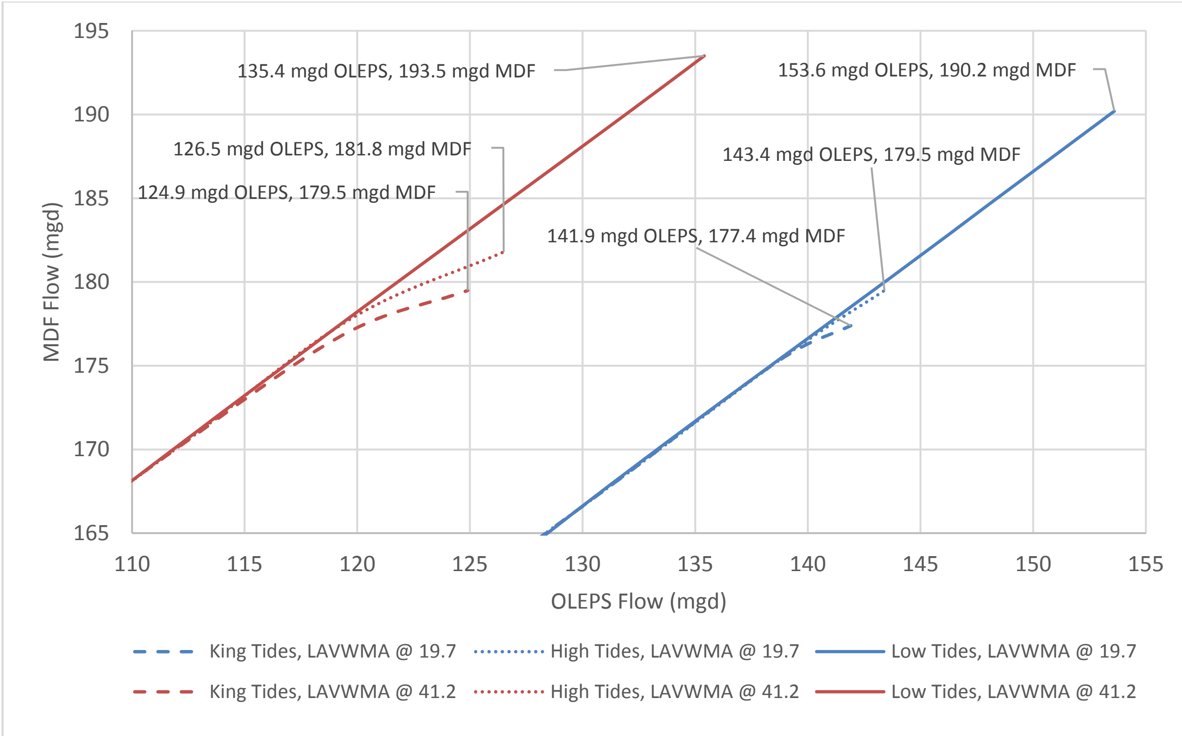


Figure 1.11 MDF Flow vs. OLEPS Flow (Detail)

The endpoints of each line in as shown in Figure 1.10 and Figure 1.11 represent the capacity of OLEPS under the corresponding flow conditions, and the resultant flow seen at OLEPS. As shown, the capacity of OLEPS and the corresponding flows seen at MDF increase substantially under low tide conditions when compared to high tide and King tide conditions. While high tide only provides approximately 2 mgd greater OLEPS capacity when compared to King tide, low tide provides approximately 13 mgd greater capacity over King tide conditions.

1.5 Summary

As part of this project, Carollo updated and recalibrated the EBDA hydraulic model, and performed a capacity analysis of various elements of the EBDA system under varying flow scenarios. The EBDA hydraulic model, originally built in 2011, was recalibrated using flow data from the winter of 2016-2017 for dry and wet weather conditions. Both the dry and wet weather calibrations fell within industry standards of the field measured data, and the trends seen in the field are well predicted by the model.

Following model recalibration, Carollo used the hydraulic model to evaluate the capacity of the transport system. The following flows and operational conditions were identified by EBDA for analysis:

- AEPS – 60/55 mgd
- HEPS – 20/15 mgd
- OLSD & CVSD – 30 mgd

- SLEPS – 17 mgd
- LAVWMA – 19.7/41.2 mgd
- With/without discharge to the Hayward Marsh
- OLEPS wet well level at 5 ft./7 ft./12 ft.
- King tide/high tide

Based on the above parameters, Carollo evaluated the capacity of the transport system for the following model scenarios:

1. Using the flows and conditions above, determine the capacity of the transport system between AEPS and OLEPS as a function of the different AEPS and HEPS flows and OLEPS wet well levels.
2. Using the flows and conditions above, determine the capacity of AEPS.
3. Using the flows and conditions above, determine the capacity of HEPS.
4. Determine the impact of OLEPS flows and different tides on the MDF capacity.

The findings of each scenario are summarized below. Tabular results have been developed for Scenarios 1 through 3. Because the available capacity at AEPS is dependent upon the flow at HEPS, and vice-versa, the hydraulic model was run at 5 mgd intervals of HEPS and AEPS flow (depending on the scenario). The maximum capacity of AEPS and HEPS was then determined (depending on the scenario). In each table, there are some flow values that do not coincide with a 5 mgd flow interval. These values coincide with the maximum pumping capacity of either AEPS or HEPS at a given OLEPS wet well level. Values listed as "N/A" were not analyzed for that particular OLEPS wet well depth. It should be noted that Carollo evaluated the capacity of the transport system between AEPS and OLPS based on maximizing the flow level in the AEPS surge tower. Currently the operations staff at USD do not like to operate at the maximum level. However, because this study evaluated maximum capacity, Carollo allowed the HGL in the surge tower to rise to its maximum height.

The purpose of Scenario 1 was to determine the capacity of the EBDA transport system between AEPS and OLEPS. The results of the capacity analysis for Scenario 1 are summarized in Table 1.6 and Table 1.7. As shown, the capacity of the transport system without discharge to the Hayward Marsh varies from 50.6 mgd to 84.8 mgd, depending on HEPS discharge and OLEPS wet well level. With discharge to the Hayward Marsh included, the transport system capacity from AEPS to OLEPS varies between 56.6 mgd and 95.0 mgd.

Table 1.6 Scenario 1 - AEPS-OLEPS Transport System Capacity Summary (Without Hayward Marsh)

		Transport System Capacity (mgd)		
		OLEPS Wet Well Level		
		5 ft.	7 ft.	12 ft.
HEPS Flow (mgd)	0	54.4	53.2	50.6
	5	58.1	57.1	54.2
	10	61.7	60.7	58.1
	15	65.2	64.1	61.5
	20	69.0	67.8	64.9
	25	72.2	71.2	68.5
	30	75.6	74.4	71.9
	35	78.6	77.4	74.8
	40	81.9	80.7	77.8
	43.3	N/A	N/A	80.1
	44.5	N/A	83.7	N/A
	44.8	84.8	N/A	N/A

Table 1.7 Scenario 1 - AEPS-OLEPS Transport System Capacity Summary (With Hayward Marsh)

		Transport System Capacity (mgd)		
		OLEPS Wet Well Level		
		5 ft.	7 ft.	12 ft.
HEPS Flow (mgd)	0	60.2	59.1	56.6
	5	64.2	62.8	60.3
	10	68.2	67.0	64.4
	15	71.5	70.7	68.3
	20	75.5	74.4	71.4
	25	79.5	78.0	75.4
	30	82.8	81.7	79.1
	35	86.9	85.0	82.5
	40	89.8	88.6	85.9
	45	93.2	92.0	89.4
	46.2	N/A	N/A	90.2
	47.4	N/A	93.5	N/A
	47.9	95.0	N/A	N/A

The purpose of Scenario 2 was to determine the capacity of AEPS using the varying flow conditions at HEPS. The results of the capacity analysis for Scenario 2 are summarized in Table 1.8 and Table 1.9. As shown, the capacity of AEPS without discharge to the Hayward Marsh varies from 36.8 mgd to 54.4 mgd, depending on HEPS discharge and OLEPS wet well level. With discharge to the Hayward Marsh included, the AEPS capacity ranges from 44.0 mgd to 60.2 mgd.

Table 1.8 Scenario 2 - AEPS Capacity Summary (Without Hayward Marsh)

		AEPS Capacity (mgd)		
		OLEPS Wet Well Level		
		5 ft.	7 ft.	12 ft.
HEPS Flow (mgd)	0	54.4	53.2	50.6
	5	53.1	52.1	49.2
	10	51.7	50.7	48.1
	15	50.2	49.1	46.5
	20	49.0	47.8	44.9
	25	47.2	46.2	43.5
	30	45.6	44.4	41.9
	35	43.6	42.4	39.8
	40	41.9	40.7	37.8
	43.3	N/A	N/A	36.8
	44.5	N/A	39.2	N/A
	44.8	40.0	N/A	N/A

Table 1.9 Scenario 2 - AEPS Capacity Summary (With Hayward Marsh)

		AEPS Capacity (mgd)		
		OLEPS Wet Well Level		
		5 ft.	7 ft.	12 ft.
HEPS Flow (mgd)	0	60.2	59.0	56.4
	5	59.2	57.9	55.5
	10	58.0	56.9	54.3
	15	56.7	55.6	53.0
	20	55.7	54.3	51.7
	25	54.2	53.0	50.4
	30	52.8	51.6	49.1
	35	51.4	50.2	47.5
	40	49.7	48.7	46.0
	45	48.2	47.0	44.4
	46.2	N/A	N/A	44.0
	47.4	N/A	46.1	N/A
	47.9	47.1	N/A	N/A

The purpose of Scenario 3 was to determine the capacity of HEPS using the varying flow conditions at AEPS. The results of the capacity analysis for Scenario 3 are summarized in Table 1.10 and Table 1.11. As shown, the capacity of HEPS without discharge to the Hayward Marsh varies from 43.3 mgd to 51.8 mgd, depending on AEPS discharge and OLEPS wet well level. With discharge to the Hayward Marsh included, the HEPS capacity ranges from 46.2 mgd to 51.8 mgd.

Table 1.10 Scenario 3 - HEPS Capacity Summary (Without Hayward Marsh)

		HEPS Capacity (mgd)		
		OLEPS Wet Well Level		
		5 ft.	7 ft.	12 ft.
AEPS Flow (mgd)	0	51.8	51.8	50.9
	5	51.8	51.7	50.0
	10	51.5	50.7	49.1
	15	50.5	49.9	48.1
	20	49.6	48.9	47.2
	25	48.6	47.7	46.1
	30	47.2	46.6	44.8
	35	46.1	45.4	43.6
	36.8	N/A	N/A	43.3
	39.1	N/A	44.5	N/A
	39.3	44.6	N/A	N/A

Table 1.11 Scenario 3 - HEPS Capacity Summary (With Hayward Marsh)

		HEPS Capacity (mgd)		
		OLEPS Wet Well Level		
		5 ft.	7 ft.	12 ft.
AEPS Flow (mgd)	0	51.8	51.8	51.8
	5	51.8	51.8	51.3
	10	51.8	51.8	50.8
	15	51.8	51.6	50.3
	20	51.8	51.3	50.0
	25	51.6	51.0	49.7
	30	51.1	50.6	49.0
	35	50.4	49.8	48.0
	40	49.5	48.8	47.0
	44	N/A	N/A	46.2
	45	48.5	47.6	N/A
	46.1	N/A	47.4	N/A
	47.1	47.9	N/A	N/A

The purpose of Scenario 4 was to determine the flows at MDF based on varying OLEPS flows and tidal levels. Three different tidal levels were modeled – low tide, high tide, and King tide. The following summarizes the results of the Scenario 4 evaluation:

- **LAVWMA flow = 19.7 mgd and SLEPS flow = 17 mgd.** The pumping capacity of OLPES ranges from 141.9 mgd to 153.6 mgd depending on the tide condition. This corresponds to a flow range of 177.4 mgd to 190.2 mgd at MDF.

- **LAVWMA flow = 41.2 mgd and SLEPS flow = 17 mgd.** The pumping capacity of OLPES ranges from 124.9 mgd to 135.4 mgd depending on the tide condition. This corresponds to a flow range of 179.5 mgd to 193.5 mgd at MDF.

Appendix A

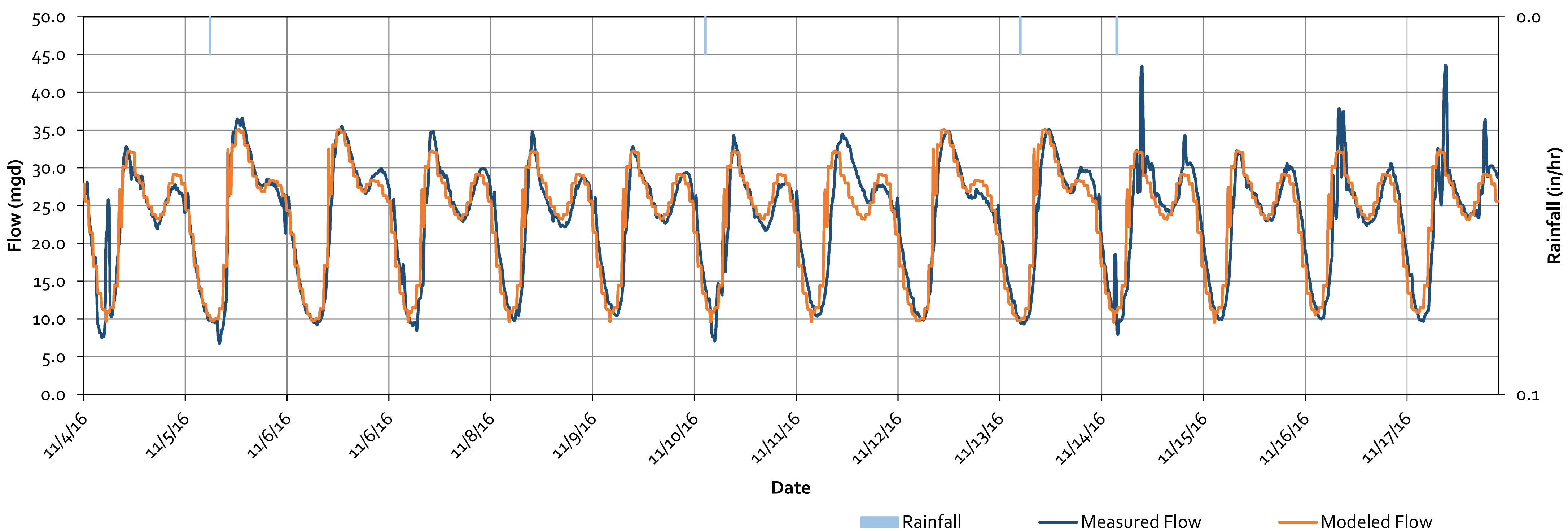
HYDRAULIC MODEL CALIBRATION SUMMARY

EBDA

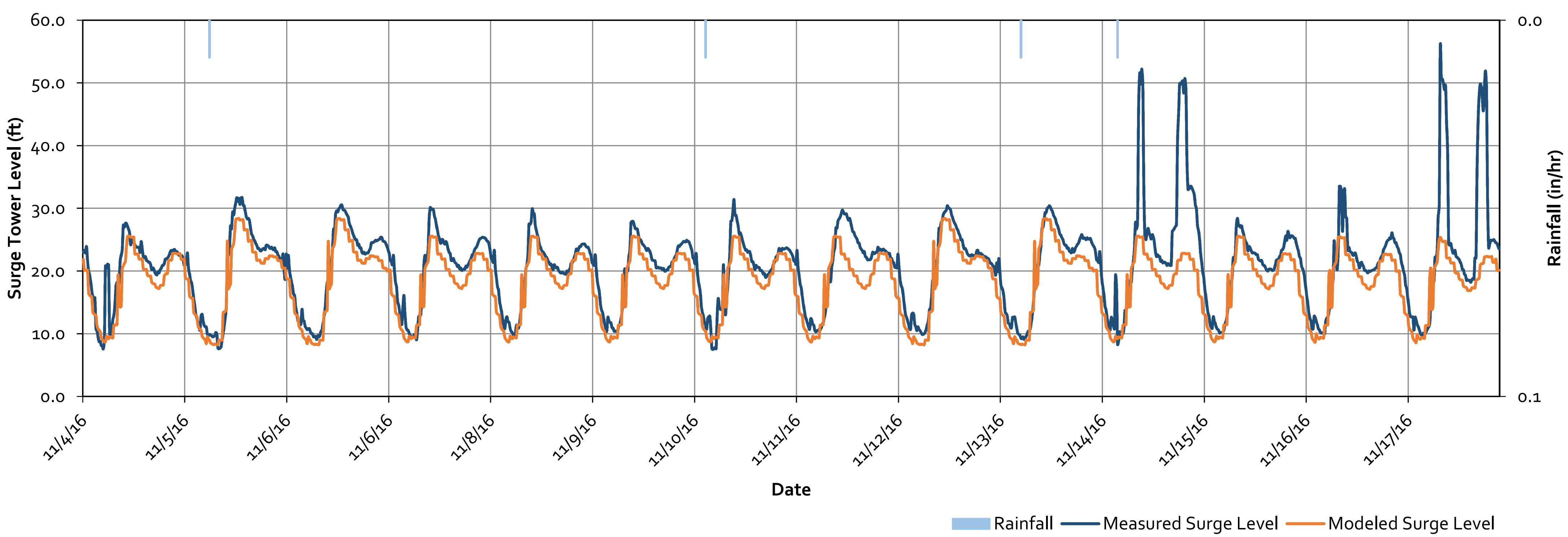
DRY WEATHER HYDRAULIC MODEL CALIBRATION

ALVARADO EFFLUENT PUMP STATION

Flow Calibration



Surge Level Calibration



DWF Calibration Summary (11/4/16 - 11/17/16)

Variable	Measured[1] Avg. (mgd)	Measured[1] Max. (mgd)	Measured[1] Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[2] Avg.	Percent Diff.[2] Max.
Flow	23.2	36.5	6.8	23.4	35.1	9.5	1.1%	-4.0%
Surge Level	20.1	31.7	7.5	18.1	28.4	8.2	-9.8%	-10.5%

Notes:

(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

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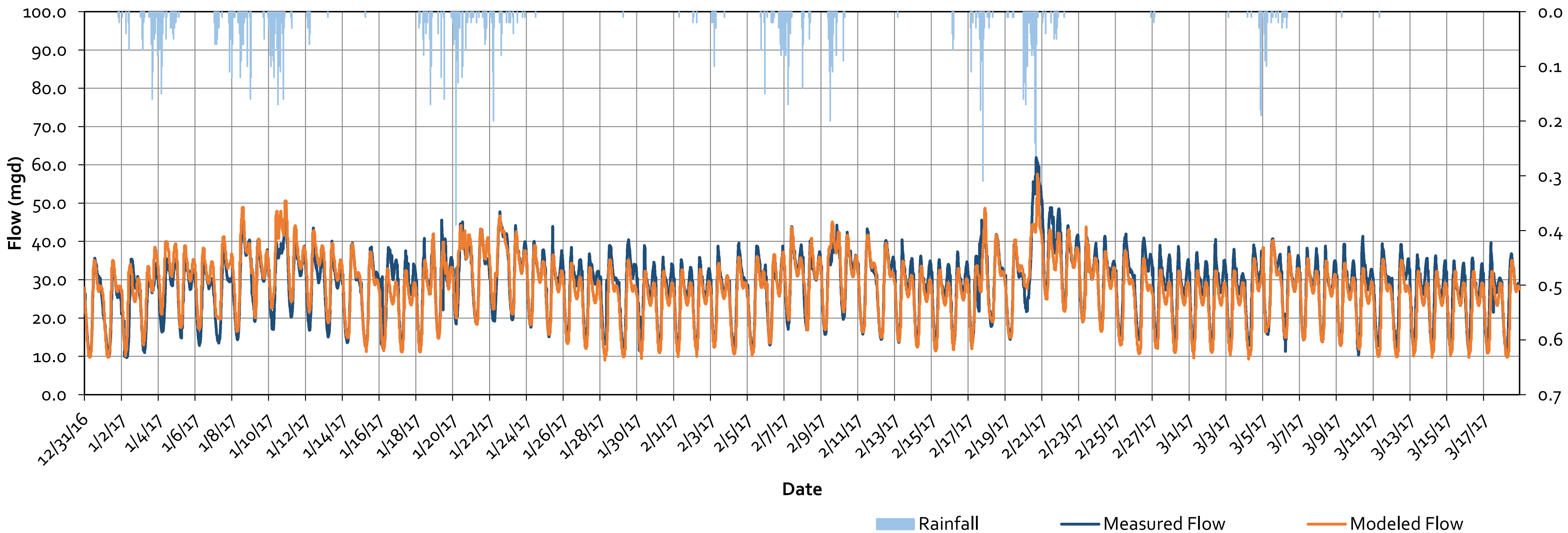
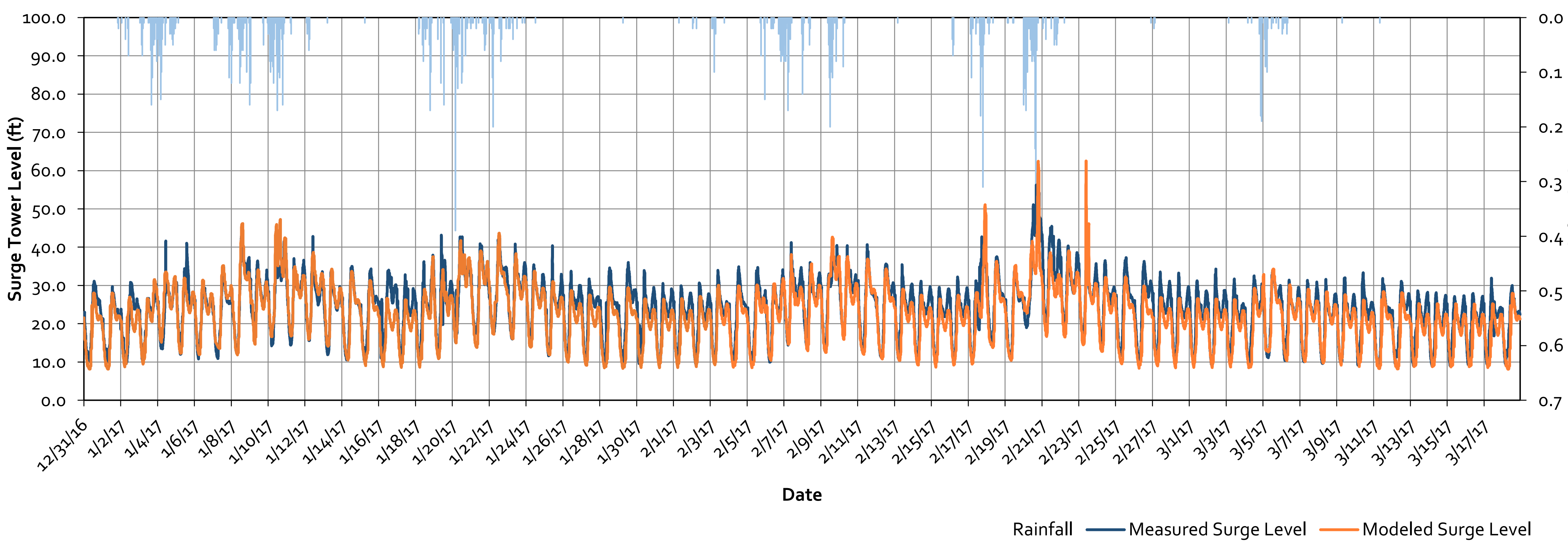
WET WEATHER HYDRAULIC MODEL CALIBRATION

ALVARADO EFFLUENT PUMP STATION

Flow Calibration



Surge Level Calibration



WWF Calibration Summary - Storm 1 - 1/7/17 - 1/16/17

Variable	Measured[(1)] Avg. (mgd)	Measured Max. (mgd)	Measured Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[(2)] Avg.	Percent Diff. Max.
Flow	29.4	47.1	12.3	31.3	50.6	11.2	6.3%	7.4%
Surge Level	25.6	42.8	10.4	25.4	47.2	8.7	-0.7%	10.4%

WWF Calibration Summary - Storm 2 - 2/3/17 - 2/13/17

Variable	Measured[(1)] Avg. (mgd)	Measured Max. (mgd)	Measured Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[(2)] Avg.	Percent Diff. Max.
Flow	29.0	44.2	11.6	28.6	45.1	10.2	-1.3%	2.0%
Surge Level	24.9	41.2	9.5	23.5	42.6	8.5	-5.9%	3.5%

WWF Calibration Summary - Storm 3 - 2/16/17 - 3/4/17

Variable	Measured[(1)] Avg. (mgd)	Measured Max. (mgd)	Measured Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[(2)] Avg.	Percent Diff. Max.
Flow	30.4	61.9	12.9	27.7	57.5	9.3	-8.7%	-7.1%
Surge Level	25.6	56.2	9.0	22.8	62.5	8.4	-10.7%	11.2%

Notes:

(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

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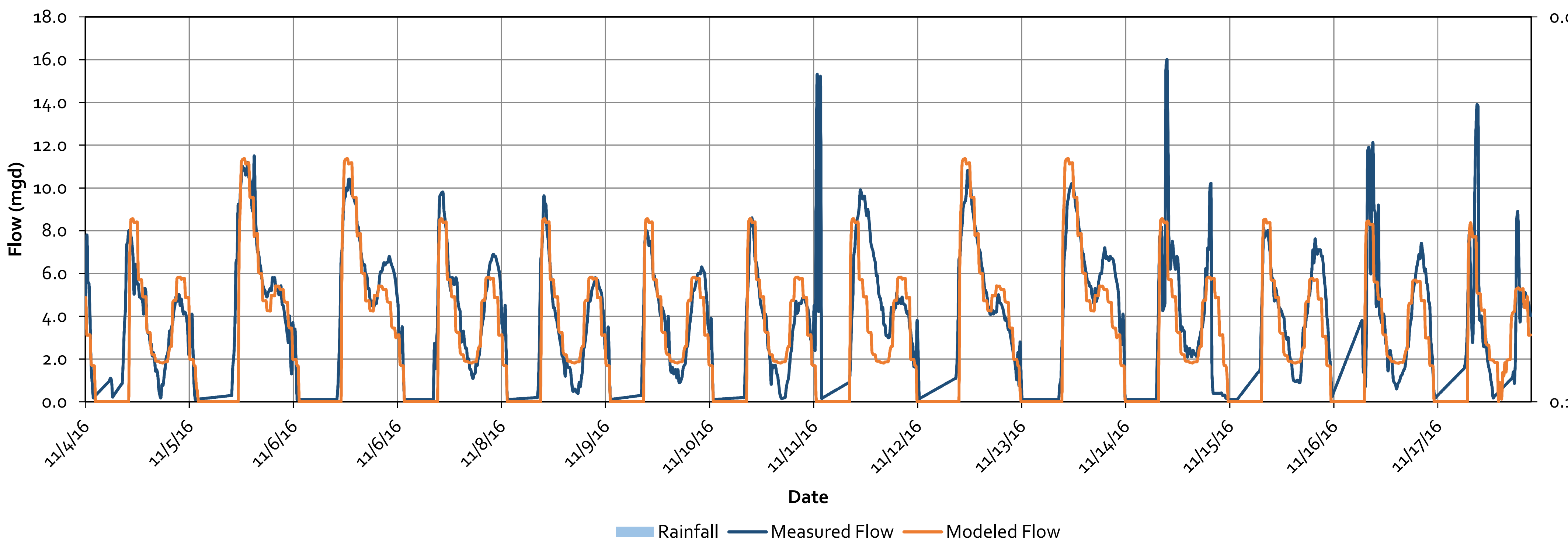
EBDA DRY WEATHER HYDRAULIC MODEL CALIBRATION

HAYWARD MARSH

Flow Calibration



DWF Calibration Summary

Variable	Measured[(1)] Avg. (mgd)	Measured Max. (mgd)	Measured Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[(2)] Avg.	Percent Diff. Max.
Flow	3.2	11.5	0.1	3.0	11.4	0.0	-7.6%	-1.1%

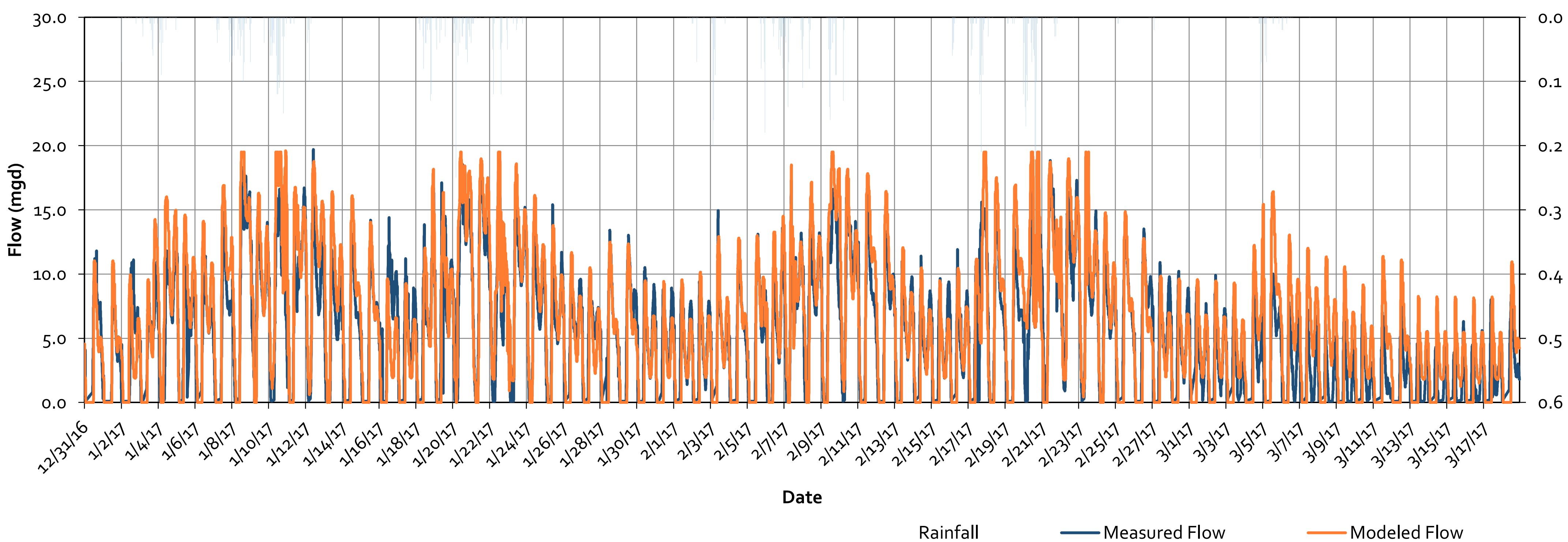
Notes:

(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

EBDA HYDRAULIC MODEL CALIBRATION
HAYWARD MARSH

Flow Calibration



WWF Calibration Summary - Storm 1 - 1/7/17 - 1/16/17

Variable	Measured[1]			Modeled			Percent Diff.[2]	
	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	7.0	19.7	0.1	8.4	19.5	0.0	20.3%	-1.0%

WWF Calibration Summary - Storm 2 - 2/3/17 - 2/13/17

Variable	Measured[1]			Modeled			Percent Diff.[2]	
	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	6.3	17.3	0.1	7.3	19.5	0.0	15.7%	12.7%

WWF Calibration Summary - Storm 3 - 2/16/17 - 3/4/17

Variable	Measured[1]			Modeled			Percent Diff.[2]	
	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	5.8	18.8	0.1	6.4	19.5	0.0	10.8%	3.7%

Notes:

(1) Source: Data provided by EBDA staff and member agencies.

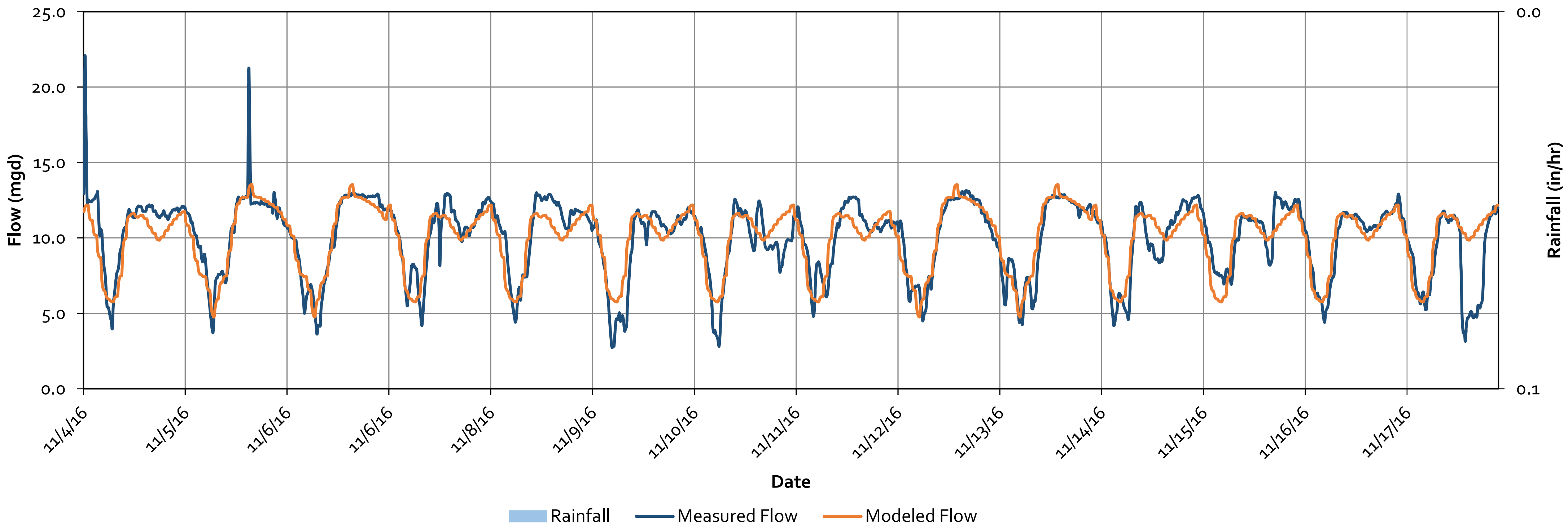
(2) % Difference = (Modeled - Measured) / Measured x 100

EBDA

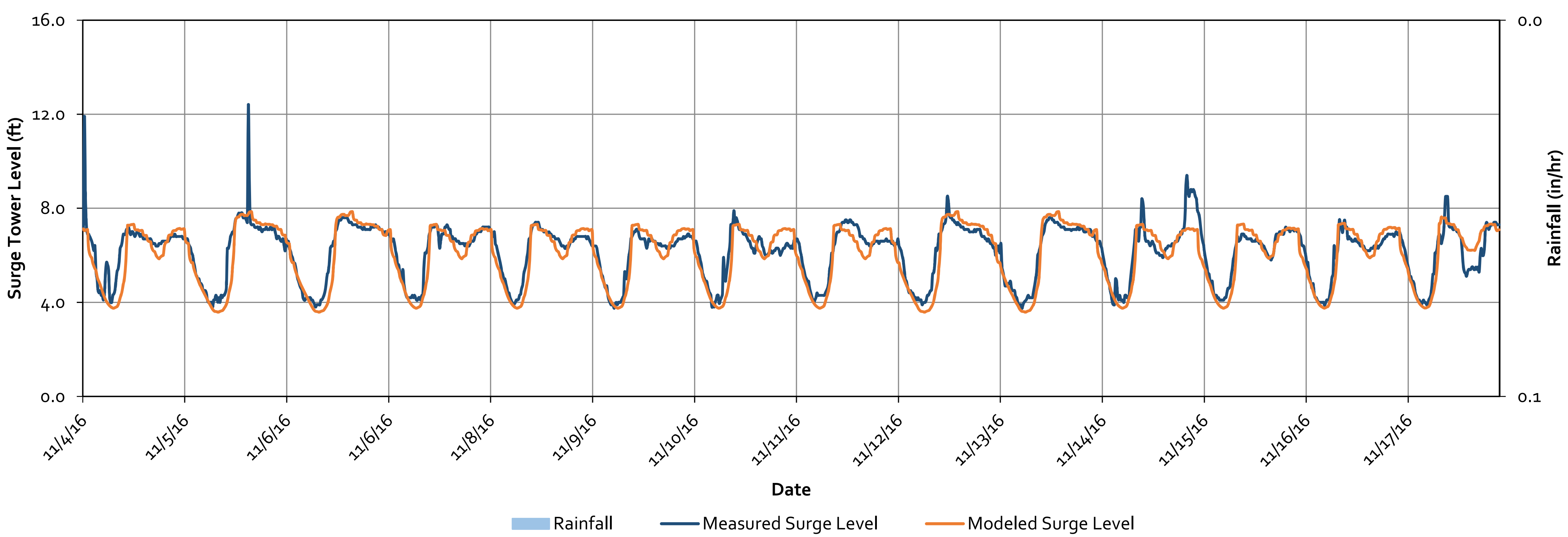
DRY WEATHER HYDRAULIC MODEL CALIBRATION

HAYWARD EFFLUENT PUMP STATION

Flow Calibration



Surge Level Calibration



DWF Calibration Summary

	Measured(1)			Modeled			Percent Diff.(2)	
Variable	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	10.0	13.1	2.7	10.0	13.5	4.8	0.3%	3.0%
Surge Level	6.1	9.4	3.7	6.0	7.9	3.6	-2.1%	-16.4%

Notes:

(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

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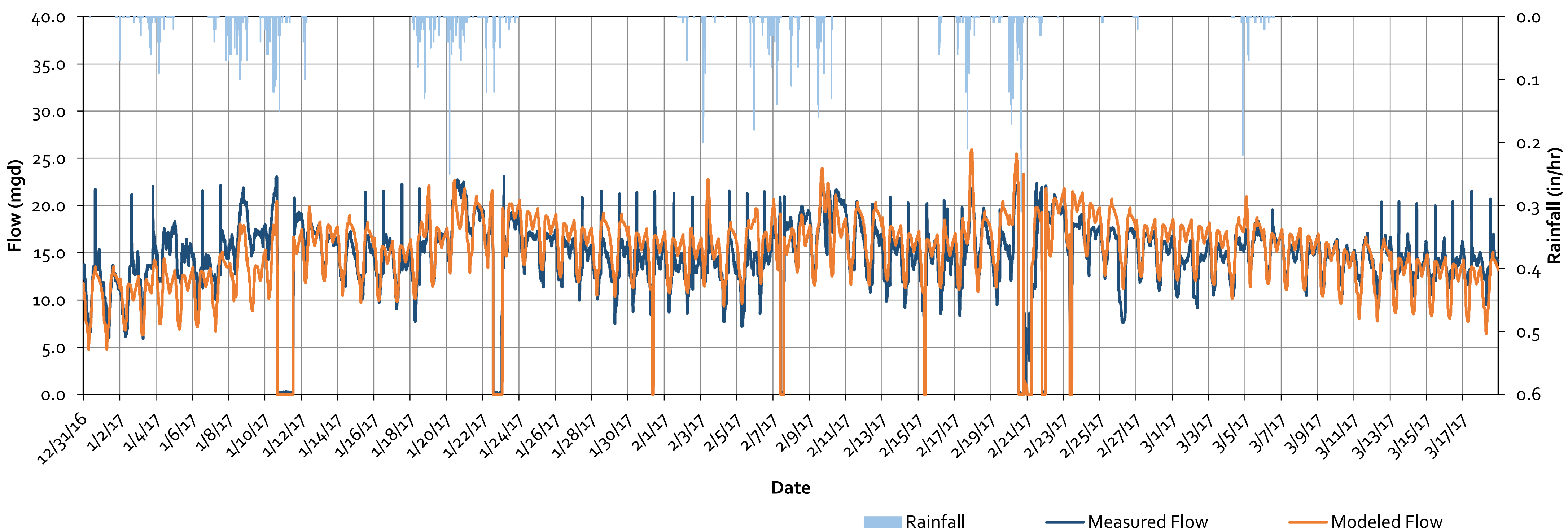
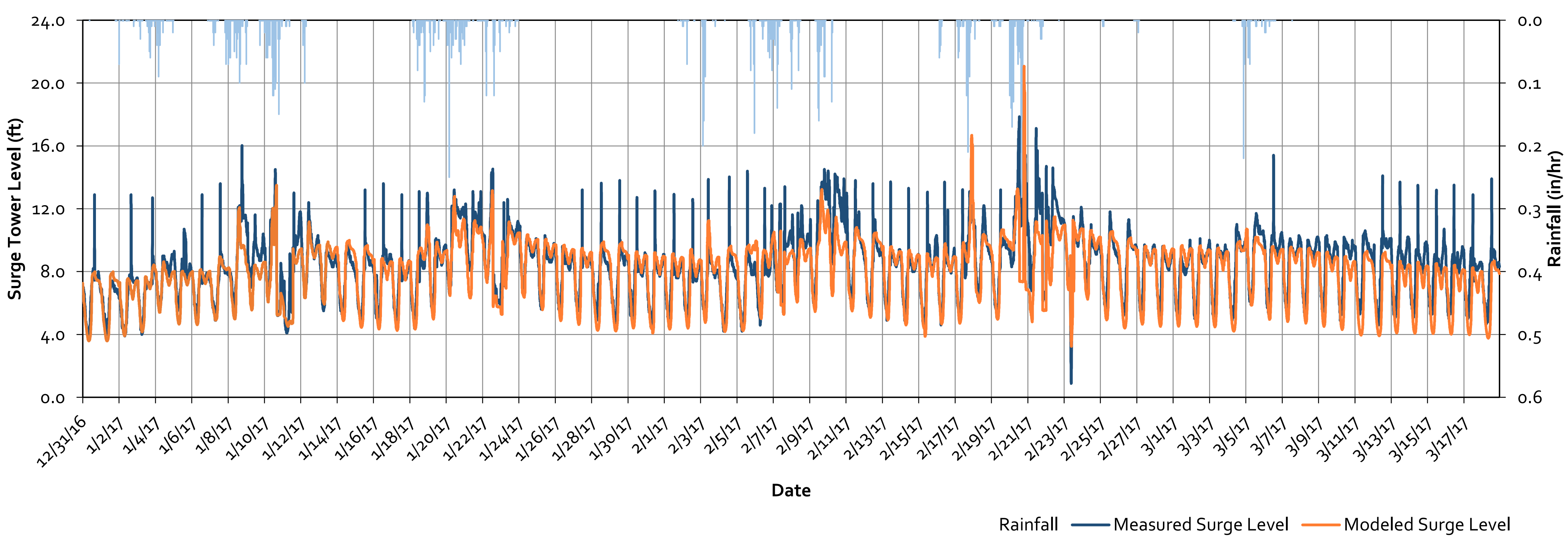
EBDA HYDRAULIC MODEL CALIBRATION

HAYWARD EFFLUENT PUMP STATION

Flow Calibration



Surge Level Calibration



WWF Calibration Summary - Storm 1 - 1/7/17 - 1/16/17

	Measured[1]			Modeled			Percent Diff.[2]	
Variable	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	14.4	23.0	0.0	13.3	20.4	0.0	-7.8%	-11.3%
Surge Level	8.3	16.0	4.1	7.9	13.5	4.3	-4.9%	-15.7%

WWF Calibration Summary - Storm 2 - 2/3/17 - 2/13/17

	Measured[1]			Modeled			Percent Diff.[2]	
Variable	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	15.4	22.0	0.0	16.2	23.9	0.0	5.4%	9.0%
Surge Level	8.8	14.5	4.2	8.4	13.2	4.2	-4.2%	-8.8%

WWF Calibration Summary - Storm 3 - 2/16/17 - 3/4/17

	Measured[1]			Modeled			Percent Diff.[2]	
Variable	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	14.7	22.3	0.0	16.0	25.9	0.0	9.5%	16.2%
Surge Level	8.9	17.8	0.9	8.5	21.0	3.2	-5.1%	18.1%

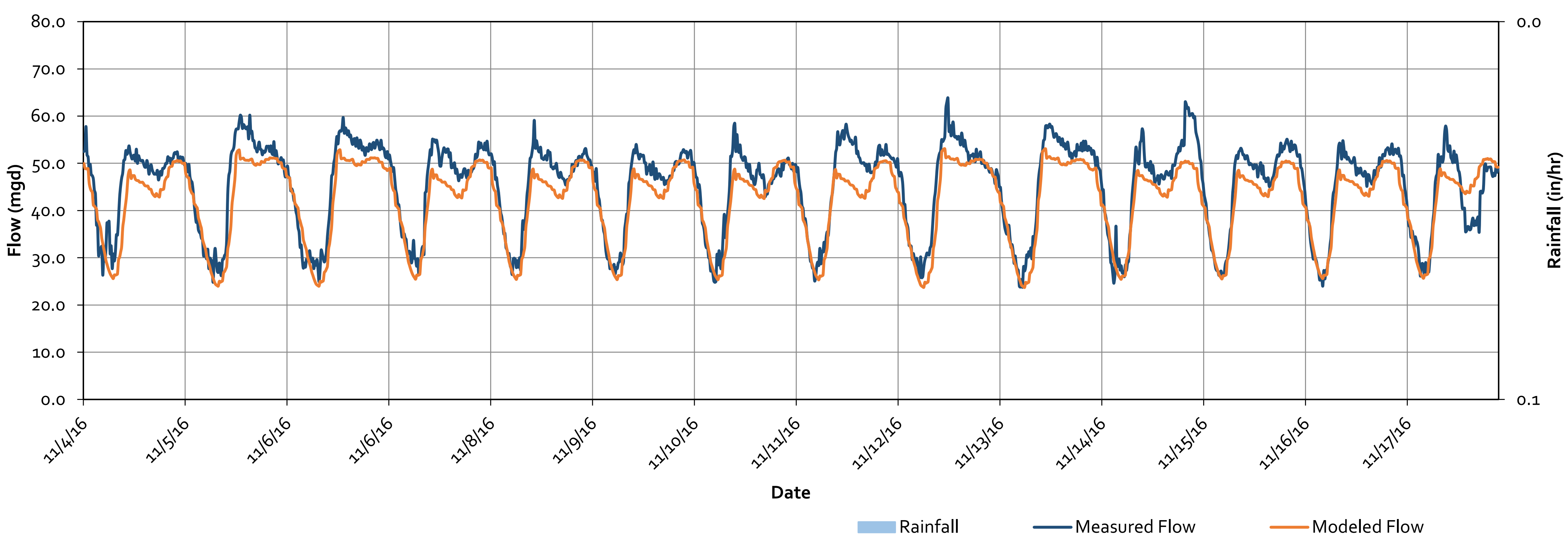
Notes:

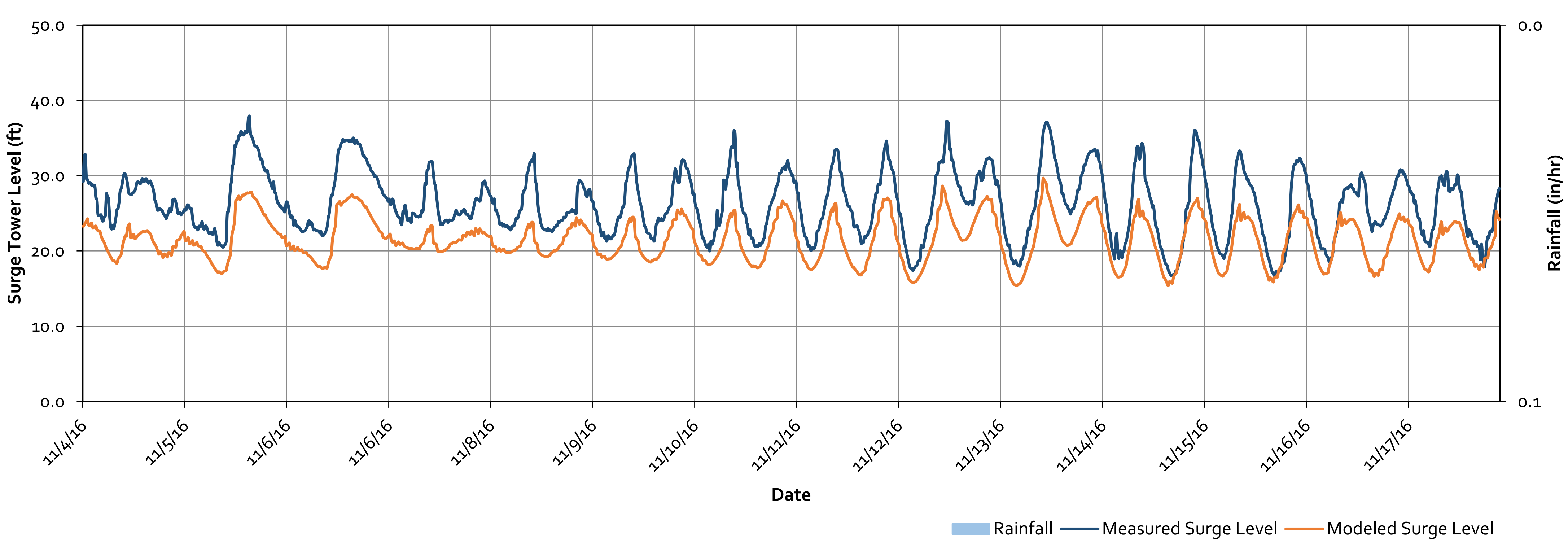
(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

DRY WEATHER HYDRAULIC MODEL CALIBRATION

ORO LOMA EFFLUENT PUMP STATION





DWF Calibration Summary

Variable	Measured[1] Avg. (mgd)	Measured[1] Max. (mgd)	Measured[1] Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[2] Avg.	Percent Diff.[2] Max.
Flow	45.1	63.8	23.8	42.2	53.1	23.7	-6.5%	-16.8%
Surge Level	26.3	37.9	16.6	21.5	29.7	15.4	-18.2%	-21.8%

Notes:

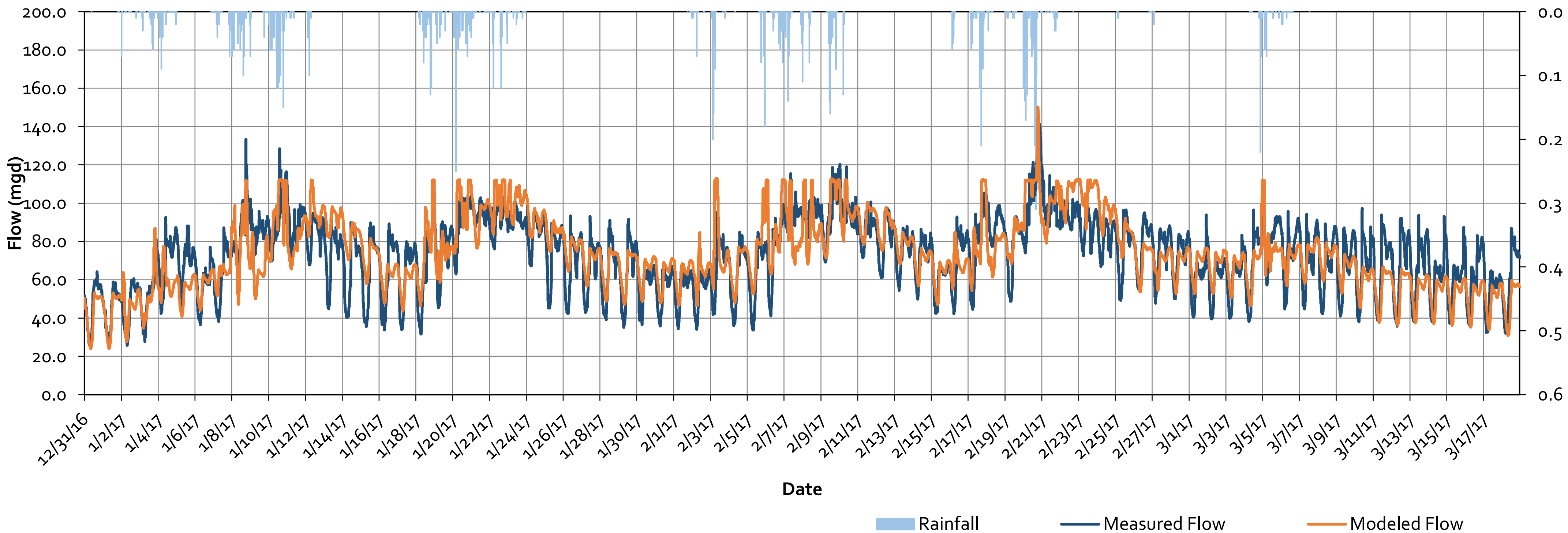
(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

EBDA HYDRAULIC MODEL CALIBRATION

ORO LOMA EFFLUENT PUMP STATION

Flow Calibration



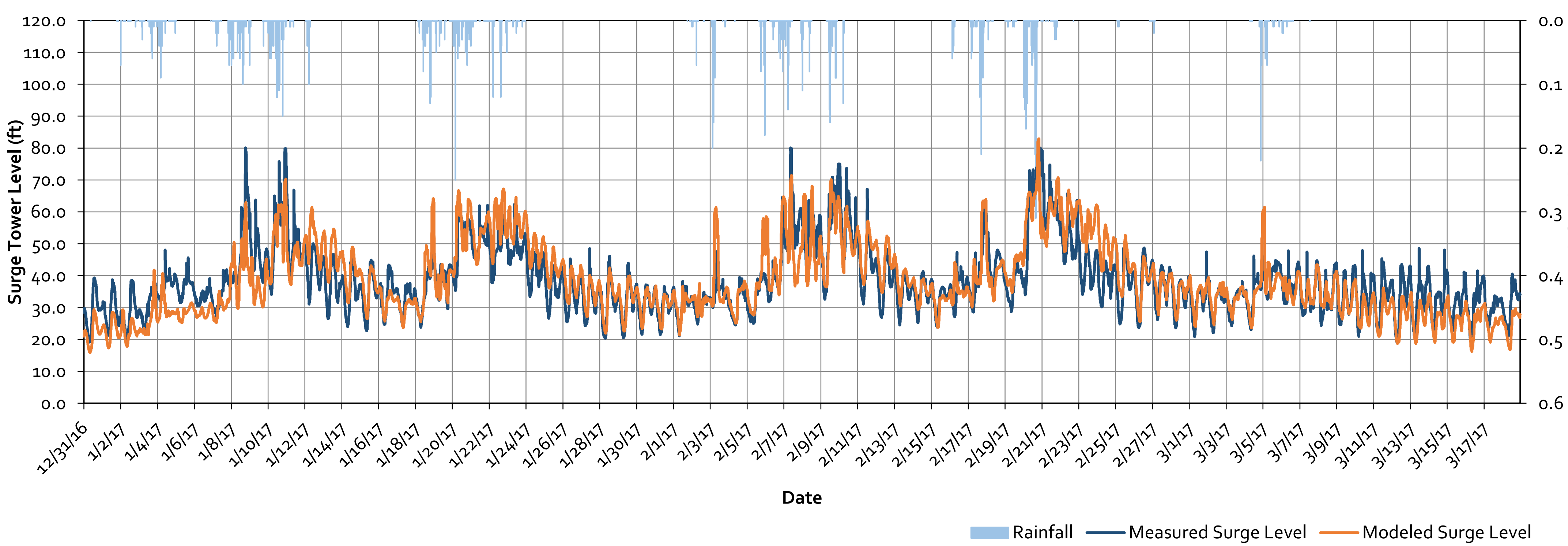
WWF Calibration Summary - Storm 1 - 1/7/17 - 1/16/17

Variable	Measured[1] Avg. (mgd)	Measured[1] Max. (mgd)	Measured[1] Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[2] Avg.	Percent Diff.[2] Max.
Flow	77.2	132.1	33.7	79.1	112.3	47.2	2.4%	-15.0%
Surge Level	42.0	80.0	22.7	41.8	70.3	25.3	-0.5%	-12.2%

WWF Calibration Summary - Storm 2 - 2/3/17 - 2/13/17

Variable	Measured[1] Avg. (mgd)	Measured[1] Max. (mgd)	Measured[1] Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[2] Avg.	Percent Diff.[2] Max.
Flow	81.0	120.3	33.7	84.6	113.1	48.0	4.5%	-6.0%
Surge Level	43.3	80.0	24.5	44.5	71.4	25.1	2.8%	-10.7%

Surge Level Calibration



WWF Calibration Summary - Storm 3 - 2/16/17 - 3/4/17

Variable	Measured[1] Avg. (mgd)	Measured[1] Max. (mgd)	Measured[1] Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[2] Avg.	Percent Diff.[2] Max.
Flow	78.9	141.4	38.2	81.6	150.2	46.4	3.4%	6.2%
Surge Level	40.6	80.0	20.9	43.2	82.9	23.6	6.4%	3.6%

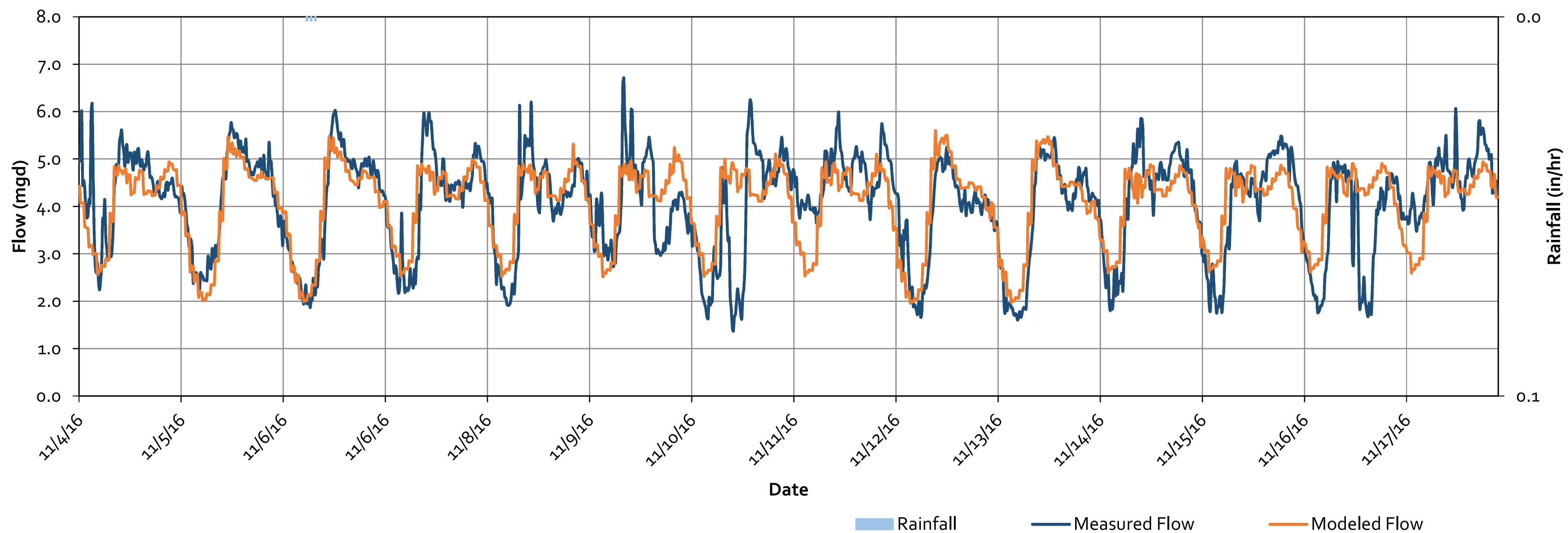
Notes:

(1) Source: Data provided by EBDA staff and member agencies.

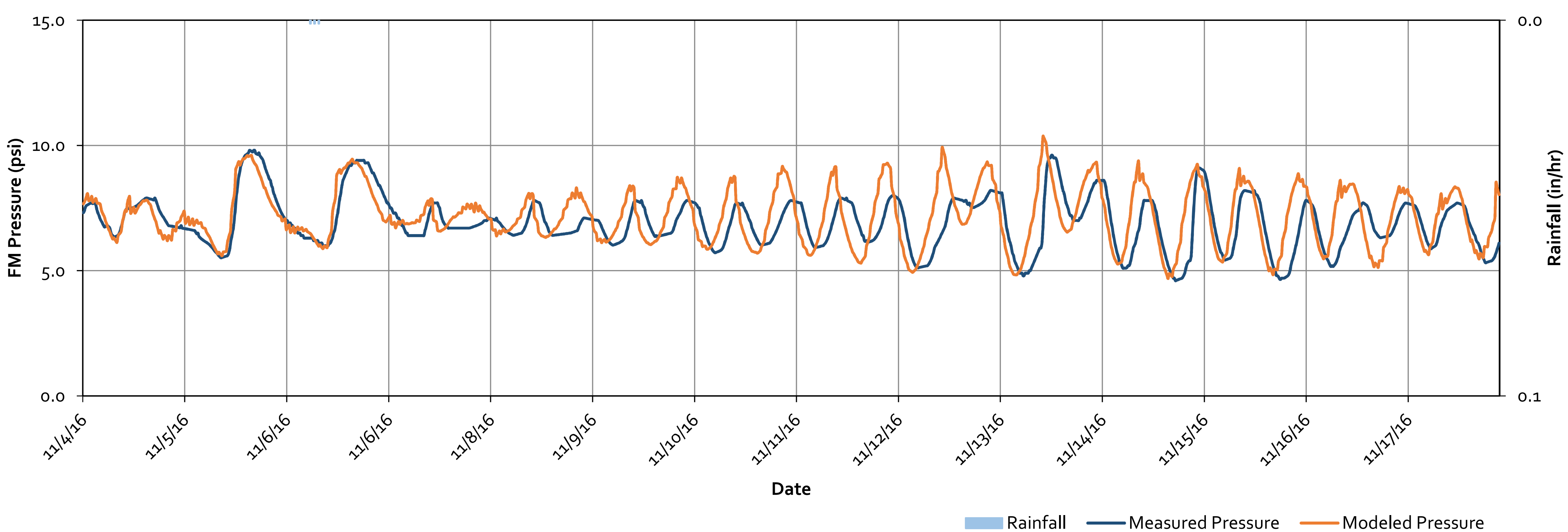
(2) % Difference = (Modeled - Measured) / Measured x 100

EBDA DRY WEATHER HYDRAULIC MODEL CALIBRATION
SAN LEANDRO EFFLUENT PUMP STATION

Flow Calibration



Pressure Calibration



DWF Calibration Summary

	Measured[1]			Modeled			Percent Diff.[2]	
Variable	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg. (mgd)	Max. (mgd)	Min. (mgd)	Avg.	Max.
Flow	4.1	6.7	1.4	4.1	5.6	2.0	0.1%	-16.6%
Pressure	6.9	9.8	4.6	7.2	10.4	4.7	3.6%	5.8%

Notes:

(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

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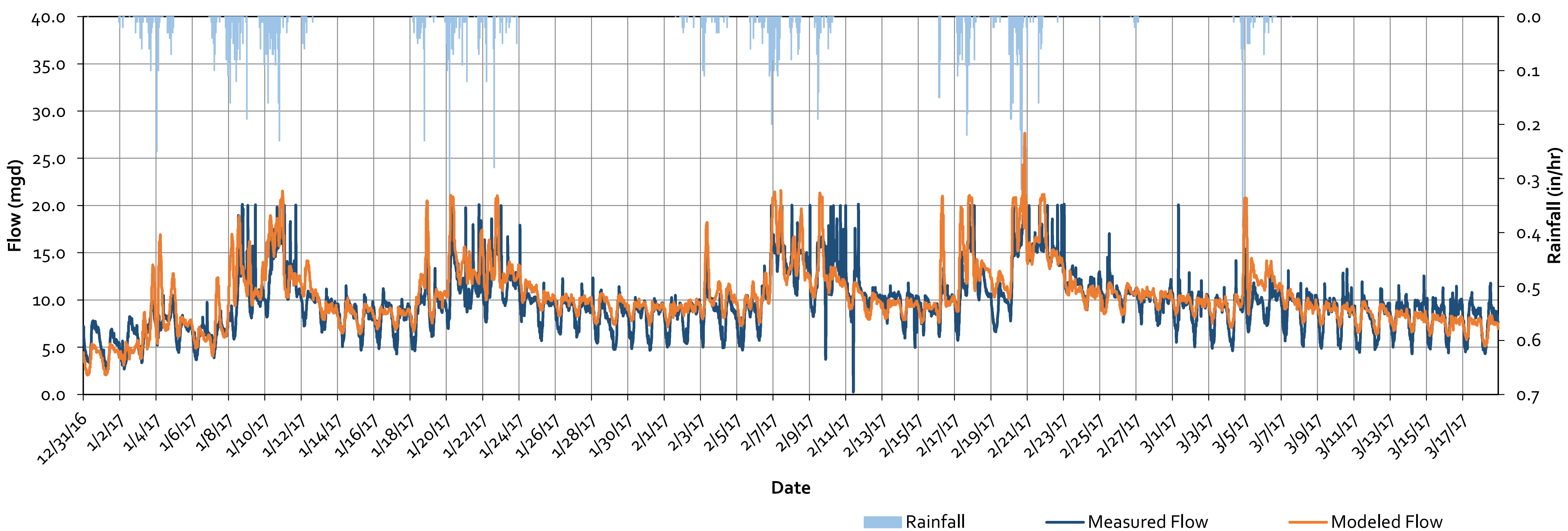
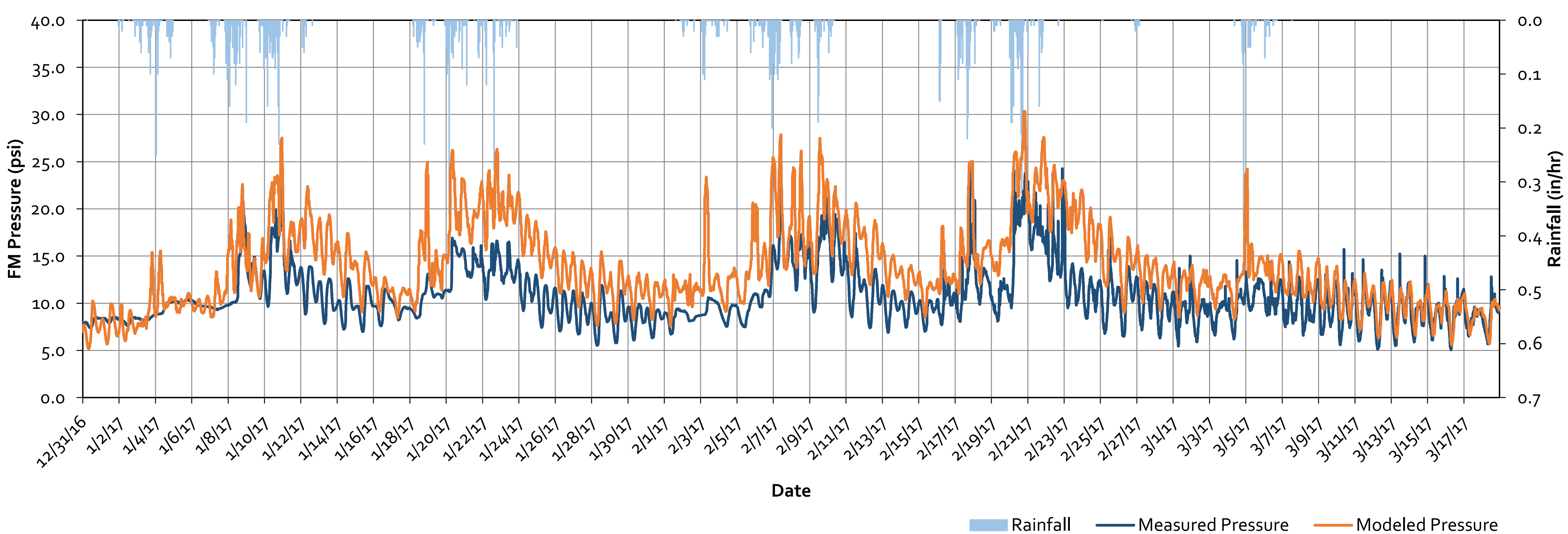
HYDRAULIC MODEL CALIBRATION

SAN LEANDRO EFFLUENT PUMP STATION

Flow Calibration



Pressure Calibration



WWF Calibration Summary - Storm 1 - 1/7/17 - 1/16/17

Variable	Measured[1] Avg. (mgd)	Measured[1] Max. (mgd)	Measured[1] Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[2] Avg.	Percent Diff.[2] Max.
Flow	9.8	20.0	3.9	10.7	21.5	4.1	9.6%	7.7%
Pressure	11.7	22.8	7.0	15.1	27.5	8.5	29.5%	20.7%

WWF Calibration Summary - Storm 2 - 2/3/17 - 2/13/17

Variable	Measured[1] Avg. (mgd)	Measured[1] Max. (mgd)	Measured[1] Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[2] Avg.	Percent Diff.[2] Max.
Flow	11.1	20.0	0.3	11.6	21.6	7.3	5.2%	8.0%
Pressure	12.1	22.8	6.9	16.2	27.9	9.1	33.4%	22.2%

WWF Calibration Summary - Storm 3 - 2/16/17 - 3/4/17

Variable	Measured[1] Avg. (mgd)	Measured[1] Max. (mgd)	Measured[1] Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[2] Avg.	Percent Diff.[2] Max.
Flow	11.2	20.0	4.6	11.9	27.7	7.1	6.7%	38.3%
Pressure	11.5	24.5	5.4	15.8	30.3	8.3	37.0%	23.8%

Notes:

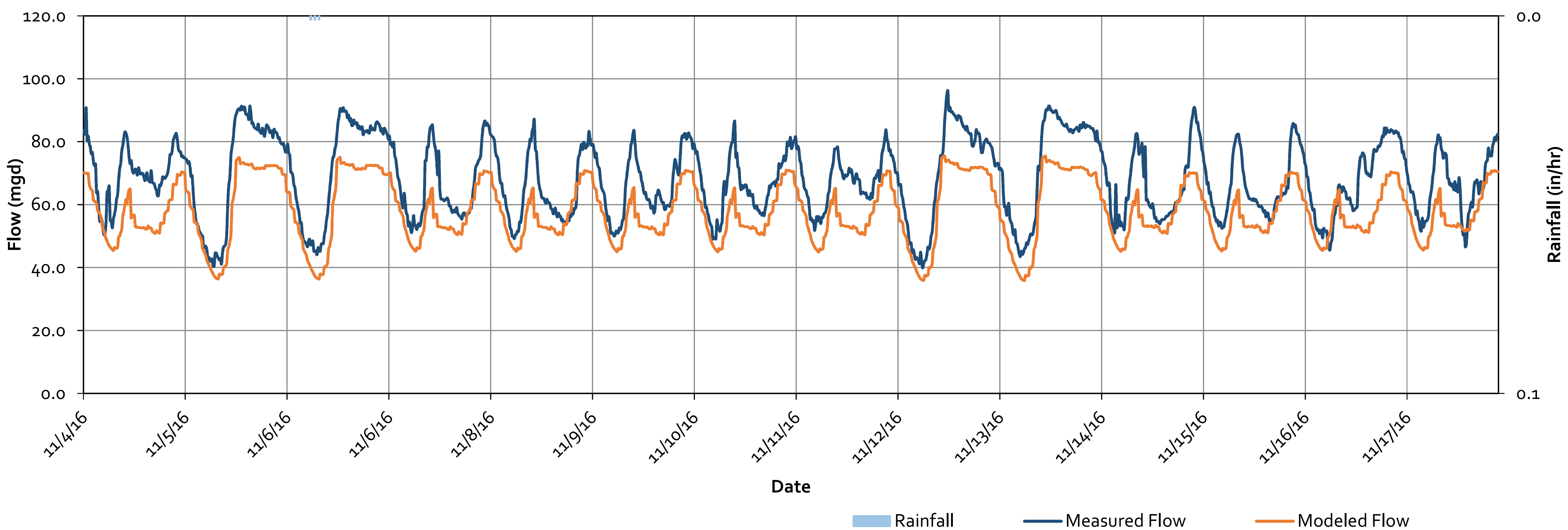
(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

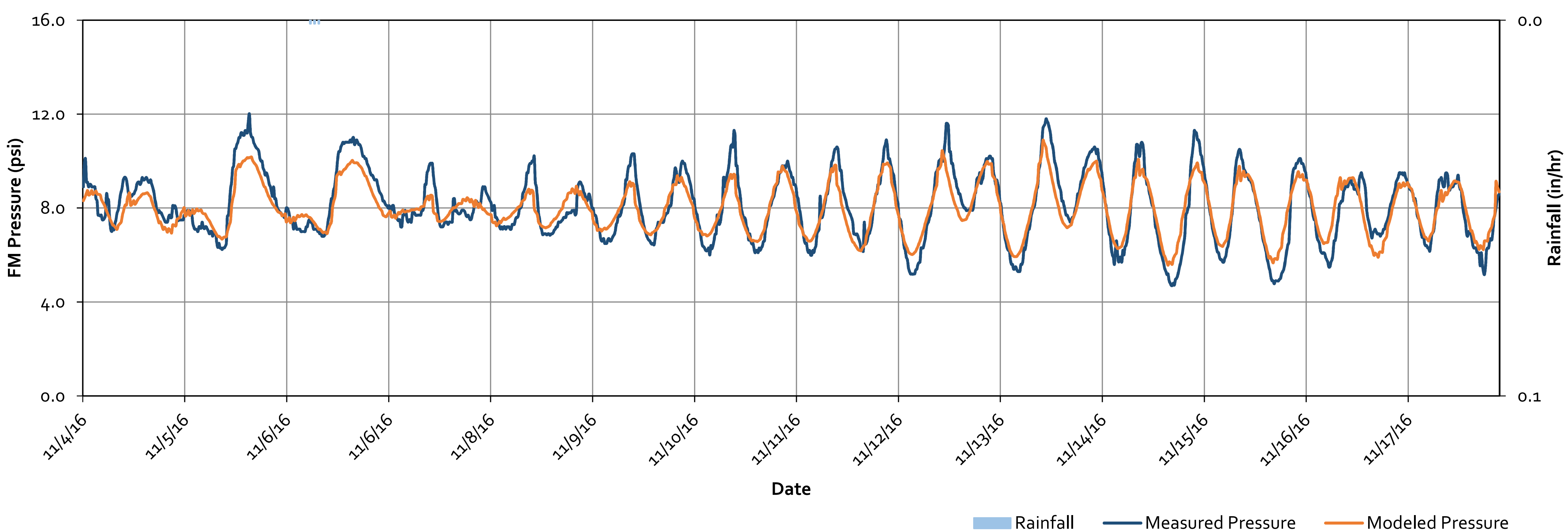
EBDA DRY WEATHER HYDRAULIC MODEL CALIBRATION

MARINA DECHLORINATION FACILITY

Flow Calibration



Pressure Calibration



DWF Calibration Summary

Variable	Measured[1] Avg. (mgd)	Measured[1] Max. (mgd)	Measured[1] Min. (mgd)	Modeled Avg. (mgd)	Modeled Max. (mgd)	Modeled Min. (mgd)	Percent Diff.[2] Avg.	Percent Diff.[2] Max.
Flow	68.1	96.1	39.9	57.9	75.4	35.9	-14.9%	-21.5%
Pressure	8.1	12.0	4.7	8.0	10.9	5.6	-1.3%	-9.3%

Notes:

(1) Source: Data provided by EBDA staff and member agencies.

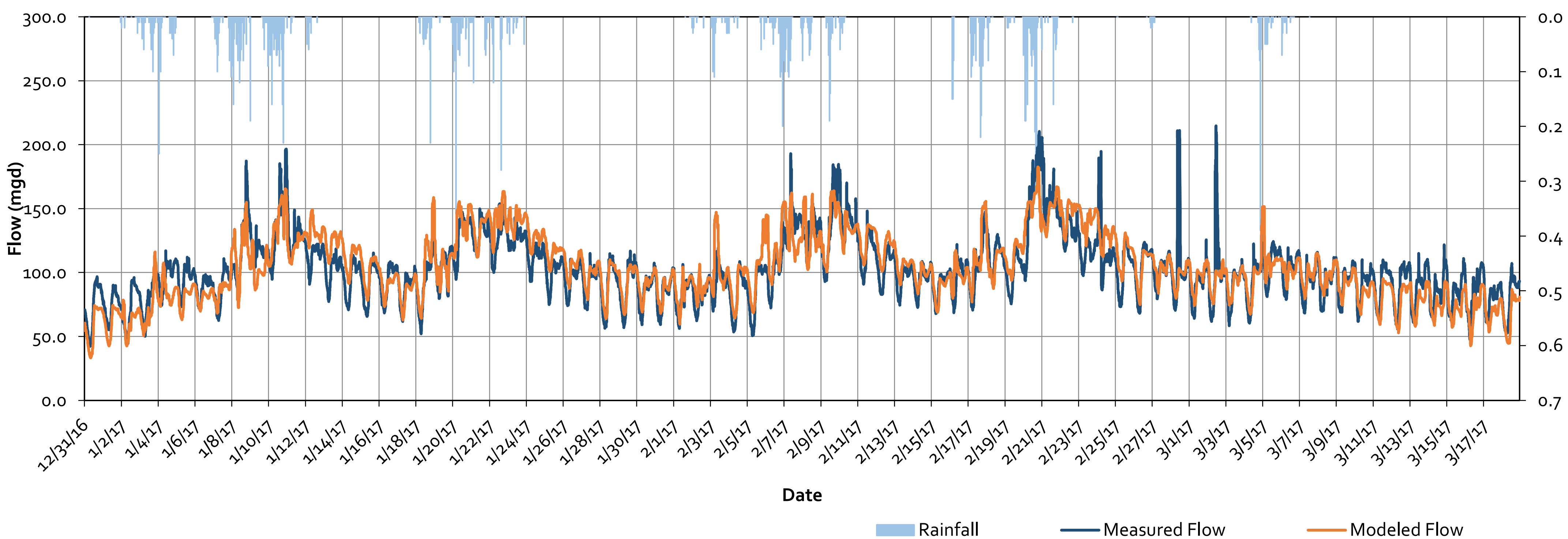
(2) % Difference = (Modeled - Measured) / Measured x 100

EBDA

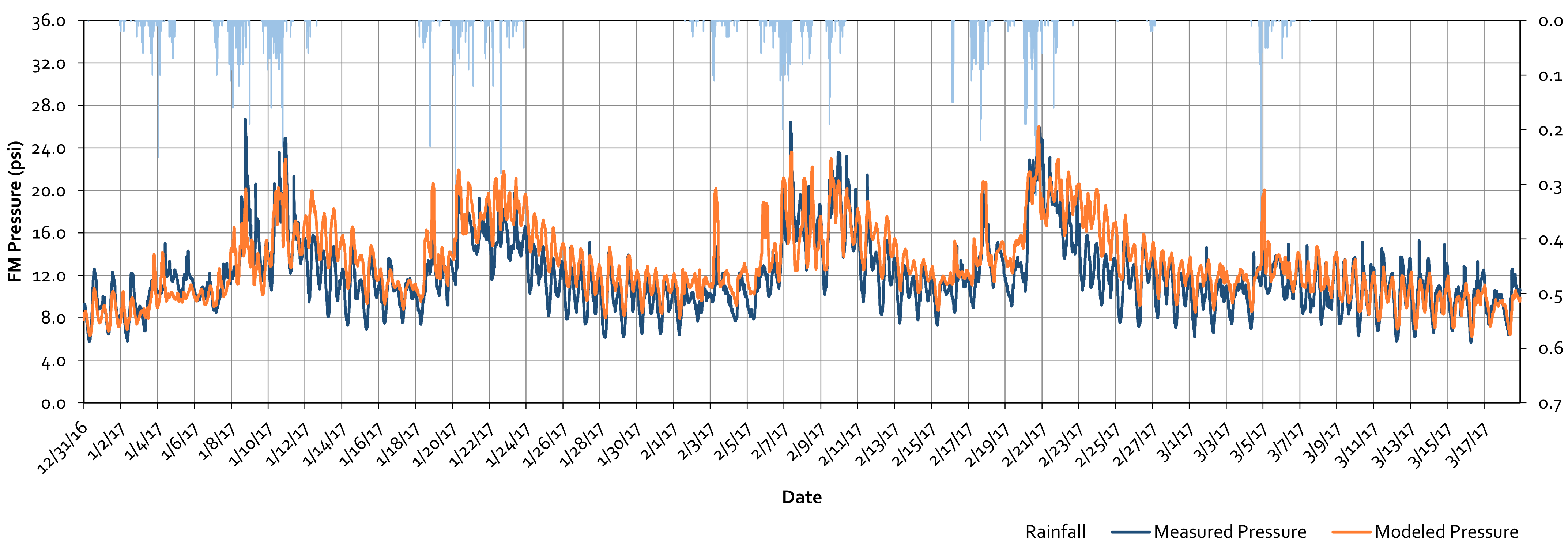
HYDRAULIC MODEL CALIBRATION

MARINA DECHLORINATION FACILITY

Flow Calibration



Pressure Calibration



WWF Calibration Summary - Storm 1 - 1/7/17 - 1/16/17

Variable	Measured[1] Avg. (mgd)	Max. (mgd)	Min. (mgd)	Modeled Avg. (mgd)	Max. (mgd)	Min. (mgd)	Percent Diff.[2] Avg.	Max.
Flow	109.5	196.4	62.5	112.6	165.5	68.2	2.9%	-15.7%
Pressure	13.1	26.6	6.9	14.1	23.0	9.0	7.8%	-13.7%

WWF Calibration Summary - Storm 2 - 2/3/17 - 2/13/17

Variable	Measured[1] Avg. (mgd)	Max. (mgd)	Min. (mgd)	Modeled Avg. (mgd)	Max. (mgd)	Min. (mgd)	Percent Diff.[2] Avg.	Max.
Flow	112.2	192.6	50.6	117.9	163.9	64.4	5.1%	-14.9%
Pressure	13.6	26.3	7.5	14.9	23.6	9.2	9.9%	-10.2%

WWF Calibration Summary - Storm 3 - 2/16/17 - 3/4/17

Variable	Measured[1] Avg. (mgd)	Max. (mgd)	Min. (mgd)	Modeled Avg. (mgd)	Max. (mgd)	Min. (mgd)	Percent Diff.[2] Avg.	Max.
Flow	111.2	211.7	58.4	114.8	182.5	67.4	3.2%	-13.8%
Pressure	12.6	25.9	6.2	14.5	26.0	8.5	15.1%	0.5%

Notes:

(1) Source: Data provided by EBDA staff and member agencies.

(2) % Difference = (Modeled - Measured) / Measured x 100

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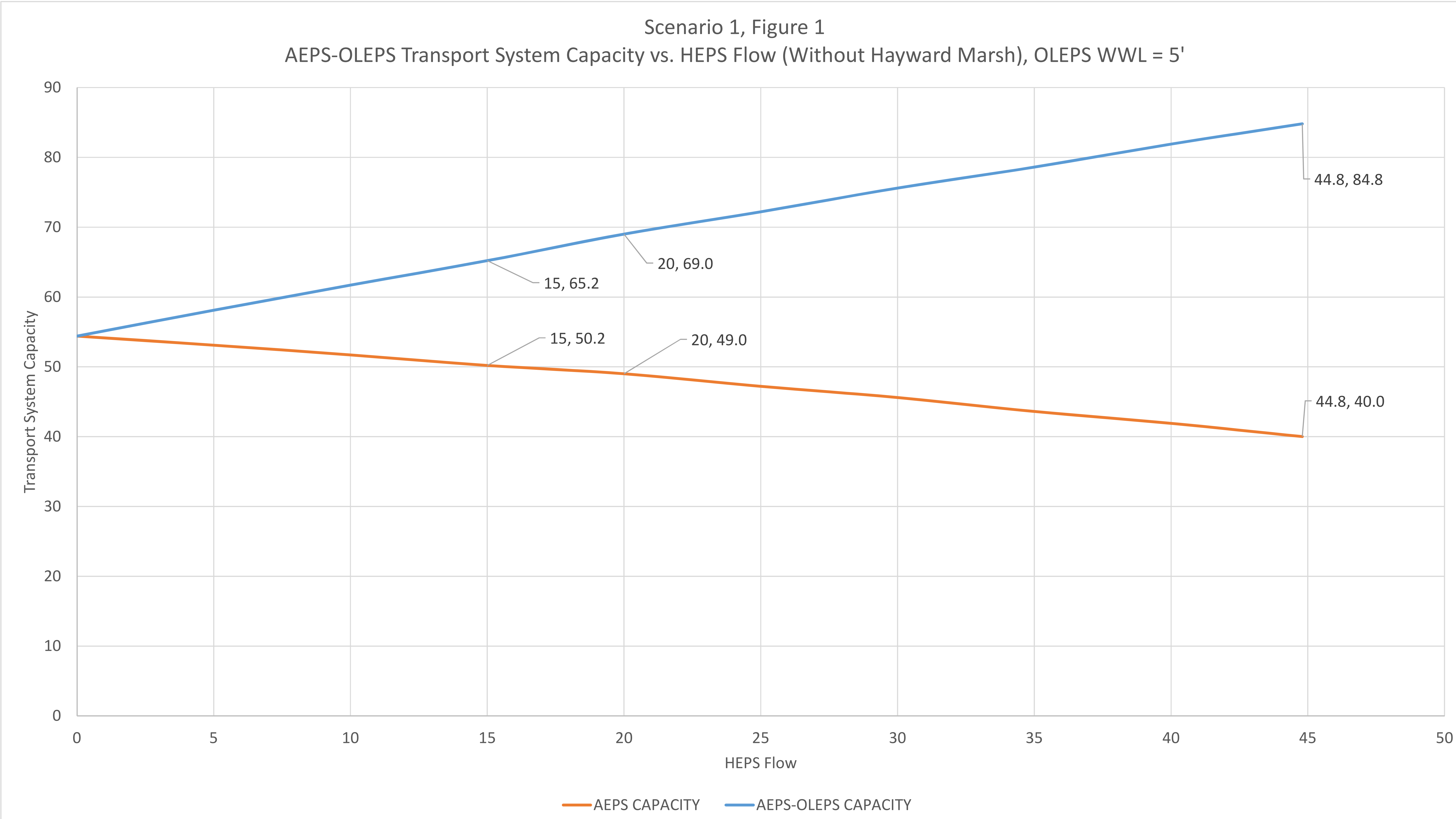
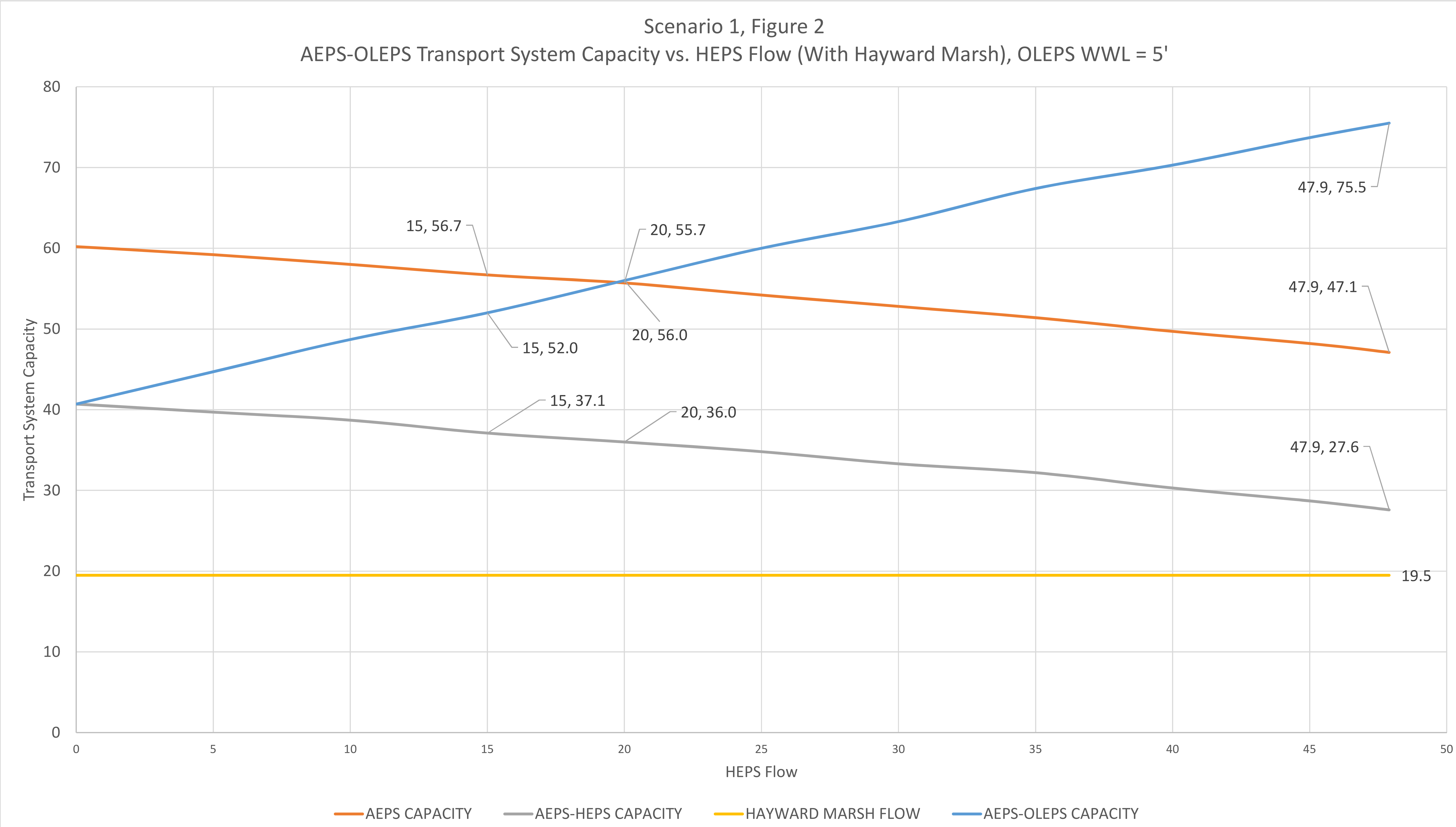
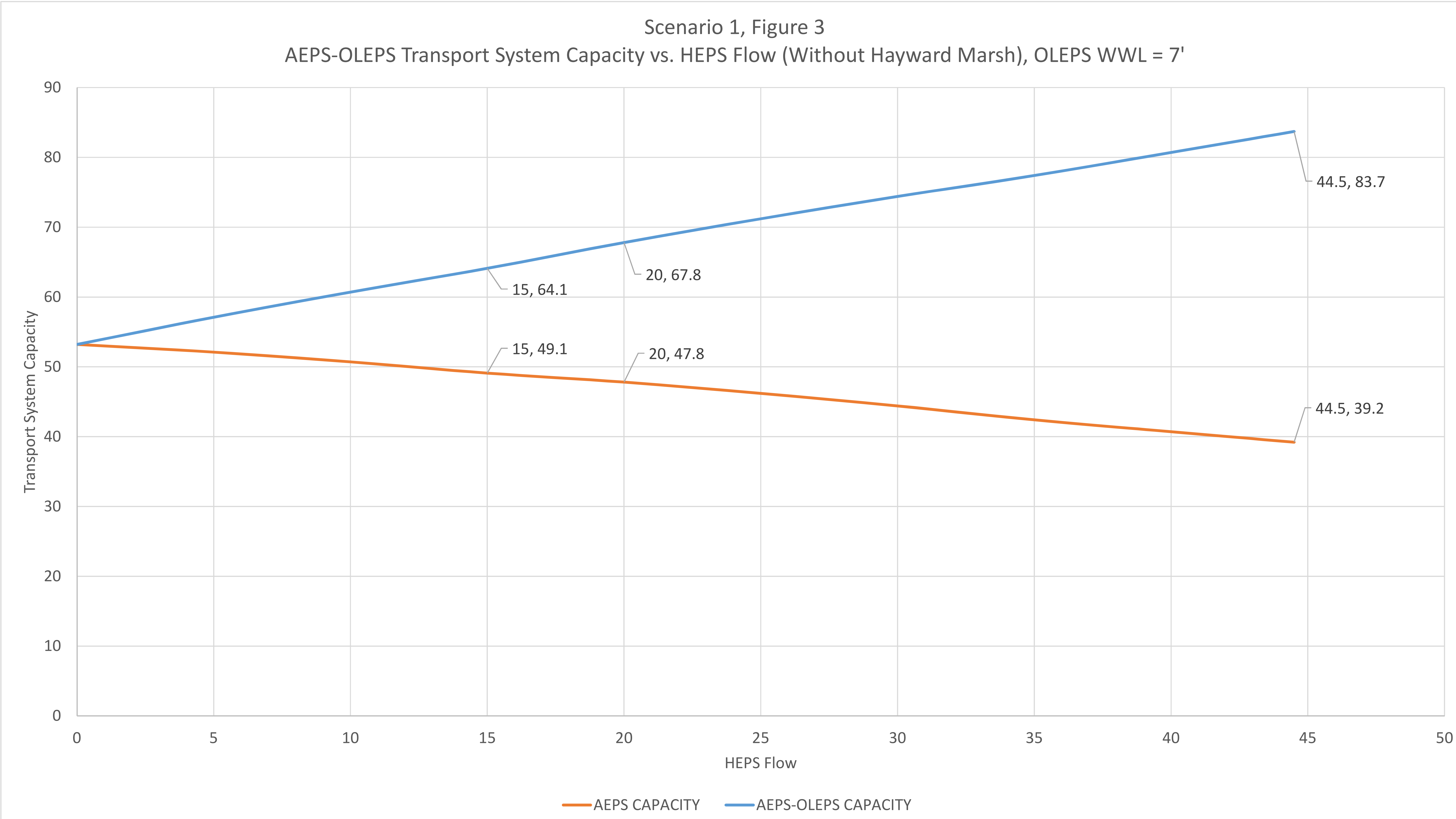
Appendix B

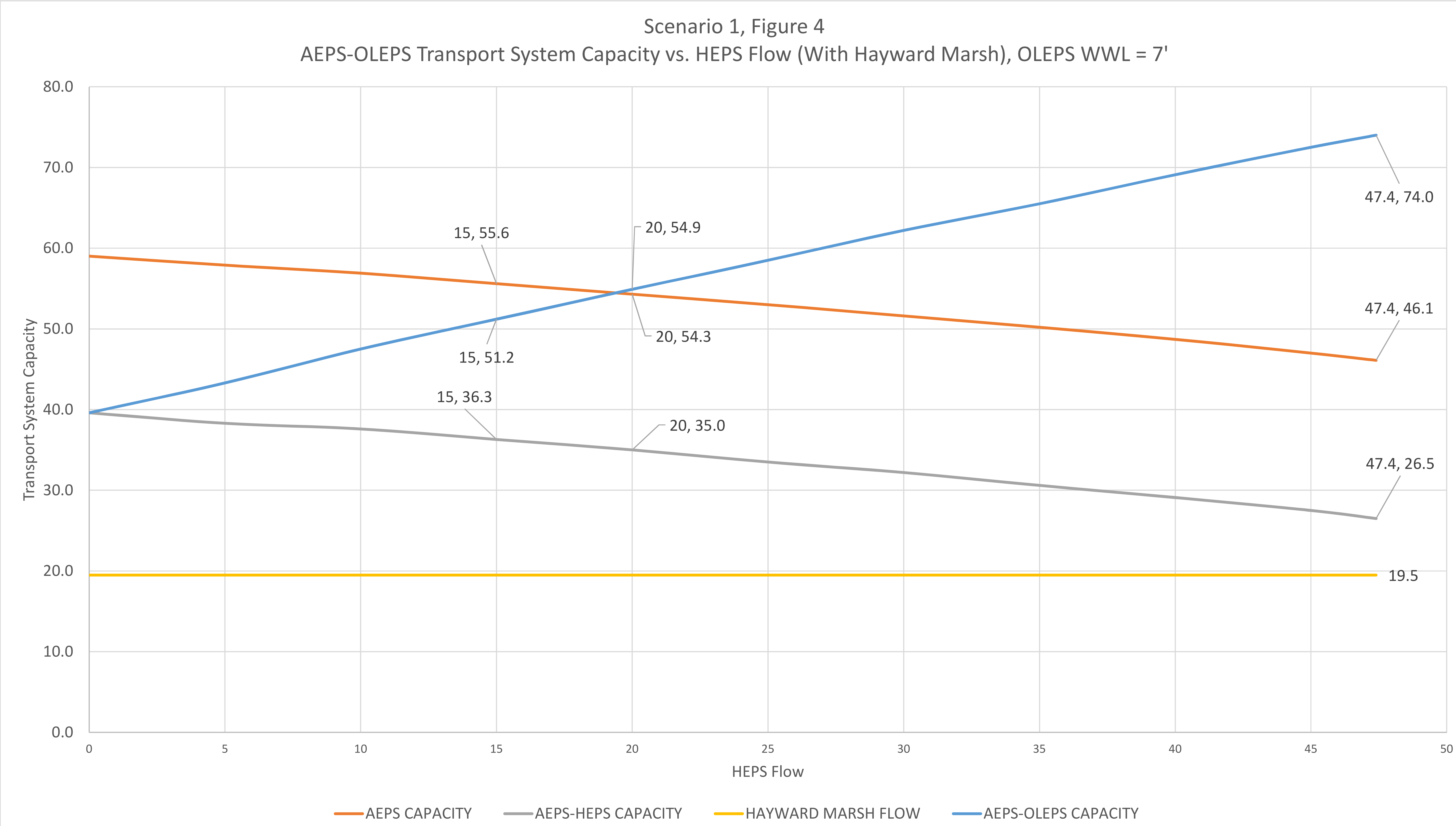
SCENARIO 1 MODEL RESULTS

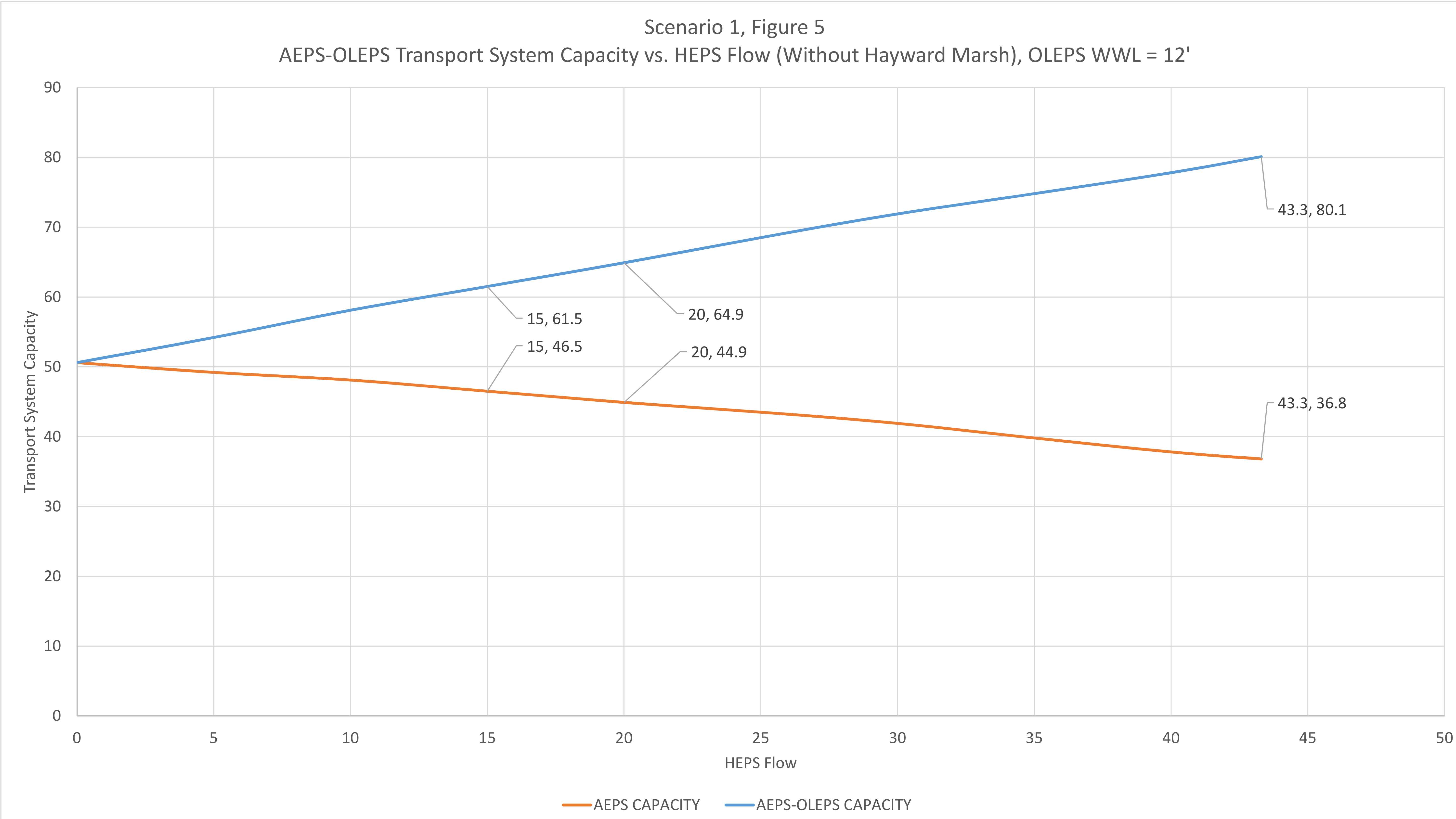


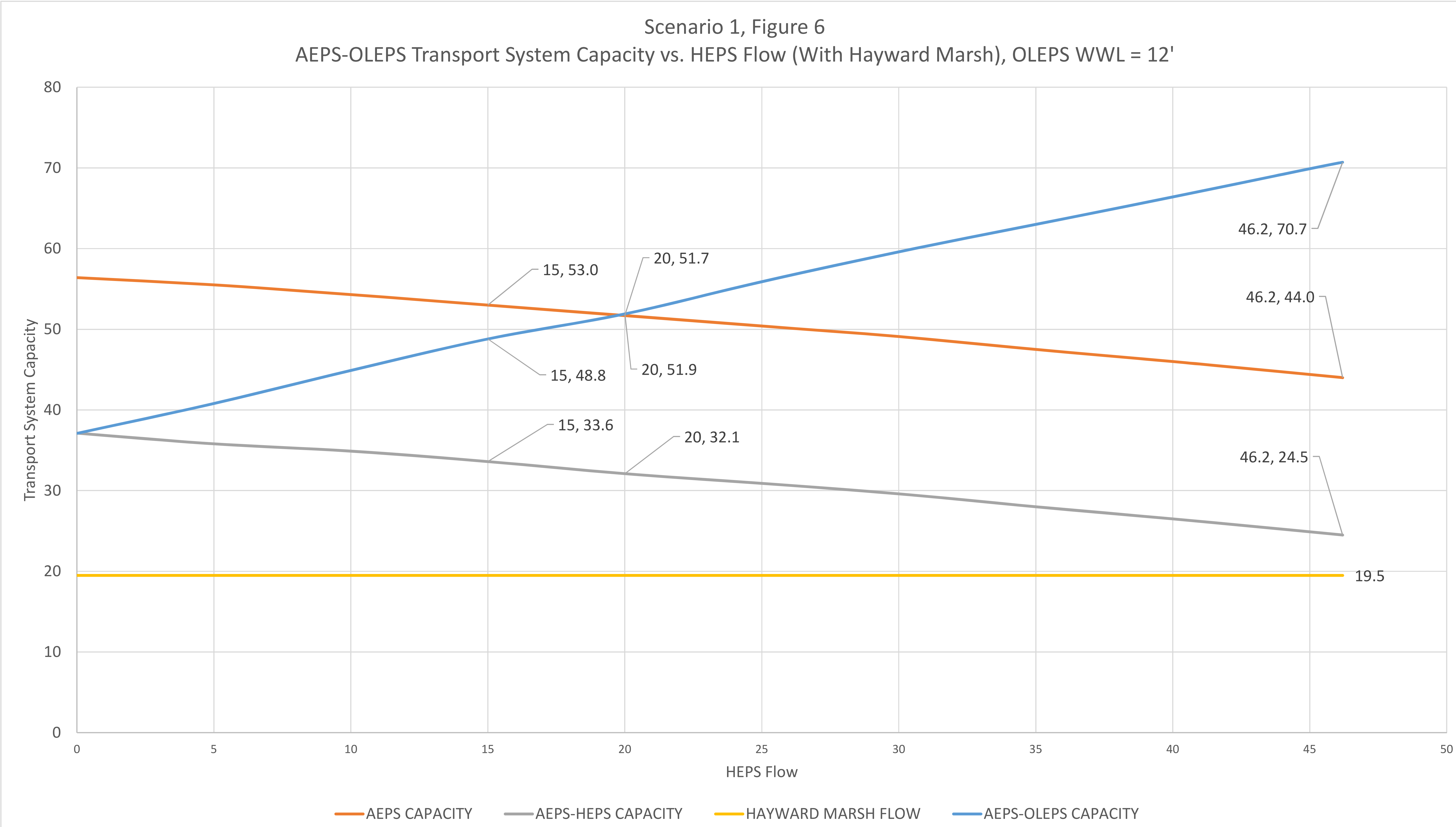
Scenario 1, Figure 1
AEPS-OLEPS Transport System Capacity vs. HEPS Flow (Without Hayward Marsh), OLEPS WWL = 5'
Transport System Capacity
HEPS Flow
0
10
20
30
40
50
60
70
80
90
0
5
10
15
20
25
30
35
40
45
50
44.8, 84.8
20, 69.0
15, 65.2
15, 50.2
20, 49.0
44.8, 40.0
AEPS CAPACITY
AEPS-OLEPS CAPACITY


Scenario 1, Figure 2
AEPS-OLEPS Transport System Capacity vs. HEPS Flow (With Hayward Marsh), OLEPS WWL = 5'
Transport System Capacity
HEPS Flow
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40
45
50
47.9, 75.5
15, 56.7
20, 55.7
47.9, 47.1
15, 52.0
20, 56.0
15, 37.1
20, 36.0
47.9, 27.6
19.5
AEPS CAPACITY
AEPS-HEPS CAPACITY
HAYWARD MARSH FLOW
AEPS-OLEPS CAPACITY


Scenario 1, Figure 3
AEPS-OLEPS Transport System Capacity vs. HEPS Flow (Without Hayward Marsh), OLEPS WWL = 7'
Transport System Capacity
HEPS Flow
0
10
20
30
40
50
60
70
80
90
0
5
10
15
20
25
30
35
40
45
50
44.5, 83.7
20, 67.8
15, 64.1
15, 49.1
20, 47.8
44.5, 39.2
AEPS CAPACITY
AEPS-OLEPS CAPACITY


Scenario 1, Figure 4
AEPS-OLEPS Transport System Capacity vs. HEPS Flow (With Hayward Marsh), OLEPS WWL = 7'
Transport System Capacity
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
5
10
15
20
25
30
35
40
45
50
HEPS Flow
47.4, 74.0
15, 55.6
20, 54.9
47.4, 46.1
20, 54.3
15, 51.2
15, 36.3
20, 35.0
47.4, 26.5
19.5
AEPS CAPACITY
AEPS-HEPS CAPACITY
HAYWARD MARSH FLOW
AEPS-OLEPS CAPACITY


Scenario 1, Figure 5
AEPS-OLEPS Transport System Capacity vs. HEPS Flow (Without Hayward Marsh), OLEPS WWL = 12'
Transport System Capacity
HEPS Flow
0
10
20
30
40
50
60
70
80
90
0
5
10
15
20
25
30
35
40
45
50
43.3, 80.1
15, 61.5
20, 64.9
15, 46.5
20, 44.9
43.3, 36.8
AEPS CAPACITY
AEPS-OLEPS CAPACITY


Scenario 1, Figure 6
AEPS-OLEPS Transport System Capacity vs. HEPS Flow (With Hayward Marsh), OLEPS WWL = 12'
Transport System Capacity
HEPS Flow
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40
45
50
46.2, 70.7
15, 53.0
20, 51.7
46.2, 44.0
15, 48.8
20, 51.9
15, 33.6
20, 32.1
46.2, 24.5
19.5
AEPS CAPACITY
AEPS-HEPS CAPACITY
HAYWARD MARSH FLOW
AEPS-OLEPS CAPACITY