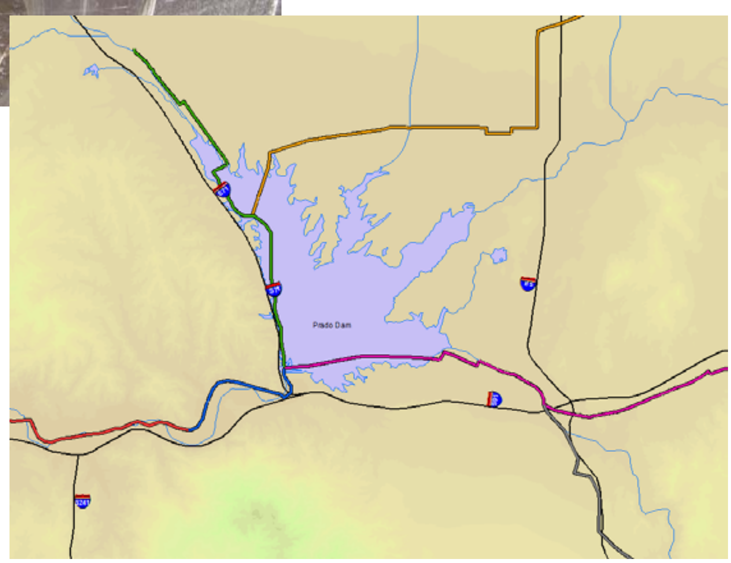
Final Report

Santa Ana Regional Interceptor Hydraulic Model and Capacity Assessment



SAWPA

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Santa Ana Regional Interceptor Hydraulic Model and Capacity Assessment

16 January 2006

Prepared for

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K/J Project No. 0585012*00

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Executive Summary

In its entirety, the Santa Ana Regional Interceptor (SARI) comprises approximately 92 miles of pipeline running through Orange, Riverside, and San Bernardino Counties. The interceptor was initially constructed to provide for disposal of highly saline brine discharges by conveying these discharges out of the Upper Santa Ana River Watershed and to treatment and outfall facilities.

Two developments in the Upper SARI system have required SAWPA to develop more detailed information on the capacity and predicted future flows in the Upper SARI system. The first of these developments is the possible high-volume flushing of Reach V for improved operations and maintenance. The second development is the future capacity needs of the Upper SARI system member agencies.

A hydraulic model was developed to determine flows and capacity in the Upper SARI system under a variety of scenarios. These scenarios are described in further detail in Section 5. The results and implications of these scenarios are presented and discussed in detail in Section 6 – Section 9.

The hydraulic model's accuracy is constrained by the following factors:

- The inflow and infiltration factors (I&I) applied to the model represent the best information known by SAWPA staff, but they are untested and uncalibrated by field values.
- The diurnal peak factors developed for the model do not represent the maximum values allowed by contract with the dischargers.
- The diurnal peak factors developed for the model are based upon best available monitored data, but they underestimate the true peak discharges seen in the Upper SARI system.
- Horizontal and vertical curves in the Upper SARI system's pipelines are not captured in the model data, but these curves will affect hydraulic performance.

- Lateral lines jutting into a pipe and other such imperfections affect system performance in ways that cannot be captured by the hydraulic model.
- Hydrodynamic phenomena, such as air bubbles trapped due to poor blow-off valve performance, affect system performance in ways that cannot be captured by the hydraulic model.
- Average condition values relating to Manning's n values were used.
- Unknown defects may exist and cannot be captured by the hydraulic model.
- Unknown maintenance issues may exist and cannot be captured by the model.

The model results, subject to the above-described constraints, are given in detail in Section 6. The results from three scenarios given by reach are summarized in Figure 1. The theoretical maximum capacity listed in the figure is the full-pipe capacity of the capacity-constraining pipe for each reach. The operational capacity listed for each reach is the capacity of the constraining pipe for each at a depth-to-diameter (d/D) ration of 0.75. Finally, the maximum modeled flow is the maximum flow passing through the constraining pipe for each reach under the "30 MGD Peaked + 3 MGD" scenario (see Chapter 5). These results, in conjunction with SAWPA staff discussions, led to the development of the following recommendations about the future study and management of the Upper SARI system:

- Inflow and infiltration (I&I) should be quantified.
- Video analysis of the pipes and visual inspection of the manhole structures should focus on identifying areas of deterioration that would lead to exfiltration. Areas of the Upper SARI system that demonstrate high I&I values should be subjected to pipe joint inspection to identify ways to prevent both I&I and exfiltration.
- As the system nears capacity, flow equalization basins should be placed on each private lateral from an industrial user or municipal corporation sewer collection system to trim peaking of discharge to a rate of flow that is as near to constant as possible.
- Flow characteristics of desalters should be confirmed.
- Flow meters with data loggers should be installed on private service laterals that enter the SARI. These meters will establish flow patterns and provide the data necessary for

SAWPA to work proactively with industrial users and municipalities to maintain acceptable flow levels and reduce peaking.

- The installation of flow control devices (principally weirs) should be considered on private service laterals to help ensure a consistent flow rate. These devices are normally installed as detention basin outlet structures. If such a device is placed on a desalter line that has a reasonably constant flow rate, then some capacity to store flow above the flow control point would be needed. This minor amount of detention could mitigate the effects of unusual operational circumstances that could create limited-duration flow spikes.
- The various reaches of the Upper SARI system should be evaluated for low points and points of diversion and bypass.

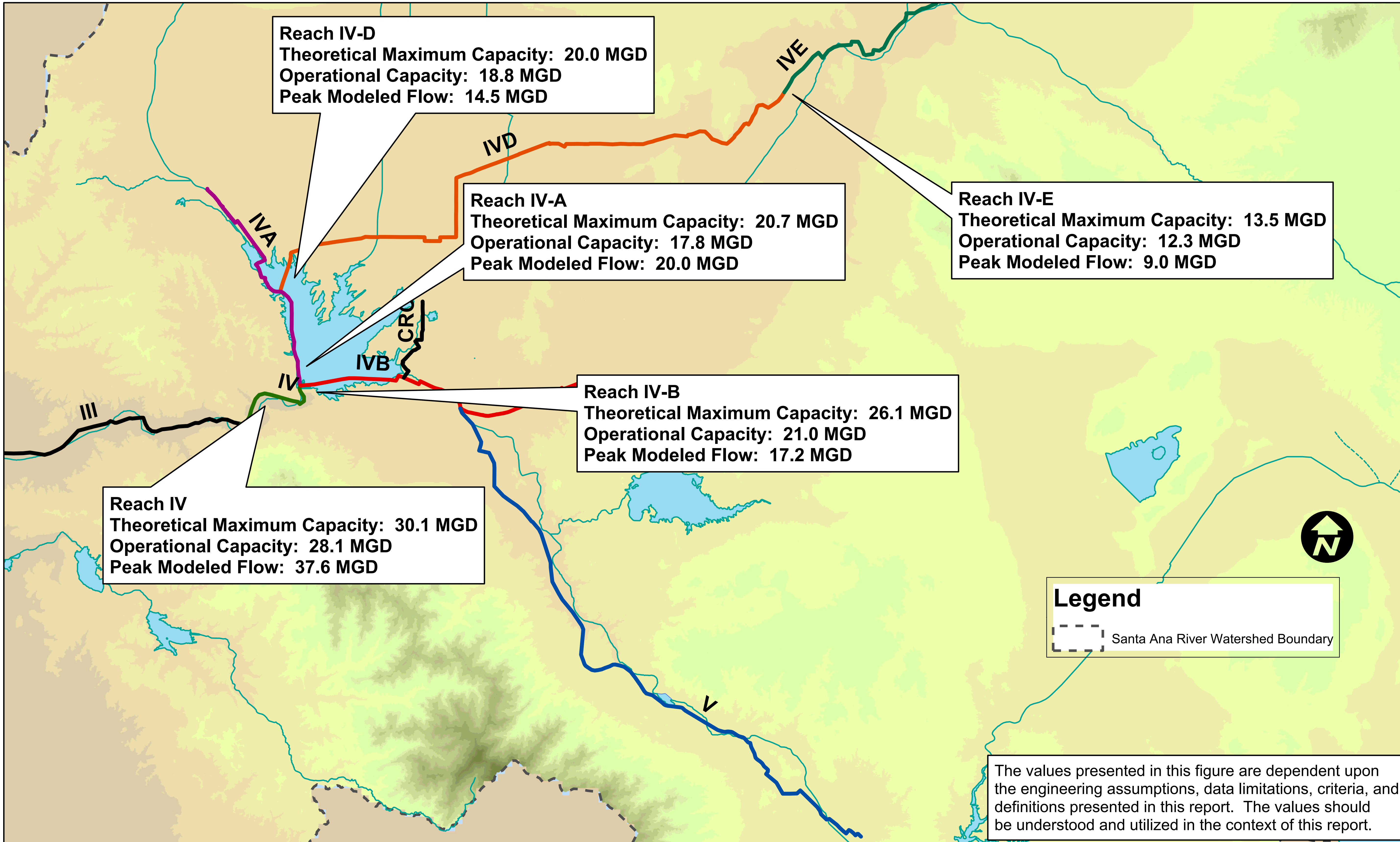

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Figure 1
Summary of Model Results

Section 1: Project Understanding and Background

Section 1 first describes the existing Santa Ana Regional Interceptor. The section then outlines the conditions and the resulting questions that have defined this study.

1.1 Existing System

In its entirety, the Santa Ana Regional Interceptor (SARI) comprises approximately 92 miles of pipeline running through Orange, Riverside, and San Bernardino Counties. The interceptor was initially constructed to provide for disposal of highly saline brine discharges by conveying these discharges out of the Upper Santa Ana River Watershed and to treatment and outfall facilities.

The Santa Ana Watershed Project Authority (SAWPA) owns the 72 miles of the SARI line upstream of the Orange County border. This portion of the SARI is hereinafter referred to as the Upper SARI system. The Upper SARI system serves the following SAWPA member agencies: Inland Empire Utilities Agency, San Bernardino Valley Municipal Water District, Western Municipal Water District, and Eastern Municipal Water District. The Lower SARI system begins at the Orange County border and runs through Orange County to treatment and outfall into the Pacific Ocean. Figure 2 shows the entire SARI system. As can be seen, both the Upper and Lower SARI systems are broken into numbered reaches for identification.

As will be discussed in further detail in the following sections, measurements taken in July 2005 show that the Upper SARI system currently conveys an average of approximately 9.7 million gallons per day (mgd) into Reach III at the Orange County border. The current flows are composed of a mixture of brine and temporary domestic flows. At the current flow levels, there is excess capacity throughout the Upper SARI system. Peak flows are now absorbed by this excess capacity, which allows operation of the Upper SARI system without strict accounting for the diurnal or monthly peaking of the existing dischargers.

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Figure 2
SARI System

1.2 Future System

Two developments in the Upper SARI system have required SAWPA to develop more detailed information on the capacity and predicted future flows in the Upper SARI system. The first of these developments is the possible high-volume flushing of Reach V for improved operations and maintenance. The topography of Reach V necessitates several siphons, some of which include more than 100 vertical feet of reverse slopes. These siphons, combined with the low existing flows in Reach V, create areas of flow that are conducive to deposition. At the same time, the limited access into Reach V makes many of the traditional line-cleaning measures not viable. Thus, flushing of Reach V with large volumes of flow is being considered as the primary maintenance method. The hydraulic implications of this flushing program require the development of a hydraulic model.

The second development impacting the Upper SARI system is that increased use of groundwater desalters, new power plants, and industrial users may increase the required system capacity needs. SAWPA's member agencies have estimated future flows by SARI reach, member agency, and projected discharge source. These estimates project that potential flow in the Santa Ana Watershed may exceed the design capacity of the Upper SARI system. It is therefore important to determine both the maximum theoretical capacity and the operating capacity of the Upper SARI system. The maximum theoretical capacity is determined through a strictly technical evaluation of the hydraulic capacity of the pipes in the Upper SARI system. The operating capacity is determined by balancing the hydraulic capacity of the pipes with the potential likelihood and magnitude of hydraulic failure (surcharging and overflow) so that the system can continue to serve member agencies while maintaining acceptable operational risk.

This study responds to the two developments by 1) creating a hydraulic model to predict the conditions of the Upper SARI system under flushing and future flow conditions and 2) recommending changes that will allow improvements to the operations of the Upper SARI system.

1.3 Authorization

This project is authorized by SAWPA under Task Order No. KENN240-01, dated 24 August, 2005. The complete Scope of Work authorized under this task order can be found in Appendix A of this document.

Section 2: Model of Reach V Flushing Flow Rate

The operational environment of Reach V may require flushing to reduce deposition in the siphons of this reach. For this project, Kennedy/Jenks Consultants initially built a steady-state model to analyze the required flushing flow rate. Section 2 describes this initial model.

2.1 Background on Reach V

As shown in Figure 1, Reach V runs from southern Riverside County to a connection with Reach IV-B in the City of Corona. Recently, developers within the Alberhill area of Elsinore Valley Municipal Water District have requested an interim connection to the SARI line in order to dispose of domestic wastewater until the Alberhill Water Reclamation Facility is constructed and becomes operational.

Because of the nature of the terrain it traverses, Reach V contains many pipes with negative slopes. In these pipes, a siphon situation is created, resulting in pressurized flow. Currently, the flow in Reach V is small in comparison with the capacity of this reach and those downstream. As a result, the velocity of the flow, especially in the pressurized pipes, is low. Because of the proposed discharge of domestic wastewater into Reach V, SAWPA staff is concerned about possible low velocities that would increase the amount of solids deposition and scaling in the reach, reducing the reach's hydraulic performance.

Previously, the feasibility of pigging Reach V was considered. In fact, SAWPA included pig launching stations along Reach V to allow such cleaning. In light of the considerable expense and risk involved in pigging Reach V, however, it is necessary to evaluate alternative methods for cleaning the siphons to help prevent solids deposition.

One such method involves increasing the amount of flow in the siphons until flushing velocities are achieved. The flushing flow would remove materials deposited during routine flow, and, if performed regularly, it would help maintain unobstructed flow throughout the SARI line. Because SAWPA maintains gates at several points in the SARI line, it was originally thought that flushing velocities could be created by closing one or more gates, allowing fluid to pond behind the gate, and then rapidly opening the gate to release the fluid. Subsequent calculations indicate that sufficient water volume for flushing would not be achieved under this method. SAWPA has access to other sources of water for flushing; therefore, SAWPA staff desires evaluation of the flow rate required for flushing within Reach V.

2.2 Construction of Reach V Steady-State Flushing Model

SAWPA staff provided data on the attributes of approximately 325 pipes that are part of the SARI line in Reach V, extending from Elsinore Valley Municipal Water District into the City of Corona. These attribute data were used to create a steady-state hydraulic model to evaluate the steady-state flow rate needed to create flushing flows within the siphons. The steady-state hydraulic model was constructed in H20Map Sewer from the electronic file (cleaningflowcalcs20050407_REV.xls). This file indicated stationing for the reach, with each station delineating a segment of pipe. For each pipe segment, physical data, including pipe material, diameter and invert elevations, were available in the electronic file. The invert elevations and pipe lengths were imported from Excel to AutoCAD and then exported to the H20Map Sewer model. Information on the pipe material and diameters were then added through database exchange from the Excel file to the H2OMap Sewer model. A Manning's 'n' value of .010 was used for all PVC and HDPE pipe. Assumptions were required to create a running model. These assumptions included manhole diameters of 4 feet each and a rim elevation of 7 feet higher than the invert elevation for each manhole. (Because Reach V is sealed for pressure, rim elevation is not an essential attribute.) In several cases, representations of manholes and short segments of pipe were inserted into the model to create logical connections between segments in the input data. These insertions were noted in the input data for verification. The input data can be found in Appendix B, Reach V-Table 1, The notations for inserted sections are highlighted in red.

Discussion with SAWPA staff indicated that the typical flow observed in Reach V is 400 gallons per minute (gpm). This flow rate was used as the baseline flow rate in the model. The flow was assigned as a point load at the furthest upstream manhole in the model.

2.3 Criteria and Constraints for Reach V Model

A velocity of 2.0 feet per second (fps) is generally prescribed as a "self-cleansing velocity" within a wastewater system. At this velocity, particles will not fall out of the liquid stream to deposit in the pipe. After discussion with SAWPA staff, it was decided that 3.0 fps would be designated as the flushing velocity for this study. At this higher velocity, existing deposits in the pipe would be lifted back into the liquid stream, cleaning areas that have not experienced flushing flows for some time.

During creation of flushing flow conditions in the siphons, one must be careful not to exceed the design constraints of the pipes. Discussion with SAWPA staff indicated that the pipes and joints of Reach V have a maximum design pressure of 80 pounds per square inch (psi); therefore, no action taken to clean the siphons should result in pressures greater than 80 psi anywhere in Reach V.

2.4 Results from Reach V Model

Reach V-Table 2 (Appendix B) presents model outputs for the baseline scenario of 400 gpm. As in Reach V-Table 1, the results are presented in order of stations, from the downstream to the upstream section of the modeled reach; the three large siphons are called out in gray. As expected, the velocities in the siphons resulting from the baseline flow scenario are much lower than velocities that would be necessary to achieve flushing. In the largest-diameter siphons (30 inches diameter), the baseline flow results in pressurized velocities of only 0.18 fps.

The steady-state model indicates that a flow of 6,600 gpm would be required to achieve flushing velocities in the siphon sections throughout the modeled reach of the SARI line. This flow is the lowest at which all siphon sections of the modeled reach achieve flushing.

Reach V-Table 3 (Appendix B) presents model outputs for this steady-state flow rate. The siphons are called out in yellow in the results. As indicated, the pressurized velocity in the siphon sections ranges from 3.0 fps for the 30-inch-diameter lines to 4.6 fps in the 24-inch-diameter lines.

Information in Table 3 that is of concern is the velocities produced in some of the open-channel gravity pipes located between siphons; these velocities are greater than 10 fps in several sections, under 6,600 gpm flows. Velocities greater than10 fps are cause for concern because of the scouring damage they can cause to the pipe material.

2.5 Flushing Effects on the Upper SARI System

As noted in Section 2.4, the steady-state model indicates that a flow of 6,600 gpm would be required to achieve flushing velocities in the siphon sections throughout the modeled reach of the SARI line. The model also indicates that this flow rate could produce high velocities in some of the gravity pipes of the modeled reach.

Of more importance is the potential impact of these Reach V flushing flows on the rest of the Upper SARI system. This potential impact is explored with the development of a full Upper SARI system model, described in the following sections.

Section 3: Upper SARI Hydraulic Model Creation

A hydraulic model is a mathematical representation of the physical infrastructure, fluid flows, and control mechanisms of a hydraulic system. Section 3 describes the process, for this project, by which an appropriate modeling software was selected, refined, and populated with data on the Upper SARI system. The end result is a powerful, flexible tool for the hydraulic analysis of the entire Upper SARI system.

3.1 Model Selection

The goal in creating any hydraulic model is to construct a tool that accurately represents the existing hydraulics of the modeled system so that questions about existing and future operations can be analyzed with confidence. The analytic capabilities of the software and the model's degree of accuracy depend upon the detail and complexity of the questions to be analyzed. In successful hydraulic modeling efforts, software appropriately matches the system and the required analysis.

The Upper SARI system requires a very robust model. The majority of the system consists of open-channel flow, but numerous siphons and areas of reverse slope also yield many pipes with pressurized flow. The non-steady-state discharges into the system necessitate dynamic flow analysis. Finally, the fact that the Upper SARI system is expected to run at a very high percentage of total capacity in the future necessitates a model that can maintain accuracy in near-surcharge conditions.

For this project, Kennedy/Jenks Consultants utilized the H20MapSWMM hydraulic model, which meets the above-described criteria. Based upon the EPA-SWMM hydraulic engine, this model solves the fully dynamic St. Venant's equations for open-channel flow. It also allows for real-time control of weir and orifice conditions in the model. More details concerning the history and capability of this model can be found at http://www.epa.gov/ednnrmrl/swmm. The H20MapSWMM program incorporates the EPA-SWMM engine into a user interface that surpasses the original EPA interface.

3.2 Model Schematization

Figure 2, shown above, displays the actual physical layout of the SARI line. The detailed information available for creating a hydraulic model of the SARI line did not include the accurate spatial location of the line's entities, however. Thus, the decision was made to create a schematic model of the Upper SARI line. The schematic model is hydraulically accurate in relation to SARI line lengths, inverts, slopes, diameters, and material, but it is not spatially representative. Figure 3 shows the schematic representation of the Upper SARI model, divided by reach. While this model looks different from the system presented in Figure 2, it is hydraulically identical. Should the spatial attributes of the Upper SARI system become available, they can be easily incorporated into the hydraulic model.

The model is as hydraulically accurate as the information provided to build the model. The model schematic was populated with data that had been assembled by SAWPA staff as part of an earlier modeling effort. These data were assembled according to reach and contract from record drawings of the Upper SARI line. Model node identification was assigned by SAWPA staff. The data were "cleaned" to correspond with H20MapSWMM data import conventions. During the cleaning process, data order may have been re-arranged, and "placeholder" nodes were inserted as noted below, requiring a re-calculation of stationing; however no data values were deleted or changed.

The following are key aspects of the model schematization:

- The H20MapSWMM program uses nodes to calculate the invert elevations of the pipes. Since a node is needed to decipher any change in alignment, "placeholder" nodes were assigned at siphon locations and throughout Reach V. They have been identified by "KJ" in the node ID; they do not reflect the actual presence of manholes.
- Manning's numbers, reflecting the pipe condition, were applied to each segment of pipe. The following values were assumed based upon pipe material following commonly used average values. (Sections of pipe lined with PVC were given the Manning's number corresponding to PVC).
  - RCP: 0.013
  - VCP: 0.013

- HDPE: 0.010
- PVC: 0.010

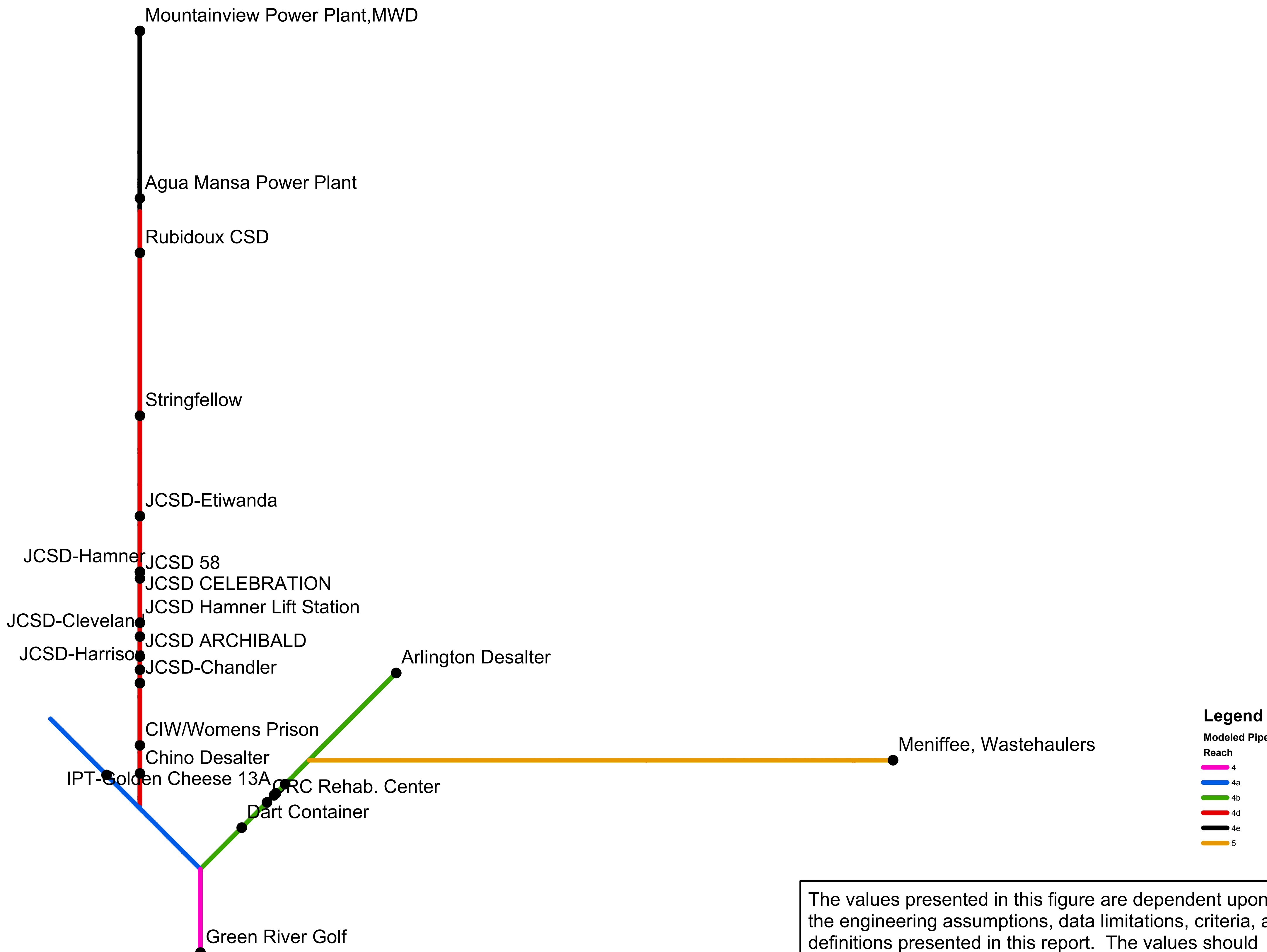
- The outfall of the Upper SARI system was assumed to be a free outfall with no backwater effects. This assumes that the current meter at the county line will be replaced with a free-flowing apparatus. Should it become necessary to model the effects of the current meter, an orifice will be placed at the model outfall and an orifice co-efficient will be developed based upon the geometry of the current meter.

For locations that appeared anomalous, the information imported into the model was checked against the record drawings. Any conflicts were resolved by using the record drawing information, along with confirmation by SAWPA staff. Vertical datum shifts were originally thought to be a concern, but work done in the previous modeling effort to reconcile vertical data among reaches eliminated nearly all problems in this regard.

Future scenarios that were analyzed using the model incorporate hydraulic changes according to plans prepared by CDM and Krieger and Stewart. These plans describe changes to be made to Reach IV of the SARI line as it passes through the Prado Dam area. Because this construction is not currently complete, it was not reflected in existing modeling scenarios. In general, the new designs flatten the slope of the line in the Prado Dam area.

3.3 Existing Flows in Upper SARI System

Existing flows (discharges) were identified by SAWPA staff. Monthly discharge information was provided for the years 2001-2005. At the direction of SAWPA staff, flows from July 2005 were chosen as representative of existing conditions within the Upper SARI line. SAWPA staff provided the manhole location of each discharger. Because some the manholes listed were not included in the hydraulic schematic model, the nearest manhole upstream of the given manhole was used as the loading manhole in the model. The list of the existing dischargers, the load discharged by each, and the loading manhole are listed in Table 1. It should be noted that more recent data has called the Table 1 flows into question for being too low. These flows should be re-examined and perhaps remodeled. Figure 3 shows the locations of the dischargers in the model.



The values presented in this figure are dependent upon the engineering assumptions, data limitations, criteria, and definitions presented in this report. The values should be understood and utilized in the context of this report.

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Figure 3

Existing Discharge Locations

Table 1: Existing Discharge Amounts into Upper SARI System (July 2005)

Permit No	Discharger	Discharge Manhole	Model Manhole	Discharge Amount (mgd)
5	IEUA	4A-0389	4A-0390	0.55
11	Wastehaulers		4A-0390	0.12
13A	IPT-Golden Cheese	4B-0262	4B-0270	1.09
13B	IPT-Golden Cheese	4B-0252	4B-0260	0.08
19	CRC Rehab. Center	4B-0215	4B-0220	0.75
20	Corona Energy Part.	4B-0258	4B-0260	0.09
21	JCSD-Cleveland	4D-0458	4D-0460	0.35
22	Arlington Desalter	4B-0888	4B-0890	1.49
24	JCSD-Hamner	4D-0588	4D-0590	0.02
25	Green River Golf	4-0008	4-0010	0.01
26	CIW/Women's Prison	4D-0218	4D-0220	0.29
28	JCSD-Etiwanda	4D-0748	4D-0750	0.49
29	Rubidoux CSD	4D-1458	4D-1460	0.01
32	Temescal Desalter	4B-0328	4B-0330	1.22
34	Chino Desalter	4D-0118	4D-0120	1.39
35	Mountainview Power	4E-0385	4E-0390	0.14
36	JCSD-Chandler	4D-0378	4D-0380	0.35
40	JCSD 58th Street	4D-0562	4D-0570	0.06
41	Menifee Desalter	REACH V	J1	0.44
42	MWD	4E-0385	4E-0390	0.04
46	Unilever	REACH V	J1	0.01
48	JCSD-Harrison	4D-0398	4D-0400	0.15
49	JCSD Hamner Lift Station	4D-0488	4D-0490	0.29
50	Dart Container	4B-0102	4B-0110	0.03
53	Agua Mansa Power Plant	4E-0018	4E-0020	0.02
54	JCSD CELEBRATION	4D-0572	4D-0580	0.04
55	JCSD ARCHIBALD		4D-0420	0.06
97	IEUA Pond	4A-0389	4A-0390	0.00
101	Stringfellow	4D-1068	4D-1070	0.13
220	Bonview		4A-0390	0.00
	Total			**9.70**

3.4 Diurnal Flow Peak Factors

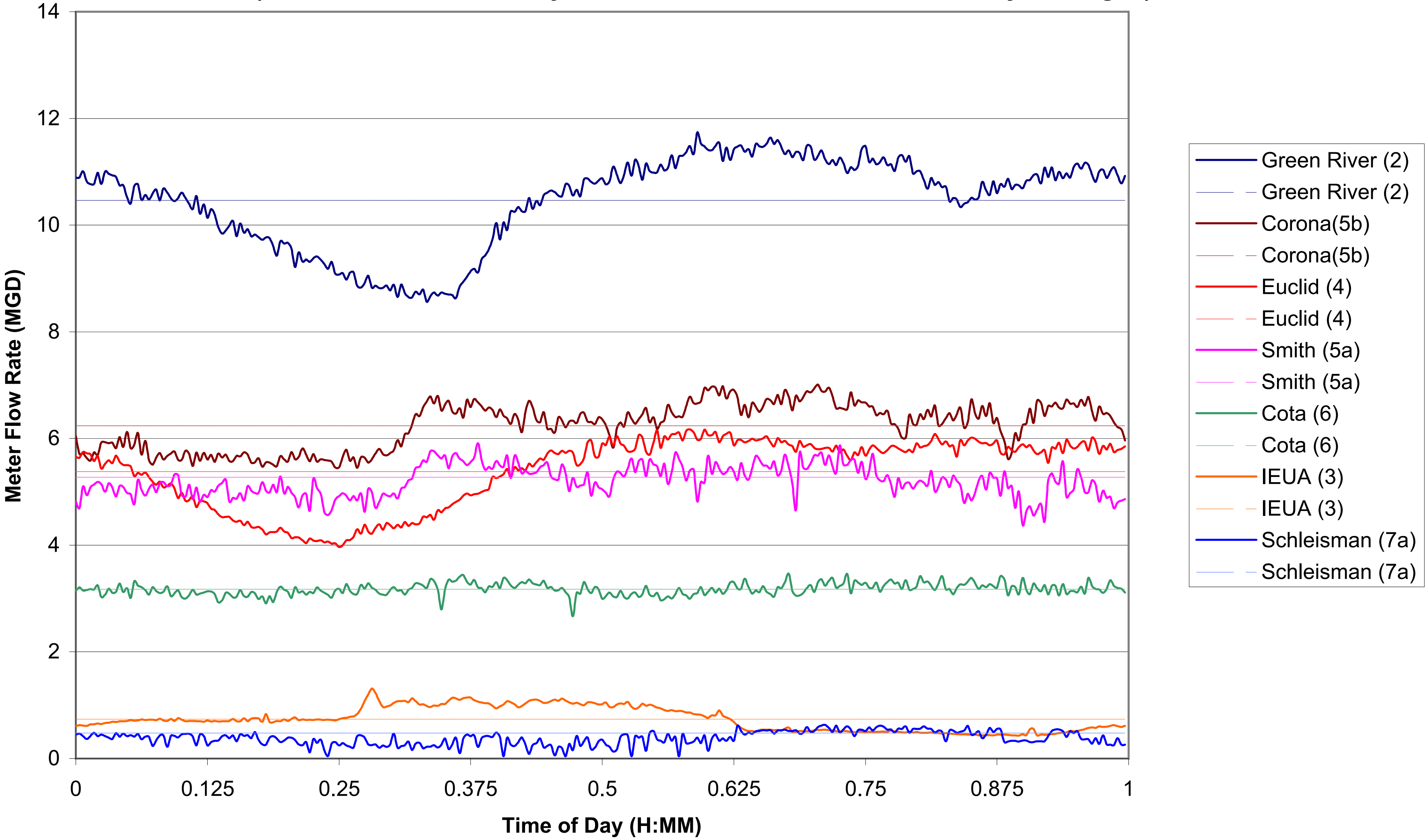
The flow data listed in Table 1 were gathered on the basis of a monthly total; the data give no indication of peak discharge values during that month. Flow monitoring data collected by SAWPA, however, do give an indication of peak values for specific reaches of the Upper SARI system.

At the direction of SAWPA staff, diurnal peak curves for the reaches were used as representative diurnal patterns for the dischargers to that reach. Although this tactic is not entirely precise in representing conditions in the line, it offers the best representation of the data available. It should be noted that these peak factors likely underestimate the true peaks at the individual dischargers, because of travel time and dynamic flow dampening.

Figure 4 shows the diurnal patterns developed from the raw data recorded by the flow monitors. The information in Figure 4 corresponds with what is known about the Upper SARI system and the dischargers. For example, the IEUA curve corresponds with a 12-hour industrial cycle. The Euclid curve shows evidence of both the industrial dischargers and the domestic dischargers represented by the JCSD connections. Figure 5 shows the locations of the flow monitors in the Upper SARI system.

Table 2 lists the diurnal peak curves developed from the flow monitoring data presented in Figure 4 and applied to the average flows listed in Table 1. As noted in Figure 4, each value in Table 2 represents the weekday flow at a given hour of the day divided by the average flow for the meter for that week. It should be noted that desalters and other dischargers known to have steady diurnal flows were not given a peak curve.

Figure 4
Representative Diurnal Flow Patterns Based On Flow Monitoring
(Solid Lines are Weekday Diurnal Patterns; Dashes are Weekly Averages)



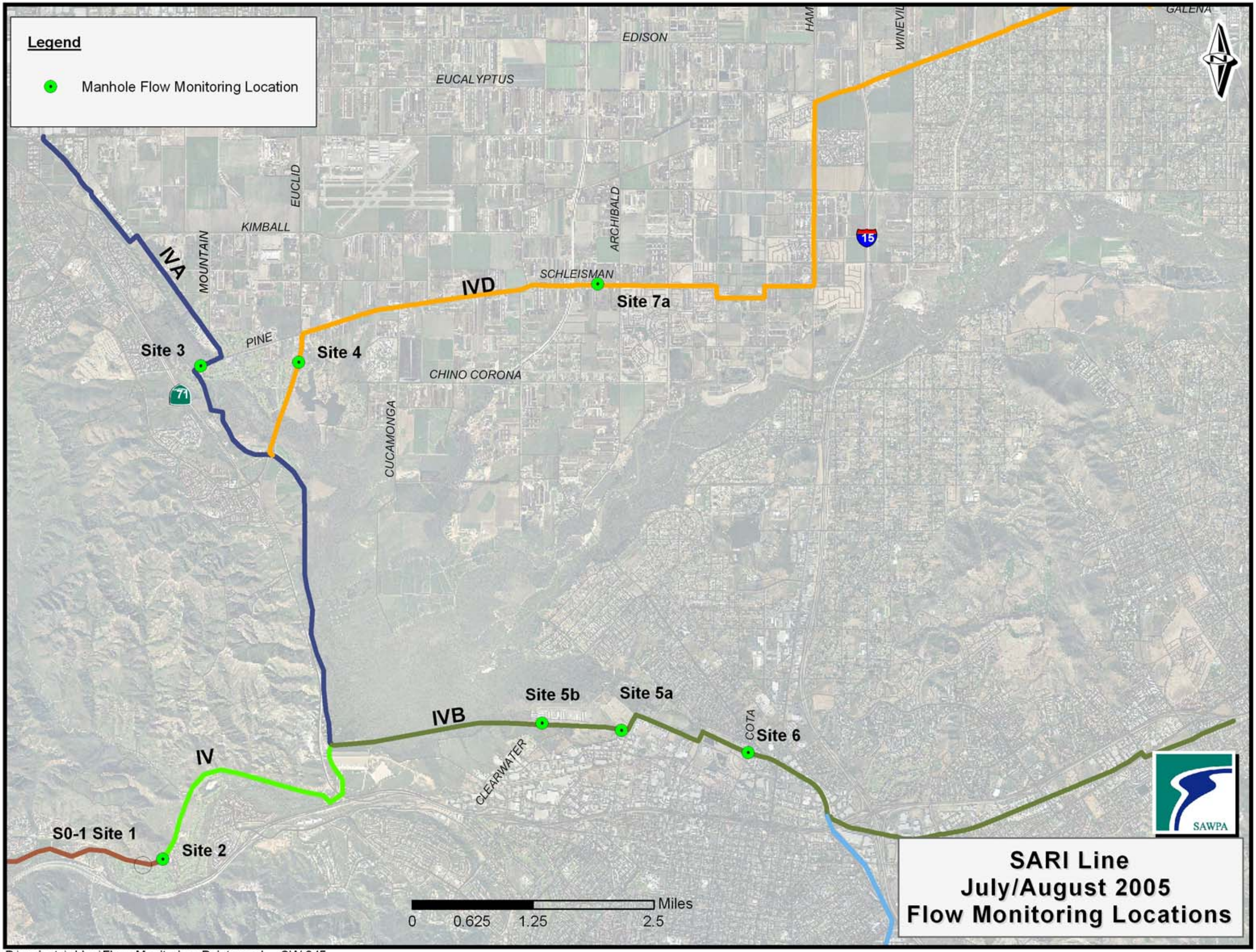


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Table 2: Diurnal Peak Curve Values

	Corona	Cota	Euclid	Green River	IEUA	Schleishman	Smith
12:00 AM	0.97	1.02	1.07	1.05	0.94	1.06	0.98
1:00 AM	0.98	1.05	1.03	1.03	1.01	0.99	0.99
2:00 AM	0.92	1.02	0.96	1.02	1.02	1.06	1.01
3:00 AM	0.92	0.99	0.89	0.98	1.02	1.03	0.99
4:00 AM	0.92	1.02	0.81	0.94	1.13	1.03	1
5:00 AM	0.93	1.01	0.77	0.91	1.05	1.15	0.99
6:00 AM	0.93	1.04	0.82	0.87	**1.78**	1.03	0.96
7:00 AM	1.06	1.03	0.84	0.85	1.53	1.09	1.06
8:00 AM	1.08	1.08	0.99	0.96	1.55	1.03	1.12
9:00 AM	1.07	1.06	1.06	1.01	1.49	0.99	1.08
10:00 AM	1.04	1.04	1.11	1.04	1.52	0.99	1.05
11:00 AM	1.04	1.01	1.12	1.07	1.43	1.03	1.07
12:00 PM	1.06	1.02	1.14	1.08	1.39	1.1	1.09
1:00 PM	**1.12**	1.01	**1.15**	**1.12**	1.22	1.01	1.08
2:00 PM	1.11	1.06	1.14	1.1	1.05	1.27	1.08
3:00 PM	1.11	**1.09**	1.12	1.11	0.78	**1.33**	1.09
4:00 PM	1.12	**1.09**	1.09	1.09	0.73	1.31	**1.11**
5:00 PM	1.08	1.06	1.09	1.1	0.71	1.27	1.08
6:00 PM	1.06	1.08	1.13	1.08	0.68	1.27	1.02
7:00 PM	1.08	1.07	1.12	1.03	0.64	1.27	1.01
8:00 PM	1.07	1.08	1.11	1.04	0.74	1.31	1.02
9:00 PM	1.08	1.03	1.11	1.06	0.75	1.19	1.06
10:00 PM	1.09	1.07	1.12	1.07	0.85	1.1	1.03
11:00 PM	0.99	1	1.09	1.04	0.83	0.95	0.92

Section 4: Hydraulic Model Calibration

Hydraulic model calibration is the process by which modeled results are compared to observed hydraulic data on the modeled system. Calibration is used to confirm that the model accurately represents known conditions in the system, making it more likely that the model can accurately predict hypothetical "what-if" conditions.

4.1 Selection of Calibration Points

Hydraulic model calibration is performed using points in the hydraulic system at which data can be observed and compared to modeled data. Because the July 2005 flows into the Upper SARI system were chosen to represent existing conditions in the system, measured data for calibration must have been collected at this time in order for an accurate comparison to be made.

While flow monitoring data was collected by SAWPA staff at several locations throughout July 2005, several of the monitors had recently been moved and a couple of others showed unreliable data, as pointed out by SAWPA staff upon review of the preliminary data; therefore, reliable calibration points within the system were limited.

The Green River flow monitor provided reliable data for the majority of the month, and it had a known location throughout the month. Also, the Green River flow monitor measures all flows passing through the Upper SARI system, because it is at the far downstream end of the system. For these reasons, the Green River flow monitor was chosen as the current calibration point for the Upper SARI system hydraulic model.

4.2 Calibration Data

Model data for calibration was generated from Pipe P-40040 (upstream of Manhole 4-0040) in the hydraulic model. Hourly flow information was downloaded from the model for a 24-hour diurnal pattern. These data were taken from the calibration scenario (see Section 5 for definitions and descriptions of various model scenarios) for a 24-hour period after all transient effects of model startup had been dissipated. The downloaded data included data on both depth of flow in the pipe and velocity of flow in the pipe.

Observed data for calibration were taken from raw 15-minute flow monitoring data provided by SAWPA staff. The data for each 15-minute interval throughout the day were averaged across the available data to produce an average diurnal curve. As with the modeled data, the process took place for both depth and velocity of flow through the flow monitor.

As can be seen in Figure 6, the modeled depth at the calibration point consistently is slightly lower than the observed depth, but never by more than 7 percent. This fact is consistent with the fact that the peak factors applied to the average flows probably underestimate the true peaks at the discharge points (as discussed in Section 3). Also, the modeled velocity is consistently lower than the observed velocity, but less noticeably so, as can be seen in Figure 7. The observed velocity pattern shows the oscillations typical in ultrasonic velocity sensors used to measure open channel flow velocities. Figure 8 shows the flow profile through Reach IV with maximum values of calibration flows.

Figure 6
Calibration of Depth Values For Green River Flow Monitor

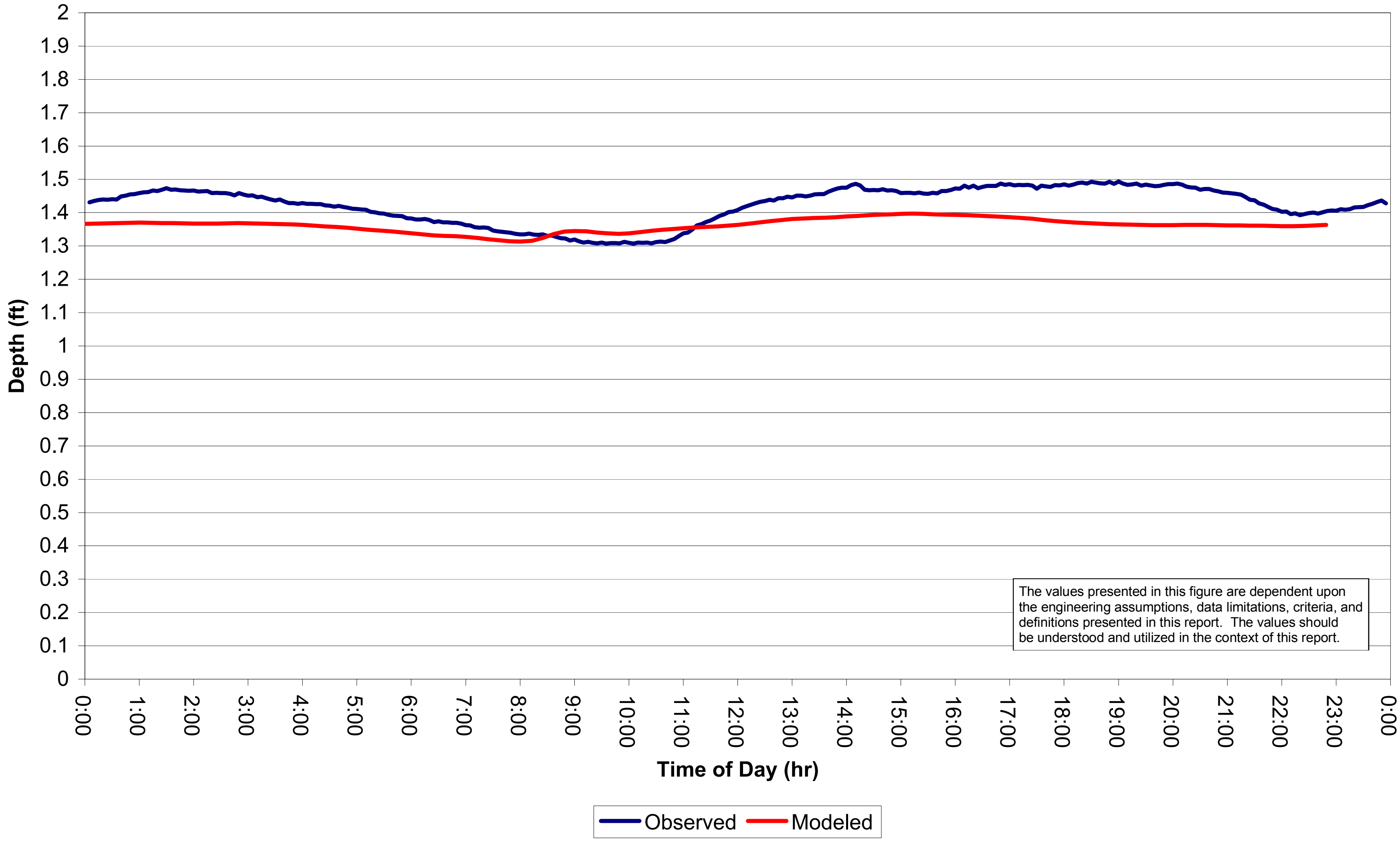
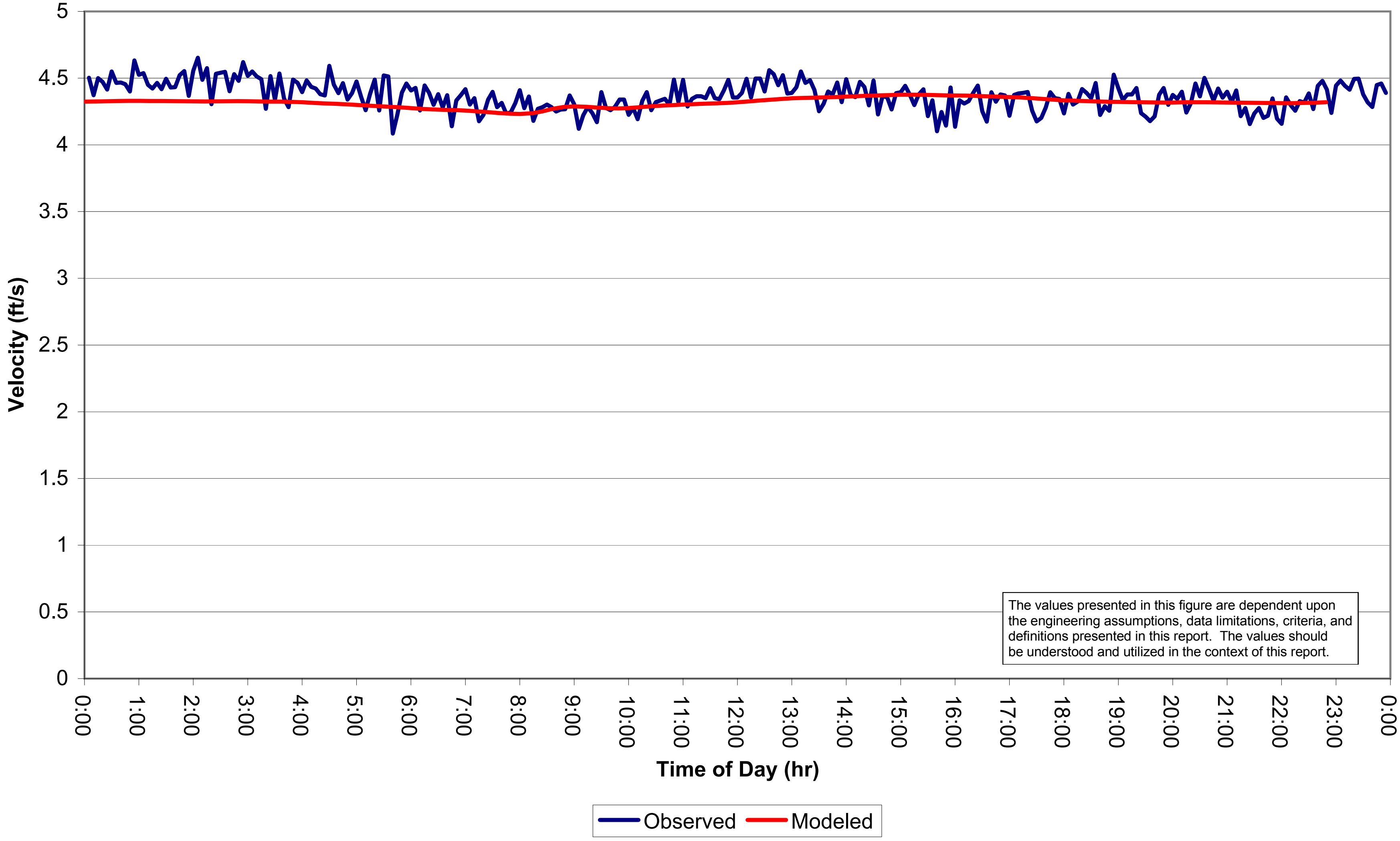


Figure 7
Calibration of Velocity Values For Green River Flow Monitor



The values presented in this figure are dependent upon the engineering assumptions, data limitations, criteria, and definitions presented in this report. The values should be understood and utilized in the context of this report.

Reach IV Peak Calibration Flows

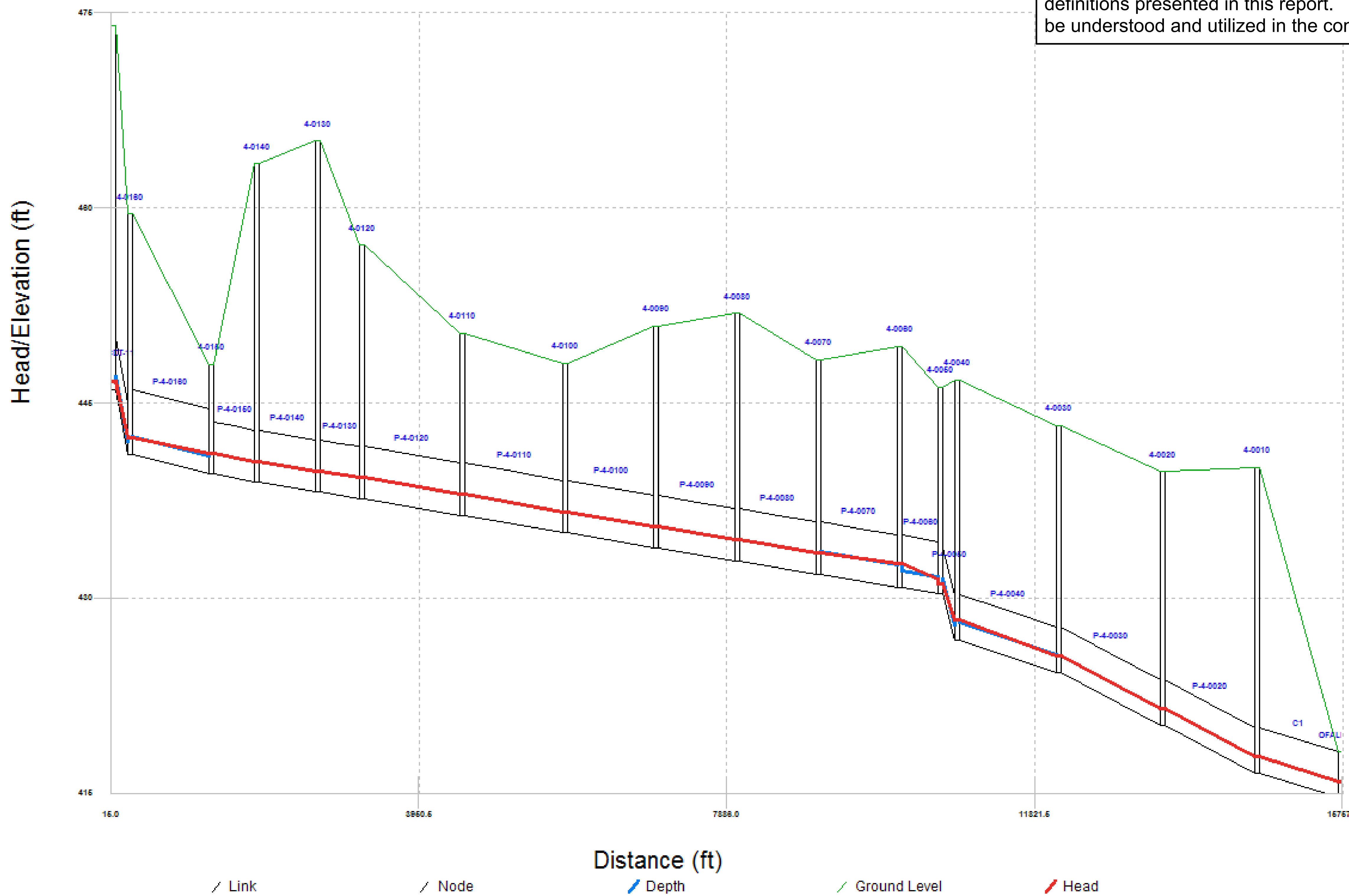


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Figure 8

Reach IV CalibrationProlile - Peak Flows

Section 5: Hydraulic Model Scenario Creation

As described previously in this report, a hydraulic model is a mathematical representation of the infrastructure, fluid flows, and hydraulic control features in a hydraulic system. A scenario in such a model is a particular combination of infrastructure, flows, and controls chosen for analysis. Such a combination may consist of existing elements for which the model results can be compared with measured values (e.g., a calibration scenario, as developed for Section 4), or it may be a combination of hypothetical elements chosen to reflect anticipated future conditions of a system.

5.1 Upper SARI System Scenario

The purpose of creating future scenarios is to anticipate changes to the infrastructure and flow loading of the Upper SARI system so that the model can be used to calculate the performance of the system under these predicted conditions. As described in Section 1, the two primary set of conditions to be modeled in the Upper SARI system concern the effects of flushing Reach V and the effects of continued discharge increases inside the system. The following scenarios were created to simulate these conditions of concern. As described below, these scenarios incorporate not only anticipated flow changes, but also anticipated infrastructure changes concerning the alignment of the SARI line through the Prado Dam Area (the confluence of Reaches IVA and IVB into Reach IV).

5.2 Reach V Flushing Scenario

As described in Section 1, the steady-state hydraulic model developed for Reach V indicated that a flow of 6,600 gpm would achieve flushing flows in the largest siphons. This flow equates to approximately 9.5 mgd. For the Reach V flushing scenario, 9.5 mgd was added to the upstream end of Reach V, supplementing the existing average Upper SARI system flow of 9.7 mgd.

The results of this scenario indicate that the critical area created by the flushing flows is the lower stretch of Reach IV-B. As shown in the profile presented in Figure 9, a depth-to-diameter (d/D) ratio of 0.68 in this area has been identified . Reach V reaches pressure conditions by design and therefore shows no critical areas.

Flushing Scenario - Peak Flows Reach IV-B

The values presented in this figure are dependent upon the engineering assumptions, data limitations, criteria, and definitions presented in this report. The values should be understood and utilized in the context of this report.

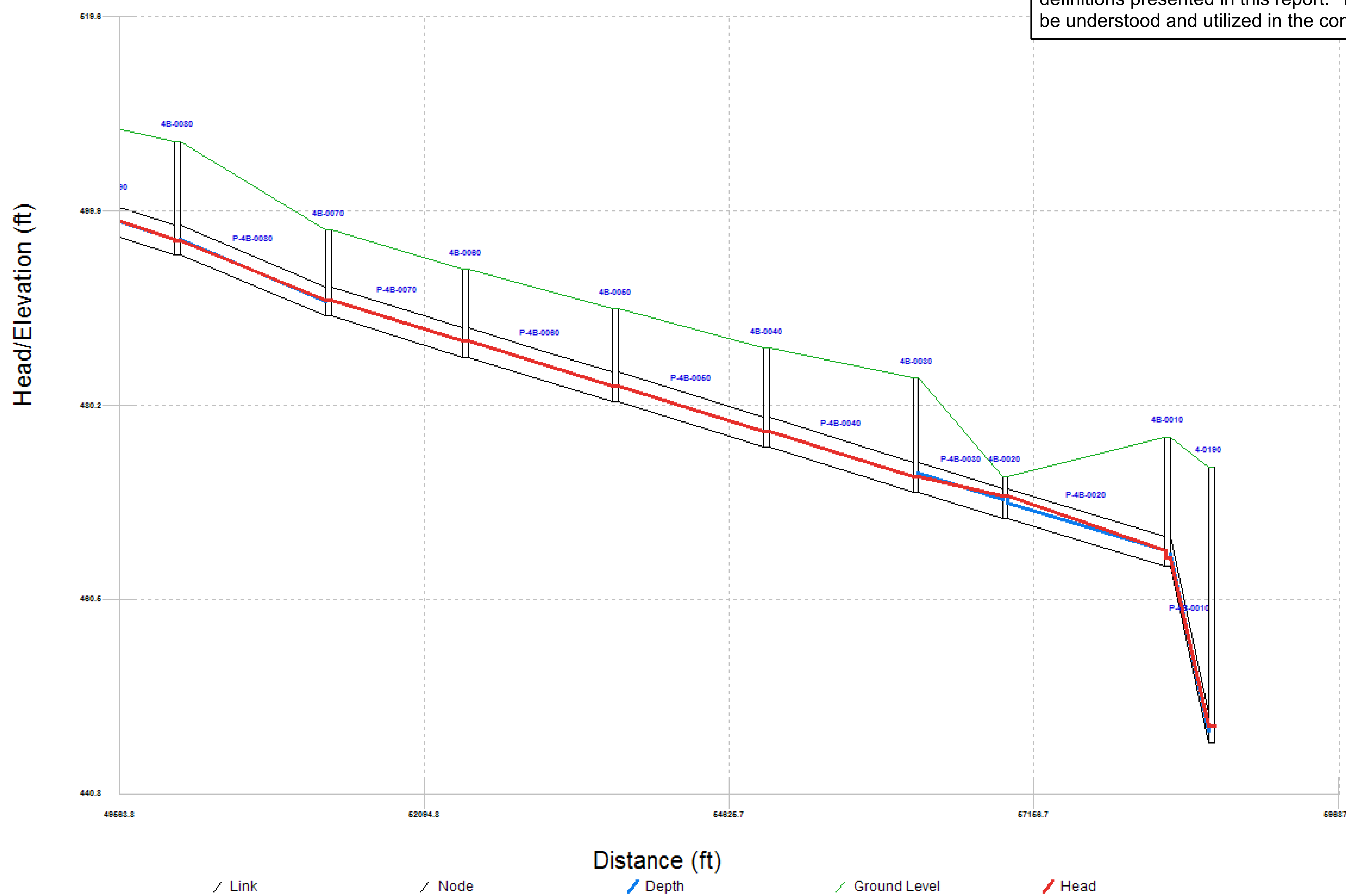

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Figure 9
Flushing Flow Critical Elements

5.3 30-mgd Future Flows

The future scenario of 30-mgd flows was modeled. For this scenario, SAWPA provided data on the projected discharges into the Upper SARI line for the year 2025. Table 3 lists the dischargers, discharge location, and projected flow amounts for this scenario.

Table 3: Future Upper SARI System Dischargers

Site Name	SARI Reach	Model Node ID	2025 Projected Flow (mgd)
Menifee Desalter	Beg. Reach V	J275	1.2
Perris Desalter	Beg. Reach V	J275	1.6
Perris Desalter II	Beg. Reach V	J275	1.6
Chino Desalter I	Reach IV-D, S-34	4D-0120	2.05
Chino Desalter II	Reach IV-D, S-28	4D-0750	1.62
Chino Desalter III	Reach IVD, S-28	4D-0750	1.5
California Institution for Men	Reach IV-A, S-05	4A-0390	0.19
City of Chino Hills	Reach IV-A, S-05	4A-0390	0.04
RCSD, Anita Smith Ion Exchange	Reach IV-D, S-29	4D-1460	0.03
Temescal Desalter	Reach IV-B, S-32	4B-0330	1.5
Elsinore Desalter	Beg. Reach V	J275	1
JCSD Ion Exchange	Reach IV-D, S-28	4D-0750	0.59
JCSD Industrial	Reach IV-D	4D-0750	1.1
Arlington Desalter Facility (Transition to WMWD)	Reach IV-B, S-22	4B-0890	1.7
Hexfet	Beg. Reach V	J275	0.01
Inland Empire Energy Center (2007)	Beg. Reach V	J275	1.2
Industrial (EMWD)	Beg. Reach V	J275	1.5
Mission Uniform and Linen Service	Reach IV-A, S-05	4A-0390	0.71
Future Uniform and Linen Service (Aramark)	Reach IV-A, S-05	4A-0390	0.2
OLS Energy	Reach IV-A, S-05	4A-0390	0.13
Paradise Textile Corp.	Reach IV-A, S-05	4A-0390	0.67
RP-5 Renewable Energy	Reach IV-A, S-05	4A-0390	0.1
Mountainview Power Company, LLC (Operational 2006)	Beg. Reach IV-E	4E-0390	0.432
SBVMWD (formely SCE Highgrove PP) - No Current Permit	Beg. Reach IV-E	4E-0390	0.08
SBVMWD (YVWD or Future Industrial)	Beg. Reach IV-E	4E-0390	0.568
City of San Bernardino - No Current Permit	Beg. Reach IV-E	4E-0390	2.5
City of Colton - No Current Permit	Reach IV-E, S-31	4B-0120	2

Site Name	SARI Reach	Model Node ID	2025 Projected Flow (mgd)
City of Realto - No Current Permit	Reach IV-E, S-53	4E-0020	1.5
YVWD, includes Future Ion Exchange - No Current Permit	Beg. Reach IV-E	4E-0390	1.432
Corona Energy Partners	Reach IV-B, S-20	4B-0260	0.1
Metropolitan Water District	Reach IV-E, SP42	4E-0390	0.05
Unilever Food Solutions	Reach V, S-46	J1	0.02
Stingfellow Pretreatment Facility	Reach IV-D, S-101	4D-1070	0.26
El Colton (formerly Agua Mansa PP)	Reach IV-E, S-53	4E-0020	0.04
Golden Cheese	Reach IV-B, S-13A/B	4A-0320	1.2
Alcoa	Reach IV-B, S-52	4D-0120	0.01
Dart container	Reach IV-B, S-50	4B-0110	0.03
Wastehaulers (S-11 = total of all wastehaulers)	Reach IV-A, S-05	4A-0390	0.1
	Total		**30.56**

5.4 30-mgd Peaked Scenario

Also modeled was the 30-mgd peaked scenario, which is based upon the 30-mgd scenario with the following additions:

- Peak curves were added to data on relevant discharges. This increases the total modeled flow in the Upper SARI system to approximately 33 mgd.
- Five percent of the base flow in the future scenario was added as an approximation of I&I. The I&I flows accounted for 1.5 mgd and raised the total flow in the scenario to 34.5 mgd. The infiltration flows were loaded on manholes at the far upstream of Reach IV-A, IV-B, and IV-E.

5.5 30-mgd Peaked + 3-mgd Scenario

This scenario is based upon the 30-mgd peaked scenario with the following addition:

- 3 mgd was added at the end of Reach V to account for requested flow by a member agency at this point. This raised the total peak flow of the scenario to approximately 37.5 mgd.

The 30-mgd peaked + 3-mgd scenario takes the Upper SARI system right up to, and in some cases beyond, its maximum theoretical capacity. The following figures show the profile results of this scenario in the most critical areas of each reach of the Upper SARI system. As can be seen in Figure 10, Reach IV achieves surcharge conditions under peak flows in this scenario. Figure 11 shows that Reach IV-A nearly surcharges as well. Figure 12 shows the critical elements of Reach IV-B, where flow reaches the maximum theoretical capacity of the pipe. Figure 13 shows the critical elements of the Reach IV-E. Figure 14 shows the critical elements of Reach IV-D.

Reach IV 30 MGD Peaked + 3 MGD Peak Flows

The values presented in this figure are dependent upon the engineering assumptions, data limitations, criteria, and definitions presented in this report. The values should be understood and utilized in the context of this report.

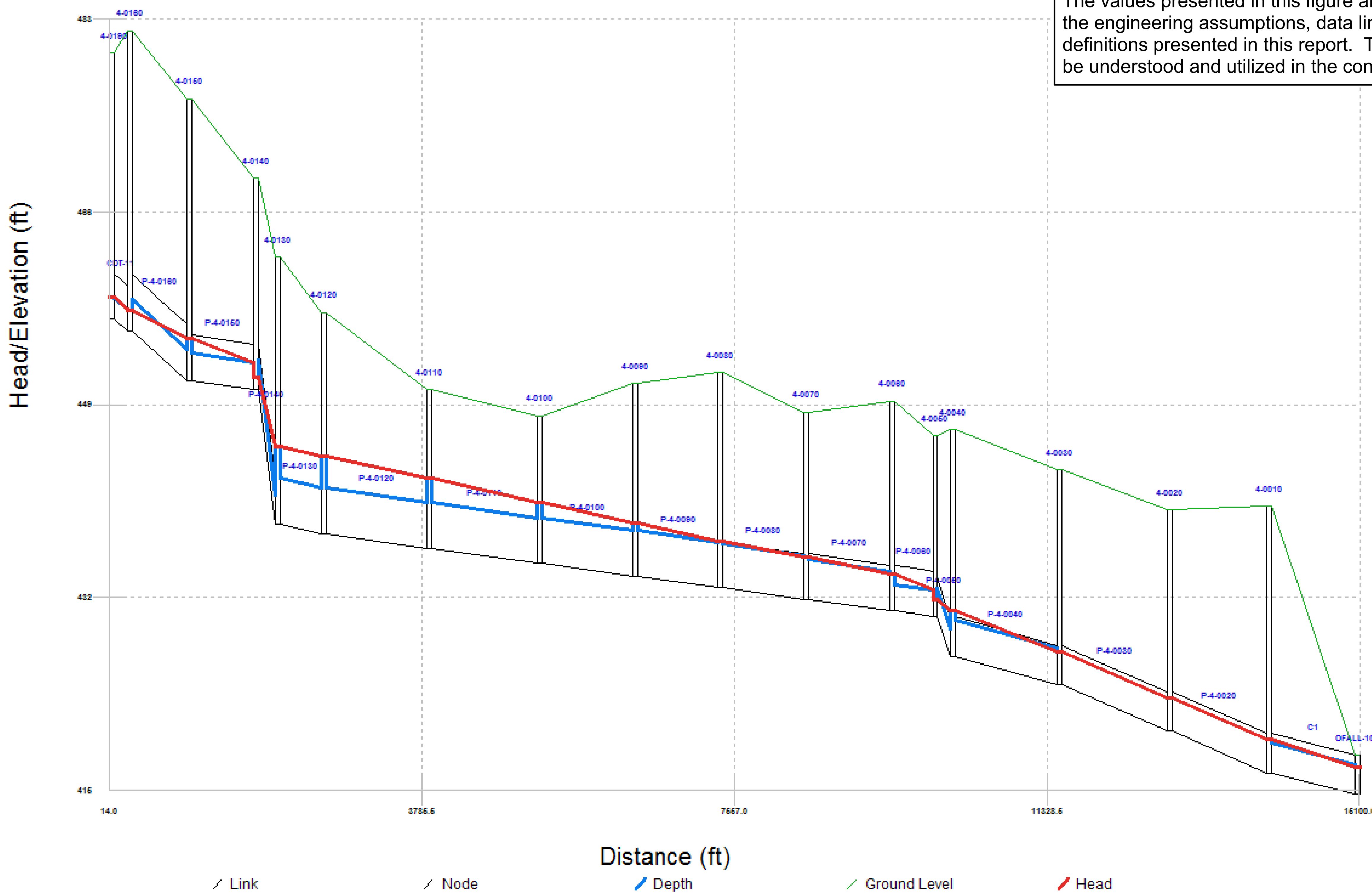

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Figure 10
Reach IV 30-mgd Peaked + 3-mgd Peak Flow Profile

Reach IV-A 30 MGD Peaked + 3 MGD Critical Element Peak Flows

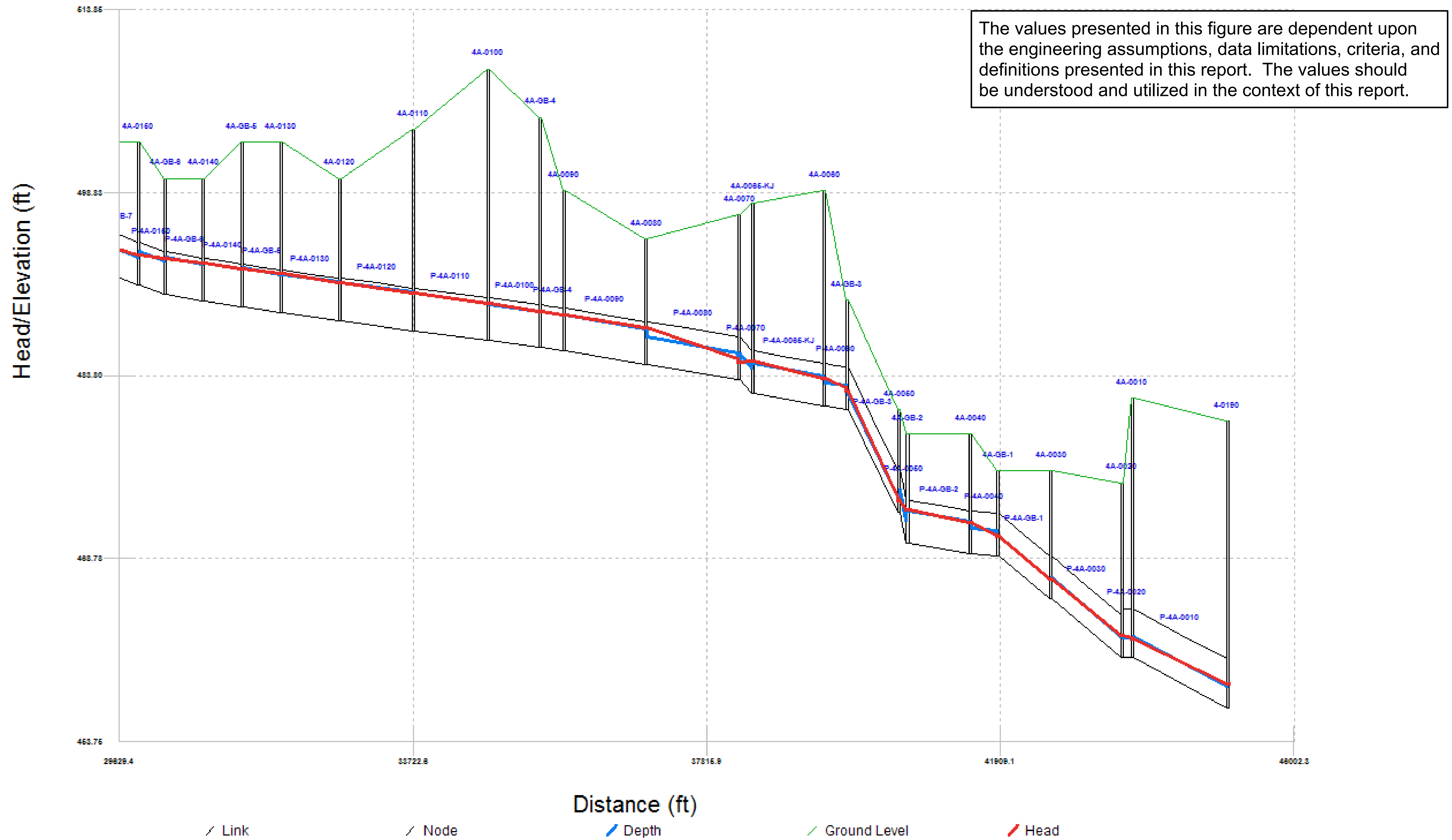

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Figure 11

Reach IV-A 30-mgd Peaked +3-mgd Peak Flow Profile

Reach IV-B 30 MGD Peaked + 3 MGD Critical Element Peak Flows

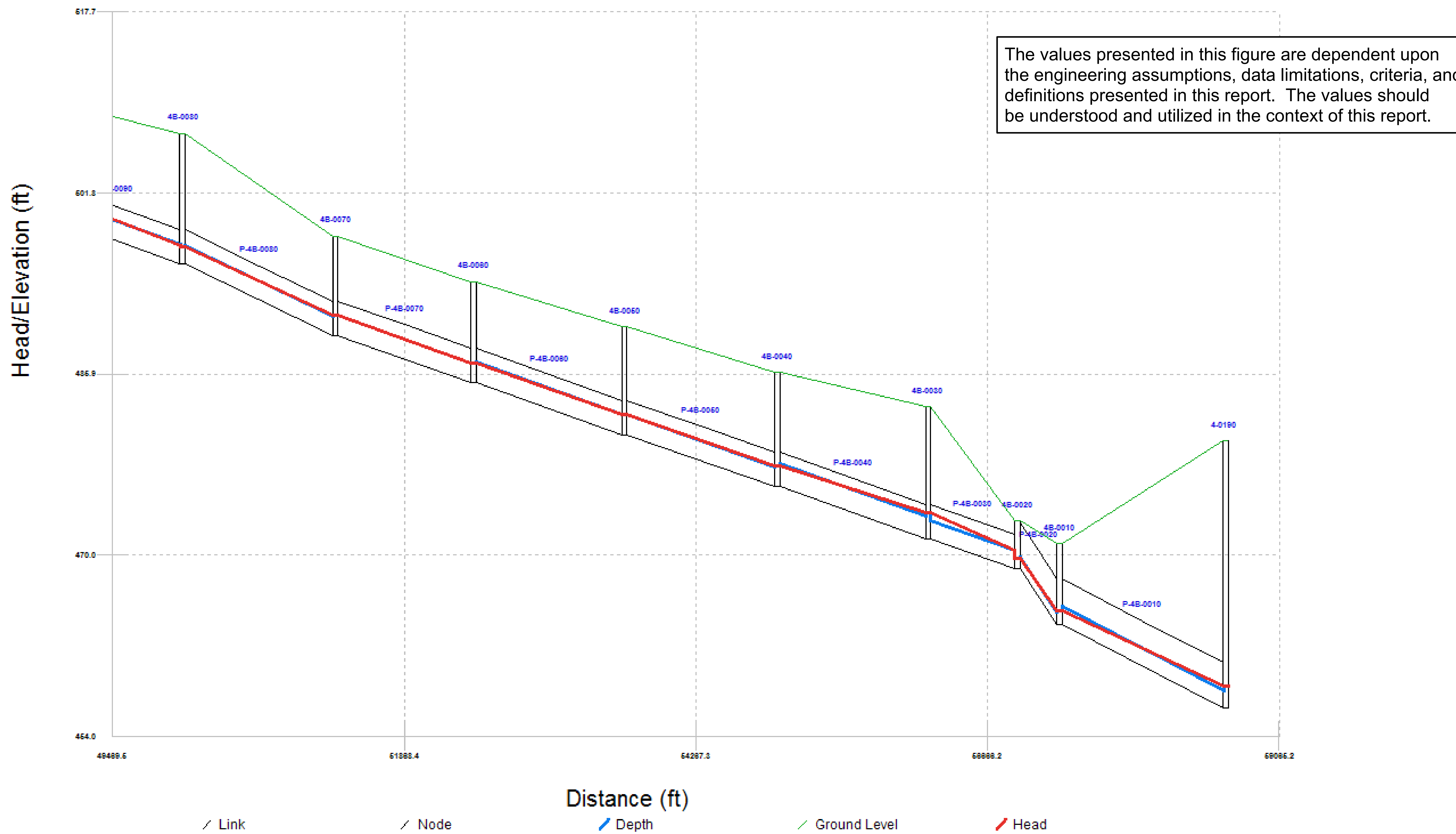

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Figure 12
Reach IV-B 30-mgd Peaked + 3-mgd Peak Flow Profile

Reach IV-E 30 MGD Peaked + 3 MGD Critical Element Peak Flows

The values presented in this figure are dependent upon the engineering assumptions, data limitations, criteria, and definitions presented in this report. The values should be understood and utilized in the context of this report.

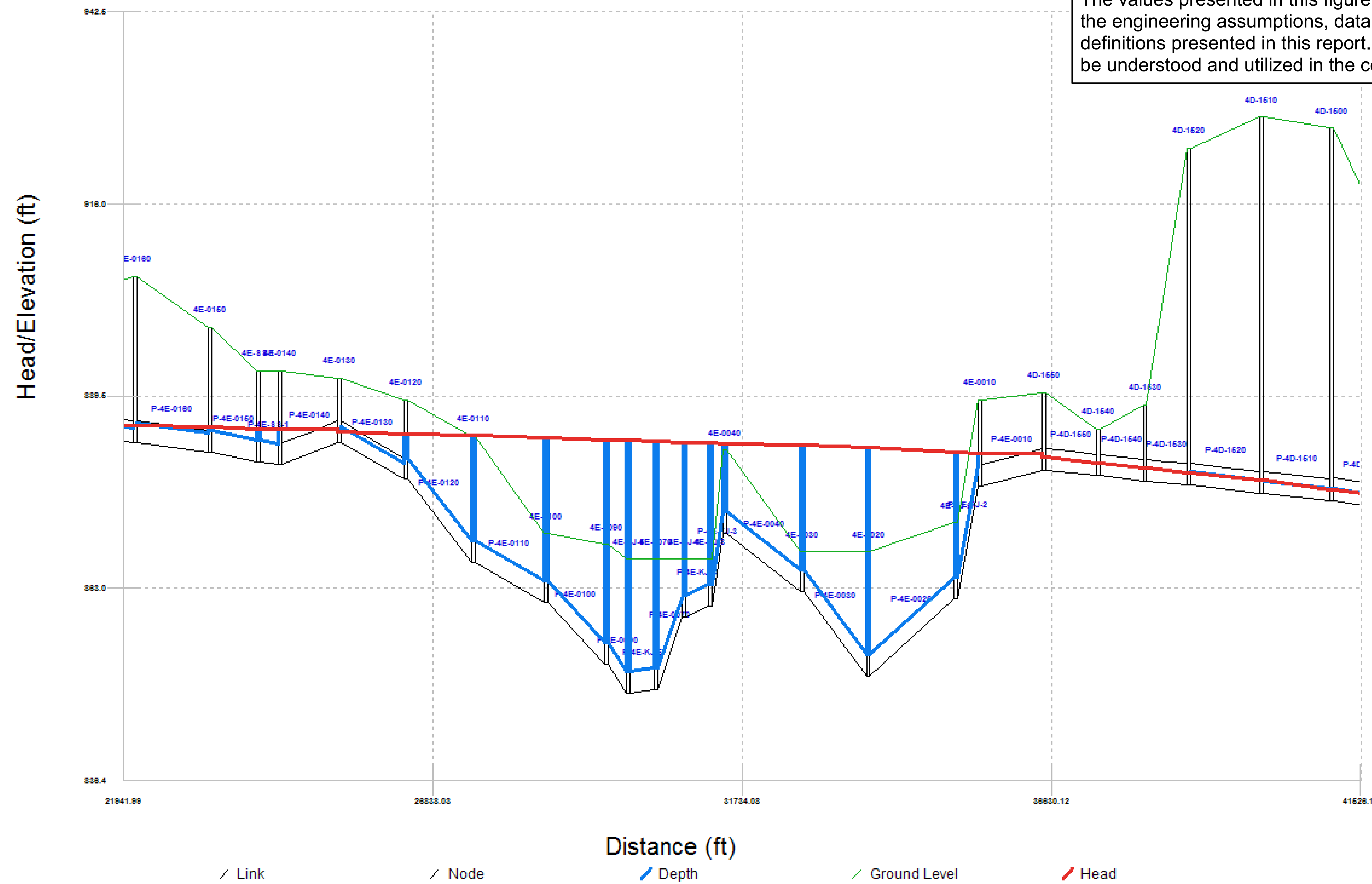

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Figure 13

Reach IV-E 30-mgd Peaked + 3-mgd Peak Flow Profile

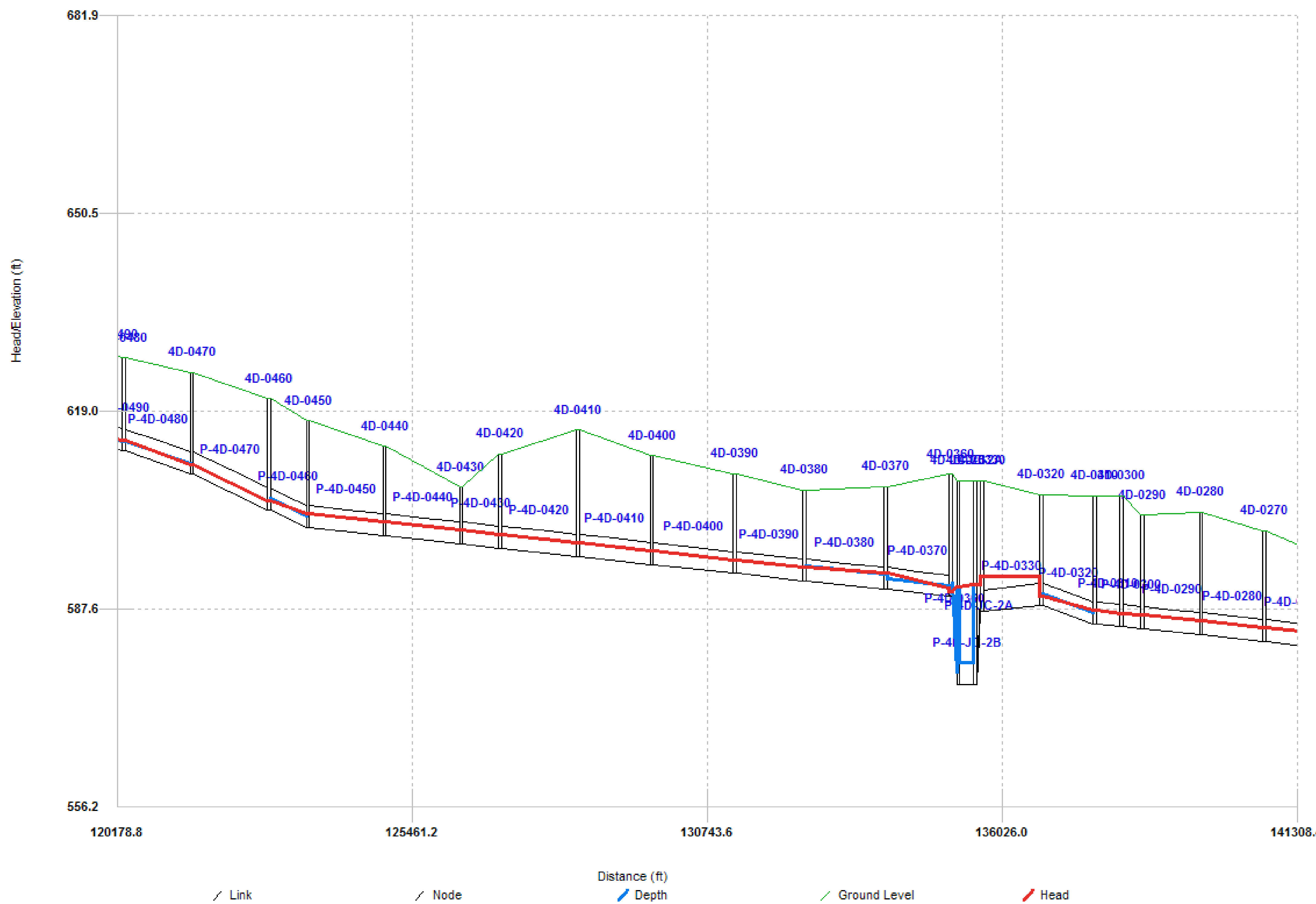

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Figure 14
Reach IV-D

Section 6: Implications of Model Results

6.1 Identification of Critical Infrastructure in the Upper SARI Line

The flow profiles shown in Section 5 help identify the critical infrastructure in the Upper SARI system: the specific infrastructure that is being used at or close to capacity under the maximum-flow scenario. Inspection of the profiles helps us identify six distinct areas where capacity is of concern:

- Siphon over the La Sierra Channel at the upper end of Reach IV-B (IVB-0830 to IVB-079)
- Lower section of Reach IV-B as it enters Reach IV (IVB-0070 to IV-0180)
- Siphon section at the lower end of Reach IV-E (IVE-0110 to IVE-0010)
- Lower section of Reach IV-D (IVD-0380)
- Area of low slope at the lower end of Reach IV-A (IVA-0100)
- Upper end of Reach IV (IV-0130 to IV-0060)

These critical elements of infrastructure are summarized in Figure 15, which shows maximum modeled flow in comparison to maximum theoretical flow through the line at the critical areas in each reach. Maximum theoretical flow is defined as flow at full pipe subject to the modeling limitations discussed below.

6.2 Maximum Theoretical Flow and Limitations of Current Hydraulic Model

The maximum theoretical flow in the hydraulic model is limited by the following conditions:

- Horizontal and vertical curves in the Upper SARI system's pipelines are not captured in the model data, but these curves will affect hydraulic performance.
- Lateral lines jutting into a pipe are not represented.
- Hydrodynamic phenomena, such as air bubbles trapped due to poor blow-off valve performance, are not represented.

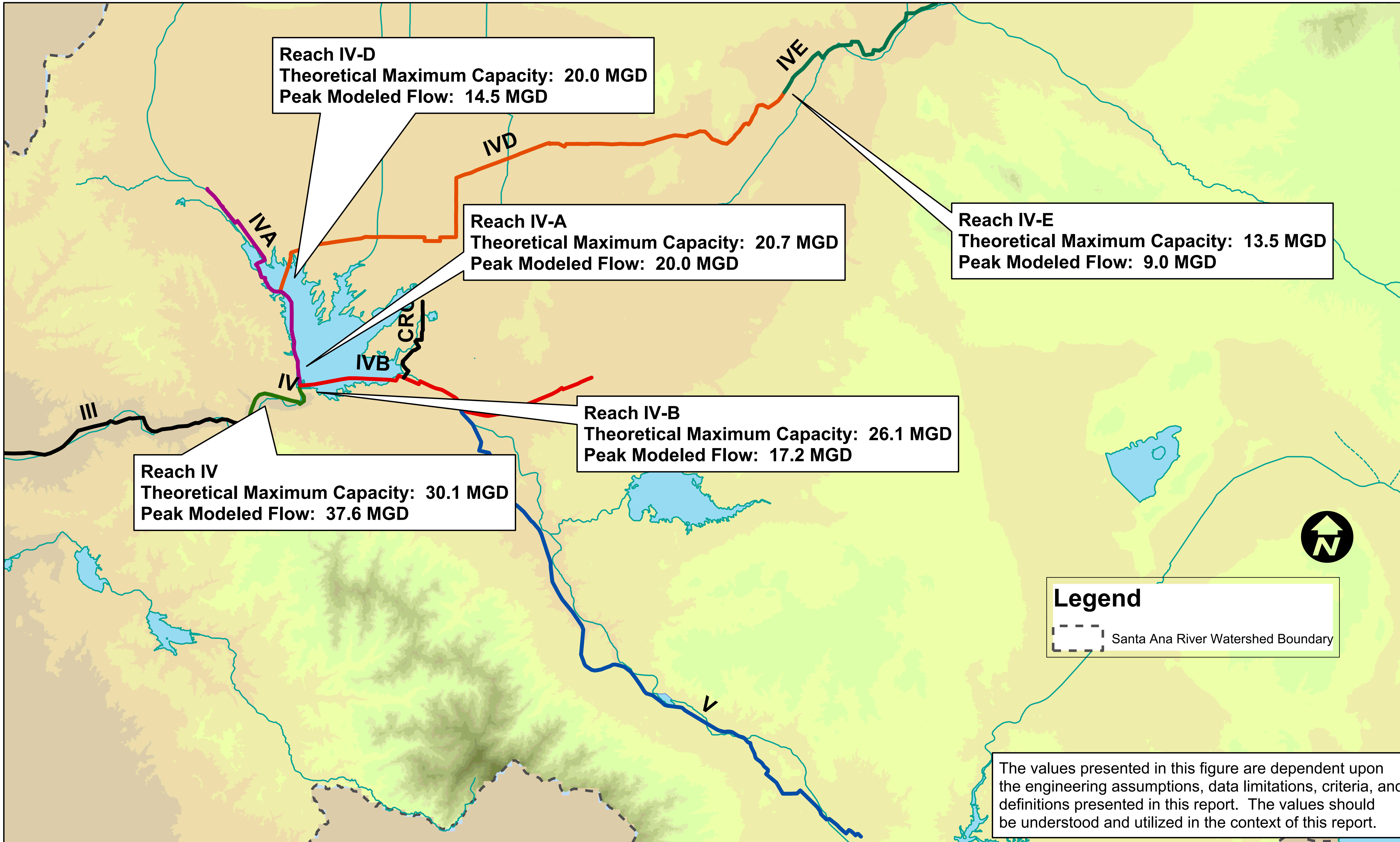

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Figure 15

Summary of Critical Infrastructure in the Upper SARI Line

6.3 Discussion of Critical Infrastructure

The critical areas identified in the model and listed above were discussed with SAWPA staff. Through these discussions, possible methods of alleviating capacity constriction of critical infrastructure were developed, which can be categorized into the following types of solutions:

- Policy and management solutions (discussed in Section 7)
- Operation and maintenance solutions (discussed in Section 7)
- Establishment of firm operational criteria for capacity (discussed in Section 8)
- Possible capital improvements (discussed in Section 9)

Section 7: Policy and Management Solutions

7.1 Flow Peaking and Equalization

As an example of how Upper SARI system capacity can be quickly utilized or over-utilized, consider a scenario in which all major users have peak hourly flow rates of double the average daily flow rate. If these flows were to be added together in a short time period, the available average capacity would be reduced to approximately one-half the maximum theoretical capacity.

Because of the current excess in the Upper SARI system's capacity, the relationship of peak flow from a discharger to average flow is of little concern, but as the flow contributions to the SARI pipeline increase, this relationship will need to be considered.

To address the impact of discharges from users at peak levels on the pipeline capacity, SAWPA might construct detention basins between the user (whether industry or municipal) and the SARI. Where desalters can demonstrate only a slight difference between peak flow and average flow, detention basins may not be required. In these cases, small storage areas in the pipeline flow path, which include installation of a weir to control flow rate, are often used.

SAWPA might consider requiring placement of detention basins with outlet flow controls (weirs) for all new users. (This type of flow equalization is most effective when installed on private service laterals between the user and the SARI line.) The same requirement could be considered for existing users, as part of a discharge permit/agreement renewal. While requiring both may represent a challenge to SAWPA, the implementation of individual flow equalization for each discharger will make a significant difference.

The detention basins can be sized to discharge flow collected over an operating time-frame at a constant rate throughout the entire day. Basins also can be sized to discharge at the maximum allowable continuous rate noted in the agreement between SAWPA and industry or a municipal entity.

7.2 Flow Monitoring

If SAWPA implements flow controls on industrial users, it should also consider a continuous flow monitoring program. The benefits of flow monitoring on private laterals entering the SARI could be considerable. For example, improved data on discharge frequency and flow from dischargers could be obtained and used to refine the understanding of system capacity. The greater the understanding of discharges and their timing, the greater the confidence in developing a maximum operational flow in relation to the maximum theoretical flow of 38 mgd.

7.3 Partnering with Industrial and Municipal Users

Industrial users and municipal entities discharging non-desalter flows should be a particular focus, as they exhibit the greatest variability in flow rate. SAWPA may be able to identify opportunities for industry to operate swing and/or graveyard shifts, or to store flow and discharge it during daily low flow periods. Rate structures to encourage the off-peak discharge could be considered.

7.4 Modifying Existing Agreements at Renewal

It has been indicated by SAWPA staff that a number of existing agreements allow peaking factors of 1.5 times the average flow rate. SAWPA could develop a policy to encourage the removal of peaking factors at the renewal of discharge permits/agreements. Additionally, SAWPA could work to help shift discharges to off-peak periods.

7.5 Infiltration/Inflow Forecasting

The flow model just completed for the Upper SARI system includes a reservation of 5 percent of the total average projected flow of 30 mgd, or 1.50 mgd, for flows entering the system from I&I, which, in the SAWPA service area, results from high groundwater and surface runoff in the Prado basin. It is of concern that the 5 percent estimation of flow is likely too low for a 73-mile-long interceptor along with private service laterals, industrial sites, and municipal sewer collection systems. Further, as the piping system ages, inflow will increase.

More accurate forecasting is important to predict the reduction in available capacity from I&I within the Upper SARI system. An in-depth approach to forecasting I&I contributions should be developed as capacity for the future is being allocated.

Inflow is defined as water entering the piping system from surface-water sources, including parking lots, roofs, foundation drains, catch basins, and holes in pipe open to the surface. Infiltration is the movement of water from saturated soil through cracks and leaky joints in the pipe.

For the SAWPA service area, a very preliminary discussion with SAWPA staff of I&I indicates that water contributions from infiltration are currently limited because the groundwater table is below the elevation of the pipe in most locations. A notable exception is the areas located in Reaches IV, IV-A, and IV-B behind the Prado Dam. Since this dam is used for flood control, completely saturated soil above the pipe, with a varying amount of head due to changing water depth, should be expected.

Other locations of potential infiltration could exist in low-lying areas through which private laterals run and within municipal sewer collection systems traversing wet areas (e.g., JCSD).

Inflow is known to provide some contribution of flow to the upper SARI system during and immediately after rainfall events. This can be verified by comparing the near-term flow rates at the metering stations with longer-interval “before and after” flows from the same meter. It is currently unknown what range of percentage of increase is actually being experienced.

7.6 Overflows

Within the SAWPA basin today, concern about overflows of the Upper SARI system is minimal. This is due in large part to the relative newness of the system. The other contributing factor is the low current ratio of flow to capacity. SAWPA, however should prepare for the eventuality of an emergency overflow condition.

As the flows entering the SARI increase and the piping system ages, the system will be less able to absorb and attenuate high peak flows. Normally, operating a gravity piping system in a full pipe-flow configuration with an expectation of no overflows or bypasses is difficult as the system ages and flow reaches peak levels.

A number of agencies faced with increasing age and flow in a gravity system prepare for the eventuality of an emergency overflow condition by establishing where an overflow will occur in each topographic reach of piping. Other utilities have prevented overflows by developing bypass locations to other piping systems located in the area. The RIX system is an example of a piping system in the basin that could be used as a bypass. There is a concrete box where both the SARI and RIX pipeline lie in parallel. An overflow pathway could be created to the RIX line at this location. Other opportunities for bypass facilities may also exist where wastewater outfalls cross the SARI pipeline and right-of-way. When bypass locations are developed, an event counter is typically installed and a method of estimating the duration of bypass and level of flow is established.

Planning for the eventuality of an emergency overflow in a particular reach of piping could include a piped transport of high flow from the SARI to an area of least impact, where the overflow can be accommodated. One option to consider is to develop a piping system from the overflow point to a lined detention basin off site. If an overflow occurs, an alarm sounds and operations and maintenance staff are summoned to the overflow to determine the issue and implement a timely repair. The captured flows are reintroduced to the SARI system at a controlled rate once the overflow condition is satisfied. In this case, an overflow never reaches beyond the facilities of the utility. In planning, SAWPA may wish to consider development of a system of bypasses and overflow points to detention basins that could be acceptable and may want to develop a capital improvement plan (CIP) to implement them over time. Developing a backup system of bypasses and off-line detention basins greatly reduces the potential for a high-profile overflow, with its substantial expense and heightened public awareness. Developing the agreements for bypass to area pipelines and acquiring land for off-line detention facilities is usually easier in the earlier stages of the basin's development.

7.7 Regulatory Interaction

As the Upper SARI system increases its flow, healthy interaction between SAWPA and the Regional Board should continue. This relationship can help develop a common level of understanding of the constraints and concerns of each body. When such a relationship has been maintained in other locations, each agency has been able to move toward increasingly common ground.

A sound relationship between SAWPA and the Regional Board is particularly helpful should the unexpected happen. If it does, and it involves a possible regulatory violation, the first response from regulators usually is more positive in the case of existing cordial communications.

One of the ways to continue fostering a strong relationship with the Regional Board is to invite its representatives to periodic site visits. For example, the Prado Dam project, currently nearing completion, will change the head of water above the pipeline and that area of the SARI system that will be under water in the winter months. The Dam reconstruction requires a relocation of piping through the dam and immediately downstream in an area along the contractor's temporary bypass channel. Increased opportunity for infiltration behind the dam during the construction and initial startup phase exists. Developing an expectation by the Regional Board of the challenges faced in the raising of the Dam crest could be positive, especially should an unexpected event affecting the SARI occur during startup.

7.8 Loss of Staff institutional Knowledge

During our recent work with the Management, Engineering and Maintenance staff of SAWPA, Kennedy/Jenks came to understand that a substantial amount of knowledge is maintained by the SAWPA staff. As time passes, staff will retire, and with them will go a wealth of knowledge about the physical properties, operational characteristics, and users of the SARI system. It is recommended that SAWPA begin to develop additions to its database to capture the institutional knowledge of its long-term and valued staff.

7.9 Funding for the Future

SAWPA should consider the creation of a capital improvement plan (CIP) and development of funding for the future.

The reasons for identifying funding methods and sources are many. The SARI system is extensive in its geographic coverage. The expansive nature of the area that could be served suggests that capacity beyond the firm fixed capacity of the existing pipeline may be needed. Often a CIP is developed to create new capacity for the future.

Additional funding may be required to upgrade the levels and location of treatment and discharge. Further, funding may be needed for improvements intended to increase the reliability of the SARI to carry peak flows without overflow beyond the SARI system as it develops in the future.

Capital for new improvements can be gained by a number of funding vehicles, including connection fees, use fees, system development charges, and state and federal grants, including earmarking of funding at the national level.

7.10 Operations and Maintenance

Changes in the Upper SARI system operations and maintenance (O&M) will be driven by at least three factors: 1) implementation of new policies and management systems enacted by the Board, 2) the need to meet increasingly stringent regulatory requirements, and 3) increased maintenance activities as flow increases toward the allowable pipeline capacity. These changes will be enacted by O&M staff in response to requests from management and in reaction to encountering changing conditions in the piping system that require increased maintenance and oversight to prevent problems, especially overflows.

O&M should be considered to include the cataloging, in permanent form, of unwritten knowledge held in the minds of District staff.

Section 8: Establishing a Maximum Operating Capacity Within the Upper SARI Line

8.1 General Approach to Establishing Maximum Operating Capacity

For any piping system, a maximum hydraulic capacity can be established by modeling that is normally considered to be its theoretical or ideal capacity. The actual pipeline capacity often is less than the ideal capacity, because of unknowns inherent in the actual construction of the pipeline. Factors that could reduce the capacity of the piping system include high spots in vertical alignment from poor installation of the pipeline. Where this occurs, a series of high pockets that retain air is developed. Air pockets in full-flowing pipelines tend to reduce capacity. Other construction issues that can reduce ideal capacity include laterals that protrude into the pipeline, pipelines installed at flatter grade than designed, entrance losses at manholes from incoming flow at laterals, pipe with greater roughness than shown on the plans (concrete vs. PVC lined), and sanding-in of gently sloping pipelines. Sanding-in of pipelines occurs in areas where sandy soil migrates into the piping systems or in beach communities where it enters the domestic sewer system from clothes washing and bathing.

In addition to the physical factors of the pipeline construction that can limit the capacity, the maximum operating capacity for approved users can be reduced. The calculated reductions should include at least an estimate of the contribution of flow during wet weather from I&I, a reduction for the flow increase due to peaking of discharges, and a reduction that provides an appropriate safety factor to help insure that overflows do not occur.

The decision to establish a maximum operating capacity is a combination of the science of flow estimation and the art of evaluating risk. One method of establishing the maximum operating capacity (or maximum allowable flow) in the Upper SARI system is for SAWPA to determine an acceptable balance of maximum flow and risk of overflow.

Methods to raise the maximum allowable flow while maintaining an acceptable factor of safety include developing bypasses and off-site detention facilities for overflow protection.

8.2 Determination of Maximum Operating Flow Criteria

Development of the maximum operating flow in any system requires establishment of system criteria that can be applied to all of the elements in that system. Commonly, these criteria are based upon a maximum depth, flow rate, or velocity to be allowed in the system.

In pressurized flow systems, maximum amounts of head loss are also used as operational criteria.

Typical open-channel flow system operational criteria are based upon depth-to-diameter (d/D) ratios. Criteria of d/D ratios can be consistently applied across a system of varying diameter. Maximum flow in an open circular conduit occurs at d/D = 0.82. A typical operational maximum for wastewater systems is d/D = 0.75. This value is often seen as an acceptable balance between maximizing the capacity used in infrastructure and reserving some capacity for flow contingencies.

At the direction of SAWPA staff, Kennedy/Jenks implemented a value of d/D = 0.75 as the operational criteria for the Upper SARI system. Using this criterion, the hydraulic model was run to determine flow values in the various reaches. Figure 16 displays the values developed in the hydraulic model.

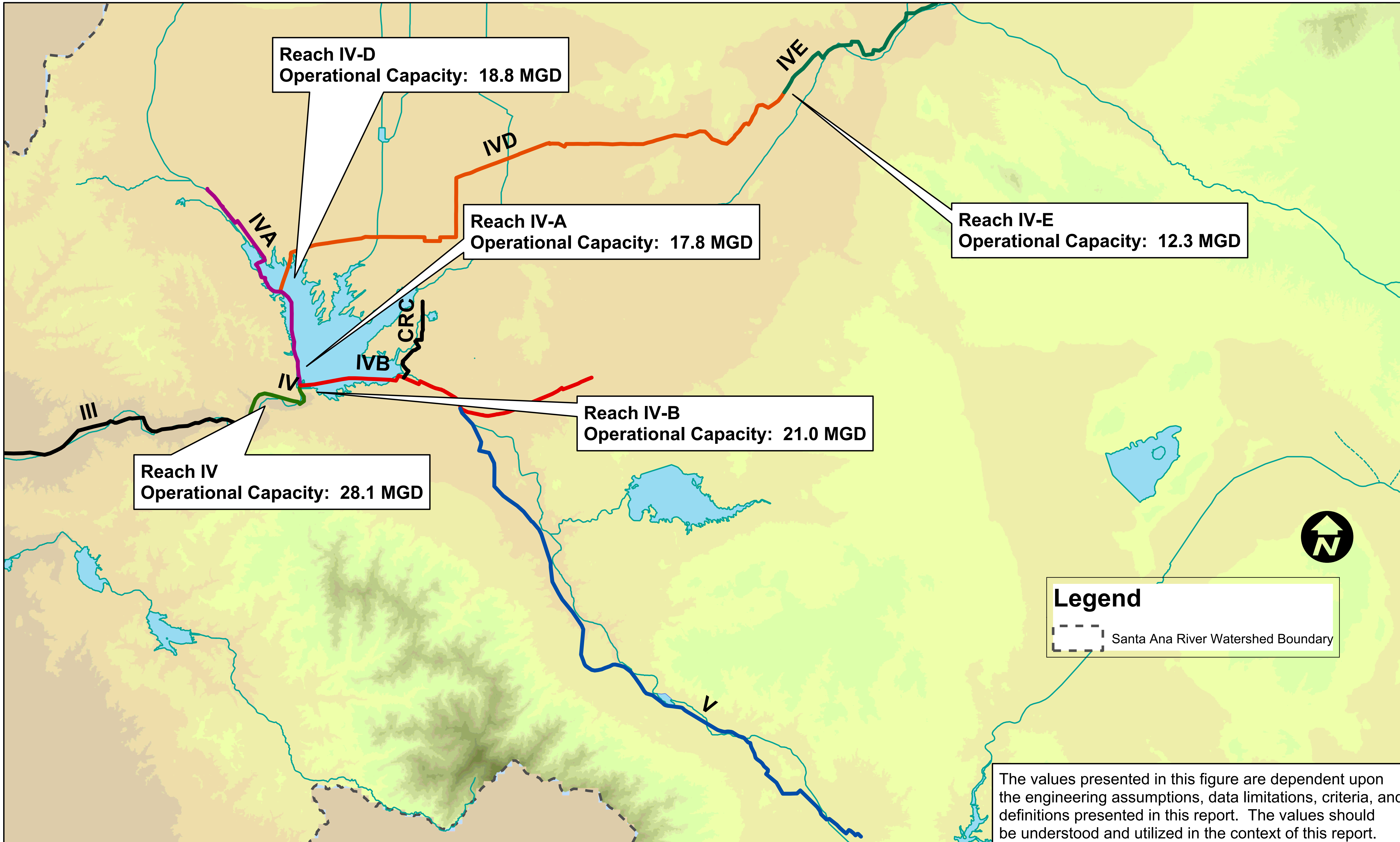

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Figure 16
Maximum Operating Flows

Section 9: Capital Improvement Projects

9.1 High-Flow Impact on the SARI Piping System

A program of manhole inspection in areas where future surcharging is expected to occur is recommended. This inspection could be performed as a portion of the annual O&M program.

The need for the manhole inspection program is driven by the fact that, as discussed above, the theoretical capacity of the Upper SARI system has been estimated by modeling to approach maximum theoretical capacity. To come close to this level of flow requires operation at full or near-full pipe flow in most reaches of the alignment. Where steeply sloping pipeline alignments exist, the depth of flow is reduced. Because the depth of flow is lower, the resulting velocity is necessarily higher to transport the same volume of water. In reaches of the pipeline where the topography is gently sloping or flat, the flow backs up into the manhole barrels in a surcharge condition.

These areas were examined to determine if the added level of surcharging of manholes could create a chance of an overflow as the allowable capacity of the pipe is approached. A number of manholes were identified with rim (ground surface elevation) elevations below the hydraulic grade line (expected water surface).

SAWPA staff was queried about these locations, and staff members indicated that the manholes are already constructed in a pressure-rated watertight configuration. This configuration tends to consist of a manhole with the SARI pipeline running continuously through it. At the approximate center of the manhole, a vertical standing tee with a flanged outlet has been installed in the pipeline. A blind flange has been bolted to the flanged outlet to make a watertight connection. Access to the pipeline can be obtained only by removing the blind flange. The only purpose of the manhole in this location is to provide an access point to the vertical tee and blind flange assembly.

Manholes have been identified where the surcharge conditions in the pipeline will cause flow to back up vertically into the open barrels of manholes to a height of a few feet or more. Most of the manholes that will be surcharged were installed with a PVC or similar lining system to prevent corrosion. It is expected that the manholes were water tested at the time of installation; however, this is not certain.

Since the nature of the waste is considered to be industrial and hazardous, the release of effluent through joints between the manhole barrel and the base and between manhole rings should be prevented.

Effluent surcharging in the manholes that are not configured to be internally pressure-tight should not be allowed to rise to the level above which cast-in-place or manhole barrel construction ends. Between this location and the manhole lid and casting, pre-cast grade rings are typically used to match the top of the manhole with the ground surface. Seldom are these grade rings installed to prevent infiltration or exfiltration as the pipeline ages. Problems with the cement grout seal used to connect one to the other typically allow them to leak. It is not unusual to see up to 3 feet of grade rings stacked vertically on top of precast or cast-in-place manhole barrels in many systems.

During annual general maintenance activities a log book of manhole problems could be developed, which would include the depth of grade rings and other areas of potential concern.

It should also be noted that a number of manholes have been constructed to prevent outside flow from entering the SARI system during rainfall or flood conditions. The most notable of these manholes exist above the Prado Dam, which is currently being raised. These manholes are at the branch of Reaches IV and IV-B and include manholes upstream on each reach. Because the manholes are in the main portion of the water pool behind the dam, they will be exposed to substantial head and the potential for leakage. The same condition exists in the pipelines that traverse the area underneath the pool. The head on the external joints between the pipe barrels will be significantly greater than has been applied previously. During filling of the dam, monitoring of outflows from the SARI pipeline to insure that they stay at normal levels may be appropriate.

It should also be noted that a siphon over the La Sierra Drainage canal in the upper area of Reach IV-B will restrict the future allowable flow contribution above this location. Maintenance and engineering personnel indicate that this area carries the flow of a single desalter facility

(Arlington Desalter) and that the SARI would be improved only in response to siting of a new discharger upstream of this location. Accordingly, there has been no development of a plan and an associated cost estimate to remedy this area of flow restriction.

9.2 Recommended Capital Improvements to Undertake Now

The work discussed in this report indicates that there are no specific added improvements be undertaken currently to increase the capacity of the SARI pipeline. Areas that were identified as being susceptible to overflow as a peak flow rate is approached are already being modified (Prado Dam impoundment and immediate downstream reach) or have internal pressure-rated watertight manholes in existence. The siphon in the upper part of Reach IV-B will not require capacity-increasing improvements until an additional user is sited above the area of restriction.

We suggest that a series of steps be taken as a part of the annual O&M program to identify and replace corroded or defective valves (principally air and vacuum relief valves). We also suggest a comprehensive inspection of manhole integrity and watertightness, especially in areas where surcharging is likely. A database of issues to correct should be developed, followed by a plan of maintenance to undertake the repairs.

9.3 Recommended Capital Improvements to Consider for the Future

When the flow rate of 30 mgd is approached in the Upper SARI system, the ability of the piping network to store flows from peaking discharges, and to attenuate these flows over the long run of piping, will be effectively removed. The factor of safety available today within the piping system to prevent overflows will be lost.

It is seldom recommended that a pipeline be operated while approaching its maximum capacity with an absolute expectation that overflows from the system will never occur. The operating histories of other gravity systems operated at or above full pipe capacity, and with overflow points at low-lying manholes similar to the SARI system, indicates that SAWPA should consider the potential for overflow.

Appendix A: Scope of Work

Task 1 – Build and Load Model

A hydraulic model comprises two basic sets of data: the physical system to be modeled (gravity pipes, force mains, outfalls, pumps, manholes, etc) and the flows to be modeled. Task 1 encompasses the steps necessary to accurately build the physical model and to load the correct flows at the correct places in the system. The following subtasks are part of this task:

Subtask 1.1 Build Physical Schematic

The SARI line physical data currently exists in excel spreadsheet format, broken down by reach and contract. Each pipe listed in the spreadsheet will be drawn in AutoCAD format to the length specified by the spreadsheet. The pipes will connected as indicated by the data. The pipes will be drawn so that each reach is identifiable, but the pipes will not be truly spatially referenced. Points will be drawn at the intersection of the lines to represent manholes. The points will be labeled with unique identifiers according to the convention specified by SAWPA. When all pipes and manholes have been thus digitized, they will be imported into the model as separate layers. Physical connectivity will be established so that each pipe becomes linked with its upstream and downstream manholes. At this point, attribute data will be imported from the spreadsheet using the unique identifier to populate the model. Pipes will be populated with upstream and downstream invert elevations, slope, diameter, and material attributes. Manholes will be populated with manhole diameter and rim elevation information. Manhole sump elevation will be calculated from the lowest invert in the manhole according to a convention established by SAWPA.

Subtask 1.2 Verify Physical Schematic

The physical connectivity and attribute data will be verified to the extent allowed by the data. Test flows will be placed at the upstream end of each reach so that the hydraulic grade line (HGL) can be tracked and examined for inconsistencies that would indicate inaccurate data. Critical flow areas will be identified and the data for these areas will be checked according to record drawings for accuracy. Manholes that serve to tie multiple reaches together will receive particular attention because of their importance to the hydraulics. Inconsistent data that cannot be reconciled will be referred to SAWPA.

Subtask 1.3 Identify, Calculate, and Attach Flow Loads

In order to be a useful tool in the assessment of the capacity of the SARI system, the model must be able to represent both average and peak flow conditions within the system. To this end, a list of dischargers to the SARI system will be established. The list will include the unique identifier of the manhole to which the discharger's flows enter the system. For each discharger, the last 12 months of available data will be plotted. By examining the patterns in these flows, K/J will develop an Existing Average Day (EAD) flow for each discharger. For those dischargers for whom "strip" data showing diurnal patterns is available, an Existing Peak Day (EPD) flow will be developed. These loads will be attached to the correct model manhole using a table import and the unique identifiers of the model manholes.

Subtask 1.4 Verify Loads

The list of dischargers and discharge location will be provided to SAWPA for review. Model output at the downstream end of the SARI system will be checked versus historical field flows to verify that the model flows are reasonable and "in the ballpark" for pre-calibrated values.

Task 1 Deliverable

A plan view model schematic annotated with reach information, discharger location, uncalibrated flow at junctions, and uncalibrated flow through key areas of the system will be delivered. Profiles of key system areas will be delivered as well.

<u>Task 2 – Calibrate Model</u>

Calibration is the process by which modeled flows through the system are compared with known field values to verify that the model accurately represents field conditions. Calibration includes the following subtasks:

Subtask 2.1 Identify Calibration Points

By definition, calibration points must be chosen to correspond to areas of known flow in the system. SAWPA is currently collecting flow data at several points within the system. KJ will work with SAWPA to identify the unique identifiers of the manholes currently being monitored. These manholes will be calibration points. The outlet of the upper SARI system into the lower SARI system is monitored and will be a calibration point as well. Any other points of known flow will be identified and located according manhole to serve as calibration points.

Subtask 2.2 Develop Calibration Field Values

Once the calibration points throughout the system are known, flow data will be collected for each of the points. Because the model will be run for EAD and EPD flows, values representative of these conditions must be calculated at each point. In order to accomplish this, time series flows at each calibration point will be plotted. Typical days will be identified and values for these days will be averaged to develop EAD field flows. Peak daily values will be identified from the plots and will be developed into EPD field flows.

Subtask 2.3 Compare Model and Field Values

Tables will be developed showing each calibration point, the EAD and EPD field values, and the modeled values for these flows. The field and modeled values will also be shown on the schematic for spatial comparison. Percent difference values will be calculated at each calibration point.

Subtask 2.4 Assess Flows, Peaks, and I&I for Calibration

For those calibration points at which modeled and field flows differ significantly, possible relevant discharges upstream will be re-evaluated to determine possible reasons for the modeled and field flows not matching. For those dischargers that did not initially have diurnal data available, diurnal patterns may be assumed in order to calibrate EPF flows. Inflow and infiltration (I&I) will be investigated for those areas that consistently show modeled flows beneath field flows.

Task 2 Deliverable

The model schematic will be delivered showing calibration points, field values, and model values. A supplementary table will be delivered with the schematic detailing all assumptions and calibration adjustments made to discharges, peaks, and I&I in order to create a calibrated model.

<u>Task 3 – Create and Run Model Scenarios</u>

Model scenarios are the means by which we organize the future discharges and infrastructure changes whose effects we want to test on the calibrated model. The task of creating and running the model scenarios is composed of the following subtasks:

Subtask 3.1 Identify and Create Required Model Scenarios

In collaboration with SAWPA staff, K/J and SAWPA will identify scenarios to be modeled. This scope of work assumes that the number of modeled scenarios will be less than seven.

Subtask 3.2 Run Scenarios

Once the scenarios have been input in the model, each scenario will be run separately. Preliminary analysis of the results will be done after each model run to ensure that model behavior is as expected.

Subtask 3.3 Extract and Present Scenario Results

Results from each scenario will be extracted from the model and placed in tools such as spreadsheets and GIS shapefiles so that the results can be presented in easily understood visual format. Results will be displayed in the plan view schematic and in hydraulic profiles of key results.

Task 3 Deliverable

A table will be delivered detailing the composition and significance of each scenario. Schematics and profiles of key results will be delivered for SAWPA review.

<u>Task 4 – CIP Development</u>

The ultimate goal of this project is the development of a capital improvement program that recommends facilities to meet the ultimate projected flows of the SARI system. The hydraulic model scenarios run above will be used as tools in the development of the CIP. The following subtasks will be required:

Subtask 4.1 Identify Critical Infrastructure

The model results will be used in conjunction with discussion with SAWPA staff in order to determine the critical infrastructure in the SAWPA system. Critical infrastructure includes those entities that are existing capacity chokepoints.

Subtask 4.2 Assess Critical Infrastructure

Working in collaboration with SAWPA staff, K/J will evaluate existing SARI facilities to identify additional improvements required to support project wastewater flows within the SARI system. This effort will be performed with SAWPA staff through two (2) eight hour meetings held at SAWPA's offices.

Subtask 4.3 Develop CIP Based Upon Assessment

Where hydraulic deficiencies are found based upon the results of Task 3, capital improvements will be identified to alleviate the deficiencies. Alternative improvements will be delineated where available, and the focus will be on improvements that are integrated across the entire system. Capital costs will be identified for each proposed improvement. Recommended improvements will be remodeled, if relevant, to verify that they have the desired effect.

Task 4 Deliverable

A technical memorandum will be delivered listing the proposed capital improvements in tabular form, with description of each improvement. Schematics will be attached showing locations of improvements and their relationships to the overall system.

Task 5 – Project Communication

As discussed in the schedule section below, the deadlines required by this project require a very aggressive schedule. Tasks 1-4 will have to be completed under best case scenarios if the deadlines are to be met. To facilitate this schedule, project communication and cooperation between K/J and SAWPA will be of utmost importance. Project communication will consist of weekly conference calls or meetings between the project teams, as laid out in the schedule. In addition project communication will consist of K/J support for meetings and presentations so that the results of all of the above efforts can be communicated to decision makers.

Appendix B: Reach V Steady State Model Tables

Table 1 : Model Input Data

Pipe ID	Revised Downstream Station	From Invert (ft)	To Invert (ft)	Revised Length (ft)	Material	Diameter (in)	Comments
1	66.1	602.33	598.50	66.1	HDPE	26	
2	558.1	603.32	602.33	492	HDPE	26	Gate per Lee Slate
3	891.1	609.00	603.32	333	HDPE	26	
4	1097.1	609.50	609.00	206	HDPE	26	
5	2097.1	614.40	609.50	1000	HDPE	26	
6	2597.1	616.40	614.40	500	HDPE	26	
7	2897.1	618.00	616.40	300	HDPE	26	
8	3162.1	620.40	618.00	265	HDPE	26	
9	3475.1	611.36	620.40	313	HDPE	26	
10	3544.1	621.90	611.36	69	HDPE	26	
11	4067.1	621.90	621.90	523	HDPE	26	
12	4332.1	625.20	621.90	265	HDPE	26	
13	4870.1	626.78	625.20	538	HDPE	26	
14	5797.1	628.73	626.78	927	HDPE	26	
15	6137.1	633.90	628.73	340	HDPE	26	
16	6651.1	651.48	633.90	514	HDPE	26	
17	7047.1	672.93	651.48	396	HDPE	26	
328	7161.1	674.05	672.93	114	HDPE	26	
18	7177.1	697.04	674.05	16	PVC	24	
19	7516.1	705.10	697.04	339	PVC	24	
20	7817.46	714.41	705.10	301.36	PVC	24	
21	7997.1	732.50	714.41	179.64	PVC	24	
22	8722.1	728.00	732.50	725	PVC	24	
23	8744.59	727.20	728.00	22.49	PVC	24	
24	9149.1	719.00	727.20	404.51	PVC	24	
25	9687.1	708.43	719.00	538	PVC	24	
26	9927.1	708.10	708.43	240	PVC	24	
27	10147.1	713.99	708.10	220	PVC	24	
28	10507.1	715.85	713.99	360	PVC	24	
29	10797.1	718.63	715.85	290	PVC	24	
30	11022.1	742.25	718.63	225	PVC	24	
31	11427.1	745.91	742.25	405	PVC	24	
32	11582.1	746.27	745.91	155	PVC	24	
33	11762.1	748.63	746.27	180	PVC	24	
34	11902.1	749.43	748.63	140	PVC	24	
35	12162.1	756.45	749.43	260	PVC	24	
36	12412.1	758.56	756.45	250	PVC	24	
37	12667.1	765.51	758.56	255	PVC	24	
38	12827.1	786.54	765.51	160	PVC	24	
39	13587.1	792.00	786.54	760	PVC	24	
40	13687.1	792.40	792.00	100	PVC	24	
41	13747.1	791.00	792.40	60	PVC	24	
42	13787.1	817.00	791.00	40	PVC	24	
43	14587.1	818.48	817.00	800	PVC	24	
44	14707.1	832.91	818.48	120	PVC	24	
45	15097.1	848.00	832.91	390	PVC	24	
46	15697.1	850.20	848.00	600	PVC	24	
47	15867.1	862.49	850.20	170	PVC	24	
48	16097.1	882.20	862.49	230	PVC	24	
49	16657.1	882.39	882.20	560	PVC	24	
50	16717.1	891.06	882.39	60	PVC	24	
51	16847.1	894.89	891.06	130	PVC	24	
52	17297.1	897.30	894.89	450	PVC	30	
53	18047.1	900.00	897.30	750	PVC	30	
54	18162.1	900.07	900.00	115	PVC	30	
55	18232.1	896.00	900.07	70	PVC	30	
56	18347.1	900.28	896.00	115	PVC	30	
57	18597.1	898.50	900.28	250	PVC	30	
58	18707.1	900.57	898.50	110	PVC	30	
59	18907.1	900.84	900.57	200	PVC	30	
60	19152.1	890.40	900.84	245	PVC	30	
61	19397.1	889.89	890.40	245	PVC	30	
62	19862.1	886.99	889.89	465	PVC	30	
63	19997.1	885.31	886.99	135	PVC	30	
64	20237.1	868.50	885.31	240	PVC	30	
65	20797.1	866.98	868.50	560	PVC	30	
66	21197.1	865.09	866.98	400	PVC	30	
67	21497.1	862.24	865.09	300	PVC	30	
68	21667.1	854.90	862.24	170	PVC	30	

Table 1 : Model Input Data

Pipe ID	Revised Downstream Station	From Invert (ft)	To Invert (ft)	Revised Length (ft)	Material	Diameter (in)	Comments
69	21717.1	854.57	854.90	50	PVC	30	
70	22017.1	853.57	854.57	300	PVC	30	
71	22097.1	849.20	853.57	80	PVC	30	
72	22161.85	848.01	849.20	64.75	PVC	30	
73	22682.1	856.99	848.01	520.25	PVC	30	
74	23117.1	858.38	856.99	435	PVC	30	
75	23527.1	852.83	858.38	410	PVC	30	
76	23627.1	847.88	852.83	100	PVC	30	
77	23938.33	838.90	847.88	311.23	PVC	30	
78	24472.1	836.22	838.90	533.77	PVC	30	
79	24597.1	829.50	836.22	125	PVC	30	
80	24661.78	828.96	829.50	64.68	PVC	30	
81	25197.1	825.00	828.96	535.32	PVC	30	
82	25482.1	822.64	825.00	285	PVC	30	
83	25671.1	816.00	822.64	189	PVC	30	
84	25697.1	816.20	816.00	26	PVC	30	
85	25727.1	822.00	816.20	30	PVC	30	
86	25757.1	822.03	822.00	30	PVC	30	
87	25797.1	823.25	822.03	40	PVC	30	
88	25839.16	816.98	823.25	42.06	PVC	24	
89	25894.16	821.70	816.98	55	PVC	24	
90	25934.16	821.40	821.70	40	PVC	24	
91	26042.16	804.60	821.40	108	PVC	24	
92	26304.16	801.40	804.60	262	PVC	24	
93	26534.16	794.60	801.40	230	PVC	24	
94	26889.16	790.50	794.60	355	PVC	24	
95	27204.16	791.00	790.50	315	PVC	24	
96	27299.16	799.30	791.00	95	PVC	24	
97	27584.16	798.20	799.30	285	PVC	24	
98	27834.16	790.00	798.20	250	PVC	24	
99	27934.16	791.00	790.00	100	PVC	24	
100	28034.16	799.80	791.00	100	PVC	24	
101	28170.16	801.71	799.80	136	PVC	24	
102	28934.16	796.00	801.71	764	PVC	24	
103	29004.16	796.50	796.00	70	PVC	24	
104	29054.16	802.10	796.50	50	PVC	24	
105	29094.16	802.90	802.10	40	PVC	24	
106	29414.16	805.00	802.90	320	PVC	24	
107	29964.16	809.00	805.00	550	PVC	24	
108	30154.16	810.40	809.00	190	PVC	24	
109	30284.16	813.60	810.40	130	PVC	24	
110	30384.16	823.50	813.60	100	PVC	24	
111	30963.16	845.70	823.50	579	PVC	24	
112	31854.16	857.90	845.70	891	PVC	24	
113	32204.16	857.00	857.90	350	PVC	24	
114	32318.16	844.00	857.00	114	PVC	24	
115	32395.16	843.00	844.00	77	PVC	24	
116	32458.16	853.80	843.00	63	PVC	24	
117	32549.16	861.40	853.80	91	PVC	24	
118	32728.16	857.70	861.40	179	PVC	24	
119	33008.16	858.85	857.70	280	PVC	24	
120	33584.16	853.00	858.85	576	PVC	24	
121	33634.16	853.60	853.00	50	PVC	24	
122	33774.16	857.60	853.60	140	PVC	24	
123	33824.16	855.00	857.60	50	PVC	24	
124	34354.16	858.00	855.00	530	PVC	24	
125	34718.16	864.80	858.00	364	PVC	24	
126	34796.16	875.00	864.80	78	PVC	24	
127	35369.16	881.70	875.00	573	PVC	24	
128	36001.16	903.80	881.70	632	PVC	24	
129	36889.16	901.00	903.80	888	PVC	24	
130	37594.16	911.00	901.00	705	PVC	24	
131	38122.16	915.50	911.00	528	PVC	24	
132	38482.16	918.30	915.50	360	PVC	24	
133	38634.16	923.60	918.30	152	PVC	24	
134	39124.16	924.00	923.60	490	PVC	24	
135	39234.16	916.00	924.00	110	PVC	24	
136	39280.16	916.00	916.00	46	PVC	24	
137	39341.16	922.30	916.00	61	PVC	24	

Table 1 : Model Input Data

Pipe ID	Revised Downstream Station	From Invert (ft)	To Invert (ft)	Revised Length (ft)	Material	Diameter (in)	Comments
138	39372.76	923.60	922.30	31.6	PVC	24	
139	39814.16	926.10	923.60	441.4	PVC	24	
140	40740.26	921.70	926.10	549	PVC	24	
141	40884.16	924.10	921.70	521	PVC	24	
142	40912.16	922.30	924.10	28	PVC	24	
143	41154.16	917.45	922.30	242	PVC	24	
144	41594.16	908.00	917.45	440	PVC	24	
145	41794.16	900.00	908.00	260	PVC	24	
146	42104.16	900.00	900.00	190	PVC	24	
147	42154.16	901.80	900.00	68	PVC	24	
148	42214.16	917.40	901.80	102	PVC	24	
149	42664.16	918.45	917.40	370	PVC	24	
150	42834.16	914.25	918.45	130	PVC	24	
151		910.50	914.25	156	PVC	24	
329	43013.16	911.00	910.50	143	PVC	24	
152	43486.16	919.49	911.00	473	PVC	24	
153	43864.16	920.40	919.49	378	PVC	24	
154	44434.16	922.60	920.40	570	PVC	24	
155	45119.66	943.60	922.60	685.5	PVC	24	
156	45855.16	934.50	943.60	735.5	PVC	24	
157	45984.16	935.00	934.50	129	PVC	24	
158	46014.16	944.90	935.00	30	PVC	24	
159	46120.16	948.20	944.90	106	PVC	24	
160	46234.16	956.00	948.20	114	PVC	24	
161	46624.16	948.00	956.00	390	PVC	24	
162	46704.16	949.00	948.00	80	PVC	24	
163	46794.16	956.80	949.00	90	PVC	24	
164	46874.16	960.40	956.80	80	PVC	24	
165	47004.16	966.00	960.40	130	PVC	24	
166	47144.16	969.50	966.00	140	PVC	24	
167	47174.16	976.00	969.50	30	PVC	24	
168	47364.16	981.50	976.00	190	PVC	24	
169	47447.16	984.64	981.50	83	PVC	24	
170	47754.16	989.80	984.64	307	PVC	24	
171	47884.16	994.50	989.80	130	PVC	24	
172	47934.16	1002.50	994.50	50	PVC	24	
173	48154.16	1006.78	1002.50	220	PVC	24	
174	48364.16	1013.00	1006.78	210	PVC	24	
175	48414.16	1045.10	1013.00	50	PVC	24	
176	49664.16	1047.00	1045.10	1250	PVC	24	
177	49909.16	1051.00	1047.00	245	PVC	24	
178	50034.16	1062.10	1051.00	125	PVC	24	
179	50474.16	1065.30	1062.10	440	PVC	24	
180	50794.16	1050.00	1065.30	320	PVC	24	
181	50894.16	1050.80	1050.00	100	PVC	24	
182	50964.16	1069.00	1050.80	70	PVC	24	
183	51166.16	1070.10	1069.00	202	PVC	24	
184	51339.16	1074.80	1070.10	173	PVC	24	
185	51514.16	1077.00	1074.80	175	PVC	24	
186	51729.16	1075.00	1077.00	215	PVC	24	
187	51834.16	1079.00	1075.00	105	PVC	24	
188	52034.16	1073.00	1079.00	200	PVC	24	
189	52134.16	1075.00	1073.00	100	PVC	24	
190	52334.16	1083.25	1075.00	200	PVC	24	
191	52412.06	1082.93	1083.25	77.9	PVC	24	
192	52465.06	1080.32	1082.93	53	HDPE	26	
193	52522.06	1080.34	1080.32	57	HDPE	26	
194	52542.06	1086.05	1080.34	20	HDPE	26	
195	52662.06	1088.30	1086.05	120	HDPE	26	
196	52902.06	1097.80	1088.30	240	HDPE	26	
197	53182.06	1099.20	1097.80	280	HDPE	26	
198	53582.06	1092.05	1099.20	400	HDPE	26	
199	53962.06	1086.11	1092.05	380	HDPE	26	
200	54129.06	1083.50	1086.11	167	HDPE	26	
201	54169.06	1080.19	1083.50	40	HDPE	26	
202	54357.06	1078.35	1080.19	188	HDPE	26	
203	54439.06	1076.25	1078.35	82	HDPE	26	
204	54642.06	1076.14	1076.25	203	HDPE	26	
205	54991.06	1070.40	1076.14	349	HDPE	26	

Table 1 : Model Input Data

Pipe ID	Revised Downstream Station	From Invert (ft)	To Invert (ft)	Revised Length (ft)	Material	Diameter (in)	Comments
206	55332.06	1067.00	1070.40	341	HDPE	26	
207	55492.06	1060.40	1067.00	160	HDPE	26	
208	55962.06	1055.20	1060.40	470	HDPE	26	
209	56472.06	1036.60	1055.20	510	HDPE	26	
210	57202.06	1021.40	1036.60	730	HDPE	26	
211	57662.06	1020.07	1021.40	460	HDPE	26	
212	57962.06	1009.50	1020.07	300	HDPE	26	
213	58462.06	1002.40	1009.50	500	HDPE	26	
214	58932.06	999.40	1002.40	470	HDPE	26	
215	59312.06	1000.76	999.40	380	HDPE	26	
216	59512.06	1003.00	1000.76	200	HDPE	26	
217	59562.06	1003.56	1003.00	50	HDPE	26	
218	60212.06	1010.68	1003.56	650	HDPE	26	
219	61012.06	1014.61	1010.68	800	HDPE	26	
220	61422.06	1019.92	1014.61	410	HDPE	26	
221	61712.06	1027.22	1019.92	290	HDPE	26	
222	62032.56	1050.96	1027.22	320.5	HDPE	26	
223	62712.06	1089.00	1050.96	679.5	HDPE	26	
224	63672.06	1091.50	1089.00	960	HDPE	26	
225	63772.06	1098.00	1091.50	100	HDPE	26	
226	63922.06	1103.00	1098.00	150	HDPE	26	
227	64022.06	1104.80	1103.00	100	HDPE	26	
228	64122.06	1111.40	1104.80	100	HDPE	26	Gate per spreadsheet
229	64222.06	1131.80	1111.40	100	HDPE	26	
230	64652.06	1147.82	1131.80	430	HDPE	26	
231	65052.06	1148.31	1147.82	400	HDPE	26	
232	65417.64	1147.07	1148.31	365.58	HDPE	26	
233	65532.06	1132.92	1147.07	114.42	HDPE	26	
234	65942.06	1130.53	1132.92	410	HDPE	26	
235	66092.06	1130.30	1130.53	150	HDPE	26	
236	66132.06	1118.80	1130.30	40	HDPE	26	
237	66362.06	1119.00	1118.80	230	HDPE	26	
238	66412.06	1128.00	1119.00	50	HDPE	26	
239	66422.06	1129.36	1128.00	10	HDPE	26	
240	66652.06	1132.60	1129.36	230	HDPE	26	
241	66800.21	1134.68	1132.60	148.15	HDPE	26	
242	66952.06	1134.58	1134.68	189	HDPE	26	
330		1134.53	1134.58	95.59	HDPE	26	
243	67047.65	1126.00	1134.53	19.17	HDPE	26	
244	67080.06	1116.12	1126.00	18	HDPE	26	
331		1116.60	1116.12	64	HDPE	26	
245	67176.06	1137.00	1116.60	96	HDPE	26	
246	67412.06	1138.10	1137.00	236	HDPE	26	
247	67572.06	1149.80	1138.10	160	HDPE	26	
248	67862.06	1151.02	1149.80	290	HDPE	26	
249	68042.06	1159.50	1151.02	180	HDPE	26	
250	68262.06	1163.90	1159.50	220	HDPE	26	
251	68952.06	1163.40	1163.90	690	HDPE	26	
252	69232.06	1159.00	1163.40	280	HDPE	26	
253	69432.06	1159.00	1159.00	200	HDPE	26	
254	69562.06	1159.00	1159.00	130	HDPE	26	
255	69712.06	1157.32	1159.00	150	HDPE	26	
256	70067.06	1146.06	1157.32	355	HDPE	26	
257	70292.06	1142.26	1146.06	225	HDPE	26	
258	70462.06	1143.80	1142.26	170	HDPE	26	
259	70532.06	1148.45	1143.80	70	HDPE	26	
260	70642.06	1165.75	1148.45	110	HDPE	26	
261	70962.06	1172.97	1165.75	320	HDPE	26	
262	71342.06	1173.84	1172.97	380	HDPE	26	
263	72062.06	1174.06	1173.84	720	HDPE	26	
264	72242.06	1178.00	1174.06	180	HDPE	26	
265	72351.99	1178.67	1178.00	109.93	HDPE	26	
266	72885.56	1182.67	1178.67	533.57	HDPE	26	
267	73045.56	1185.47	1182.67	160	HDPE	26	
268	73138.06	1191.00	1185.47	92.5	HDPE	26	
269	73321.01	1192.00	1191.00	182.95	HDPE	26	
270	73431.01	1198.40	1192.00	110	HDPE	26	
271	73651.01	1201.68	1198.40	220	HDPE	26	
272	74111.56	1203.20	1201.68	460.55	HDPE	26	

Table 1 : Model Input Data

Pipe ID	Revised Downstream Station	From Invert (ft)	To Invert (ft)	Revised Length (ft)	Material	Diameter (in)	Comments
273	74474.01	1184.07	1203.20	362.45	HDPE	26	
274	75121.09	1171.46	1184.07	647.08	HDPE	26	
275	75515.96	1168.00	1171.46	394.87	HDPE	26	
276	75803.37	1167.70	1168.00	287.41	HDPE	26	
277	75907.37	1170.00	1167.70	104	HDPE	26	
278	75993.37	1174.00	1170.00	86	HDPE	26	
279	76243.37	1174.50	1174.00	250	HDPE	26	
280	76488.37	1167.00	1174.50	245	HDPE	26	
281	76693.37	1166.75	1167.00	205	HDPE	26	
282	76843.37	1162.25	1166.75	150	HDPE	26	
283	77043.37	1162.20	1162.25	200	HDPE	26	
284	77182.69	1161.25	1162.20	139.32	HDPE	26	
285	77243.37	1166.30	1161.25	60.68	HDPE	26	
286	77443.37	1167.00	1166.30	200	HDPE	26	
287	77728.37	1172.00	1167.00	285	HDPE	26	
288	77923.37	1177.00	1172.00	195	HDPE	26	
289	78293.37	1178.00	1177.00	370	HDPE	26	
290	78573.37	1178.63	1178.00	280	HDPE	26	
291	78643.37	1179.05	1178.63	70	HDPE	26	
292	78736.37	1180.29	1179.05	93	HDPE	26	
293	78803.37	1187.00	1180.29	67	HDPE	26	
294	79293.37	1187.80	1187.00	490	HDPE	26	
295	79343.37	1188.22	1187.80	50	HDPE	26	
296	79763.37	1185.35	1188.22	420	HDPE	26	
297	79968.37	1191.20	1185.35	205	HDPE	26	
298	80002.41	1212.67	1191.20	34.04	HDPE	26	
299	80702.41	1197.10	1212.67	700	HDPE	26	
300	81852.41	1211.00	1197.10	1150	HDPE	26	
301	84302.41	1205.60	1211.00	2450	HDPE	26	
302	84713.41	1205.20	1205.60	411	HDPE	26	
303	84811.41	1225.29	1205.20	98	HDPE	26	
304	87402.41	1356.10	1225.29	1524.1	HDPE	26	Gate per spreadsheet
305	94202.41	1343.58	1356.10	6275.68	HDPE	26	
306	94602.41	1374.04	1343.58	400	HDPE	26	
307	96202.41	1317.00	1374.04	1600	HDPE	26	
308	98102.41	1329.94	1317.00	1900	PVC	30	
309	98702.41	1305.75	1329.94	600	PVC	30	
310	99852.41	1262.60	1305.75	1150	PVC	30	
311	101829.41	1253.50	1262.60	1977.71	PVC	30	
312	102629.41	1251.20	1253.50	782.35	PVC	30	
313	104329.41	1305.85	1251.20	1700	PVC	30	
314	105879.41	1290.50	1305.85	1550	PVC	30	
315	106379.41	1312.00	1290.50	500	PVC	30	
316	106629.41	1247.50	1312.00	250	PVC	30	
317	108557.41	1239.40	1247.50	1928	PVC	30	
318	108565.41	1240.00	1239.40	8	PVC	30	
319	108979.41	1251.96	1240.00	414	HDPE	26	
320	108991.41	1252.00	1251.96	12	PVC	30	
321	112329.41	1259.93	1252.00	3338	PVC	30	
322	113729.41	1255.00	1259.93	1400	PVC	30	
323	113748.41	1258.36	1255.00	19	PVC	30	
324	113929.41	1259.00	1258.36	181	PVC	30	
325	114569.41	1262.00	1259.00	640	PVC	30	
326	114589.41	1278.65	1262.00	20	PVC	30	
327	116494.41	1279	1278.65	1905	PVC	30	
			1279.00				

Table 2 : 400 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
1	26	66.1	0.058	Free Surface	7.685	0.071	0.01	0.154	39,438.50
2	26	492	0.002	Free Surface	2.374	0.158	0.054	0.343	7,349.48
3	26	333	0.017	Free Surface	5.019	0.095	0.019	0.206	21,398.03
4	26	206	0.002	Free Surface	2.536	0.151	0.05	0.328	8,071.85
5	26	1,000.00	0.005	Free Surface	3.243	0.128	0.035	0.277	11,468.85
6	26	500	0.004	Free Surface	3.022	0.134	0.039	0.291	10,362.19
7	26	300	0.005	Free Surface	3.341	0.125	0.033	0.271	11,965.23
8	26	265	0.009	Free Surface	4.02	0.11	0.026	0.239	15,592.09
9	26	313	-0.029	Pressurized	0.242	1	1	2.167	400
10	26	69	0.153	Free Surface	10.764	0.057	0.006	0.123	64,035.01
11	26	523	0	Pressurized	0.242	1	1	2.167	400
12	26	265	0.012	Free Surface	4.492	0.102	0.022	0.222	18,283.35
13	26	538	0.003	Free Surface	2.712	0.145	0.045	0.313	8,878.90
14	26	927	0.002	Free Surface	2.411	0.157	0.053	0.34	7,514.48
15	26	340	0.015	Free Surface	4.818	0.098	0.02	0.211	20,203.54
16	26	514	0.034	Free Surface	6.397	0.08	0.013	0.174	30,300.49
17	26	396	0.054	Free Surface	7.503	0.072	0.01	0.156	38,131.84
328	26	114	0.01	Free Surface	4.14	0.108	0.025	0.234	16,239.71
18	24	16	1.437	Free Surface	23.755	0.037	0.003	0.074	158,646.72
19	24	339	0.024	Free Surface	5.696	0.097	0.02	0.194	20,407.48
20	24	301.36	0.031	Free Surface	6.242	0.091	0.017	0.182	23,262.35
21	24	179.64	0.101	Free Surface	9.423	0.069	0.01	0.138	41,999.04
22	24	725	-0.006	Pressurized	0.284	1	1	2	400
23	24	22.49	-0.036	Pressurized	0.284	1	1	2	400
24	24	404.51	-0.02	Pressurized	0.284	1	1	2	400
25	24	538	-0.02	Pressurized	0.284	1	1	2	400
26	24	240	-0.001	Pressurized	0.284	1	1	2	400
27	24	220	0.027	Free Surface	5.936	0.094	0.018	0.189	21,655.49
28	24	360	0.005	Free Surface	3.337	0.14	0.042	0.28	9,513.21
29	24	290	0.01	Free Surface	4.149	0.12	0.031	0.241	12,958.21
30	24	225	0.105	Free Surface	9.56	0.068	0.009	0.137	42,881.53
31	24	405	0.009	Free Surface	4.064	0.122	0.032	0.244	12,581.56
32	24	155	0.002	Free Surface	2.521	0.17	0.063	0.34	6,378.33
33	24	180	0.013	Free Surface	4.627	0.112	0.026	0.224	15,154.49
34	24	140	0.006	Free Surface	3.46	0.136	0.04	0.273	10,004.67
35	24	260	0.027	Free Surface	5.958	0.094	0.018	0.188	21,747.21
36	24	250	0.008	Free Surface	3.966	0.124	0.033	0.249	12,158.86
37	24	255	0.027	Free Surface	5.975	0.094	0.018	0.188	21,849.62
38	24	160	0.131	Free Surface	10.343	0.065	0.008	0.13	47,982.32
39	24	760	0.007	Free Surface	3.749	0.129	0.036	0.258	11,217.89
40	24	100	0.004	Free Surface	3.051	0.149	0.048	0.298	8,370.50
41	24	60	-0.023	Pressurized	0.284	1	1	2	400
42	24	40	0.65	Free Surface	18.028	0.045	0.004	0.089	106,703.41
43	24	800	0.002	Free Surface	2.328	0.179	0.07	0.359	5,692.56
44	24	120	0.12	Free Surface	10.02	0.066	0.009	0.132	45,894.87
45	24	390	0.039	Free Surface	6.754	0.086	0.015	0.173	26,033.58
46	24	600	0.004	Free Surface	2.959	0.152	0.05	0.304	8,014.15
47	24	170	0.072	Free Surface	8.394	0.075	0.011	0.149	35,585.50
48	24	230	0.086	Free Surface	8.905	0.072	0.01	0.143	38,743.69
49	24	560	0	Free Surface	1.276	0.274	0.164	0.548	2,437.84
50	24	60	0.144	Free Surface	10.684	0.063	0.008	0.127	50,310.14
51	24	130	0.029	Free Surface	6.139	0.092	0.018	0.184	22,716.91
52	30	450	0.005	Free Surface	3.282	0.104	0.023	0.261	17,561.19
53	30	750	0.004	Free Surface	2.856	0.115	0.028	0.287	14,398.02
54	30	115	0.001	Free Surface	1.532	0.176	0.068	0.44	5,920.41
55	30	70	-0.058	Pressurized	0.182	1	1	2.5	400
56	30	115	0.037	Free Surface	6.457	0.066	0.009	0.165	46,293.98
57	30	250	-0.007	Pressurized	0.182	1	1	2.5	400
58	30	110	0.019	Free Surface	5.087	0.077	0.012	0.193	32,918.53
59	30	200	0.001	Free Surface	2.027	0.145	0.045	0.363	8,816.95
60	30	245	-0.043	Pressurized	0.182	1	1	2.5	400
61	30	245	-0.002	Pressurized	0.182	1	1	2.5	400
62	30	465	-0.006	Pressurized	0.182	1	1	2.5	400
63	30	135	-0.012	Pressurized	0.182	1	1	2.5	400
64	30	240	-0.07	Pressurized	0.182	1	1	2.5	400
65	30	560	-0.003	Pressurized	0.182	1	1	2.5	400
66	30	400	-0.005	Pressurized	0.182	1	1	2.5	400

Table 2 : 400 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
67	30	300	-0.009	Pressurized	0.182	1	1	2.5	400
68	30	170	-0.043	Pressurized	0.182	1	1	2.5	400
69	30	50	-0.007	Pressurized	0.182	1	1	2.5	400
70	30	300	-0.003	Pressurized	0.182	1	1	2.5	400
71	30	80	-0.055	Pressurized	0.182	1	1	2.5	400
72	30	64.75	-0.018	Pressurized	0.182	1	1	2.5	400
73	30	520.25	0.017	Free Surface	4.937	0.079	0.013	0.197	31,527.07
74	30	435	0.003	Free Surface	2.74	0.118	0.029	0.295	13,564.83
75	30	410	-0.014	Pressurized	0.182	1	1	2.5	400
76	30	100	-0.05	Pressurized	0.182	1	1	2.5	400
77	30	311.23	-0.029	Pressurized	0.182	1	1	2.5	400
78	30	533.77	-0.005	Pressurized	0.182	1	1	2.5	400
79	30	125	-0.054	Pressurized	0.182	1	1	2.5	400
80	30	64.68	-0.008	Pressurized	0.182	1	1	2.5	400
81	30	535.32	-0.007	Pressurized	0.182	1	1	2.5	400
82	30	285	-0.008	Pressurized	0.182	1	1	2.5	400
83	30	189	-0.035	Pressurized	0.182	1	1	2.5	400
84	30	26	0.008	Pressurized	3.724	0.096	0.019	0.239	21,046.50
85	30	30	0.193	Free Surface	11.444	0.045	0.004	0.112	105,512.74
86	30	30	0.001	Free Surface	1.823	0.156	0.053	0.39	7,588.42
87	30	40	0.03	Free Surface	6.023	0.069	0.01	0.173	41,908.44
88	24	42.06	-0.149	Pressurized	0.284	1	1	2	400
89	24	55	0.086	Pressurized	8.917	0.072	0.01	0.143	38,771.38
90	24	40	-0.007	Pressurized	0.284	1	1	2	400
91	24	108	-0.156	Pressurized	0.284	1	1	2	400
92	24	262	-0.012	Pressurized	0.284	1	1	2	400
93	24	230	-0.03	Pressurized	0.284	1	1	2	400
94	24	355	-0.012	Pressurized	0.284	1	1	2	400
95	24	315	0.002	Pressurized	2.206	0.186	0.076	0.373	5,272.92
96	24	95	0.087	Free Surface	8.973	0.071	0.01	0.143	39,120.00
97	24	285	-0.004	Pressurized	0.284	1	1	2	400
98	24	250	-0.033	Pressurized	0.284	1	1	2	400
99	24	100	0.01	Pressurized	4.211	0.119	0.03	0.239	13,234.93
100	24	100	0.088	Free Surface	8.996	0.071	0.01	0.142	39,261.14
101	24	136	0.014	Free Surface	4.741	0.11	0.026	0.22	15,684.43
102	24	764	-0.007	Pressurized	0.284	1	1	2	400
103	24	70	0.007	Pressurized	3.739	0.129	0.036	0.259	11,185.56
104	24	50	0.112	Free Surface	9.779	0.067	0.009	0.135	44,292.54
105	24	40	0.02	Free Surface	5.366	0.101	0.021	0.202	18,717.02
106	24	320	0.007	Free Surface	3.633	0.132	0.037	0.264	10,721.52
107	24	550	0.007	Free Surface	3.765	0.129	0.035	0.258	11,286.79
108	24	190	0.007	Free Surface	3.78	0.128	0.035	0.257	11,360.80
109	24	130	0.025	Free Surface	5.765	0.096	0.019	0.193	20,764.67
110	24	100	0.099	Free Surface	9.373	0.069	0.01	0.138	41,642.73
111	24	579	0.038	Free Surface	6.726	0.087	0.015	0.173	25,915.45
112	24	891	0.014	Free Surface	4.695	0.111	0.026	0.221	15,486.84
113	24	350	-0.003	Pressurized	0.284	1	1	2	400
114	24	114	-0.114	Pressurized	0.284	1	1	2	400
115	24	77	-0.013	Pressurized	0.284	1	1	2	400
116	24	63	0.171	Free Surface	11.341	0.061	0.007	0.122	54,797.81
117	24	91	0.084	Free Surface	8.828	0.072	0.01	0.144	38,247.91
118	24	179	-0.021	Pressurized	0.284	1	1	2	400
119	24	280	0.004	Pressurized	3.08	0.148	0.047	0.296	8,481.87
120	24	576	-0.01	Pressurized	0.284	1	1	2	400
121	24	50	0.012	Pressurized	4.483	0.114	0.028	0.229	14,498.14
122	24	140	0.029	Pressurized	6.074	0.093	0.018	0.186	22,371.11
123	24	50	-0.052	Pressurized	0.284	1	1	2	400
124	24	530	0.006	Pressurized	3.446	0.137	0.04	0.274	9,957.36
125	24	364	0.019	Free Surface	5.235	0.103	0.022	0.206	18,089.45
126	24	78	0.131	Free Surface	10.314	0.065	0.008	0.13	47,860.19
127	24	573	0.012	Free Surface	4.445	0.115	0.028	0.23	14,311.39
128	24	632	0.035	Free Surface	6.516	0.089	0.016	0.177	24,749.09
129	24	888	-0.003	Pressurized	0.284	1	1	2	400
130	24	705	0.014	Free Surface	4.756	0.11	0.025	0.219	15,762.57
131	24	528	0.009	Free Surface	3.977	0.124	0.033	0.248	12,218.30
132	24	360	0.008	Free Surface	3.855	0.127	0.034	0.253	11,672.11
133	24	152	0.035	Free Surface	6.509	0.089	0.016	0.177	24,713.70

Table 2 : 400 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
134	24	490	0.001	Free Surface	1.742	0.22	0.106	0.439	3,781.41
135	24	110	-0.073	Pressurized	0.284	1	1	2	400
136	24	46	0	Pressurized	0.284	1	1	2	400
137	24	61	0.103	Free Surface	9.51	0.069	0.009	0.137	42,533.09
138	24	31.6	0.041	Free Surface	6.897	0.085	0.015	0.17	26,844.16
139	24	441.4	0.006	Free Surface	3.451	0.137	0.04	0.273	9,960.37
140	24	549	-0.008	Pressurized	0.284	1	1	2	400
141	24	521	0.005	Pressurized	3.206	0.144	0.045	0.288	8,982.73
142	24	28	-0.064	Pressurized	0.284	1	1	2	400
143	24	242	-0.02	Pressurized	0.284	1	1	2	400
144	24	440	-0.021	Pressurized	0.284	1	1	2	400
145	24	260	-0.031	Pressurized	0.284	1	1	2	400
146	24	190	0	Pressurized	0.284	1	1	2	400
147	24	68	0.026	Pressurized	5.913	0.095	0.019	0.189	21,532.94
148	24	102	0.153	Free Surface	10.901	0.063	0.008	0.125	51,758.76
149	24	370	0.003	Free Surface	2.707	0.162	0.057	0.323	7,050.43
150	24	130	-0.032	Pressurized	0.284	1	1	2	400
151	24	156	-0.024	Pressurized	0.284	1	1	2	400
329	24	143	0.003	Pressurized	2.912	0.154	0.051	0.307	7,825.98
152	24	473	0.018	Free Surface	5.163	0.104	0.023	0.208	17,731.48
153	24	378	0.002	Free Surface	2.555	0.168	0.062	0.336	6,493.76
154	24	570	0.004	Free Surface	3.015	0.15	0.049	0.3	8,222.34
155	24	685.5	0.031	Free Surface	6.224	0.091	0.017	0.183	23,164.75
156	24	735.5	-0.012	Pressurized	0.284	1	1	2	400
157	24	129	0.004	Pressurized	3.019	0.15	0.049	0.3	8,239.71
158	24	30	0.33	Free Surface	14.242	0.052	0.005	0.104	76,028.88
159	24	106	0.031	Free Surface	6.254	0.091	0.017	0.182	23,352.08
160	24	114	0.068	Free Surface	8.234	0.076	0.012	0.151	34,619.16
161	24	390	-0.021	Pressurized	0.284	1	1	2	400
162	24	80	0.013	Pressurized	4.547	0.113	0.027	0.226	14,797.10
163	24	90	0.087	Free Surface	8.939	0.071	0.01	0.143	38,962.58
164	24	80	0.045	Free Surface	7.114	0.083	0.014	0.167	28,075.52
165	24	130	0.043	Free Surface	7.008	0.084	0.015	0.169	27,469.07
166	24	140	0.025	Free Surface	5.797	0.096	0.019	0.192	20,926.26
167	24	30	0.217	Free Surface	12.297	0.058	0.006	0.115	61,605.24
168	24	190	0.029	Free Surface	6.097	0.093	0.018	0.185	22,517.81
169	24	83	0.038	Free Surface	6.699	0.087	0.016	0.174	25,742.30
170	24	307	0.017	Free Surface	5.05	0.105	0.023	0.211	17,158.42
171	24	130	0.036	Free Surface	6.589	0.088	0.016	0.176	25,165.11
172	24	50	0.16	Free Surface	11.076	0.062	0.008	0.124	52,939.72
173	24	220	0.019	Free Surface	5.309	0.102	0.022	0.204	18,460.02
174	24	210	0.03	Free Surface	6.151	0.092	0.018	0.184	22,777.56
175	24	50	0.642	Free Surface	17.936	0.045	0.004	0.089	106,044.74
176	24	1,250.00	0.002	Free Surface	2.171	0.188	0.078	0.377	5,159.93
177	24	245	0.016	Free Surface	4.999	0.106	0.024	0.212	16,910.97
178	24	125	0.089	Free Surface	9.019	0.071	0.01	0.142	39,439.20
179	24	440	0.007	Free Surface	3.765	0.129	0.035	0.258	11,286.79
180	24	320	-0.048	Pressurized	0.284	1	1	2	400
181	24	100	0.008	Pressurized	3.893	0.126	0.034	0.252	11,837.68
182	24	70	0.26	Free Surface	13.112	0.055	0.006	0.11	67,485.16
183	24	202	0.005	Free Surface	3.402	0.138	0.041	0.276	9,766.58
184	24	173	0.027	Free Surface	5.97	0.094	0.018	0.188	21,814.61
185	24	175	0.013	Free Surface	4.562	0.113	0.027	0.226	14,839.32
186	24	215	-0.009	Pressurized	0.284	1	1	2	400
187	24	105	0.038	Free Surface	6.713	0.087	0.015	0.174	25,831.94
188	24	200	-0.03	Pressurized	0.284	1	1	2	400
189	24	100	0.02	Pressurized	5.366	0.101	0.021	0.202	18,717.02
190	24	200	0.041	Free Surface	6.905	0.085	0.015	0.17	26,880.27
191	24	77.9	-0.004	Pressurized	0.284	1	1	2	400
192	26	53	-0.049	Pressurized	0.242	1	1	2.167	400
193	26	57	0	Pressurized	1.28	0.244	0.13	0.528	3,069.02
194	26	20	0.285	Free Surface	13.394	0.049	0.005	0.106	87,543.68
195	26	120	0.019	Free Surface	5.185	0.093	0.018	0.201	22,434.81
196	26	240	0.04	Free Surface	6.725	0.078	0.012	0.168	32,597.02
197	26	280	0.005	Free Surface	3.266	0.127	0.035	0.276	11,585.29
198	26	400	-0.018	Pressurized	0.242	1	1	2.167	400
199	26	380	-0.016	Pressurized	0.242	1	1	2.167	400

Table 2 : 400 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
200	26	167	-0.016	Pressurized	0.242	1	1	2.167	400
201	26	40	-0.083	Pressurized	0.242	1	1	2.167	400
202	26	188	-0.01	Pressurized	0.242	1	1	2.167	400
203	26	82	-0.026	Pressurized	0.242	1	1	2.167	400
204	26	203	-0.001	Pressurized	0.242	1	1	2.167	400
205	26	349	-0.016	Pressurized	0.242	1	1	2.167	400
206	26	341	-0.01	Pressurized	0.242	1	1	2.167	400
207	26	160	-0.041	Pressurized	0.242	1	1	2.167	400
208	26	470	-0.011	Pressurized	0.242	1	1	2.167	400
209	26	510	-0.036	Pressurized	0.242	1	1	2.167	400
210	26	730	-0.021	Pressurized	0.242	1	1	2.167	400
211	26	460	-0.003	Pressurized	0.242	1	1	2.167	400
212	26	300	-0.035	Pressurized	0.242	1	1	2.167	400
213	26	500	-0.014	Pressurized	0.242	1	1	2.167	400
214	26	470	-0.006	Pressurized	0.242	1	1	2.167	400
215	26	380	0.004	Pressurized	2.906	0.138	0.041	0.299	9,801.65
216	26	200	0.011	Pressurized	4.332	0.105	0.023	0.227	17,339.27
217	26	50	0.011	Pressurized	4.332	0.105	0.023	0.227	17,339.27
218	26	650	0.011	Free Surface	4.295	0.105	0.023	0.229	17,147.67
219	26	800	0.005	Free Surface	3.243	0.128	0.035	0.277	11,479.08
220	26	410	0.013	Free Surface	4.556	0.101	0.021	0.22	18,650.90
221	26	290	0.025	Free Surface	5.743	0.087	0.015	0.188	25,994.66
222	26	320.5	0.074	Free Surface	8.366	0.067	0.009	0.145	44,591.09
223	26	679.5	0.056	Free Surface	7.588	0.072	0.01	0.155	38,765.67
224	26	960	0.003	Free Surface	2.6	0.149	0.048	0.322	8,360.96
225	26	100	0.065	Free Surface	7.997	0.069	0.01	0.15	41,771.34
226	26	150	0.033	Free Surface	6.34	0.081	0.013	0.175	29,913.08
227	26	100	0.018	Free Surface	5.111	0.094	0.018	0.203	21,981.53
228	26	100	0.066	Free Surface	8.039	0.069	0.01	0.149	42,091.43
229	26	100	0.204	Free Surface	11.907	0.053	0.005	0.115	74,000.87
230	26	430	0.037	Free Surface	6.588	0.079	0.013	0.171	31,624.14
231	26	400	0.001	Free Surface	1.993	0.179	0.07	0.387	5,734.42
232	26	365.58	-0.003	Pressurized	0.242	1	1	2.167	400
233	26	114.42	-0.124	Pressurized	0.242	1	1	2.167	400
234	26	410	-0.006	Pressurized	0.242	1	1	2.167	400
235	26	150	-0.002	Pressurized	0.242	1	1	2.167	400
236	26	40	-0.287	Pressurized	0.242	1	1	2.167	400
237	26	230	0.001	Pressurized	1.766	0.195	0.083	0.422	4,831.40
238	26	50	0.18	Free Surface	11.396	0.054	0.006	0.118	69,511.71
239	26	10	0.136	Free Surface	10.347	0.058	0.007	0.126	60,421.45
240	26	230	0.014	Free Surface	4.688	0.099	0.021	0.215	19,433.99
241	26	148.15	0.014	Free Surface	4.688	0.099	0.021	0.215	19,432.10
242	26	189	-0.001	Pressurized	0.242	1	1	2.167	400
330	26	95.59	-0.001	Pressurized	0.242	1	1	2.167	400
243	26	19.17	-0.445	Pressurized	0.242	1	1	2.167	400
244	26	64	-0.154	Pressurized	0.242	1	1	2.167	400
331	26	18	0.027	Pressurized	5.865	0.085	0.015	0.185	26,755.07
245	26	96	0.212	Free Surface	12.072	0.052	0.005	0.113	75,526.82
246	26	236	0.005	Free Surface	3.186	0.129	0.036	0.28	11,185.67
247	26	160	0.073	Free Surface	8.332	0.067	0.009	0.146	44,305.20
248	26	290	0.004	Free Surface	3.075	0.133	0.038	0.287	10,626.80
249	26	180	0.047	Free Surface	7.152	0.075	0.011	0.162	35,561.77
250	26	220	0.02	Free Surface	5.303	0.091	0.017	0.198	23,170.57
251	26	690	-0.001	Pressurized	0.242	1	1	2.167	400
252	26	280	-0.016	Pressurized	0.242	1	1	2.167	400
253	26	200	0	Pressurized	0.242	1	1	2.167	400
254	26	130	0	Pressurized	0.242	1	1	2.167	400
255	26	150	-0.011	Pressurized	0.242	1	1	2.167	400
256	26	355	-0.032	Pressurized	0.242	1	1	2.167	400
257	26	225	-0.017	Pressurized	0.242	1	1	2.167	400
258	26	170	0.009	Pressurized	4.02	0.11	0.026	0.239	15,594.00
259	26	70	0.066	Free Surface	8.06	0.069	0.009	0.149	42,227.87
260	26	110	0.157	Free Surface	10.885	0.056	0.006	0.122	64,975.32
261	26	320	0.023	Free Surface	5.535	0.089	0.016	0.192	24,610.21
262	26	380	0.002	Free Surface	2.487	0.153	0.051	0.332	7,848.53
263	26	720	0	Free Surface	1.216	0.253	0.14	0.548	2,850.91
264	26	180	0.022	Free Surface	5.474	0.089	0.017	0.194	24,240.05

Table 2 : 400 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
265	26	109.93	0.006	Free Surface	3.499	0.121	0.031	0.263	12,790.90
266	26	533.57	0.007	Free Surface	3.764	0.115	0.028	0.25	14,185.87
267	26	160	0.018	Free Surface	5.062	0.094	0.018	0.204	21,674.08
268	26	92.5	0.06	Free Surface	7.773	0.07	0.01	0.153	40,060.23
269	26	182.95	0.005	Free Surface	3.369	0.125	0.033	0.27	12,113.11
270	26	110	0.058	Free Surface	7.694	0.071	0.01	0.154	39,519.86
271	26	220	0.015	Free Surface	4.787	0.098	0.02	0.212	20,005.40
272	26	460.55	0.003	Free Surface	2.822	0.141	0.042	0.305	9,412.50
273	26	362.45	-0.053	Pressurized	0.242	1	1	2.167	400
274	26	647.08	-0.019	Pressurized	0.242	1	1	2.167	400
275	26	394.87	-0.009	Pressurized	0.242	1	1	2.167	400
276	26	287.41	-0.001	Pressurized	0.242	1	1	2.167	400
277	26	104	0.022	Pressurized	5.491	0.089	0.016	0.193	24,365.14
278	26	86	0.047	Free Surface	7.118	0.075	0.011	0.162	35,334.79
279	26	250	0.002	Free Surface	2.368	0.159	0.055	0.344	7,327.18
280	26	245	-0.031	Pressurized	0.242	1	1	2.167	400
281	26	205	-0.001	Pressurized	0.242	1	1	2.167	400
282	26	150	-0.03	Pressurized	0.242	1	1	2.167	400
283	26	200	0	Pressurized	0.242	1	1	2.167	400
284	26	139.32	-0.007	Pressurized	0.242	1	1	2.167	400
285	26	60.68	0.083	Free Surface	8.715	0.065	0.008	0.141	47,265.54
286	26	200	0.004	Free Surface	2.884	0.139	0.041	0.3	9,692.95
287	26	285	0.018	Free Surface	5.067	0.094	0.018	0.204	21,701.23
288	26	195	0.026	Free Surface	5.785	0.086	0.015	0.187	26,235.50
289	26	370	0.003	Free Surface	2.634	0.147	0.047	0.319	8,517.67
290	26	280	0.002	Free Surface	2.469	0.154	0.051	0.334	7,771.65
291	26	70	0.006	Free Surface	3.483	0.122	0.032	0.264	12,691.04
292	26	93	0.013	Free Surface	4.605	0.101	0.021	0.218	18,918.69
293	26	67	0.1	Free Surface	9.302	0.062	0.008	0.135	51,849.62
294	26	490	0.002	Free Surface	2.205	0.167	0.06	0.361	6,620.16
295	26	50	0.008	Free Surface	3.918	0.112	0.027	0.243	15,016.25
296	26	420	-0.007	Pressurized	0.242	1	1	2.167	400
297	26	205	0.029	Free Surface	6.003	0.084	0.014	0.182	27,677.24
298	26	34.04	0.631	Free Surface	17.627	0.041	0.003	0.088	130,119.67
299	26	700	-0.022	Pressurized	0.242	1	1	2.167	400
300	26	1,150.00	0.012	Free Surface	4.445	0.103	0.022	0.223	18,012.76
301	26	2,450.00	-0.002	Pressurized	0.242	1	1	2.167	400
302	26	411	-0.001	Pressurized	0.242	1	1	2.167	400
303	26	98	0.205	Free Surface	11.927	0.053	0.005	0.114	74,182.02
304	26	1,524.10	0.086	Free Surface	8.813	0.065	0.008	0.14	47,999.36
305	26	6,275.68	-0.002	Pressurized	0.242	1	1	2.167	400
306	26	400	0.076	Free Surface	8.457	0.067	0.009	0.144	45,212.31
307	26	1,600.00	-0.036	Pressurized	0.242	1	1	2.167	400
308	30	1,900.00	0.007	Free Surface	3.569	0.098	0.02	0.246	19,803.50
309	30	600	-0.04	Pressurized	0.182	1	1	2.5	400
310	30	1,150.00	-0.038	Pressurized	0.182	1	1	2.5	400
311	30	1,977.71	-0.005	Pressurized	0.182	1	1	2.5	400
312	30	782.35	-0.003	Pressurized	0.182	1	1	2.5	400
313	30	1,700.00	0.032	Free Surface	6.134	0.068	0.009	0.17	43,025.13
314	30	1,550.00	-0.01	Pressurized	0.182	1	1	2.5	400
315	30	500	0.043	Free Surface	6.789	0.064	0.008	0.159	49,760.62
316	30	250	-0.258	Pressurized	0.182	1	1	2.5	400
317	30	1,928.00	-0.004	Pressurized	0.182	1	1	2.5	400
318	30	8	0.075	Pressurized	8.236	0.056	0.006	0.14	65,717.67
319	26	414	0.029	Free Surface	6.029	0.084	0.014	0.181	27,847.56
320	30	12	0.003	Free Surface	2.782	0.117	0.029	0.292	13,854.50
321	30	3,338.00	0.002	Free Surface	2.471	0.127	0.034	0.316	11,696.21
322	30	1,400.00	-0.004	Pressurized	0.182	1	1	2.5	400
323	30	19	0.177	Pressurized	11.094	0.046	0.004	0.114	100,912.36
324	30	181	0.004	Pressurized	2.838	0.115	0.028	0.288	14,269.29
325	30	640	0.005	Free Surface	3.133	0.108	0.024	0.269	16,429.42
326	30	20	0.833	Free Surface	19.014	0.032	0.002	0.08	218,949.35
327	30	1,905.00	0	Free Surface	1.003	0.237	0.123	0.592	3,252.66

Table 3 : 6,600 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
1	26	66.1	0.058	Free Surface	17.677	0.277	0.167	0.6	39,438.50
2	26	492	0.002	Free Surface	5.025	0.74	0.898	1.604	7,349.48
3	26	333	0.017	Free Surface	11.383	0.381	0.308	0.826	21,398.03
4	26	206	0.002	Free Surface	5.441	0.688	0.818	1.49	8,071.85
5	26	1,000.00	0.005	Free Surface	7.175	0.544	0.575	1.179	11,468.85
6	26	500	0.004	Free Surface	6.637	0.58	0.637	1.256	10,362.19
7	26	300	0.005	Free Surface	7.406	0.53	0.552	1.149	11,965.23
8	26	265	0.009	Free Surface	9.03	0.454	0.423	0.984	15,592.09
9	26	313	-0.029	Pressurized	3.988	1	1	2.167	6,600.00
10	26	69	0.153	Free Surface	24.965	0.217	0.103	0.47	64,035.01
11	26	523	0	Pressurized	3.988	1	1	2.167	6,600.00
12	26	265	0.012	Free Surface	10.149	0.416	0.361	0.9	18,283.35
13	26	538	0.003	Free Surface	5.873	0.643	0.743	1.392	8,878.90
14	26	927	0.002	Free Surface	5.125	0.727	0.878	1.574	7,514.48
15	26	340	0.015	Free Surface	10.93	0.393	0.327	0.852	20,203.54
16	26	514	0.034	Free Surface	14.653	0.317	0.218	0.687	30,300.49
17	26	396	0.054	Free Surface	17.271	0.281	0.173	0.61	38,131.84
328	26	114	0.01	Free Surface	9.304	0.444	0.406	0.962	16,239.71
18	24	16	1.437	Free Surface	55.488	0.139	0.042	0.278	158,646.72
19	24	339	0.024	Free Surface	12.913	0.391	0.323	0.782	20,407.48
20	24	301.36	0.031	Free Surface	14.2	0.365	0.284	0.729	23,262.35
21	24	179.64	0.101	Free Surface	21.704	0.268	0.157	0.536	41,999.04
22	24	725	-0.006	Pressurized	4.681	1	1	2	6,600.00
23	24	22.49	-0.036	Pressurized	4.681	1	1	2	6,600.00
24	24	404.51	-0.02	Pressurized	4.681	1	1	2	6,600.00
25	24	538	-0.02	Pressurized	4.681	1	1	2	6,600.00
26	24	240	-0.001	Pressurized	4.681	1	1	2	6,600.00
27	24	220	0.027	Free Surface	13.476	0.379	0.305	0.758	21,655.49
28	24	360	0.005	Free Surface	7.286	0.613	0.694	1.226	9,513.21
29	24	290	0.01	Free Surface	9.235	0.505	0.509	1.011	12,958.21
30	24	225	0.105	Free Surface	22.041	0.265	0.154	0.53	42,881.53
31	24	405	0.009	Free Surface	9.025	0.515	0.525	1.029	12,581.56
32	24	155	0.002	Pressurized	4.681	1	1.035	2	6,378.33
33	24	180	0.013	Free Surface	10.38	0.461	0.436	0.923	15,154.49
34	24	140	0.006	Free Surface	7.581	0.593	0.66	1.186	10,004.67
35	24	260	0.027	Free Surface	13.523	0.378	0.303	0.756	21,747.21
36	24	250	0.008	Free Surface	8.803	0.525	0.543	1.05	12,158.86
37	24	255	0.027	Free Surface	13.57	0.377	0.302	0.754	21,849.62
38	24	160	0.131	Free Surface	23.876	0.25	0.138	0.501	47,982.32
39	24	760	0.007	Free Surface	8.273	0.552	0.588	1.104	11,217.89
40	24	100	0.004	Free Surface	6.573	0.67	0.788	1.34	8,370.50
41	24	60	-0.023	Pressurized	4.681	1	1	2	6,600.00
42	24	40	0.65	Free Surface	41.983	0.169	0.062	0.337	106,703.41
43	24	800	0.002	Pressurized	4.681	1	1.159	2	5,692.56
44	24	120	0.12	Free Surface	23.142	0.256	0.144	0.512	45,894.87
45	24	390	0.039	Free Surface	15.409	0.343	0.254	0.687	26,033.58
46	24	600	0.004	Free Surface	6.346	0.691	0.824	1.383	8,014.15
47	24	170	0.072	Free Surface	19.284	0.292	0.185	0.583	35,585.50
48	24	230	0.086	Free Surface	20.493	0.279	0.17	0.559	38,743.69
49	24	560	0	Pressurized	4.681	1	2.707	2	2,437.84
50	24	60	0.144	Free Surface	24.687	0.245	0.131	0.489	50,310.14
51	24	130	0.029	Free Surface	13.959	0.369	0.291	0.738	22,716.91
52	30	450	0.005	Free Surface	7.404	0.425	0.376	1.062	17,561.19
53	30	750	0.004	Free Surface	6.397	0.475	0.458	1.188	14,398.02
54	30	115	0.001	Pressurized	2.996	1	1.115	2.5	5,920.41
55	30	70	-0.058	Pressurized	2.996	1	1	2.5	6,600.00
56	30	115	0.037	Free Surface	14.891	0.255	0.143	0.638	46,293.98
57	30	250	-0.007	Pressurized	2.996	1	1	2.5	6,600.00
58	30	110	0.019	Free Surface	11.672	0.304	0.2	0.759	32,918.53
59	30	200	0.001	Free Surface	4.388	0.646	0.749	1.614	8,816.95
60	30	245	-0.043	Pressurized	2.996	1	1	2.5	6,600.00
61	30	245	-0.002	Pressurized	2.996	1	1	2.5	6,600.00
62	30	465	-0.006	Pressurized	2.996	1	1	2.5	6,600.00
63	30	135	-0.012	Pressurized	2.996	1	1	2.5	6,600.00
64	30	240	-0.07	Pressurized	2.996	1	1	2.5	6,600.00
65	30	560	-0.003	Pressurized	2.996	1	1	2.5	6,600.00
66	30	400	-0.005	Pressurized	2.996	1	1	2.5	6,600.00

Table 3 : 6,600 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
67	30	300	-0.009	Pressurized	2.996	1	1	2.5	6,600.00
68	30	170	-0.043	Pressurized	2.996	1	1	2.5	6,600.00
69	30	50	-0.007	Pressurized	2.996	1	1	2.5	6,600.00
70	30	300	-0.003	Pressurized	2.996	1	1	2.5	6,600.00
71	30	80	-0.055	Pressurized	2.996	1	1	2.5	6,600.00
72	30	64.75	-0.018	Pressurized	2.996	1	1	2.5	6,600.00
73	30	520.25	0.017	Free Surface	11.318	0.311	0.209	0.776	31,527.07
74	30	435	0.003	Free Surface	6.113	0.492	0.487	1.23	13,564.83
75	30	410	-0.014	Pressurized	2.996	1	1	2.5	6,600.00
76	30	100	-0.05	Pressurized	2.996	1	1	2.5	6,600.00
77	30	311.23	-0.029	Pressurized	2.996	1	1	2.5	6,600.00
78	30	533.77	-0.005	Pressurized	2.996	1	1	2.5	6,600.00
79	30	125	-0.054	Pressurized	2.996	1	1	2.5	6,600.00
80	30	64.68	-0.008	Pressurized	2.996	1	1	2.5	6,600.00
81	30	535.32	-0.007	Pressurized	2.996	1	1	2.5	6,600.00
82	30	285	-0.008	Pressurized	2.996	1	1	2.5	6,600.00
83	30	189	-0.035	Pressurized	2.996	1	1	2.5	6,600.00
84	30	26	0.008	Pressurized	8.448	0.385	0.314	0.962	21,046.50
85	30	30	0.193	Free Surface	26.674	0.17	0.063	0.424	105,512.74
86	30	30	0.001	Free Surface	3.882	0.721	0.87	1.802	7,588.42
87	30	40	0.03	Free Surface	13.873	0.268	0.157	0.671	41,908.44
88	24	42.06	-0.149	Pressurized	4.681	1	1	2	6,600.00
89	24	55	0.086	Pressurized	20.493	0.279	0.17	0.559	38,771.38
90	24	40	-0.007	Pressurized	4.681	1	1	2	6,600.00
91	24	108	-0.156	Pressurized	4.681	1	1	2	6,600.00
92	24	262	-0.012	Pressurized	4.681	1	1	2	6,600.00
93	24	230	-0.03	Pressurized	4.681	1	1	2	6,600.00
94	24	355	-0.012	Pressurized	4.681	1	1	2	6,600.00
95	24	315	0.002	Pressurized	4.681	1	1.252	2	5,272.92
96	24	95	0.087	Free Surface	20.644	0.278	0.169	0.556	39,120.00
97	24	285	-0.004	Pressurized	4.681	1	1	2	6,600.00
98	24	250	-0.033	Pressurized	4.681	1	1	2	6,600.00
99	24	100	0.01	Pressurized	9.385	0.499	0.499	0.998	13,234.93
100	24	100	0.088	Free Surface	20.695	0.277	0.168	0.555	39,261.14
101	24	136	0.014	Free Surface	10.643	0.453	0.421	0.905	15,684.43
102	24	764	-0.007	Pressurized	4.681	1	1	2	6,600.00
103	24	70	0.007	Pressurized	8.255	0.553	0.59	1.105	11,185.56
104	24	50	0.112	Free Surface	22.565	0.261	0.149	0.521	44,292.54
105	24	40	0.02	Free Surface	12.119	0.41	0.353	0.82	18,717.02
106	24	320	0.007	Free Surface	7.994	0.567	0.616	1.135	10,721.52
107	24	550	0.007	Free Surface	8.318	0.549	0.585	1.099	11,286.79
108	24	190	0.007	Free Surface	8.355	0.547	0.581	1.095	11,360.80
109	24	130	0.025	Free Surface	13.077	0.387	0.318	0.775	20,764.67
110	24	100	0.099	Free Surface	21.594	0.269	0.158	0.538	41,642.73
111	24	579	0.038	Free Surface	15.35	0.344	0.255	0.688	25,915.45
112	24	891	0.014	Free Surface	10.539	0.456	0.426	0.912	15,486.84
113	24	350	-0.003	Pressurized	4.681	1	1	2	6,600.00
114	24	114	-0.114	Pressurized	4.681	1	1	2	6,600.00
115	24	77	-0.013	Pressurized	4.681	1	1	2	6,600.00
116	24	63	0.171	Free Surface	26.228	0.234	0.12	0.469	54,797.81
117	24	91	0.084	Free Surface	20.294	0.281	0.173	0.563	38,247.91
118	24	179	-0.021	Pressurized	4.681	1	1	2	6,600.00
119	24	280	0.004	Pressurized	6.65	0.663	0.778	1.326	8,481.87
120	24	576	-0.01	Pressurized	4.681	1	1	2	6,600.00
121	24	50	0.012	Pressurized	10.035	0.474	0.455	0.947	14,498.14
122	24	140	0.029	Pressurized	13.811	0.372	0.295	0.744	22,371.11
123	24	50	-0.052	Pressurized	4.681	1	1	2	6,600.00
124	24	530	0.006	Pressurized	7.551	0.595	0.663	1.189	9,957.36
125	24	364	0.019	Free Surface	11.819	0.418	0.365	0.836	18,089.45
126	24	78	0.131	Free Surface	23.843	0.251	0.138	0.501	47,860.19
127	24	573	0.012	Free Surface	9.942	0.477	0.461	0.954	14,311.39
128	24	632	0.035	Free Surface	14.859	0.353	0.267	0.705	24,749.09
129	24	888	-0.003	Pressurized	4.681	1	1	2	6,600.00
130	24	705	0.014	Free Surface	10.688	0.451	0.419	0.902	15,762.57
131	24	528	0.009	Free Surface	8.834	0.523	0.54	1.047	12,218.30
132	24	360	0.008	Free Surface	8.534	0.538	0.565	1.076	11,672.11
133	24	152	0.035	Free Surface	14.831	0.353	0.267	0.706	24,713.70

Table 3 : 6,600 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
134	24	490	0.001	Pressurized	4.681	1	1.745	2	3,781.41
135	24	110	-0.073	Pressurized	4.681	1	1	2	6,600.00
136	24	46	0	Pressurized	4.681	1	1	2	6,600.00
137	24	61	0.103	Free Surface	21.9	0.266	0.155	0.533	42,533.09
138	24	31.6	0.041	Free Surface	15.745	0.338	0.246	0.676	26,844.16
139	24	441.4	0.006	Free Surface	7.551	0.595	0.663	1.189	9,960.37
140	24	549	-0.008	Pressurized	4.681	1	1	2	6,600.00
141	24	521	0.005	Pressurized	6.967	0.637	0.735	1.273	8,982.73
142	24	28	-0.064	Pressurized	4.681	1	1	2	6,600.00
143	24	242	-0.02	Pressurized	4.681	1	1	2	6,600.00
144	24	440	-0.021	Pressurized	4.681	1	1	2	6,600.00
145	24	260	-0.031	Pressurized	4.681	1	1	2	6,600.00
146	24	190	0	Pressurized	4.681	1	1	2	6,600.00
147	24	68	0.026	Pressurized	13.429	0.38	0.307	0.76	21,532.94
148	24	102	0.153	Free Surface	25.183	0.241	0.128	0.482	51,758.76
149	24	370	0.003	Free Surface	5.683	0.768	0.936	1.535	7,050.43
150	24	130	-0.032	Pressurized	4.681	1	1	2	6,600.00
151	24	156	-0.024	Pressurized	4.681	1	1	2	6,600.00
329	24	143	0.003	Pressurized	6.22	0.704	0.843	1.408	7,825.98
152	24	473	0.018	Free Surface	11.656	0.422	0.372	0.845	17,731.48
153	24	378	0.002	Pressurized	4.681	1	1.016	2	6,493.76
154	24	570	0.004	Free Surface	6.478	0.679	0.803	1.357	8,222.34
155	24	685.5	0.031	Free Surface	14.162	0.365	0.285	0.73	23,164.75
156	24	735.5	-0.012	Pressurized	4.681	1	1	2	6,600.00
157	24	129	0.004	Pressurized	6.498	0.677	0.801	1.354	8,239.71
158	24	30	0.33	Free Surface	33.059	0.199	0.087	0.398	76,028.88
159	24	106	0.031	Free Surface	14.239	0.364	0.283	0.728	23,352.08
160	24	114	0.068	Free Surface	18.909	0.296	0.191	0.592	34,619.16
161	24	390	-0.021	Pressurized	4.681	1	1	2	6,600.00
162	24	80	0.013	Pressurized	10.198	0.468	0.446	0.936	14,797.10
163	24	90	0.087	Free Surface	20.593	0.278	0.169	0.557	38,962.58
164	24	80	0.045	Free Surface	16.258	0.33	0.235	0.66	28,075.52
165	24	130	0.043	Free Surface	16.014	0.334	0.24	0.667	27,469.07
166	24	140	0.025	Free Surface	13.155	0.386	0.315	0.771	20,926.26
167	24	30	0.217	Free Surface	28.52	0.221	0.107	0.442	61,605.24
168	24	190	0.029	Free Surface	13.872	0.371	0.293	0.742	22,517.81
169	24	83	0.038	Free Surface	15.29	0.345	0.256	0.69	25,742.30
170	24	307	0.017	Free Surface	11.378	0.43	0.385	0.86	17,158.42
171	24	130	0.036	Free Surface	15.029	0.35	0.262	0.699	25,165.11
172	24	50	0.16	Free Surface	25.584	0.239	0.125	0.477	52,939.72
173	24	220	0.019	Free Surface	12.005	0.413	0.358	0.826	18,460.02
174	24	210	0.03	Free Surface	13.984	0.369	0.29	0.737	22,777.56
175	24	50	0.642	Free Surface	41.809	0.169	0.062	0.338	106,044.74
176	24	1,250.00	0.002	Pressurized	4.681	1	1.279	2	5,159.93
177	24	245	0.016	Free Surface	11.26	0.434	0.39	0.867	16,910.97
178	24	125	0.089	Free Surface	20.746	0.277	0.167	0.554	39,439.20
179	24	440	0.007	Free Surface	8.318	0.549	0.585	1.099	11,286.79
180	24	320	-0.048	Pressurized	4.681	1	1	2	6,600.00
181	24	100	0.008	Pressurized	8.622	0.534	0.558	1.067	11,837.68
182	24	70	0.26	Free Surface	30.416	0.211	0.098	0.422	67,485.16
183	24	202	0.005	Free Surface	7.434	0.603	0.676	1.205	9,766.58
184	24	173	0.027	Free Surface	13.546	0.377	0.303	0.755	21,814.61
185	24	175	0.013	Free Surface	10.211	0.467	0.445	0.935	14,839.32
186	24	215	-0.009	Pressurized	4.681	1	1	2	6,600.00
187	24	105	0.038	Free Surface	15.32	0.345	0.255	0.689	25,831.94
188	24	200	-0.03	Pressurized	4.681	1	1	2	6,600.00
189	24	100	0.02	Pressurized	12.119	0.41	0.353	0.82	18,717.02
190	24	200	0.041	Free Surface	15.777	0.337	0.246	0.675	26,880.27
191	24	77.9	-0.004	Pressurized	4.681	1	1	2	6,600.00
192	26	53	-0.049	Pressurized	3.988	1	1	2.167	6,600.00
193	26	57	0	Pressurized	3.988	1	2.151	2.167	3,069.02
194	26	20	0.285	Free Surface	31.133	0.186	0.075	0.403	87,543.68
195	26	120	0.019	Free Surface	11.789	0.372	0.294	0.805	22,434.81
196	26	240	0.04	Free Surface	15.436	0.305	0.202	0.661	32,597.02
197	26	280	0.005	Free Surface	7.223	0.541	0.57	1.172	11,585.29
198	26	400	-0.018	Pressurized	3.988	1	1	2.167	6,600.00
199	26	380	-0.016	Pressurized	3.988	1	1	2.167	6,600.00

Table 3 : 6,600 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
200	26	167	-0.016	Pressurized	3.988	1	1	2.167	6,600.00
201	26	40	-0.083	Pressurized	3.988	1	1	2.167	6,600.00
202	26	188	-0.01	Pressurized	3.988	1	1	2.167	6,600.00
203	26	82	-0.026	Pressurized	3.988	1	1	2.167	6,600.00
204	26	203	-0.001	Pressurized	3.988	1	1	2.167	6,600.00
205	26	349	-0.016	Pressurized	3.988	1	1	2.167	6,600.00
206	26	341	-0.01	Pressurized	3.988	1	1	2.167	6,600.00
207	26	160	-0.041	Pressurized	3.988	1	1	2.167	6,600.00
208	26	470	-0.011	Pressurized	3.988	1	1	2.167	6,600.00
209	26	510	-0.036	Pressurized	3.988	1	1	2.167	6,600.00
210	26	730	-0.021	Pressurized	3.988	1	1	2.167	6,600.00
211	26	460	-0.003	Pressurized	3.988	1	1	2.167	6,600.00
212	26	300	-0.035	Pressurized	3.988	1	1	2.167	6,600.00
213	26	500	-0.014	Pressurized	3.988	1	1	2.167	6,600.00
214	26	470	-0.006	Pressurized	3.988	1	1	2.167	6,600.00
215	26	380	0.004	Pressurized	6.359	0.601	0.673	1.301	9,801.65
216	26	200	0.011	Pressurized	9.768	0.428	0.381	0.927	17,339.27
217	26	50	0.011	Pressurized	9.768	0.428	0.381	0.927	17,339.27
218	26	650	0.011	Free Surface	9.68	0.431	0.385	0.933	17,147.67
219	26	800	0.005	Free Surface	7.175	0.544	0.575	1.179	11,479.08
220	26	410	0.013	Free Surface	10.31	0.411	0.354	0.89	18,650.90
221	26	290	0.025	Free Surface	13.104	0.344	0.254	0.745	25,994.66
222	26	320.5	0.074	Free Surface	19.303	0.26	0.148	0.563	44,591.09
223	26	679.5	0.056	Free Surface	17.461	0.279	0.17	0.605	38,765.67
224	26	960	0.003	Free Surface	5.601	0.67	0.789	1.451	8,360.96
225	26	100	0.065	Free Surface	18.423	0.269	0.158	0.582	41,771.34
226	26	150	0.033	Free Surface	14.514	0.319	0.221	0.691	29,913.08
227	26	100	0.018	Free Surface	11.613	0.376	0.3	0.814	21,981.53
228	26	100	0.066	Free Surface	18.541	0.268	0.157	0.58	42,091.43
229	26	100	0.204	Free Surface	27.634	0.202	0.089	0.437	74,000.87
230	26	430	0.037	Free Surface	15.101	0.31	0.209	0.672	31,624.14
231	26	400	0.001	Pressurized	3.988	1	1.151	2.167	5,734.42
232	26	365.58	-0.003	Pressurized	3.988	1	1	2.167	6,600.00
233	26	114.42	-0.124	Pressurized	3.988	1	1	2.167	6,600.00
234	26	410	-0.006	Pressurized	3.988	1	1	2.167	6,600.00
235	26	150	-0.002	Pressurized	3.988	1	1	2.167	6,600.00
236	26	40	-0.287	Pressurized	3.988	1	1	2.167	6,600.00
237	26	230	0.001	Pressurized	3.988	1	1.366	2.167	4,831.40
238	26	50	0.18	Free Surface	26.439	0.208	0.095	0.451	69,511.71
239	26	10	0.136	Free Surface	23.961	0.223	0.109	0.483	60,421.45
240	26	230	0.014	Free Surface	10.611	0.402	0.34	0.871	19,433.99
241	26	148.15	0.014	Free Surface	10.611	0.402	0.34	0.871	19,432.10
242	26	189	-0.001	Pressurized	3.988	1	1	2.167	6,600.00
330	26	95.59	-0.001	Pressurized	3.988	1	1	2.167	6,600.00
243	26	19.17	-0.445	Pressurized	3.988	1	1	2.167	6,600.00
244	26	64	-0.154	Pressurized	3.988	1	1	2.167	6,600.00
331	26	18	0.027	Pressurized	13.39	0.338	0.247	0.733	26,755.07
245	26	96	0.212	Free Surface	28.07	0.2	0.087	0.433	75,526.82
246	26	236	0.005	Free Surface	7.034	0.553	0.59	1.198	11,185.67
247	26	160	0.073	Free Surface	19.227	0.261	0.149	0.565	44,305.20
248	26	290	0.004	Free Surface	6.769	0.57	0.621	1.236	10,626.80
249	26	180	0.047	Free Surface	16.431	0.292	0.186	0.632	35,561.77
250	26	220	0.02	Free Surface	12.067	0.365	0.285	0.791	23,170.57
251	26	690	-0.001	Pressurized	3.988	1	1	2.167	6,600.00
252	26	280	-0.016	Pressurized	3.988	1	1	2.167	6,600.00
253	26	200	0	Pressurized	3.988	1	1	2.167	6,600.00
254	26	130	0	Pressurized	3.988	1	1	2.167	6,600.00
255	26	150	-0.011	Pressurized	3.988	1	1	2.167	6,600.00
256	26	355	-0.032	Pressurized	3.988	1	1	2.167	6,600.00
257	26	225	-0.017	Pressurized	3.988	1	1	2.167	6,600.00
258	26	170	0.009	Pressurized	9.03	0.454	0.423	0.984	15,594.00
259	26	70	0.066	Free Surface	18.565	0.267	0.156	0.579	42,227.87
260	26	110	0.157	Free Surface	25.208	0.215	0.102	0.467	64,975.32
261	26	320	0.023	Free Surface	12.613	0.354	0.268	0.766	24,610.21
262	26	380	0.002	Free Surface	5.316	0.702	0.841	1.521	7,848.53
263	26	720	0	Pressurized	3.988	1	2.315	2.167	2,850.91
264	26	180	0.022	Free Surface	12.472	0.356	0.272	0.772	24,240.05

Table 3 : 6,600 gpm Steady-State Results

Pipe ID	Diameter (in)	Length (ft)	Slope	Flow Type	Velocity (fps)	d/D	q/Q	Water Depth (ft)	Full Flow (gpm)
265	26	109.93	0.006	Free Surface	7.792	0.509	0.516	1.103	12,790.90
266	26	533.57	0.007	Free Surface	8.416	0.479	0.465	1.039	14,185.87
267	26	160	0.018	Free Surface	11.502	0.378	0.305	0.82	21,674.08
268	26	92.5	0.06	Free Surface	17.897	0.274	0.165	0.595	40,060.23
269	26	182.95	0.005	Free Surface	7.475	0.526	0.545	1.14	12,113.11
270	26	110	0.058	Free Surface	17.72	0.276	0.167	0.599	39,519.86
271	26	220	0.015	Free Surface	10.84	0.396	0.33	0.857	20,005.40
272	26	460.55	0.003	Free Surface	6.156	0.617	0.701	1.337	9,412.50
273	26	362.45	-0.053	Pressurized	3.988	1	1	2.167	6,600.00
274	26	647.08	-0.019	Pressurized	3.988	1	1	2.167	6,600.00
275	26	394.87	-0.009	Pressurized	3.988	1	1	2.167	6,600.00
276	26	287.41	-0.001	Pressurized	3.988	1	1	2.167	6,600.00
277	26	104	0.022	Pressurized	12.519	0.355	0.271	0.77	24,365.14
278	26	86	0.047	Free Surface	16.355	0.293	0.187	0.634	35,334.79
279	26	250	0.002	Free Surface	5.011	0.742	0.901	1.608	7,327.18
280	26	245	-0.031	Pressurized	3.988	1	1	2.167	6,600.00
281	26	205	-0.001	Pressurized	3.988	1	1	2.167	6,600.00
282	26	150	-0.03	Pressurized	3.988	1	1	2.167	6,600.00
283	26	200	0	Pressurized	3.988	1	1	2.167	6,600.00
284	26	139.32	-0.007	Pressurized	3.988	1	1	2.167	6,600.00
285	26	60.68	0.083	Free Surface	20.122	0.252	0.14	0.547	47,265.54
286	26	200	0.004	Free Surface	6.298	0.605	0.681	1.312	9,692.95
287	26	285	0.018	Free Surface	11.502	0.378	0.304	0.82	21,701.23
288	26	195	0.026	Free Surface	13.207	0.342	0.252	0.741	26,235.50
289	26	370	0.003	Free Surface	5.685	0.661	0.775	1.432	8,517.67
290	26	280	0.002	Free Surface	5.269	0.708	0.849	1.534	7,771.65
291	26	70	0.006	Free Surface	7.745	0.512	0.52	1.109	12,691.04
292	26	93	0.013	Free Surface	10.409	0.408	0.349	0.883	18,918.69
293	26	67	0.1	Free Surface	21.488	0.241	0.127	0.522	51,849.62
294	26	490	0.002	Free Surface	4.563	0.816	0.997	1.769	6,620.16
295	26	50	0.008	Free Surface	8.784	0.464	0.44	1.005	15,016.25
296	26	420	-0.007	Pressurized	3.988	1	1	2.167	6,600.00
297	26	205	0.029	Free Surface	13.714	0.333	0.238	0.72	27,677.24
298	26	34.04	0.631	Free Surface	41.171	0.153	0.051	0.332	130,119.67
299	26	700	-0.022	Pressurized	3.988	1	1	2.167	6,600.00
300	26	1,150.00	0.012	Free Surface	10.04	0.419	0.366	0.908	18,012.76
301	26	2,450.00	-0.002	Pressurized	3.988	1	1	2.167	6,600.00
302	26	411	-0.001	Pressurized	3.988	1	1	2.167	6,600.00
303	26	98	0.205	Free Surface	27.682	0.202	0.089	0.437	74,182.02
304	26	1,524.10	0.086	Free Surface	20.344	0.25	0.138	0.543	47,999.36
305	26	6,275.68	-0.002	Pressurized	3.988	1	1	2.167	6,600.00
306	26	400	0.076	Free Surface	19.509	0.258	0.146	0.559	45,212.31
307	26	1,600.00	-0.036	Pressurized	3.988	1	1	2.167	6,600.00
308	30	1,900.00	0.007	Free Surface	8.088	0.397	0.333	0.994	19,803.50
309	30	600	-0.04	Pressurized	2.996	1	1	2.5	6,600.00
310	30	1,150.00	-0.038	Pressurized	2.996	1	1	2.5	6,600.00
311	30	1,977.71	-0.005	Pressurized	2.996	1	1	2.5	6,600.00
312	30	782.35	-0.003	Pressurized	2.996	1	1	2.5	6,600.00
313	30	1,700.00	0.032	Free Surface	14.143	0.265	0.153	0.662	43,025.13
314	30	1,550.00	-0.01	Pressurized	2.996	1	1	2.5	6,600.00
315	30	500	0.043	Free Surface	15.689	0.246	0.133	0.615	49,760.62
316	30	250	-0.258	Pressurized	2.996	1	1	2.5	6,600.00
317	30	1,928.00	-0.004	Pressurized	2.996	1	1	2.5	6,600.00
318	30	8	0.075	Pressurized	19.088	0.214	0.1	0.535	65,717.67
319	26	414	0.029	Free Surface	13.783	0.331	0.237	0.718	27,847.56
320	30	12	0.003	Free Surface	6.215	0.486	0.476	1.215	13,854.50
321	30	3,338.00	0.002	Free Surface	5.468	0.538	0.564	1.344	11,696.21
322	30	1,400.00	-0.004	Pressurized	2.996	1	1	2.5	6,600.00
323	30	19	0.177	Pressurized	25.839	0.173	0.065	0.433	100,912.36
324	30	181	0.004	Pressurized	6.355	0.478	0.463	1.194	14,269.29
325	30	640	0.005	Free Surface	7.049	0.441	0.402	1.102	16,429.42
326	30	20	0.833	Free Surface	44.535	0.119	0.03	0.298	218,949.35
327	30	1,905.00	0	Pressurized	2.996	1	2.029	2.5	3,252.66