SEWER SYSTEM INFILTRATION AND INFLOW EVALUATION REPORT

Prepared for City of Poulsbo

July 2021

POU 119.149

Prepared by:

RH2 Engineering, Inc.

22722 29th Drive SE, Suite 210

Bothell, WA 98021

1.800.720.8052 / rh2.com

THIS PAGE INTENTIONALLY LEFT BLANK

City of Poulsbo

Sewer System Infiltration and Inflow Evaluation Report

July 2021

Prepared by RH2 Engineering, Inc.

Prepared for City of Poulsbo

Note: This Sewer System Infiltration and Inflow Evaluation Report was completed under the supervision of the following Licensed Professional Engineers registered in the State of Washington.

Sincerely,

RH2 ENGINEERING, INC.

Dated:
07/19/2021

Dated:
07/19/2021

THIS PAGE INTENTIONALLY LEFT BLANK

City of Poulsbo

Sewer System Infiltration and Inflow Evaluation Report

Table of Contents

Executive Summary 1
Introduction 4
Background 4
Purpose 4
Definitions and Acronyms 4
Existing Sewer System 5
Previous I&I Analyses 6
Previous I&I Reduction Efforts 7
Description of Analysis 10
Data Collection Devices 10
Flow Metering 10
Analyses and Results 11
System Wide I&I Analyses 11
I&I Rate Summary 15
Lift Station/Sewer Drainage Basin Monitoring 17
Instream Flow Metering 28
Conclusions and Recommendations 38
System-Wide I&I 38
Lift Station/Sewer Drainage Basin I&I 39
Next Steps and Additional Investigation 39
Additional Investigation 39
Recommended Improvements 40
Overflow Event Analyses 41
Offline Peak Storage Structure 42

City of Poulsbo

Sewer System Infiltration and Inflow Evaluation Report

Table of Contents

Tables

Table ES-1 – December 21, 2020 Storm Event Recurrence Intervals
Table 1 – General Sewer System Data
Table 2 – Historical Inflow Analyses
Table 3 – Historical Infiltration Analyses
Table 4 – Liberty Instream Flow Monitor Flow Comparison Before and After City's 2020 I&I Reduction Efforts
Table 5 – Johnson Way Flume, Lift Station, and Instream Flow Meter Recording Dates
Table 6 – Potential Excessive Inflow Analysis 2019 to 2020 Peak Daily Flow
Table 7 – Peak Day I&I Johnson Way Flume
Table 8 – Peak Hour I&I Johnson Way Flume
Table 9 – Johnson Way Flume Flows and Peaking Factors
Table 10 – Maximum Day I&I Analysis
Table 11 – Peak Hour I&I Analysis
Table 12 – Sol Vei and Overflow Manhole Elevations
Table 13 – 2020 System-Wide Annual I&I and Costs Incurred by City by I&I
Table 14 – Estimated OPSS Size Needed Based on Potential Central Interceptor Capacities

Figures

Figure 1 – Sewer System Flow Schematic
Figure 2 – Existing Sewer System and Flow Monitoring Locations Map
Figure 3 – Liberty Instream Flow Monitor Flows on May 2, 2020
Figure 4 – Liberty Instream Flow Monitor Flows on November 16, 2020
Figure 5 – Johnson Way Flume I&I on December 21, 2020
Figure 6 – 6th Avenue Lift Station I&I on January 12, 2021
Figure 7 – City's Storm Infrastructure near Marine Science Lift Station
Figure 8 – Marine Science Lift Station I&I on December 21, 2020
Figure 9 – 9th Avenue Lift Station I&I on January 13, 2021
Figure 10 – Alasund Lift Station I&I on December 21, 2020
Figure 11 – Village Lift Station I&I on December 21, 2020
Figure 12 – Applewood Lift Station I&I on January 4, 2021
Figure 13 – Bond Lift Station I&I on December 21, 2020
Figure 14 – Liberty Lift Station I&I on December 21, 2020
Figure 15 – Bond and Lindvig Drainage Basin I&I on December 21, 2020
Figure 16 – 6th Avenue Instream Flow Meter Location
Figure 17 – 6th Avenue Instream Flow Meter I&I on January 12, 2021
Figure 18 – Village South Instream Flow Meter Location

City of Poulsbo

Sewer System Infiltration and Inflow Evaluation Report

Table of Contents

Figure 19 – Village South Instream Flow Meter I&I on February 1, 2021
Figure 20 – Village Instream Flow Meter Location
Figure 21 – Village Instream Flow Meter I&I on January 12, 2021
Figure 22 – Liberty Instream Flow Meter Location
Figure 23 – Liberty Instream Flow Meter I&I on December 21, 2020
Figure 24 – Noll Road Instream Flow Meter Location
Figure 25 – Noll Road Instream Flow Meter I&I on February 1, 2021
Figure 26 – Sol Vei Manhole Location
Figure 27 – Sol Vei Level Readings on December 21, 2020 to December 22, 2020
Figure 28 – Central Interceptor Hydrograph for December 21, 2020
Figure 29 – Flow Data – Johnson Way Flume
Figure 30 – Flow Data – 6th Avenue Lift Station
Figure 31 – Flow Data – Marine Science Lift Station
Figure 32 – Flow Data – 9th Avenue Lift Station
Figure 33 – Flow Data – Alasund Lift Station
Figure 34 – Flow Data – Village Lift Station
Figure 35 – Flow Data – Applewood Lift Station
Figure 36 – Flow Data – Bond Lift Station
Figure 37 – Flow Data – Liberty Lift Station
Figure 38 – Flow Data – 6th Flow Meter
Figure 39 – Flow Data – Village South Flow Meter
Figure 40 – Flow Data – Village Flow Meter
Figure 41 – Flow Data – Liberty Flow Meter
Figure 42 – Flow Data – Noll Road Flow Meter

Appendices

Appendix A – Preliminary Offline Peak Storage Sizing

THIS PAGE INTENTIONALLY LEFT BLANK

City of Poulsbo

Sewer System Infiltration and Inflow Evaluation Report

Executive Summary

The City of Poulsbo's (City) wastewater collection system is a major component of the City's infrastructure and largely goes unnoticed. The City has a longstanding goal to reduce inflow and infiltration (I&I) into the sewer system and has implemented several projects over the last 15 years to maximize capacity, reduce I&I, and extend the useful life of the existing system.

These projects have been successful, reducing maximum daily flow 27 percent per capita between 2006 and 2020. Based on prior analysis, infiltration was reduced 19 percent between 2006 and 2014. Overall, the past actions by the City have been successful and the City has been able to defer multiple large capital improvement projects to increase hydraulic capacity; however, based on the analysis contained within this report, it is unlikely additional cost-effective I&I reduction will be achievable at the level necessary on a system-wide basis to further defer these projects to increase hydraulic capacity.

System-wide I&I for the City accounts for approximately 19 percent of the City's sewer flows on an annual basis. This costs the City (at current Kitsap County (County) rates) about $35,000 per year. While this is a relatively modest expense compared to implementing I&I reduction projects that provide a limited return, the benefit is minimizing flow to the County's Central Kitsap Wastewater Treatment Plant and maximizing its available capacity to accommodate for future growth.

As part of this analysis, three sewer drainage basins were identified as having high levels of I&I. The commonalities in these basins include they are in the oldest/historic parts of the City, they are in areas developed with no standalone storm infrastructure, and they are generally located near sea level (bottom of the hill). The basins identified are served by the following lift stations.

- 6th Avenue Lift Station
- Marine Science Center Lift Station
- 9th Avenue Lift Station

Based on the analysis in this report, the 2020 peak day flow rate was 160 gallons per capita per day (gpcd), which is below the U.S. Environmental Protection Agency's (EPA) guideline for "excessive inflow" of 275 gpcd. Based on the analysis of the peak storm event, the peaking factor for the City is 4.2, which is within the expected range for jurisdictions of similar size.

The City experiences peak hour I&I rates ranging from 78 gallons per acre per day (gpad) to 2,265 gpad, which are relatively low for some of the sewer systems in the region. Other jurisdictions within the Pacific Northwest region experience peak hour I&I rates that are significantly higher, ranging from 3,584 gpad to 9,218 gpad. As a comparison, King County

Wastewater Treatment Division (KCWTD) has estimated new construction to experience I&I rates of around 1,500 gpad. Comparatively, the City is succeeding in reducing and maintaining lower peak hour I&I rates.

While flow monitoring was being performed for this analysis, the City experienced a sanitary sewer overflow on December 21, 2020. This is the first overflow since 2016 (after the Central Interceptor was lined with cured-in-place pipe) and was partially attributed to a few different factors, including the downstream Pump Station 67 failures, manhole lids not being appropriately bolted down, and a significant high-intensity rainfall event. BHC Consultants, LLC, assessed that the rainfall event proceeding this overflow correlates to a 50-year, 2-hour event and the storm events presented in **Table ES-1**.

Table ES-1: December 21, 2020 Storm Event Recurrence Intervals

Storm Event Length (Hours)	Recurrence Interval (years)
24	Between 2 and 5
6	25
2	50

In order to reduce the chance of future overflows occurring, it is recommended that the City construct an Offline Peak Storage Structure (OPSS) in the immediate future along the Central Interceptor near Nordness Place NE in order to capture and detain the wet weather peak flows.

The City has several capital projects in the sewer Capital Improvement Plan (CIP) that will make improvements to infrastructure that currently limit sewer capacity. These projects are not addressed within this report and will be part of the City's upcoming Sewer Comprehensive Plan. It is important to note that construction of the OPSS will not remove the need for these conveyance improvements; however, it allows time for implementation of these large-scale projects and a method to prevent overflows.

The other recommendations to further reduce I&I into the sewer system and reserve remaining capacity for growth within the major trunklines, including the Central Interceptor and Lemolo Siphon, are as follows:

- Develop a program to inspect private side sewers, especially in the basins served by the 6th Avenue, Marine Science Center, and 9th Avenue Lift Stations.
    - Inspect private side sewers with a push camera, smoke test, or dye test to determine if private storm systems are connected to sewer.
        - This recommendation was made because other sewer purveyors in the region, such as Valley View Sewer District and Kitsap County Public Works, have performed these inspections as part of sewer main replacement projects and have disconnected illicit connections, such as down spouts and sump pumps, as part of these projects.
        - This recommendation also was based on the following conclusions from KCWTD's *Regional Infiltration and Inflow Control Program Pilot Project Report*, which was completed in October 2004:

> "There is a strong indication that in many service basins, a high percentage of I&I originates in laterals and side sewers.
>
> In the Kent and Ronald pilot projects, the focus of system rehabilitation was laterals and side sewers only. An I&I reduction effectiveness of approximately 75 percent in each indicates that in these cases, the majority of I&I originated in laterals and side sewers.
>
> In the Manhole Project, manhole rehabilitation resulted in very little I&I reduction. This signifies that I&I sources in the basin are from other sewer system components.
>
> In the Mercer Island pilot project, which included only sewer main rehabilitation, a 37-percent reduction in I&I indicates that a high percentage of I&I originates in other system components, most likely laterals and side sewers.
>
> However, in Lake Forest Park, I&I was reduced by 69 percent by rehabilitating sewer mains and manholes only. Therefore, while laterals and side sewers may be highly suspect sources of I&I, it is necessary to evaluate flow data, review the results of SSES [Sanitary Sewer Evaluation Survey] investigations, and possibly use pre-rehabilitation system modeling to identify likely sources of I&I."

  - Look for opportunities to disconnect illicit connections, redirect down spouts and sump pumps, etc.
  - In areas with no storm infrastructure, consider a capital project to install storm main and include private storm/sewer investigation, and disconnect as necessary.
- Public Works to use camera truck to video inspect the remaining approximately 40 percent of the City's sewer system, identify I&I sources, and implement spot repairs and corrections.
  - Identify pipe conditions and opportunities for re-lining projects.
  - Correct deficiencies and implement pipe patches, joint sealing, root removal, etc., as needed.
- Consider replacing older sewer mains adjacent to water mains that are scheduled for replacement. At a minimum, the sewer mains should be evaluated to determine the existing condition.

Introduction

Background

The City of Poulsbo Public Works (City) staff sought an analysis of its peak wastewater flows to evaluate if recent improvements to its wastewater collection system have significantly reduced peak flows in the City's Central Interceptor. The purpose was to determine if some of the capital improvements recommended in the City's 2016 *Comprehensive Sanitary Sewer Plan* (CSSP) could be deferred if peak hour wastewater flows had decreased in recent years. These improvements include the State Route 305 (SR 305) force main extension, which would alleviate hydraulic capacity deficiencies along the Central Interceptor, and the Lemolo Siphon, which would increase the hydraulic capacity in Kitsap County's (County) downstream sewer conveyance system. Additionally, the City's Contract for Sanitary Sewer Service with Kitsap County Public Works potentially could be negotiated to more favorable terms if the City can establish that peak wastewater flows have been dampened. At the beginning of this project, it appeared that wastewater flows had decreased over the previous 2 years due to wastewater collection system rehabilitation improvements, including pipe replacements, pipe linings, and manhole sealing. The City sought to evaluate the apparent infiltration and inflow (I&I) reductions through an analysis of rainfall events and flow monitoring data from lift stations and instream flow meters. This report will discuss the observed flows, the rainfall events that caused them, and the apparent success of I&I reduction projects undertaken in recent years.

Purpose

The purpose of the evaluation is to utilize flow metering in various parts of the sewer system to quantify and segregate domestic and I&I flows. Based on these I&I analyses, RH2 Engineering, Inc., (RH2) will recommend next steps for further I&I evaluation, preferred follow-up I&I inspection methods to be performed, and repairs to reduce I&I. This supports the City's effort to implement practical recommendations and prioritize expenditures in its sewer capital program for the growing city.

Definitions and Acronyms

The abbreviations and definitions listed below are used throughout this report.

- AAF – Average Annual Flow: The average of the flow volumes that occurred over a calendar year, expressed as an annual average.
- BHC – BHC Consultants, LLC
- City – City of Poulsbo
- CIPP – cured-in-place pipe
- CSSP – *Comprehensive Sanitary Sewer Plan*
- County – Kitsap County
- EPA – U.S. Environmental Protection Agency

- Flume – Johnson Way Flume: The location where the City's wastewater is measured and discharged to the County's sewer system, which is near the intersection of Johnson Way NE and Peterson Way NE.
- GIS – Geographic Information System
- gpad – gallons per acre per day
- gpcd – gallons per capita per day
- gpm – gallons per minute
- hp – horsepower
- I&I – infiltration and inflow:
    - Infiltration: The addition of groundwater into a sewer through pipe or manhole joints, cracks, and other defects.
    - Inflow: The addition of rainfall-caused surface water drainage into a sewer from roof drains, yard drains, basement drains, street catch basins, etc.
- KCWTD – King County Wastewater Treatment Division
- LF – linear feet
- Marine Science Lift Station – Marine Science Center Lift Station
- MDF – Maximum Day Flow: The largest volume of flow that occurred during a 1-day period, expressed as a daily average.
- MGD – million gallons per day
- MH – Manhole
- MH ID – Manhole identification number
- MTU – master telemetry unit
- OPSS – Offline Peak Storage Structure: The storage of sewage adjacent to the sewer pipe in a tank or other storage device during peak flows.
- overflow – Sanitary Sewer Overflow
- PHF – Peak Hour Flow: The largest volume of flow that occurred during a 1-hour period, expressed as an hourly average.
- RH2 – RH2 Engineering, Inc.
- SCADA – supervisory control and data acquisition
- SR 305 – State Route 305

Existing Sewer System

The City owns and operates the sewer system, which covers a service area of approximately 4 square miles. A summary of general sewer system data is presented in **Table 1**.

Table 1: General Sewer System Data

Description	Data
Estimated Population Served (City, 2020)	11,511[1]
Number of Major Sewer Drainage Basins	8
Total Length of Sewer Gravity Main	Approx. 48.7 miles
Number of Manholes	1,274
Total Length of Sewer Force Main	Approx. 5.4 miles
Number of Lift Stations	9
Johnson Way Flume Average Annual Flow (2020)	0.86 MGD

1. From 2019 *Siphon Feasibility Memo, BHC Consultants, LLC*.

The sewer system schematic from the 2016 CSSP is shown in **Figure 1**. This graphic was modified to show where instream flow meters were installed in the City's sewer system for this project. Additionally, a map of the City's sewer system is shown in **Figure 2**. As shown in **Figures 1** and **2**, the vast majority of the wastewater flow from the City's customers is conveyed by gravity sewer mains and lift stations to the Central Interceptor. The Central Interceptor converges with wastewater flows from Noll Road immediately upstream of the Johnson Way Flume (Flume). The Flume is owned and operated by Kitsap County Public Works and measures all the City's wastewater before it enters the County's conveyance system, where it flows through the Lemolo Siphon and Pump Station 67 before it enters the Central Kitsap Wastewater Treatment Plant.

Previous I&I Analyses

I&I analyses were performed for the sewer basins as part of the City's 2008 and 2016 CSSPs. According to the 2016 CSSP I&I analyses, the City's system-wide wastewater flows were below the U.S. Environmental Protection Agency's (EPA) guidelines for infiltration and inflow of 120 gallons per capita per day (gpcd) and 275 gpcd, respectively. However, those analyses also indicated that there was a significant I&I problem in some of the City's sewer basins, and the capital improvement plans on those CSSPs outlined an Annual Inflow Reduction Program for the City.

The results of the highest flows from the analyses in the 2008 and 2016 CSSPs, along with the inflow analysis presented later in this report, are shown in **Tables 2** and **3** for inflow and infiltration, respectively. For inflow, there was a 27 percent reduction in maximum day flow per capita from 2006 to 2020, as shown in **Table 2**. For infiltration, there was a 19 percent reduction in flow per capita from 2006 to 2014, as shown in **Table 3**. These results indicate the City's I&I reduction efforts over the last 15 years have been successful.

Table 2: Historical Inflow Analyses

Source	Years Evaluated	Date of Highest Flow	Daily Total Flow (MGD)	Population	Daily Total Flow per Capita (gpcd)
2008 CSSP	2005 to 2006	1/21/2006	1.673	7,584	221
2016 CSSP	2014 to 2015	3/6/2014	1.580	9,775	162
This Evaluation[1]	2017 to 2020	12/21/2020	1.846	11,511	160

1 = Max day flow presented is based on the reconstructed hydrograph for this day.

Table 3: Historical Infiltration Analyses

Source	Years Evaluated	Date of Highest Infiltration	Daily Total Flow (MGD)	Population	Daily Total Flow per Capita (gpcd)
2008 CSSP	2005 to 2006	1/18/2006	1.040	7,584	137
2016 CSSP	2014 to 2015	3/8/2014	1.091	9,775	112

Previous I&I Reduction Efforts

The City has extended the useful life of its existing sewer system components and increased remaining available capacity in its major trunklines by implementing improvements to reduce I&I. As identified in the City's 2016 CSSP, the following efforts were previously implemented by the City as part of its ongoing I&I Reduction Program:

- Marine Science Lift Station (Central Poulsbo sewer drainage basin) – System rehabilitation and I&I reduction was completed in 2008 through pipe bursting of the sewer trunklines and replacement of side sewers, which led to a large reduction of I&I flows in this basin.
- 6th Avenue Lift Station Basin – Most of the older mains and side sewers in this basin were replaced in 2000 and 2001 with a pipe bursting project, including some trunklines off 6th Avenue. As stated in the 2016 CSSP, this project likely reduced the sewer flow in this basin by 35 percent.
- Village Lift Station Basin – This basin previously experienced high levels of I&I following storm events. The City performed smoke testing to find I&I entry points to the sanitary sewer.
- Liberty Lift Station Basin – This basin also previously experienced elevated levels of I&I following storm events. In 2020, City staff worked with one of the property owners in this basin to identify that their drainage system was connected to the City's sewer collection system and get the business's storm infrastructure connected to the City's

storm drainage system so it could be disconnected from the sewer system. These efforts noticeably reduced rainfall-induced I&I in this basin, as shown in **Table 4** and **Figures 3** and **4**. These statistics were developed by analyzing the peak flow event before the investigation, which occurred on May 2, 2020, to a similarly sized storm event occurring on November 16, 2020. These statistics also can be observed in **Table 4**. **Figures 3** and **4** illustrate the impact the City's efforts to disconnect illicit sewer connections have had on the hydrograph response to a 24-hour, 1-inch storm; similarly, the peak hour precipitation on both these days was approximately 0.22 inches per hour (in/hr). The peak flow dropped from more than 120 gallons per minute (gpm) to approximately 45 gpm.

Table 4: Liberty Instream Flow Monitor Flow Comparison Before and After City's 2020 I&I Reduction Efforts

Date	Daily Average Flow (gpm)	Peak Hour Flow (gpm)	Daily Precipitation Total (in)	Peak Hour Precipitation (in/hr)
May 2, 2020	37.6	102.3	1.01	0.22
Novermber 16, 2020	19.4	40.8	1.06	0.21
Percent Flow Reduction	**48%**	**60%**	-	-

Figure 3: Liberty Instream Flow Monitor Flows on May 2, 2020

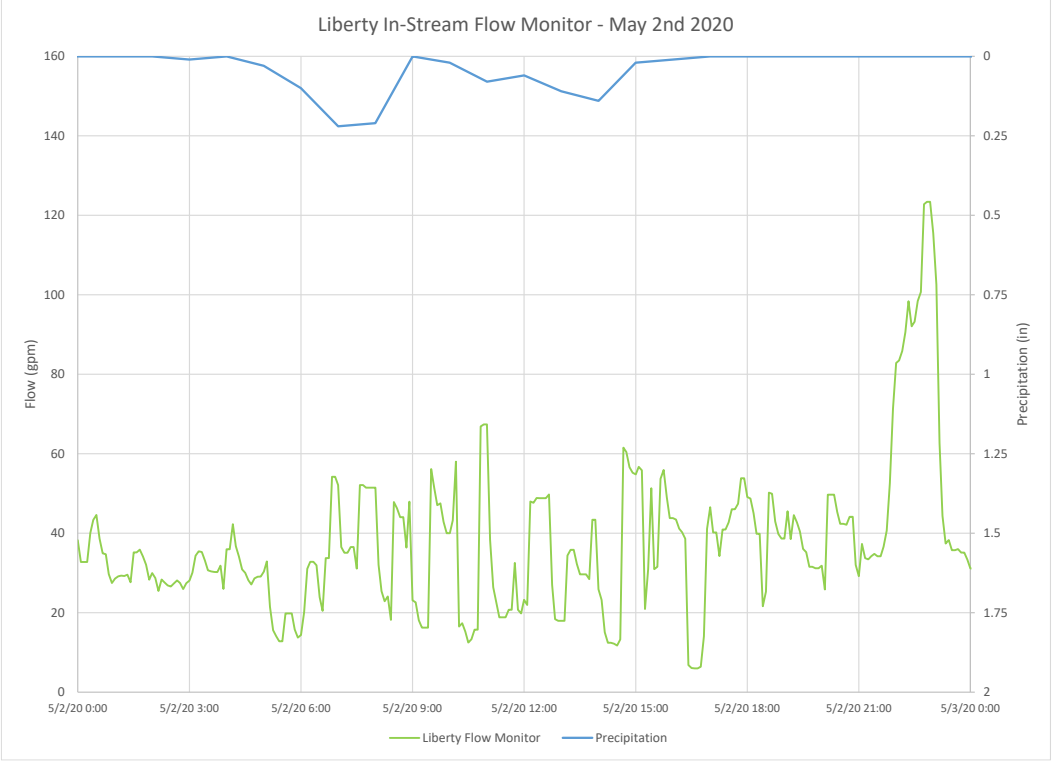
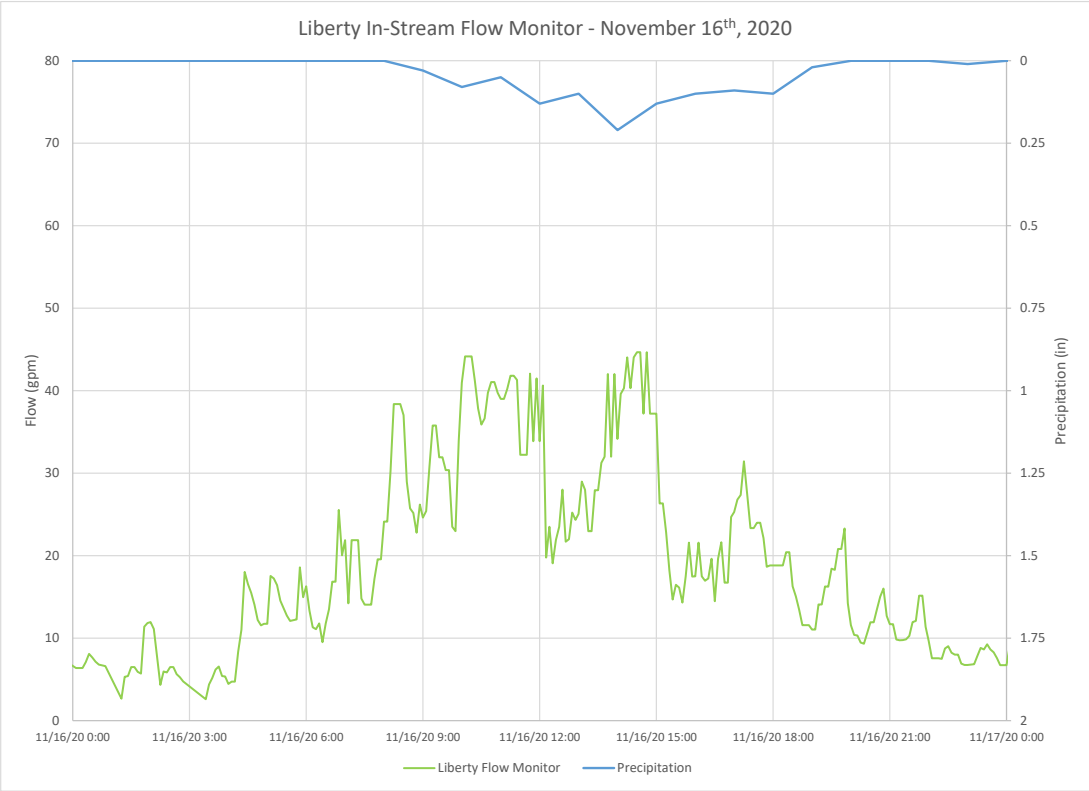


Figure 4: Liberty Instream Flow Monitor Flows on November 16, 2020



Additionally, the City completed the following projects to reduce I&I in its sewer system:

- Rehabilitation of 35 manholes in the Noll Road sewer drainage basin and along the Central Interceptor. A number of these manholes showed signs of deterioration and I&I entering the sewer system.
- Cured-in-place pipe (CIPP) lining of approximately 1,900 linear feet (LF) of gravity sewer main in the East Poulsbo sewer drainage basin that had defects (such as joint offsets, cracked pipes, and root intrusion) that may have been a source of I&I. The primary purpose for this project was to rehabilitate the pipe defects and inhibit root intrusion in this area, which was causing sewer backups to occur in these sewer mains.
- CIPP lining of the Central Interceptor from NE Tollefson Road to Johnson Road (approximately 5,000 LF). The primary purpose for this project was to rehabilitate the structural integrity of the sewer interceptor since the existing host pipe was deteriorating and close to structurally failing in places.
- Purchase of a camera truck in 2015. Sixty (60) percent of the City's sewer system has been videoed to date and identified deficiencies have been repaired.
- Minor spot repairs, patches, crack repair, and seams were sealed on several sewer mains immediately implemented as part of video inspection follow-up procedures.

- Installation of Rainstoppers™ on all manhole lids.
- Resealing of the wet well and repairing a pipe at the Liberty Bay Lift Station.

Description of Analysis

Data Collection Devices

For this evaluation, Johnson Way Flume flows, rainfall, and flow metering data from the City's lift stations and instream flow meters were used to collect data. A rain gauge installed at the Kitsap County Public Utility District, which records hourly rainfall data, also was used for this evaluation.

Over the period of 2019 to the present, the City's instream flow meters were used to measure and record real-time flows at selected locations within the sewer system. The instream flow monitors used were HACH Flo-Dars.

Eight of the City's nine lift stations have a functional flow meter installed: Liberty; Village; 9th Avenue; 6th Avenue; Alasund; Applewood; Marine Science; and Bond. These lift stations record data through the City's supervisory control and data acquisition (SCADA) system. The Lindvig Lift Station is the City's only lift station that does not have a flow meter that is integrated into the City's SCADA system. In addition, six more instream flow meters were installed at various locations throughout the system, which are shown in **Figure 2**. These meters became active in 2019 and, as of the writing of this report, calibration is still being performed.

Flow Metering

To supplement flow data from the Flume, flow meters were installed at each of the City's lift stations so that each drainage basin could be evaluated for I&I. Additionally, instream flow meters were utilized to measure flows through various locations throughout the sewer system. The goal was to obtain sufficient flow data to estimate I&I in all regions of the City's wastewater collection system. This will allow repair efforts to be focused on those basins that are found to be most deficient.

The instream flow meters were installed within the flow path of a pipe by accessing the pipe at a manhole. The City set up the monitors to record flow in gallons per minute. The start and end dates of each flow monitor recording period is presented in **Table 5**. The evaluations contained in this report were performed based on this limited data set.

Table 5: Johnson Way Flume, Lift Station, and Instream Flow Meter Recording Dates

	Data Recording Start Date	Data Recording End Date
Johnson Way Flume	10/16/2019	ongoing

Lift Stations	Data Recording Start Date	Data Recording End Date
6th Avenue	9/22/2020	ongoing
Marine Science	9/22/2020	ongoing
9th Avenue	9/22/2020	ongoing
Alasund	9/22/2020	ongoing
Applewood	9/22/2020	ongoing
Bond	9/22/2020	ongoing
Village	9/22/2020	ongoing
Liberty	9/22/2020	ongoing

In-Stream Flow Meters	Data Recording Start Date	Data Recording End Date
6th Avenue Flow	4/6/2020	ongoing
Sol Vei	12/17/2019	ongoing
Liberty	4/6/2020	1/5/2021
Village South	1/11/2021	ongoing
Village	4/6/2020	ongoing
SR 305	12/17/2019	ongoing
Noll Road	1/14/2021	ongoing

To track the flow monitor installation locations (referred to as flow metering locations), each instream flow monitor was correlated to the manhole identification number (MH ID) shown in the City's sewer system map. The flow metering locations utilized in this evaluation are shown in **Figure 2**.

Monitoring will continue throughout the year at the Flume, Sol Vei, and SR 305, and then the instream flow monitors that were rented by the City for this project will be returned to the supplier.

Analyses and Results

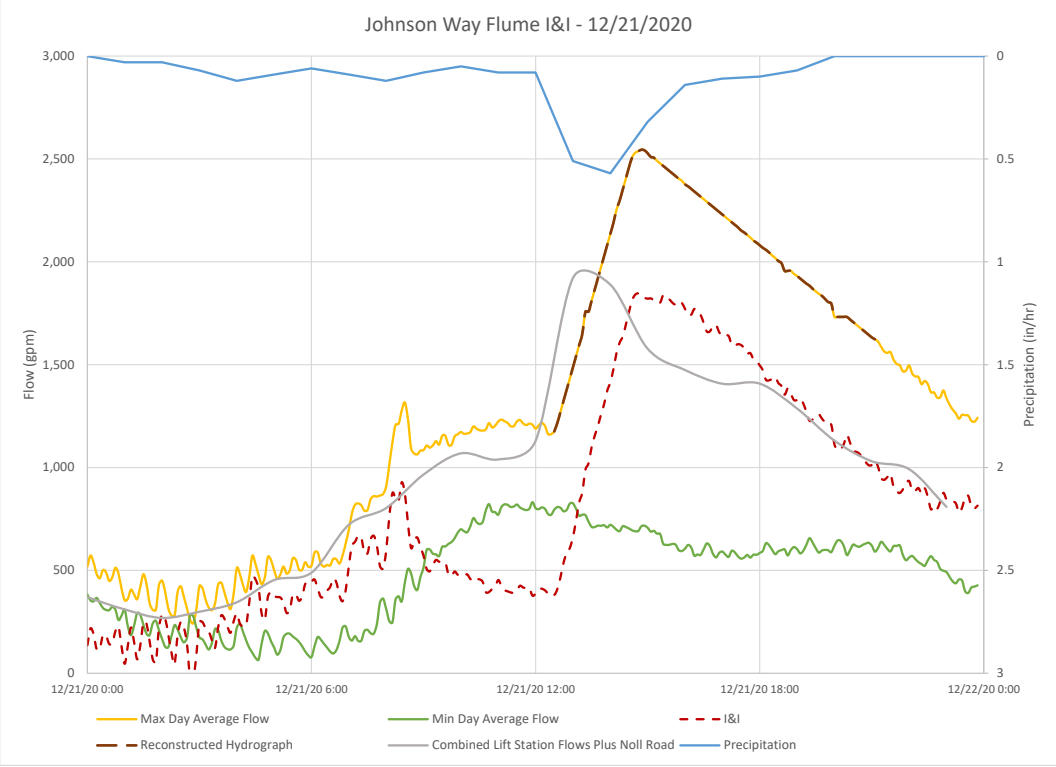
System Wide I&I Analyses

Data from 2019 and 2020 were reviewed, and the peak Flume daily flow recorded was 1.85 million gallons per day (MGD), which occurred on December 21, 2020 (which was a Monday). This value was estimated from the reconstructed hydrograph. The Flume did not accurately measure flow during peak flow conditions; there is a downstream constriction which causes the water level in the Flume to surcharge during peak flows. The surcharged water level causes the Flume to read flows of more than 7,000 gpm, which are not reasonable for the City. The hydrograph for these time periods were reconstructed by RH2 to estimate the peak flows through the Flume over these time periods, by extending the flow trends of the hydrograph from the rising trend before and subsiding trend after these time periods to recreate flows

during these time periods. The reconstructed hydrograph was essential in the effort to accurately predict the peak flow values observed at the Flume during the surcharging event. The peak flows that occurred on December 21, 2020 primarily were due to the I&I experienced in the sewer system as a result of 2.3 inches of rainfall that occurred over the 24 hours prior to the overflow event. This corresponds to a 2-year, 24-hour rain event for the City according to the isopluvial maps found in the 1997 *Kitsap County Stormwater Design Manual*. The overflow occurred along the City's Central Interceptor near the intersection of SR 305 and Nordness Place NE. The overflow may have been partially due to wastewater flows surcharging immediately upstream of the Lemolo Siphon, which may have been amplified by a failure of the County's Pump Station 67 force main. Additionally, the overflow manhole was not correctly bolted down as it is supposed to be, to prevent overflows from occurring at this location. It should be noted that the City has a controlled discharge at Sol Vei, and it has not surcharged since the Central Interceptor CIPP project was completed in early 2018.

The Johnson Way Flume, which measures sewer flows the City sends to the County, surcharged between 12:30 pm and 9:00 pm on December 21, 2020 and was measuring flows inaccurately during this time. The hydrograph for this time period was reconstructed by RH2 to estimate the peak flows through the City's Flume over this time period. The reconstructed hydrograph for the Flume was based on the sum of combined lift stations flows and flows estimated for the East Poulsbo Sewer Basin (**Figure 5**).

Figure 5: Johnson Way Flume I&I on December 21, 2020



Using the projected 2020 population from the 2019 *Siphon Feasibility Memo* (BHC Consultants (BHC)), the peak Flume daily flow on December 21st equates to 160 gpcd, which is below the EPA's threshold for indication of excessive inflow (275 gpcd). These results are summarized in **Table 6** and indicate the City does not have an excessive inflow issue according to EPA's guidelines.

Table 6: Potential Excessive Inflow Analysis 2019 to 2020 Peak Daily Flow

Description	Date	Flume Daily Flow (MGD)	Daily Precipitation Total (inches)	Flow per Capita (gpcd)	EPA Threshold for Excessive (gpcd)
Max Day Flow[1]	12/21/2020	1.85	2.72	160	275

1 = Max day flow presented is based on the reconstructed hydrograph for this day.

Further I&I analysis was performed for the peak day (December 21, 2020). I&I in the basin was determined by subtracting the 2020 minimum day flows (which was assumed to be domestic wastewater only for the purposes of these analyses), which occurred on September 6, 2020 from the maximum day flow. On the minimum day, 0.7 MGD was discharged through the Flume. The resulting peak day I&I was determined to be 1.15 MGD. I&I rates also were developed on a flow per sewer basin area basis of gallons per acre per day (gpad) so that the basins with higher rates of I&I could be identified. The City's I&I on an area basis was determined to be 520 gpad, as shown in **Table 7**.

Table 7: Peak Day I&I Johnson Way Flume

	Max Day Average Flow (gpd)	Minimum Day Average Flow (gpd)	Peak Day I&I (gpd)	Sewer Basin Area (acre)	Peak Day I&I (gpad)
Johnson Way Flume	1,845,692	694,912	1,150,781	2,215	**520**

gpd = gallons per day

I&I was calculated from the peak hour flows on the peak day. Following the same steps as the peak day calculations, the system-wide peak hour I&I was 2.59 MGD or 1,168 gpad. **Table 8** summarizes these results.

Table 8: Peak Hour I&I Johnson Way Flume

	Max Day Peak Hour Flow (gpd)	Minimum Day Peak Hour Flow (gpd)	Peak Hour I&I (gpd)	Sewer Basin Area (acre)	Peak Hour I&I (gpad)
Johnson Way Flume	3,610,433	1,022,677	2,587,756	2,215	**1,168**

gpd = gallons per day

Average Annual Flow (AAF), Maximum Day Flow (MDF), and Peak Hour Flow (PHF) also were determined for the Flume. Flume data was only available back to October 16, 2019. The County did not release data prior to this time because of possible errors in the data record. Part of the reason older data was not used for this I&I study is because the Flume was replaced in 2018 due to the old flume underestimating the City's wastewater flows. Additionally, the Flume does not measure flows accurately during high flow events. This was observed on the peak flow event that occurred on December 21, 2020 and five other instances, which date back to 2019. The Flume hydrograph was reconstructed to accurately predict the peak flows on these days. It is recommended that a second level sensor is installed with the programming updated so the Flume can measure flow more accurately when the water level in the siphon downstream of the City's sewer system surcharges back into the Flume.

In 2019 and 2020, the MDF/AAF peaking factor was 2.1. PHFs were not determined for 2019 because reliable data was not available. The water level in the Flume may surcharge during 2019 peak flows due to the downstream capacity restriction, which would have caused the Flume to overestimate flows. No overflows were experienced by the City in 2017 through 2019; therefore, it is assumed the peak flow since 2017 in the City's sewer system occurred on December 21, 2020. From the PHF event on December 21, 2020, the PHF/MDF and PHF/AAF peaking factors were 2.0 and 4.2, respectively. **Table 9** documents these results.

Table 9: Johnson Way Flume Flows and Peaking Factors

Year	Annual Average Flow (gpm)	Maximum Daily Flow (gpm)	Peak Hour Flow (gpm)[1]	MDF/AAF Peaking Factor	PHF/MDF Peaking Factor[1]	PHF/AAF Peaking Factor[1]
2019[2]	565	1,160	-	2.1	-	-
2020	599	1,282	2,507	2.1	2.0	4.2

1 = Peak Hour Flows were not determined for 2019. The water level in the flume may have surcharged during 2019 peak flows due to the downstream siphon capacity restriction, which would have caused the Flume to overestimate flows. No overflows were experienced by the City in 2017 through 2019 so it is assumed the peak flow since 2017 in the City's sewer system occurred on December 21, 2020.

2 = Flow analyses for year 2019 only contains data for October 16, 2019 through December 31, 2019.

I&I Rate Summary

Tables 10 and **11** summarize the I&I analysis presented in the following sections of this report. The tables are presented such that the lift stations and instream flow meters are sorted from highest to lowest peak day I&I gpad. The 6th Avenue, Marine Science, and 9th Avenue Lift Stations were among the highest I&I rates for peak day and peak hour I&I. This makes sense as these basins are the older downtown areas of the City that may have been constructed as a combined sewer system in the early part of the 20th Century. Additionally, the Alasund Basin had an exceptionally high peak hour I&I (gpad) rate, which was over twice as much as the next highest basin rate. Fortunately this is a small basin, so the volume of I&I from this basin is small. Detailed analyses for each lift station and instream flow meter is summarized in **Table 10**.

Table 10: Maximum Day I&I Analysis

Lift Stations	Max Day Average Flow (gpd)	Minimum Day Average Flow (gpd)	Peak Day I&I (gpd)	Sewer Basin Area (acre)	Peak Day I&I (gpad)	Percent of Minimum Day Flow[1] (%)
6th Avenue	165,763	25,350	140,413	62	**2,265**	3.6%
Marine Science	345,347	64,440	280,907	156	**1,801**	9.3%
9th Avenue	59,252	11,017	48,234	30	**1,608**	1.6%
Alasund	31,710	12,872	18,838	20	**937**	1.9%
Village	226,403	82,419	143,985	272	**529**	11.9%
Applewood	10,927	3,160	7,766	15	**528**	0.5%
Bond	386,309	99,911	286,398	912	**314**	14.4%
Liberty	45,615	17,755	27,860	96	**290**	2.6%

Drainage Basin	Max Day Average Flow (gpd)	Estimated Domestic Flow (gpd)	Peak Day I&I (gpd)	Sewer Basin Area (acre)	Peak Day I&I (gpad)	Percent of Minimum Day Flow[1] (%)
Bond and Lindvig	340,694	82,156	258,538	816	**317**	11.8%

In-Stream Flow Meters	Max Day Average Flow (gpd)	Minimum Day Average Flow (gpd)	Peak Day I&I (gpd)	Sewer Basin Area (acre)	Peak Day I&I (gpad)	Percent of Minimum Day Flow[1] (%)
6th Avenue	145,960	20,558	125,402	33	**3,800**	3.0%
Village South	77,255	48,709	28,546	45	**634**	7.0%
Village	120,746	30,854	89,893	200	**449**	4.4%
Liberty	41,623	10,887	30,736	79	**389**	1.6%
Noll Road	37,515	16,673	20,842	268	**78**	2.4%

1 = Based on minimum day average flow at lift station, drainage basin, or instream flow meter compared to minimum day average flow at Flume.

Table 11: Peak Hour I&I Analysis

Lift Stations	Max Day Peak Hour Flow (gpd)	Minimum Day Peak Hour Flow (gpd)	Peak Hour I&I (gpd)	Sewer Basin Area (acre)	Peak Hour I&I (gpad)
Alasund	214,405	8,182	206,223	20	**10,260**
9th Avenue	184,197	18,514	165,683	30	**5,523**
Marine Science	694,016	131,857	562,159	156	**3,604**
6th Avenue	215,997	22,292	193,705	62	**3,124**
Applewood	42,000	3,165	38,835	15	**2,642**
Liberty	140,678	19,228	121,450	96	**1,265**
Village	479,185	161,880	317,305	272	**1,167**
Bond	765,489	75,286	690,203	912	**757**

Drainage Basin	Max Day Peak Hour Flow (gpd)	Estimated Domestic Peak Hour Flow (gpm)	Peak Hour I&I (gpd)	Sewer Basin Area (acre)	Peak Hour I&I (gpad)
Bond and Lindvig	632,668	57,286	575,382	816	**705**

In-Stream Flow Meters	Max Day Peak Hour Flow (gpd)	Minimum Day Peak Hour Flow (gpd)	Peak Hour I&I (gpd)	Sewer Basin Area (acre)	Peak Hour I&I (gpad)
6th Avenue	176,464	11,521	164,944	33	**4,998**
Liberty	159,847	14,642	145,205	79	**1,838**
Village South	125,988	62,376	63,611	45	**1,414**
Village	174,150	9,411	164,740	200	**824**
Noll Road	64,514	26,047	38,467	268	**144**

Lift Station/Sewer Drainage Basin Monitoring

The flow metering data and analyses presented below are organized by sewer drainage basin and manhole(s). The pump run times for each lift station are short, which results in a flow spike measured by the lift station and downstream flow meters. Flow spikes also may occur due to inflow during rainfall events; however, inflow-caused spikes should noticeably vary relative to each other in terms of magnitude and frequency.

Each lift station went through an I&I analysis where the MDF was compared to the minimum day flow. Data from the City's SCADA system was used for this analysis. Hourly averages were used to compare the flow data. A summary of the I&I results can be found in the **I&I Rate**

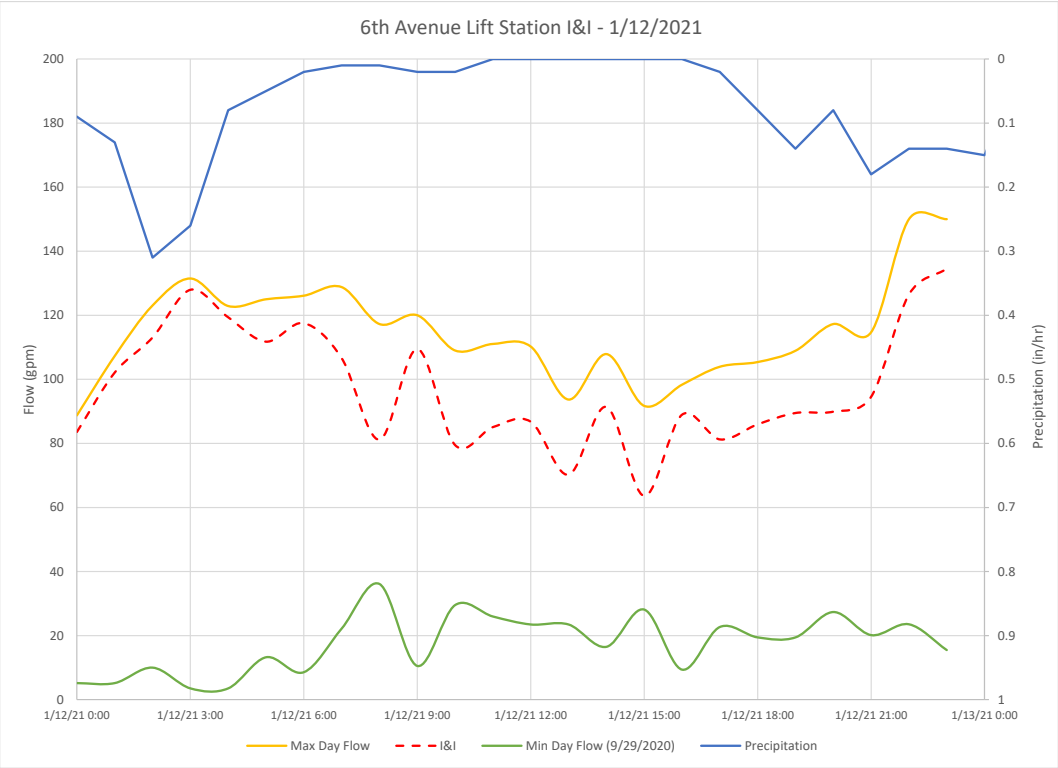
Summary section presented earlier in this report. Additionally, hydrographs for each basin are presented to help illustrate I&I and peak flows. Sharp spikes in the wastewater flow coincident with rainfall represent inflow into the system, whereas gradual increases and decreases after rainfall events point to groundwater infiltration in the basin.

6th Avenue Lift Station

This older, established area south of Hostmark Street has been an area of significant infiltration. The mains in this basin were replaced via pipe bursting in 2005 to reduce the I&I in this basin. The project reduced I&I in this basin and was successful. However, City staff speculate that I&I remains elevated due to storm infrastructure on private properties that are still connected to the City's sewer system, in part because many side streets in this basin do not have City storm infrastructure to tie residential downspouts and sump pumps into. In 2015, the lift station and wet wells were upgraded, and the force main was realigned so that wastewater is pumped up Matson Street via a 4-inch force main, connecting to the gravity sewer manhole on 9th Avenue and Tollefson Street. From there, wastewater is conveyed into the Central Interceptor located on SR 305. Little growth is expected within this basin, and any growth that does occur will be minor in-fill as the basin is almost entirely built out.

The 6th Avenue Lift Station saw peak flows on January 12, 2021 (**Figure 6**), the result of 3.2 inches of rain occurring on January 11th to January 12th combined. On January 12, 2021, there was an average peak day flow of 0.166 MGD discharged to the lift station. When compared to the minimum day occurring on September 9, 2020, significant I&I was observed. There was 0.140 MGD of I&I, which is approximately 2,265 gpad on a per area basis, making the 6th Avenue Lift Station basin one of the higher I&I basins in the City.

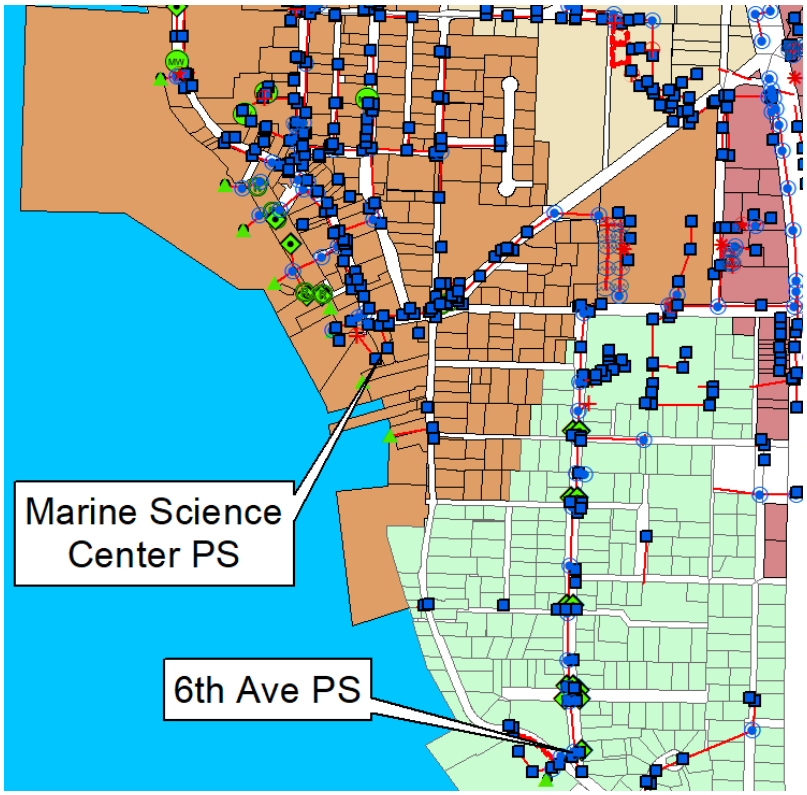
Figure 6: 6th Avenue Lift Station I&I on January 12, 2021



Marine Science Center Lift Station

The Marine Science Center (Marine Science) Lift Station provides service to the central area of the City, including the downtown business area, the Port of Poulsbo, Waterfront Park, and the Poulsbo Place neighborhood. A lot of the mains in the north end of this basin were previously replaced, and the mains in the south end of this basin are older and contain submerged gravity mains along the beach. City staff have noted there are some manholes in this basin with active infiltration. It is suspected by City staff that much of the I&I in this basin occurs on private property. The City's GIS data indicates the City has limited storm infrastructure in the south end of this basin, as shown in **Figure 7**. This is an older part of town, and construction techniques that were allowable in the past are no longer used. Roof downspouts, foundation, and yard drains connected to the sewer may be relics from the days the City had a combined collection system.

Figure 7: City's Storm Infrastructure near Marine Science Lift Station

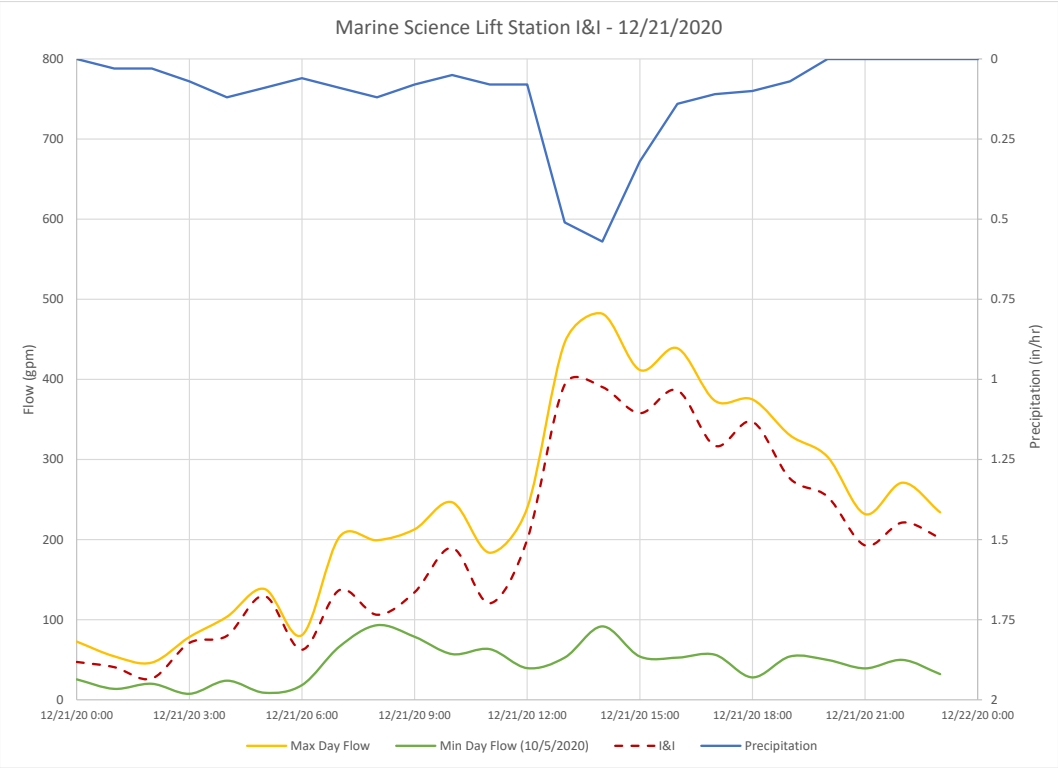


The Marine Science Lift Station is located off Front Street, immediately adjacent to the Marine Science Center. It pumps flow through a 12-inch force main south along the beach and then runs east along Harrison Street, where it connects to the gravity system at the intersection of Harrison Street and 9th Avenue. This basin is almost entirely built out and any new developments would be in-fill, with a minimal increase of sewer flows.

The Marine Science Lift Station experienced the highest flows in the data record used for this report on December 21, 2020 (**Figure 8**). This was the result of 1.75 inches of rain within a 6-hour period on December 21st and a total of 2.72 inches of precipitation throughout the day. An average peak day flow of 0.345 MGD was discharged from the lift station. When compared to the minimum day occurring on October 5, 2020, 0.281 MGD of I&I was observed. When applying a per-acre basis, it equated to 1,801 gpad.

This basin's immediate (or flashy) response to rainfall indicates surface water enters the collection system as inflow.

Figure 8: Marine Science Lift Station I&I on December 21, 2020

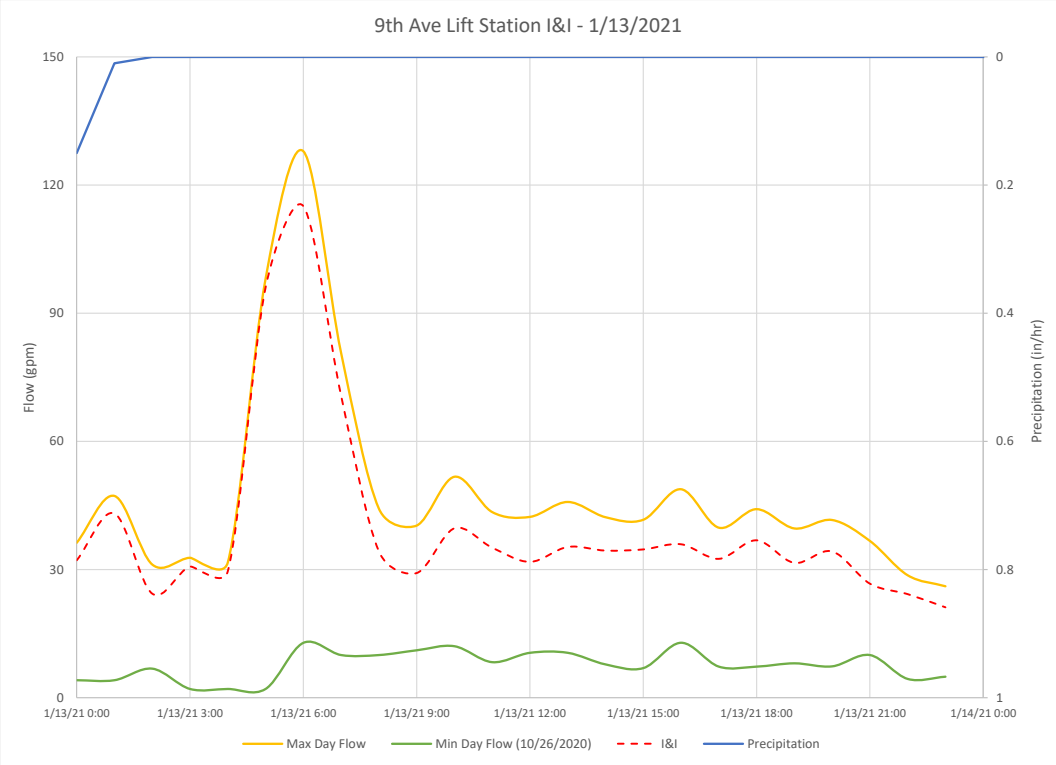


9th Avenue Lift Station

This older, established area south and east of the 6th Avenue Sewer Drainage Basin contains many of the older sewer mains and side sewers in the City and is primarily residential. A new lift station rebuild in 2015 handles the wastewater from 9th Avenue, as well as flows from Fjord Drive to the southern City limit. The lift station, located at the intersection of 9th Avenue and Fjord Drive, pumps wastewater via a 4-inch force main along 9th Avenue to Nordness Street, then southeast to the Central Interceptor. Little growth is expected within this basin, and growth that occurs will be minor in-fill.

The 9th Avenue Lift Station saw peak flows on January 13, 2021 (**Figure 9**), the result of 3.2 inches of rain occurring on January 11th and January 12th combined. An average peak day flow of 0.059 MGD was discharged from the lift station. When compared to the minimum day occurring on October 26, 2020, 0.048 MGD of I&I was observed, which is 1,608 gpad on a per-acre basis. The I&I per acre is high for this basin relative to the other sewer basins, but the total I&I volume is low compared to the other basins, especially the Marine Science and 6th Avenue Lift Station Basins.

Figure 9: 9th Avenue Lift Station I&I on January 13, 2021



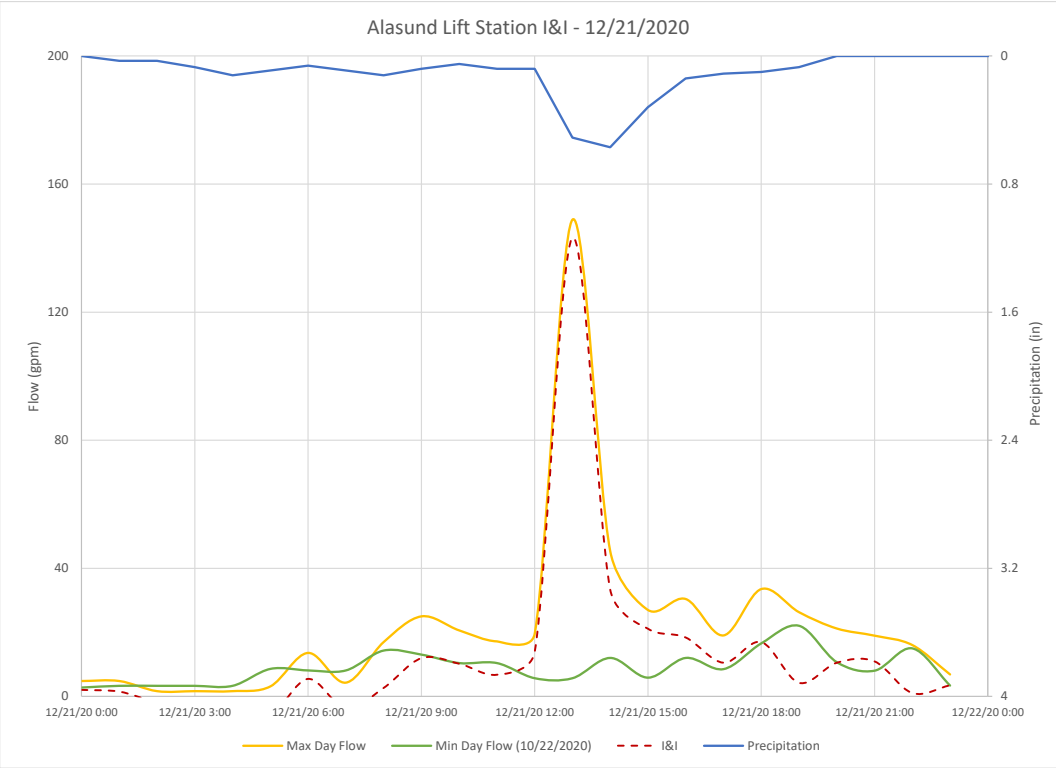
Alasund Lift Station

This small 0.18 MGD lift station serves several housing areas located east of Noll Road. This area was developed in the early 2000s. Two 15 horsepower (hp) pumps deliver wastewater via a 4-inch force main to a gravity main in Noll Road that flows west to the Poulsbo East Basin.

Data for the Alasund Lift Station was sparse compared to the other lift stations, resulting in more interpolation between recorded data points. Peak flow occurred on December 21, 2020 (**Figure 10**). A total of 2.73 inches of precipitation occurred on December 21st, leading to sharp peaking. The station pumped 0.032 MGD of flow, compared to an average of 0.013 MGD on the minimum day of October 22, 2020. Total I&I was 0.019 MGD and 937 gpad.

The Alasund Lift Station saw an unusually high peak on December 21, 2020, with readings reaching 400 gpm. Given the lift station's conservative pumping capacity of 250 gpm, the recorded flows were scaled down by the ratio of these two values to predict actual flow rates at the lift station for the purposes of this report. Because the sewer collection system in this basin was mostly developed in the last 20 years and is constructed of polyvinyl chloride (PVC) pipe and modern concrete manholes), the I&I could be a result of construction defects (such as a rolled pipe gasket). Further video inspections, smoke and dye tests, and flow isolations would be effective diagnostic steps to identify the I&I sources.

Figure 10: Alasund Lift Station I&I on December 21, 2020



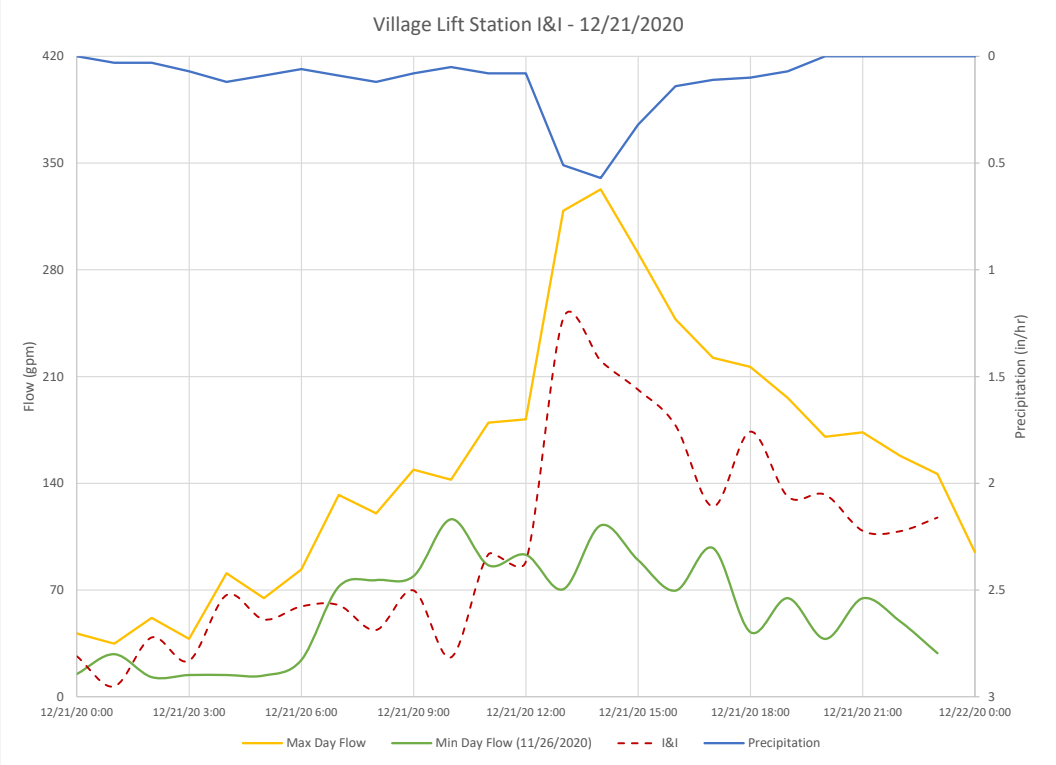
Village Lift Station

This drainage basin, also referred to as the Poulsbo Village Basin, collects commercial wastewater from the shopping and business centers along 7th Avenue NE and 10th Avenue NE south to NE Lincoln Road, which were initially constructed in the 1980s. The Village Basin includes single-family residential and apartments along NE Iversen Street as far west as 4th Avenue NE, the Public Library, and the City's Public Works Facility. It also collects wastewater from a portion of Forest Rock Hills located on the hillside to the east of SR 305 via a deep gravity sewer line under SR 305 that connects to the Village Lift Station wet well at an elevation of 26 feet below ground surface. Wastewater is pumped from the Village Lift Station via a 6-inch force main south along 7th Avenue into the manhole between Lincoln Road and Hostmark Street that gravity flows south to the Central Interceptor. The Village Basin is expecting 30-percent growth from 2006 to 2036. Much of the Village Basin area consists of wetlands and steep hillsides, but it also contains large tracts of undeveloped commercial property.

This basin was smoke tested in 2016, but the results were inconclusive according to City staff. City staff suspects the I&I in this basin predominantly comes from the portion of the basin east of SR 305. During the flow monitoring period for this project, City staff eliminated some I&I in this basin by plugging a side sewer north of the Village Lift Station that is not in use and was allowing active infiltration.

Peak day flow was observed on December 21, 2020 (**Figure 11**). The large storm mentioned previously caused a large, immediate spike in the hydrograph for this lift station, indicative of rainfall-induced inflow. The peak day average flow at the lift station was 0.226 MGD. The minimum day occurred on November 26, 2020, resulting in a peak day I&I of 0.144 MGD and 529 gpad. There are no definitive sources of I&I at this time; however, the City suspects the east side of the Basin is the largest source of I&I in this basin.

Figure 11: Village Lift Station I&I on December 21, 2020



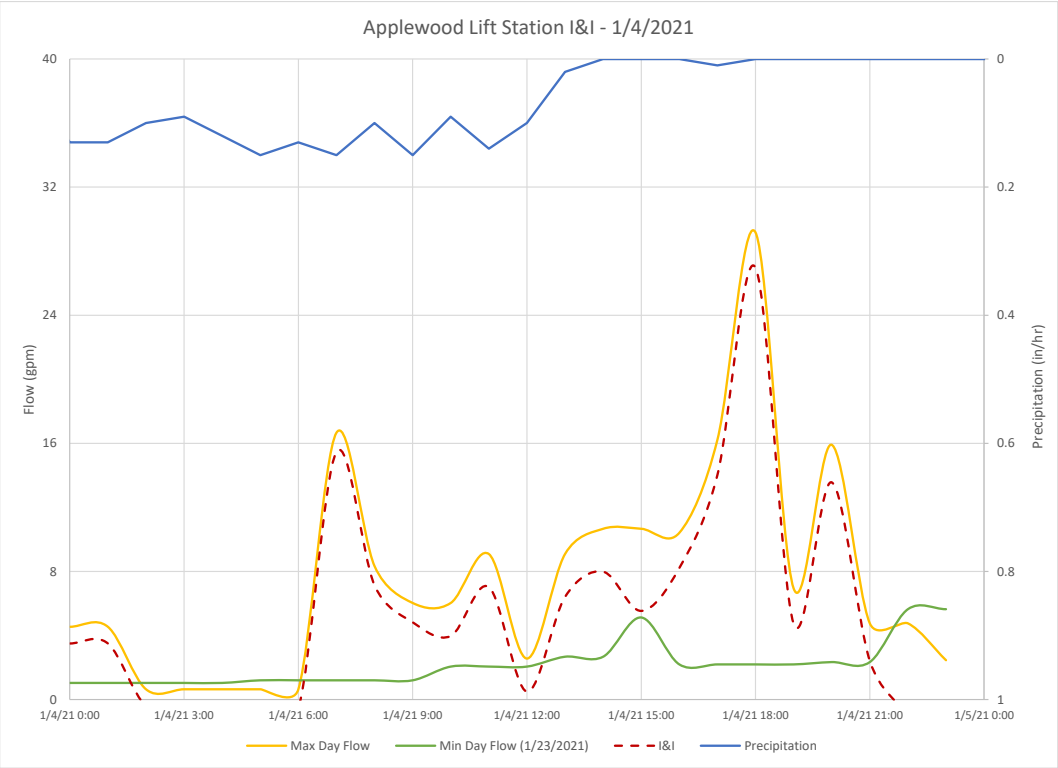
Applewood Lift Station

This small 0.2 MGD lift station serves a small housing development in the Poulsbo East Basin. This area was developed in the early 1990s. Two small pumps located above a small wet well pump wastewater via a 4-inch force main to a manhole that connects to a gravity main in Caldart Avenue, which ultimately leads to the Central Interceptor.

Data for the Applewood Lift Station was limited compared to the other lift stations; therefore, more interpolation was required between data points. The peak day flow occurred on January 4, 2021 (**Figure 12**). A total of 1.61 inches of precipitation occurred on January 4th, leading to the high flows and hydrograph peaking. The lift station pumped 0.0109 MGD of flow, compared to an average of 0.003 MGD on the minimum day. Total I&I was 0.0077 MGD and 528 gpad.

The dual spike in **Figure 12** that does not correspond directly to rainfall could indicate that a sump pump is activating to remove water from an area flooded by sustained rainfall. Efforts should be made to access private property suspected of containing a pumped system to learn if this is the cause of the flow spikes.

Figure 12: Applewood Lift Station I&I on January 4, 2021



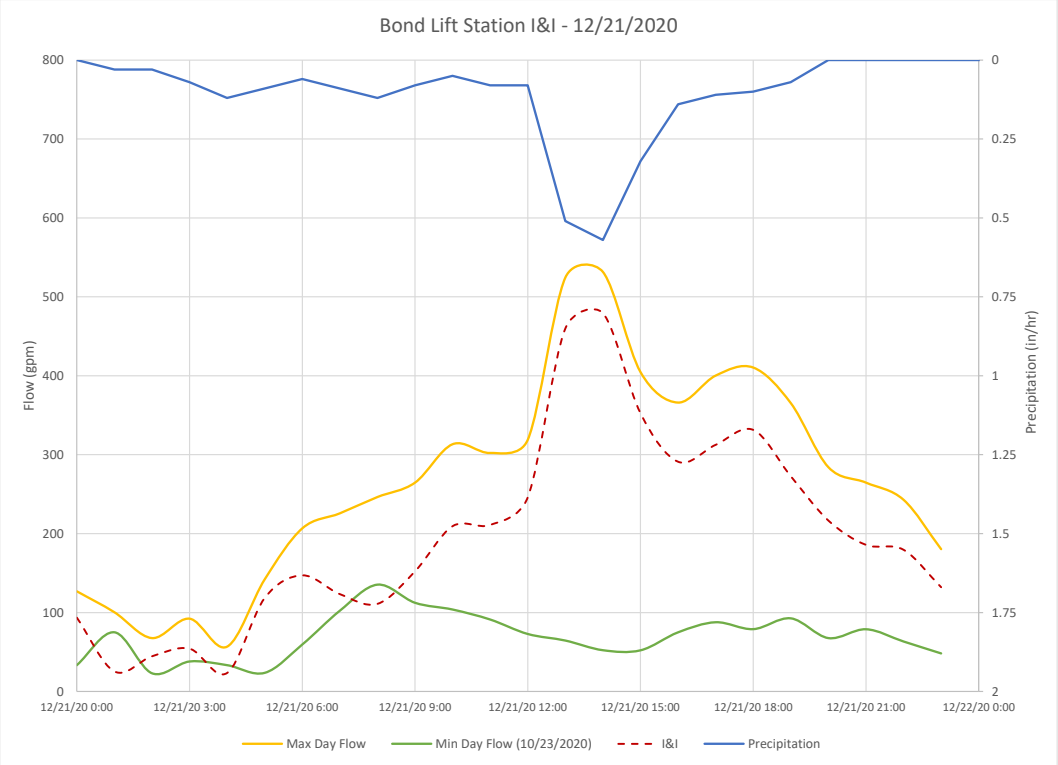
Bond Lift Station

This lift station serves the Finn Hill Basin, which includes Olhava and the Olympic College annex, as well as the Liberty Bay and Lindvig Lift Stations. The Bond Lift Station discharges to the SR 305 Interceptor approximately 600 to 700 feet upstream of the Sol Vei manhole and is the largest lift station in the City.

The total peak flow through Bond Lift Station occurred on December 21, 2020 (**Figure 13**). This was the direct result of 1.75 inches of rain within a 6-hour period on December 21st and a total of 2.72 inches of precipitation throughout the day. There was an average peak day flow of 0.386 MGD conveyed through the lift station. The minimum day occurred on October 23, 2020, resulting in 0.286 MGD of I&I, which is 314 gpad on a per area basis.

Further analyses with the Bond and Lindvig Lift Station basins isolated are discussed later in this report.

Figure 13: Bond Lift Station I&I on December 21, 2020



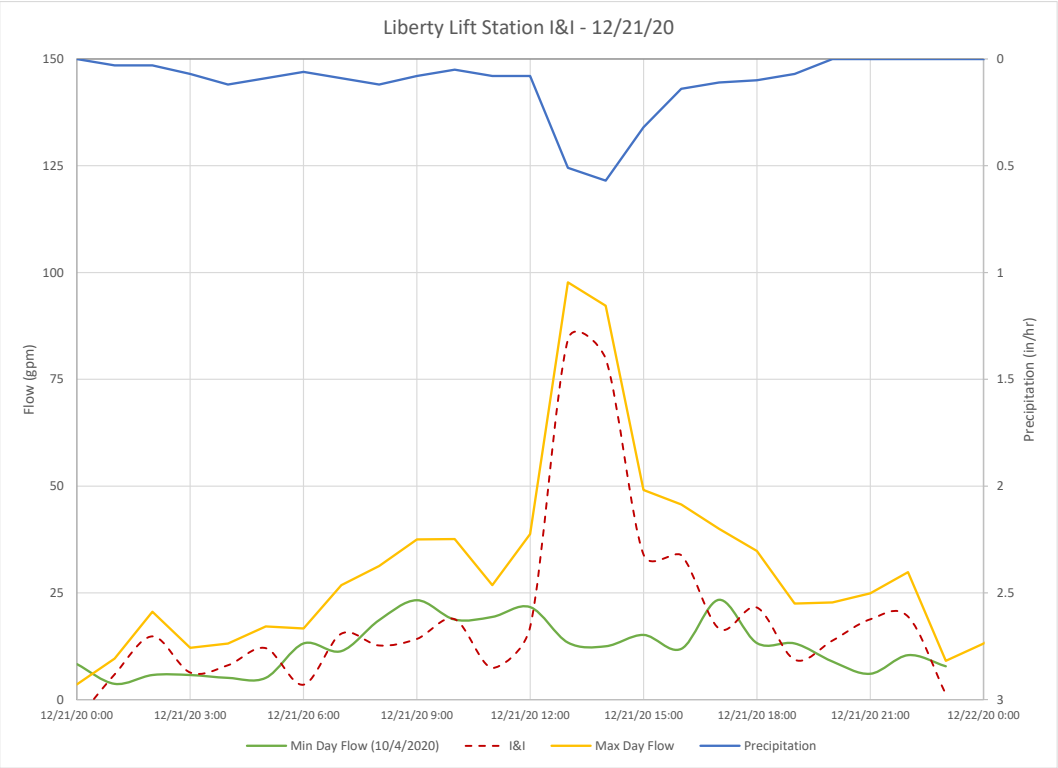
Liberty Bay Lift Station

The Liberty Bay Lift Station serves a portion of the Viking Avenue Basin. It collects wastewater from the south Viking Avenue area and pumps it to the Lindvig Lift Station. This small 0.14 MGD lift station currently has two 7.5 hp pumps mounted at grade above a 48-inch-diameter wet well.

Liberty Lift Station also experienced peak flows on December 21, 2020 (**Figure 14**). There was an average peak day flow of 0.045 MGD to the lift station. The minimum day occurred on October 5, 2020, resulting in 0.028 MGD of I&I. When applying a per-acre basis, it equates to 290 gpad.

The I&I in this basin is lower than the City's other basin, which is a result of recent I&I investigations and measures taken by City staff to remove I&I in this basin. Investigations by City staff identified that one of the businesses in this basin had all its storm infrastructure (including roof drains and catch basins in the parking lot) connected to the sanitary sewer. City staff worked with the property owner to get the business's storm infrastructure connected to the City's storm drainage system and disconnected from the sewer. City staff are aware of a couple other businesses with storm infrastructure connected to the City's sewer system and are taking steps to get these businesses disconnected from the City's sewer system as well.

Figure 14: Liberty Lift Station I&I on December 21, 2020



Lindvig Lift Station

The Lindvig Lift Station serves a portion of the Viking Avenue and Finn Hill Basins, as well as the Liberty Bay Lift Station. The Lindvig Lift Station conveys wastewater to the Bond Lift Station. Currently, the flow meter at the Lindvig Lift Station is not properly reporting flows to the lift station's master telemetry unit (MTU); the City's SCADA system is not able to record lift station flows due to this issue. Therefore, an I&I analysis for this lift station was not performed. All the analyses for the Bond Lift Station include the gravity drainage basin served by the Lindvig Lift Station as well.

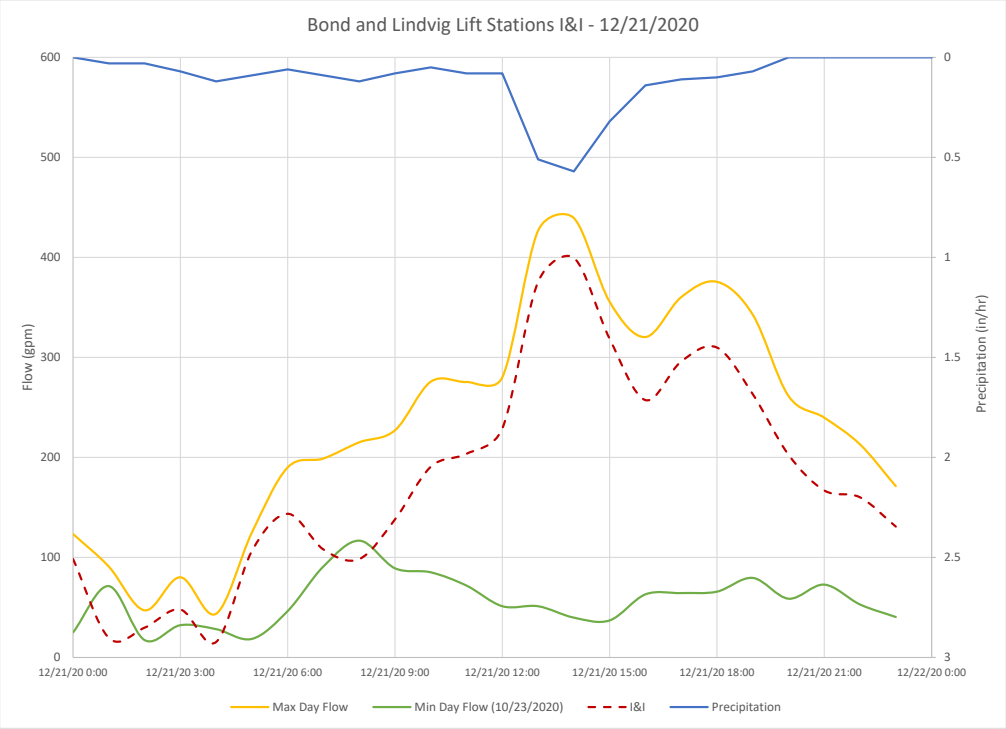
Bond and Lindvig Drainage Basins

Since the Bond Lift Station pumps wastewater from gravity sewer in the Finn Hill Basin, as well as the Liberty Bay and Lindvig Lift Stations, and since the Lindvig Lift Station is not reporting flows, additional I&I analyses were performed for the gravity sewer in the Finn Hill and Viking Avenue Basins that are served directly by the Bond and Lindvig Lift Stations (referred to in this report as the Bond and Lindvig Drainage Basins). Like the prior analysis for the Bond and Liberty Lift Stations, peak flows occurred in this area on December 21, 2020 (**Figure 15**). For this analysis, flows for the Liberty Bay Lift Station were subtracted from the flows for the Bond Lift Station to isolate the Bond and Lindvig Drainage Basin flows. In addition, only the areas in the Bond and Lindvig Drainage Basins were used to estimate these I&I rates per unit of area (i.e., gpad). The average peak day flow in this area was 0.341 MGD. The minimum day occurred on October 23, 2020, resulting in 0.258 MGD of I&I, which is 317 gpad on a per area basis.

Relative to the other basins in the City, and surrounding municipal sewer collection systems operated by other agencies, this is a low rate of I&I.

The wastewater collection system for this area was mostly developed in the past 30 years and is constructed of PVC pipe and modern concrete manholes. It stands to reason that I&I rates are low in this basin because of the age and quality of the materials used to build this portion of the collection system.

Figure 15: Bond and Lindvig Drainage Basin I&I on December 21, 2020



Instream Flow Metering

6th Avenue (MH 53-36)

The 6th Avenue instream flow meter is housed in manhole (MH) 53-36 located just north of the 6th Avenue Lift Station, as shown in **Figure 16**. This manhole conveys flow from 33 upstream acres.

Similar to the 6th Avenue Lift Station, significant I&I was observed through this flow meter. Peak day flow occurred on January 12, 2021 (**Figure 17**), the result of 3.2 inches of rain occurring on January 11th to January 12th combined. The peak day average flow at the manhole was 0.146 MGD. The minimum day occurred on October 8, 2020, resulting in a peak day I&I of 0.125 MGD and 3,800 gpad for the upstream sewer drainage basin.

The peak day and hour I/I rates per acre are at least 60 percent higher for the instream flow meter than the 6th Avenue Lift Station. Additional I&I investigations should be performed in this

basin, but the northern portion of this basin (that is upstream of this flow meter) should be prioritized.

Figure 16: 6th Avenue Instream Flow Meter Location

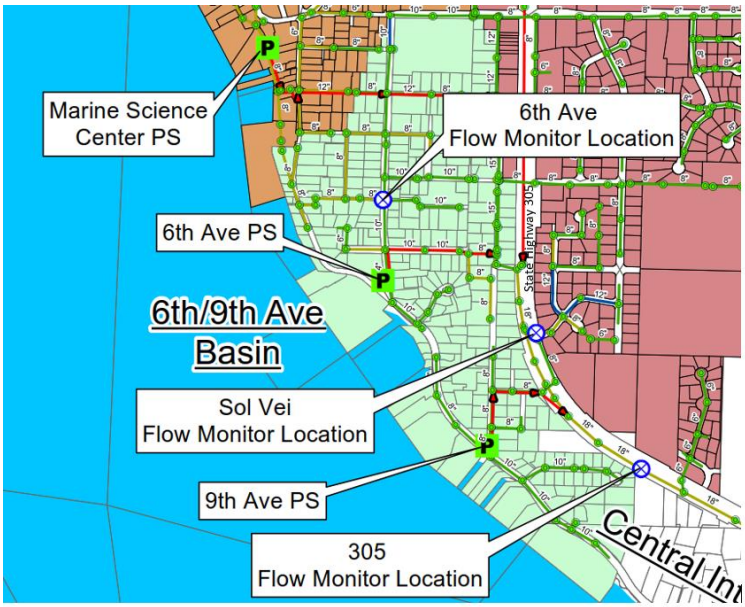
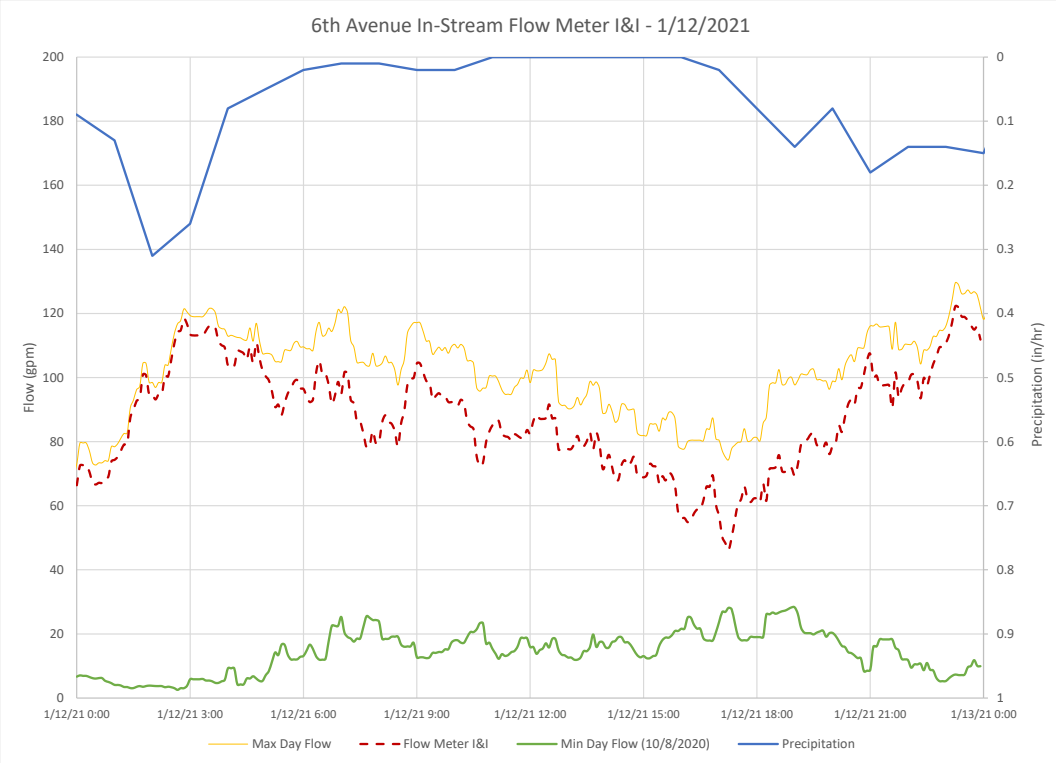


Figure 17: 6th Avenue Instream Flow Meter I&I on January 12, 2021



Village South (MH 51-73)

The Village South instream flow meter is located in MH 51-73 just south of the Village Lift Station, as highlighted in **Figure 18**. This manhole conveys flows from the Village Basin south of the lift station. The total drainage area to the flow meter is approximately 45 acres.

Data for the Village South flow meter is limited due to it being installed at a later date than the other flow meters. From the data recorded, the day with the maximum day flow occurred on February 1, 2021 (**Figure 19**). A total of 1.16 inches of precipitation occurred on this day, leading to 0.077 MGD of flow at the manhole. Total I&I was 0.029 MGD when comparing the maximum day flow to the minimum day flow occurring on January 17, 2021. In addition, on a per acre basis, I&I was 634 gpad. Once again, this is a relatively new basin built with modern standards and materials giving the basin low I&I rates. Additionally, I&I rates may be skewed low for this site since the flow meter was installed on January 11, 2021; therefore, limited flow data for these I&I evaluations was available.

The peak day and hour I/I rates per acre are at least 20 percent higher for this instream flow meter than the Village Lift Station. Investigations in this basin should be focused on the southern portion (that is upstream of this flow meter) first.

Figure 18: Village South Instream Flow Meter Location

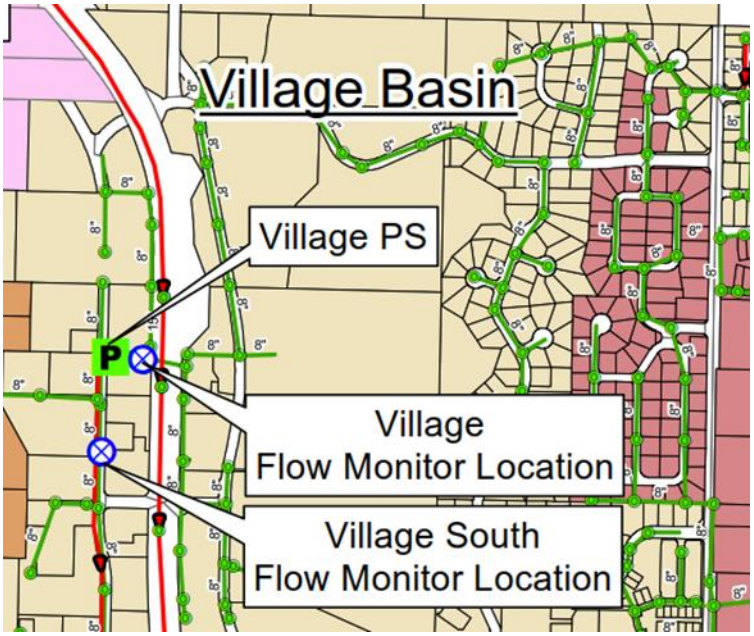
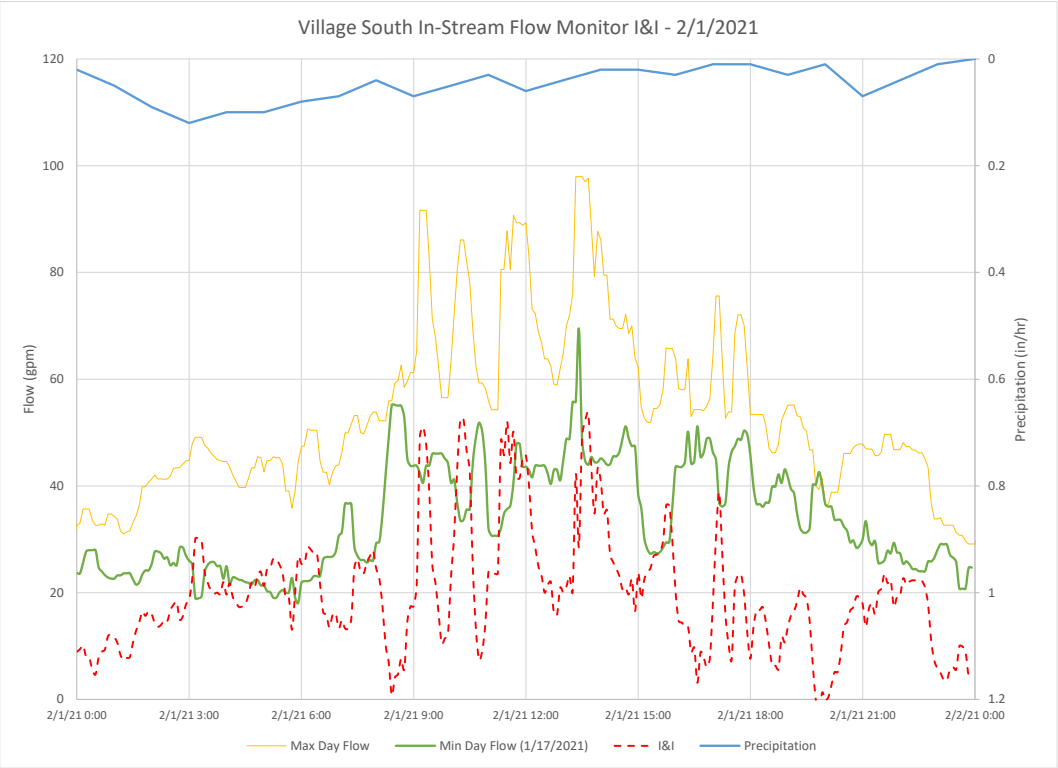


Figure 19: Village South Instream Flow Meter I&I on February 1, 2021



Village (MH 50-54)

The Village instream flow meter is located in MH 50-54 just east of the Village Lift Station, as highlighted in **Figure 20**. This manhole conveys flows from the Village Basin east of the lift station. The total drainage area to the flow meter is approximately 200 acres.

Peak day flow occurred on January 12, 2021 (**Figure 21**) and was the result of 3.2 inches of rain occurring on January 11th to January 12th combined. The peak day average flow at the manhole was 0.121 MGD. The minimum day occurred on August 29, 2020, resulting in a peak day I&I of 0.09 MGD and 449 gpad. The peak day and hour I/I rates per acre are at least 15 percent lower for this instream flow meter than the Village Lift Station. These are acceptable I&I rates and lower the need for I&I detection in this basin until solutions to other older basins with higher rates have been found.

Figure 20: Village Instream Flow Meter Location

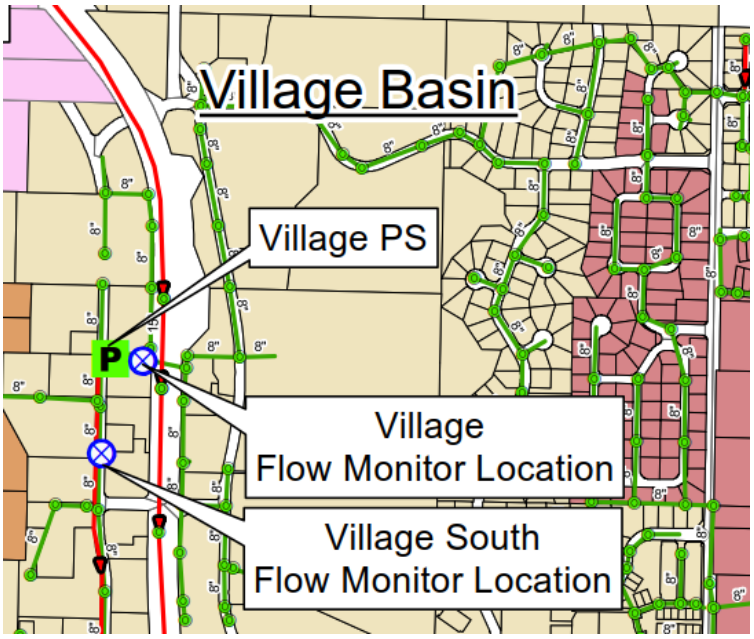
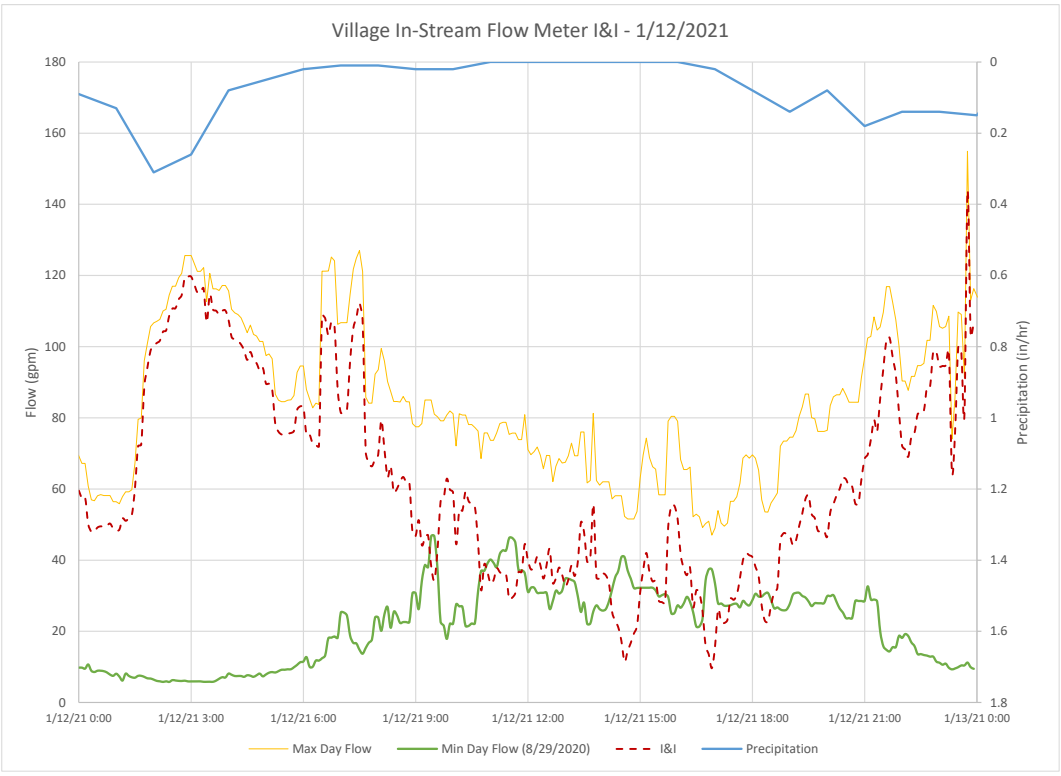


Figure 21: Village Instream Flow Meter I&I on January 12, 2021



Liberty (MH 37-17)

The Liberty instream flow meter is located in MH 37-17 near the Liberty Bay Lift Station, as highlighted in **Figure 22**. This manhole conveys flow from 79 acres to the southwest of the Liberty Lift Station.

Peak day flow was observed on December 21, 2020 (**Figure 23**), despite a portion of the hydrograph needing to be reconstructed because of a gap in data recording. A linear interpolated curve was used to estimate flows during the data gap and create a better picture of the total I&I occurring. The peak day event was likely the result of 2.72 inches of rain occurring on December 21st. The peak day average flow at the manhole was 0.042 MGD. The minimum day occurred on April 9, 2020, resulting in a peak day I&I of 0.03 MGD and 389 gpad.

The peak day and hour I/I rates are at least 34 percent higher for the instream flow meter than the Liberty Lift Station. Investigations in this basin should be focused on the southern portion (upstream of the flow meter) first because of the higher I&I rate per acre in this area.

Figure 22: Liberty Instream Flow Meter Location

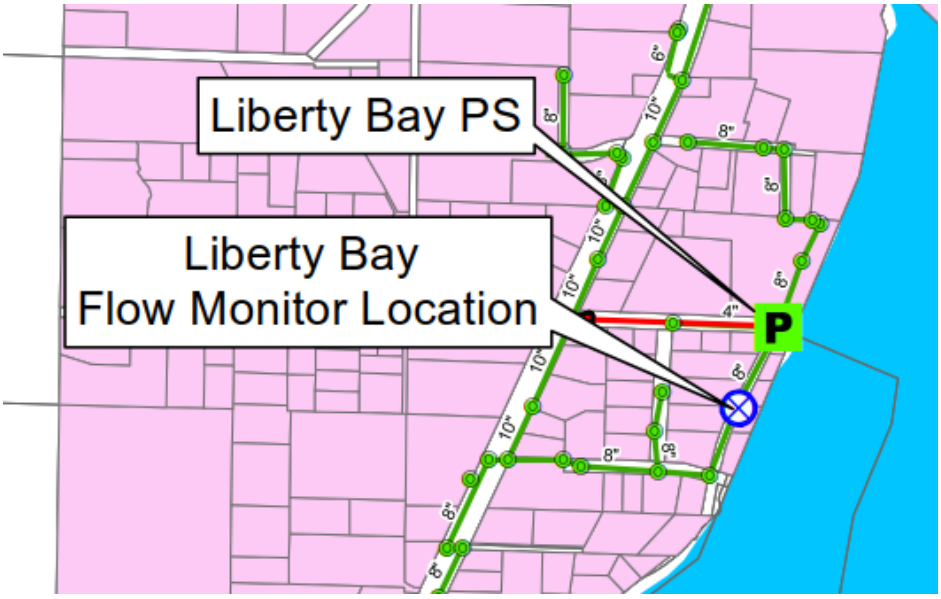
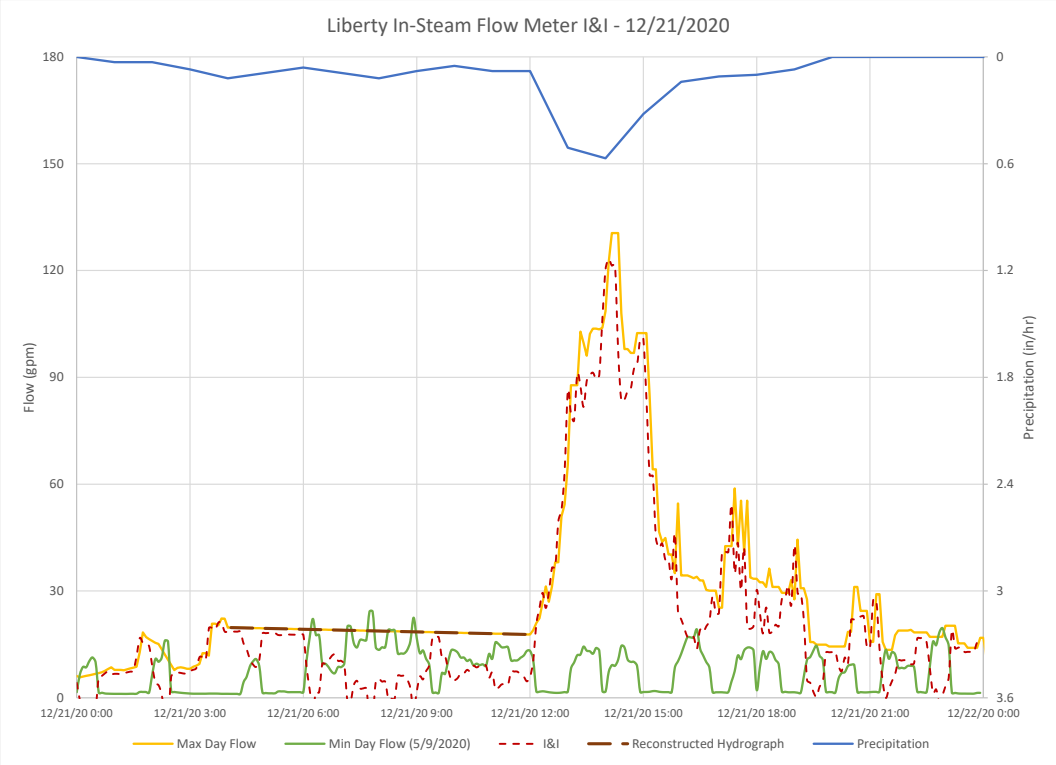


Figure 23: Liberty Instream Flow Meter I&I on December 21, 2020



Noll Road (MH 83-08)

The Noll Road flow meter is in MH 83-08 in the southeast corner of the system along SR 305, as shown in **Figure 24**. The drainage area to the manhole is the Noll Road Basin, which encompasses approximately 268 acres.

The Noll Road instream flow meter was not put in place until 2021; therefore, a full data set was not available for this site. From the available data, peak day flow occurred on February 1, 2021 (**Figure 25**) when a 0.038 MGD flow passed through the manhole with an I&I component of 0.021 MGD. A total of 1.17 inches of precipitation occurred on February 1st, producing the I&I hydrograph shown in the **Figure 25**. The I&I per acre was 78 gpad. These are low rates of I&I that warrant expending effort elsewhere in the City's collection system. It should be noted though that the flow meter was installed on January 14, 2021, so the limited data record may have skewed the I&I rates low.

Figure 24: Noll Road Instream Flow Meter Location

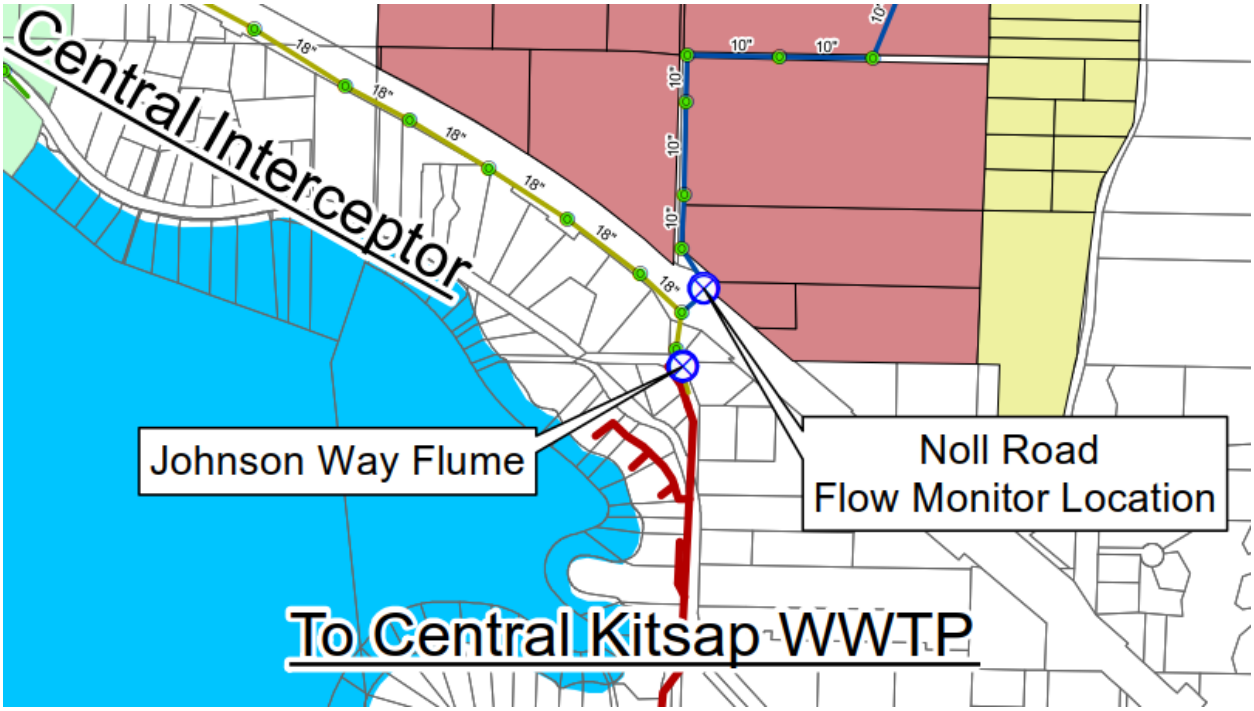
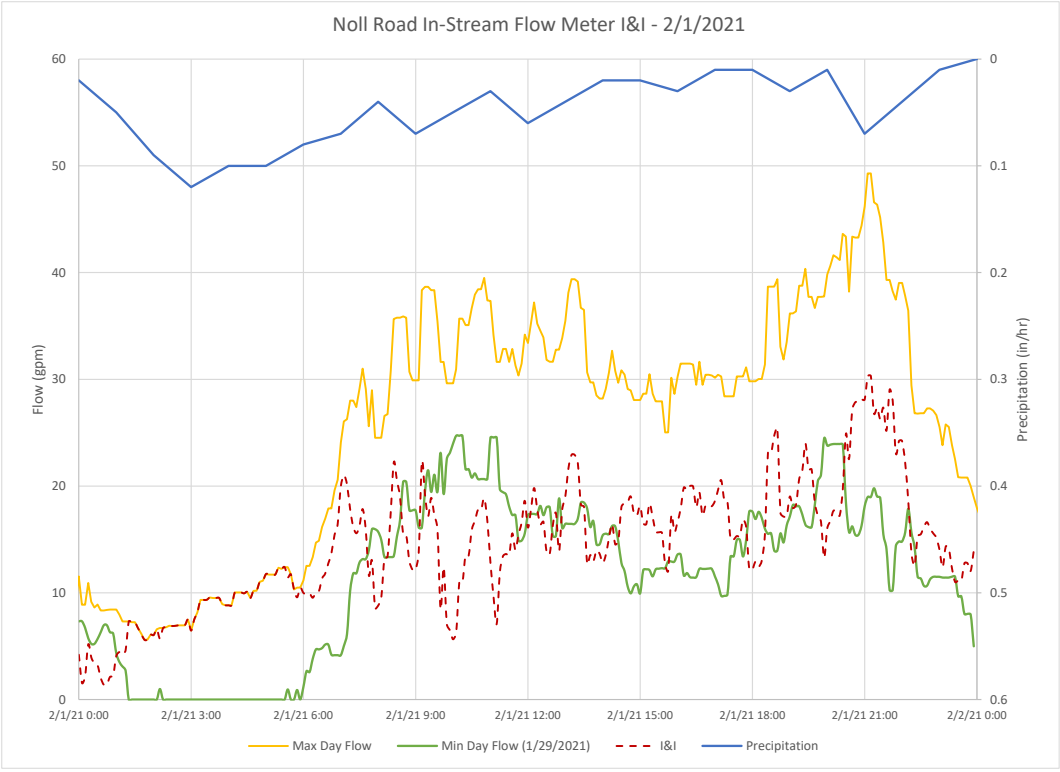


Figure 25: Noll Road Instream Flow Meter I&I on February 1, 2021



Sol Vei (MH 68-04)

The Sol Vei Manhole (68-04) is in the southwest region of the East Poulsbo Basin along SR 305, as shown in **Figure 26** . The drainage area to the manhole is small at approximately 14 acres.

The City has a level sensor installed at the Sol Vei Manhole to help monitor the level in the Central Interceptor so City staff can respond quickly if an overflow has occurred or is anticipated. This site does not measure flow. The level in the Sol Vei Manhole peaked for a few hours on December 21, 2020, as shown in **Figure 27**, indicating the water level in the Central Interceptor was elevated to higher than normal levels during this time. Elevations for the Sol Vei and Overflow Manholes from the City's as-built drawings are shown in **Table 12**. The Sol Vei Manhole invert elevation is higher than the Overflow Manhole rim elevation, so an increased water level in the Sol Vei Manhole is a good indicator of an elevated water level in the Overflow Manhole. The time of the elevated water level correlates well with when overflow occurred at the Central Interceptor (a duration of approximately 4 hours).

Figure 26: Sol Vei Manhole Location

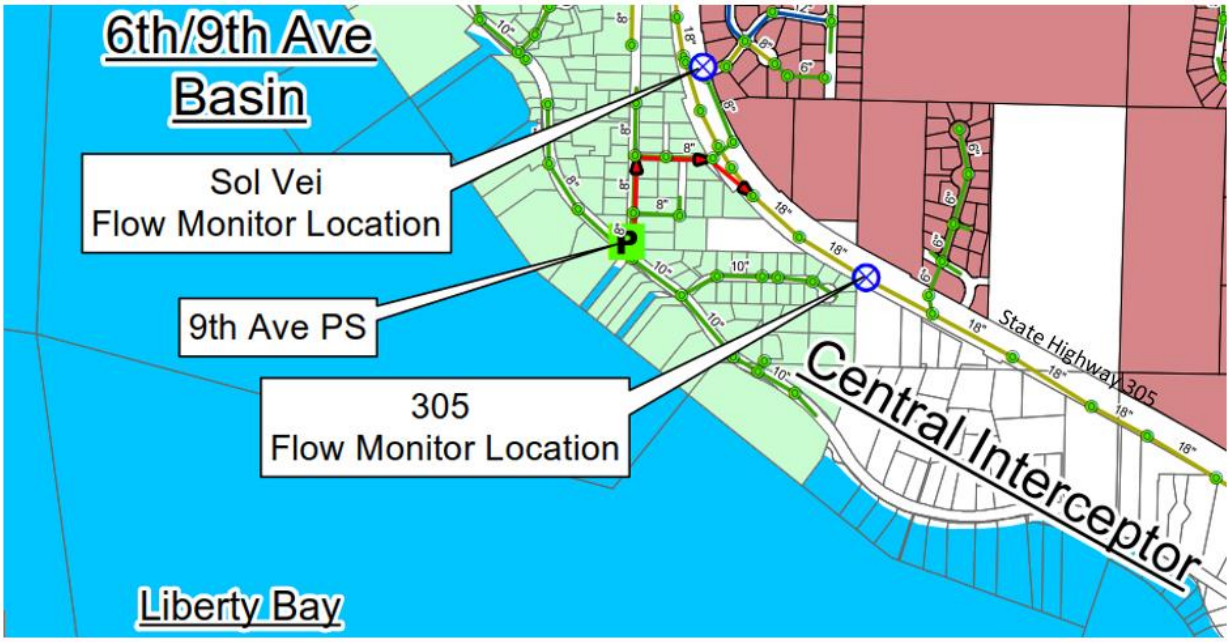


Figure 27: Sol Vei Level Readings on December 21, 2020 to December 22, 2020

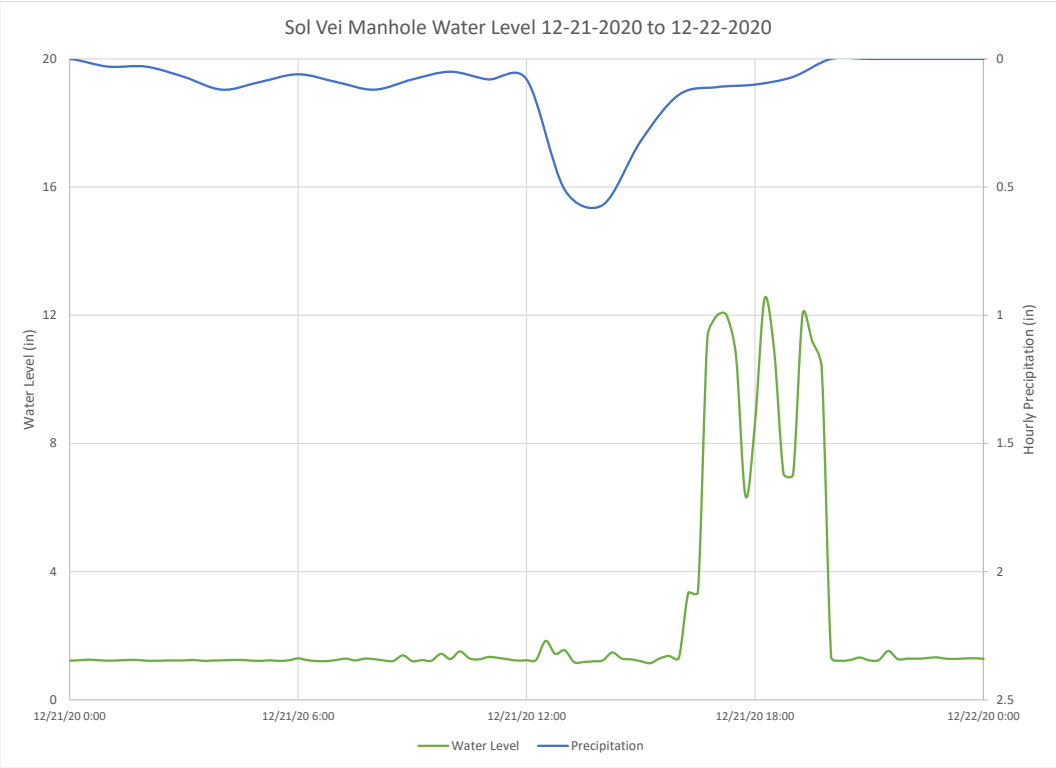


Table 12: Sol Vei and Overflow Manhole Elevations

Description	Sol Vei Manhole	Overflow Manhole
MH ID No.	68-04	68-07
Rim Elevation (ft)	84.28	77.1
Invert Elevation (ft)	78.3	71.84

SR 305 (MH 68-13)

The SR 305 flow meter was not used for these I&I evaluations because it was incorrectly reading flows during the majority of the flow monitoring for this project. The SR 305 flow meter consistently read flows that were much higher than the Flume was reading. The SR 305 flow meter was re-calibrated on March 14, 2021 and is now reading flows that are more consistent with readings at the Flume. The SR 305 flow meter can now be utilized more accurately for future I&I evaluations. The City added additional instrumentation to this flow meter in late January 2021 to allow it to read flows even after becoming fully submerged. This is a feature it lacked during the December 21, 2020 storm that caused the overflow in the Sol Vei area. RH2 is certain this flow meter surcharged on December 21, 2020 because the Flume showed evidence of surcharge, and the level readings at the SR 305 flow meter and the Sol Vei were well above pipe crown elevations. The SR 305 flow meter is now equipped to read hourly flows under all conditions, surcharged or not.

Conclusions and Recommendations

System-Wide I&I

As shown in the I&I analyses in this report and the City's 2016 CSSP, system-wide I&I in the sewer system are both considered non-excessive per the EPA's guidelines. However, due to recent and previous overflows on the Central Interceptor, it is recommended that the City focus on reducing inflow in areas where it is most prevalent when it rains as identified in this report, such as Central Poulsbo (the drainage basin for the Marine Science Lift Station), and where cost-effective solutions can be identified.

Every well run sewer utility should be working towards reducing rainfall-induced I&I. The City has done this and achieved superior results as shown in the low rates of I&I per unit area. However, these efforts have not been enough to free-up enough capacity to accommodate the needs of the growing City. RH2 recommends that the capacity increases, discussed later in this section of the report, be implemented. The improvements were described in the 2016 CSSP but the City had hoped to delay them because of the progress made in I&I reduction projects over the past 4 years. The projects should not be delayed as evidenced by the overflow that occurred on December 21, 2020 during a 25 year, 6-hour duration rainstorm. Reducing I&I is often a time consuming, trial and error process to significantly reduce flows. The City does not have the time and cannot withstand the risk of uncertainty that the projects will reduce flows in the volume needed to create additional capacity for new customers. The projects increasing wastewater conveyance capacity will provide the certainty the City needs.

In 2020, the Flume had a minimum day flow 0.69 MGD and an AAF of 0.86 MGD. Based on this information, it is estimated the City had a total of approximately 61 MG of I&I in 2020, which was 19 percent of the City's total wastewater discharged to the County. In addition to fixed costs, the City pays the County a variable operations and maintenance (O&M) cost as well, which is $560 per million gallons of wastewater discharged to have the City's wastewater conveyed and treated in the County's sewer system. **Table 13** summarizes the 2020 system-wide annual I&I and the variable O&M costs this I&I incurred to the City.

Table 13: 2020 System-Wide Annual I&I and Costs Incurred by City by I&I

Year	Average Annual Flow (MGD)	Minimum Day Flow (MGD)	Annual I&I (MG)	Cost per Gallon of I&I ($/MG)	Total Annual Cost ($)
2020	0.86	0.69	61.1	$560	$34,242

Reducing I&I in the City's sewer system would not significantly lower the City's variable O&M costs paid to the County. However, I&I reduction would increase the remaining available capacity in major trunklines, such as the Central Interceptor and Lemolo Siphon, and could decrease the County's operational costs for the Central Kitsap Wastewater Treatment Plant, which could indirectly lower the fixed O&M costs the City pays to the County for O&M of this treatment plant.

Lift Station/Sewer Drainage Basin I&I

This I&I evaluation identified there is significant I&I in the historic downtown region of the City. Both the 6th Avenue flow meter and lift station, the Marine Science Lift Station, and 9th Avenue Lift Station Basins showed higher levels of inflow per area than other basins in the City's sewer system. The 6th Avenue basin experienced a higher peak day I&I rate per acre when compared to the Marine Science basin; however, the latter had a greater peak hour I&I rate per acre. The 9th Avenue Basin had a lower peak day I&I rate per acre when compared to the aforementioned basins, but experienced significant peaking, resulting in the highest peak hour I&I rate per acre of the lift stations evaluated. Moreover, the Alasund Lift Station experienced the highest peak hour I&I rate per acre of all sites evaluated on January 13, 2021. As stated previously, these high inflow rates are likely caused by roof downspouts, catch basins, and area drains tied directly into the sanitary sewers. Steps to remove these connections should be integrated into the City's capital improvement program.

Next Steps and Additional Investigation

Additional Investigation

It is recommended that the City perform the following actions to identify the sources of inflow in areas where higher peak hour and peak day I&I rates are identified in this report.

- Smoke testing, which could identify storm infrastructure (such as roof drains or catch basins) that is connected to the sewer system.
    - This is highly recommended in the 6th Avenue, Marine Science, and 9th Avenue Lift Station Basins to assist with determining potential sources of inflow.
    - For the 6th Avenue Lift Station Basin, the private side sewers should be inspected since the sewer mains in this basin were replaced in 2005.
    - For the Marine Science Lift Station Basin, the south end of this basin should be prioritized since this is the older part of the basin and there is limited storm infrastructure in this area.
- Dye testing, which could identify if suspected storm infrastructure (such as roof drains or catch basins) are connected to the sewer system.
    - It is recommended to dye test in coordination with areas being smoke tested.
- Visual inspection of manholes, which could identify infiltration at manhole joints or if storm infrastructure is connected directly to the manhole.
- Use the camera truck to video the remaining 40 percent of the City's sewer system, which could identify I&I sources. The older basins with high inflow mentioned previously should receive top priority for inspection.

- Visual flow isolations when it rains at strategic locations, which could help identify specific City blocks where significant sources of inflow are coming from.
    - This technique can be paired with manhole inspections.
- Purchase a push camera to inspect private sewer laterals.
    - It is recommended to inspect private sewer laterals in coordination with areas being smoke and dye tested.
- The City now owns one instream flow monitor that can be relocated for flow monitoring. It is recommended that this flow monitor be used to continue monitoring at the following locations.
    - Noll Road – Flow monitoring for this study at this location did not start until January 14, 2021, which was after the December 21, 2020 rain event. It is recommended to have this flow monitor installed during a future rain event of similar nature so a more accurate evaluation can be made for the peak hour inflow in this basin. Additionally, data from this location along with the Flume can be used to confirm if the SR 305 monitor continues to report flows reasonably.
    - Village South – Flow monitoring for this study at this location did not start until January 11, 2021, which was after the December 21, 2020 rain event. It is recommended to have this flow monitor installed during a future rain event of similar nature so a more accurate evaluation can be made for the peak hour inflow in this basin.
    - Central Poulsbo Sewer Drainage Basin – Flow monitor at strategic locations in this basin to further evaluate the sources of inflow in this basin.
- The City is working to disconnect the storm infrastructure from two businesses in the Liberty Bay Lift Station Basin that are connected to the City's sewer system.

Recommended Improvements

It is recommended that the City perform the following improvements to address inflow in its sewer system and increase the remaining available capacity in major trunklines.

- Develop a program to inspect private side sewers. The program could be instituted in one of the following manners.
    - The City could implement a progressive approach by undertaking public project(s) with City sewer funds to inspect private side sewers (via smoke testing, dye testing, and a push camera) to disconnect illicit connections when found. This diagnostic testing to determine if there are inflow sources on the private property being served or a deficient side sewer can be performed during the construction project. Without replacing private side sewers during the replacement of City-owned mains and manholes, only marginal I&I reductions will be made.

  - The City could update its code to require homeowners to inspect their private side sewers when a property is sold. The City could incentivize this program by partially funding private side sewer replacements to limit its impact on homeowners and real estate transactions.

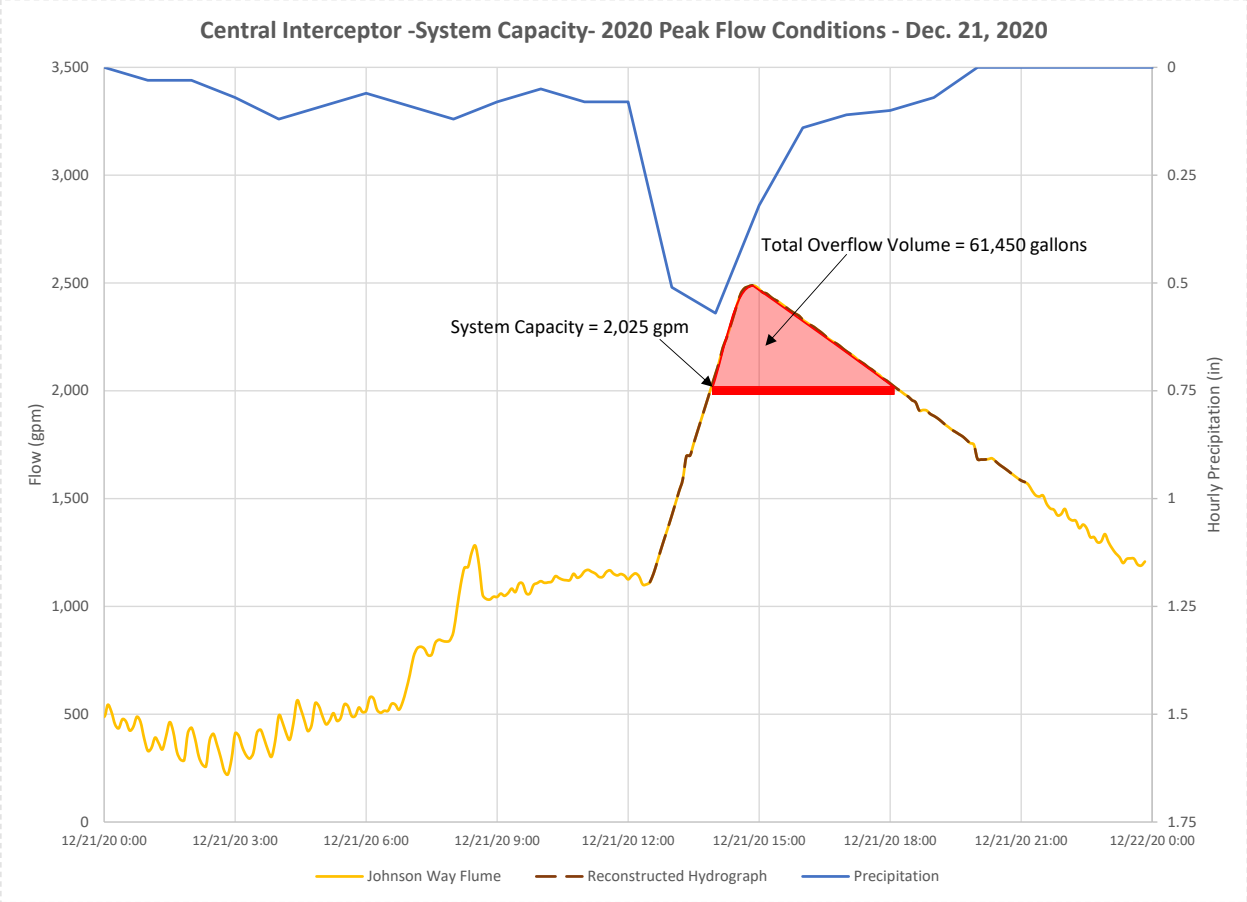
- When the SR 305 force main extension is implemented, consider extending the force mains for the Marine Science, 6th Avenue, 9th Avenue, and Village Lift Stations so they connect and discharge to the SR 305 force main (for Bond Lift Station). This would increase the remaining available capacity in the Central Interceptor by diverting flow into the future force main that will discharge downstream of SR 305.
- The City should consider replacing older sewer mains adjacent to water mains that are being replaced. At a minimum, the City should inspect these sewer mains to evaluate if they need to be replaced.
- The City should investigate having a second level sensor installed in the Flume and the programming updated so that flows can be more accurately measured at the Flume when the water level in the siphon downstream of the City's sewer system surcharges back into the Flume.

Overflow Event Analyses

The overflow event on December 21, 2020 lasted approximately 4 hours. This was determined by analyzing the elevated water level recordings in the Sol Vei Manhole. Using this 4-hour interval, the capacity of the Central Interceptor was estimated by determining the flow rate that was separated by 4 hours on the Central Interceptor hydrograph when the overflow occurred. The Central Interceptor hydrograph (shown in **Figure 28**) was developed by subtracting flows estimated for the Noll Road and Baywatch Court NE areas from the Flume hydrograph since these locations are connected to the Central Interceptor downstream of where the overflow occurred. Using this method, the Central Interceptor capacity was estimated to be approximately 2,025 gpm. This is lower than the capacity BHC estimated from its hydraulic modeling analyses, which is discussed in the following section.

The total overflow volume was computed by determining the total area of the Central Interceptor hydrograph above the 2,025 gpm capacity. The overflow volume was estimated to be 61,450 gallons.

Figure 28: Central Interceptor Hydrograph for December 21, 2020



Offline Peak Storage Structure

It also is recommended that the City construct an Offline Peak Storage Structure (OPSS) in the immediate future on the Central Interceptor near Nordness Place NE to reduce the chance of another overflow occurring at this location in the near future. This will allow the City to continue to grow over the next few years while the following hydraulic capacity improvements identified in the City's 2016 CSSP are implemented (to accommodate for long-term growth in the City's sewer system):

- SR 305 force main extension.
- County's Lemolo Shores Pipeline capacity improvements.
- County's Lemolo Siphon capacity improvements.

It was assessed by BHC that the December 21, 2020 rainfall event correlates to a 50-year 2-hour event, 25-year 6-hour event, and between a 2- and 5-year 24-hour event. Since this rainfall event could be correlated to a 50-year 2-hour event or 25-year 6-hour event, it was determined the storm event was large enough to base the I&I component of the hydrograph for sizing the OPSS. I&I for this rainfall event was determined by subtracting the 2020 minimum day flow

(which was assumed to be domestic wastewater only for the purposes of these analyses), which occurred on September 6, 2020.

The domestic component of the hydrograph was developed from the minimum day flow with estimated flows for the Noll Road and Baywatch Court NE areas removed from the hydrograph for the Central Interceptor since these locations are connected to the Central Interceptor downstream of where the overflow event occurred. The domestic component of the hydrograph was then scaled by an additional approximately 16 percent to account for a population growth of 3 percent per year for the next 5 years.

Based on the projected hydrograph (with domestic and I&I flows combined), OPSS sizing was estimated to determine how much storage the City would need to construct at the identified site to prevent an overflow from occurring. These volumes were estimated based on a range of capacities for the Central Interceptor and are shown in **Table 14**. BHC estimated the capacity of the Central Interceptor to be 2,600 gpm if surcharging to the rim of MH 68-07 (where the overflow occurred) is allowed, and 2,275 gpm if surcharging to within 2 feet of the rim of MH 68-07 is allowed.

Table 14: Estimated OPSS Size Needed Based on Potential Central Interceptor Capacities

Central Interceptor Capacity (gpm)	OPSS Volume (gal)
2,400	11,652
2,300	24,918
2,275	29,041
2,200	43,119
2,100	66,184
2,000	94,143
1,900	127,173

It was concluded by others that the selected site is only able to accommodate 100,000 gallons of storage. If the OPSS is 100,000 gallons, it should be large enough to significantly reduce the chance of another sewer overflow occurring on the Central Interceptor in the next few years.

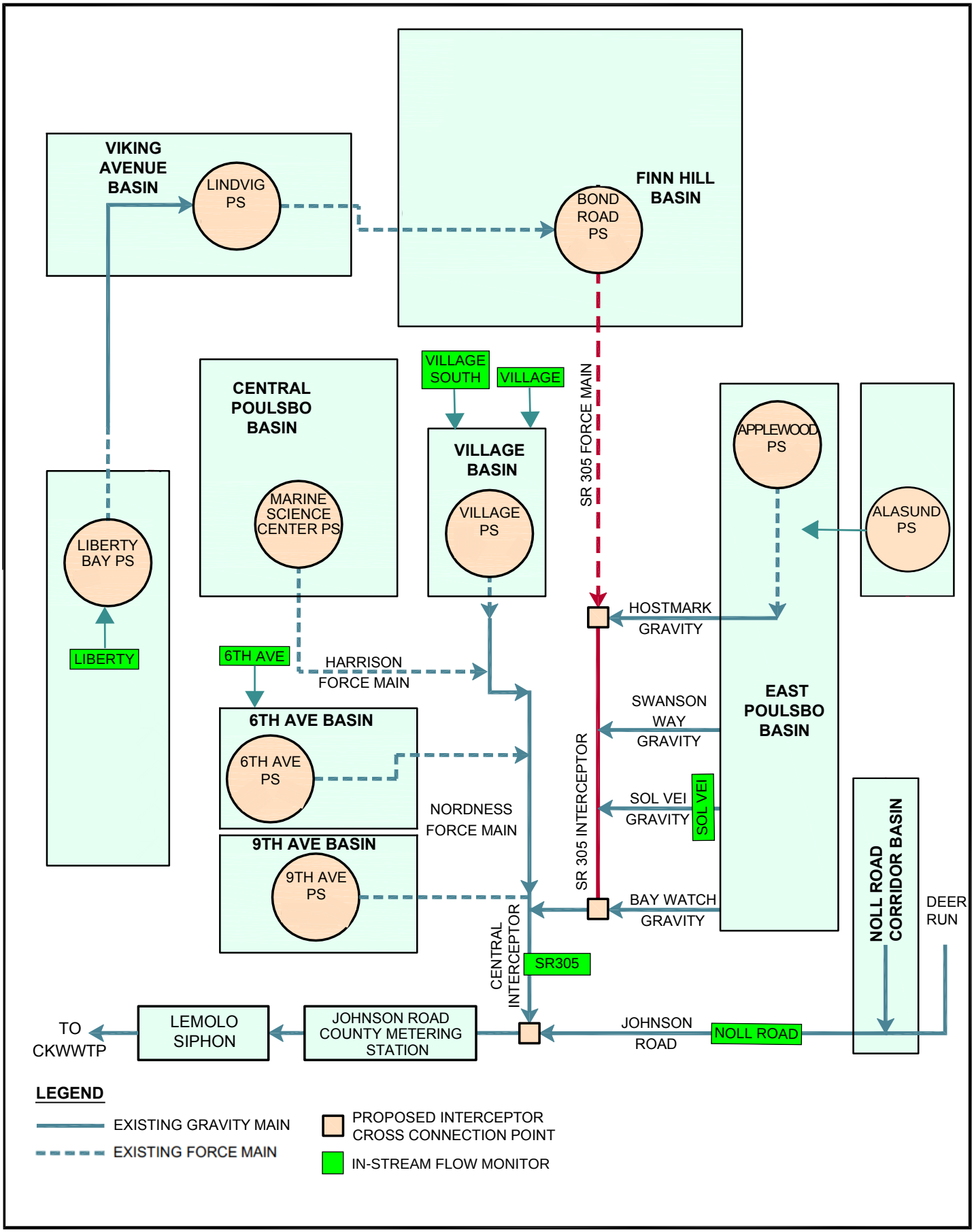
Appendix A contains additional discussion of sizing the OPSS based on the 24-hour precipitation total for the December 21, 2020 storm (assuming it was a 2-year event) and scaling up the I&I component of the hydrograph for the 5-year, 10-year, and 25-year storm events.

It should be noted that the recommended OPSS volumes were based on current isopluvial maps, which do not account for any intensification that may occur in the future due to climate change or similar effects.

THIS PAGE INTENTIONALLY LEFT BLANK

Figures

THIS PAGE INTENTIONALLY LEFT BLANK

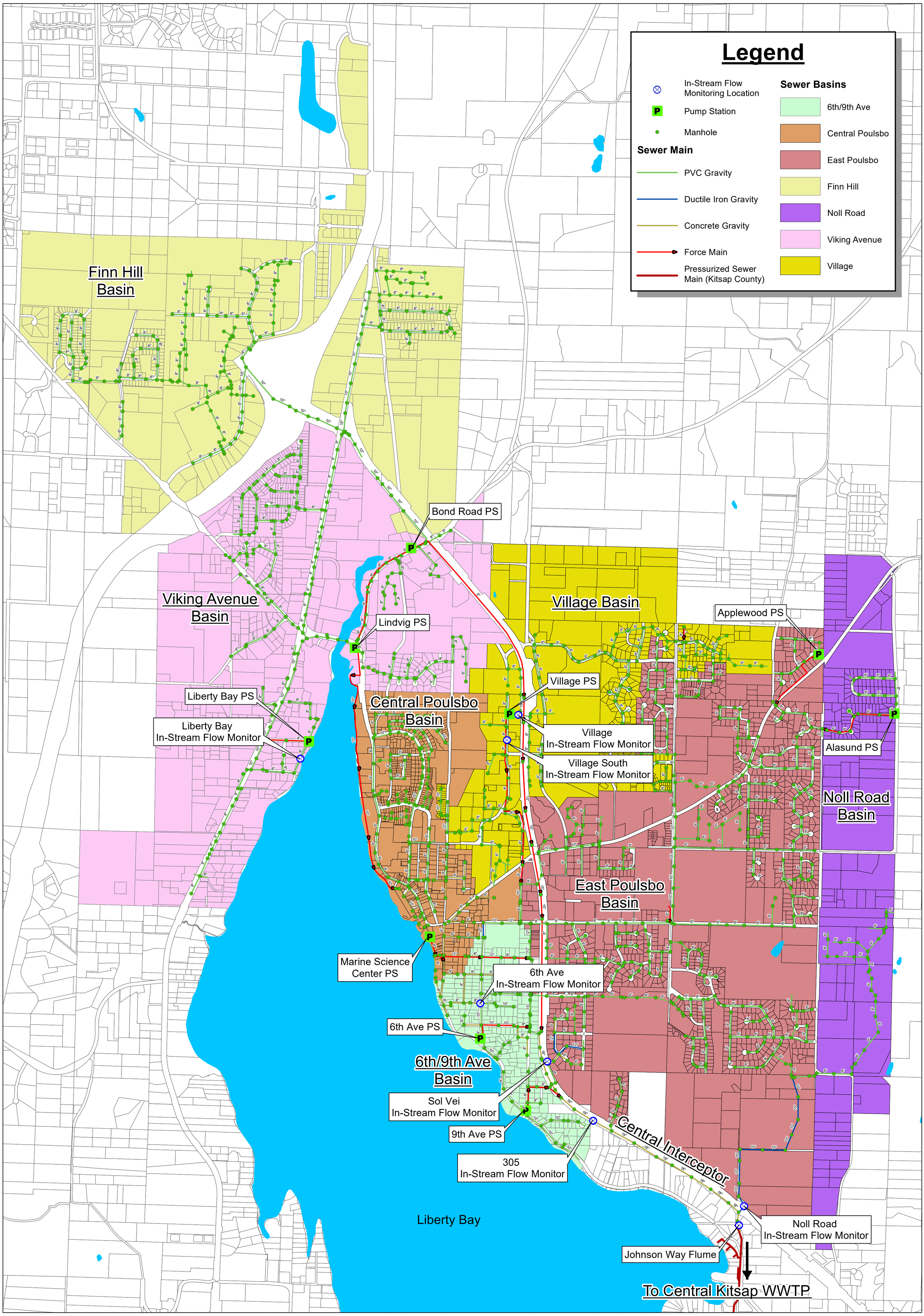


Sewer System I&I Evaluation Report

Sewer System Flow Schematic

City of Poulsbo
April 2021

Figure 1



J:\DATA\POU\119-149\GIS\MAPS\FLOW METER LOCATIONS.MXD BY: AARGER PLOT DATE: APR 6, 2021 COORDINATE SYSTEM: NAD 1983 HARN STATEPLANE WASHINGTON NORTH FIPS 4601 FEET

NORTH

RH2

1 inch = 800 feet

0 400 800 1,600 Feet

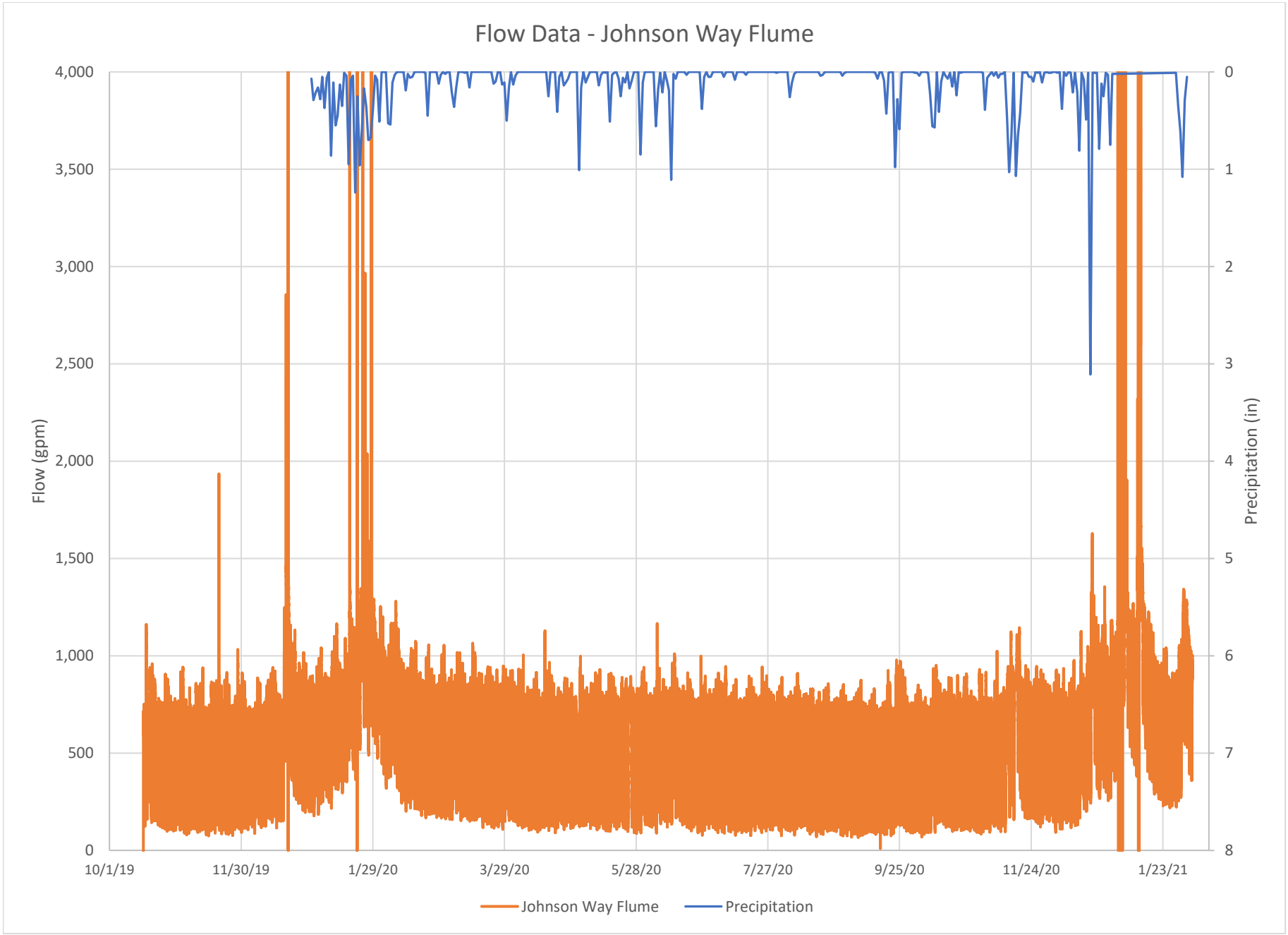
DRAWING IS FULL SCALE WHEN BAR MEASURES 2”

Figure 2 - Existing Sewer System and Flow Monitoring Locations Map

City of Poulsbo

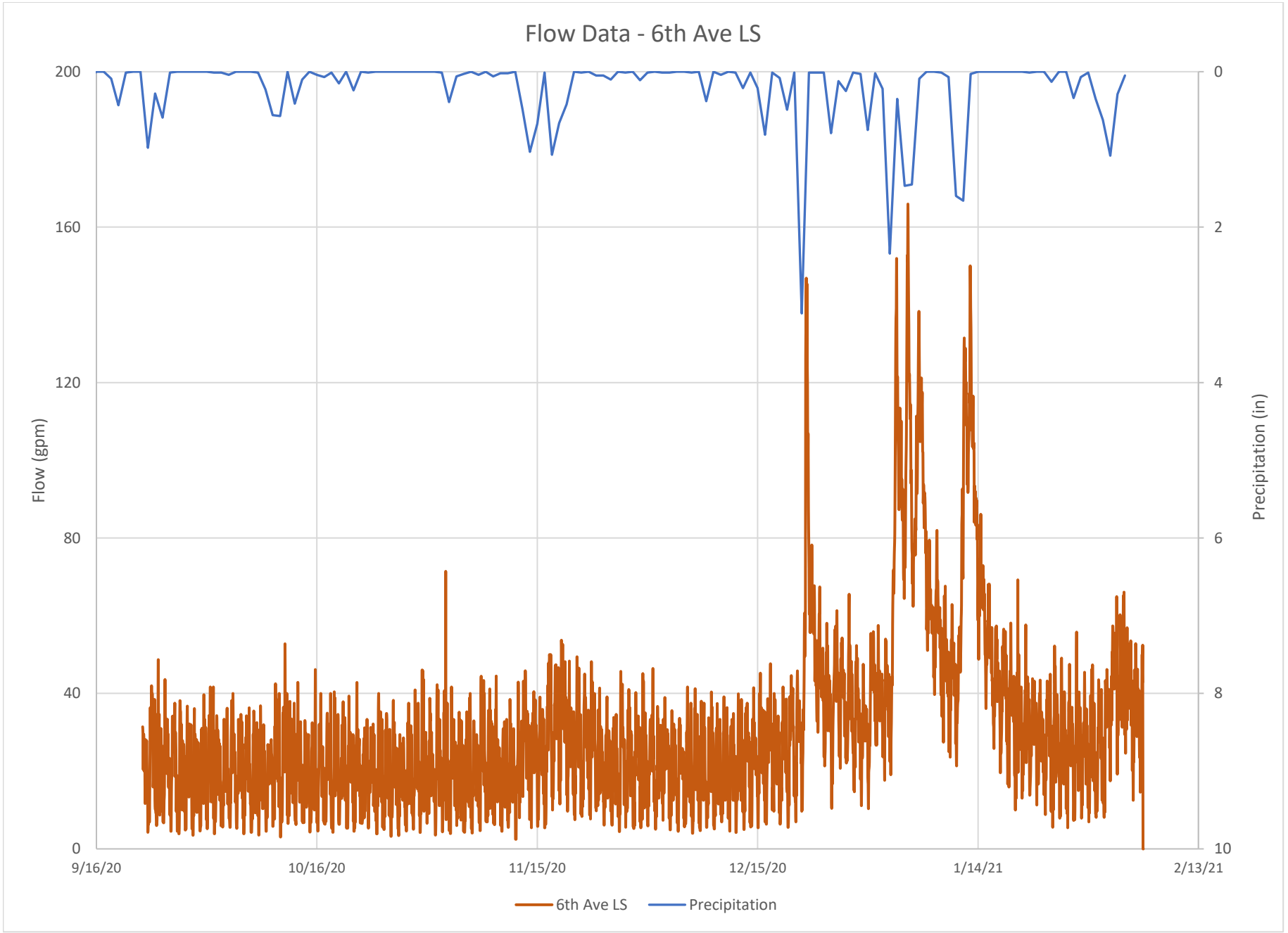
Sewer System I&I Evaluation Report

Figure 29



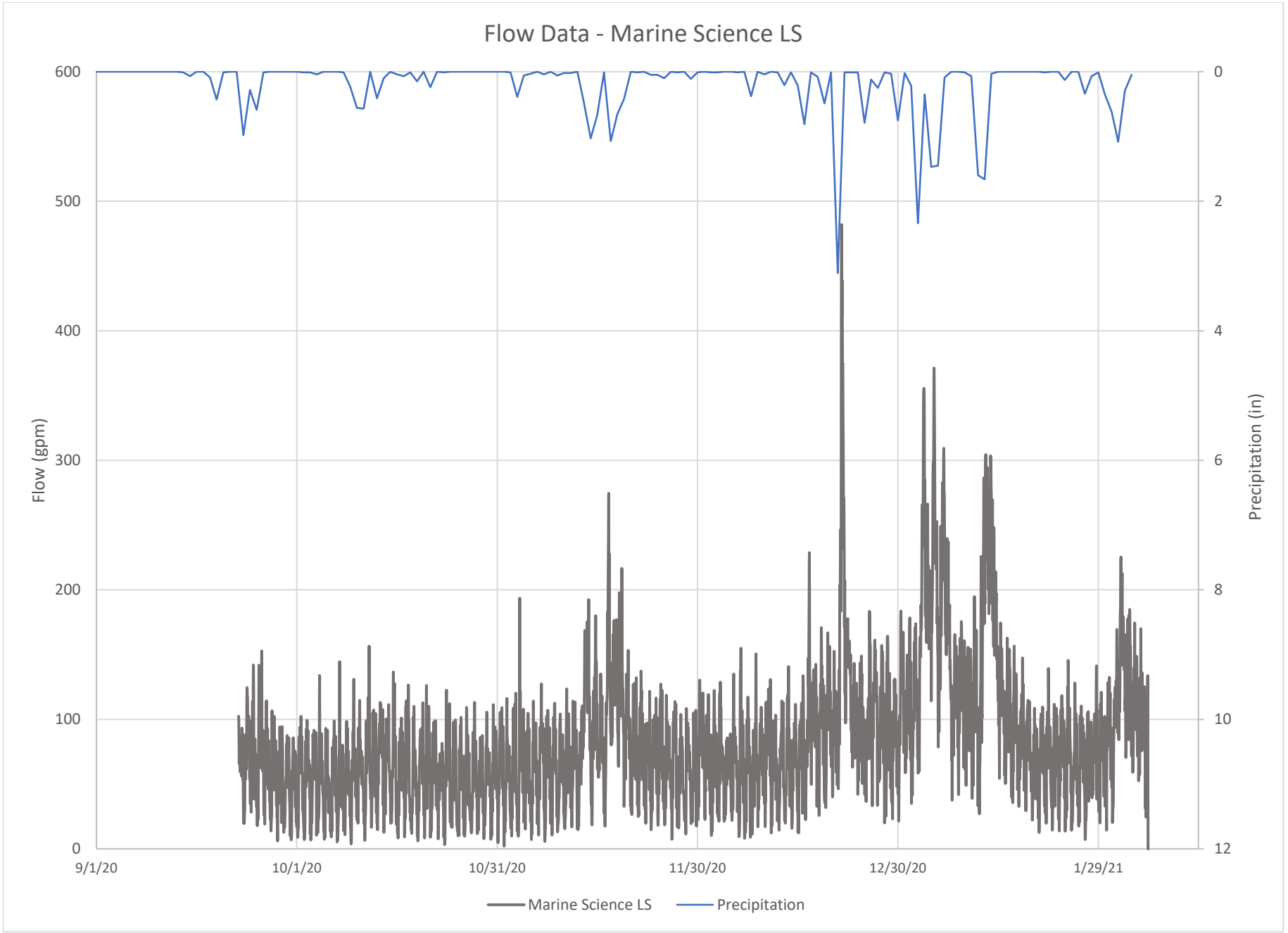
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 30



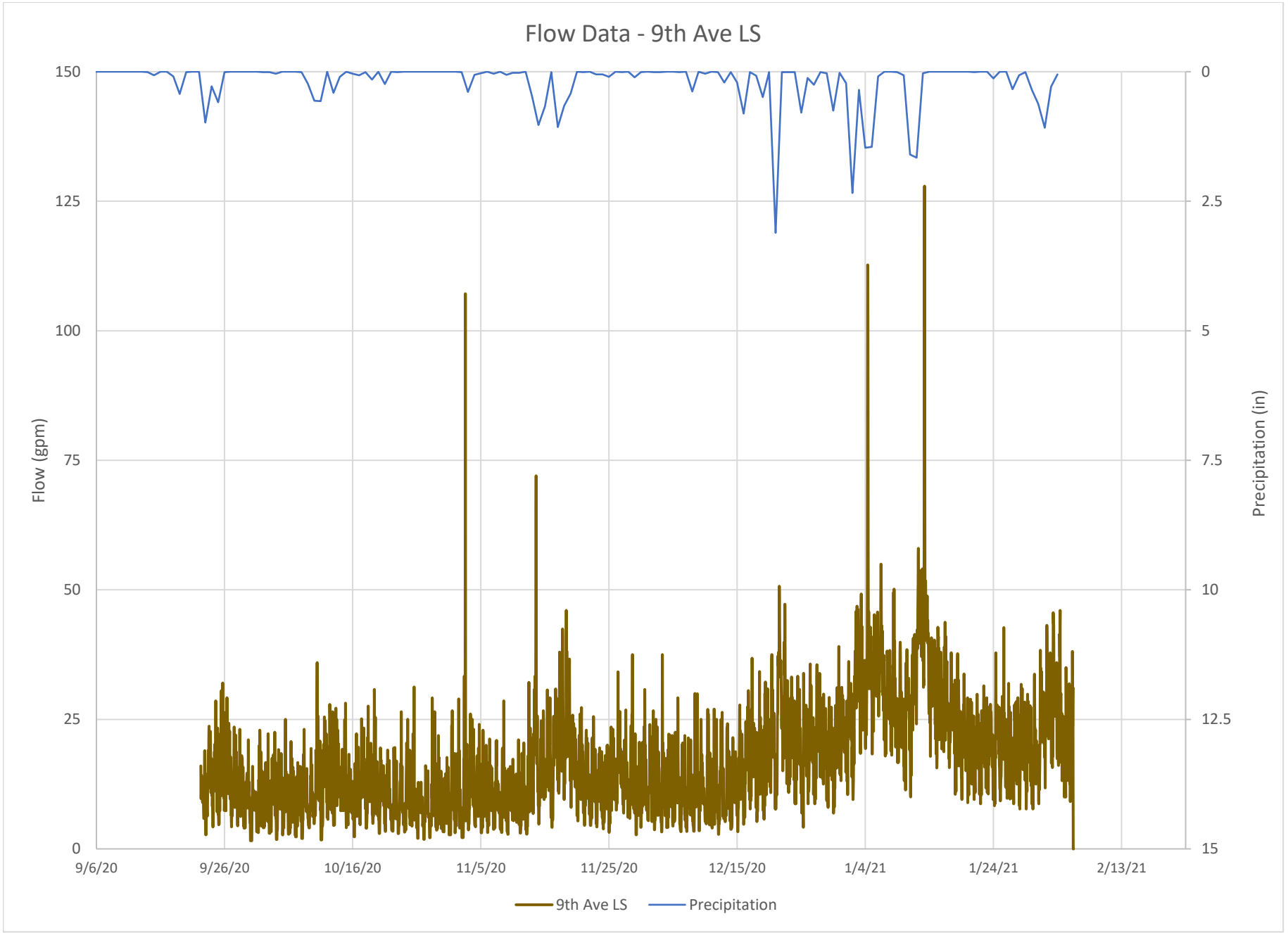
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 31



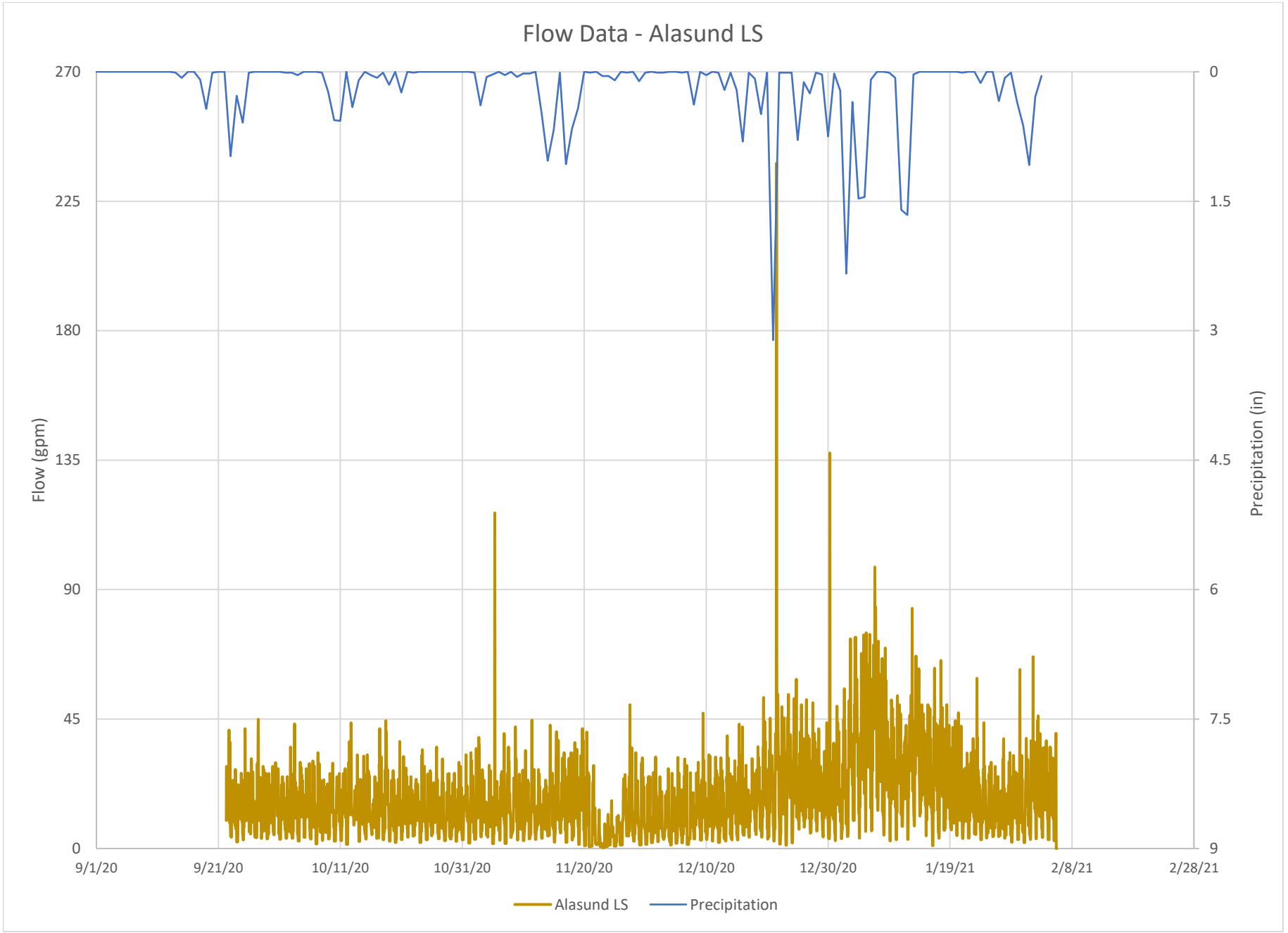
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 32



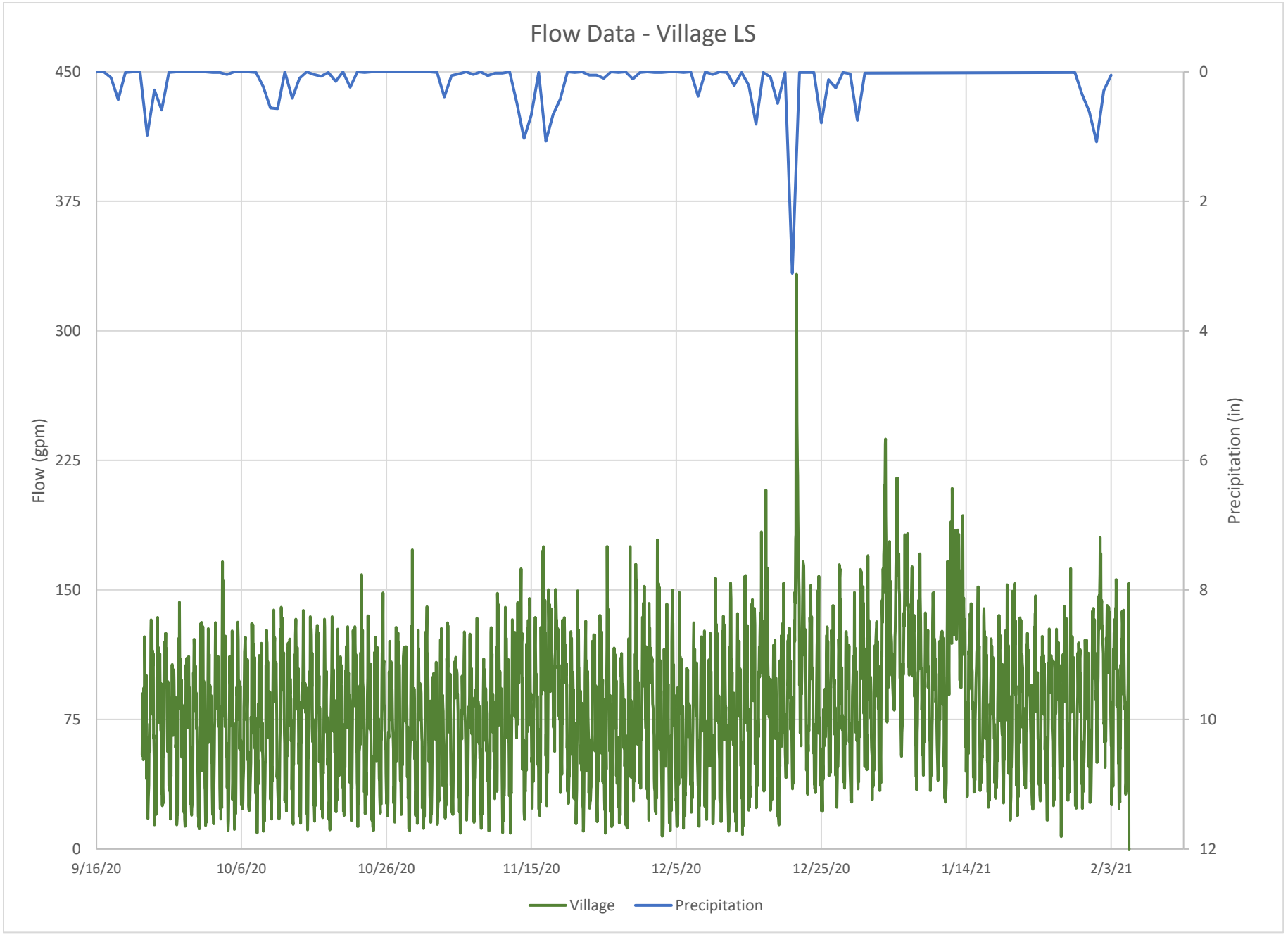
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 33



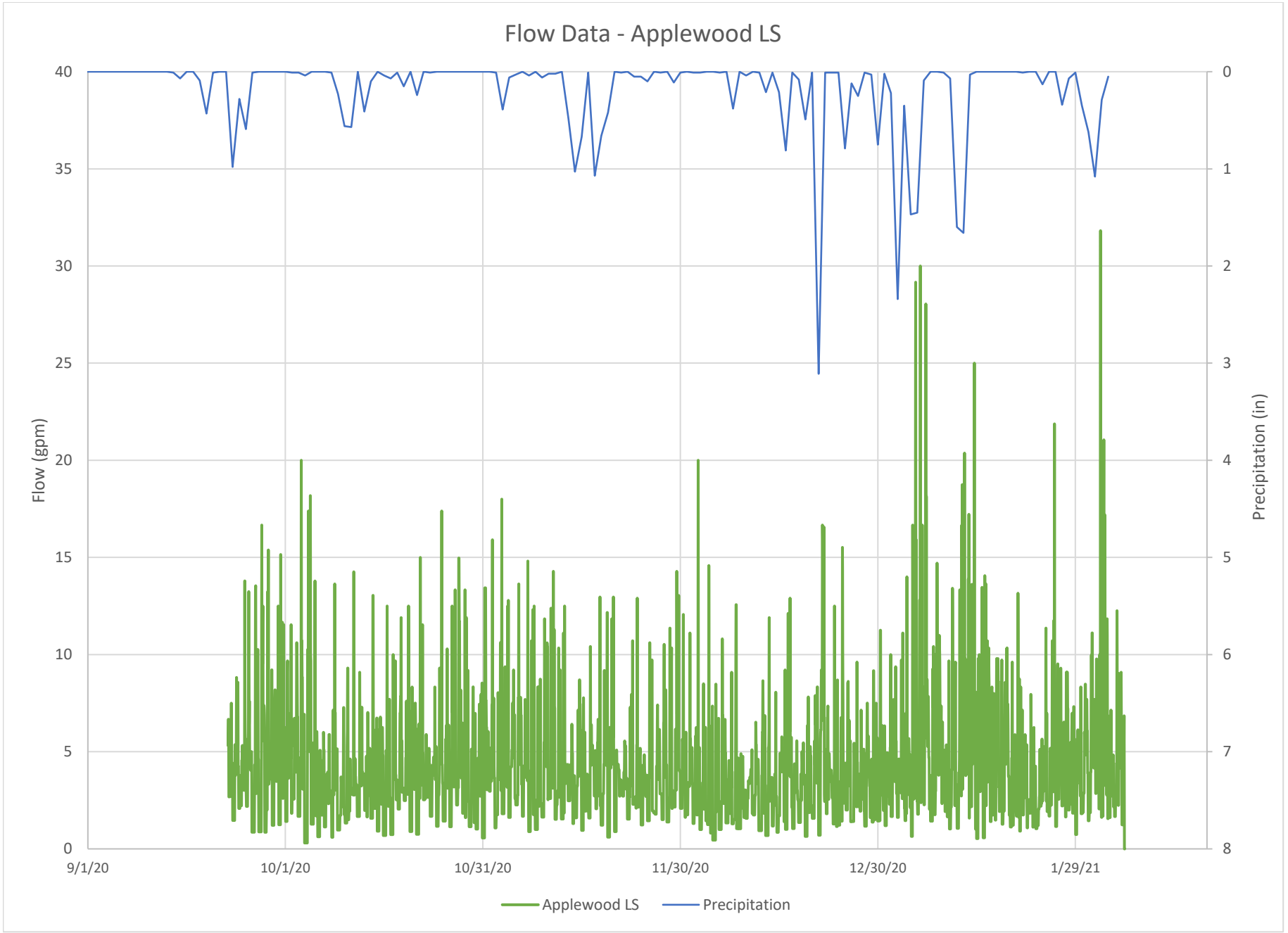
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 34



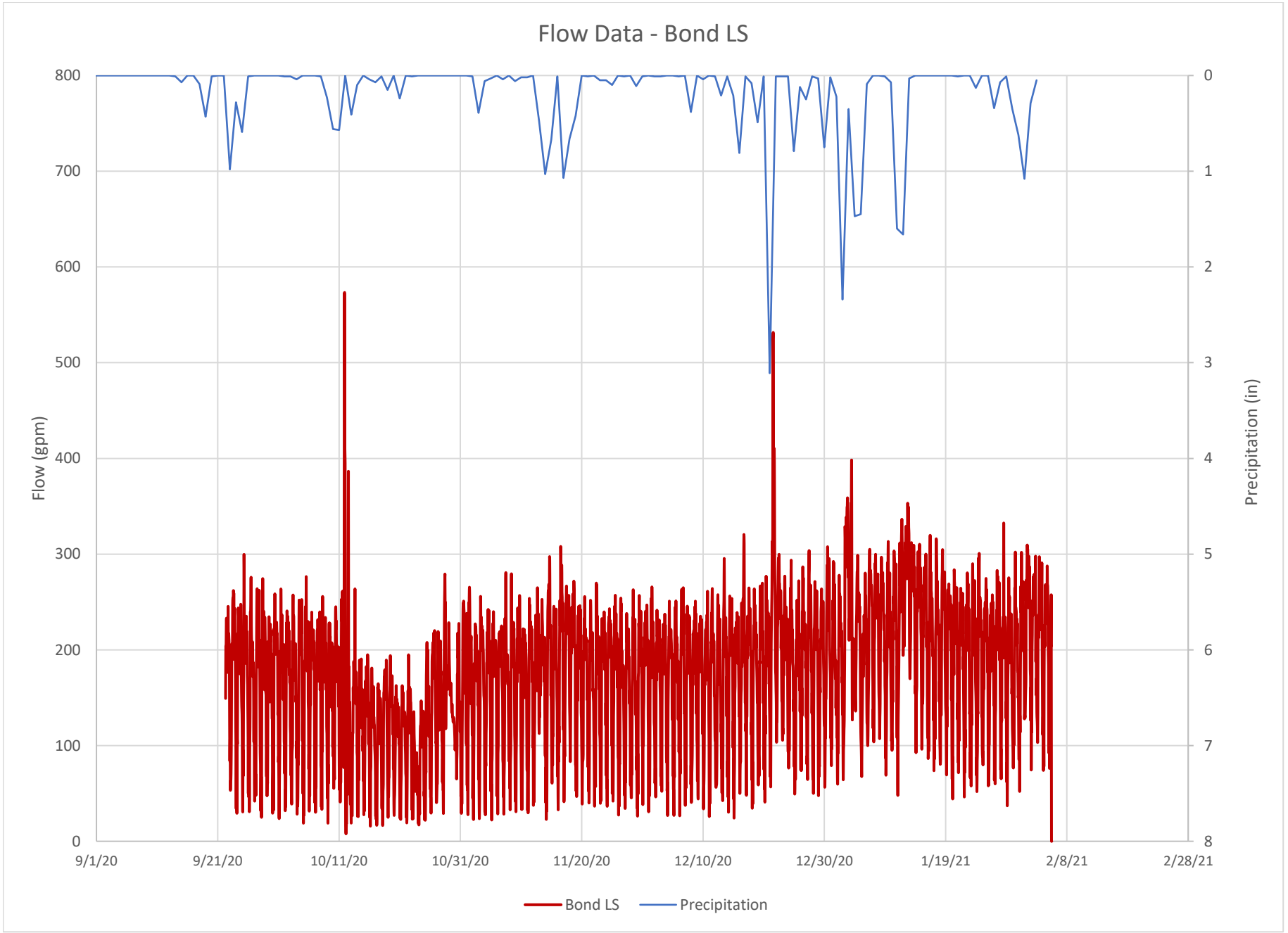
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 35



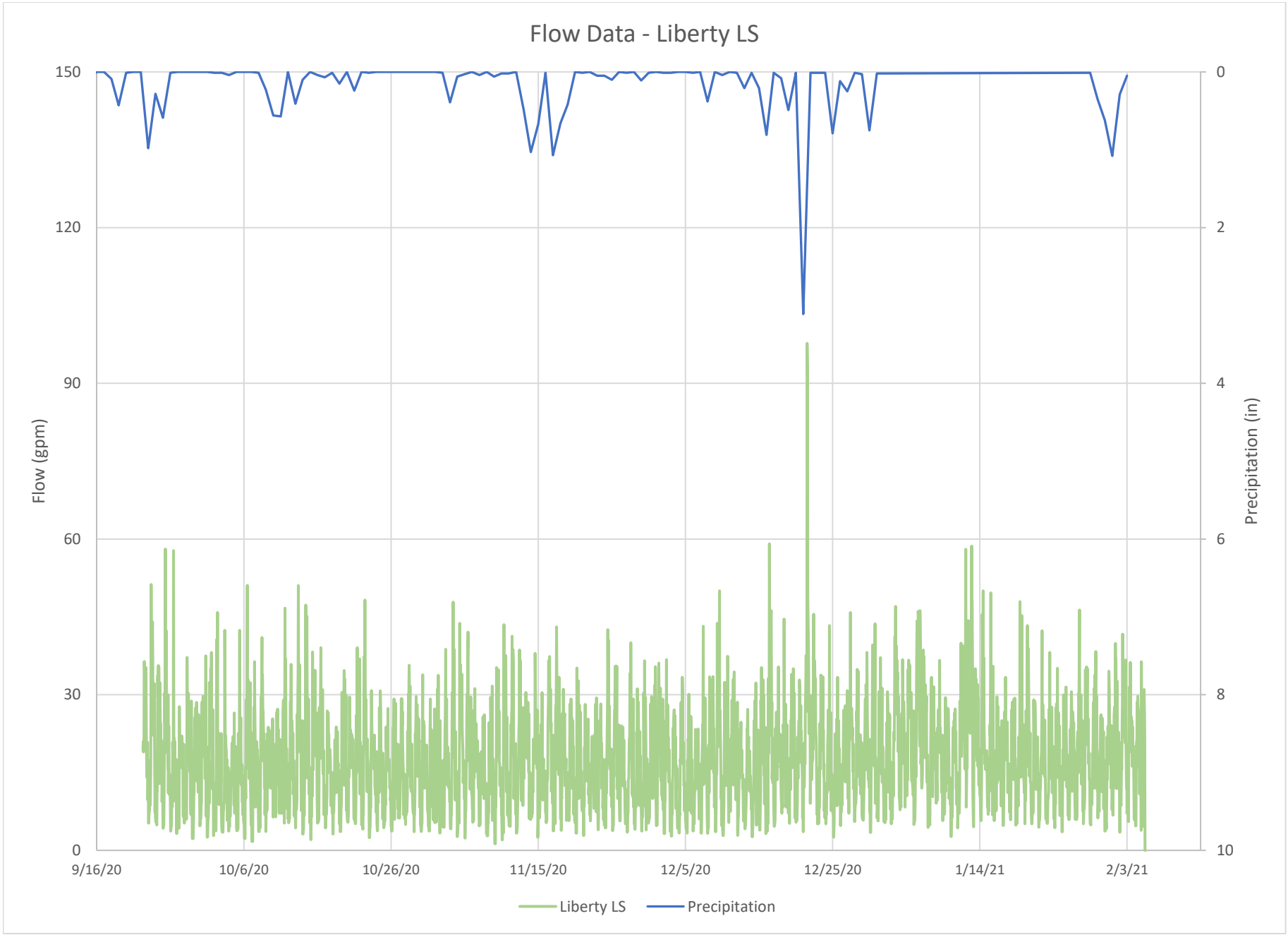
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 36



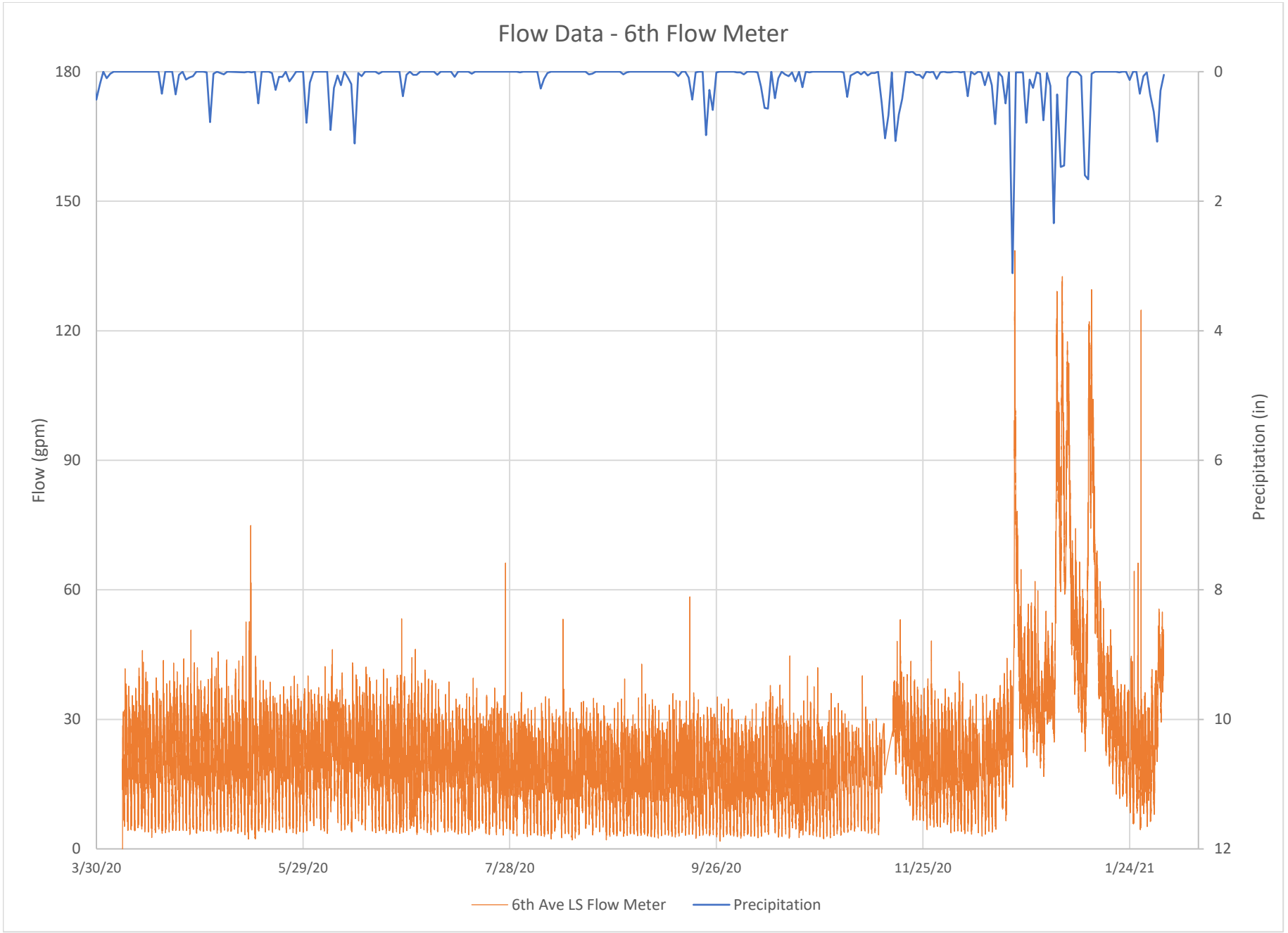
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 37



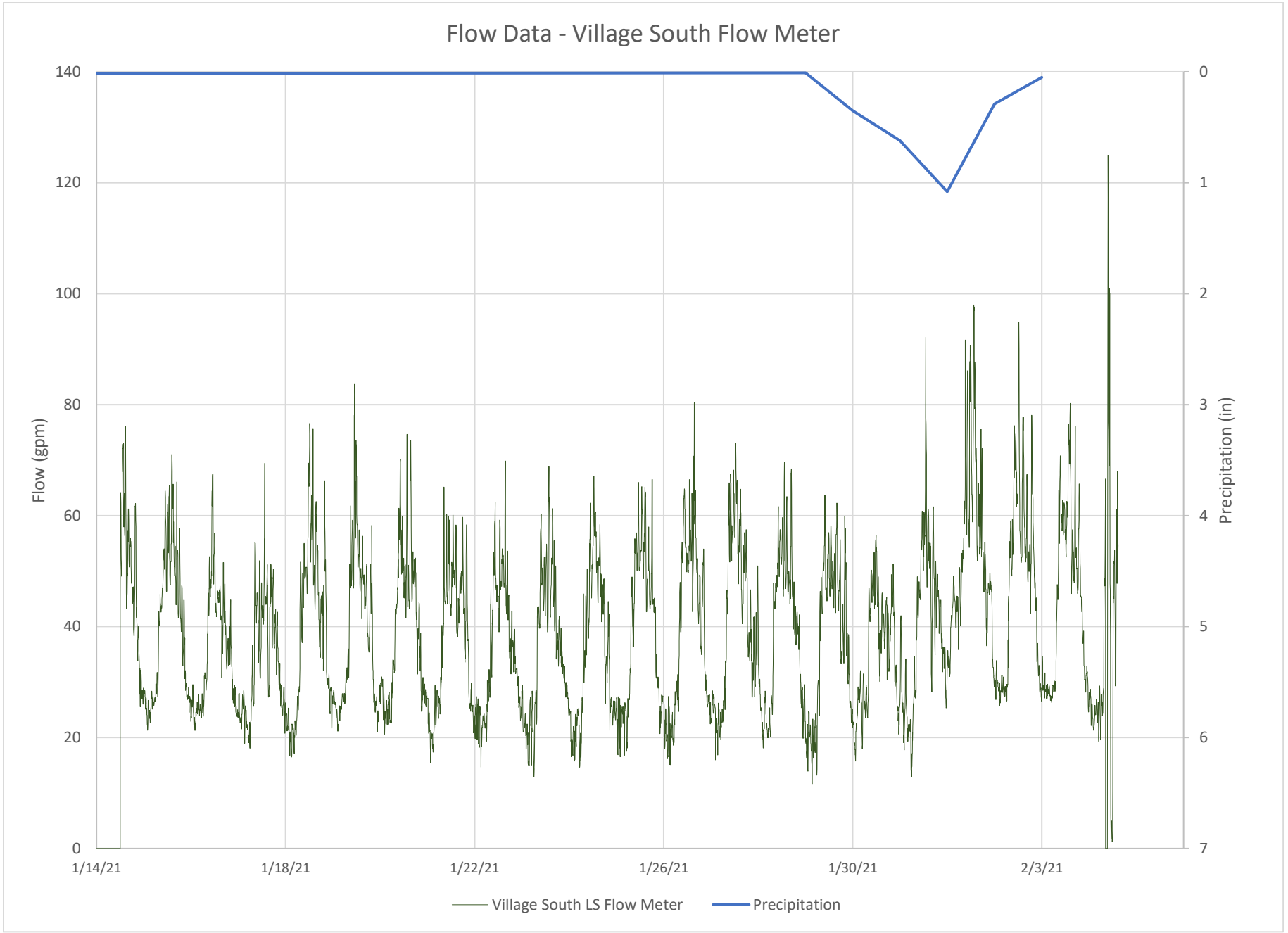
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 38



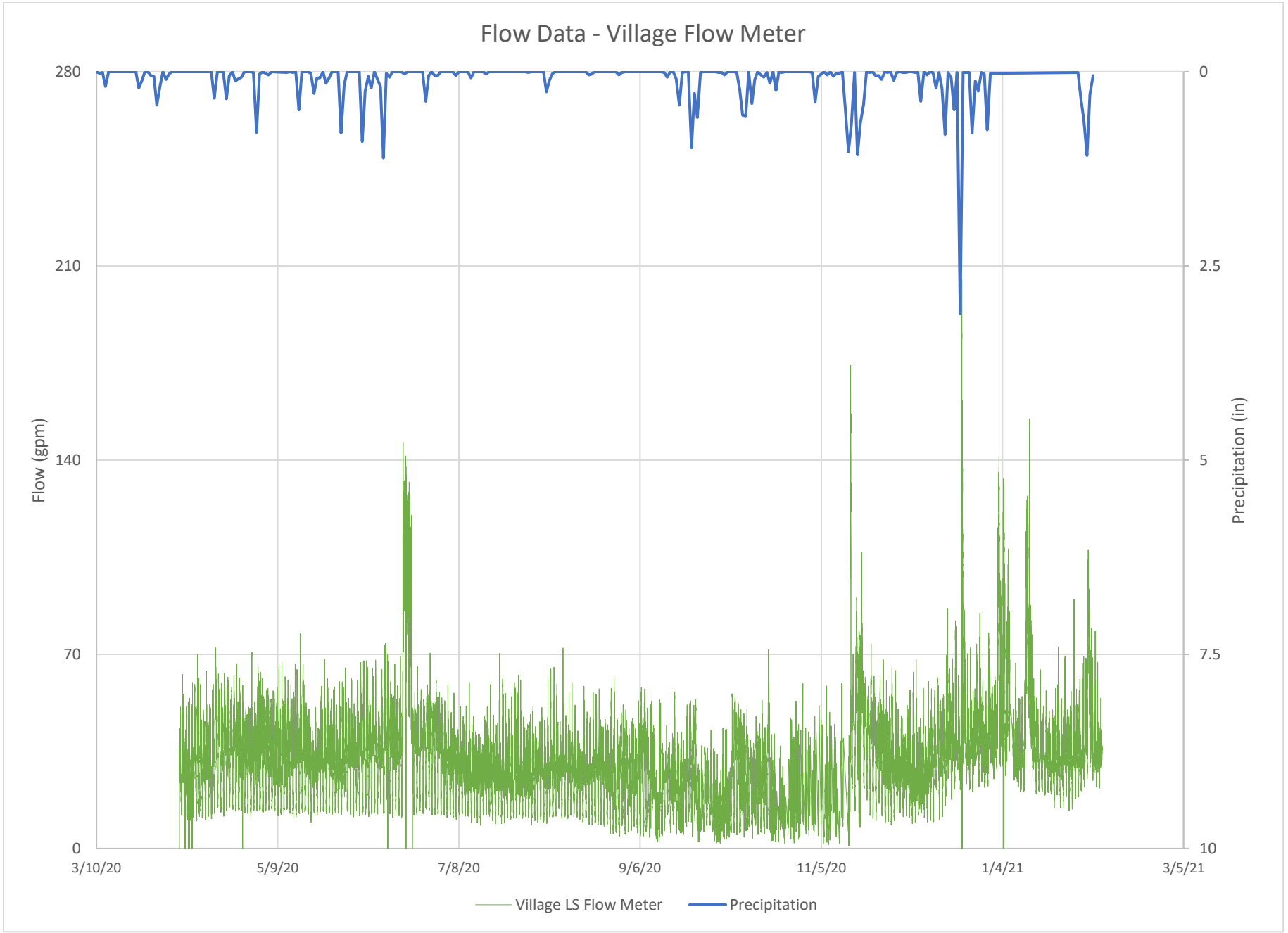
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 39



J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 40

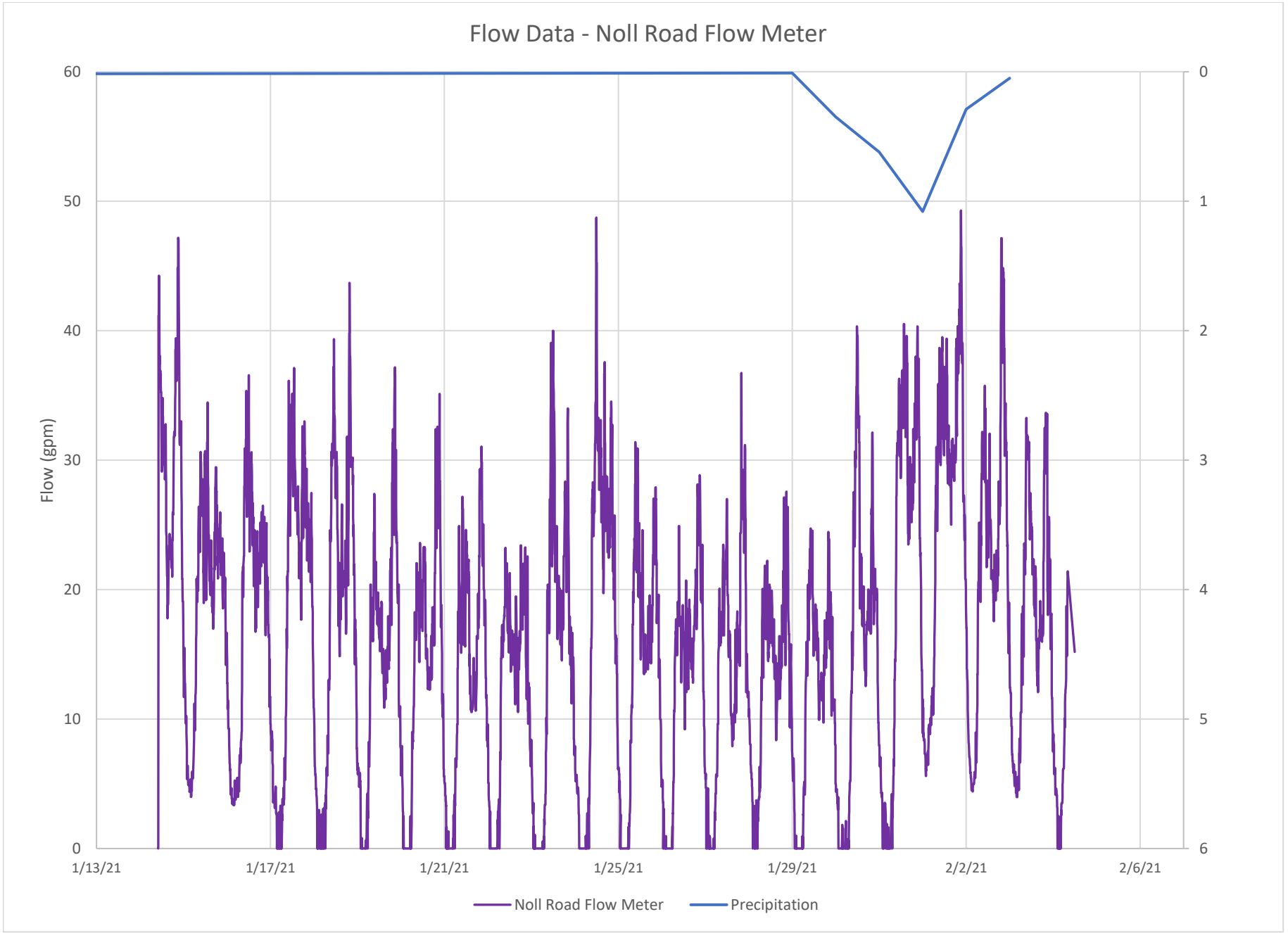


J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 41

J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Figure 42



J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Appendix A
Preliminary Offline Peak Storage Sizing

THIS PAGE INTENTIONALLY LEFT BLANK

Kenny Gomez

From: Kenny Gomez
Sent: Sunday, March 14, 2021 3:53 PM
To: Diane K. Lenius
Cc: Mike J. Lund; Charlie S. Roberts; Chris Kelsey; Sara Palmerton; John Hendron; Alex Arger
Subject: Poulsbo - Preliminary Offline Peak Storage Sizing
Attachments: PRELIMINARY - OPSS Project Charts.pdf

Diane,

RH2 began working with the City of Poulsbo (City) to monitor and analyze flows throughout the City of Poulsbo's wastewater system in 2020 as part of the Infiltration and Inflow (I&I) Study. During the course of that project, the City experienced a sewer overflow event on December 21, 2020 along the City's Central Interceptor (near the intersection of State Route 305 and Nordness Place NE). As a result, the City requested that RH2 Engineering (RH2) and BHC Consultants (BHC) assist the City with investigating why the overflow occurred and determine preliminary sizing of an offline peak storage structure (OPSS), so that the chance of another overflow event could be reduced while anticipated growth within the City over the next five (5) years continues to take place. Our teams understands the City's urgency in getting this OPSS project started, so the following preliminary analyses and results of our findings are being documented to the City. This should allow the City to further their plans and design of this OPSS project while the projected design criteria are refined. Our team will continue working with the City to further refine the design criteria for the City's OPSS project as additional information becomes available and additional analyses are performed.

The peak flows seen on December 21, 2020 were primarily due to the I&I experienced in the sewer system as a result of the 2.3 inches of rainfall that occurred over the 24 hours prior to the overflow event. This corresponds to a 2-year rain event for the City according to the isopluvial maps found in the 1997 Kitsap County (County) Stormwater Design Manual (KCSDM). The Johnson Way Flume (flume), which measures sewer flows the City sends to the County, surcharged between 12:30 pm and 9:00 pm on that date so was measuring flows inaccurately during this time. The hydrograph for this time period was reconstructed by RH2 to estimate the peak flows through the City's flume and Central Interceptor over this time period, by extending the flow trends of the hydrograph from the rising trend before and subsiding trend after this time period to recreate flows during this time period. The recreated hydrograph was then compared to the hydrograph of the combined lift stations flows and flows estimated for the East Poulsbo Sewer Basin to confirm its conical shape (see attached Chart 1). I&I for December 21, 2020 was then determined by subtracting the 2020 driest day flows (which was assumed to be domestic wastewater only for the purposes of these analyses), which occurred on September 6th, 2020.

To determine the preliminary sizing of the offline peak storage structure, the rainfall event and domestic flows were multiplied by different ratios to reflect larger design storms and an anticipated increase in population. The isopluvial maps found in the 1997 KCSDM were used to determine the amount of precipitation for a 24-hour storm with a 25-year, 10-year, and 5-year recurrence interval to be 3.9 inches, 3.3 inches, and 2.8 inches, respectively. The ratio between these amounts and the 24-hour total rainfall for December 21, 2020 was multiplied by the I& I hydrograph to project a hydrograph for these storm events. Additionally, the 2020 driest day flows hydrograph was amplified by a 5-year growth projection of 3% compounded annually, which was discussed in a City Population Forecast Memorandum prepared by City staff in 2019. Estimated flows for the Noll Road and Baywatch Court NE areas were removed from the hydrographs developed for the Central Interceptor since these locations are connected to the Central Interceptor downstream of where the overflow event occurred. With the domestic and I&I hydrographs amplified to reflect the projected conditions, Central Interceptor projected peak flow hydrographs were established (see attached Charts 2, 3, and 4).

The next step was to determine the capacity of the Central Interceptor before an overflow event occurs. Based on their preliminary modeling results, BHC recommended using 2,500 gpm as the capacity of the Central Interceptor at this time,

but the capacity of the Central Interceptor is still being modeled and evaluated by BHC at this time. At 2,500 gpm, modeling predicts that the hydraulic grade line will be at the ground surface at one of the manholes in the Sol Vei area. Based on this information, the total volume needed for the OPSS was calculated by determining the total area of the projected hydrographs above the 2,500 gpm capacity threshold. This calculation resulted in the following volumes, including inflation of domestic flows 5 years hence, for a 24-hour storm with the three storm occurrence intervals, as shown in Charts 2, 3, and 4. Note, these volumes do not have any safety factors applied to them.

- For the 25-year event, 310,000 gallons.
- For the 10-year event, 160,000 gallons.
- For the 5-year event, 60,000 gallons.

During a recent project meeting, City staff indicated they planned to size the OPSS to be 100,000 gallons to temporality store wastewater and reduce the chance for future potential overflows. This solution may be sufficient for the City's short-term plans but may not be large enough to prevent overflows during 25-year and 10-year storm events. During our team's investigation, RH2 contacted a local expert on sanitary-sewer-overflows (SSO) who recommended sizing the OPSS, which would be considered a SSO structure, for at least a 5-year storm event.

BHC's hydraulic modeling was performed with the assumption that the Central Interceptor had the pipe roughness characteristics of concrete pipe. However, the Central Interceptor was lined with cured-in-place pipe (CIPP) in 2018 to extend the life of this critical piece of the City's sewer infrastructure. RH2 suggests that BHC perform additional hydraulic modeling to determine the capacity of the Central Interceptor with pipe roughness characteristics more akin to that of CIPP. Furthermore, RH2 recommends that BHC perform additional hydraulic modeling to verify these tank sizes would be adequate for the OPSS to prevent an overflow event during the projected storm events developed by RH2.

In addition, RH2 recommends that the City further investigate having another level sensor installed in the flume so that flows can be more accurately measured at the flume when the water level in the siphon downstream of the City's sewer system surcharges into the flume.

Please note that these are the preliminary analyses and results of our findings. Our team will continue working with the City to further refine the design criteria for the City's OPSS project as additional information becomes available and additional analyses are performed.

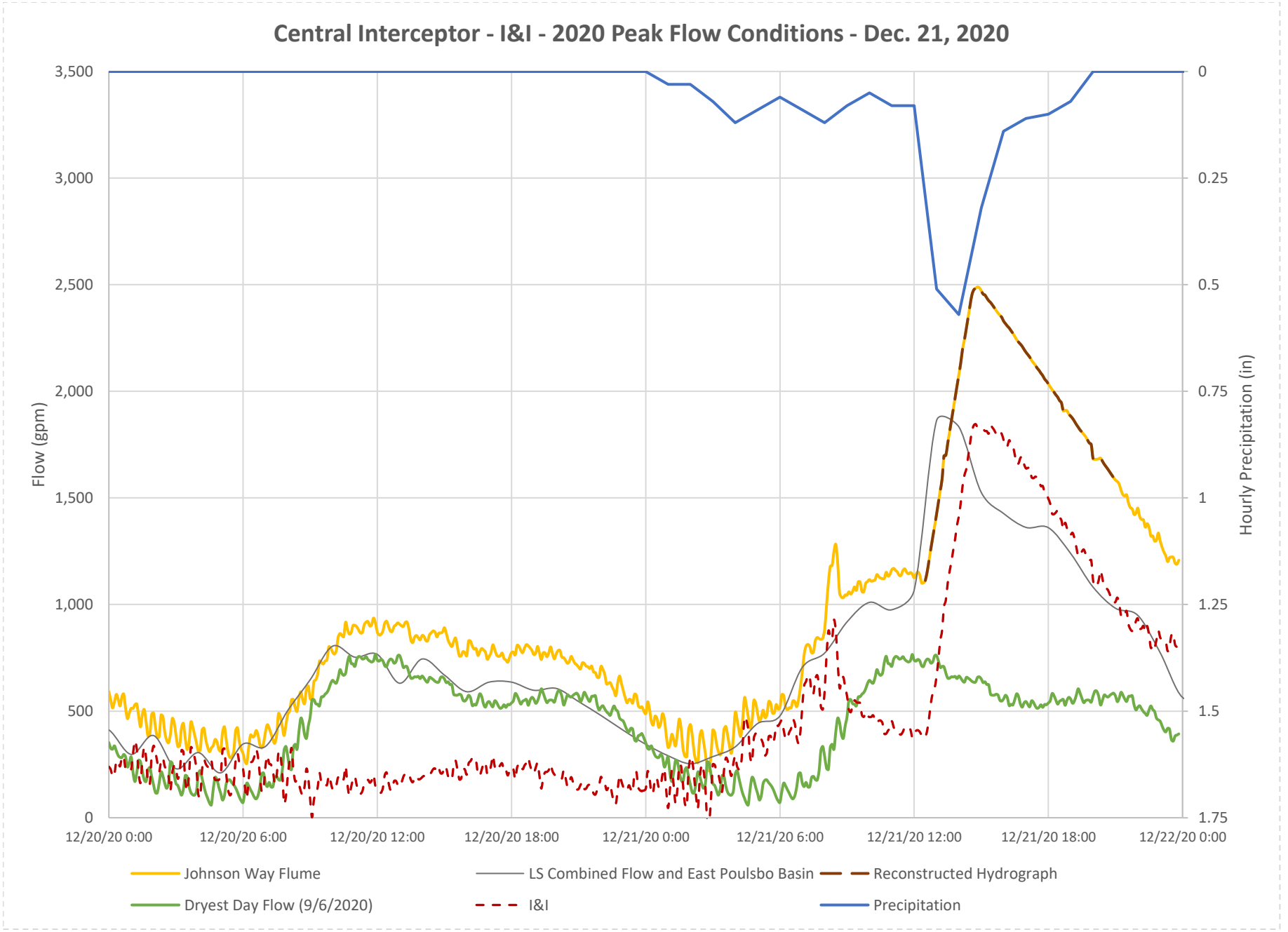
If you would like to discuss further, please let us know what day and time works best for the City staff.

Thank you,

Kenny Gomez PE
Project Engineer | RH2 Engineering, Inc.

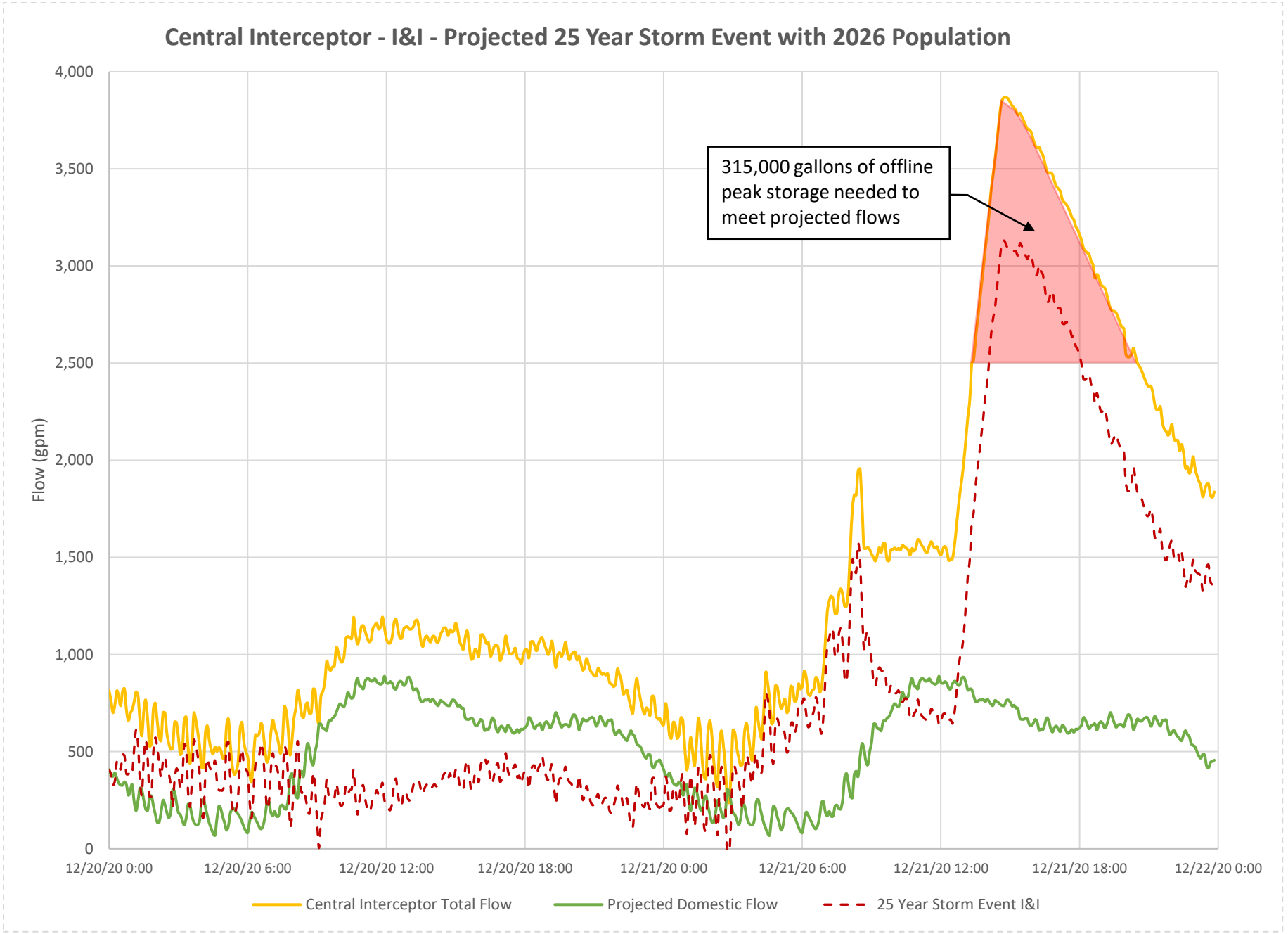
22722 29th Drive SE, STE 210
Bothell, WA 98021
O: 425.951.5416
kgomez@rh2.com
www.rh2.com

Chart 1



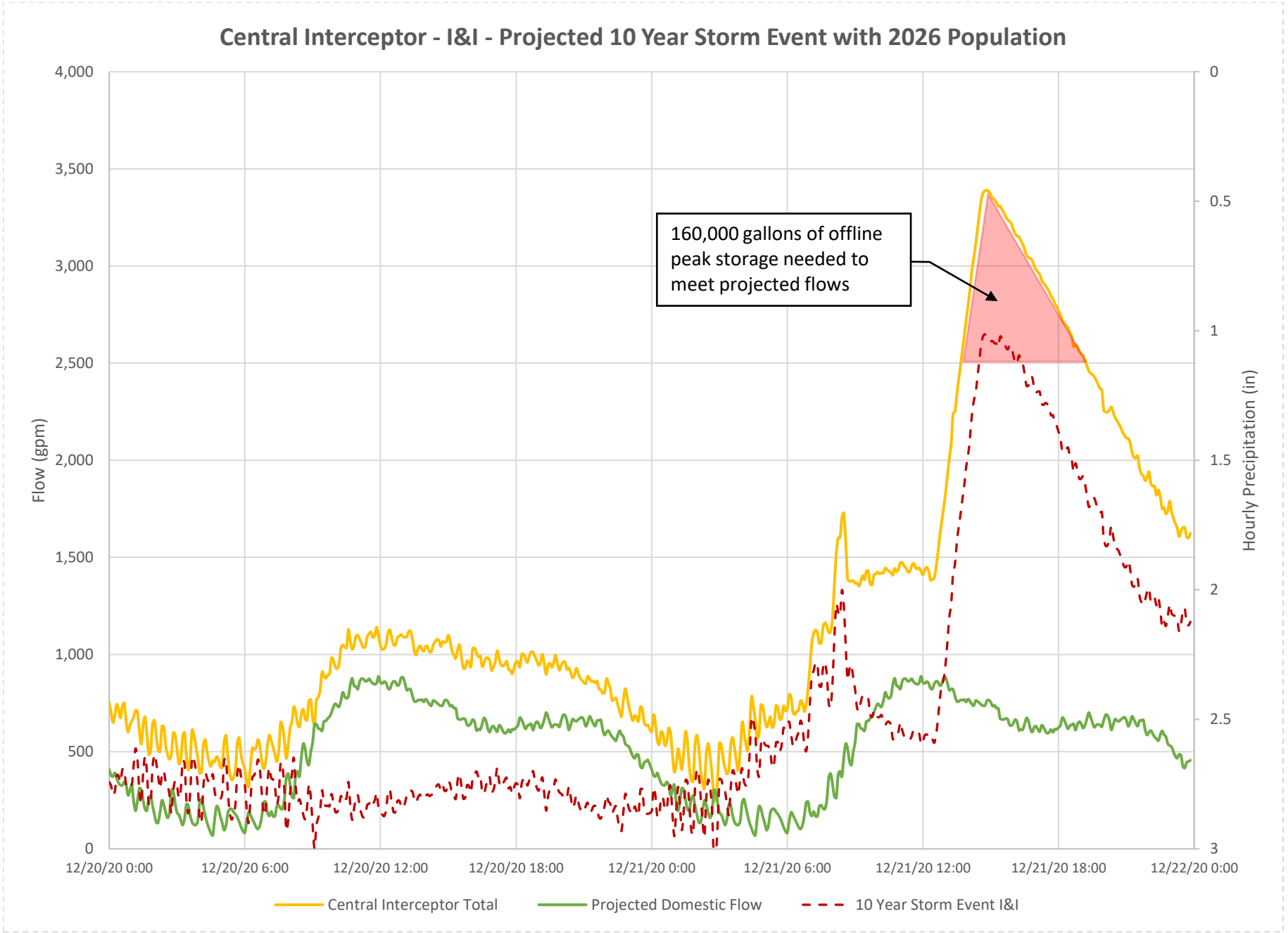
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Chart 2



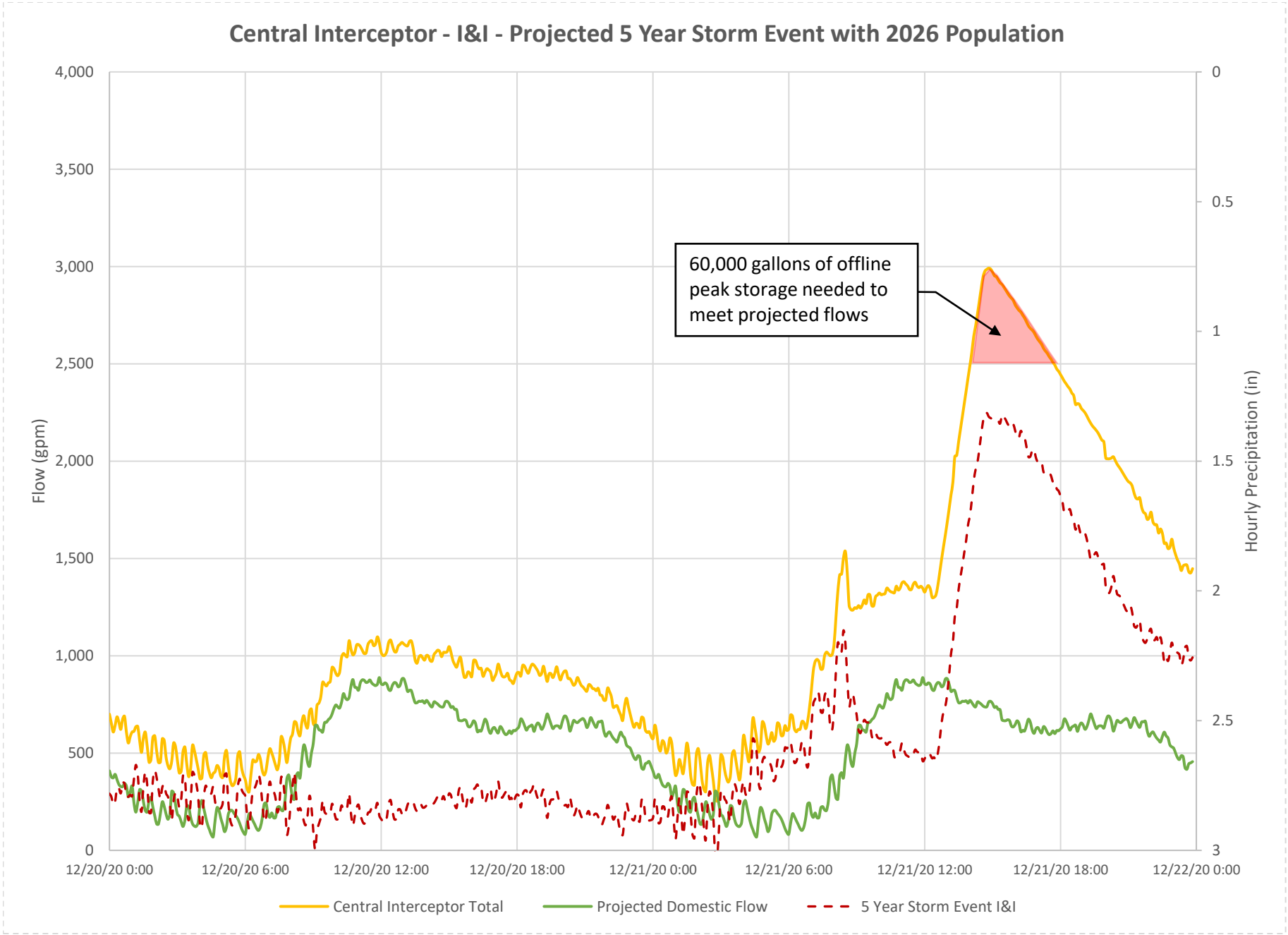
J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Chart 3



J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021

Chart 4



J:\Data\POU\119-149\20 Analyses\Master Chart with SCADA-3-5-2021