PADUCAH McCRACKEN JSA JOINT SEWER AGENCY

September 12, 2016

Mr. Jeff Cummins
Division of Enforcement
Department for Environmental Protection
300 Fair Oaks Lane
Frankfort, KY 40601

Re: **Paducah-McCracken County Joint Sewer Agency (JSA) Long Term Control Plan**
Commonwealth of Kentucky Environmental and Public Protection Cabinet v. Paducah McCracken County Joint Sewer Agency – Civil Action No.: 07-CI-1252
U.S. EPA Administrative Order, Docket No.: CWA-04-2008-4756

Dear Mr. Cummins:

In response to your letter dated June 7, 2016 (received on June 15, 2016), and recent discussions with the Cabinet, we are transmitting our revised *Long Term Control Plan*. The revised plan includes responses to comments included in the June 7 letter, as well as a revised implementation schedule. It is our understanding, based on conversations with your organization, that the original proposed schedule of 30 years was unacceptable, and that a revised schedule was necessary for approval of the document.

Accordingly we are submitting this document within the timeframe specified documented in our electronic mail conversation on July 22, 2016.

Sincerely,

John C. Hodges, PE, LS
Executive Director

cc: Denisse Diaz, US EPA Region 4

PADUCAH MCCRACKEN
JOINT SEWER AGENCY

REVISED LONG TERM CONTROL PLAN FOR COMBINED SEWER OVERFLOWS

SEPTEMBER 2016

PADUCAH McCRACKEN
JSA
JOINT SEWER AGENCY

CDM Smith

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Section 1

Background

The Paducah McCracken Joint Sewer Agency (JSA) entered into a Consent Judgment (No. 07-CI-1252) with the Commonwealth of Kentucky Environmental and Public Protection Cabinet on September 5, 2007. Additionally, on December 21, 2007, JSA was sent an Administrative Order (CWA-04-2008-4756) from the Environmental Protection Agency (EPA).

As one of the requirements of the Consent Judgment and Administrative Order, JSA was required to submit a Long Term Control Plan (LTCP) that complies with the Combined Sewer Overflow (CSO) Control Policy (April 1994) and is consistent with EPA's "Guidance for Long Term Control Plan" (September 1995). The LTCP was submitted on September 2, 2010, for regulatory review and approval.

The Kentucky Department of Environmental Protection (KDEP), in conjunction with EPA, provided comments on the LTCP in a letter dated May 7, 2014, which JSA responded to in a letter dated June 20, 2014. On October 14, 2014, all parties met in Nashville to discuss the comments in more detail and outline a path forward for updating and approval of the LTCP. That path forward was described by JSA in a letter dated October 27, 2014, and following additional discussions, was subsequently revised in a letter dated January 30, 2015, from KDEP and EPA to JSA.

The path forward includes the following three major deliverables, with submission dates relative to JSA's receipt of the January 30, 2015, letter, which occurred on February 2, 2015:

- *Updated CSO Control Alternatives Evaluation Report*. This deliverable, which was submitted on May 1, 2015, provided additional information on alternative CSO control projects, including protection of the drinking water intake and endangered mussels found in the Ohio River. It was required to be submitted within 90 days (May 2, 2015).

- *CSO Control Project Selection and Implementation Schedule Report*. This deliverable, which was submitted on July 1, 2015, described the selected CSO control projects, discussed the financial capability analysis, and included a proposed implementation schedule. This deliverable was due within 150 days (July 1, 2015).

- *Revised LTCP*. The *Revised LTCP* incorporates information from the two above-named documents and subsequent conversations with KDEP and EPA. It also includes the proposed Post Construction Monitoring Plan. This deliverable was originally due within 180 days (July 31, 2015), but the timeframe was extended to October 9, 2015, to allow time for further discussion and comment on the previous deliverables. Comments on this deliverable were received from KDEP on June 7, 2016, and this updated *Revised LTCP* was resubmitted in September 2016.

The *Revised LTCP* serves as the third and final deliverable. It incorporates the information presented in the two interim submittals as well as information from the LTCP submitted in 2010. Additionally, it addresses comments received from KDEP in 2016.

1.1 Combined Sewer Overflows

According to EPA's "Report to Congress – Impacts and Control of CSOs and SSOs", published in 2004, combined sewer systems (CSSs) are found in older metropolitan communities in 32 states, although they are primarily concentrated in the Northeast and Great Lakes regions. The report indicates there are 746 communities with CSSs with a total of 9,438 permitted CSO outfalls.

CSOs carry untreated stormwater and wastewater into rivers and streams. The discharge can contain contaminants with potential to elevate bacteria levels and reduce oxygen in the water, creating water conditions harmful to aquatic habitats, aquatic life, and humans. Many factors contribute to water quality concerns in the rivers and streams that traverse JSA's boundaries, including stormwater runoff from urban, rural, and agricultural areas, failing septic systems, leachate, and upstream pollution.

CSOs are regulated under the Clean Water Act and its wastewater permitting program, known as the National Pollutant Discharge Elimination System, or NPDES, program. NPDES permits are issued by the Kentucky Division of Water (KDOW), under a delegation agreement with EPA. Both State and Federal regulators have authority to enforce these permits.

In 1990, the KDOW drafted a CSO permitting strategy designed to complement the control programs previously identified by EPA. This strategy established a statewide approach to developing and issuing Kentucky Pollutant Discharge Elimination System (KPDES) permits for municipalities with CSOs. The objectives of this strategy include:

- Ensure that if CSOs occur, they are only as a result of wet-weather.
- Bring all wet-weather CSO discharge points into compliance with the technology-based and water quality-based requirements of the Clean Water Act.
- Minimize the impacts of CSOs on water quality, aquatic biota, and human health.

1.2 JSA System Overview

On July 1, 1999, JSA was established by the City of Paducah and McCracken County to provide comprehensive wastewater collection and treatment within McCracken County. JSA was established by the merger of the Sanitation District No. 5 (Concord), Sanitation District No. 2 (Lone Oak), the sanitary sewer facilities and operations of Woodlawn Water and Sewer District and Reidland Water-Sewer District, and the sanitary and combined sewer facilities and operations of the City of Paducah Wastewater and Stormwater Utility Division.

Although this merger resulted in a utility encompassing roughly 25,000 acres, the majority of the system is separate sanitary sewer, which was addressed separately in the *Sanitary Sewer Overflow Plan, March 2010*. The focus of the LTCP is the combined sewer system consisting of approximately 6,780 acres of drainage area and approximately 188 miles of pipe.

1.3 Project Goals

JSA's CSO control program is designed to employ affordable and cost-effective solutions for controlling solids and floatables, capturing first-flush discharges, and reducing CSO pollutants so that the Kentucky and Federal requirements for dissolved oxygen, bacteria, and other water quality concerns are more attainable.

JSA and the City of Paducah work in conjunction to collectively perform CSO control activities on the CSS to prevent and minimize the impacts of CSOs. JSA has implemented several programs including the inspection and cleaning of regulators, the inspection and cleaning of interceptor sewers, floatables control, and public education to reduce impacts of CSOs. The City of Paducah is responsible for stormwater within the JSA service area and has implemented catch basin cleaning, street sweeping, public education, solid/hazardous waste collections, control of illegal dumping, and best management practices for construction. The programs implemented by JSA and the City of Paducah are discussed in more detail in Section 2.

LTCP control alternatives and strategies have been evaluated based on their ability to achieve the goals of the CSO Control Policy. JSA envisions reducing its CSO impacts to receiving streams by 1) implementing affordable and cost-effective long-term CSO controls and 2) continuing to address structural and maintenance problems as part of its routine operation and maintenance activities. Other factors, such as failed septic systems, upstream agricultural runoff, and discharges from upstream urban areas likely also impact water quality; however, these contributions are outside of JSA's jurisdiction.

1.4 Progress Since Consent Judgment

Although the LTCP has not been approved, JSA has continued to improve water quality in their service area through construction of improvements in both their sanitary sewer system and their combined sewer system. The most significant projects completed since JSA entered into the Consent Judgment are described below:

- Paducah Wastewater Treatment Plant (WWTP) Improvements. Pursuant to the JSA's Early Action Plan, this project increased Paducah WWTP's peak hydraulic capacity from 9 million gallons per day (mgd) to 18 mgd to facilitate management of wet-weather flow. This project involved the following:

  - Construct a new fine bar screen for the separation of Perkins Creek lift station from the combined sewer system,

  - Construct a new flow splitting weir box to evenly distribute flow from primary clarification to aeration,

  - Construct a new secondary clarifier for increased settling capacity,

  - Construct a new Return Activated Sludge (RAS) pumping station and force main to the new flow splitting box, and

  - Construct various piping changes to remove hydraulic bottlenecks throughout the wastewater treatment plant.

  The project was completed in 2009, and the cost of the project was $4,500,000.

- Perkins Creek Lift Station Refurbishment and Force Main Extension. Pursuant to the JSA's Early Action Plan, JSA completed separating the flow from the Perkins Creek lift station from the combined sewer system via a new force main directly to the Paducah WWTP. The project's substantial completion date was December 18, 2009, ahead of the Consent Judgment deliverable date of June 31, 2010. The project removed 1.5 to 2 mgd of dry-day wastewater flow from the CSS, approximately one-third of the dry-day flow of the Paducah WWTP. Total cost of the project was $2,500,000.

- Terrell Street Pump Station Stand-by Electrical Power and Upgrades. This project involved the installation of a stand-by electrical generator at the Terrell Street Pump Station, which serves as one of the two influent pump stations to the WWTP, along with various other electrical upgrades. The construction of this project eliminated dry-weather sewer overflows at the regulator located near the Paducah WWTP influent pump station due to power outages. Previously, when there was a power outage at the pump station, dry-weather sewer overflows could occur at the regulator, resulting in a CSO discharge at EPA 003. This project was substantially complete during the spring of 2010.

- Terrell Street Pump Station Force Main Replacement. This project involved the replacement of one of two 18-inch cast iron force mains with a new 18-inch C900 PVC force main. The cast iron force main had degraded due to wear. This project was completed in September of 2007, and increased the reliability of this station.

- Terrell Street Small Bar Screen Refurbishment. Project involved the complete refurbishment of the original coarse bar screen for the Paducah WWTP to eliminate build-up of leaves and other debris which may lead to blinding of the screen during high flow periods. This project was completed in August of 2008. In addition, the largest coarse bar screen at the Paducah WWTP was replaced in the fall of 2010 with a new continuous rake bar screen. Total cost of the project was approximately $590,000.

- Husband Street Lift Station Refurbishment Project. This station, located within the CSS in proximity to EPA 006 and EPA 007, underwent a complete electrical refurbishment, including the following:

  - Placement of a stand-by generator for alternate power – previously the station did not have stand-by power,
  - New seal water system for the pumps (pumps previously upgraded in 2005),
  - Installation of a comminutor for reduced floatables and solids,
  - New level control and pump control systems, and
  - New motor control center, weather head, and power service.

- Bridge Street Sewer Separation. This project involved the separation of combined sewers associated with permitted outfall EPA 014. The project was completed in two phases and involved construction of a new sanitary main, rehabilitation and reconstruction of several laterals, and removal of the combined sewer regulator. The project was completed in the fall of 2012 and has eliminated the discharge at EPA 014.

- Wallace Park (Lone Oak) Sewer Separation. This project involved the separation of combined sewers associated with outfall EPA 012 and included the construction of a 600,000 gallon underground stormwater retention structure and the construction of 8,865 linear feet of gravity sanitary and storm sewer. The project was completed in late 2015. Total costs were approximately $5,000,000.

- Massac Creek Interceptor Project. This project was completed in two phases.
  - Phase 1 involved the construction of a 6 MGD pump station, 11,000 linear feet of gravity sewer, and 35,000 linear feet of force main. The project is listed in JSA's Sanitary Sewer Overflow (SSO) Plan with an eventual goal of providing an alternative path to the Paducah WWTP for a portion of the community of Lone Oak's dry- and wet-weather flow. Phase 1 was substantially complete in spring of 2012 and the total cost was approximately $8,900,000.
  - Phase 2 involved the construction of 33,500 linear feet of gravity interceptor and 5,000 linear feet of gravity main. Total cost for Phase 2 was approximately $4,700,000 and was completed in October 2013.

  Phases 1 and 2 of this project eliminated five pumping stations and provided infrastructure to continue smaller capital projects to continue to offload sanitary and wet-weather flow from other infrastructure. In addition, this project has allowed nearby private treatment plants to be eliminated.

- Sewer main rehabilitation to reduce CSOs and SSOs by correcting inflow / infiltration. JSA continues to assess the condition of the combined and sanitary sewer systems and perform rehabilitation as needed. This includes the following activities completed from 2011 to 2014:
  - 114,206 linear feet of sewer rehabilitation of 6 to 24-inch gravity sewer main utilizing the cured-in-place pipe (CIPP) process,
  - Rehabilitation of approximately 209 manholes,
  - Over 360 point repairs of the gravity sewer system,
  - Approximately 972,000 linear feet of gravity main cleaning and inspection, and
  - Over 350,000 linear feet of smoke testing.

- Reconstruction of Cook Street Lift Station and sewer main rehabilitation to eliminate SSOs in the Cook Street drainage basin (Woodlawn Phase III). This project involved the following:
  - Construction of approximately 7,000 linear feet of 10-inch PVC force main to connect the Cook Street Lift Station to the recently constructed Woodlawn Interceptor
  - Refurbishment of the Cook Street Lift Station from a 250 gallons per minute (gpm) flooded suction lift station to a 700 gpm submersible station
  - Placement of a stand-by generator for alternate power for the Cook Street Lift Station
  - Performed 7184 linear feet of sewer main rehabilitation by the CIPP process

  This project was listed in the Consent Judgment with a scheduled completion date of June 30, 2008. The initiation of operations date for the project is December 6, 2007. Substantial completion date for the project was achieved on January 8, 2008. Total cost of the project is $897,000 compared to the $850,000 listed in the Consent Judgment.

- Old US Highway 45 Lift Station Refurbishment. The Old Highway 45 Lift Station is a developer driven station completed in 1977. The pumps and control panel had outlived their service life, and the station had been listed in the Consent Judgment as a recurring SSO. The project involved the total refurbishment of the station, including the replacement of the pumps, level control and control panel. The project was completed in September of 2007.

- Hillington Drive SSO Removal Project. The intersection of Hillington Drive and Thorndale Drive in Lone Oak had been a recurring SSO due to hydraulic deficiencies with the manhole at the intersection. The project rerouted the flow from Hillington away from the manhole, eliminating the overflow. The project was substantially complete in October of 2008.

- Pebblebrook Lift Station Remediation. The Pebblebrook Lift Station is listed as a recurring overflow per Exhibit A of the Consent Judgment. The project converted the pump station from a suction lift pump station to a duplex pump submersible station. A complete refurbishment of the station was performed, with new controls and pumps, eliminating this station as a recurring overflow. The project was completed in August of 2009.

- Fieldmont Pump Station. This station is listed in the Consent Judgment as a recurring overflow. The project was originally planned for calendar year 2012, but significant reductions in infiltration and inflow were achieved through rehabilitation of the collection system at this station. These measures eliminated the station as a recurring overflow, and no improvements at the station itself were needed.

- Woodlawn Pump Station Improvements. The project involved the complete replacement and upgrade of two pump stations with listed sanitary sewer overflows associated with them. These were the Homewood Pump Station and Milliken Lift Station. Each station was replaced and hydraulically upgraded to pump more flow. The work was completed in December 2013 at a total cost of approximately $990,000.

- Gatewood Lift Station Remediation. The Gatewood Lift Station was constructed in the early 1970s. The Gatewood Lift Station has endured mechanical and piping failures over the last two years. The project converted the pump station from a suction lift pump station to a duplex pump, submersible station. A complete refurbishment of the station occurred, with new controls and pumps. This work was completed in April of 2010.

- Gatewood Drive Pump Station Elimination. The project will eliminate a failing private package plant, as well as the SSO related to the Gatewood Drive pump station, which is listed in the Consent Judgment. The project entails construction of a new sanitary sewer line to accept the flows from the failing package plant, as well as eliminating the Gatewood Drive pump station by gravity extension. This project was only made possible by the construction of the Massac Creek Interceptor. The project was completed in June 2015, and the total project cost was $310,000.

- Homewood Avenue Overflow Tank. This project involves the construction of a 500,000 gallon overflow tank to eliminate the SSO related to the Homewood Avenue drainage basin. Property selection and funding commitment were completed in 2014, and the property is currently under construction. Total project costs are expected to be approximately $950,000.

- Cook Street Overflow Tank. This project constructed a 250,000 gallon overflow tank to eliminate the SSO related to the Cook Street drainage basin. Engineer selection, preliminary engineering, funding commitment, and property selection were completed in 2014.

Construction of the project was completed in January 2016. Total project costs were approximately $630,000.

- Stonegate Lift Station Refurbishment. The Stonegate Lift Station was constructed as a suction-lift type lift station in the early 1970s and has endured mechanical and piping failures over the last few years. The project converted the station to a duplex submersible station with a new and enlarged wet well, PLC controls, and valve vault with bypass connection. The refurbishment work was completed in spring of 2011 with a total cost of approximately $125,000.

From 2008 through 2015, JSA has spent over $39 million on improvements to their combined and sanitary sewer systems.

1.5 Small System Considerations

In April 1994, EPA published the national CSO Control Policy (59 Federal Register 18688) to explain how communities and states can control CSOs and meet Clean Water Act requirements. In 1997, the Kentucky control strategy was updated to incorporate the 1994 EPA CSO Control Policy. KDOW's Combined Sewer Overflow Control Strategy states that a CSO LTCP should incorporate the following items:

- Characterization, monitoring, and modeling of the combined sewer system
- Public participation
- Consideration of sensitive areas
- Evaluation of alternatives
- Cost and performance considerations
- Operational plan
- Maximizing treatment at the existing publicly owned treatment works (POTW)
- Implementation schedule
- Post-construction compliance monitoring

However, both the Consent Judgment and the CSO Control Policy acknowledge that incorporating each of these nine elements may be difficult for small systems, such as JSA. Section I.D. of the CSO Control Policy allows for systems serving populations of less than 75,000 to request exemptions to these steps, as long as the system complies with the nine minimum controls, public participation, sensitive areas, and post-construction compliance monitoring portions of the CSO Control Policy. The decision to grant exemptions under the small-system considerations is at the discretion of KDOW, and according to paragraph 7 of the Consent Judgment, JSA qualifies for those small system considerations.

Although JSA could have pursued the exemptions for small systems, JSA believes that the additional characterization and evaluation of the combined sewer system, described in the LTCP submitted in September 2010 and this document, while it greatly exceeds the LTCP requirements for small systems, is beneficial to ensure that the CSO control projects selected provide cost-effective solutions that are constructible, meet performance expectations, and can be operated by JSA staff.

1.6 Organization of Report

This document is organized as follows:

- Section 1 provides background and regulatory context for this report. It also provides a list of projects completed by JSA since 2007.
- Section 2 describes the JSA collection and treatment system. It also summarizes the activities that JSA and the City of Paducah are undertaking to control CSOs.
- Section 3 describes the current water quality conditions and sensitive areas.
- Section 4 provides the basis of the analysis including the development of the hydraulic model for the combined sewer system, selection of the five-year representative rainfall period, and baseline statistics for the system.
- Section 5 provides an overview of the alternatives evaluation process when considered at each CSO individually.
- Section 6 describes the performance objectives of the LTCP, summarizes the evaluation of alternatives, and presents combinations of CSO control alternatives to achieve the target system-wide percent capture.
- Section 7 provides the financial capability analysis and discusses JSA's ability to fund various CSO control programs.
- Section 8 describes the public participation process conducted by JSA to obtain citizen input into the various alternatives.
- Section 9 summarizes the selected CSO control alternatives, describes how the selected LTCP meets the performance objectives, and discusses the program's implementation schedule.

1.7 LTCP Considerations

As described in Kentucky Revised Statute (KRS) 224.16-040, when issuing permits under KRS 224.16-050 for discharges consisting of CSOs, requiring and approving LTCPs for wet weather discharges from combined or separate sanitary sewer systems, or enforcing provisions of the federal Water Pollution Control Act, 33 U.S.C. secs. 1251 et seq., the Kentucky Energy and Environment Cabinet shall consider the following, to the extent allowable under Kentucky statutes and the federal Water Pollution Control Act:

(1) Limitations on a community's financial capabilities and ability to raise or secure necessary funding;

(2) Affordability of control options;

(3) An evaluation of the effectiveness and affordability of control technologies;

(4) Promotion of green infrastructure;

(5) Reducing economic impacts on regulated entities, other state and local governmental entities, and residents of the Commonwealth;

(6) Allowing for reasonable accommodations for regulated entities and other state and local governmental entities when inflexible standards and fines would impose a disproportionate financial hardship in light of the environmental benefits to be gained;

(7) Giving preference, where proposed by a permittee, to control options that meet presumption approach performance criteria and demonstrate significant pollution reduction rather than mandating specific designs;

(8) Allowing adequate time and flexibility for implementation schedules when justified by a clear environmental benefit, a community's ability to raise or secure adequate funds, an analysis concluding that the costs of a shorter implementation schedule outweigh the benefits of faster implementation, or other factors; and

(9) Factors set forth in the United States Environmental Protection Agency's "Combined Sewer Overflow Control Policy" that may ease the cost burdens of implementing long-term control plans, including but not limited to small system considerations, the attainability of water quality standards, and the development of wet weather standards.

In a letter dated June 7, 2016, the KDEP requested that JSA provide a discussion of how the *Revised LTCP* addresses each of these factors. That information is provided below, including references to the applicable portions of the *Revised LTCP*:

1. Limitations on a community's financial capabilities and ability to raise or secure necessary funding.

To reduce the financial burden to JSA and its customers, JSA requested, in the *Revised LTCP* submitted in October 2015, that the selected CSO control projects be implemented over a 30-year program duration. Subsequent discussions with the Commonwealth of Kentucky and EPA, however, indicated a 22-year program duration is the longest acceptable timeframe, and the *Revised LTCP* was edited to reflect that change. However, the affordability analysis completed by JSA has shown that there will be a significant financial burden placed on the community, especially the lower income members of the community, with program durations less than 30 years. As program implementation proceeds on the 22-year schedule, JSA may therefore request that the program duration be extended beyond 22 years if at any time JSA is unable to secure the necessary sewer service rate increases to meet this accelerated implementation schedule.

Section 7 of the *Revised LTCP* describes the development of a financial model that projects future utility revenue requirements based on JSA's operating costs, the existing capital improvement program, the incremental impacts of the LTCP capital program, and anticipated expenditures to ensure the integrity of the JSA system. Section 9.3 of the *Revised LTCP* describes the financial impact of the selected CSO control projects over program durations between 10 and 30 years.

As discussed, implementation of the LTCP program over a 30-year duration would impose a significant financial burden on JSA's customers. The projected residential burden approaches 2 percent when considering the Paducah median household income. When considering the lowest quintile, the residential burden is approximately 5 percent, representing a very significant impact to JSA's low income customers. For program durations shorter than 30 years, the financial impacts on JSA's customers only increase.

2. Affordability of control options.

Screening-level costs estimates for CSO control alternatives are provided in Appendices H through N for each CSO location, and the costs associated with various combinations of these individual CSO control alternatives (global alternatives) are described in Section 6 of the *Revised LTCP*. Certain CSO control alternatives were eliminated from consideration because they were determined to be economically infeasible relative to other options providing a similar level of control.

Additionally, the selected CSO control alternatives attempt to maximize water quality benefits while minimizing cost. The Fine Screening and Disinfection global alternative, as described in Section 6.2, is approximately one third less expensive than the High Rate Treatment and Disinfection global alternative, described in Section 6.4, while providing equal bacteria reductions and significant TSS and BOD reductions.

3. An evaluation of the effectiveness and affordability of control technologies.

JSA evaluated each CSO location to assess the feasibility and costs of a full range of alternative technologies for the elimination and/or capture and treatment of CSO discharges. This includes the following technologies:

- Sewer separation
- Storage
- Pumping to a consolidated wet-weather treatment facility
- Fine screening
- Fine screening with disinfection
- High rate treatment
- High rate treatment with disinfection

These technologies represent a broad range of viable, contemporary, and widely-recognized approaches for effectively addressing CSO impacts. In addition to evaluating CSO technologies at individual CSO locations, JSA also evaluated combinations of CSO alternatives (global alternatives), assessing how they collectively would protect sensitive areas, meet the needs of the community, and meet the intent of the CSO Control Policy.

These evaluations are described in Section 5, Section 6, Section 9, and the appendices of the *Revised LTCP*.

4. Promotion of green infrastructure.

To the extent practical, JSA will look for opportunities to incorporate green infrastructure improvements into planned projects in the combined sewer system. However, JSA does not own significant property to implement green infrastructure improvements and does not control surface stormwater drainage, zoning, building permits, etc. and thus lacks a mechanism for implementing or enforcing green infrastructure improvements.

Additional information is presented in Section 5.2, which has been added to the *Revised LTCP*.

5. Reducing economic impacts on regulated entities, other state and local governmental entities, and residents of the Commonwealth.

As documented in Section 7 of the *Revised LTCP*, JSA has endeavored to minimize the economic impacts of the LTCP program on its ratepayers by extending the program duration to 30 years. As discussed above, a shorter duration has been requested by the Commonwealth of Kentucky and EPA, and JSA has revised the LTCP implementation schedule to accommodate this request. However, as discussed above, JSA may request that the program duration be extended beyond 22 years if at any time it is unable to secure the necessary sewer service rate increases from both the City of Paducah and McCracken County to meet this accelerated implementation schedule.

Further, the evaluation of alternatives carefully considered the economic impacts of the various alternatives, and these impacts factored heavily into the selection of fine screens over high rate treatment as documented in Section 6 and Section 9.

6. Allowing for reasonable accommodations for regulated entities and other state and local governmental entities when inflexible standards and fines would impose a disproportionate financial hardship in light of the environmental benefits to be gained.

The selection of fine screening over high rate treatment at three CSO locations demonstrates the careful consideration of both costs and benefits, and the need to provide flexibility in the application of regulatory standards, in the alternatives evaluation process. The CSO Control Policy specifies that captured CSO flows receive treatment "…equivalent to primary clarification". As documented in Appendix G of the *Revised LTCP*, JSA acknowledges that the proposed fine screening facilities do not meet this standard; however, because the cost (and associated financial hardship) of facilities that would meet this standard (i.e. high rate treatment) would be significantly greater, and the incremental water quality benefits of meeting this standard would be minimal, fine screening facilities were selected at three locations in conjunction with disinfection.

7. Giving preference, where proposed by a permittee, to control options that meet presumption approach performance criteria and demonstrate significant pollution reduction rather than mandating specific designs.

As discussed in the Section 6, JSA has selected CSO control alternatives that meet the criteria of the presumptive approach of the CSO Control Policy (II.C.4.a.ii). This approach indicates that "the elimination or capture for treatment of no less than 85 percent by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis" provides an adequate level of control to meet water quality objectives. As noted in item 6 above, the ability to achieve significant pollution reduction for the flows captured for treatment with fine screening was demonstrated, and therefore fine screening with disinfection was selected at three CSO locations (rather than high rate treatment) although strict interpretation of regulatory policy could have mandated the more costly high rate treatment designs.

The selected CSO control alternatives provide increased protection of sensitive areas by focusing on the CSOs located on the Ohio and Tennessee Rivers and providing a higher level of control (reduction to 4 overflows per year based on the representative period analysis) at the CSO in closest proximity to the drinking water intake.

8. Allowing adequate time and flexibility for implementation schedules when justified by a clear environmental benefit, a community's ability to raise or secure adequate funds, an analysis concluding *that the costs of a shorter implementation schedule outweigh the benefits of faster implementation, or other factors.*

JSA originally proposed a 30-year program duration and does not feel that the water quality benefits of a shorter LTCP implementation duration, such as 10 or 20 years, offsets the significant financial burdens that JSA and its customers will face or the challenges that a small system such as JSA will face when implementing a large capital program. However, as discussed above, the Commonwealth of Kentucky and EPA have requested a shorter schedule and JSA has revised the LTCP to accommodate this request.

As discussed in Section 7.5 of the *Revised LTCP*, Paducah has a lower median household income, higher poverty rates, and an older population when compared to Kentucky and the United States. Additionally, it has been identified as an Economically Distressed Area by the U.S. Department of Transportation. These factors suggest that JSA faces significant challenges in moving forward with a LTCP of any magnitude.

A 30-year program duration will pose a significant burden, requiring rate increases of 9 percent per year for the first ten years of the program. Additionally, the projected residential burden approaches 2 percent when considering the Paducah median household income. When considering the household income of the lowest quintile, the residential burden is approximately 5 percent, representing a very significant impact to JSA's low income customers. For program durations shorter than 30 years, the financial impact on JSA's customers only increase. Therefore, as discussed above, JSA may request that the program duration be extended beyond 22 years if at any time it is unable to secure the necessary sewer service rate increases from both the City of Paducah and McCracken County to meet this accelerated implementation schedule.

9. Factors set forth in the United States Environmental Protection Agency's "Combined Sewer Overflow Control Policy" that may ease the cost burdens of implementing long-term control plans, including but not limited to small system considerations, the attainability of water quality standards, and the development of wet weather standards.

The proposed LTCP was developed with a clear recognition of the CSO Control Policy provisions for small systems (see Section 1.5), water quality standards reviews, waterbody use attainability, and differences between the various CSO-impacted waterbodies. CSO discharges from the JSA system impact both small local streams and the much larger Tennessee and Ohio Rivers. The selection of CSO control alternatives, and the schedule for implementing specific projects, account for the differences in these waterbodies and the relative impacts of the CSOs from JSA's system on the uses of these waterbodies. Also, as noted above, because the cost burdens of the requested 22-year schedule may be excessive, and the water quality benefits of some projects may be limited (e.g. disinfection of CSO discharges after treatment with fine screens), JSA may request that some project schedules be extended to avoid excessive cost burdens on JSA ratepayers.

Section 2

Existing System

This section discusses existing conditions in JSA's collection and treatment systems. It also summarizes the activities that JSA and the City of Paducah are undertaking to control CSOs.

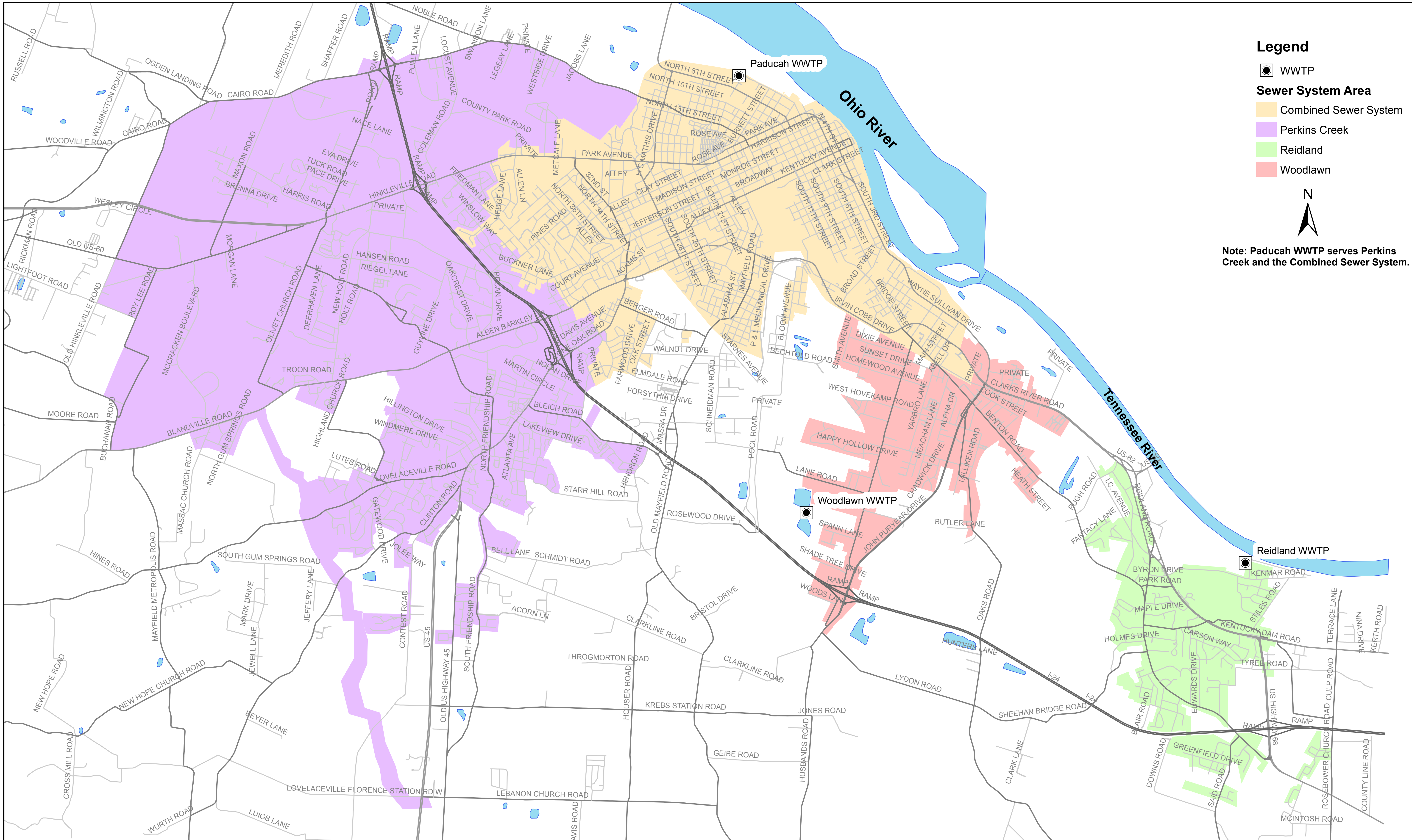
2.1 Collection System Description

As shown in Figure 2-1, the JSA service area is divided into four sections, Paducah, Perkins Creek, Reidland, and Woodlawn. Reidland and Woodlawn are separate sewer system areas and are served by their own WWTPs. Both the Perkins Creek and Paducah areas are served by the Paducah WWTP. However, they are distinguished from one another because Perkins Creek is a separate sanitary sewer system (SSS), with flows arriving at the WWTP via the Perkins Creek Pump Station and force main while the Paducah area represents the CSS. The Perkins Creek flows were removed from the CSS via a force main that transports flows directly to the Paducah WWTP, which was completed in December 2009. System evaluation and recommended improvements to address sanitary sewer overflows in the Reidland, Woodlawn, and Perkins Creek areas are described in the *Sanitary Sewer Overflow Plan, March 2010*. Figure 2-2 shows a location map of the combined sewer area, location of outfalls, regulators, and the Paducah WWTP. It also shows the Perkins Creek pump station. A detailed system map, including flow direction of major system components, is included in Appendix A.

The CSS serves approximately 6,780 acres of drainage area and consists of approximately 188 miles of pipe with diameters up to 102 inches. The CSS mainly includes pipes of vitrified clay and brick, and recent construction materials include polyvinyl chloride, cured-in-place pipe lining, high-density polyethylene, and ductile iron pipe.

As the LTCP development was initiated, the CSS contained 11 permitted combined sewer outfalls, as shown in Figure 2-2. Sewer separation projects have been constructed in the areas associated with EPA 012 and EPA 014. EPA 014 has been eliminated, and EPA 012 is being monitored to confirm that anticipated flow reductions have been achieved under a variety of rainfall and river level conditions.

Including the regulators associated with those two separation areas, the CSS contains 39 regulator/diversion structures that route the dry-weather or low flow to the interceptor sewers that convey this flow to the Paducah WWTP. There are many types of diversion structures in the CSS. They may consist of an orifice that connects to the interceptor, weirs, troughs, elevated pipe inverts, and trapped inlets. Multiple regulators contributing to a single outfall, and the ability for flow to be discharged through multiple CSOs as its makes it way to the WWTP, significantly increase the complexity of the CSS. A listing of the regulators within the CSS is provided in Table 2-1. During wet-weather events, flows are diverted to the permitted combined sewer outfalls within the area. Table 2-2 summarizes the permitted outfalls within the CSS. Figure 2-3 shows sewered areas, both sanitary only and combined, that are upstream of each of the outfalls. Drainage areas based on storm flow may be delineated differently; these are not show on the figure.



0 2,500 5,000 10,000 15,000 20,000 Feet

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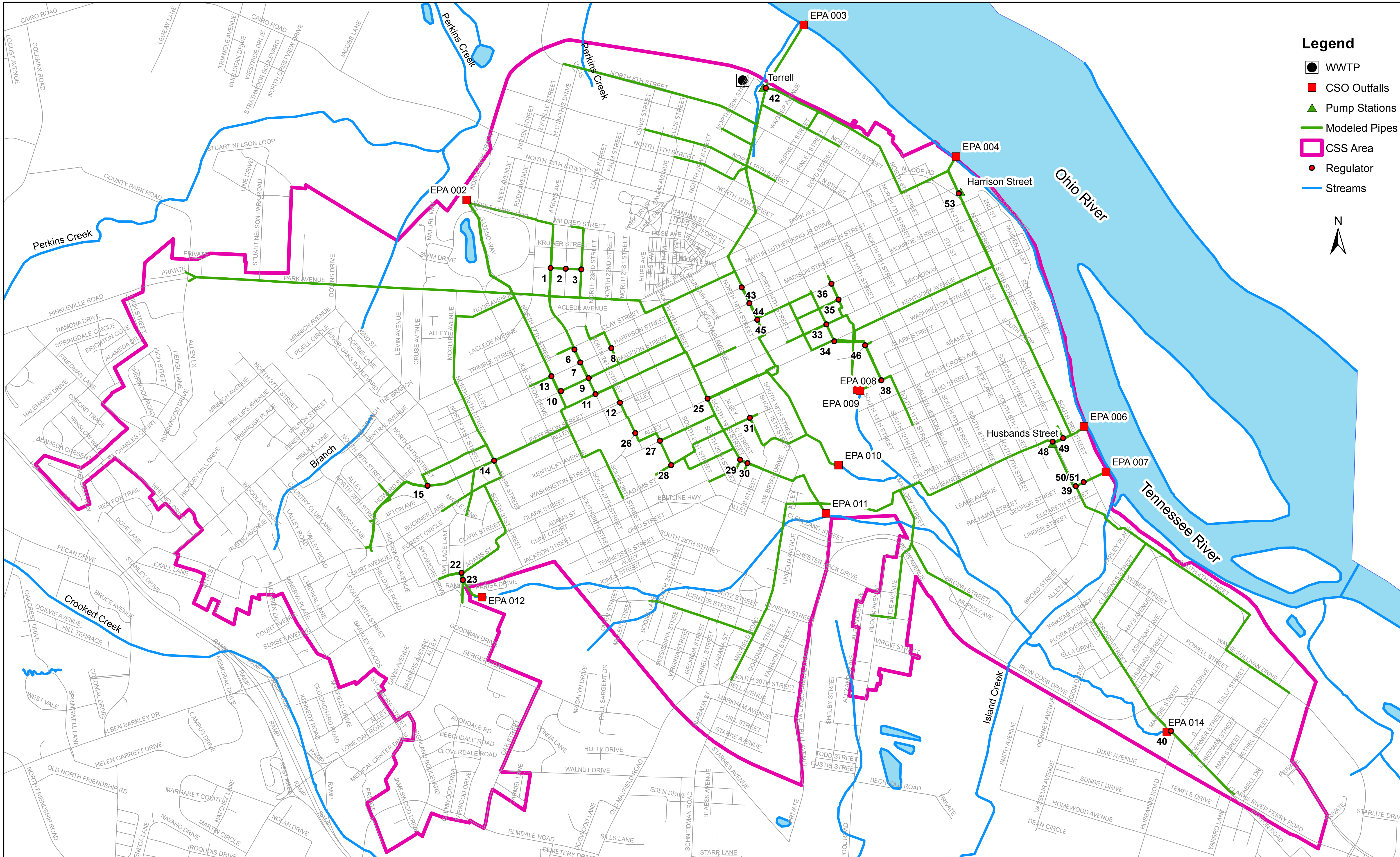
Figure 2-1 - JSA Service Area



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0 1,250 2,500 5,000 7,500 10,000 Feet

Figure 2-2 - Key Combined Sewer System Overview

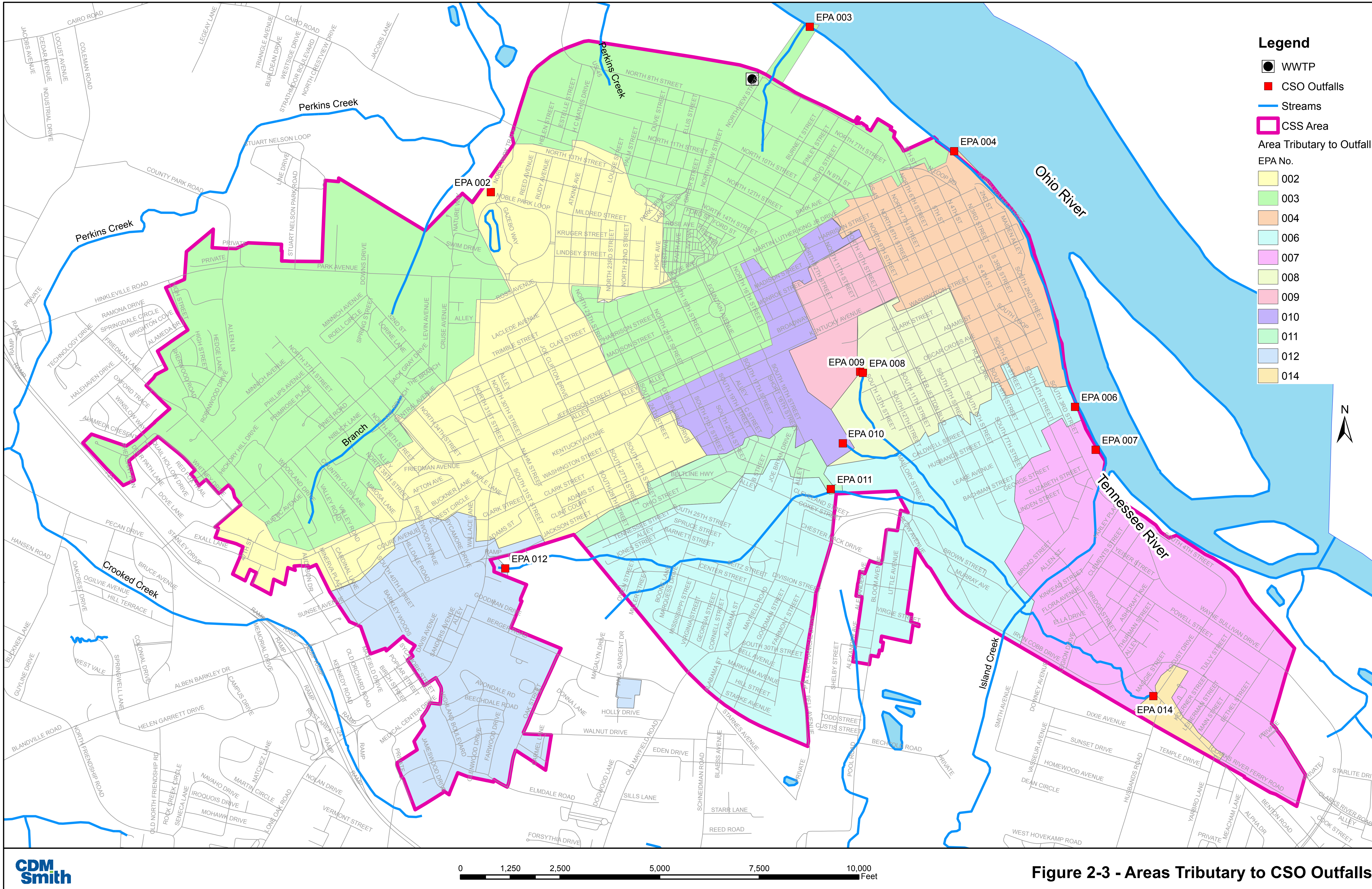

Figure 2-3 - Areas Tributary to CSO Outfalls

Table 2-1 Summary of CSS Diversion Structures

Regulator	Associated Outfall	Approximate Location of Regulator	Type
1	EPA 002	26th Street & Lindsey Street	Overflow
2	EPA 002	25th Street & Lindsey Street	Trough Regulator
3	EPA 002	24th Street & Lindsey Street	Weir & Orifice
6	EPA 002	25th Street & Clay Street	Overflow
7	EPA 002	25th Street & Harrison Street	Overflow
8	EPA 003	23rd Street & Harrison Street	Trough Regulator
9	EPA 002	25th Street & Madison Street	Gate Regulator
10	EPA 002	27th Street & Madison Street	Overflow
11	EPA 002	25th Street & Monroe Street	Trough Regulator
12	EPA 002	24th Street & Jefferson Street	Trough Regulator
13	EPA 002	27th Street & Harrison Street	Overflow
14	EPA 002	30th Street & Jefferson Street	Weir
15	EPA 002	34th Street & Jefferson Street	Overflow
22[1]	EPA 012	Lone Oak Road & Forest Circle	Weir & Orifice
23[1]	EPA 012	Lone Oak Road North of Jackson Street	Trough Regulator
25	EPA 010	19th Street & Kentucky Avenue	Weir
26	EPA 002	24th Avenue & Kentucky Avenue	Trough Regulator
27	EPA 002	Otis Dining Drive & Washington Street	Overflow & Orifice
28	EPA 002	Otis Dining Drive & Polk	Overflow
29	EPA 011	19th Street & Jackson Street	Weir & Orifice
30	EPA 011	"C" Street & Guthrie Avenue	Trough Regulator
31	EPA 010	17th Street & Clark Street	Weir
33	EPA 009	12th Street & Broadway Street	Weir
34	EPA 009	12th Street & Kentucky Avenue	Orifice
35	EPA 009	11th Street & Jefferson Street	Trough Regulator
36	EPA 009	11th Street & Monroe Street	Overflow
38	EPA 008	11th Street - 12th Street & Adams Street	Weir & Orifice
39	EPA 007	4th Street & George Street	Weir
40[2]	EPA 014	Bridge Street & Locust Drive	Overflow
42	EPA 003	North 6th Street at Northview Street	Weir
43	EPA 008	Harrison Street at Harahan Boulevard	Trapped Inlet
44	EPA 003	Madison Street at Harahan Boulevard	Trapped Inlet
45	EPA 003	Monroe Street & Harahan Boulevard	Trapped Inlet
46	EPA 003	Washington Street west of Walter Jetton	Overflow
48	EPA 006	Husbands Street and South 4th Street	Weir
49	EPA 006	Husbands Street East of South 4th Street	Weir
50	EPA 007	George Street between 3rd & 4th Street	Weir
51	EPA 007	George Street between 3rd & 4th Street	Weir
53	EPA 004	North 3rd Street near Harrison Street	Overflow

[1]Regulator 22 was eliminated with the sewer separation project associated with EPA012. Regulator 23 was modified during the sewer separation project and will continue to be monitored for future elimination.
[2]This regulator was eliminated with the sewer separation project associated with EPA014.

Table 2-2 JSA Permitted Outfalls in the CSS

Discharge Number	Location	Receiving Water
EPA 002	37º 05' 24" Latitude 88º 38' 26" Longitude	Unnamed Tributary to Perkins Creek
EPA 003	37º 05' 50" Latitude 88º 36' 55" Longitude	Ohio River
EPA 004	37º 05' 32" Latitude 88º 36' 00" Longitude	Ohio River
EPA 006	37º 04' 22" Latitude 88º 35' 20" Longitude	Ohio River
EPA 007	37º 04' 32" Latitude 88º 35' 12" Longitude	Ohio River
EPA 008	37º 04' 40" Latitude 88º 36' 25" Longitude	Unnamed Tributary to Island Creek
EPA 009	37º 04' 40" Latitude 88º 36' 24" Longitude	Unnamed Tributary to Island Creek
EPA 010	37º 04' 23" Latitude 88º 36' 30" Longitude	Unnamed Tributary to Island Creek
EPA 011	37º 04' 17" Latitude 88º 36' 34" Longitude	Unnamed Tributary to Island Creek
EPA 012[1]	37º 04' 48" Latitude 88º 38' 12" Longitude	Unnamed Tributary to Island Creek
EPA 014[1]	37º 03' 23" Latitude 88º 34' 50" Longitude	Unnamed Tributary to Island Creek

[1] Sewer separation has been completed and the status EPA 012 is being evaluated.
[2] EPA 014 was eliminated through sewer separation.

2.2 Treatment Plant Description

Although JSA operates three WWTPs, only the Paducah WWTP receives flows from the CSS. Flows from the CSS arrive at the WWTP, primarily from either a 27- or 102-inch sewer and are then pumped to the plant's preliminary treatment via the Terrell Street pump station. The diversion structure for EPA 003, JSA's largest overflow by volume, is located near this pump station.

Additionally, flows from the Perkins Creek area, a sanitary sewer system, are also treated at the Paducah WWTP. These flows were removed from the CSS in December 2009 with the construction of a force main that routes flows from the Perkins Creek pump station directly to the WWTP.

The Paducah WWTP is a conventional activated-sludge facility that discharges to the Ohio River. The Paducah WWTP serves approximately 14,000 customers within the City limits of Paducah and boundaries of McCracken County. The existing Paducah wastewater treatment plant was constructed in 1959 and still includes some original equipment and structures. In the mid-1970s, the WWTP was upgraded to a capacity of 6 million gallons per day (mgd) and expanded to include secondary treatment and disinfection to comply with EPA requirements. The plant was upgraded again in 1988 to increase capacity from 6 to 9 mgd. Another expansion to improve the hydraulic capacity and performance of the plant during wet weather was completed in June 2009. Improvements included construction of a fine screening building, additional secondary clarifier, aeration basin, and secondary clarifier splitter box to increase peak hydraulic capacity to 18 mgd. This addition also included upgrades to various yard piping around the plant and a new recycled activated-sludge pump station and force main to improve sludge recycling capability, although numerous portions of the plant are original to the 1959 initial plant construction. A new influent manifold was constructed prior to the fine screen building to allow for the direct pumping of the Perkins Creek pump station, eliminating these separate sanitary flows from the CSS. Currently, flow from the Perkins Creek Pump Station contributes approximately one-third of the dry-weather flow at the Paducah WWTP. These updates have maximized the capacity of the Paducah WWTP, although JSA anticipates that significant rehabilitations and replacements will be required in the coming years to maintain the plant's operation.

Pursuant to completion of the WWTP expansion and Perkins Creek separation, JSA performed stress tests during various rainfalls at the WWTP to further investigate the effect of wet-weather flows on the new hydraulic capacity of the plant. Increased flows can upset biological processes and decrease performance for extended periods after wet-weather flow has subsided, and stress testing can provide an accurate representation of the maximum flows that can be successfully treated by the plant during wet-weather conditions. The results of the stress testing are presented in Table 2-3.

Table 2-3 Results of Stress Testing at Paducah WWTP

Date	Maximum Flow (mgd)	Influent BOD (mg/L)	Effluent BOD (mg/L)	Influent TSS (mg/L)	Effluent TSS (mg/L)	E. coli (cfu/100mL)
08/20/09	15.5	--	11.1	156	4.8	--
03/23/10	18.7	236	6.2	146	1.1	88
03/25/10	19.5	161	6.7	120	1.6	10
04/08/10	19.0	196	5.3	106	2.4	10

2.3 Previous and Ongoing CSO Control Programs

Although JSA is responsible for the collection and treatment of wastewater, including flows from the combined sewer system, stormwater within the CSS is under the jurisdiction of the City of Paducah. As such, JSA and the City of Paducah work in conjunction to collectively perform CSO control activities on the CSS to prevent and minimize the impacts of CSOs. JSA has implemented several programs including the inspection and cleaning of regulators, floatables control, and public education to reduce the impacts of CSOs. The City of Paducah has implemented catch basin cleaning, street sweeping, public education, solid/hazardous waste collections, control of illegal dumping, and best management practices for construction.

The following summarizes each of the programs the City of Paducah and JSA perform to reduce the impacts of CSOs on the receiving waters:

- Inspection and Cleaning of Sewers and Diversion Chambers/Regulators - Routine maintenance of the CSS, including the regulators and interceptor sewers, is necessary to ensure optimum performance during wet-weather events and to ensure that dry-weather overflows are prevented. Regulators are inspected on a monthly basis and after certain wet-weather events, as discussed in the approved *CSS Operational Plan, August 2008*, which describes JSA's Nine Minimum Controls compliance plan. JSA has met EPA CMOM guidelines for cleaning and inspection of gravity sewers over the last several years.

- Rehabilitation of Sewers – JSA has performed approximately 40 miles of pipeline rehabilitation with cured-in-place pipe (CIPP) lining since 2006, constituting over 10 percent of the system's gravity pipes. JSA continues to perform approximately $800,000 of pipeline and manhole rehabilitation each year.

- Catch Basin Cleaning – Reducing the impacts of the first flush by reducing the accumulation of surface pollutants in the catch basins can decrease the amount of debris discharged into receiving waters during wet-weather events. The City of Paducah operates one vacuum truck with a 2-man crew, working 8 hours per day during normal operating hours.

- Street Sweeping – Reducing the amount of debris that can accumulate on streets in curbs and gutters can reduce the impacts of the first flush during wet-weather events to receiving streams. The City of Paducah currently conducts a street sweeping program to reduce the amount of solids and debris entering the catch basins and, eventually, the CSS. The City currently operates two street sweeping machines 8 hours per day.

- Floatables Control – Capturing solids and floatables during an overflow event can reduce the impact of CSOs on the receiving waters. Following the elimination of the CSO at EPA 014, JSA currently has debris screens at seven outfalls within the CSS, with each of these screens being made of chain-link fence material. The outfalls EPA 003 and EPA 004 do not have floatables control due to the proximity to barge traffic, which would result in the destruction of any end-of-pipe technology.

- Public Education – Litter and other solid wastes that are not properly disposed of can be a significant source of pollution from CSOs, and toxic constituents found dumped or leaking into storm drains can affect water quality within the receiving waters. The City of Paducah has public education programs that focus on anti-litter campaigns and waste reduction through a wide variety of programs and activities, including public presentations, public workshops, newsletters, and informative brochures. In addition, JSA has developed brochures describing the basics of sanitary and combined sewer systems and the requirements of the Consent Judgment. Additionally, public forums were held to educate and solicit feedback from the public as part of the development of this LTCP. These activities are described in further detail in Section 8.

- Solid Waste/Hazardous Waste Collection – The City provides leaf collection, household solid waste collection, household yard waste collection, and composting facility services to all residents and commercial establishments. The City also hosts an annual hazardous waste collection day that pays waste disposal contractors to collect and properly dispose of household hazardous waste.

- Control of Illegal Dumping – The City has enacted an Illicit Discharge Ordinance that prohibits illicit discharges to the storm sewer system and establishes enforcement provisions to ensure compliance with the regulations. The City is also available to respond to customer complaints concerning illicit discharges and has created a plan to conduct preliminary screenings for illicit discharges.

- Best Management Practices for Construction – The City uses the *Kentucky Best Management Practices for Construction Activities*, prepared by the Division of Conservation and Division of

Water, Natural Resources and Environmental Protection Cabinet, for construction site waste control requirements and requires submittal of all BMP plans for construction sites.

Section 3

Water Quality and Sensitive Areas

An important component of the development of this *Revised LTCP* is the consideration of sensitive areas and the evaluation of the existing water quality of the creeks that traverse Paducah. Both elements, along with the potential impact from industrial discharges, are discussed in this section.

3.1 Stream Assessment

As part of the development of the LTCP, the water quality of Perkins Creek, Island Creek, and the tributaries contributing to these bodies was evaluated, and the benefits achieved by reducing CSO discharges were assessed to the extent practical. The Consent Judgment excludes the characterization, monitoring, and modeling of the Ohio River and the Tennessee River at the confluence of the Ohio River.

The steps conducted as part of the stream assessments include the following:

- Review the appropriate state regulations regarding stream usage.
- Review the current KDOW stream usage designation for the streams in Paducah.
- Assess the current actual uses of the streams.
- Review the proposed future uses of the streams.

Figure 3-1 shows the locations of the streams that were reviewed.

3.1.1 Kentucky Department of Water Stream Use Regulations

KDOW is the responsible entity for enforcing the state regulations pertaining to surface water quality. The state water quality regulations, contained in the Kentucky Administrative Regulations (KAR), reflect the national water quality objective contained in the Clean Water Act, which is “to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters.” That objective is often referred to as the fishable/swimmable goal.

Pertinent regulations regarding water quality standards can be found in Title 401 of the KAR. For the purpose of this report, the following sections were reviewed for applicability:

- 401 KAR 10:031 describing the stream use surface water standards for waters in Kentucky.
- 401 KAR 10:026 describing the designations of uses of surface waters.

Additionally, KDOW publishes the 303(d) List of Waters, which identifies streams and lakes that are impaired for one or more pollutants and do not meet one or more water quality standards. Impaired waters are identified through assessment and monitoring programs conducted by KDOW personnel, volunteer networks, and other local, state, and federal agencies. The report is developed as an Integrated Report (IR) in two volumes, following guidance by EPA. Information on impaired water bodies on the 303(d) list includes:

- A description of the watershed basin.
- The location of the impaired stream (using river miles) or number of acres of an impaired lake.
- Causes that are likely contributing or causing the impairment, (e.g., excessive algal growth or low pH).
- Sources that are likely causing or contributing to the impairment, (e.g., wastewater treatment plant overflows or surface mining).

The 303(d) list is typically produced every other year for Kentucky. Every 303(d) list that is published includes a status of previously listed waters and any new waters assessed since the last report. The most recent 303(d) list published for Kentucky is from 2012—published in October 2013. It is anticipated that the 2014 303(d) list will be published in the very near future, and this information should be reviewed upon its publication to determine if there are any changes to the status of the streams in this report.

3.1.2 Stream Use Guidance

Warm-water habitats are those waters defined as inhabited by the typical warm-water assemblage of aquatic organisms for Kentucky rivers and streams. Primary contact recreation involves direct-contact activities, such as swimming; while secondary contact recreation involves uses where contact with water could possibly occur, such as boating or canoeing.

To meet primary contact recreation standards, a stream must meet both of the following criteria as defined from 401 KAR 10:031:

- Fecal coliform or *E. coli* content shall not exceed 200 colonies per 100 mL (cfu/100mL) or 130 cfu/100 mL, respectively, as a geometric mean based on not less than five samples taken during a 30-day period. Content shall also not exceed 400 cfu/100 mL in twenty percent or more of all samples taken during a thirty day period for fecal coliform or 240 cfu/100 mL for *E. coli.* These standards apply to the primary contact recreation water season from May 1st through October 31st.
- pH shall be between 6.0 to 9.0 and shall not change more than 1.0 within this range over a period of 24 hours.

To meet secondary contact recreation standards, a stream must meet both of the following criteria as defined from 401 KAR 10:031:

- Fecal coliform content shall not exceed 1,000 cfu/100mL as a 30-day geometric mean based on not less than five samples, nor exceed 2,000 cfu/100 mL in 20 percent or more of all samples taken during a 30-day period.
- pH shall be between 6.0 to 9.0 and shall not change more than 1.0 within this range over a period of 24 hours.

Fish consumption, in conjunction with aquatic life use, assesses attainment of the fishable goal of the Clean Water Act. Assessment of the fishable goal was separated into these two categories in 1992, because the fish consumption advisory does not preclude attainment of the aquatic life use and vice versa. Separating fish consumption and aquatic life use support gives a clearer picture of actual water quality conditions. Kentucky revised its methodology for issuing fish consumption advisories in 1998 to a risk-based approach patterned after the Great Lakes Initiative, which is often more stringent than EPA standards. Impaired waters due to fish consumption advisories are reported on the 305(b) list, as detailed in the *2012 Integrated Report.*

3.1.3 Study Area

As shown in Figure 3-1, the study area includes tributaries to both Island Creek and Perkins Creek. Island Creek and its tributaries flow through the City of Paducah prior to entering the Tennessee River immediately upstream of the confluence of the Tennessee and the Ohio Rivers. The designation for Island Creek is warm-water aquatic habitat, primary contact recreation, secondary contact recreation, and fish consumption. The *Final 2012 Integrated Report to Congress on the Condition of Water Resources in Kentucky* assesses the condition of Island Creek, which is summarized in Table 3-1. While CSOs are not identified as contributors to the stream impairments in these two reaches, several of the CSOs investigated in this study do flow into tributaries of Island Creek. In addition to being the receiving water for CSO flows, the stream is apparently used as a disposal site for unwanted trash and debris. Figure 3-2 shows examples of the debris found along Island Creek.

In addition to Island Creek, a tributary to Perkins Creek receives the flow from one outfall location. Perkins Creek flows into the Ohio River, downstream of the Tennessee/Ohio River confluence. While Perkins Creek appears to be perennial, it is not described in either the 305(b) or 303(d) 2012 Report to Congress.

Table 3-1 Designated Uses and Assessment of Uses in Island Creek

Island Creek into Tennessee River[1]	River Mile 0.0 to 5.7 Assessment Date – 5/2/2002	River Mile 5.7 to 10.1 Assessment Date – 4/1/1998
Designated Uses	1. Warm-water Aquatic Habitat 2. Primary Contact Recreation 3. Secondary Contact Recreation 4. Fish Consumption	1. Warm-water Aquatic Habitat 2. Primary Contact Recreation 3. Secondary Contact Recreation 4. Fish Consumption
Use Assessment[2]	1. 5-Partial Support 2. 5-Non Support 3. 3 4. 3	1. 5-Partial Support 2. 3 3. 3 4. 3
Pollutant(s)[3]	Cause Unknown; Fecal Coliform	Cause Unknown
Suspected Sources[3]	Source Unknown	Source Unknown

[1]Data presented in this table for Designated Uses were taken from the Final 2012 Integrated Report to Congress on Water Quality in Kentucky: Volume I. 305(b) Assessment Results with Emphasis on the Salt River – Licking River Basin Management Unit and the Upper Cumberland River – 4-Rivers Basin Management Unit

[2]Use assessment designation "3" indicates that the designated use(s) has/have not been assessed (insufficient or no data available) and designation "5" indicates that a TMDL is required.

[3]Data presented in this table for Pollutant(s) and Suspected Sources were taken from the *2012 Integrated Report to Congress on Water Quality in Kentucky: Volume II. 303(d) List of Surface Waters*

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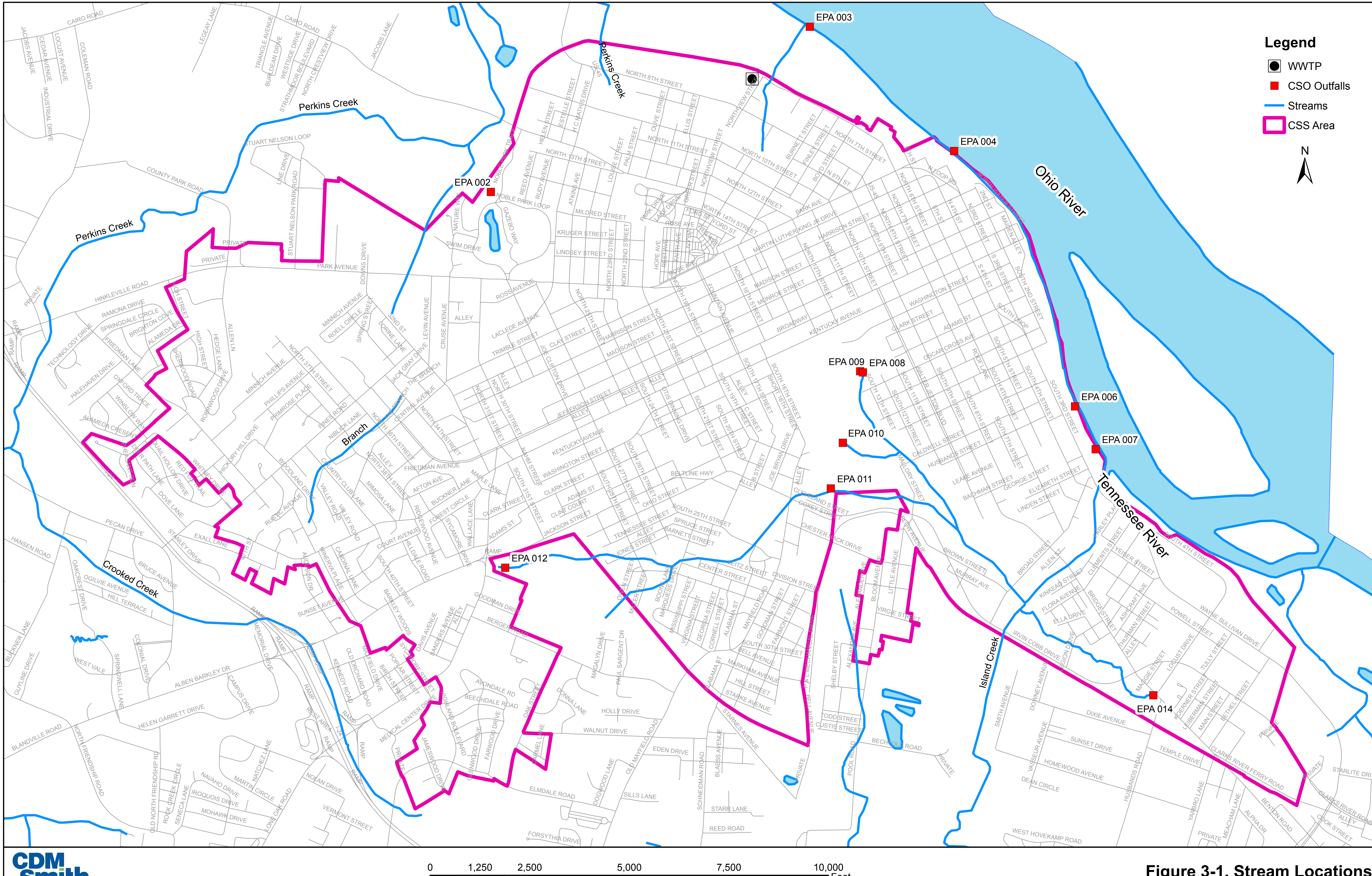

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Figure 3-1. Stream Locations

Figure 3-2 Debris Found In and Around Island Creek

3.1.4 Water Quality Monitoring Program

A bacterial water quality monitoring and sampling plan was developed to identify locations of water quality sampling sites and frequency of sampling. Section 20, paragraph a.2.(i) of the Consent Judgment excludes the characterization, monitoring, and modeling of the Ohio River and Tennessee River at the confluence of the Ohio River for the basis of selection and design of CSO controls. Because of this, sampling locations were selected further upstream within the CSS system. Figure 3-3 is a map showing the sampling locations and relative proximity to each outfall location.

Sampling was conducted during two wet-weather events and during two periods of dry-weather in 2008. Water quality sampling focused on bacteriological sampling and appropriate field parameters that are indicators of the health of aquatic life. Additionally, KDOW was consulted prior to implementation of the water quality sampling, and nutrient samples were also collected per KDOW's request to obtain additional ambient data for nutrients in these streams for future nutrient Total Maximum Daily Load (TMDL) analyses.

Dry- and wet-weather sampling was conducted to qualitatively assess the impact of CSOs on the water quality of Island Creek, Perkins Creek, and various outfalls and determine if there are significant background contributions to bacteria loadings. Additional data collected during 2008 supplemented existing water quality data collected during two previous studies conducted for JSA titled *Combined Sewer Operational Plan, Volume I Report* (GRW, 1994) and *Paducah/McCracken County JSA Combined Sewer Overflow Water Quality Data Assessment* (LAN, 2004).

In addition to the previously conducted studies, KDOW provided results from their sampling which is summarized in Table 3-2. The location information provided for these samples indicate they were collected upstream of where the JSA permitted outfalls flow into Island Creek. The sampling location is also shown in Figure 3-3.

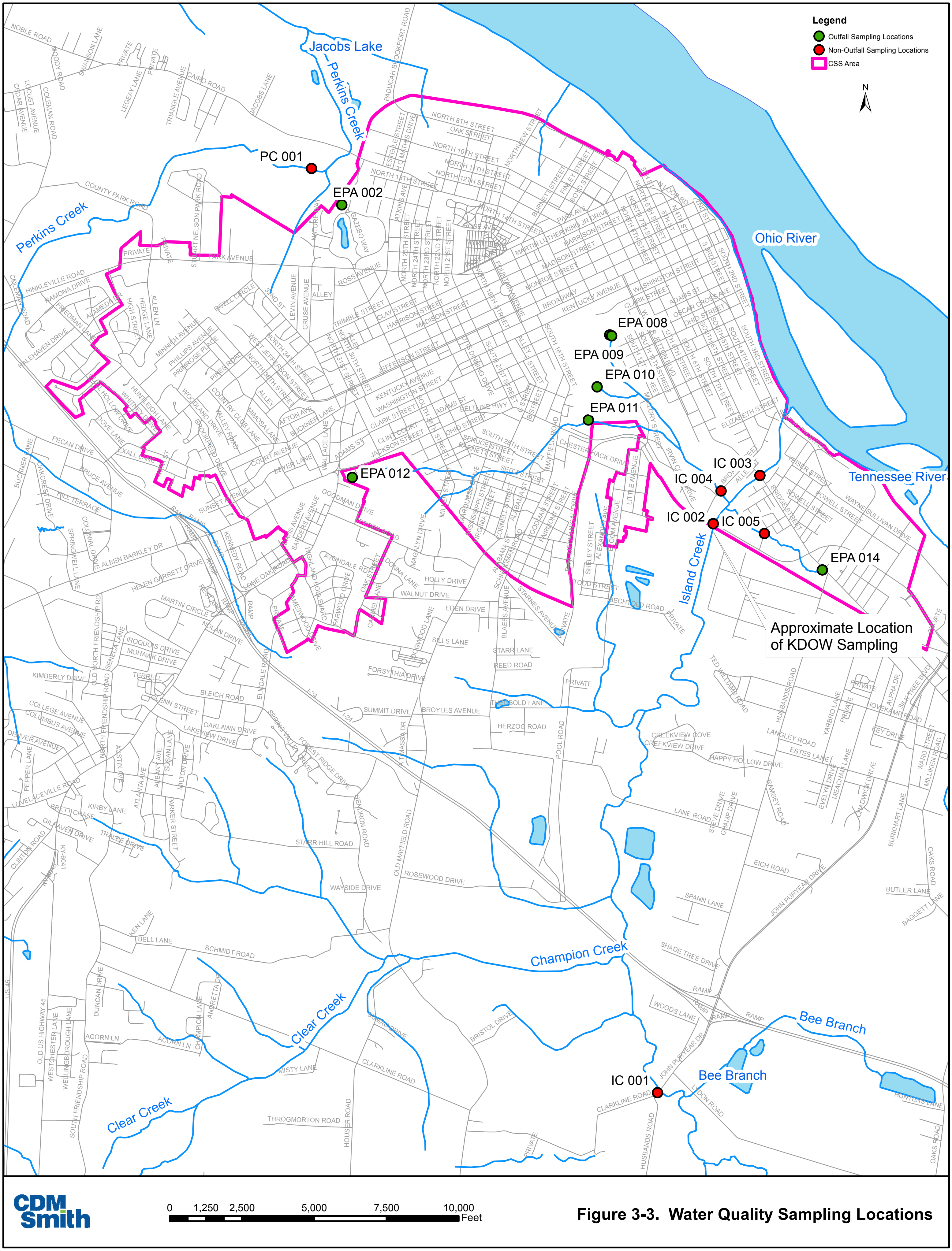

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Figure 3-3. Water Quality Sampling Locations

3.1.4.1 Sampling and Analysis

Water samples were collected from CSO discharges and locations within Island Creek and tributaries and Perkins Creek as shown in Figure 3-3. Grab samples were collected during two dry-weather and two wet-weather events and delivered to a laboratory for analysis. Field parameters were also measured during sample collection and included flow, pH, dissolved oxygen, and temperature. Flow measurements were collected at all locations where it was possible for field personnel to access flow measurement points. Flow at CSO locations were taken from the nearest temporary flow meter installed on the CSO pipe. If a CSO was not flowing during the time of sampling, a bacteria sample was collected from the nearest flowing water downstream, and an in-stream flow measurement was made at the sample collection location.

Table 3-2 KDOW Sampling Results

Date Sampled	Sampling Location	Fecal Coliform (cfu/100mL)
05/24/00	Island Creek at 60/62 Bridge	1,800
06/20/00	Island Creek at 60/62 Bridge	2,750
07/24/00	Island Creek at 60/62 Bridge	260
08/21/00	Island Creek at 60/62 Bridge	210
09/25/00	Island Creek at 60/62 Bridge	21,000
10/23/00	Island Creek at 60/62 Bridge	40

Samples requiring laboratory analysis were delivered to a laboratory in Paducah, KY within 6 hours, which is the maximum holding time for fecal coliform analysis. A summary of the analytical parameters and methods of analysis is provided in Table 3-3.

Table 3-3 Dry-Weather Sampling and Analysis Plan Methodology

Parameter	Analytical Method
Fecal Coliform	Standard Method 9222D
Total Kjeldahl Nitrogen	Standard Method SM 4500
Nitrate-Nitrogen	EPA Method 300.1
Total Phosphorus	EPA Method 365.1

3.1.4.2 Dry-Weather Sampling

Dry-weather sampling was conducted following a period that received no precipitation for a minimum of 3 days. Dry-weather samples were collected on June 19, 2008 and July 16, 2008. A summary of the locations sampled and the parameters analyzed is provided in Table 3-4.

3.1.4.3 Wet-Weather Sampling

The sampling and analysis plan for wet-weather included sampling after a minimum of 1/2-inch precipitation and as soon as reasonably possible after the CSOs began to flow. Wet-weather sampling was conducted on March 14, 2008 and April 3, 2008, during which time temporary flow monitoring devices were installed in the CSO system. The flow datasets collected during the wet-weather sampling were used to establish the flow regime during which the bacterial samples were collected. A summary of the locations sampled and the parameters analyzed for each location is provided in Table 3-5.

Table 3-4 Dry-Weather Sampling and Analysis Plan

*Station ID	Sample ID		Field Parameters		Nutrients D-W Event 1	Fecal Coliform[3]
	Dry-weather Event 1	Dry-weather Event 2	Flow[4]	pH, D.O., Temperature	TP, TKN, Nitrate	
Perkins Creek Sample Locations						
EPA 002[1]	EPA002-DW1-DATE08	EPA002-DW2-DATE08	if in-stream	X	---	X
Island Creek Sample Locations						
PC 001	PC001-DW1-DATE08	IC001-DW2-DATE08	X	X	---	X
EPA 008[1]	EPA008-DW1-DATE08	EPA008-DW2-DATE08	if in-stream	X	X	X
EPA 009[1]	EPA009-DW1-DATE08	EPA009-DW2-DATE08	if in-stream	X	---	X
EPA 010[1]	EPA010-DW1-DATE08	EPA010-DW2-DATE08	if in-stream	X	---	X
EPA 011[1]	EPA011-DW1-DATE08	EPA011-DW2-DATE08	if in-stream	X	---	X
EPA 012[1]	EPA012-DW1-DATE08	EPA012-DW2-DATE08	if in-stream	X	X	X
EPA 014[1]	EPA014-DW1-DATE08	EPA014-DW2-DATE08	if in-stream	X	---	X
WWTP	WWTP-DW1-DATE08	WWTP-DW1-DATE08	---	---	---	X
IC 001	IC001-DW1-DATE08	IC001-DW2-DATE08	X	X	X	X
IC 002[2]	IC002-DW1-DATE08	IC002-DW2-DATE08	X	X	---	X
IC 002[2]	IC200-DW1-DATE08	---	X	X	---	X
IC 003	IC003-DW1-DATE08	IC003-DW2-DATE08	X	X	X	X
IC 004	IC004-DW1-DATE08	IC004-DW2-DATE08	X	X	---	X
IC 005[2]	IC005-DW1-DATE08	IC005-DW2-DATE08	X	X	---	X
IC 005[2]	---	IC500-DW2-DATE08	X	X	---	X

*Samples with an "EPA" prefix are CSO locations; all other locations are in-stream sample locations
[1] The sample was collected at the nearest downstream location with in-stream flow.
[2]Duplicate samples were collected at this location
[3]Sample was collected in pre-preserved containers provided by the laboratory; samples were stored on ice and immediately transported to the laboratory to meet the hold time.
[4]Flow was measured at sample location excluding sampling conducted at CSOs.

Table 3-5 Wet-Weather Sampling and Analysis Plan

*Station ID	Sample ID		Field Parameters		Nutrients W-W Event 2	Fecal Coliform[3]
	Wet-weather Event 1	Wet-weather Event 2	Flow[4]	pH, D.O., Temperature	TP, TKN, Nitrate	
Perkins Creek Sample Locations						
EPA 002[1]	EPA002-WW1-DATE08	EPA002-WW2-DATE08	-	X	---	X
PC 001	PC001-WW1-DATE08	PC001-WW2-DATE08	X	X	---	X
Island Creek Sample Locations						
EPA 008[1]	EPA008-WW1-DATE08	EPA008-WW2-DATE08	-	X	X	X
EPA 009[1]	EPA009-WW1-DATE08	EPA009-WW2-DATE08	-	X	---	X
EPA 010[1]	EPA010-WW1-DATE08	EPA010-WW2-DATE08	-	X	---	X
EPA 011[1,2]	EPA011-WW1-DATE08	EPA011-WW2-DATE08	-	X	X	X
EPA 011[1,2]	EPA110-WW1-DATE08	---	-	X	---	X
EPA 012[1,2]	EPA012-WW1-DATE08	EPA012-WW2-DATE08	-	X	X	X
EPA 012[1,2]	---	EPA210-WW2-DATE08	-	X	---	X
EPA 014[1]	EPA014-WW1-DATE08	EPA014-WW2-DATE08	-	X	X	X
IC 001	IC001-WW1-DATE08	IC001-WW2-DATE08	X	X	X	X
IC 002	IC002-WW1-DATE08	IC002-WW2-DATE08	X	X	---	X
IC 003	IC003-WW1-DATE08	IC003-WW2-DATE08	X	X	X	X
IC 004	IC004-WW1-DATE08	IC004-WW2-DATE08	X	X	---	X
IC 005	IC005-WW1-DATE08	IC005-WW2-DATE08	X	X	---	X

*Samples with an "EPA" prefix are CSO locations; all other locations are in-stream sample locations
[1]If the CSO is not flowing, the sample was collected at the nearest downstream location with in-stream flow
[2]Duplicate samples were collected at this location
[3]Sample was collected in pre-preserved containers provided by the laboratory; samples were stored on ice and immediately transported to the laboratory to meet the hold time.
[4]Flow was measured at each sample location excluding CSOs. At CSOs, flow was taken from the temporary monitors installed in the system

The goal of the wet-weather sampling was to attempt to characterize the first flush, which is the early portion of a hydrograph that typically contains the highest concentration of constituents. After a period of dry-weather, storm water picks up particles and contaminants that have accumulated on the ground surface and in storm drains (including combined sewers). First-flush monitoring results can illustrate the impact of point and non-point sources of bacteria on in-stream water quality. The data collected during the wet-weather portion of this study, was evaluated for its representativeness with respect to the first flush.

3.1.4.4 Results

Nutrient data collected for samples during both wet- and dry-weather sampling is provided in Table 3-6. Nitrate data was originally planned for collection during one wet- and one dry-weather event. However, due to issues with field sampling, nitrate samples were not collected for analysis during either of the wet-weather sampling events. The fecal coliform results for both dry-weather samples are provided in Tables 3-7 and 3-8, along with flow, pH, dissolved oxygen, and temperature, where available. Table 3-9 provides the quality control (QC) results for the fecal coliform samples.

Due to the nature of the topography and hydrology of the Island Creek watershed, flow from Island Creek is often backed up, especially when the floodwall gates at the confluence with the Tennessee

River are closed. Although this is not believed to impact the combined sewer system except during extreme flooding conditions, this hydrologic condition made measurement of flow impossible for the field sampling team at some locations.

Table 3-6 Nutrient Data for Dry- and Wet-Weather Sampling

Station ID	Dry-Weather (6/19/2008)			Wet-Weather (4/3/2008)		
	TKN (mg/L)	Nitrate-N (mg/L)	TP (mg/L)	TKN (mg/L)	Nitrate-N (mg/L)	TP (mg/L)
EPA 008	0.89	1.2	< 0.050	0.66	-	0.18
EPA 011	-	-	-	0.68	-	0.21
EPA 012	0.60	0.98	0.090	0.46	-	0.063
EPA 014	0.81	0.85	0.14	0.51	-	0.062
IC 001	1.3	< 0.55	0.20	1.0	-	0.19
IC 003	0.72	0.75	0.13	0.88	-	0.10

'-' indicates no sample was collected.

Table 3-7 Field Parameters and Fecal Coliform Results for Dry-Weather Sampling

Station ID	6/19/08					7/16/08				
	pH (s.u.)	Temp. (C)	D.O. (mg/L)	Fecal Coliform (cfu/100 mL)	Flow[1] (gpm)	pH (s.u.)	Temp. (C)	D.O. (mg/L)	Fecal Coliform (cfu/100 mL)	Flow[1] (gpm)
Sample Locations in the Perkins Creek Drainage Basin										
EPA002	7.26	23.0	6.0	500	-	7.36	27.1	5.0	40,000	-
PC001	7.20	25.8	8.0	110	956[2]	-	-	-	400	-
Sample Locations in the Island Creek Drainage Basin										
EPA008	7.20	23.0	5.0	10,000	-	7.20	28.6	7.0	1,000	-
EPA009	7.60	22.9	6.0	300	-	7.41	27.7	7.0	< 10	-
EPA010	6.84	22.6	6.0	200	-	6.95	24.8	6.0	2,000	-
EPA011	7.04	24.7	5.0	460	-	7.20	29.5	6.0	440	-
EPA012	7.19	23.8	6.0	1,300	-	6.84	26.2	8.0	500	-
EPA014	6.83	22.0	8.0	2,400	-	8.13	30.7	6.0	4,000	-
IC001	6.51	26.7	5.0	150	577[2]	6.2	28.6	4.0	200	-
IC002	7.00	28.7	7.0	200	-	6.45	29.4	3.0	30	-
IC003	6.53	27.8	6.0	400	-	6.45	30.1	3.0	30	-
IC004	6.73	28.1	6.0	200	-	6.75	28.2	5.0	400	-
IC005	7.22	25.8	6.0	1,700	14.5[2]	7.10	24.7	5.0	700	-
Wastewater Treatment Plant										
WWTP	6.89	26.9	2.0	140,000	-	-	-	-	-	-

'-' indicates no sample was collected.
[1]Flow was measured at a continuous flow monitoring device in the combined sewer unless otherwise noted.
[2]Flow was measured in the field using depth-velocity measurements.

Table 3-8 Field Parameters and Fecal Coliform Results for Wet-Weather Sampling

Station ID	3/14/08					4/3/08				
	pH (s.u.)	Temp. (C)	D.O. (mg/L)	Fecal Coliform (cfu/100 mL)	Flow[1] (gpm)	pH (s.u.)	Temp. (C)	D.O. (mg/L)	Fecal Coliform (cfu/100 mL)	Flow[1] (gpm)
Sample Locations in the Perkins Creek Drainage Basin										
EPA002	7.56	11.3	7.0	1,200	104	7.11	15.5	7.0	3,100	0
PC001	7.76	14.3	10.0	60	7000[2]	7.62	11.8	9.0	400	45000[2]
Sample Locations in the Island Creek Drainage Basin										
EPA008	7.45	12.5	9.0	300	410	7.35	11.4	9.0	> 6,000	349
EPA009	7.74	14.1	10.0	3,000	9.5	7.67	13.2	9.0	35,000	33.8
EPA010	7.40	12.3	8.0	200	112	7.39	12.9	9.0	800	157
EPA011	7.45	12.8	9.0	70	0	7.42	12.5	8.0	1,200	138
EPA012	7.38	11.9	10.0	3,200	*	7.58	13.1	8.0	1,000	46.3
EPA014	7.91	15.2	9.0	60,000	*	7.64	11.6	11.0	700	*
IC001	7.09	13.0	6.0	60	865[2]	7.46	13.4	9.0	4,400	286[2]
IC002	7.70	12.4	11.0	40	**	7.43	13.2	10.0	600	**
IC003	7.98	11.0	12.0	20	**	7.35	12.4	10.0	140	**
IC004	7.75	11.8	11.0	10	**	7.62	11.8	9.0	30	**
IC005	7.57	12.5	10.0	170	99[2]	7.46	10.6	9.0	4,000	116[2]

'*' indicates that there were issues with the flow monitoring device
'**' no flow was observed, water was backed-up at these sample locations
[1]Flow was measured at a continuous flow monitoring device in the combined sewer unless otherwise noted
[2]Flow was measured in the field using depth-velocity measurements

Table 3-9 QC Sample Results for Fecal Coliform

Station ID	Fecal Coliform QC Samples (cfu/100 mL)			
	3/14/2008	4/3/2008	6/19/2008	7/16/2008
EPA011 - duplicate	200	-	-	-
EPA012 - duplicate	-	200	-	-
IC002 – duplicate	-	-	60	-
IC005 - duplicate	-	-	-	500

Dry-weather sampling occurred when there would be no overflows within the sewer. However, there was low flow at all CSO locations during both dry-weather sampling events. Rather than indicating that a CSO occurred or that the diversion structure was triggered, this is believed to be the result of groundwater infiltration or other flow sources which enter the outfall conduit downstream of the diversion structure. In several cases, the length of conduit from the regulator structure to the outfall discharge exceeds 0.5 miles.

It is not practical to collect sufficient data to make statistically robust comparisons of bacterial concentrations between dry- and wet- weather results. However, general trends may be noted for samples collected either at or near CSOs and samples collected in-stream. Bacterial samples collected at CSOs during wet-weather events had concentrations of fecal coliforms similar in order of magnitude to those collected downstream of CSO locations, in-stream during dry weather. This indicates that although CSOs are not flowing, there are still bacterial contributions to tributaries to Island Creek and

Perkins Creek. A count of in-stream samples that exceeded the primary contact recreation water quality standard of 200 cfu/100 mL of fecal coliform shows that water quality criterion is exceeded more often during dry-weather than during wet weather. While dilution may explain the low fecal coliform counts during wet-weather sampling, there appear to be background water quality issues that need to be addressed as indicated by the dry-weather bacteria results both upstream and downstream of CSO locations. Results for other parameters, such as pH and dissolved oxygen, do not indicate impacts to the stream from wet-weather CSO discharges. No analysis was performed to assess the background water quality issues; the impacts may be attributed to domestic or wild animals, septic tanks, or other sources.

3.1.5 Proposed Future Stream Uses

JSA does not expect to have significant land use changes near Island Creek, with land use remaining similar to what is currently observed. The CSS area of Perkins Creek is similar and is not expected to develop any further than what is currently observed.

3.2 Other Sensitive Areas

In addition to the streams located within Paducah's combined sewer system, JSA has reviewed the system for other potentially sensitive areas and has identified the following areas:

- Paducah's drinking water intake
- Habitat of threatened and endangered species of mussels on the Ohio and Tennessee Rivers
- Recreational areas in proximity to CSO locations

A sensitive-area map has been prepared to document the location and spatial extent of areas designated as "sensitive." This map is shown in Figure 3-4.

3.2.1 Drinking Water Intake

No drinking water intakes are located along Island Creek or Perkins Creek. Most water, including industrial cooling water, is taken from the City's water supply which takes raw water from the Ohio River approximately 1,500 feet upstream of EPA 003. Additional information on the operation of the Paducah Water Treatment Plant, potential impacts from CSO discharges, and alternatives to further protect the drinking water intake are described in Appendix B.

3.2.2 Habitat of Threatened and Endangered Species

The Kentucky Environmental Field Services Office of the U.S. Fish and Wildlife Service (USFWS) was contacted in 2008 to determine if waters in the CSO-impacted areas could be considered critical habitat for threatened or endangered species. After review of the USFWS database, no records of threatened or endangered species were found in Perkins Creek, Island Creek, or tributaries associated with outfalls. However, in the Ohio River in the vicinity of the confluences with Island Creek and Perkins Creek, the USFWS has records of four endangered species of mussels: *Plethobasus cooperianus* (Orangefoot pimpleback), *Potamilus capax* (Fat pocketbook), *Lampsilis abrupta* (Pink mucket), and *Obovaria retusa* (Ring pink). Analysis of the potential impacts to these species from CSO is further described in Appendix C.

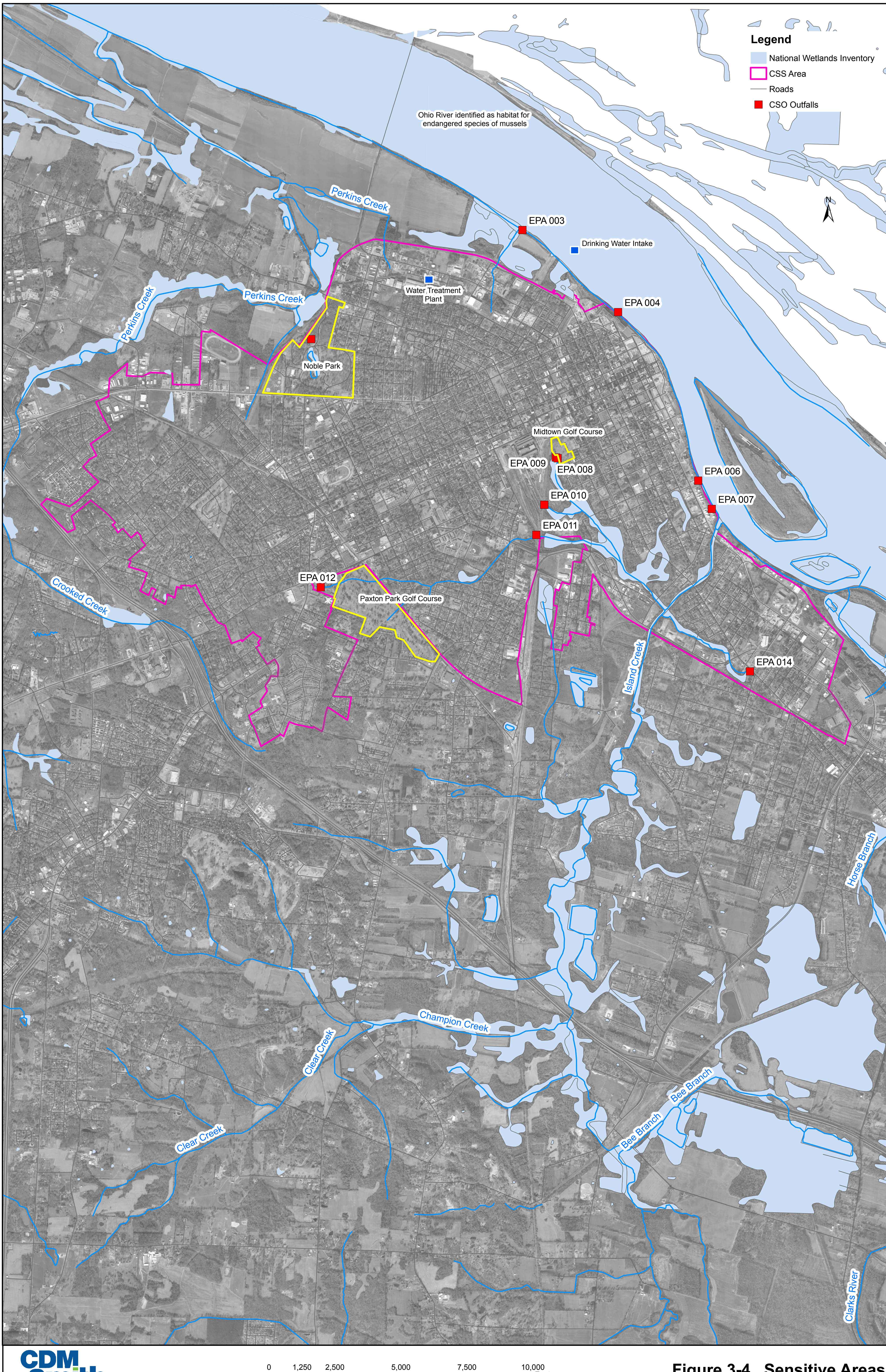

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Figure 3-4. Sensitive Areas

3.2.3 Additional Recreational Areas

Sensitive areas within the study area due to primary contact could include recreational areas or designated bathing and/or fishing areas. The following outfalls are located in proximity to an area with known recreational uses:

- EPA 002 is located adjacent to the Bob Noble Park.
- EPA 008 and EPA 009 are adjacent to the Midtown Golf Course.
- EPA 012, where a sewer separation project has been completed, is upstream of Paxton Park Golf Course.

3.3 Industrial Impacts on Water Quality

Each day, industrial facilities discharge wastewater into the CSS. This wastewater is suitable for treatment at the Paducah WWTP. However, it can potentially impact a receiving stream when discharged through a CSO during wet weather.

The JSA system has four permitted significant industrial users (SIUs) located within the boundaries of the combined sewer system, as shown in Figure 3-5. Table 3-10 presents the SIUs in the CSS and their 2014 flow contributions to the WWTP. Based on this information, provided in Table 3-10, the 2014 total industrial flow contribution, on an average daily basis, is approximately 2.1 percent of the flow to Paducah WWTP.

Table 3-10 Industrial Contributors to the Combined Sewer System (2014)

Permit Number	Industry Name	CSO ID	2014 Average Flow (mgd)	Industrial Percentage of WWTP Average Flow (mgd)
IDP-2	Baptist Health Paducah	EPA 002	0.164	2.01%
IDP-6	Hawley Products	EPA 003	0.0042	0.05%
IDP-11	Ingram Barge Company	EPA 006	0.0023	0.03%
IDP-14	Transmontaigne	EPA 007	0.0003	0.00%
Total Industrial Flow in CSS			**0.1708**	**2.09%**
WWTP Average Flow			**8.17**	

Wastewater discharges from all the regulated industrial users are monitored and sampled annually in accordance with the requirements of the Sewer Use Ordinance. JSA collects split samples annually from each SIU and performs semi-annual compliance inspections.

JSA recognizes that the control of non-domestic discharges to specific portions of the CSS during wet-weather periods may reduce the CSO impacts. As outlined in the Sewer Use Ordinance, JSA may require an industry to provide temporary on-site storage of process wastewater. These efforts, if implemented, will assure that no additional pollutant loads are discharged to the CSS during wet weather.

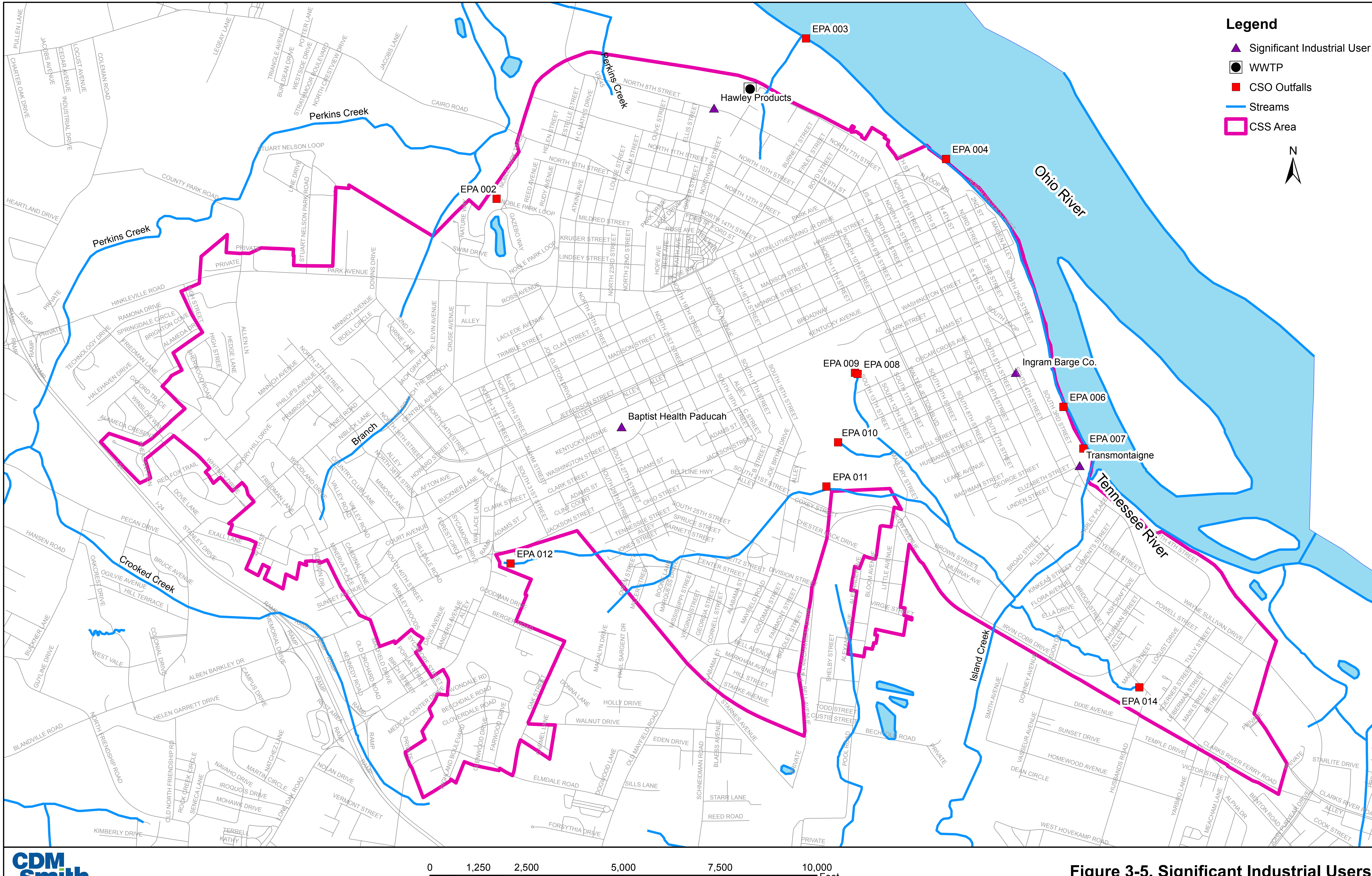

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Figure 3-5. Significant Industrial Users

The conventional permitted pollutants for all industrial discharge permittees are listed below:

- Ammonia (NH_3-N)
- Total Suspended Solids (TSS)
- Biochemical Oxygen Demand (BOD)
- Oil and Grease
- Flash Point Temperature

The toxic inorganic pollutants monitored consist of those listed below:

- Arsenic
- Cadmium
- Chloride
- Chromium, Total
- Chromium, Hexavalent
- Copper
- Cyanide
- Lead
- Mercury
- Nickel
- pH
- Selenium
- Silver
- Tetrachloroethylene
- Zinc

JSA does not experience any SIUs discharging to the combined system that have been in significant noncompliance with the pretreatment limits for a significant amount of time. The parameters violated from January to June of 2015 include:

- Baptist Health Paducah – ammonia

Because of this insignificant non-compliance, the Paducah WWTP does not experience any abnormal slug changes due to varying discharges and does not charge SIUs with violations. There is a program in place for fines and wastewater discharge holding, but it has not been used to date.

A review of the location of each industry with respect to the combined sewer outfall boundaries is also included in Table 3-10. This table reveals that permitted industrial facilities could potentially contribute to toxic effects, if their wastewater is discharged during an overflow event. Of the four industrial users, Baptist Health Paducah could contribute to water quality issues in Perkins Creek; and Hawley Products, the Ingram Barge Company, and Transmontaigne overflow directly into the outfalls leading to the Tennessee and Ohio Rivers.

Based on Table 3-10, prioritization of CSO control facilities and/or pilot CSO reduction programs will not create a significant difference, if focused on the outfalls related to the industrial users summarized above.

Section 4

Basis of Analysis

Although EPA's CSO Control Policy (Section I.D.) recognizes that detailed monitoring and modeling of the CSO may be difficult for small systems like JSA, JSA elected to complete flow monitoring and develop a calibrated hydraulic model of the system. Considerable resources have been devoted to this effort, yielding an effective tool to evaluate control options. Precipitation and flow monitoring analyses were performed. These datasets were then used with infrastructure data to develop a calibrated hydraulic model of the CSS that was used to estimate average annual overflow statistics for each CSO outfall.

4.1 Flow and Precipitation Monitoring

As part of developing the LTCP, in particular to support model calibration, 30 temporary flow monitors were installed in the CSS area from late January 2008 through early April 2008. Flow monitoring locations are shown on Figure 4-1. The flow monitors recorded depth and velocity of flow in 5-minute intervals and included monitors located on each CSO outfall, excluding those that discharge directly to the Tennessee or Ohio Rivers. Monitors were also located on combined trunk sewers to collect data that could be used to calibrate model runoff parameters from different land use types, on key interceptors within the CSS to calibrate hydraulic parameters for those sewers, and on separate sanitary sewers that drain a significant area before connecting to the CSS to define dry- and wet-weather flows into the CSS from those areas. For the CSO outfalls that discharge directly to the Tennessee or Ohio Rivers (EPA 003, EPA 004, EPA 006, and EPA 007), monitoring of the outfalls themselves was not feasible, however, adjacent monitoring and pump station information was adequate to estimate the discharge of those outfalls.

Eight rain gauges were installed throughout the CSS area during the temporary monitoring period. Additional rainfall data from temporary rain gauges installed as part of the sanitary sewer overflow plan was also available for analysis. Locations for the rain gauges are also provided in Figure 4-1. Rain gauges recorded rainfall data in 0.01 inch increments at 5-minute intervals.

On average, approximately 20 inches of precipitation was recorded over the three month temporary monitoring period, with 17 days receiving 0.25 inches or more of precipitation. This includes rainfall events as well as some snow/ice events. Table 4-1 summarizes the precipitation statistics for March 2008, which served as the primary calibration and verification period. These are based on the average data for the eight rain gauges that were included in the analysis. No statistics are provided for the March 7-8 event, which was primarily a snow event totaling 1.8 inches as measured at the airport.

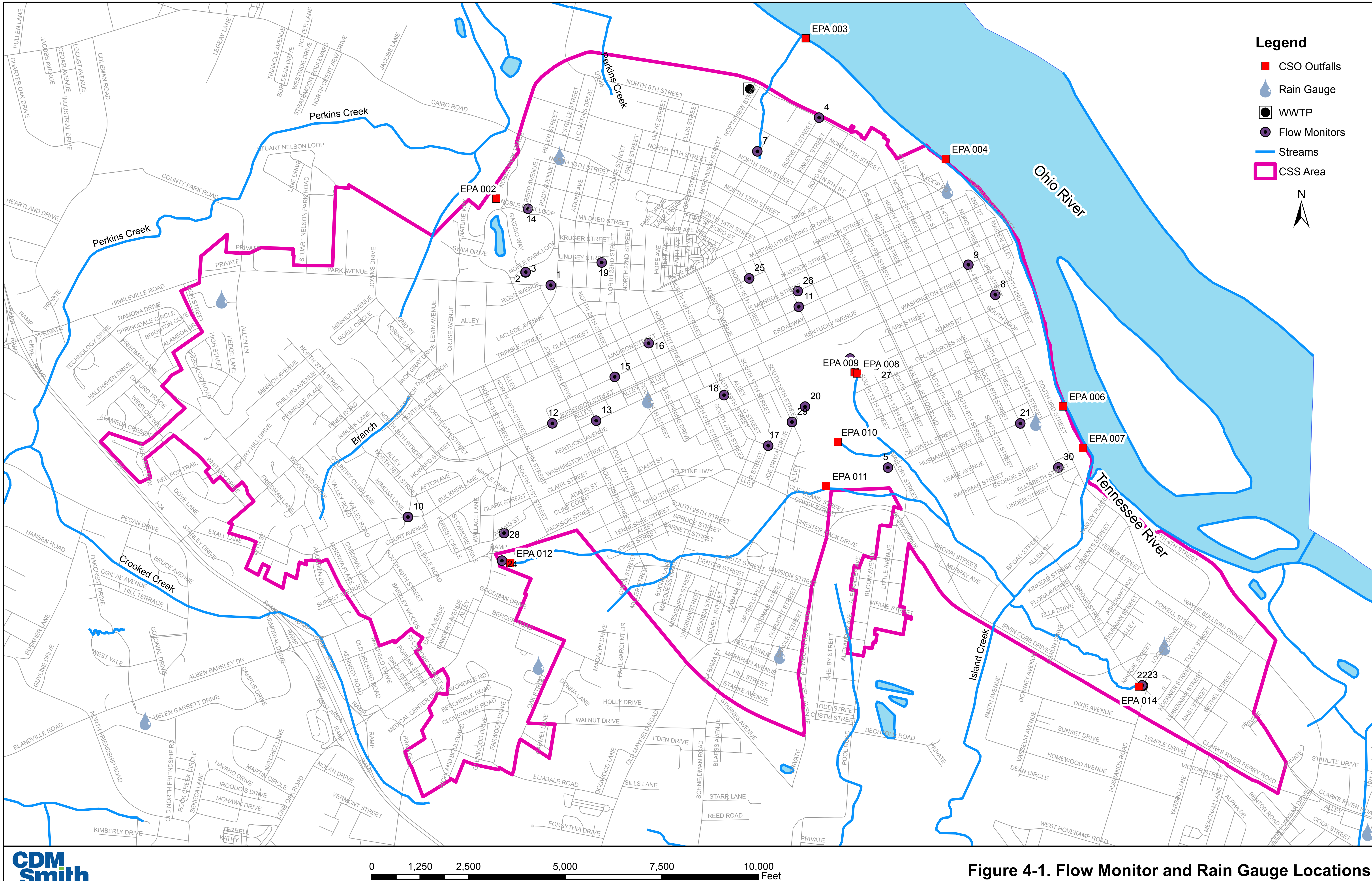

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Figure 4-1. Flow Monitor and Rain Gauge Locations

Table 4-1 Summary of March Rainfall Events

	Return Frequency by Duration				
Rainfall Event	**1 hour**	**2 hour**	**6 hour**	**12 hour**	**24 hour**
March 3-4, 2008	>3 month	>6 month	>2 year	>2 year	>2 year
March 14-15, 2008	<1 month	<1 month	<1 month	<1 month	<1 month
March 18-19, 2008	>1 year	>2 year	>5 year	>10 year	>10 year
March 28, 2008	<1 month	<1 month	<1 month	<1 month	<1 month
March 28, 2008	<1 month	<1 month	<1 month	<1 month	<1 month
March 31, 2008	>1 year	>6 month	>3 month	>3 month	>1 month

4.2 Modeling of the Existing System

A hydraulic model of the combined sewer system using the EPA Stormwater Management Model (SWMM) Version 5.0.016 was developed to support the original LTCP (submitted in September 2010). The model included separate sanitary sewer upstream of the combined sewer system, combined trunk sewers, CSO outfalls, and regulators that capture and convey flow to the WWTP. The hydraulic model includes approximately 35 miles of pipe, providing an adequate skeletonized model that is representative of the combined sewer system and includes all features necessary to properly evaluate the combined sewer system's performance under both existing (baseline) and improved conditions.

The model includes the Husbands Pump Station, the Harrison Pump Station, and the Terrell Pump Station. Infrastructure data utilized to develop the hydraulic model was obtained from JSA's geographic information system (GIS), record drawings, and field investigations. After the model was constructed, it was calibrated using the flow and precipitation data that was collected in 2008.

The temporary flow monitoring data was analyzed to establish dry-weather flow model inputs. Because of the location of flow monitors 4 and 7 (each approximately one quarter mile upstream of the WWTP), the vast majority of the system was monitored. For the small portion of the system that was unmonitored, dry-weather flows were estimated utilizing available flow monitoring data for other areas of the system and allocated on a flow per acre of sewered area basis.

Wet-weather flows in the combined sewer were established by delineating drainage areas utilizing storm sewer catchment data, elevation data, and the location of sewers not included in the model. With GIS data, zoning information, and aerial photography, each drainage area was evaluated to estimate the pervious and impervious areas, catchment width, catchment slope, and other runoff parameters. For portions of the study area representing separate sanitary sewer systems, wet-weather flows were represented in the model utilizing rainfall derived infiltration and inflow (RDII) unit hydrograph parameters.

The primary goal of the model development and calibration was to represent the overflow frequency, volume, and peak flow rates at the CSO discharge locations. The ability of the model to accurately simulate these characteristics was ensured through the calibration process, in which simulated volume, peak flow, and peak depth were evaluated relative to the observed data at monitoring locations within the combined sewer system. The focus of the calibration was the large March 3 event with secondary focus placed on the smaller events on March 14 and March 31. The primary verification event was the March 18 event. (Note that after the March 18 event the floodwall gates were closed resulting in backwater effects in the system and causing observed levels at several sites to rise and remain above the normal levels that are reflected in the model at several CSO outfall meters.) Calibration graphs are provided in Appendix D of the *Revised LTCP*.

The calibration results demonstrate that the model accurately represents system performance, to the extent that flow monitoring data was available. JSA also intends to collect additional flow monitoring data, as needed, as part of the preliminary design of the selected CSO control projects.

Although JSA has continued to analyze portions of the system and has constructed sewer separation projects associated with CSOs EPA 012 and EPA 014 since the modeling conducted as part of the September 2010 LTCP, additional comprehensive modeling of the full combined sewer system has not been necessary. Therefore, the modeling results presented herein are based upon the 2008-2010 (baseline) hydraulic model unless otherwise noted.

4.3 Representative Rainfall Period

Based on an analysis of the historical precipitation records for the Paducah area, JSA selected a representative five-year period to use in the modeling analysis of the system. This five-year period includes the years 1965, 1973-1975, and 1977, which combined have been determined to reasonably represent the full historical precipitation record for the Paducah combined sewer system. Since a continuous simulation period, as opposed to a single design storm, includes periods of both dry- and wet-weather flows, it better accounts for the sequencing of storm events over time and, as such, allows a better evaluation of the effects of dry periods on parameters, such as soil infiltration, and aids in the development of average annual overflow statistics. The five-year representative period dataset was utilized in conjunction with the hydraulic model to predict annual CSO volume, duration, and frequency and to evaluate the effectiveness of potential improvements for inclusion in the LTCP. The development of the five-year representative period is described in Appendix E.

For this five-year period, the number of relatively large (those with a 1-year recurrence interval or greater) storm events for a given recurrence interval and duration are shown in Table 4-2. Ideally, the representative five-year rainfall record for continuous simulation would include five 1-year storms, two to three 2-year storms, and one 5-year storm at durations from 1 to 24 hours. Although the representative period does not match the ideal storm distribution, it is reasonably close.

Table 4-2 Count of Large Storms by Recurrence Intervals

Minimum Recurrence Interval	Number of Storm Events at Duration							
	1 hour	2 hour	3 hour	4 hour	6 hour	8 hour	12 hour	24 hour
1-year	5	6	5	6	5	4	4	4
2-year	4	4	3	2	2	3	2	2
5-year	2	1	0	0	1	2	1	0

A comparison of the storm depths at 3-month, 6-month, 1-year, 2-year, and 5-year recurrence intervals determined for the long-term, historical dataset and the five-year representative period is shown in Table 4-3. Additionally, because the frequency of CSO events can be sensitive to events smaller than a storm with a 3-month recurrence interval, the average annual number of small events for the selected five-year representative period was compared to the full, historical dataset. This comparison is shown in Table 4-4.

Table 4-3 Comparison of Storm Depths

Recurrence Interval	Duration	Storm Depth (inches)	
		Long-Term, Historical Dataset	1965, 1973-1975, 1977
3-month	1-hour	0.71	0.70
	6-hour	1.35	1.40
	12-hour	1.60	1.70
	24-hour	1.85	1.90
6-month	1-hour	0.90	0.90
	6-hour	1.68	1.70
	12-hour	1.92	2.00
	24-hour	2.40	2.28
1-year	1-hour	1.17	1.10
	6-hour	2.06	2.00
	12-hour	2.50	2.13
	24-hour	3.06	2.60
2-year	1-hour	1.41	1.70
	6-hour	2.45	2.56
	12-hour	3.01	2.88
	24-hour	3.60	3.40
5-year	1-hour	1.68	2.00
	6-hour	2.93	2.97
	12-hour	3.64	3.62
	24-hour	4.31	4.13

Table 4-4 Comparison of Small Storm Events

Event Size (inches)	Average Number of Events per Year	
	Long-Term, Historical Dataset	1965,1973-1975,1977
<0.1	42.5	42.6
0.1 to 0.25	17.1	16.4
0.25 to 0.5	17.6	18.4
0.5 to 1.0	15.4	16.6
1.0 to 2.0	8.7	8.2
>2	2.5	2

4.4 Baseline Model Results

The SWMM-based hydraulic model was used to generate stormwater runoff estimates using information on land use and other basin characteristics, as well as routing flows through the combined sewer system. The representative five-year precipitation record was used with the system modeling results to assess the average annual volume, duration, and frequency of CSOs at each outfall. The model was also used to characterize system performance during extreme events when the system may behave differently than it does during more frequent rainfall conditions to define limits of system capacity and performance.

Baseline outfall statistics from the calibrated model under the five-year representative period are shown in Table 4-5. This analysis includes monthly dry-weather flow parameters that were established from historical WWTP flow records and modeled to account for seasonal variations in groundwater infiltration. The baseline model also assumes that the system is not in a flood control scenario, which allows for a conservative estimate of the discharges from CSOs. (In flood control scenarios, the outfalls are submerged and flood control pump stations are utilized to discharge flow, creating a tailwater condition that may store excess combined sewer flow within the trunk sewers and reduce the discharge of flow at the CSO outfalls.) Additional information on the flood control system is presented in Appendix F.

Average volumes in Table 4-5 are shown for both the total volume of the overflow and the volume contributed by the regulators only. The storm sewer pipes continue to receive additional direct stormwater flows downstream of the regulators, which accounts for annual discharges of approximately 360 million gallons (MG) from the outfalls or 20 percent of the system's total annual discharge. For EPA 002, EPA 008, EPA 010, and EPA 014, over half of the CSO volume is attributed to this.

As shown in the table, CSO events are predicted to occur from 14 times per year at EPA 006 to 85 times per year at EPA 011. The significant number of events, in some cases, are driven by local stormwater that is discharged into the CSO outfall pipe downstream of the regulator locations.

Table 4-5 Average Annual Statistics at CSO Outfalls

Outfall	Description	Average Annual Statistics				
		Duration (hours)	Volume (MG)	Volume from Regulators (MG)	Volume Difference (MG)*	Events (number)
EPA 002	Noble Park	1758	308	124	184	68
EPA 003	Terrell	1251	843	843	0	50
EPA 004	Harrison	1055	83	83	0	40
EPA 006	Husbands	456	32	32	0	14
EPA 007	Husbands	2047	221	221	0	36
EPA 008	Rail yard	1764	75	20	55	67
EPA 009	Rail yard	1954	47	43	4	58
EPA 010	Rail yard	2065	82	13	69	64
EPA 011	Rail yard	970	17	10	7	85
EPA 012	Lone Oak	926	42	41	1	45
EPA 014	Bridge Street	1692	46	7	39	70
	Total:		**1796**	**1437**	**359**	

* The volume difference between total outfall volume and the volume from the regulators is the amount of storm only flows that enter the system downstream of a regulator.

Table 4-5 presents the baseline statistical analysis conducted as part of the original LTCP submittal. Because the baseline condition does not include the sewer separation projects at EPA 012 and EPA 014, the table does not reflect the elimination of these CSO discharges.

In addition to developing average annual statistics, the model was used during the LTCP development process for evaluating the potential benefit of alternative system improvement modifications to reduce CSO impacts as discussed in the following sections of this report.

Section 5

CSO Control Alternatives

In order to provide the requested additional information on CSO control alternatives, JSA has re-evaluated each CSO location to assess the feasibility of a full range of alternative technologies for the elimination and/or capture and treatment of CSO discharges. Unless otherwise noted, the following alternative technologies were evaluated at each location:

- **Sewer separation.** Sewer separation is the conversion of a combined sewer system into separate stormwater and sanitary sewer systems. Fully separated sewers eliminate CSOs and prevent untreated sanitary sewage from entering receiving waters during wet weather.
- **Storage.** Storage provides additional capacity to the system by storing peak flows in excess of sewer capacity until flow rates return to levels that allow the captured flow to be returned to the system for conveyance and treatment. For the purposes of this analysis, off-line, above-ground storage facilities were assumed, which require a wet-weather pump station to fill the storage facilities. When necessary, dewatering pump stations and dewatering piping are also included.
- **Pumping to a consolidated wet-weather treatment facility.** This alternative provides increased conveyance capacity (new pump station and force main) to route excess wet-weather flows from the combined sewer system to a new, consolidated wet-weather treatment facility that would be located near the existing WWTP to treat flows associated with EPA 003. This alternative assumes the wet-weather treatment facility includes high rate treatment and disinfection and includes the costs to incrementally increase the capacity of the wet-weather treatment facility to handle the additional flow.
- **Fine screening.** Fine screening alternatives assume a continuously cleaned, mechanical fine screen with openings of no more than 4 to 6 millimeters. Where possible, screened materials remain in the combined sewer system for conveyance to the WWTP. However, because of the configuration of the combined sewer system in many locations in the JSA system, including those with multiple regulator structures, many CSO locations would require on-site capture and handling of screened materials for disposal.
- **Fine screening with disinfection.** This alternative combines the fine screening alternative described above followed by disinfection. Three disinfection alternatives were evaluated – ultraviolent (UV), chlorination / dechlorination, and peracetic acid (PAA).
- **High rate treatment.** This alternative consists of installing a high rate clarification system that is designed to remove settleable solids and the insoluble BOD fraction with a construction footprint that is much smaller than conventional primary treatment processes, while providing a higher level of treatment than conventional primary treatment processes.
- **High rate treatment with disinfection.** This alternative combines the high rate treatment alternative described above followed by disinfection. The same three disinfection alternatives were evaluated – UV, chlorination / dechlorination, and PAA.

The above alternative technologies represent a broad range of viable, contemporary, and widely-recognized approaches for effectively addressing CSO impacts, although all technologies may not be feasible or applicable at all locations in the JSA system. It should also be recognized that they provide differing levels of treatment, and thus variable levels of protection of water quality, while imposing varying levels of costs for construction and operation / maintenance. The costs and benefits of each have been evaluated for each location in preparing this report. It should be noted that variations on the above technologies, for instance micro screens or plate settlers, may provide levels of treatment between those demonstrated for fine screens and high rate treatment. Additional information on the feasibility of each of the above technologies to provide a level of treatment equivalent to primary clarification is further discussed in Appendix G.

Descriptions of each alternative evaluated, screening-level site layouts, and screening-level costs are provided for each CSO location in the appendices, as follows:

- Appendix H – EPA 002: Noble Park
- Appendix I – EPA 003: Terrell
- Appendix J – EPA 004: Harrison
- Appendix K – EPA 006 and EPA 007: Husbands
- Appendix L – EPA 008 and EPA 009: Rail yard
- Appendix M – EPA 010: Rail yard
- Appendix N – EPA 011: Rail yard

Note that CSO control alternatives are not presented for EPA 012 and EPA 014 since sewer separation has been conducted at those outfalls.

Excluding the sewer separation alternatives, each alternative was evaluated based on the proposed sizing of improvements selected in the LTCP submitted in 2010. For each outfall, that size represents the knee-of-the-curve sizing for fine screening, excluding EPA 004 which was sized in the LTCP to achieve an average of four overflow events per year when the representative rainfall period was modeled. The knee-of-the-curve sizing represents the sizing where there are diminishing improvements in the capture of additional wet-weather flow for the additional cost spent. JSA acknowledges that an important objective of the LTCP is to achieve a minimum system-wide wet-weather capture of 85 percent and believes retaining these sizes for further analysis allow them to achieve this system-wide goal. Utilizing these target sizes also allows a comparison of alternatives.

5.1 Additional Considerations

As discussed with EPA and KDEP, JSA has three additional elements to consider when selecting CSO control projects, including:

- Protection of Drinking Water Intake
- Protection of Threatened / Endangered Mussels
- Operation of the Floodwall Pump Stations

These items are discussed in more detail in Appendix B, Appendix C, and Appendix F, respectively.

5.2 Green Infrastructure Considerations

Green infrastructure, or low-impact development techniques, helps divert, store, and promote infiltration, evapotranspiration, and reuse of stormwater. The effects of green infrastructure in combined sewer systems is thereby a reduction in CSOs, achieved by reducing the amount of stormwater entering the combined sewer system. Green infrastructure may include a variety of controls such as bioretention, green roofs, reforestation, and the disconnection of impervious surfaces, among others.

While green infrastructure can have significant environmental, aesthetic, and social benefits to the community, JSA's ability to implement green infrastructure projects is limited. JSA does not own significant property to implement green infrastructure improvements and does not control surface stormwater drainage, zoning, building permits, etc. and thus lacks a mechanism for implementing or enforcing green infrastructure improvements. For those reasons, green infrastructure alone is not considered a viable CSO control alternative.

However, to the extent practical, JSA will look for opportunities to incorporate green infrastructure improvements into planned projects in the combined sewer system, such as the stormwater retention that was incorporated as part of the Wallace Park (EPA 012) Sewer Separation project. Additionally, JSA will encourage the City of Paducah to consider the incorporation of green infrastructure in the management of surface stormwater drainage.

Section 6

Global CSO Control Alternatives

As discussed in Section 5, JSA re-evaluated each CSO location to assess the feasibility of a full range of alternative technologies for the elimination and/or capture and treatment of CSO discharges. These alternative technologies represent a broad range of viable, contemporary, and widely-recognized approaches for effectively addressing CSO impacts, although all technologies may not be feasible or applicable at all locations in the JSA system. It should also be recognized that they provide differing levels of treatment, and thus variable levels of protection of water quality, while imposing varying levels of cost for construction and operation / maintenance.

Table 6-1 provides a comparison of the screening-level capital costs associated with each alternative. Note that the costs presented are not life-cycle costs and thus do not include anticipated operations and maintenance (O&M) costs associated with the alternatives. For selection of the alternatives, a qualitative assessment of O&M requirements has been considered and is sufficient. An increase in JSA's O&M costs to represent the additional facilities was included in the financial capability analysis.

Table 6-1 Screening-level Costs (in millions of dollars)

CSO Location	Separation	Storage	Pump to Treatment	Fine Screening	Fine Screening and Disinfection	HRT	HRT and Disinfection
EPA 002	110	171	31	13	17	26	31
EPA 003	75	--	--	14	33	44	49
EPA 004	38	12[1]	13[2]	4	8	13	14
EPA 006/007[3]	24	102	21[4]	9	13	20	21
EPA 008/009	30	73	23	12	15	23	25
EPA 010	14	49	20	10	12	19	22
EPA 011	11	22	15	7	9	14	15
EPA 012	Separation is complete						
EPA 014	Separation is complete						

1. Sizing based on target of 85 percent capture, not 4 overflows per year.
2. Assumes existing Harrison Pump Station is replaced with a new, larger facility to convey dry- and wet-weather flows.
3. Includes separation / rerouting of flows from smaller regulators for all alternatives.
4. Assumes existing Husbands Pump Station is replaced with a new, larger facility to convey dry- and wet-weather flows.

Excluding the sewer separation alternatives, each alternative presented in Table 6-1 was evaluated based on the proposed sizing of improvements presented in the LTCP submitted in 2010. For each outfall, that size represents the knee-of-the-curve sizing for fine screening, excluding EPA 004 which was sized in the LTCP to achieve an average of four overflow events per year when the representative period was modeled. The knee-of-the-curve sizing represents the sizing where there are diminishing improvements in the capture of additional wet-weather flow for the additional cost spent.

The alternatives with shaded costs in Table 6-1 have been eliminated for further consideration based on the following:

- For each CSO location, CSO control alternatives with screening-level costs which were more than twice the fine screening and disinfection alternative were found to be cost-prohibitive and were eliminated. This eliminated separation at several locations and storage at all locations excluding EPA 004.
- Because of the location of EPA 004 and the associated Harrison Pump Station, a storage or treatment facility at this site is impractical for this highly visible location. The site is in proximity to the Paducah Expo Center, a future hotel development planned by the City of Paducah, a smaller private events center, a nursing home facility, and several commercial establishments. Additionally, the site is located adjacent to the flood wall, adding to the difficulty of constructing any improvements at this location.
- The limited capacity of the discharge pipe at EPA 003, which is also used as the effluent discharge pipe for the wastewater treatment plant, and the associated flood wall pump station eliminated the option of pumping flows from EPA 002 to a consolidated wet-weather treatment facility. Based on the results of the hydraulic model and confirmed through observations by JSA, the capacity of the existing system is limited during the large rainfall events, which surcharge the 102-inch trunk sewer and utilize the full capacity of the discharge system. Since it is expected that the timing of peak flows from EPA 002 would be similar to those experienced by the remainder of the system, the additional flow from EPA 002 (assumed to be 40 million gallons per day) would increase the risk of surcharging and overflows in the area upstream. Further improvements to the discharge system may be possible, but they would result in significant cost increases making this alternative cost-prohibitive relative to other options. This limitation should also be considered if the pump to treatment option is selected for smaller CSO locations.
- Sewer separation of EPA 006 and EPA 007 was also eliminated from the list of viable alternatives. The separation costs presented were established by considering the known areas of combined sewer upstream of those outfalls. However, there are significant areas of separate sanitary sewer (25 miles or more) upstream of the known combined area that may require further evaluation, inflow source correction, and rehabilitation to fully address EPA 006 and EPA 007. If those costs were included in the screening-level estimate, it is expected that the separation alternative would become cost-prohibitive relative to other options.

The evaluations of alternatives presented in Appendices H through N primarily consider each CSO location independently. The presumptive approach of the CSO Control Policy (II.C.4.a.ii), however, indicates that "the elimination or the capture for treatment of no less than 85 percent by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis" provides an adequate level of control to meet water quality objectives. As such, this system-wide target allows JSA to focus their investments on certain CSO locations while providing lesser levels of controls (but at least satisfying the Nine Minimum Controls requirements) at other locations.

The remaining alternatives presented were evaluated in various combinations to establish global or system-wide alternatives. JSA's approach to selecting global alternatives includes the following objectives:

- Emphasis on outfalls located on the Ohio and Tennessee Rivers upstream of the Paducah drinking water intake (EPA 004, EPA 006, and EPA 007)

- Emphasis on outfalls on the Ohio and Tennessee Rivers due to the presence of threatened / endangered mussels (EPA 003, EPA 004, EPA 006, and EPA 007)
- Focus on the largest outfalls (by volume) in order to minimize the number of remote facilities requiring on-going operation and maintenance while achieving the 85 percent capture target (EPA 002 and EPA 003)

Assuming technologies are selected that JSA, EPA, and KDEP agree meet water quality objectives, the knee-of-the-curve sizing of improvements, which is the basis for the alternatives evaluation and screening-level costs, exceed 85 percent capture on both an individual and collective basis. The system-wide percent capture for the alternatives as presented in Table 6-2 is over 90 percent.

Table 6-2 Percent Capture, All CSOs

Outfall No.	CSO Control Technology	Percent Capture
EPA 002	Treatment	93.4
EPA 003	Treatment	96
EPA 004	Pump and Treatment with EPA 003	>99
EPA 006-007	Treatment	95
EPA 008-009	Treatment	93.9
EPA 010	Treatment	93.6
EPA 011	Treatment	96.4
EPA 012	Separation	100
EPA 014	Separation	100

In keeping with the approach to the alternatives discussed with EPA and KDEP, JSA considered eliminating the construction of additional CSO controls at the outfalls associated with the rail yard – EPA 008, EPA 009, EPA 010, and EPA 011. In that case, system-wide percent capture for treatment is 87 percent which exceeds the 85 percent target, as presented in Table 6-3. Additional information regarding the system-wide percent capture calculation is presented in Appendix O.

Utilizing those guidelines and recognizing JSA's financial limitations, the following sections describe several global alternatives for consideration. Additional combinations of individual improvements were considered, but JSA believes those described herein illustrate a representative range of alternatives.

Table 6-3 Percent Capture, Excluding Rail Yard CSOs

Outfall No.	CSO Control Technology	Percent Capture
EPA 002	Treatment	93.4
EPA 003	Treatment	96
EPA 004	Pump and Treatment with EPA 003	>99
EPA 006-007	Treatment	95
EPA 008-009	None	65
EPA 010	None	68
EPA 011	None	86
EPA 012	Separation	100
EPA 014	Separation	100

6.1 Additional Storage at WWTP

Each of the global alternatives described below also considers the addition of approximately 10 million gallons of storage located near the WWTP. This storage is necessary to capture the increased peak flows being transferred from EPA 004 via the expanded Harrison Pump Station prior to treatment. The storage facility will also allow JSA additional operational flexibility at the WWTP and is expected to be used to capture wet-weather flow from small storm events for treatment at the WWTP as opposed to treatment through the proposed CSO control facility for EPA 003.

The need for this storage was reinforced with the recent storm events in July 2015 which resulted in significant surcharging and flooding upstream of the WWTP. Receiving increased peak flows from the Harrison Pump Station to address EPA 004 is expected to compound the potential for surcharging and flooding, and storage is included in each global alternative to address this issue.

The estimated screening-level cost for this facility, which will be located on property JSA will purchase adjacent to the WWTP, is $20 million.

6.2 Fine Screening and Disinfection

As shown in Table 6-4, this global alternative focuses on fine screening and disinfection at three CSO locations – EPA 002, EPA 003, and EPA 006/007. Increased pumping capacity at the Harrison Pump Station would reduce overflows at EPA 004. That additional flow would then be captured and treated at a consolidated facility with EPA 003. A moderate amount of storage would also be included at the site in order to capture peak flows from EPA 004. Under this scenario, no additional improvements are proposed for EPA 008/009, EPA 010, and EPA 011. The sewer separation projects for EPA 012 and EPA 014 are also shown, although no costs are provided since those projects have completed construction.

Table 6-4 Fine Screening and Disinfection

Outfall No.	CSO Control Technology	Screening-Level Cost (millions of dollars)
EPA 002	Fine screening and disinfection	17
EPA 003	Fine screening and disinfection	33
EPA 003-004	Storage at WWTP	20
EPA 004	Pump to Storage / Treatment	13
EPA 006-007	Fine screening and disinfection	13
EPA 008-009	None	0
EPA 010	None	0
EPA 011	None	0
EPA 012*	Separation	Completed
EPA 014*	Separation	Completed

*Costs associated with EPA 012 and EPA 014 are not included in total for this global alternative. JSA has completed over $39 million of improvements since 2010.

The total screening-level capital cost of this global alternative is $96 million.

The major advantages and disadvantages include the following:

- Removal efficiencies of fine screening are less than conventional primary treatment.
- Disinfection is included at three locations, two of which are at unstaffed locations within the system.
- CSOs located on the Ohio and Tennessee Rivers are prioritized allowing higher level of protection of the drinking water intake and the habitat of endangered mussels.
- Land acquisition is required at four locations.
- Lower capital costs allow JSA to better manage the financial burden to its customers while maintaining a shorter implementation schedule.

6.3 High Rate Treatment

As shown in Table 6-5, this global alternative focuses on high rate treatment at three CSO locations – EPA 002, EPA 003, and EPA 006/007. Increased pumping capacity at the Harrison Pump Station would reduce overflows at EPA 004. That additional flow would then be captured and treated at a consolidated facility with EPA 003. A moderate amount of storage would also be included at the site in order to capture peak flows from EPA 004. Under this scenario, no additional improvements are proposed for EPA 008/009, EPA 010, and EPA 011. The sewer separation projects for EPA 012 and EPA 014 are also shown, although no costs are provided since those projects have completed construction.

Table 6-5 High Rate Treatment

Outfall No.	CSO Control Technology	Screening-Level Cost (millions of dollars)
EPA 002	High rate treatment	26
EPA 003	High rate treatment	44
EPA 003-004	Storage at WWTP	20
EPA 004	Pump to Storage / Treatment	13
EPA 006-007	High rate treatment	20
EPA 008-009	None	0
EPA 010	None	0
EPA 011	None	0
EPA 012*	Separation	Completed
EPA 014*	Separation	Completed

*Costs associated with EPA 012 and EPA 014 are not included in total for this global alternative. JSA has completed over $39 million of improvements since 2010.

The total screening-level capital cost of this global alternative is $123 million.

The major advantages and disadvantages include the following:

- Removal efficiencies of high rate treatment are expected to exceed that of conventional primary treatment.
- High rate treatment facilities require significant work in advance of and following wet-weather events, such as preparing chemicals, cleaning basins, etc. This will be a challenge to operate, since there are three locations, two of which are at unstaffed locations within the system.
- CSOs located on the Ohio and Tennessee Rivers are prioritized allowing higher level of protection of the drinking water intake and the habitat of endangered mussels.
- Disinfection, which is required by KDOW, is not included at any sites.
- Land acquisition is required at four locations.
- The cost of the solution is approximately $27 million greater than the fine screening and disinfection global alternative.

6.4 High Rate Treatment and Disinfection

As shown in Table 6-6, this global alternative focuses on high rate treatment and disinfection at three CSO locations – EPA 002, EPA 003, and EPA 006/007. Increased pumping capacity at the Harrison Pump Station would reduce overflows at EPA 004. That additional flow would then be captured and treated at a consolidated facility with EPA 003. A moderate amount of storage would also be included at the site in order to capture peak flows from EPA 004. Under this scenario, no additional improvements are proposed for EPA 008/009, EPA 010, and EPA 011. The sewer separation projects for EPA 012 and EPA 014 are also shown, although no costs are provided since those projects have completed construction.

Table 6-6 High Rate Treatment and Disinfection

Outfall No.	CSO Control Technology	Screening-Level Cost (millions of dollars)
EPA 002	High rate treatment and disinfection	31
EPA 003	High rate treatment and disinfection	49
EPA 003-004	Storage at WWTP	20
EPA 004	Pump to Storage / Treatment	13
EPA 006-007	High rate treatment and disinfection	21
EPA 008-009	None	0
EPA 010	None	0
EPA 011	None	0
EPA 012*	Separation	Completed
EPA 014*	Separation	Completed

*Costs associated with EPA 012 and EPA 014 are not included in total for this global alternative. JSA has completed over $39 million of improvements since 2010.

The total screening-level capital cost of this global alternative is $134 million.

The major advantages and disadvantages include the following:

- Removal efficiencies of high rate treatment are expected to exceed that of conventional primary treatment, and when coupled with disinfection, the global alternative achieves the system-wide capture and treatment performance objective.
- High rate treatment facilities require significant work in advance of and following wet-weather events, such as preparing chemicals, cleaning basins, etc. This will be a challenge to operate, since there are three locations, two of which are at unstaffed locations within the system.
- CSOs located on the Ohio and Tennessee Rivers are prioritized allowing higher level of protection of the drinking water intake and the habitat of endangered mussels.
- Land acquisition is required at four locations.
- The cost of the solution is approximately $38 million greater than the fine screening and disinfection global alternative.

6.5 Increased Capture and Treatment

As shown in Table 6-7, this global alternative focuses on high rate treatment and disinfection at three CSO locations – EPA 002, EPA 003, and EPA 006/007. Increased pumping capacity at the Harrison Pump Station would reduce overflows at EPA 004. That additional flow would then be captured and treated at a consolidated facility with EPA 003. A moderate amount of storage would also be included at the site in order to capture peak flows from EPA 004. Under this scenario, separation is proposed for EPA 008/009, EPA 010, and EPA 011. The sewer separation projects for EPA 012 and EPA 014 are also shown, although no costs are provided since those projects have completed construction.

Table 6-7 Increased Capture and Treatment

Outfall No.	CSO Control Technology	Screening-Level Cost (millions of dollars)
EPA 002	High rate treatment and disinfection	31
EPA 003	High rate treatment and disinfection	49
EPA 003-004	Storage at WWTP	20
EPA 004	Pump to Storage / Treatment	13
EPA 006-007	High rate treatment and disinfection	21
EPA 008-009	Separation	30
EPA 010	Separation	14
EPA 011	Separation	11
EPA 012*	Separation	Completed
EPA 014*	Separation	Completed

*Costs associated with EPA 012 and EPA 014 are not included in total for this global alternative. JSA has completed over $39 million of improvements since 2010.

The total screening-level capital cost of this global alternative is $189 million.

The major advantages and disadvantages include the following:

- Sewer separation eliminates several CSO locations, reducing the number of CSOs to five and eliminating all CSOs discharging to tributaries of Island Creek.
- Sewer separation is unlikely to eliminate all wet-weather flows within the system. No reduction of wet-weather flows at the wastewater treatment plant is expected since the majority of the peak flow is currently being discharged via the CSO. Sewer separation also eliminates treatment of the "first flush" of stormwater.
- Removal efficiencies of high rate treatment are expected to exceed that of conventional primary treatment, and disinfection is included to achieve the capture and treatment performance objectives.
- High rate treatment facilities require significant work in advance of and following wet-weather events, such as preparing chemicals, cleaning basins, etc. This will be a challenge to operate, since there are three locations, two of which are at unstaffed locations within the system.
- Since all CSOs are addressed, a higher level of protection of the drinking water intake and the habitat of endangered mussels located along the Tennessee and Ohio Rivers is accomplished.
- Land acquisition is required at four locations.
- The system-wide level of control presented significantly exceeds the target system-wide capture of 85 percent.
- The cost of the solution is approximately $93 million greater than the fine screening and disinfection global alternative and would represent a significant financial burden to JSA's customers.

Section 7

Financial Analysis

To assess the financial impact of the recommended LTCP capital improvement plan on JSA's customers, a financial model was developed that projects future utility revenue requirements based on JSA's operating costs, the existing capital improvement program, the incremental impacts of the LTCP capital program, and anticipated expenditures to ensure the integrity of the JSA system.

A rate projection model was developed to project wastewater rates through 2050. The projected expenses and revenue requirements have been estimated using standard industry methods. The analysis is based on JSA's fiscal year (FY) 2015 budget and 5-year capital improvement plan (CIP) through FY 2021. The development of estimated rate increases tracks the change in revenue requirement, however the pattern of actual rate increases based on actual project cash flows will likely differ from those presented in this evaluation. JSA anticipates that the actual overall rate burden will be comparable to that presented herein for any expenditure level and implementation period.

EPA has recognized that affordability extends beyond the median household exclusively, and it also should be assessed across the income distribution and particularly sensitive population groups.

7.1 Data and Assumptions

The development of the projections for the forecast period used in this analysis requires the use of a number of assumptions related to parameters such as inflation and interest rates. JSA's actual plan of finance will likely differ from the simplified version presented here. For example, the actual timing and structure of debt issued by JSA to finance its capital program may differ from the assumptions contained herein and will be dictated by market conditions and Kentucky Infrastructure Authority (KIA) requirements and policies at the time. The intent is to provide a reasonable planning level projection of the impact of the various factors on future JSA's expenses and rates.

7.1.1 Data Sources

This analysis has used the following data sources for projections:

- JSA FY 2015 Operating Budget
- JSA 2015-2021 Proposed Capital Budget, Revised September 2015
- KIA Repayment Schedules for all outstanding loans
- JSA Schedule of Available, Designated, Restricted Funds
- U.S. Census Bureau American Community Survey 5-Year Estimates

7.1.2 Assumptions

The major assumptions are set forth below:

- Current wastewater operations and maintenance data is based on the JSA FY 2015 wastewater budget which is $4,522,000.

- Existing debt service is based on schedules for all outstanding debt through maturity.
- The miscellaneous revenues and other non-rate revenue data used in these projections are based on the JSA FY 2015 budget.
- All miscellaneous revenues, with the exception of waste hauler and treatment fees, remain constant throughout the course of projections. Waste hauler and treatment fees are increased at 4 percent annually.
- All operations and maintenance related expenses have been inflated at 3 percent annually.
- Incremental operations and maintenance associated with the LTCP is assumed to be $250,000 annually for each system-wide alternative LTCP, inflated at 3 percent annually. For the purposes of this analysis, this value is assumed to remain constant over the planning period for all LTCP alternatives.
- Inflation of capital costs is assumed to average 4 percent annually.
- The funding of projects defined in JSA's current CIP follow the assumptions provided by JSA.
- JSA has developed a CIP through FY 2021. Since the projection period for this evaluation extends significantly beyond then, this analysis assumes that after FY 2021 JSA will spend $2.5 million (2015 dollars) annually throughout the course of the projection period.
- All future debt is assumed to be issued as revenue bonds, with an average interest rate over the forecast period of 6 percent with a 20-year amortization period. Bonds are assumed to have a 1 percent cost of issuance.
- All reserve balances are assumed to be at an appropriate level, with no additions or withdrawals from reserves assumed over the course of the projections.
- Average annual household consumption is assumed to be 60,000 gallons, which is consistent with JSA's billing data. JSA's customer charges are based on a minimum monthly bill equivalent to 3,000 gallons and a per-thousand-gallon charge for consumption over 3,000 gallons per month.
- Median household income (MHI) for the City of Paducah is estimated at $34,679 for 2013 based on the most recent available data from the U.S. Census Bureau American Community Survey 5-Year Estimates for 2009-2013, and is inflated at an annual rate of 2 percent.

The JSA service area is within McCracken County but the largest population density served is within the City of Paducah, which represents more than 60 percent of JSA's customer base. JSA also serves Lone Oak, Hendron, Reidland, and Oakdale-Woodlawn, which contain the balance of customers. Given the predominance of customers within the City of Paducah and the need to have rate changes approved independently by officials from both the City of Paducah and McCracken County, the affordability evaluation presented herein is based on Paducah's median household income. The affordability evaluation is also presented considering the income for the lowest quintile of households in Paducah. The income level at the top of the lowest quintile is approximately $15,000, or less than half of the Paducah median household income.

7.2 Financial Analysis - Baseline

This section summarizes JSA's revenue requirement for the baseline projections, which are projections excluding any LTCP related costs. The impact of the improvements for each LTCP alternative are presented separately in Section 7.4.

The three main components of revenue requirement are:

- Operations and maintenance expenses
- Debt service and capital expenditures
- Miscellaneous revenues

Operations and maintenance expenses include, among other items, expenses for operations, maintenance, and administration. There are also line items for new operations and maintenance expenses that are expected to be incurred in the future. Debt service is related to outstanding debt previously issued by JSA or projected to be issued to fund portions of the capital program. It is also assumed that JSA continues to fund a portion of its capital program through current rate revenues. The last main component of revenue requirements is miscellaneous revenues, which are revenues or income (e.g. interest income) not collected through a standard user rate or charge.

7.2.1 Operations and Maintenance

Table 7-1 summarizes the operations and maintenance costs for the baseline evaluation from FY 2015 through FY 2040 in 5-year increments. Excluding any LTCP associated expenses, total operations and maintenance expenses are projected to increase from approximately $4.5 million in FY 2015 to roughly $9.5 million in FY 2040, an average annual increase of 3 percent.

Table 7-1 Operations and Maintenance

	2015	2020	2025	2030	2035	2040
Personnel	$2,365,823	$2,742,637	$3,179,468	$3,685,875	$4,272,939	$4,953,508
Chemicals and Testing	$352,250	$408,354	$473,395	$548,794	$636,203	$737,533
Utilities	$735,800	$852,994	$988,854	$1,146,352	$1,328,937	$1,540,602
Materials, Supplies, Repairs	$628,500	$728,604	$844,651	$979,183	$1,135,141	$1,315,939
General and Other	$439,250	$509,211	$590,315	$684,337	$793,334	$919,692
Incremental O&M (SSO)	$0	$0	$0	$0	$0	$0
Incremental O&M (LTCP)	$0	$0	$0	$0	$0	$0
Total Operations and Maintenance	**$4,521,623**	**$5,241,800**	**$6,076,683**	**$7,044,541**	**$8,166,554**	**$9,467,274**

7.2.2 Debt Service and Capital Expenditures

A summary of JSA's non-LTCP capital expenditure plan through FY 2021 is presented in Table 7-2. As noted in the assumptions, this projection assumes that beyond the provided plan JSA expends approximately $2.5 million annually, which represents spending to rehabilitate the existing collection and treatment systems and to ensure their long-term integrity. Based on the age of major elements of the system, JSA believes that over the long-term that is the minimum that will be required to meet that objective. For instance, the existing Paducah wastewater treatment plant was constructed in 1959 and still includes some original equipment and structures. JSA anticipates that significant rehabilitations and replacements will be required.

In Table 7-2, the Wastewater Projects category consists of a methane system upgrade, replacement of the Paducah wastewater treatment plant's (WWTP's) press building, an electrical upgrade at the Paducah WWTP, and a new wastewater treatment plant at Woodlawn. The projects in this category are assumed to be bonded.

The cash funded capital will be funded through user revenues, not debt funded, and includes replacement of vehicles and the equipment, line extensions, and other types of recurring replacement work.

The SSO projects consist of replacement or upsizing of interceptors, gravity mains, and pump stations, and equalization basins.

The non-LTCP CSO projects consist of projects that are currently planned independent of the LTCP alternatives under evaluation. It consists of general costs associated with the preparation of this *Revised LTCP*, the sewer separation project associated with EPA 012 at Lone Oak, and an annual allowance for non-outfall projects. The non-outfall projects recognize the need to continue to make improvements within the combined sewer system. Potential projects have not yet been developed in detail, and thus project details and implementation schedules are not yet available. At this time, it is expected that these projects may address local flooding, renewal of aging infrastructure, or other improvements to the combined sewer system.

Table 7-2 JSA CIP, FY 2015 to FY 2021

	2015	2016	2017	2018	2019	2020	2021
Wastewater Projects - Bonded	$0	$0	$2,000,000	$2,000,000	$2,086,000	$2,000,000	$12,000,000
Cash Funded Capital	$1,319,000	$1,583,000	$1,470,000	$1,756,000	$1,643,000	$1,598,000	$1,448,000
SSO Projects	$950,000	$4,135,000	$1,929,000	$2,700,000	$2,900,000	$0	$0
Non-LTCP CSO Projects	$5,300,000	$500,000	$500,000	$500,000	$500,000	$500,000	$500,000
Total Non-LTCP Capital	**$7,569,000**	**$6,218,000**	**$5,899,000**	**$6,956,000**	**$7,129,000**	**$4,098,000**	**$13,948,000**

Debt service and capital expenditures are shown for select years in three categories: existing debt, future revenue bonds, and cash-funded capital expenditures. Table 7-3 summarizes the debt service and cash-funded capital expenditures for the baseline, assuming no LTCP costs.

Table 7-3 Baseline Debt Service and Capital Expenditures, FY 2015 to FY 2040

	2015	2020	2025	2030	2035	2040
Existing Debt Service	$1,260,863	$1,177,674	$1,100,304	$883,209	$186,868	$189,845
Anticipated Revenue Bond	$189,375	$3,029,548	$5,383,457	$6,242,560	$7,226,049	$7,128,038
Anticipated SRF	$0	$0	$0	$0	$0	$0
Cash Funded Capital	$1,319,000	$1,944,211	$740,122	$900,472	$1,095,562	$1,332,918
Total Debt Service and Capital	**$2,769,238**	**$6,151,433**	**$7,223,883**	**$8,026,241**	**$8,508,478**	**$8,650,802**

For purposes of projecting debt service, it was assumed that in the year of loan inception there would be an interest only payment, with full annual payments commencing the following year.

7.2.3 Miscellaneous Revenues

Table 7-4 shows non-user rate or offset revenues for JSA. With the exception of waste hauler and treatment fees, all revenues presented here are assumed to be constant throughout the projection period. There is no additional income associated with the LTCP program. These revenues are applied as an offset to total rate revenue requirements.

Table 7-4 Miscellaneous Revenue

	2015	2020	2025	2030	2035	2040
Discharge Permit	$0	$6,300	$0	$0	$6,300	$0
Interest Income	$32,500	$32,500	$32,500	$32,500	$32,500	$32,500
Miscellaneous Income/Expense	$33,700	$33,700	$33,700	$33,700	$33,700	$33,700
Waste Hauler & Treatment Fees	$148,000	$180,065	$219,076	$266,540	$324,286	$394,544
Other Operating Revenue	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
Total Miscellaneous Revenue	**$216,700**	**$255,065**	**$287,776**	**$335,240**	**$399,286**	**$463,244**

7.2.4 Revenue Requirements

The revenue requirement is the total rate revenue that must be generated annually for JSA to meet its expenses after netting anticipated miscellaneous revenue offsets. Table 7-5 summarizes the total revenue requirements for the baseline, which assumes no costs associated with the LTCP. The total revenue requirement is projected to increase from $7.1 million in FY 2015 to $17.7 million in FY 2040. This is equivalent to an average annual increase of 3.7 percent.

Table 7-5 Revenue Requirement – Baseline

	2015	2020	2025	2030	2035	2040
Operations and Maintenance	$4,521,623	$5,241,800	$6,076,683	$7,044,541	$8,166,554	$9,467,274
Debt Service and Capital	$2,769,238	$6,151,433	$7,223,883	$8,026,241	$8,508,478	$8,650,802
Less: Miscellaneous Revenue	($216,700)	($255,065)	($287,776)	($335,240)	($399,286)	($463,244)
Total Revenue Requirement	**$7,074,161**	**$11,138,169**	**$13,012,790**	**$14,735,543**	**$16,275,746**	**$17,654,832**

7.3 Residential Indicator - Baseline

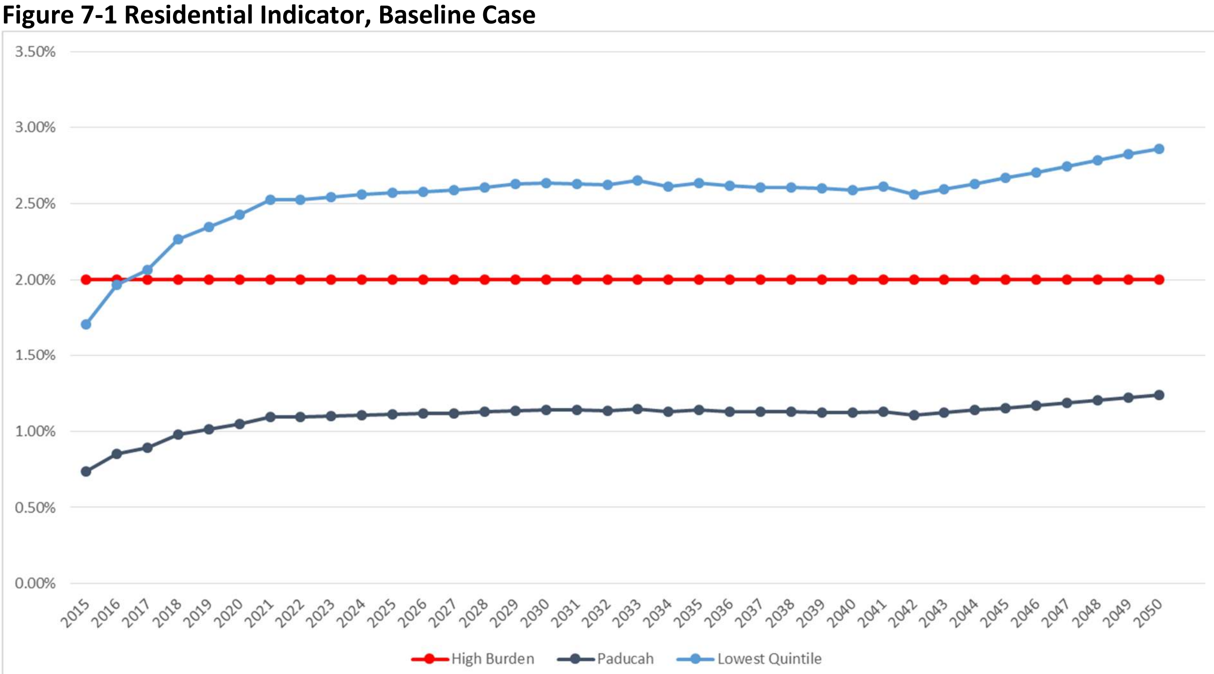
In order to adequately fund the revenue requirement, JSA will have to raise rates throughout the course of the projection period. The analysis assumed that JSA will raise rates annually to meet changes in revenue requirements and to ensure sufficient cash is available in each year to meet that fiscal year's obligations. Average monthly household sewer charges have been derived by taking the average annual consumption of 60,000 gallons and applying it to the proposed rate increase schedule.

One of the primary indicators in the EPA's guidelines of affordability is the average annual household bill as a percentage of median household income, or the residential indicator. Figure 7-1 summarizes the household burden for the baseline case, using Paducah's median household income as well as the income for the lowest quintile income group in Paducah. Currently, the burden for the median income household in Paducah is approximately 0.74 percent and given the projected increases in revenue requirements over time that burden will consistently increase through the forecast period reaching a level of 1.2 percent of median household income.

JSA is especially concerned about the impact on the lower income population within its service area. The lowest quintile in Paducah has a reported income of under $15,000 which is less than half of Paducah's median household income. As seen in Figure 7-1, the maximum residential burden for this population segment is currently 1.7 percent of income. The burden for this group will increase to almost 2.9 percent of income and will be significantly above 2 percent for nearly the entire forecast period.

JSA believes that the current income levels and distribution within the service area compromises its ability to undertake any significant LTCP without potentially serious adverse impacts on the service area and its residents.

Figure 7-1 Residential Indicator, Baseline Case



Note: The lowest quintile plot is based on the maximum income of approximately $15,000. It is inflated using the same assumptions as stated for the Paducah MHI.

7.4 Impact of LTCP Alternatives

As JSA moves towards the development of its LTCP, its capacity to undertake programs of various sizes and durations relative to the household burden has been evaluated to illustrate potential impacts. The evaluation looks at conceptual global or system-wide conceptual alternatives (all stated in 2015 dollars), as follows:

- $75 million expended over either 10, 20 or 30 years
- $100 million expended over either 10, 20 or 30 years
- $175 million expended over either 10, 20 or 30 years

For purposes of this evaluation, the following assumptions apply:

- For all conceptual program levels, expenditures are assumed even over the forecast period. So for the $75 million, 20 year program, the analysis assumes that JSA spends $3.75 million (2015 dollars) per year for 20 years. For the $75 million, 30-year program, the analysis assumes that JSA spends $2.5 million (2015 dollars) per year. It should be noted that the annual expenditures are inflated to the year of projected expenditure, consistent with the assumptions stated previously. It is assumed that JSA will issue revenue debt annually to fund the LTCP expenditures.
- An allowance of $250,000 is included for additional operations and maintenance expenses associated with the LTCP programs, and is inflated at 3 percent annually. This allowance does not vary with the size or timing of the program alternatives.

7.4.1 Impact of Conceptual LTCP Alternatives

The impacts of the conceptual program are added to the baseline evaluation described previously to project future impacts. The essential impact is that the annual amount of debt service incurred by JSA is increased consistent with the size and duration of the program. The following table summarizes the annual debt service for each of the conceptual alternatives.

Table 7-6 Incremental Debt Service, Alternative Conceptual Programs

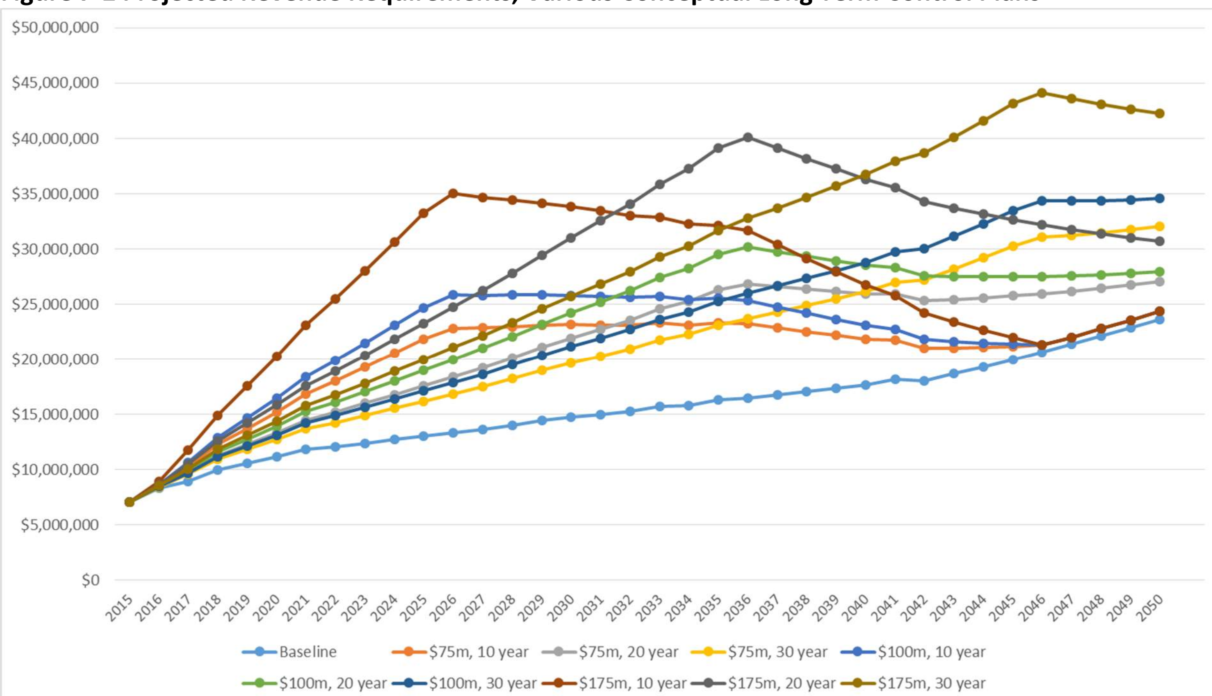
	2015	2020	2025	2030	2035	2040
$75 million, 30 years	$-	$1,261,891	$2,836,500	$4,538,905	$6,396,792	$7,943,190
$75 million, 20 years	$-	$1,892,836	$4,254,751	$6,808,358	$9,595,188	$7,767,348
$75 million, 10 years	$-	$3,785,672	$8,509,501	$8,012,996	$6,594,235	$3,673,504
$100 million, 30 years	$-	$1,682,521	$3,782,001	$6,051,873	$8,529,056	$10,590,920
$100 million, 20 years	$-	$2,523,781	$5,673,001	$9,077,810	$12,793,584	$10,356,464
$100 million, 10 years	$-	$5,047,562	$11,346,002	$10,683,995	$8,792,313	$4,898,006
$175 million, 30 years	$-	$2,944,411	$6,618,501	$10,590,779	$14,925,848	$18,534,110
$175 million, 20 years	$-	$4,416,617	$9,927,751	$15,886,168	$22,388,771	$18,123,813
$175 million, 10 years	$-	$8,833,234	$19,855,503	$18,696,992	$15,386,548	$8,571,510

To clarify, under the $75 million, 30 year program, JSA will need to increase user rates to generate additional revenue above the amount shown in Table 7-5 of $1.2 million in 2020, $2.8 million in 2025, $4.5 million in 2030, $6.4 million in 2035 and $7.9 million in 2040 to meet the additional debt service burden. With this conceptual program, the revenue requirements in 2040 would total approximately $26.1 million, an increase of over 40 percent compared to the baseline. At the other extreme, if the conceptual $175 million, 10-year program were implemented the revenue requirement would more than double from the baseline case to approximately $33.2 million by FY 2025.

Figure 7-3 shows the impact of the alternative conceptual plans on projected revenue requirements for the forecast period. This clearly shows that JSA will be facing significant increases in revenue requirements even to maintain the existing infrastructure and before addressing the appropriate LTCP. Over the next 10 years, the revenue requirements in the baseline case will increase by over 80 percent.

The financial challenges facing JSA are compounded when alternative LTCPs are considered. When considering a 20-year program duration, the conceptual $75 million program is projected to increase JSA's revenue requirement by over nine percent per year for the next 10 years, and continues to increase as the program is implemented. For a $75 million program over 10 years, the annual revenue requirement increase is projected at almost twelve percent for the next 10 years. With the $175 million conceptual program, the increases are even more substantial, illustrated in Figure 7-2. Increases of this magnitude will likely cause significant burdens on the service area and JSA's customers and may be unsustainable. This is especially true for those in the lowest quintile who already face a burden approaching 2 percent.

Figure 7-2 Projected Revenue Requirements, Various Conceptual Long Term Control Plans



The projected revenue requirements shown in Figure 7-2 will directly translate into increased rates and burdens on JSA's customers. The projected residential burden is shown in Figure 7-3 for the lowest income quintile population in Paducah. As Figure 7-3 shows, the lowest quintile income group will face a significant burden under any of the LTCP scenarios. The projected burden for this group for the 20-year, $75 million conceptual plan will exceed 4.2 percent of income (for the persons at the highest end of that income group), and for the 20-year, $175 million program, the projected burden will exceed 6.3 percent of income. This group will face a burden in excess of EPA's high burden limit for nearly the entire forecast period.

Figure 7-4 presents the residential burden information for the median income level within Paducah. Each of the conceptual programs will cause Paducah's residential burden to exceed 1.7 percent with a $175 million program peaking at close to 3 percent of median household income. This is obviously a major challenge and concern to JSA.

Considering a $75 million, 30-year program, JSA's customers will face increases of over 8 percent per year for the next 10 years and an average increase of over 6 percent (double the historical rate of inflation) over 20 years. Under a 10-year program duration, the annual increase would be closer to 12 percent for the next 10 years. JSA is concerned sewer bills with increases of this magnitude are not sustainable and could create significant economic hardship and financial burden to its customers.

Figure 7-3 Projected Residential Burden, Lowest Quintile Income, Various Conceptual Long Term Control Plans

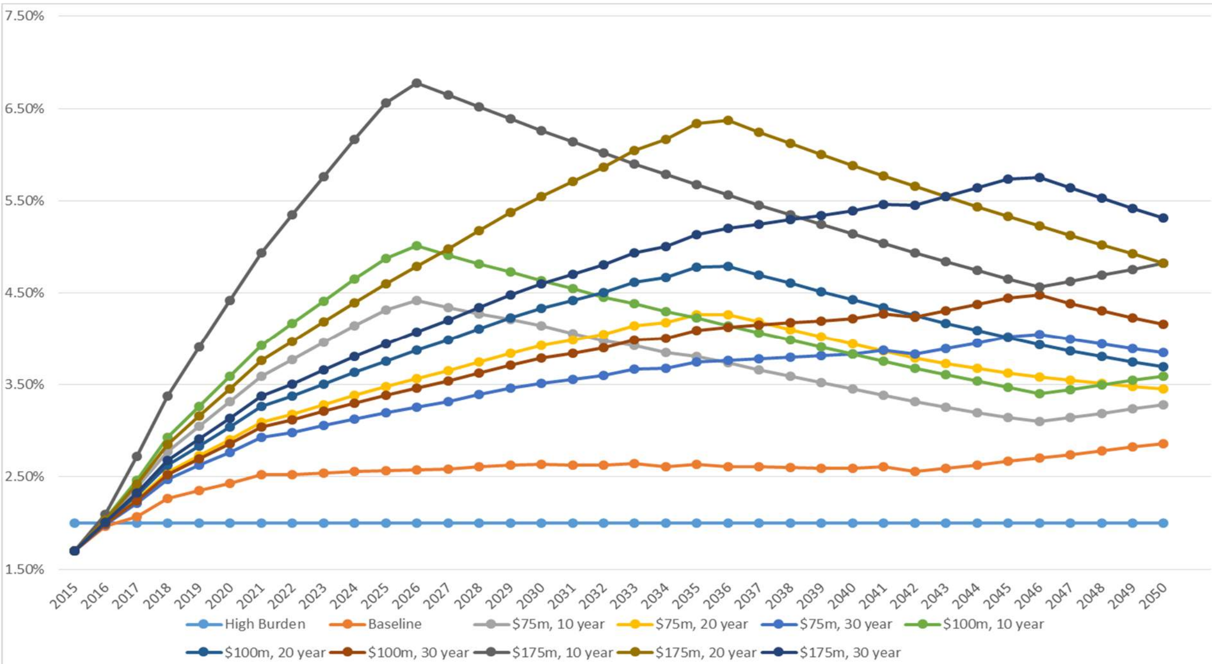
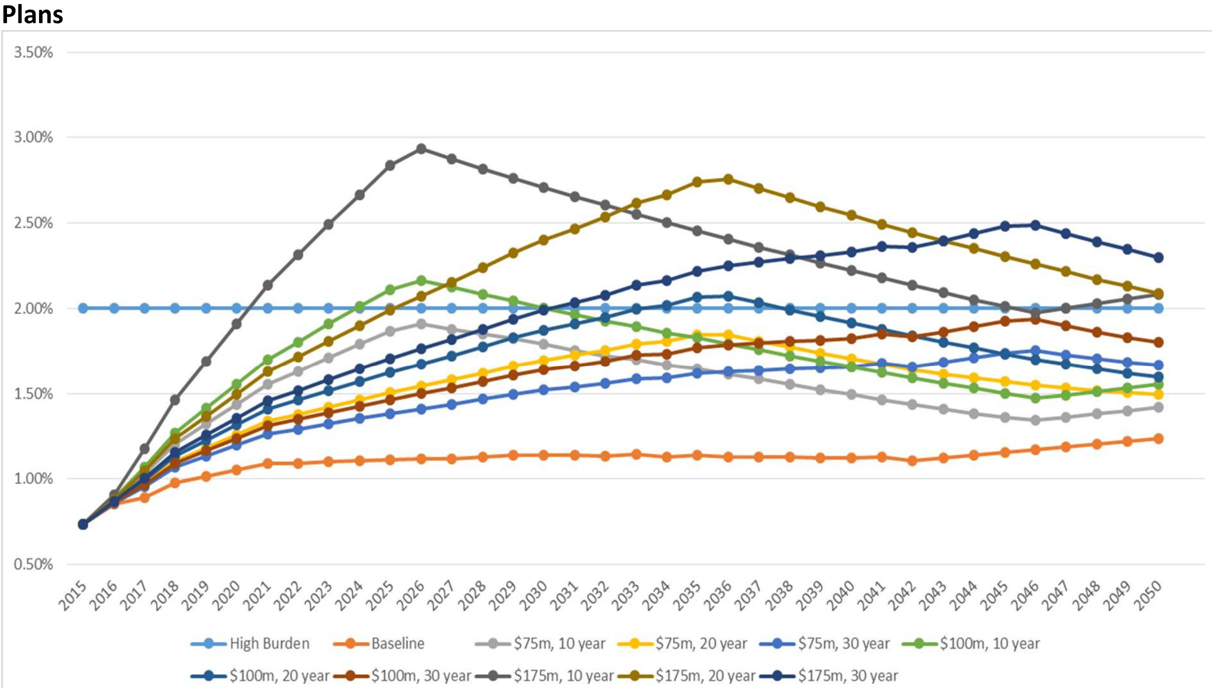


Figure 7-4 Projected Residential Burden, Median Household, Various Conceptual Long Term Control Plans

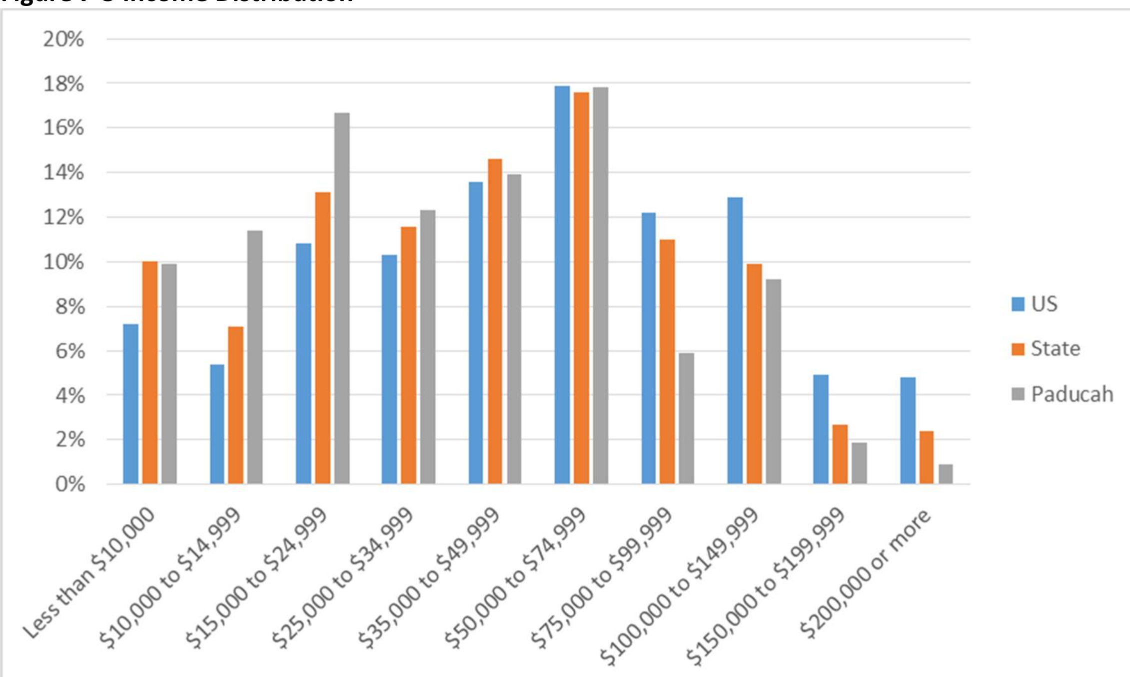


7.5 Additional Financial and Economic Factors

JSA is concerned about the financial and economic capacity of its service area to undertake an LTCP of any magnitude. The previous sections identified the projected residential burden and very steep rate curve facing the service area as a result of a range of program sizes. This concern is highlighted by the following financial, economic, and demographic factors:

- Median household income in Paducah is nearly 35 percent less than the national average and 20 percent less than the Kentucky average. Distribution of income within Paducah is towards the lower end of the spectrum compared to Kentucky and the United States, as seen in Figure 7-5.

Figure 7-5 Income Distribution



- Almost 40 percent of the households in Paducah have annual incomes of less than $25,000 per year, compared to 30 percent of the households in Kentucky and 23 percent nationwide.
- Over 20 percent of the households in Paducah are below the poverty level, which is a higher level of poverty than both Kentucky at 18.3 percent and the United States as a whole at 14.2 percent.
- Over 20 percent of Paducah's households earn less than $15,000 annually.
- Growth in median household income in Paducah has lagged behind the nation as a whole.
- Nearly 19 percent of the population in Paducah is 65 years or older, compared to 13.4 percent of the national population and 13.6 of the Kentucky population. An aging population could

result in slower long-term economic growth as residents potentially become economically dependent and income growth stalls.

- JSA currently has a relatively high debt burden which could prove problematic when combined with relatively low incomes as the JSA moves forward with trying to finance an LTCP program.
- In January 2015, the U.S. Department of Transportation Federal Aviation Administration identified Paducah as an Economically Distressed Area, qualifying the airport to receive a 95 percent share for Airport Improvement Program grants. This determination is based on a series of calculations, which include unemployment data and per capita income.

These factors suggest that JSA faces significant challenges in moving forward with an LTCP of any magnitude. The burden on Paducah households of sewer bills at any level are likely to have a far greater impact than suggested in solely examining median household income. JSA believes that given the potential rate burdens its customers will face, especially those of the lowest quintile, combined with the magnitude of the potential rate increases, it is prudent to be conservative and minimize adverse economic and financial impacts when selecting an LTCP.

Section 8

Public Involvement

As part of the EPA's CSO Control Policy, public involvement is required during the CSO management practices and controls the decision-making process. Public involvement is also specifically noted as one of the requirements that must be met in order to fulfill the intent of the Consent Judgment and Administrative Order. This section identifies the CSO decision makers and the public participation process and methods. An overview of the public meetings held in 2010, as well as more recent meetings, including those to discuss the *Revised LTCP,* is shown in Table 8-1.

Table 8-1 Public Involvement Overview

Date	Audience	Topic of Discussion
January 2010	Paducah Area Chamber of Commerce, Power in Partnership Meeting	Consent Judgment
February 25, 2010	JSA Board of Directors	Consent Judgment and LTCP alternatives analysis
March 16, 2010	City Commission	Consent Judgment and LTCP alternatives analysis
March 23, 2010	Fiscal Court	Consent Judgment and LTCP alternatives analysis
May 6, 2010	Public Meeting	Consent Judgment and LTCP alternatives analysis
June 25, 2010	JSA Board of Directors	LTCP alternatives analysis and proposed plan
July 26, 2010	Fiscal Court	LTCP alternatives analysis and proposed plan
August 10, 2010	City Commission	LTCP alternatives analysis and proposed plan
August 11, 2010	Public Meeting	LTCP alternatives analysis and proposed plan
January 2011	Power in Partnership Meeting	Consent Judgment and ongoing JSA activities
January 2011	JSA Board of Directors with local officials invited	Consent Judgment and ongoing JSA activities
January 2012	Power in Partnership Meeting	Consent Judgment and ongoing JSA activities
January 2012	City Commission	Consent Judgment and ongoing JSA activities
January 2012	Fiscal Court	Consent Judgment and ongoing JSA activities
January 2013	Power in Partnership Meeting	Consent Judgment and ongoing JSA activities
April 17, 2013	Rotary Club	Consent Judgment and ongoing JSA activities
June 4, 2013	Lions Club	Consent Judgment and ongoing JSA activities
November 19, 2013	City Commission	Consent Judgment and ongoing JSA activities
November 21, 2013	Public Meeting	Sewer separation project
January 2014	Power in Partnership Meeting	Consent Judgment and ongoing JSA activities
March 2014	City Commission	Sewer separation project
March 2014	Public Meeting	Sewer separation project
June 2014	City Commission	Consent Judgment and ongoing JSA activities
June 2014	Fiscal Court	Consent Judgment and ongoing JSA activities
March 9, 2015	Fiscal Court	Status and approach to Revised LTCP
March 10, 2015	City Commission	Status and approach to Revised LTCP
May 7, 2015	West End Homeowners Association	Combined sewer work
June 25, 2015	JSA Board of Directors	Financial Analysis and CSO Control Project Selection
September 24, 2015	JSA Board of Directors	Revised LTCP
January 11, 2016	City Commission	Consent Judgment, rates, and ongoing JSA activities
January 12, 2016	Fiscal Court	Consent Judgment, rates, and ongoing JSA activities
June 23, 2016	JSA Board of Directors	Revised LTCP
July 28, 2016	JSA Board of Directors	Revised LTCP
August 25, 2016	JSA Board of Directors	Revised LTCP and proposed schedule

It is important to note that many of the public meetings listed, as well as the comments received, were based on the LTCP developed and submitted in 2010. JSA has reviewed these comments and discussed the *Revised LTCP* with their Board of Directors, including representatives from the Fiscal Court and City Commission, and believes that the public comments received remain representative and applicable to the *Revised LTCP.*

In addition to the activities discussed herein, which are specifically related to the development of the LTCP, JSA regularly presents to officials and public organizations, such as the Chamber of Commerce, to provide information on the on-going work conducted by JSA.

8.1 CSO Decision Makers

Typically, all decisions related to the CSO system are developed by JSA and approved by the JSA Board of Directors.

8.1.1 Joint Sewer Agency

JSA was created in 1999 and is a nonprofit regional utility that provides services to the City of Paducah and McCracken County. Currently, JSA maintains an engineering and operations staff of 28 employees that are responsible for performing work related to engineering, pretreatment, collection, maintenance, relief, mapping/GIS, and inspections. JSA maintains the combined and separate sanitary sewer systems only. The City of Paducah Engineering Department and Public Works is responsible for maintaining all other stormwater pipes and appurtenances, including compliance with the MS4 Permit.

8.1.2 JSA Board of Directors

In addition to the engineering and operations staff, JSA is governed by a board of directors. This seven-member board includes three members that are appointed by the Paducah City Commission, three members that are appointed by the McCracken Fiscal Court, and a final member that is selected jointly by both commissions. Members serve 4-year overlapping terms and can be reappointed but can serve no more than two consecutive terms. The full Board meets once monthly on the fourth Thursday.

The Board of Directors was apprised of the development of the original LTCP at their monthly meetings. In addition, the original alternatives were presented to the Board for input and comments at the February 2010 meeting. The final selected set of alternatives and proposed schedule in the original LTCP was presented at the June 2010 meeting and approved by the Board.

During the revisions to the LTCP, the Board of Directors continued to be apprised of the on-going work associated with the *Revised LTCP* at their monthly meetings. The results of the financial analysis and the preliminary CSO control projects were presented at the June 2015 meeting. The information contained in the 2015 submittal of this report, including the final financial analysis and proposed CSO control projects, was presented at the September 2015 meeting. The Board of Directors was apprised of the status of on-going negotiations with EPA and KDEP regarding the *Revised LTCP*. The information presented in this *Revised LTCP* was discussed at the June, July, and August 2016 meetings.

8.1.3 City Commission and Fiscal Court

As discussed above, the Paducah City Commission and the McCracken Fiscal Court are responsible for the appointment of members to the JSA Board of Directors. In addition to this involvement, an overview of the LTCP process was presented at the onset of the project. The original LTCP alternative development process and the potential alternatives were presented to the City Commission and Fiscal

Court on March 16 and March 23, 2010, respectively. The recommended improvements and proposed schedule presented in the original LTCP submittal was presented at the Fiscal Court's July 26, 2010 meeting and the City Commission's August 10, 2010 meeting.

As JSA initiated the development of the *Revised LTCP* in early 2015, the City Commission and the Fiscal Court were apprised of the status of discussions with EPA and KDOW and the work associated with the *Revised LTCP*.

8.2 Public Participation Process and Methods

The public participation process has two main objectives:

- Promote the education of the public concerning JSA, their existing combined sewer system, and the Consent Judgment.
- Obtain input from the public about their concerns and preferences as the LTCP is developed.

8.2.1 Public Education

The main avenue used during the development of the original LTCP to educate the public involved bill stuffers, which were included with users' monthly bills, and information posted on the JSA website. Bill stuffers were sent out in November 2008 and June 2010 that provided information on the combined sewer system and the LTCP process. The bill stuffers explained the ramifications of entering into the Consent Judgment, summarized the work that has been completed in order to improve the system, and educated the user on the differences between a combined and separate sanitary sewer system.

The bill stuffers included a list of frequently asked questions, as well as referenced the JSA's website, physical address, telephone number, and encouraged users to contact the utility with questions. The website includes much of the same information as the bill stuffers and also includes a link to a copy of the Consent Judgment.

8.2.2 Public Input Meeting – May 6, 2010

A public input meeting was held on May 6, 2010 at the Paducah McCracken County Expo Center, as shown in Figure 8-1. The goal of the meeting was to provide a forum where community members could learn about the combined sewer system, water quality, and options being considered for CSO control. In addition, attendees were given an opportunity to express their comments, ask questions, and provide responses to the possible options that are available to fulfill the requirements of the Consent Judgment.

Figure 8-1 Photos from May 6, 2010 Public Meeting

8.2.2.1 Meeting Notification and Attendance

In addition to being discussed at City Commission and Fiscal Court meetings, the meeting was advertised in the Paducah Sun on May 1-3, 2010. Additionally, community leaders were invited to attend through letters from JSA. In all, 20 community members attended the input meeting, and four individuals recorded their comments for consideration as the final plan for the LTCP was developed.

8.2.2.2 Meeting Agenda and Materials

The meeting was broken out into three main sessions:

- A 15-minute open forum for speaking with JSA staff.
- A 30-minute presentation, which included an introduction to JSA, the requirements of the Consent Judgment, and sewer system improvement plans.
- A 75-minute breakout session for questions and answers.

For both the open forum and the breakout session, individually manned stations were set up around the perimeter of the meeting hall. The stations included descriptive posters to aid in the explanation of the LTCP. Additionally, one station was dedicated to the sanitary sewer system program, which had previously been submitted to both KDOW and EPA. The five stations were organized as follows:

- Overview of the JSA system,
- Overview of the flow and rainfall monitoring, modeling, and water quality testing,
- Overview of potential solutions to outfalls on the Ohio River and Perkins Creek,
- Overview of potential solutions to outfalls on Island Creek, and
- Overview of the sanitary system program.

8.2.2.3 Public Comment Summary

The following two questions were included on the public meeting comment form:

- Do you have additional questions about the operation of the Paducah McCracken Joint Sewer Agency, the combined sewer system, or the development of the long-term control plan? Is there any additional information that you would like to receive? If so, please indicate below:
- Please state any comments that you have regarding the development of the combined sewer system long-term control plan. These may include additional factors that you feel should be considered when developing the plan, preferences on improvement alternatives presented, prioritization of combined sewer overflow (CSO), etc.

Four members of the public provided comments to the second question. These have all been transcribed below. Overall, the public expressed concern over the short time period allowed under the terms of the LTCP, as well as the attention placed on Island Creek as a recreational area.

Comment #1:

> *"I noticed that the rail yard was a large contributor to outfalls 008-011. Is there a way to go back to sources and have them do a better job managing their stormwater at the source rather than JSA controlling it through a CSO program? I think this might also apply to the barge and river industries along the Tennessee River and the south side.*
>
> *I think it is unrealistic to expect rate payers to support these corrective actions in the next 8 yrs. I would rather see steady progress stretched out to 10 or 15 yrs. New technology and solutions are always coming along that are more cost effective. Plastic inserts in deteriorating pipe is a good example of a better alternative than digging up and replacing sewer lines.*
>
> *I would also like to see more analysis of the source of contaminants upstream of the CSO overflows. That analysis might save money on downstream solutions. I would rather spend 2 years investigating sources so that we can save on downstream solutions.*
>
> *Thanks for the opportunity to comment and I look forward to the next meeting."*

Comment #2:

> *"Ec[onomic] Impact of community – consider a common sense approach to Island Creek – no one expects to swim there!*
>
> *JSA is one of the best agencies in our community – it's great to have City & County services combined for our citizens. We use JSA as a model for other City & County government agencies that should be combined to better serve our community."*

Comment #3:

> *"In listening to comments by JSA at the public meeting, I have two comments: 1) while I heartily endorse clean water and minimizing the impacts of CSO's and SSO's I don't think the plan for Island Creek as a primary contact recreation area is of primary importance. As a longtime resident, Island Creek is not used by the public, or adjacent residents for recreation. The land uses along the banks do not lend themselves to recreational uses. The banks are steep and vegetation thick. The City zones the creek and top storage elevations for flood storage. So the water elevations fluctuate frequently. I don't think the heroic investment really promote[s]*

water quality and public health that dramatically. Surely prioritizing projects at the WTP seem to be more efficient & economical. 2.) Your plan to raise the funds from local rate payers (me) and do this in 10 years is quite frankly un-realistic! I am for clean water, public health, but doing it all in ten years seems too much for the public to bear. 25-30 years seem more realistic."

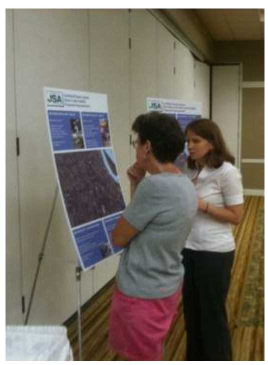
Comment #4:

"While you always want to improve environmental elements, please use common sense approach when making decisions. Please also consider the economic impact on our community."

8.2.3 Public Input Meeting – August 11, 2010

The second public input meeting was held on August 11, 2010 at the Paducah McCracken County Expo Center, as shown in Figure 8-2. As with the first meeting, one of the goals of the meeting was to provide a forum where the community could learn about the combined sewer system. Additionally, the meeting presented the proposed LTCP. Community members were again provided the opportunity to ask questions, express comments and concerns, and record responses to be included with the LTCP submittal.

Figure 8-2 Photos from August 11, 2010 Public Meeting



8.2.3.1 Meeting Notification and Attendance

Similar to the first meeting, the meeting was discussed at both the City Commission and Fiscal Court meetings and was advertised from August 7-9, 2010 in the Paducah Sun. Community leaders were also invited through letters from JSA. In all, 14 community members attended the meeting and five individuals recorded comments for inclusion in the LTCP.

8.2.3.2 Meeting Agenda and Materials

The meeting was broken into three main sessions:

- A 30-minute open forum for discussion of questions with members of JSA.
- A 30-minute presentation, which included an introduction to JSA, the requirements of the Consent Judgment, and the proposed plan to be submitted in the LTCP.
- A 60-minute breakout session for questions and answers.

As with the first public meeting, the second meeting had stations with posters in order to aid with the presentation of the proposed plan at the various outfall locations. The six stations were organized as follows:

- Overview of the JSA system,
- Overview of the flow and rainfall monitoring, modeling, and water quality testing,
- 2 stations describing the proposed solution at the Ohio River and Perkins Creek outfalls, and
- 2 stations describing the proposed solution at the Island Creek outfalls.

8.2.3.3 Public Comment Summary

The following two questions were included on the public meeting comment form:

- Do you have additional questions about the operation of the Paducah McCracken Joint Sewer Agency, the combined sewer system, or the development of the long-term control plan? Is there any additional information that you would like to receive? If so, please indicate below:
- Please state any comments that you have regarding the development of the combined sewer system long-term control plan. These may include additional factors that you feel should be considered when developing the plan, preferences on improvement alternatives presented, prioritization of combined sewer overflow (CSO), etc.

Two individuals responded to the first question; one commented that it was a very good presentation, while the other requested a copy of the executive summary of the LTCP. Two questions were raised during the informal group question and answer session immediately following the presentation. The first question dealt with the fear that JSA may be over borrowing in order to fulfill the EPA's requirements, while the second question focused on the fear that the money to fund this program would hinder the ability for JSA to grow and serve additional areas of McCracken County.

Five members of the public provided comments to the second question. These have all been transcribed below. Overall, public concern focused on the fear that this proposed plan may result in the JSA, and by extension the community, being overburdened. Questions again arose concerning the existing water quality upstream of the CSOs, particularly at Island Creek.

Comment #1:

> *"I believe that the Paducah-McCracken County Joint Sewer Agency has a clear and commonsensical plan to address the community's concerns."*

Comment #2:

> *"In listening to the detailed presentation to the public by JSA, I am in general agreement with JSA that we must get the most bang-for-the-buck. This is not a wealthy community and I do not think it's financially prudent to take a heroic leap of faith on unproven technologies that only marginally improve water. As a rate payer, sportsman, and outdoorsman, I applaud and support the regulatory laws and efforts toward the goal of public health. The efforts of the past 20 – 30 years[s] are evident in this watershed. <u>But</u> let's take a balanced effective + <u>economical</u>*

approach to cleaning up CSO's + SSO's. I think JSA and its team of consultants have done a good job a[t] seeking public comment.

Comment #3:

"1. I am concerned about up-stream contamination and waste imposing costly controls for contamination that may be illegally entering the system. I think the measure of performance should be incremental improvement from a baseline.

2. I'm concerned about the debt service ratio coverage versus the amount of spending/borrowing required by compliances. I think it would be irresponsible to spend/borrow money to meet this plan and exceed this coverage and jeopardize financial health of JSA.

3. I'm concerned about spending/borrowing for this program interfering with growth of JSA. If all the funding is allocated towards compliance, there will be no growth of the system, no new rate payers, and no new businesses to tap into the system. We need a balance to insure long term viability of [the] system."

Comment #4:

"I believe the plan that JSA has proposed is on the right track – development pace vs. cost to customers. Water quality in several areas is not the primary fact that should be consider[ed]. Many areas have been deemed by the EPA to require a higher resulting water quality than necessary – Island Creek for example. Areas that do not support or will not support humans (in the 10 – 50 year future) should not require a high level of water quality."

Comment #5:

"Allow our community to manage the water flow problems without placing a burden on the citizens."

Section 9

Selected CSO Control Alternatives and Implementation Schedule

To select the combination of CSO control projects, JSA's key performance objectives are to protect sensitive areas, meet the needs of the community it serves, and provide for the elimination or the capture for treatment of no less than 85 percent of the combined sewage collected during precipitation events on a system-wide annual average basis. This section describes the selection of CSO control projects, describes the prioritization and scheduling process, presents the financial impacts of the proposed LTCP program, and provides the average annual CSO statistics anticipated following implementation of the *Revised LTCP*.

9.1 Selection of Global CSO Control Alternative

JSA can achieve the 85 percent target with the High Rate Treatment and Disinfection global alternative described in Section 6.4. This would be accomplished through a combination of sewer separation, increased pumping capacity, storage, and high rate treatment and disinfection. This approach also limits the number of CSO control facilities required, since the 85 percent target can be achieved without improvements at EPA 008, EPA 009, EPA 010, or EPA 011, allowing JSA to better focus its limited funding.

This global alternative provides increased protection of sensitive areas by focusing on the CSOs located on the Ohio and Tennessee Rivers. Additionally, a higher level of control (reduction to 4 overflows per year based on the representative period analysis) is provided at EPA 004, which is the CSO in closest proximity to the drinking water intake.

The High Rate Treatment and Disinfection global alternative has an estimated, screening-level capital cost of $134 million. Regardless of the implementation timeframe, the impact of such a costly program on JSA's customers would be significant. To fund such a program, customers within Paducah would have sewer rates that exceed the high burden threshold of 2 percent.

Given that excessive level of burden, the Fine Screening and Disinfection global alternative was reconsidered. While it does not meet the strict definition of primary treatment, it does accomplish much of the reduction in total suspended solids (TSS) and biochemical oxygen demand (BOD) that is expected with primary treatment while meeting JSA's other objectives. Most importantly, this approach will provide for essentially the same high level of bacteria reduction to the receiving waters that would be achieved with High Rate Treatment and Disinfection.

The primary advantage of the Fine Screening and Disinfection global alternative is cost. With a screening-level capital cost of $96 million, this global alternative is approximately $38 million, or one third, less expensive than the High Rate Treatment and Disinfection global alternative. Even at the lower cost, the program still imposes a significant burden (over 2 percent for a 10-year program duration) given Paducah's median household income and a very high burden on the lowest quintile. Given these significant affordability concerns, JSA does not believe that the additional $38 million to provide high rate treatment is warranted by the marginal reduction in TSS and BOD, as these water quality benefits to the receiving waters would be imperceptible, while the key objective to provide for bacteria reduction will be equally achieved.

9.2 Project Prioritization

JSA proposes completion of the following projects to meet the objectives of its LTCP:

- EPA 002: Fine screening and disinfection
- EPA 003: Fine screening and disinfection
- EPA 003-004: Storage
- EPA 004: Increased pumping capacity for storage / treatment with EPA 003
- EPA 006 / EPA 007: Fine screening and disinfection
- EPA 012: Sewer separation (completed in 2015)
- EPA 014: Sewer separation (completed in 2012)

However, as JSA considered the implementation of these projects, the challenge for a small system to implement such large projects is apparent, and JSA proposes to separate each fine screening and disinfection facility into two separate design and construction projects. This approach, however, results in a slight increase in the total program cost to $102 million, as shown in Table 9-1. However, this approach provides several very important benefits that more than justify the slight increase in total cost:

- Increased flexibility in scheduling of smaller projects;
- Smaller projects can be defined within JSA's ability to fund and manage them; and
- Smaller projects are less likely to exceed the capacity of the local construction market.

Table 9-1 Selected CSO Control Projects

Outfall No.	CSO Control Technology	Screening-Level Cost (millions of dollars)
EPA 002	Fine screening	13
EPA 002	Disinfection	6
EPA 003	Fine screening	14
EPA 003	Disinfection	22
EPA 003-004	Storage at WWTP	20
EPA 004	Pump to Storage / Treatment	13
EPA 006-007	Fine screening	5
EPA 006-007	Disinfection	9
EPA 008-009	None	0
EPA 010	None	0
EPA 011	None	0
EPA 012*	Separation	Completed
EPA 014*	Separation	Completed
	Total	**102**

*Costs associated with EPA 012 and EPA 014 are not included in total for this global alternative. JSA has completed over $39 million worth of improvements since 2010.

To develop the proposed schedule for the selected projects, JSA considered each CSO outfall location based on its proximity to sensitive areas, the need for screening of solids and floatables, the project's operational impacts, constructability, and land acquisition challenges, and the overall annual CSO volume. This resulted in the highest priority being assigned to EPA 004, followed by EPA 003, EPA 006-007, and EPA 002. The prioritized list of CSO control projects is shown in Table 9-2; this list excludes EPA 012 and EPA 014 which are already completed.

Table 9-2 Prioritized CSO Control Projects

Prioritization Rank	Outfall No.	CSO Control Technology	Screening-Level Cost (millions of dollars)
1	EPA 003-004	Storage at WWTP	20
2	EPA 004	Pump to Storage / Treatment	13
3	EPA 003	Fine screening	14
4	EPA 006-007	Fine screening	5
5	EPA 003	Disinfection	22
6	EPA 002	Fine screening	13
7	EPA 006-007	Disinfection	9
8	EPA 002	Disinfection	6

The strategy behind this program best balances cost and benefits while substantially achieving all key objectives for the program. Although it imposes a significant financial burden on JSA's customers, it avoids what would clearly be an unacceptable burden that would likely be rejected by the community if full high rate treatment were provided in lieu of fine screening. The program can be completed as a series of affordable and manageable projects constructed over a reasonable implementation schedule.

9.3 Financial Impact of the Selected LTCP

Utilizing the prioritization of the selected CSO control projects, the financial impact of the $102 million LTCP program was evaluated under a 10-year, 22-year, and 30-year program duration. In each case, the distribution of projects over the program duration assumes that the first project is begun following approval of the LTCP and the final project is completed at the end of the assumed program duration. The remaining projects were distributed over the program's duration with the goal of smoothing the required revenue (i.e. avoiding spikes that would be difficult and/or costly to fund). Project durations, including design and construction phases, ranged between two and four years depending on the project's complexity.

The financial impacts described below utilize fiscal year 2015 as the base year and assumed approval of the LTCP would be obtained prior to the end of 2015. As a result, the analysis assumes that the first LTCP project would begin in 2016. The current status of the LTCP review and approval process will not support program implementation in 2016. However, JSA believes that the analysis remains representative of the long-term impacts and burden resulting from program implementation.

Tables 9-3, 9-4, and 9-5 summarize the assumed spending and schedule for the proposed CSO control projects for the 10-year, 22-year, and 30-year program durations. The estimated annual spending for each project is based on equal annual expenditures within the years shown. It should be noted that under each duration, program expenditures will exceed JSA's funds available from cash flow and will therefore require that debt be incurred to meeting funding needs.

Table 9-3 Project Schedule, 10-Year Duration

Prioritization Rank	Outfall No.	CSO Control Technology	Estimated Start Years from Approval	Estimated End Years from Approval
1	EPA 003-004	Storage at WWTP	1	4
2	EPA 004	Pump to Storage / Treatment	2	5
3	EPA 003	Fine screening	3	6
4	EPA 006-007	Fine screening	4	6
5	EPA 003	Disinfection	5	8
6	EPA 002	Fine screening	6	8
7	EPA 006-007	Disinfection	7	9
8	EPA 002	Disinfection	9	10

Table 9-4 Project Schedule, 22-Year Duration

Prioritization Rank	Outfall No.	CSO Control Technology	Estimated Start Years from Approval	Estimated End Years from Approval
1	EPA 003-004	Storage at WWTP	1	4
2	EPA 004	Pump to Storage / Treatment	4	7
3	EPA 003	Fine screening	7	10
4	EPA 006-007	Fine screening	10	12
5	EPA 003	Disinfection	12	15
6	EPA 002	Fine screening	16	18
7	EPA 006-007	Disinfection	19	20
8	EPA 002	Disinfection	21	22

Table 9-5 Project Schedule, 30-Year Duration

Prioritization Rank	Outfall No.	CSO Control Technology	Estimated Start Years from Approval	Estimated End Years from Approval
1	EPA 003-004	Storage at WWTP	1	4
2	EPA 004	Pump to Storage / Treatment	6	9
3	EPA 003	Fine screening	11	14
4	EPA 006-007	Fine screening	16	18
5	EPA 003	Disinfection	20	23
6	EPA 002	Fine screening	24	26
7	EPA 006-007	Disinfection	27	28
8	EPA 002	Disinfection	29	30

Similar to Section 7.4, the impacts of the programs are added to the baseline evaluation to project future requirements, with the essential impact being the annual amount of debt service incurred by JSA as a result of the program. The following table summarizes the annual debt service for the proposed LTCP under a 10-year duration, a 22-year duration, and a 30-year duration.

Table 9-6 Incremental Debt Service, Proposed LTCP

	2015	2020	2025	2030	2035	2040
$102 million, 30 years	$-	$2,339,458	$3,855,022	$5,680,005	$6,929,937	$11,194,393
$102 million, 22 years	$-	$2,878,795	$5,453,145	$9,530,303	$12,092,434	$10,592,089
$102 million, 10 years	$-	$5,341,603	$12,128,307	$10,593,823	$8,690,435	$4,710,134

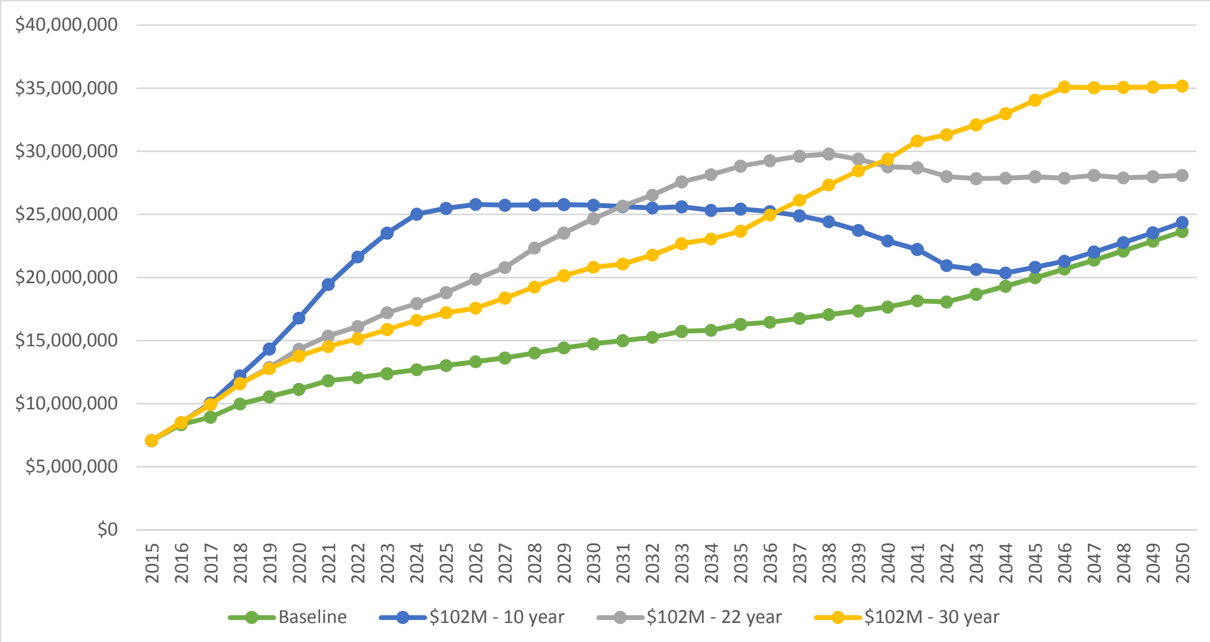
The $102 million, 30-year proposed program would require JSA to increase user rates to generate additional revenue of $2.3 million in 2020, $3.9 million in 2025, $5.6 million in 2030, $6.9 million in 2035 and $11.2 million in 2040 to meet the additional debt service burden. For this program, the revenue requirements in 2040 would total approximately $29.3 million, an increase of close to 60 percent compared to the baseline. JSA's revenue requirement is projected to increase to over 9 percent annually for the next 10 years under this program.

The $102 million program with a 22-year duration is estimated to require additional revenue generation of $2.9 million in 2020, $5.5 million in 2025, $9.5 million in 2030, $12.1 million in 2035 and $10.6 million in 2040 to meet the additional debt service burden. By 2035, the revenue requirements for this program would increase by almost 70 percent above the baseline to approximately $28.8 million. Revenue requirements are projected to increase at an average of over 10 percent annually for the next 10 years.

The $102 million program with a 10-year duration would require additional revenue generation of $5.3 million in 2020, $12.1 million in 2025, $10.6 million in 2030, $8.7 million in 2035 and $4.7 million in 2040 to meet the additional debt service burden. By 2025, the revenue requirements for this program would increase by over 90 percent above the baseline to approximately $25.4 million. This equates to a projected annual increase of over 13 percent for the next 10 years.

Figure 9-1 shows the projected increase in revenue requirements for the $102 million proposed LTCP, for a 10-year program duration, a 22-year program duration, and a 30-year program duration.

Figure 9-1 Projected Revenue Requirements, Selected CSO Control Projects



The projected residential burden for the lowest income quintile population in Paducah under the proposed LTCP is shown in Figure 9-2. For a 10-year program duration, the projected burden for this group will exceed 5 percent of income by 2024. For a 22-year program, the projected burden will peak close to 4.7 percent in 2035. The burden for the 30-year duration will steadily increase over time and is estimated to peak at nearly 4.6 percent in 2046. Similar to the conceptual level plans, under the selected CSO control projects, the lowest income group will face a burden in excess of EPA's high burden limit for nearly the entire forecast period.

The residential burden using the median income level within Paducah is shown in Figure 9-3. The 10-year program duration, 22-year program duration, and the 30-year program duration are projected to exceed the EPA's high burden limit. The program with a 10-year duration exceeds the high burden threshold by 2023, while the program with a 30-year duration is projected to reach the 2 percent threshold by 2041. The 22-year program duration is expected to exceed the high burden limit by 2033.

Figure 9-2 Projected Residential Burden, Lowest Quintile Income, Selected CSO Control Projects

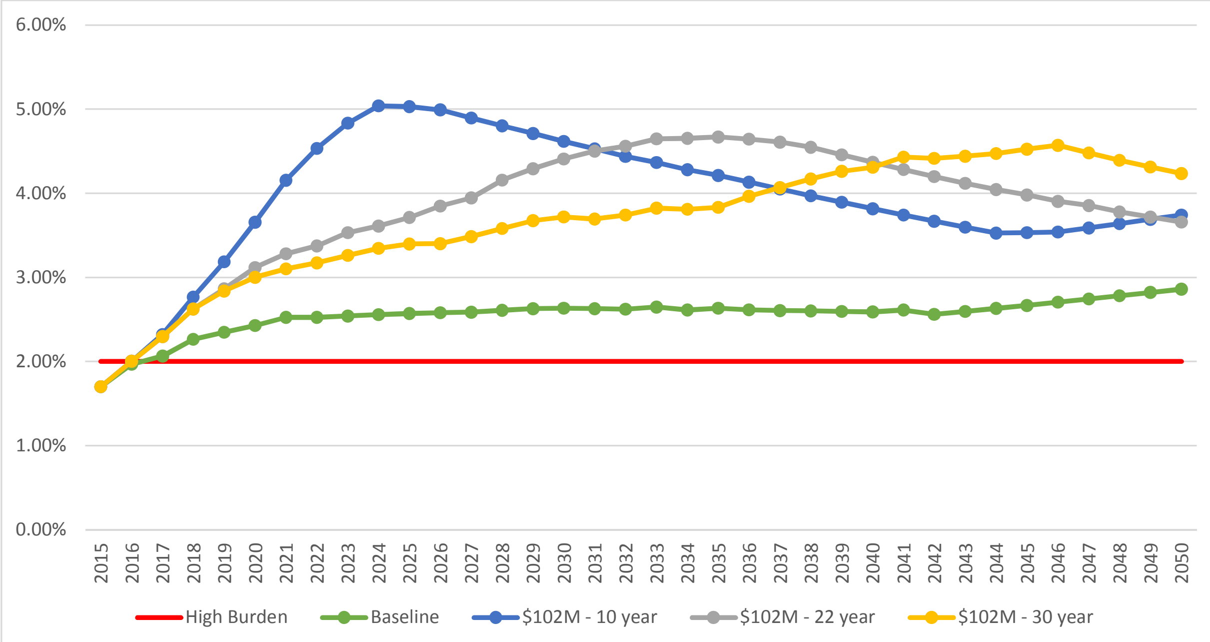
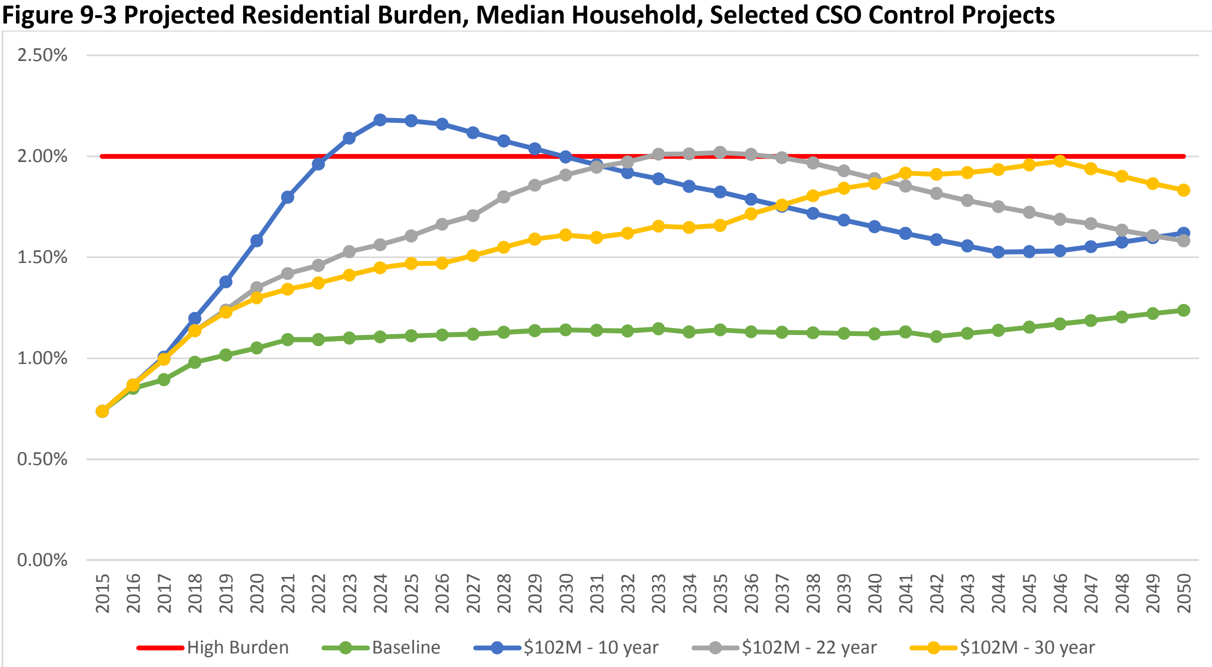


Figure 9-3 Projected Residential Burden, Median Household, Selected CSO Control Projects



9.4 Selected Duration of the LTCP

In the *Revised LTCP* submitted in October 2015, JSA proposed that the selected CSO control projects in this LTCP be implemented over a 30-year duration based on both financial and implementation concerns. Subsequent discussions with the Commonwealth of Kentucky and EPA, however, indicated a 22-year program duration is the longest acceptable timeframe, and the *Revised LTCP* was edited to reflect that change.

9.4.1 Financial Impacts

As discussed above, the 10-year, 22-year, and 30-year durations for implementation of the LTCP will impose a significant financial burden on JSA's customers. The projected residential burden is 2 percent or greater for each program durations when considering the Paducah MHI. When considering the lowest quintile, the residential burden is greater than 4.5 percent, representing a very significant impact to JSA's low income customers.

The more significant concern, though, is the rate that the average sewer bill would need to increase in order to support the program. If implemented over a 10-year period, JSA's customers will face rate increases of approximately 13 percent per year over the first ten years, which is more than quadruple the historical rate of inflation. For a 22-year duration, rate increases of approximately 10 percent per year are anticipated for the first ten years. Even under a 30-year duration, rate increases are significant, approximately 9 percent per year over the first ten years. This series of annual rate increases will be challenging for JSA to put in place, but the alternative 13 percent annual increases required by the 10-year duration would be unacceptable to the community.

9.4.2 Implementation Impacts

As a small system, JSA has a limited capacity to manage major capital improvement projects, and typically does not have construction projects costing more than $10 million. As shown in Table 9-3, if the LTCP is implemented over a 10-year duration, JSA would be responsible for managing up to four large LTCP projects concurrently which would significantly exceed the capacity of JSA's staff to manage construction work and does not account for on-going improvements in their system required outside of this *Revised LTCP*.

Additionally, given the number and scale of the CSO control projects, there are significant questions about whether the local and regional construction market has the capacity to meet this demand over the shorter 10-year duration, and even if they could, JSA anticipates the imbalance created in supply and demand would significantly increase impacts on project costs, which have not been accounted for in this analysis.

9.5 Summary

JSA believes that the selected CSO control projects presented in this *Revised LTCP* substantially achieve the key objectives of this program by protecting sensitive areas, meet the needs of the community it serves, and providing for the elimination or the capture for treatment of no less than 85 percent of the combined sewage collected during precipitation events on a system-wide annual average basis. Although it will pose a significant financial burden to JSA and its customers, a 30-year implementation period reduces financial and implementation concerns to feasible levels versus the shorter durations. JSA requested, in the *Revised LTCP* submitted in October 2015, that the selected CSO control projects be implemented over a 30-year program duration. Subsequent discussions with the Commonwealth of Kentucky and EPA, however, indicated a 22-year program duration is the longest acceptable timeframe, and the *Revised LTCP* was edited to reflect that change.

The detailed schedule and project listing is included in Table 9-7, and the anticipated average annual CSO statistics following implementation of this *Revised LTCP* is presented in Table 9-8. A map summarizing the projects is shown as Figure 9-4. A compliance monitoring plan has been prepared to enable JSA to evaluate the actual performance of the proposed facilities after they are in service against the established performance objectives. This Post-Construction Compliance Monitoring Plan is presented in Appendix P.

Table 9-7 LTCP Implementation Schedule

Prioritization Rank	Outfall No.	CSO Control Technology	Estimated Start[1]	Estimated End[1]
1	EPA 003-004	Storage at WWTP	2017	2020
2	EPA 004	Pump to Storage / Treatment	2020	2023
3	EPA 003	Fine screening	2023	2026
4	EPA 006-007	Fine screening	2026	2028
5	EPA 003	Disinfection	2028	2031
6	EPA 002	Fine screening	2032	2034
7	EPA 006-007	Disinfection	2035	2036
8	EPA 002	Disinfection	2037	2038

[1] Estimated dates presented assume that approval of the LTCP is achieved no later than December 1, 2016. The schedule will be extended in equal measure for any delay in approval beyond that date.

Table 9-8 Baseline and Anticipated Post-LTCP Average Annual Statistics at CSO Outfalls

Outfall	Description	Baseline Average Annual Statistics		Anticipated Post-LTCP Average Annual Statistics	
		Volume (MG)	Events (number)	Volume (MG)	Events (number)
EPA 002	Noble Park	308	68	74	19
EPA 003	Terrell	843	50	111	24
EPA 004	Harrison	83	40	<1	4
EPA 006-007	Husbands	253	36	26	10
EPA 008	Rail yard	75	67	75	67
EPA 009	Rail yard	47	58	47	58
EPA 010	Rail yard	82	64	82	64
EPA 011	Rail yard	17	85	17	85
EPA 012	Lone Oak	42	45	0	0
EPA 014	Bridge Street	46	70	0	0

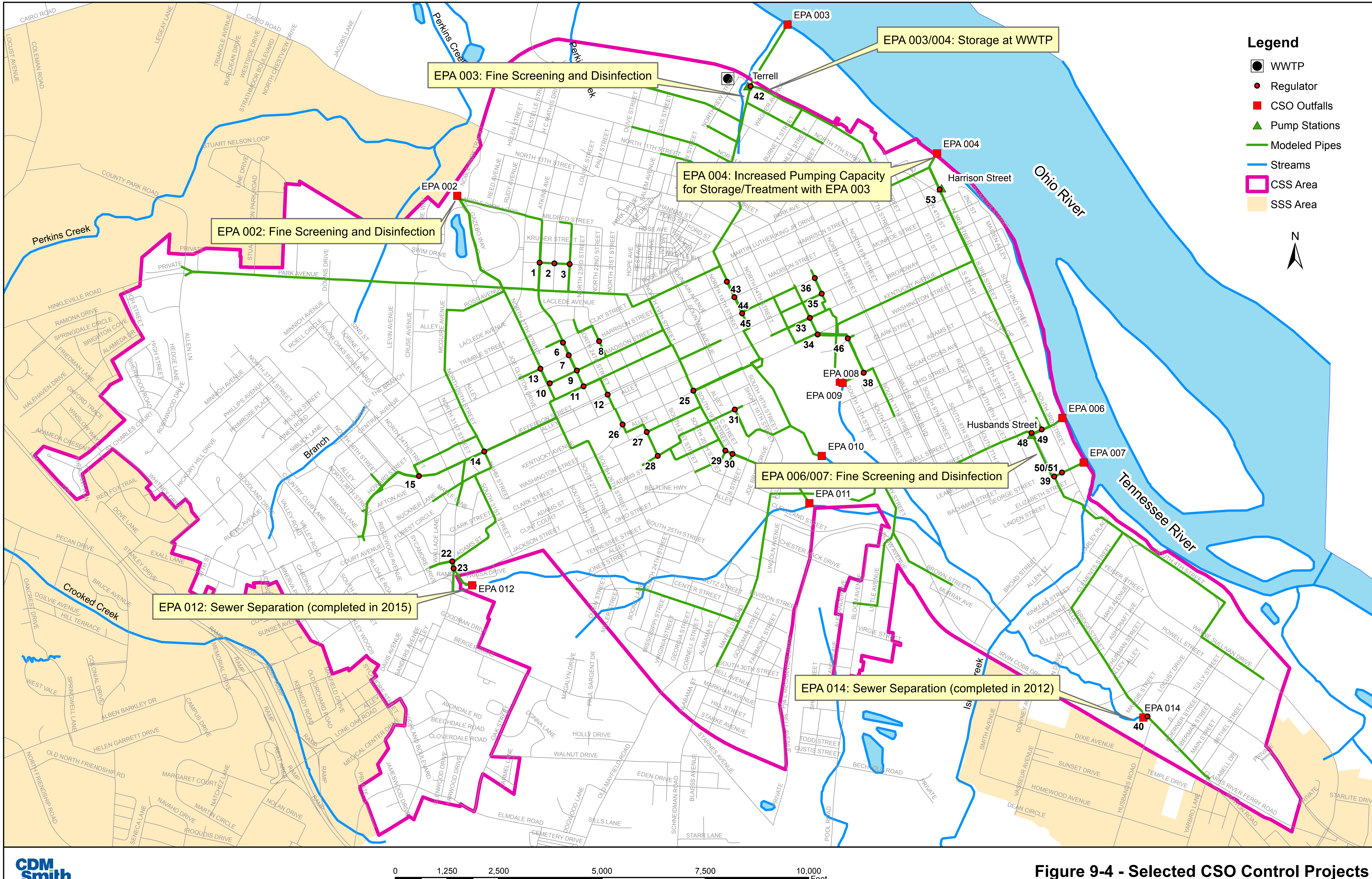


Figure 9-4 - Selected CSO Control Projects

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Appendix A

System Overview and Flow Schematic

System Overview and Flow Schematic

Notes:
1. Dry weather flow (DWF) is from March. Note that "0" indicates no dry weather flow while ">0" indicates flow is present but less than 0.1 mgd.
2. Peak flow represents the maximum modeled flow for a 3 month design storm. That storm includes a 24-hour total rainfall of 1.84 inches with a peak hour intensity of 0.7 inches. Peak flows shown do not necessarily occur at the same timestep.
3. The flows shown do not reflect the separation projects associated with CSOs EPA012 and EPA014.

Appendix B

Protection of Drinking Water Intake

Introduction

In response to the Paducah-McCracken Joint Sewer Agency (JSA) Long Term Control Plan and proposed combined sewer overflow (CSO) control projects, the Kentucky Department for Environmental Protection (KDEP) and the U.S. Environmental Protection Agency (EPA) requested additional information on the Paducah Water Treatment Plant (WTP), in particular what CSO contaminants may impact the drinking water intake and what alternatives are feasible to further protect the drinking water intake. This technical report serves as a response to these comments.

CSO Potentially Affecting the Drinking Water Intake

JSA has three CSO outfalls located upstream of the Paducah drinking water intake. EPA 004 is located on the Ohio River approximately 0.6 miles upstream of the intake. EPA 006 and EPA 007 are located on the Tennessee River, upstream of the intake a distance of approximately 2.0 miles and 2.2 miles, respectively. Because of their proximity to the drinking water intake, a request was made to evaluate both relocating the intake and separating the combined sewer system upstream of these three CSO outfalls. These evaluations are provided below.

Water Treatment Plant Background Information

The W. S. Brockenborough / Paducah WTP is located west of downtown Paducah on East 8th Street, east of the US-45 bridge over the Ohio River. The plant was constructed in 1984 and is a conventional water treatment plant, using a screening / rapid chemical mixing / flocculation / sedimentation / filtration / disinfection process train to treat water that meets or exceeds all drinking water standards. In fact, Paducah Water was been awarded the Outstanding Water Quality Award as part of the Area Wide Optimization Program. They have also received the Director's Award for the Partnership for Safe Water which is awarded by the American Water Works Association and EPA.

The water treatment plant capacity is 19.9 million gallons per day, and the plant serves approximately 26,600 connections in Paducah and the surrounding areas. The plant's water intake is located in the Ohio River, east of the US-45 Bridge and upstream of CSO EPA 003 (See Figure B-1). Depending on variable river hydraulics including operation of upstream dams, the source water may be dominated by either flows from the Tennessee River or by the Ohio River, although the former normally dominates. The intake structure consists of two Johnson Wedgewire-type screen structures with 1/8" inch screen openings located approximately 300 to 350 feet offshore from the Ohio River south bank. Each screen is attached to a 36-inch diameter ductile iron pipe that routes the water approximately 1,500 feet south to the raw water pump station. The pump station consists of 4 pumps (one 4,200 gallons per minute pump and three 5,600 gallons per minute pumps) that pump water through a 30-inch ductile iron pipe approximately 4,000 feet to the WTP. The current intake has been in service since 1984.

According to Paducah Water's 2014 Annual Report, a source water assessment has been completed (Source Water Assessment and Protection Plan Susceptibility Analysis and Protection

Recommendations for McCracken County), which indicates that susceptibility to contamination is generally high for Paducah's water supply, and mentions the following potential areas of concern: petroleum storage facilities, bridge crossings, river traffic, Island Creek, and farming practices.

Potential Impacts to the Drinking Water Intake

Through discussions with Paducah Water staff and review of available information, JSA has attempted to assess the potential impacts of their CSOs on the Paducah drinking water intake.

One method to assess the potential impact would be to correlate the presence of CSO or sewage contaminants in the raw source water at the WTP. For example, Biochemical Oxygen Demand (BOD), Carbonaceous Oxygen Demand (COD), fecal coliform bacteria, or another parameter that is prevalent in raw sewage could potentially be correlated with CSO discharges. Unfortunately, the Paducah WTP does not analyze source water for any of these parameters since (1) there is no requirement to analyze source water for these constituents and (2) there has been no historical evidence that suggest these constituents exist in the source water to a level that would cause a concern for Paducah.

Another method to determine a potential impact is to review the real and anecdotal history of the WTP to determine if there are any events in the WTP's history that would indicate raw influent water quality was impacted by the presence of CSO discharges. Discussions with Paducah Water staff indicate that, to date, raw water quality excursions over the years have not been studied to determine if there is a correlation between these events and storm flows. Paducah Water staff did note, however, that current plant treatment processes include pre-chlorination and post-chlorination of the treated water, which provides, in essence, a double disinfection process that increases confidence that any biological entities in the raw water, whether caused by CSO flows or by other sources, are inactivated prior to the potable water being distributed to the public.

Although there are CSO outfalls upstream of the drinking water intake, a comparison of the observed mean flow of the Ohio River and the maximum predicted daily flow (from the LTCP hydraulic modeling) from the outfalls indicates the contribution from any CSO outfall is insignificant relative to the flow in the Ohio. In fact, even under high flow conditions, the sum of the CSO discharges from the outfalls upstream of the drinking water intake represents approximately 0.02% of the normal Ohio River flow at Metropolis, IL. That analysis is based on the existing CSO discharges, of which the vast majority of that flow is stormwater runoff, and does not include any additional treatment or capture of CSO discharges being considered in the LTCP. Those CSO discharges are significantly mixed and diluted (typically by a factor on the order of 5000:1) by the fast-moving Ohio River when they eventually reach the vicinity of the intake.

JSA believes that any additional analysis of the impacts of the CSO discharges to the drinking water intake, which would require extensive modeling and water quality analyses of the Ohio River, is unnecessary in light of the factors described above. Further, such analysis is beyond the scope required of a community as small as Paducah and is specifically excluded in JSA's Consent Judgment.

Alternatives to Further Protect the Drinking Water Intake

In order to fulfill the requirements of the CSO Control Policy, JSA evaluated the following alternatives which provide further protection of Paducah drinking water intake:

- Relocation of the drinking water intake upstream of the CSO outfalls

- Sewer separation of CSOs upstream of the drinking water intake
- Capture and routing of CSOs for discharge downstream of the drinking water intake

Each of those options is further discussed below.

Relocation of the Drinking Water Intake to a Location Upstream of the CSO Outfalls

To eliminate the potential of JSA's CSOs impacting the drinking water intake, the intake could potentially be moved upstream of EPA 007 or placed in another location that would isolate the raw water from the CSO discharge locations. There are two potential locations, shown on Figure B-1, to be considered:

1. An intake in the Owens Island channel, upstream of EPA 007.
2. An intake north of Owens Island, as close to the northwest tip of the island as possible to minimize pipe distance but maintain isolation from JSA's CSOs.

While the Owens Island channel location would be less costly to build, there are several mitigating circumstances that are negative impacts on use of this location.

1. Significant threatened and endangered mussel populations (both density and diversity) have been identified within ¾ mile downstream of the proposed intake location. While these mussel populations have not been confirmed at the actual location of the proposed intake in the Owens Island Channel to date, it is reasonable to assume that mussels may be present near that location.
2. There is an industrial / tank farm facility in the vicinity of the intake. Any contamination from this facility would likely have an immediate impact on the intake water.
3. The source water would be 100 percent Tennessee River water, which would likely require a new source water approval.

For these reasons, an intake in the Owens island channel is not considered feasible.

An intake north of Owens Island would be constructed as close to the northwest tip of the island as practicable, to minimize pipe installation costs while isolating the intake from the CSOs (EPA 006 and EPA 007) that enter the Owens Island channel. It is assumed that the two 36-inch raw water intakes cannot be built from this point to the existing raw water pump station (hydraulics, prohibitive cost of building these pipes through downtown Paducah), so a new raw water pump station would be constructed, possibly in the vicinity of Marine Way and Oscar Cross Avenue. Because of potential mussel colonies in the Owens Island Channel, it is assumed that the piping from the screen intakes to the new pump station would be built by directional drilling under the riverbed.

This construction effort would require the following facilities:

1. Wedgewire-type screens and piping construction at the new intake by building a cofferdam to build the structure in a dry environment
2. Approximately 1,700 feet of dual 36-inch diameter intake pipe, built by directional drilling under the river and Owens Island
3. New pump station, with wetwell extending approximately 60 feet deep
4. Approximately 7,500 feet of 30-inch raw water force main, built through downtown Paducah and connecting to the existing 30-inch pipe at 6th Street and Burnett.

The screening-level cost range of this construction would be between $26 million and $42 million. In addition, this new water source would likely have to go through the KDEP/EPA new water source approval process, which would add significant time and cost to the process.

Sewer separation of CSOs upstream of the drinking water intake

As discussed in the evaluation of alternatives for each CSO location, sewer separation requirements for EPA 004, EPA 006, and EPA 007 have been reviewed. Separation for the EPA 004 contributing area was estimated to cost approximately $37.5 million dollars, and separation for the EPA 006/007 combined contributing area was estimated to cost approximately $30 million dollars (this is a total project cost). In addition to the cost and constructability challenges with separating such a significant portion of the JSA system, sewer separation would eliminate treatment of the "first flush" of stormwater that is currently being captured in the combined sewer system.

Capture and routing of CSOs for discharge downstream of the drinking water intake

Capture and routing of EPA 004, EPA 006, and EPA 007 to a location downstream of the drinking water intake would not eliminate the need to provide the equivalent of primary clarification and disinfection, as required. As such, this alternative to further protect the drinking water intake would approach the "Pumping to a consolidated wet weather treatment facility" alternatives described for EPA 004 and EPA 006 / EPA 007, which are estimated to cost $13 million and $21 million, respectively. However, to fully relocate the CSO discharges to a location downstream of the drinking water intake, the pumping and treatment facilities would need to be larger than those presented, increasing costs further.

Conclusions

Given the data provided above, the following conclusions can be drawn:

1. Paducah Water has not, to date, experienced raw water quality concerns such that additional studies were conducted to determine if there is a historical correlation between an increase in CSO flows and a degradation of raw or treated water quality.
2. The flow component attributed to JSA's CSOs represents only a small fraction (0.02 percent or less) of flow in the Tennessee / Ohio River system, and this fraction will decrease with implementation of the LTCP goal of treating / capturing of 85 percent.
3. The large capital cost associated with construction of a new raw water intake is not justified, based on the lack of evidence that CSO flow has a negative impact on finished drinking water quality. Additionally, if the drinking water intake was relocated, JSA would still be required to make improvements to the CSOs to meet the CSO Control Policy.
4. The large capital cost associated with sewer separation is not justified, based on the lack of evidence that CSO flow has a negative impact on finished drinking water quality.
5. The large capital cost associated with relocating the CSO discharges to a location downstream of the drinking water intake is not justified, based on the lack of evidence that CSO flow has a negative impact on finished drinking water quality.
6. JSA remains committed to providing CSO control at all three Tennessee / Ohio River CSOs, and increased levels of control at EPA 004, which is the CSO location in closest proximity to the drinking water intake.

Paducah LTCP

Figure B-1 - Existing Drinking Water Intake and Relocation Alternatives

Appendix C

Protection of Threatened / Endangered Mussels

Introduction

In response to the Paducah-McCracken Joint Sewer Agency (JSA) Long Term Control Plan and proposed combined sewer overflow (CSO) control projects, the Kentucky Department for Environmental Protection (KDEP) and the U.S. Environmental Protection Agency (EPA) requested additional information on the endangered mussels in the Ohio River, in particular what contaminants they are sensitive to, how CSO discharges may affect them, and how the recommended improvements will protect them (letter from EPA and KDEP dated January 30, 2015). This technical report serves as a response to these comments, and discusses the community composition of mussels in the Ohio River within the CSO discharge area, general impacts of CSOs on water quality and freshwater mussels, and potential project effects on the nearby mussel community.

Agency Coordination and Presence of Freshwater Mussels in CSO Discharge Areas

The U.S. Fish and Wildlife Service (USFWS) lists a total of 26 freshwater mussels as federally threatened or endangered for the state of Kentucky. Of these 26 federally-listed species, six were identified by the Kentucky State Nature Preserves Commission (KSNPC) as potentially occurring in McCracken County, where the City of Paducah is located (Table 1). An additional four freshwater mussel species potentially occurring in McCracken County were designated by KSNPC as threatened or endangered (Table 1).

Table 1. Freshwater mussels listed as threatened or endangered or designated as species of concern for McCracken County, KY (Kentucky State Nature Preserves Commission, August 2014)

Scientific Name	Common Name	Listing/Designation
Lampsilis abrupta	Pink Mucket	E/LE
Lampsilis ovata	Pocketbook	E
Obovaria retusa	Ring Pink	E/LE
Plethobasus cooperianus	Orangefoot Pimpleback	E/LE
Plethobasus cyphyus	Sheepnose	E/LE
Pleurobema rubrum	Pyramid Pigtoe	E/SOMC
Potamilus capax	Fat Pocketbook	E/LE
Potamilus purpuratus	Bleufer	E
Quadrula cylindrica	Rabbitsfoot	T/LT
Toxolasma lividus	Purple Liliput	E/SOMC

Kentucky State Nature Preserves Commission Status: N = None; E = Endangered; T = Threatened
U.S. Fish and Wildlife Service Status: Blank = None; LT = Threatened; LE = Endangered; SOMC = Species of Management Concern

As part of the development of the initial Long Term Control Plan submitted in 2010, the USFWS Kentucky Environmental Field Services Office was contacted to determine if waters in the CSO-impacted areas could be considered critical habitat for threatened or endangered species. After review of the USFWS database, no records of threatened or endangered species were found in Perkins Creek, Island Creek, or tributaries associated with outfalls. However, in the Ohio River in the vicinity of the confluences with Island Creek and Perkins Creek, the USFWS has records of four endangered species of mussels: Plethobasus cooperianus (orangefoot pimpleback), Potamilus capax (fat pocketbook), Lampsilis abrupta (pink mucket), and Obovaria retusa (ring pink). No designated critical habitat is located within the CSO-impact area.

In addition to the four federally-listed species above, Plethobasus cyphyus (sheepnose) was identified by USFWS in their June 6, 2012, Biological Opinion (BO) for the nearby Paducah Riverfront Redevelopment Project as an endangered species likely to be present and affected by activities in the area. As noted in Table 2, only the fat pocketbook was actually collected during 2008-2012 Ohio River mussel surveys; however, USFWS determined that based on nearby populations, optimal habitat conditions, and the diverse mussel assemblage in the area that the other four species were likely to be present (USFWS 2012). Therefore, life history requirements, preferred habitat conditions, and existential threats are discussed in detail for these five listed species to determine contaminant sensitivities and the likelihood that CSO discharges may affect them.

The portion of the Ohio River into which Paducah-McCracken Joint Sewer Agency (JSA) CSOs discharge has also been designated an outstanding state resource water (OSRW) due to the presence of endangered mussel species and a diverse mussel community. As shown in Figure C-1, the recent Paducah Riverfront Redevelopment Project ("Riverfront Park Improvements") is located between the four CSO outfalls on the Ohio River, with two outfalls (EPA 006 and EPA 007) located upstream of the Improvements and two outfalls located downstream (EPA 003 and EPA 004). Therefore, mussel surveys and mussel relocation activities conducted from 2008 to 2012 in support of the Improvements provide recent field data on the freshwater mussel assemblage present in waters potentially impacted by CSO discharges. A total of 32 live freshwater mussel species (30 native + 2 exotic) out of an estimated 4,000 individuals were observed and are listed in Table 2 (O'Neil 2012). The five target listed species tend to be more intolerant of disturbance than common species; therefore, it is assumed that an evaluation of potential CSO-related impacts on the five target listed species will also account for effects on more common species.

Table 2. Live freshwater mussel species collected from the Paducah riverfront project area in 2008-2012 and likely to be found in the Paducah CSO project area.

Scientific Name	Common Name
Amblema plicata	Threeridge
Arcidens confragosus	Rock Pocketbook
Corbicula fluminea*	Asian Clam
Cyclonaias tuberculata	Purple Wartyback
Dreissena polymorpha*	Zebra Mussel
Ellipsaria lineolata	Butterfly
Elliptio crassidens	Elephant Ear
Fusconaia ebena	Ebonyshell
Fusconaia flava	Wabash Pigtoe
Lampsilis cardium	Plain Pocketbook
Lampsilis teres	Yellow Sandshell
Lasmigona complanata	White Heelsplitter
Leptodea fragilis	Fragile Papershell
Ligumia recta	Black Sandshell

Megalonaias nervosa	Washboard
Obliquaria reflexa	Threehorn Wartyback
Obovaria olivaria	Hickorynut
Plectomerus dombeyanus	Bankclimber
Pleurobema cordatum	Ohio Pigtoe
Pleurobema sintoxia	Round Pigtoe
Potamilus alatus	Pink Heelsplitter
Potamilus capax#	Fat Pocketbook
Potamilus ohiensis	Pink Papershell
Pyganodon grandis	Giant Floater
Quadrula apiculata	Southern Mapleleaf
Quadrula metanerva	Monkeyface
Quadrula nodulata	Wartyback
Quadrula pustulosa	Pimpleback
Quadrula quadrula	Mapleleaf
Truncilla donaciformis	Fawnsfoot
Truncilla truncata	Deertoe
Utterbackia imbecillis	Paper Pondshell

*Exotic species #Federally-endangered species

Listed Freshwater Mussels in CSO Discharge Areas – Populations and Life History Characteristics

Freshwater mussels are benthic species that occur on the surface of or are partially embedded within the substrate of aquatic systems, primarily large streams and rivers. They are filter-feeders and siphon food items that drift in the water column including algae, zooplankton, diatoms, and detritus. Reproduction is similar amongst native species with males releasing sperm into the water column and females taking it up during normal siphoning activity. After fertilization, females brood larvae (glochidia) and eventually expel them into the water column to attach to host fish. Glochidia attach to the gills or fins of the host and encyst and metamorphose into juvenile mussels that drop off and settle to the river bottom. Freshwater mussels are generally long-lived and have been known to reach 20-50 years of age. Because of these life history characteristics, freshwater mussels are particularly sensitive to contamination of the water column and substrate.

Fat Pocketbook (USFWS 2012)

The fat pocketbook is confirmed to be present in the CSO-impact area, and since 1970, it has been collected in the lower Ohio River, including at the confluence of the Wabash River and from the J.T. Myers Lock and Dam Pool at the mouth of the Wabash River (River Mile [RM] 784) downstream to the mouth of the Ohio River (RM 981). Records obtained in the last 10-15 years from commercial fisherman working near Paducah, Kentucky and Metropolis, Illinois confirm the presence of the species in nearby areas of the Ohio River. Many of the records are of young individuals, so it is apparent the species has been successfully able to recruit in recent years.

The fat pocketbook is a large-river species that prefers sand and mud substrates, although individuals have been found in fine gravel and hard clay, at water depths of a few inches to eight or more feet. Unlike many other listed mussels, it is known to survive in man-made ditches, bayous, and sloughs and depositional backwaters. The life cycle is similar to other native freshwater mussels with females becoming gravid in the fall, retaining glochidia over winter, and releasing progeny during spring and summer. Rarity may be associated with host specificity as fat pocketbook glochidia have been known to only metamorphose on freshwater drum.

Pink Mucket (USFWS 2012)

Despite its wide range in historical times, it has apparently always been an uncommon species. Presently, known populations occur in the Ohio River, but they are extremely small and only a few have shown recent evidence of recruitment. Low recruitment rates or the tendency to inhabit larger streams in deeper water may account for apparent rareness. However, its inhabited range is a fraction of what it was historically due to habitat degradation. Populations are very small and isolated, which makes the species highly susceptible to localized extirpations.

The pink mucket inhabits large rivers with swift currents at depths of 1.6-26.2 feet in mixed sand/gravel/cobble substrate. However, it appears to have adapted to reservoir-type conditions in the upper reaches of some impoundments, and often inhabits regulated rivers, particularly those navigational waters modified by locks and dams. Although not tolerant of typical reservoir conditions (slackwater, low oxygen, silt deposition), it is found in tailwaters having good riverine-quality habitat (rocky substrate, adequate flow, and absence of fine sediment deposits). The life cycle is similar to other native freshwater mussels with females brooding glochidia from August through June. Identified host fishes include large piscivorous species such as walleye, sauger, white crappie, and largemouth, smallmouth, and spotted basses.

Orangefoot Pimpleback (USFWS 2012)

Orangefoot pimpleback populations have been recorded in the Ohio River within 2-3 miles of the CSO-impact area. Historically, it was recorded in the Ohio River from western Pennsylvania to southern Indiana and in the Tennessee and Cumberland River drainages. The largest known populations remain in the lower, free-flowing reach of the Ohio River downriver from the confluence of the Tennessee River at Paducah, Kentucky. Several have been recently recovered by commercial mussel harvesters in the vicinity of the lower Ohio River near Lock and Dam 52, and in dam tailwaters on the Tennessee River. This is an extremely rare mussel with populations usually consisting of one or two individuals within a restricted distribution.

The orangefoot pimpleback inhabits medium to large rivers with sand and gravel substrates. The reproductive cycle is similar to that of other native freshwater mussels. It is a short-term brooder with spawning occurring in the spring and release of glochidia during summer months. Specific fish hosts for this species are unknown; however, the sauger is reported to be a potential host species.

Ring Pink (USFWS 1997)

Once found in the Ohio River and its large tributaries from West Virginia to Illinois and Kentucky, the ring pink is known today from only two stretches of the Tennessee River and one stretch each of the Cumberland and Green rivers. Only 5 isolated, non-reproducing populations of this mussel are known to exist and their advanced age further reduces the chances of successful reproduction. In the 2006 Five-Year Review for the species, USFWS states that no viable populations of the species persist within its historic range and the mussel may be functionally extinct in the wild.

This endangered mussel is found in shallow water over silt-free sand and gravel bottoms of large rivers in the Ohio River basin. As this species is rare, little is known of its life history, but it is likely to exhibit life history characteristics similar to other native freshwater mussels. The fish host for this species has not been determined.

Sheepnose (USFWS 2012)

The sheepnose has been recorded in the Ohio River downstream of the CSO-impact area, and occurs in the Tennessee River upstream of the impact area. The species is known from the Mississippi, Ohio, Cumberland, and Tennessee River main stems, and scores of tributary streams range-wide; however, records indicate it was never very common. Historically, it was documented along the entire length of the Ohio River and in 28 tributary streams, but currently only 11 streams are thought to have extant populations. It has experienced a significant reduction in range and most of its populations are disjunct, isolated, and appear to be declining. The extirpation from over 50 streams within its historical range indicates substantial population losses have occurred. However, a population was recently recorded from the main stem Ohio River downstream of Paducah, Kentucky and the CSO-impact area. Populations are small and isolated, which makes the species highly susceptible to localized extirpations.

The sheepnose is primarily a larger stream species, usually occurring in shallow shoal habitats with moderate to swift currents over coarse sand and gravel. Habitats may also have mud, cobble, and boulders, and it may occur in deep runs. The reproductive cycle of the sheepnose is similar to that of other native freshwater mussels. It is a short-term brooder with most reproduction taking place in early summer. Little is known regarding the host fish for the sheepnose but one known host is the sauger. It is possible other fish species may also serve as a suitable host.

Listed Freshwater Mussels – Threats

North America has the highest diversity of freshwater mussels in the world, and the Ohio River Watershed has a very diverse mussel community. Analysis of historical data indicates that the number of freshwater mussel species in the Ohio River has remained essentially unchanged through time (i.e. in the last 1,000 years); however, significant changes in species composition and a reduction in the total numbers of individual mussels have occurred (Taylor 1989). Conversion of the Ohio River from a relatively shallow system with moderate flow and complex morphology and habitat structure to a completely different habitat type began in 1885 with the construction of the first dam. Eventually, a series of dams was constructed to maintain a 9 foot navigation pool. The swiftly flowing, shallow river was transformed into a series of deep pools and slow currents with greater siltation. While the change from a lotic to a lentic environment caused the elimination of approximately 17 species, it created conditions favorable to others. For example, the mapleleaf mussel (Quadrula quadrula), unknown to the most of the Ohio River until the 1920s, is now the most commonly found species (Taylor 1989).

Therefore, for the majority of rare, threatened, and endangered mussels, the primary cause of decline has been habitat alteration for navigation (e.g. maintenance dredging) and flood control activities (e.g. channelization) and the associated effects of these activities (e.g. sedimentation) (Watters 1999). For all five target listed mussel species, USFWS documents impoundments, siltation, and pollution as reasons for listing (O'Neil 2012). Channel dredging physically removes individual mussels and can affect aquatic systems physically (e.g. accelerated erosion and deposition) and biologically (e.g. altered host species composition). Construction of impoundments results in a loss of preferred mussel habitat from inundation, decreased water quality, changes in flow regime, altered temperature regimes, and sedimentation. Siltation can clog the gills of and physically smother mussels. A more comprehensive list of threats to 10.5.

Combined Sewer Overflows (CSOs) – Potential Impacts to Water Quality and Freshwater Mussels

The primary impact of CSOs on freshwater mussels is a decline in water quality related to the discharge of pollutants. CSOs are specifically designed to collect and convey sanitary wastewater (i.e. domestic sewage from homes as well as industrial and commercial wastewater) and storm water through a single pipe. During precipitation events (e.g. rainfall or snowmelt), the systems are designed to overflow when collection system capacity is exceeded, resulting in a combined system that discharges directly to surface waters (U.S. EPA 1995). Because they contain raw sewage along with large volumes of storm water, CSOs may contribute pathogens (bacteria), nutrients, total suspended solids (TSS), floatables (solid debris), and toxic pollutants to receiving waters (U.S. EPA 1994). In several reports, including the 2004 Report to Congress, the EPA has found that CSOs cause or contribute to environmental impacts that affect water quality and the attainment of designated uses (U.S. EPA 2004). Impacts from CSOs are often compounded by impacts from other sources of pollution such as storm water runoff, decentralized wastewater treatment systems, and agricultural practices. This can make it difficult to identify and assign specific cause-and-effect relationships between CSO events and observed water quality impacts and impairments. EPA assumed the causes of reported Section 303(d) stream impairment most likely attributed to or associated with CSOs were: pathogens, organic enrichment resulting in low DO, and sediment and siltation (U.S. EPA 2004).

At the local level, site-specific water quality impacts vary depending on the volume and frequency of CSO discharges; the size, type, and assimilative capacity of the receiving waterbody; degree of mixing and dilution; other sources of pollution; and, designated uses for the waterbody. Because CSO discharges are intermittent and often occur during wet weather, resulting impacts can be transient and difficult to monitor. However, they can also persist to varying degrees. Discharged nutrients can contribute to eutrophication over weeks or months and chronic toxicity associated with metals, pesticides, and synthetic organic compounds can contaminate sediment for years. Processes identified as most important in assessing the impacts of CSOs include:

Dilution and transport of pathogens and toxics in the water column;

Deposition of settleable solids;

Re-suspension or scour of settleable solids; and

Chemical exchange or dilution between the water column and sediment pore water

In general, the larger the waterbody and the smaller the discharge, the less likely it is that environmental impacts will occur. Once pollutants are discharged, fate and transport processes determine the extent and severity of environmental impacts.

Exposure Pathways – Freshwater Mussels (U.S. EPA 2005)

As benthic filter-feeding organisms, freshwater mussels are exposed to metals that are dissolved in water, associated with suspended particles, and deposited in bottom sediments. Depending on the species, glochidia larvae may be exposed to the water for seconds to days before encountering a fish host; therefore, the ecological relevance of direct exposure of glochidia to water contaminants is species-specific. While the glochidia are largely protected by the cyst formed on the host fish, limited evidence suggests that host body burdens of certain toxicants may affect encysted glochidia. Juvenile mussels occupy the interstitial spaces in sediments where they are exposed primarily to contaminants in pore water and associated sediment particles. As they grow, most species occupy the water-sediment interface and draw water mainly from the water column. However, adults may also filter pore water when they burrow below the surface. Adult mussels are suspension feeders that live partially or completely buried in sediments. Mussels filter prodigious volumes of water, capturing particles to 5 microns in size and ingesting algae, zooplankton, bacteria, and detritus. They are therefore intimately exposed to both dissolved and suspended contaminants. Once contaminants enter the bodies of mussels, they are thought to decrease metabolism and respiratory rate, disrupt ionic balance, disrupt enzyme function, disrupt endocrine function, decrease glycogen content (mussel energy reserves), destroy cells, reduce growth rate, and cause death.

Total Suspended Solids (TSS) and Sedimentation (Landis 2013)

Effects of sedimentation on freshwater mussels include loss of habitat diversity, channel instability, loss of sensitive fish hosts, and disruption of feeding and respiration by suspended sediments that clog the gills. In addition, elevated TSS levels have been shown to have significant effects on mussel reproduction, particularly early reproduction (i.e. fertilization and glochidia development). In environments with elevated TSS the number of gravid females drops sharply. This may be explained by the lack of mussel recruitment in many locations. Studies suggest a critical suspended solids threshold where successful reproduction is limited is approximately 20 mg/L.

Nutrients

Wastewater treatment plant effluents and concentrated runoff from agricultural fields are often implicated in the localized decline of freshwater mussels due to high levels of nitrogen in the form of ammonia (NH4) and nitrates (NO3-), which can be toxic to freshwater mussels (Nedeau 2008). A study on short-term mussel exposure found that a mixture of bacteria, nutrients, and chemical compounds in tertiary-treated wastewater effluent induced adverse physiological effects on mussels, including immune responses and induction of detoxification metabolism (Farcy et al 2011). Elevated nutrient levels also degrade water quality through algal blooms that reduce dissolved oxygen.

Metals and Pesticides

Sampling of CSO outfalls in the Highland-Pigeon Watershed, a tributary of the Ohio River in Indiana, and by the District of Columbia Water and Sewer Authority concluded that exceedances of surface water standards were attributed solely to E.coli bacteria and metals (zinc, copper, chromium and lead) (IDEM 2003; U.S. EPA 2004). Mussel communities have been found to be significantly degraded due to releases of heavy metals to sediment and the water column. Dissolved metals such as iron, magnesium, manganese, and zinc tend to accumulate in the gills and mantle (Webb et al 2008). In several studies, mussels seem particularly susceptible to effects of copper, lead, zinc, and cadmium, with high concentrations resulting in increased stress response, reduced growth, and low mussel species richness and abundance (U.S. EPA 2005; Molnar and Fong 2012; Webb et al 2008). For mussels in the Mississippi River near the confluence of the Illinois River, metal (zinc, strontium, manganese, iron, copper, selenium, lead) concentrations were positively correlated with organism age suggesting older individuals had a longer time to accumulate metals or younger individuals existed under lower contamination levels than those previously experienced by older individuals (Roberts et al 2009).

Studies have also shown that organo-chlorine pesticides such as methoxychlor can cause stress effects in freshwater mussels over relatively short exposure periods (Molnar and Fong 2012). Roundup (glyphosate formulation) was found to be acutely toxic to glochidia and juvenile mussels, and exposure to atrazine significantly reduced growth of juvenile mussels during chronic 21-day tests (U.S. EPA 2005).

Bacteria

Potentially, the most significant contribution of CSOs to aquatic systems is bacteria associated with the overflow of untreated wastewater. NOAA reported that the primary basis for shellfish harvest restrictions are from fecal coliform concentrations associated with untreated wastewater from livestock operations and CSOs (U.S. EPA 2004). In the Northern Kentucky Sanitation District No. 1 (SD1) service area, the Ohio River East Tributaries Watershed Characterization Report required for a CSO Long-Term Control Plan (LTCP) was prepared for 22 CSOs; 14 of which discharge directly to the Ohio River mainstem. The Report identified CSOs as the primary source of fecal coliform; however, overland storm runoff and septic systems were also major contributors (SD1 2009).

The effects of high levels of bacteria associated with CSOs, including fecal coliform and Escherichia coli, on freshwater mussels is inconclusive and largely depends on the type of bacteria present. As filter feeders, mussels siphon bacteria from the water column and pore water. Studies have shown that total and fecal coliform counts in water decrease downstream of mussel beds; however, high fecal coliform counts are correlated with a loss of weight and an increase in mussel mortality (Farcy et al 2011). Alternately, experiments with E.coli have found no ill effects of high bacteria levels and results indicate that freshwater mussels can remove up to 95% of E.coli bacteria through direct uptake. Interestingly, only 61% of recoverable E.coli was distributed in mussel tissues or in fecal matter suggesting inactivation by pathways other than digestion. These results support the use of native freshwater mussels in ecosystem restoration and for improvement in water quality via reduction of E.coli (Ismail et al 2015).

Freshwater Mussel Resilience and Coping Mechanisms

Despite documented adverse effects of municipal wastewater, metals, pesticides, some types of bacteria, and other water pollutants on freshwater mussels, they are fairly resistant to short-term, acute exposures. The majority of observed effects occur during rare, catastrophic events (e.g. chemical spills) over the short-term, or prolonged, chronic exposure to low-levels of contaminants over long time periods. Although mostly sedentary, mussels can move short distances, and many species are adapted to the dynamics of stream systems. Resilience is primarily due to freshwater mussels' ability to completely close shells and intake valves for varying periods of time, thus effectively reducing toxicant uptake over short periods (Molnar and Fong 2012). Some studies have shown that downstream of historical ore mining sites, no statistical difference was found in bioaccumulated metals in the tissues of older mussels or in mussels closer to the contamination source, suggesting mussels are able to avoid the intake of some dissolved metals. In addition, mussels, and juveniles in particular, have been shown to tolerate lower dissolved oxygen and elevated sulfate concentrations compared to other freshwater organisms (U.S. EPA 2005). Tolerance of unfavorable conditions is species-specific and depends on filtering rates, food selection, or assimilation/depuration rates which affect contaminant accumulation.

Paducah-McCracken County JSA CSOs and Freshwater Mussels

In 2008, dry and wet weather sampling of the Paducah-McCracken County JSA CSO outfalls on Island and Perkins Creek for nutrients and bacteria recorded that Total Kjehldahl Nitrogen (TKN) and Total Phosphorus (TP) decreased following rain events, suggesting that the CSO outfalls are not a significant source of nutrients. Bacterial samples collected at those CSO outfalls during wet-weather events had concentrations of fecal coliforms similar in order of magnitude to those collected downstream of CSO locations, in-stream during dry weather. This indicates that although CSOs are not flowing, there are still bacterial contributions to receiving waters. Additionally, the primary contact recreation water quality was exceeded more often during dry weather than during wet weather. While dilution may explain the low fecal coliform counts during wet-weather sampling, there are obviously background water quality issues that contribute as indicated by the dry-weather bacteria results both upstream and downstream of CSO locations. Results for other parameters, such as pH and dissolved oxygen, do not indicate impacts to the receiving waters from wet weather CSO discharges.

Conclusions

There is no known harvesting and human consumption of mussels from this area, thus the only impacts of potential concern are to the health of the mussel populations themselves. The mere presence of an extremely diverse freshwater mussel community, including one endangered species and possibly several others, within the CSO discharge area indicates that the Paducah-McCracken JSA CSOs have not historically discharged contaminants at levels that threaten mussel populations even without the CSO controls being proposed. The implementation of CSO controls will further reduce the likelihood of adverse impacts to the nearby Ohio River mussel community by reducing the frequency of events, reducing untreated volume of discharge during high-flow events, and providing additional treatment of the discharge through enhanced screening to remove floatables and solids, disinfection, and TSS reduction.

Even the complete elimination of secondary causes of freshwater decline, including pollution from CSOs, is unlikely to reverse the significant impacts that 150 years of modern dredging, damming, and channelization has had on aquatic habitat in the Ohio River. According to the EPA, controlling CSOs will improve some aspects of stream quality; however, overall stream quality will continue to decrease due to other sources (U.S. EPA 2004). While CSOs have the potential to reduce water quality, effects largely involve short-term pulses of contaminants that are quickly transported downstream. In recent decades, regulations and control of point source discharges like CSOs have sufficiently improved water quality and have allowed mussels to recolonize some streams and rivers. Given that diverse and populous mussel beds already occur in the historic CSO discharge area and the ability of mussels to close shells and intake valves during periods of poor water quality, the updated Paducah-McCracken County JSA CSO system should not have a significant adverse effect on mussel populations in the vicinity. The proposed CSO controls should benefit nearby mussel populations by improving water quality and lessening the frequency and volume of overflows.

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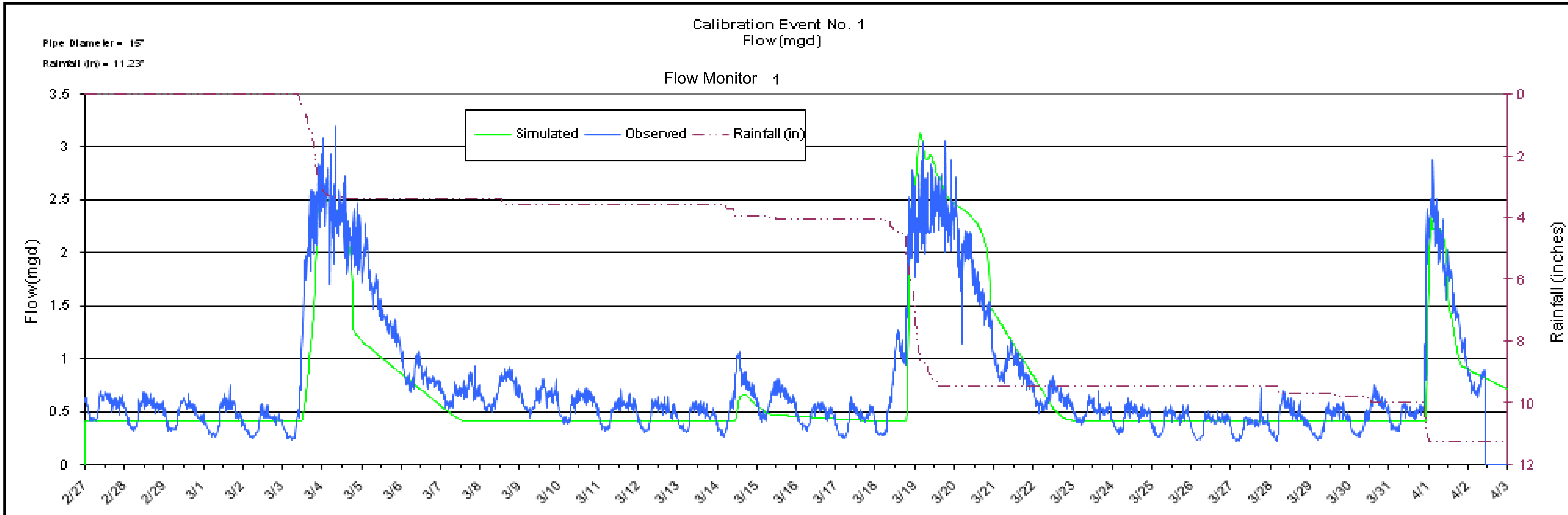
Paducah LTCP

Figure C-1 - Location of Riverfront Park Redevelopment Project

Appendix D

Hydraulic Model Calibration Graphs


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 15"
Rainfall (in) = 11.23"
Flow Monitor 1
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
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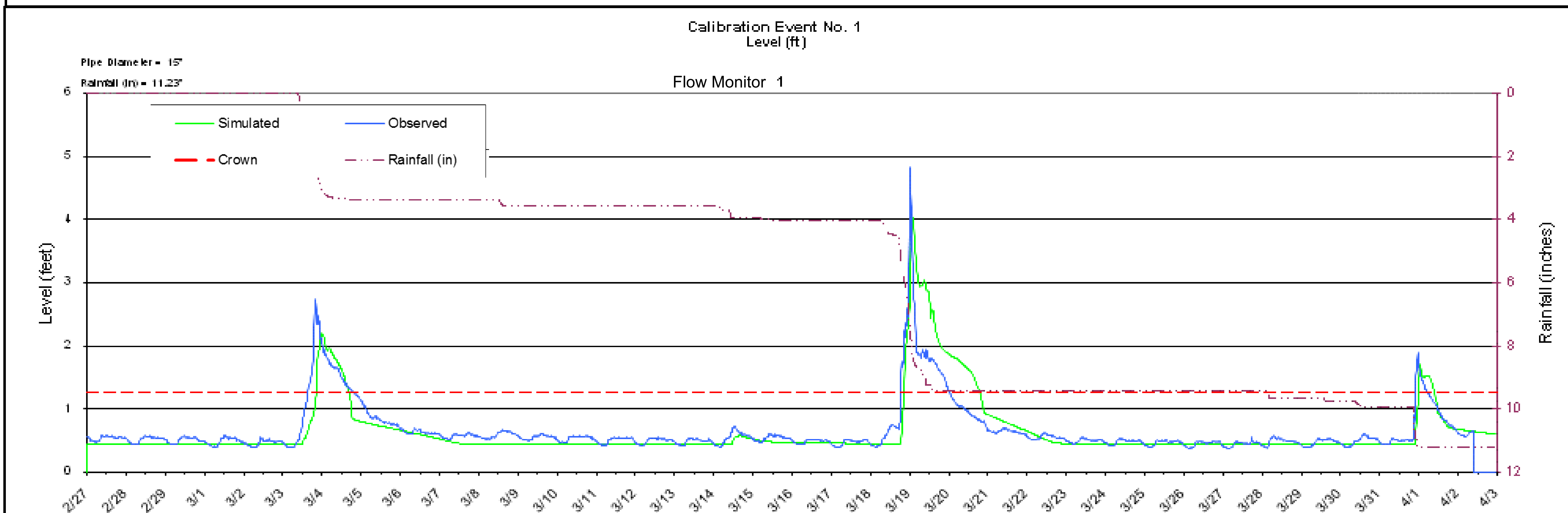
3/31
4/1
4/2
4/3


Calibration Event No. 1
Level (ft)
Pipe Diameter = 15"
Rainfall (in) = 11.23"
Flow Monitor 1
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
6
5
4
3
2
1
0
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
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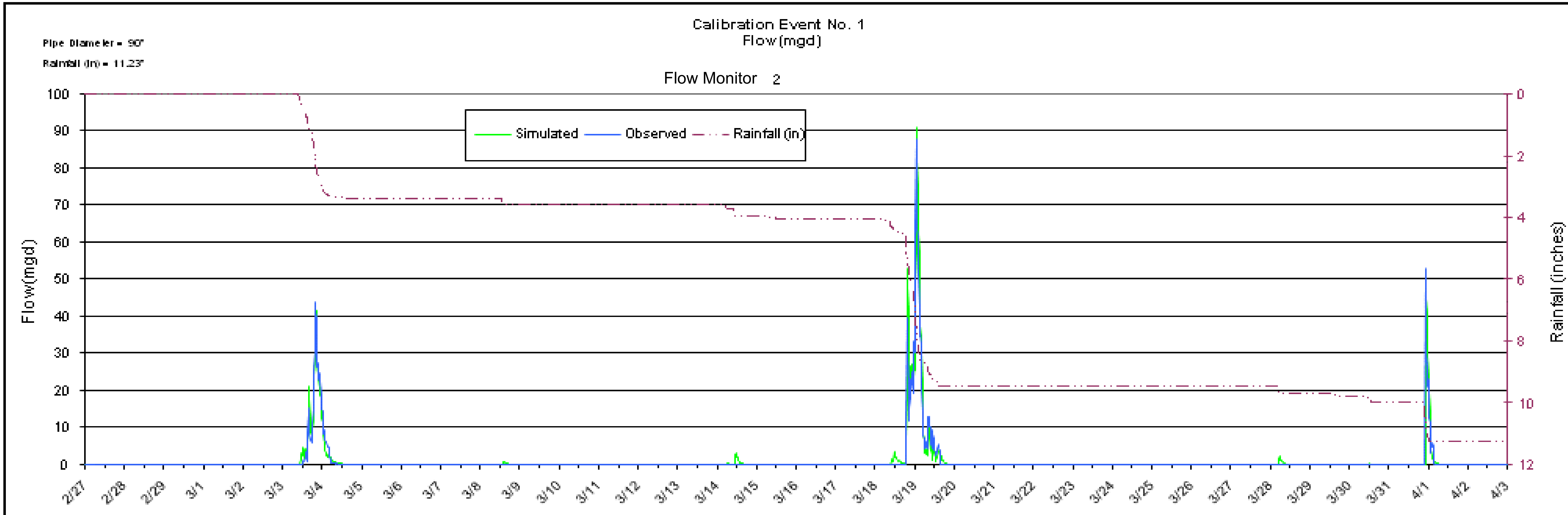
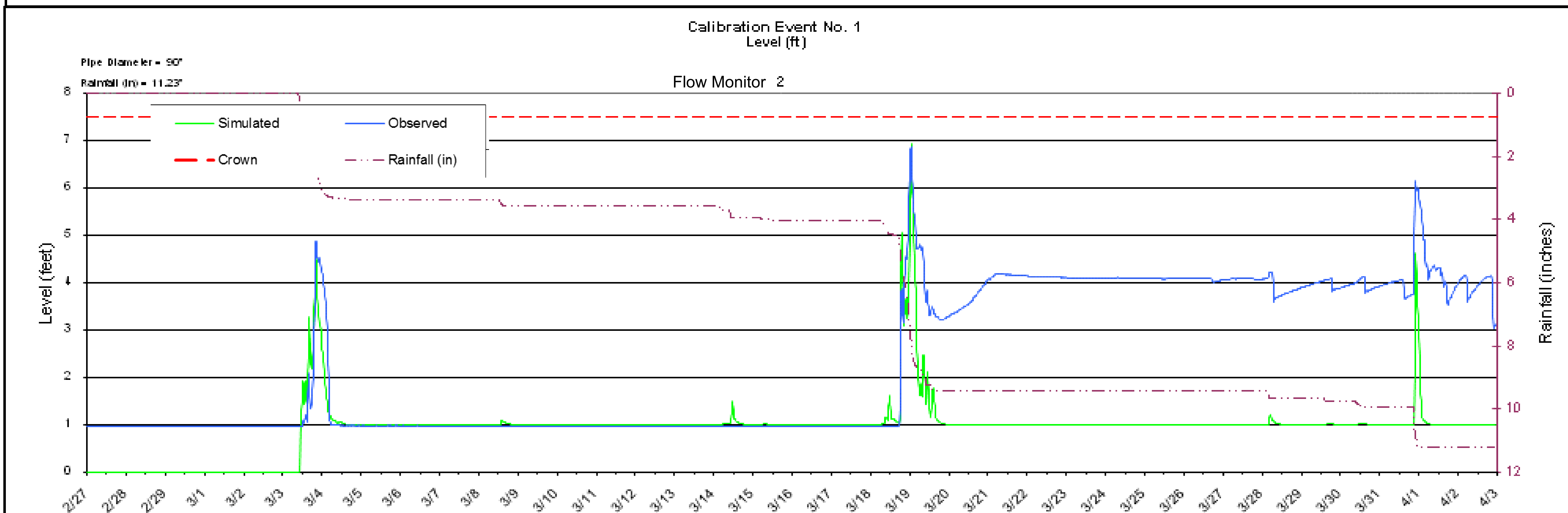
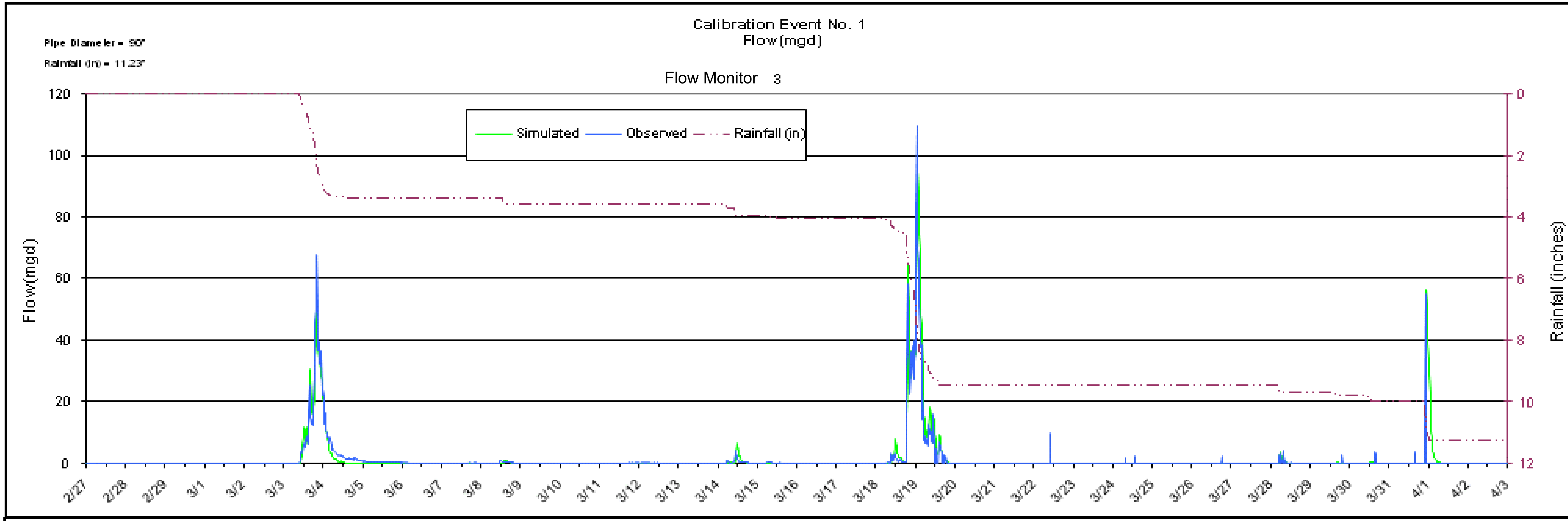
3/28
3/29
3/30
3/31
4/1
4/2
4/3

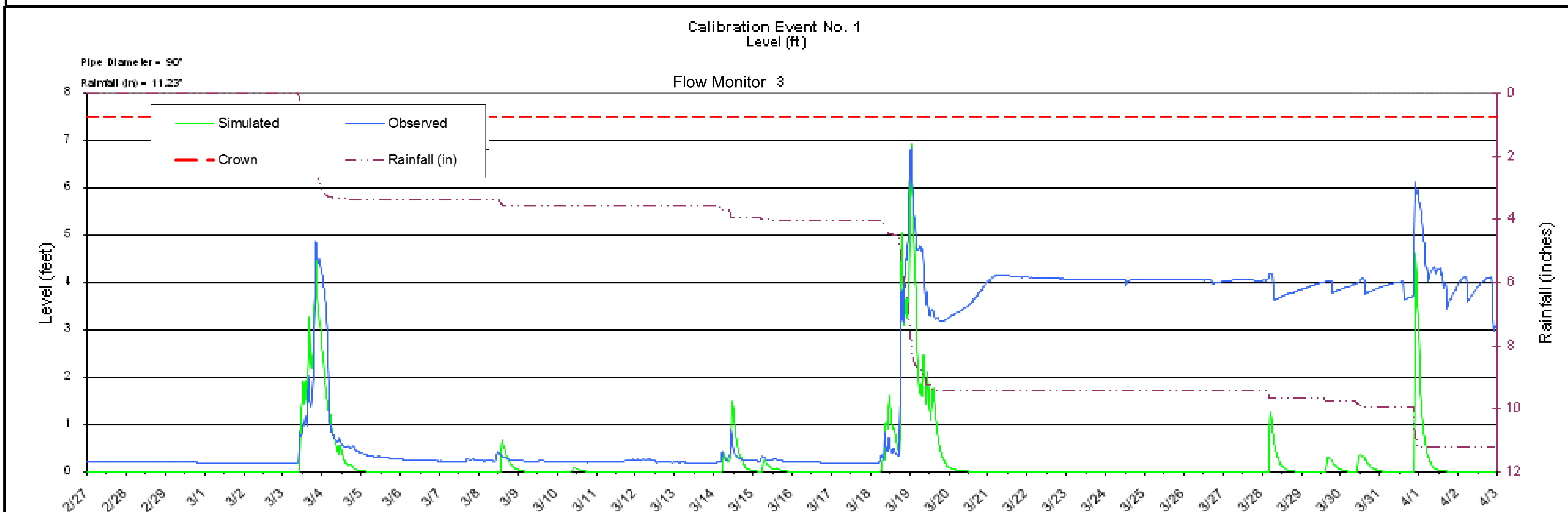


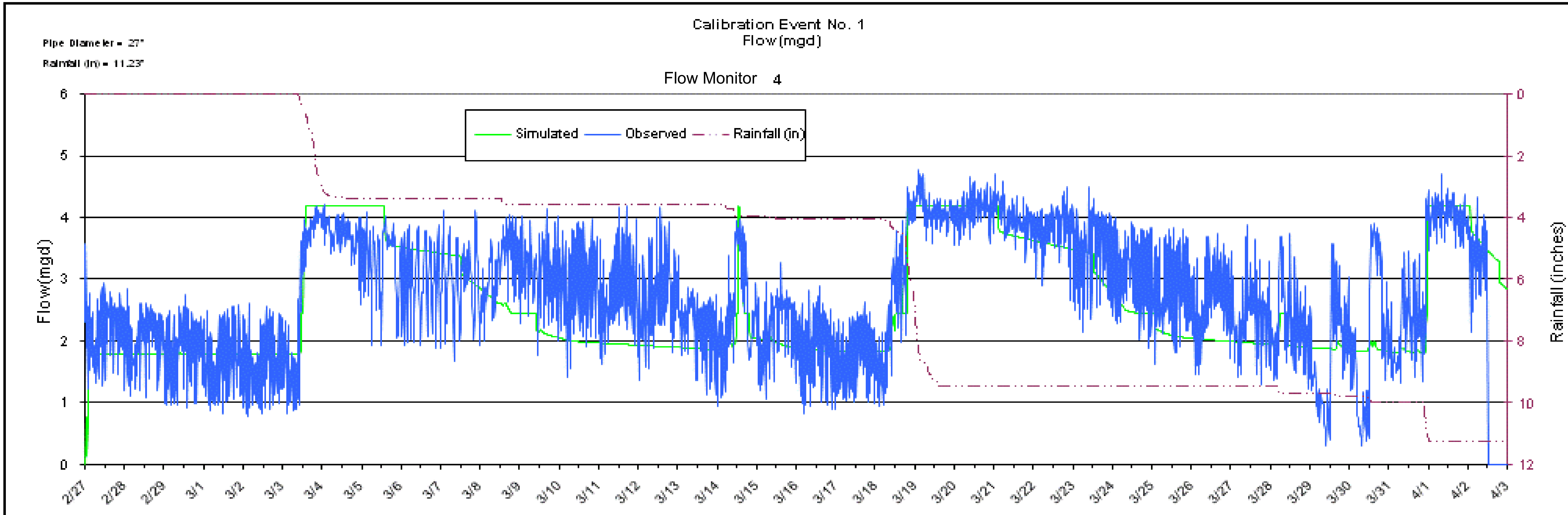
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 90"
Rainfall (in) = 11.23"
Flow Monitor 2
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)

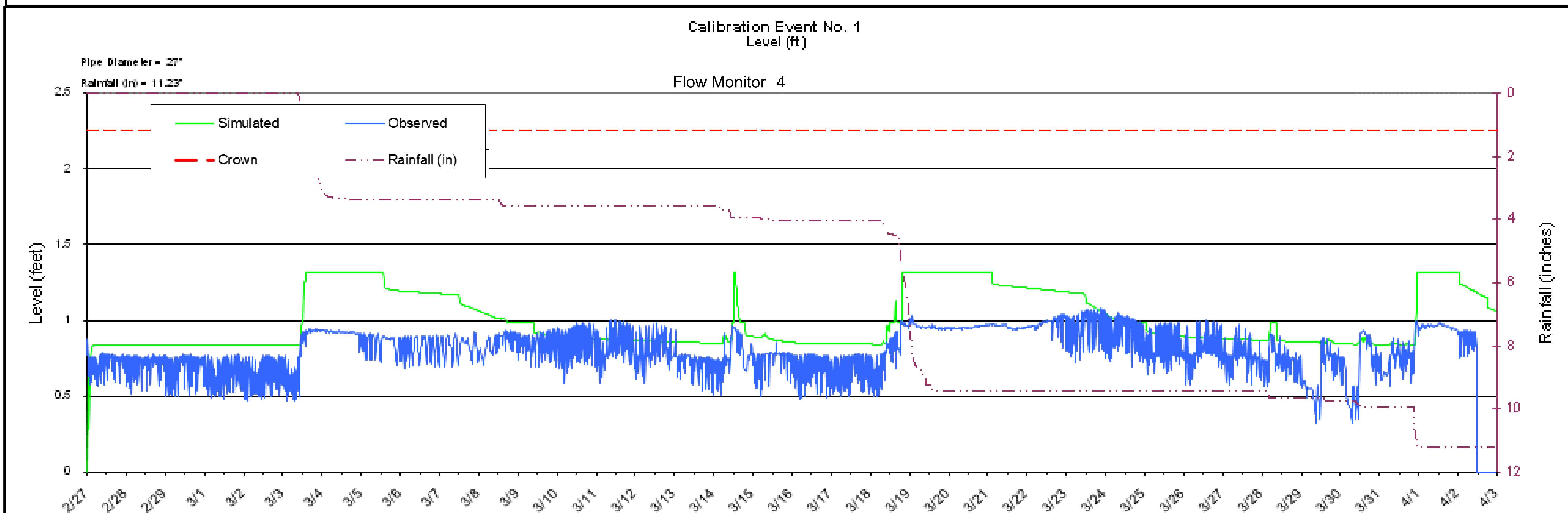


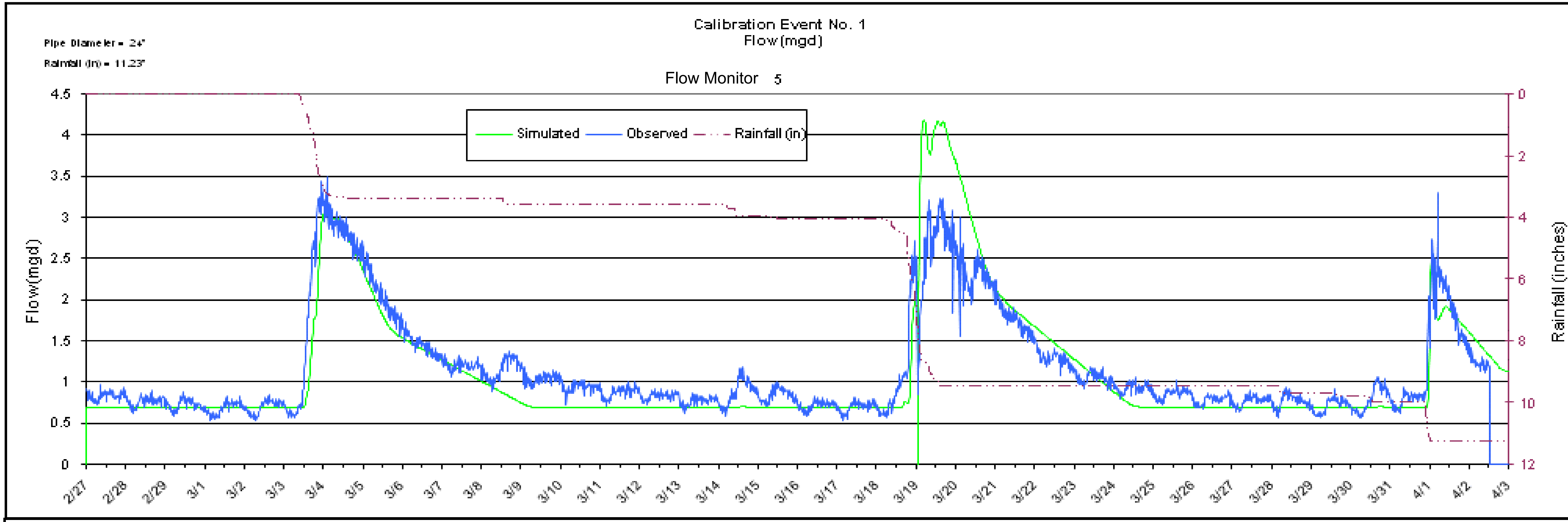
Calibration Event No. 1
Level (ft)
Pipe Diameter = 90"
Rainfall (in) = 11.23"
Flow Monitor 2
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 90"
Rainfall (in) = 11.23"
Flow Monitor 3
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
120
100
80
60
40
20
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

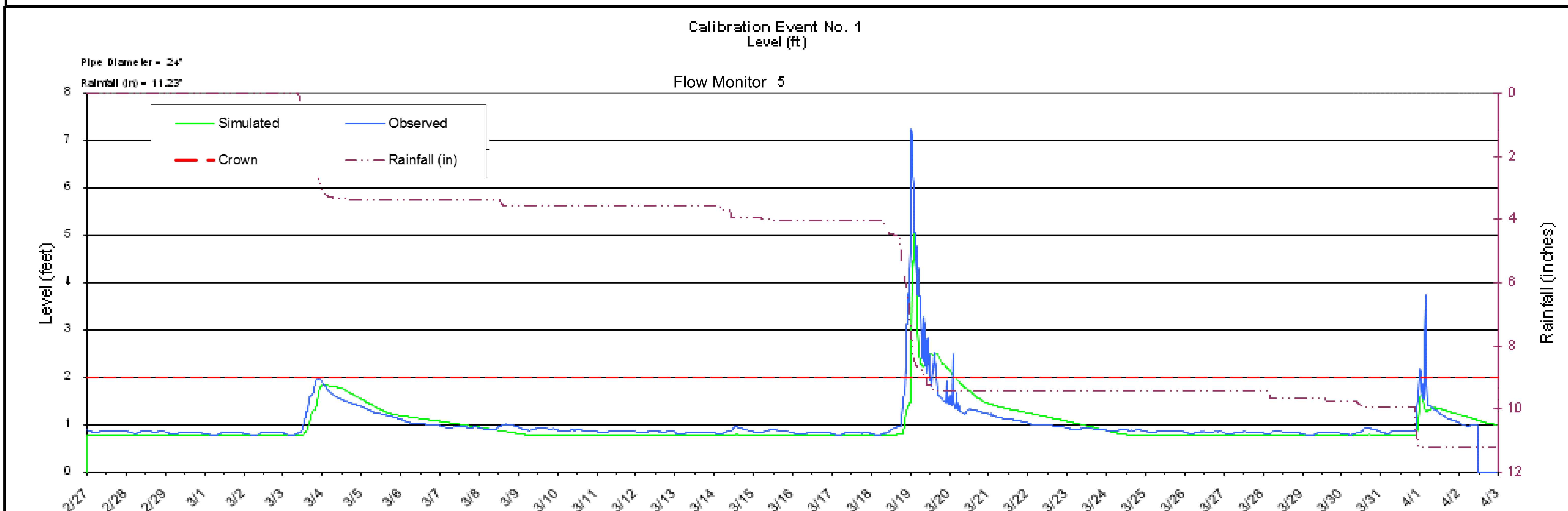

Calibration Event No. 1
Level (ft)
Pipe Diameter = 90"
Rainfall (in) = 11.23"
Flow Monitor 3
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 27"
Rainfall (in) = 11.23"
Flow Monitor 4
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

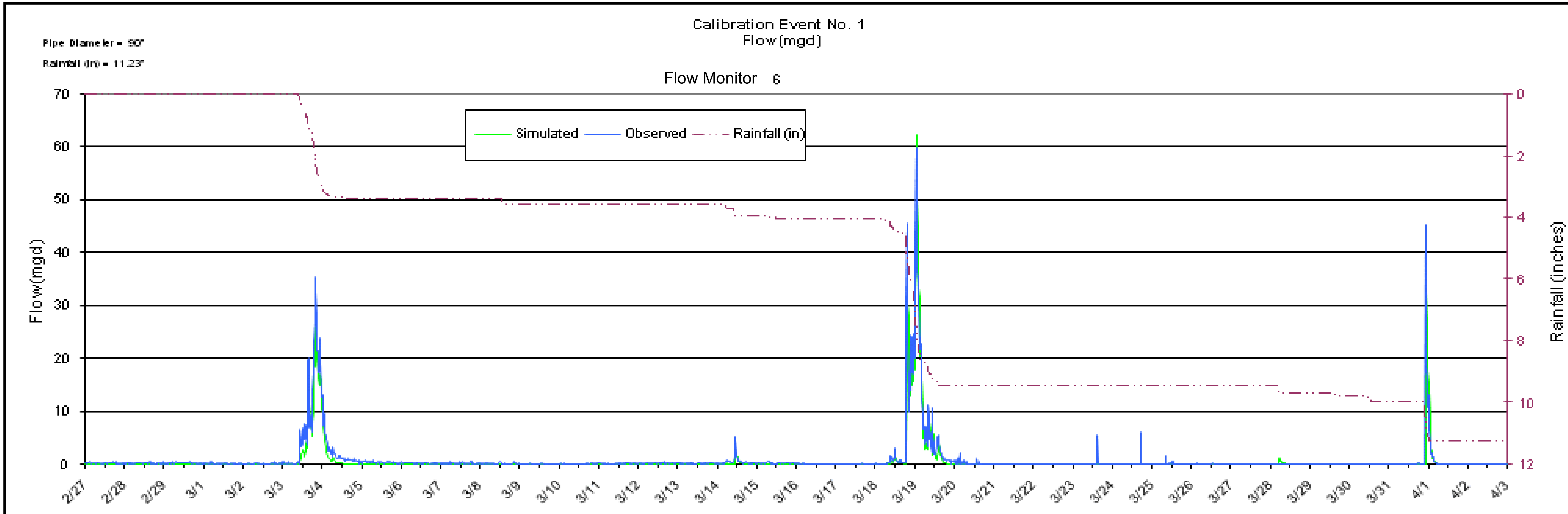

Calibration Event No. 1
Level (ft)
Pipe Diameter = 27"
Rainfall (in) = 11.23"
Flow Monitor 4
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3



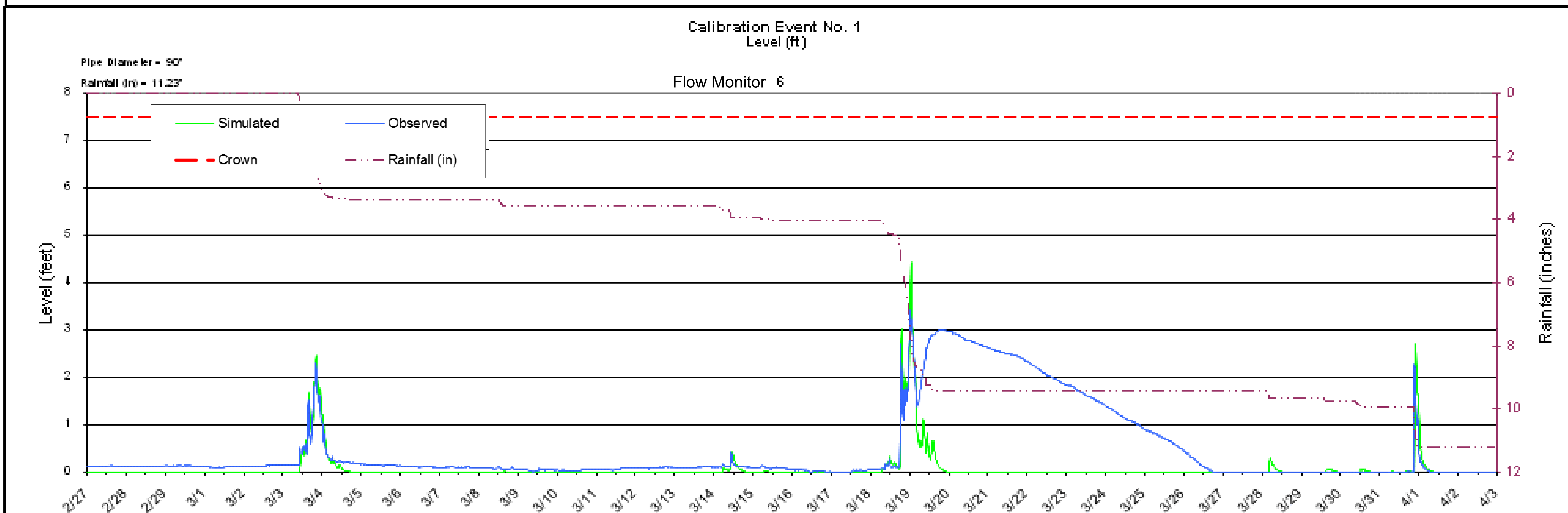
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 24"
Rainfall (in) = 11.23"
Flow Monitor 5
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3



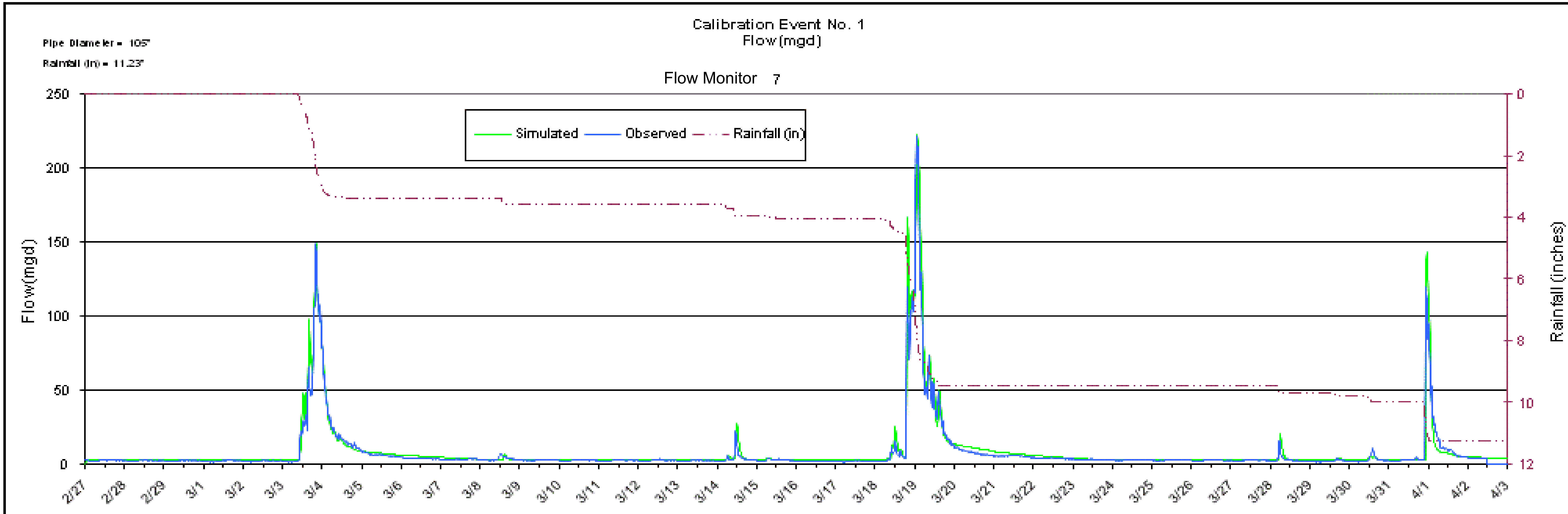
Calibration Event No. 1
Level (ft)
Pipe Diameter = 24"
Rainfall (in) = 11.23"
Flow Monitor 5
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
0
1
2
3
4
5
6
7
8
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3



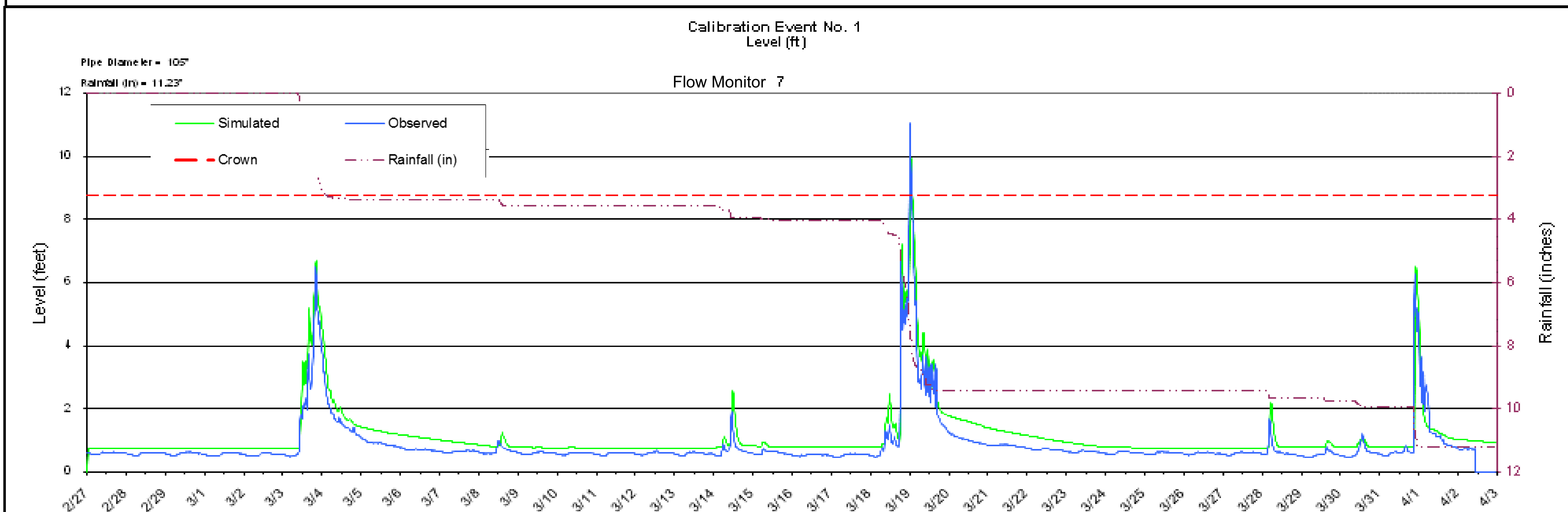
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 90"
Rainfall (in) = 11.23"
Flow Monitor 6
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)



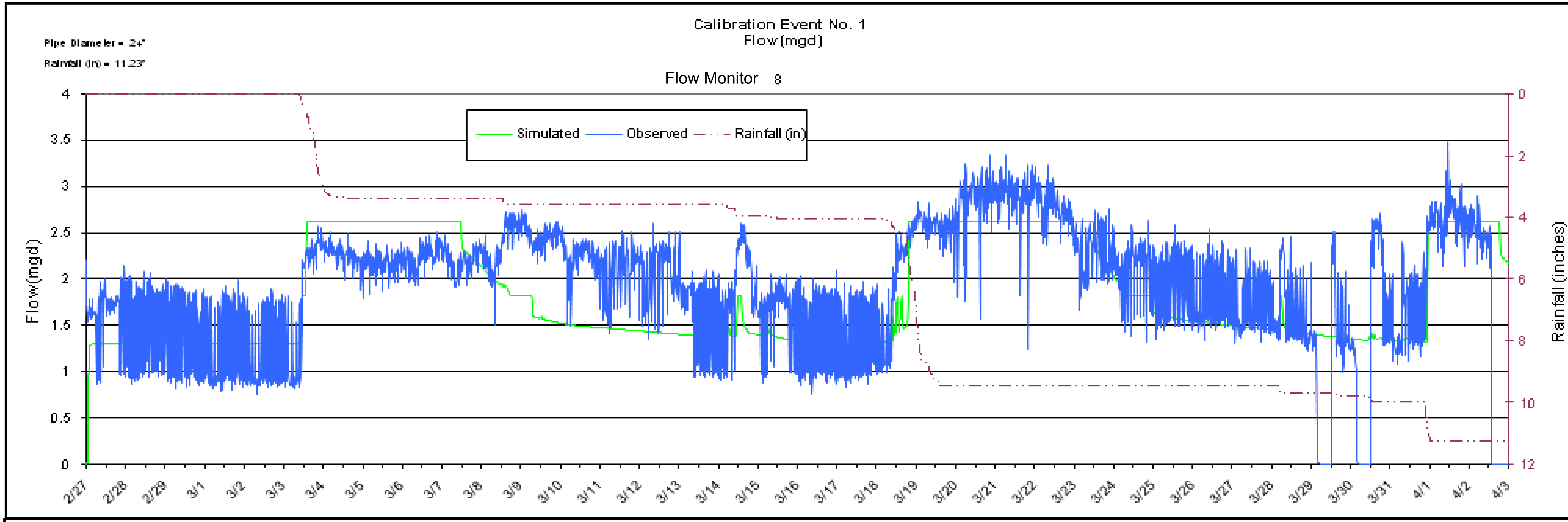
Calibration Event No. 1
Level (ft)
Pipe Diameter = 90"
Rainfall (in) = 11.23"
Flow Monitor 6
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)

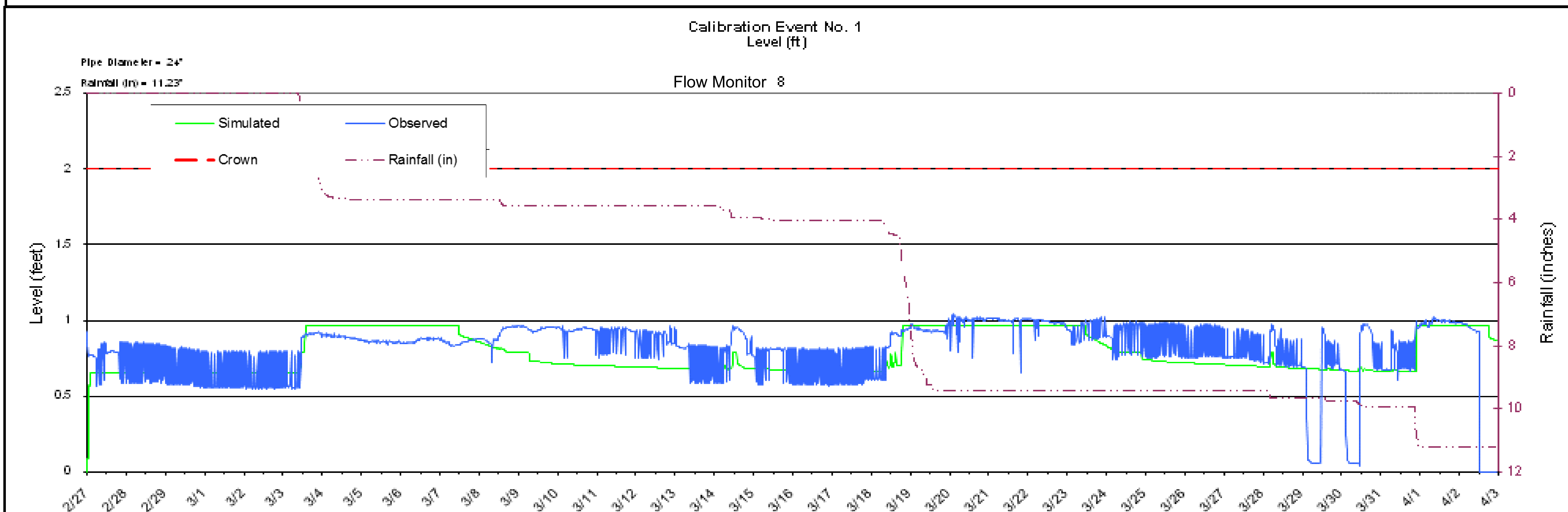


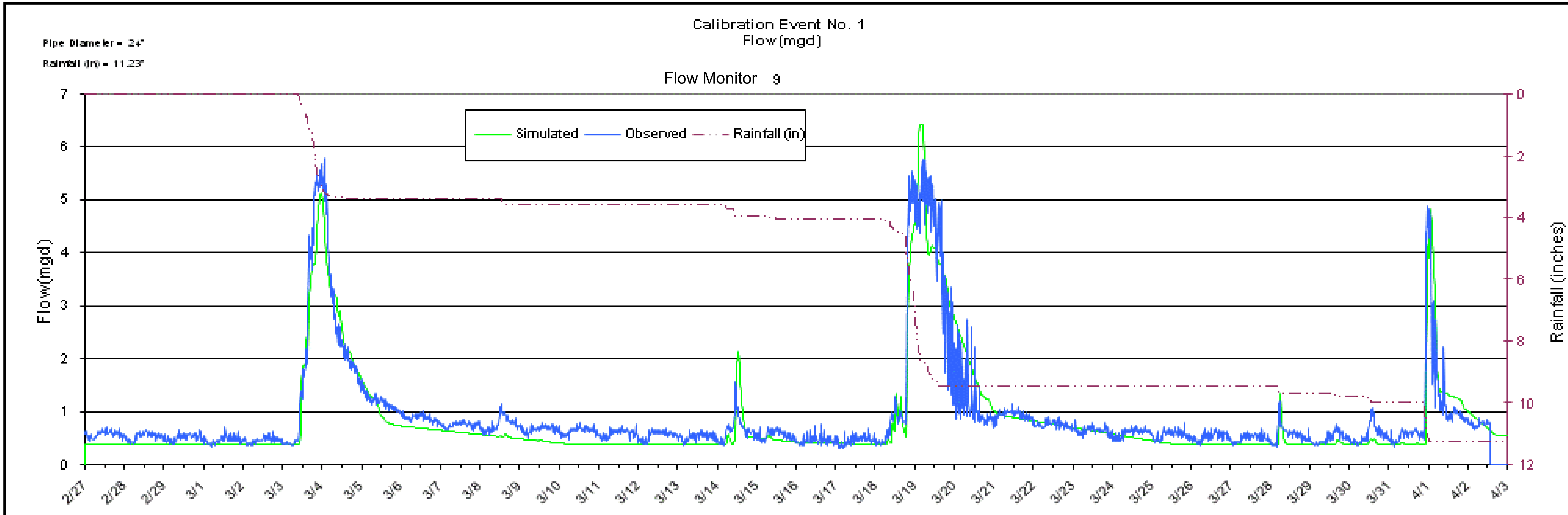
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 105"
Rainfall (in) = 11.23"
Flow Monitor 7
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
250
200
150
100
50
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3



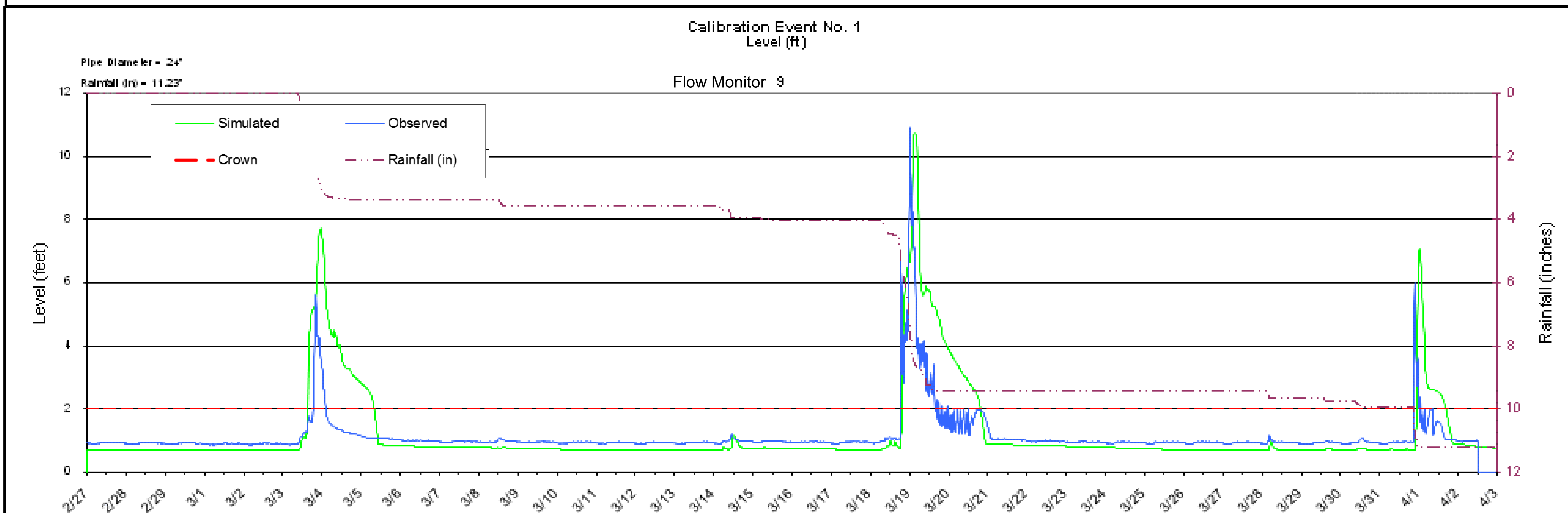
Calibration Event No. 1
Level (ft)
Pipe Diameter = 105"
Rainfall (in) = 11.23"
Flow Monitor 7
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
12
10
8
6
4
2
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 24"
Rainfall (in) = 11.23"
Flow Monitor 8
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

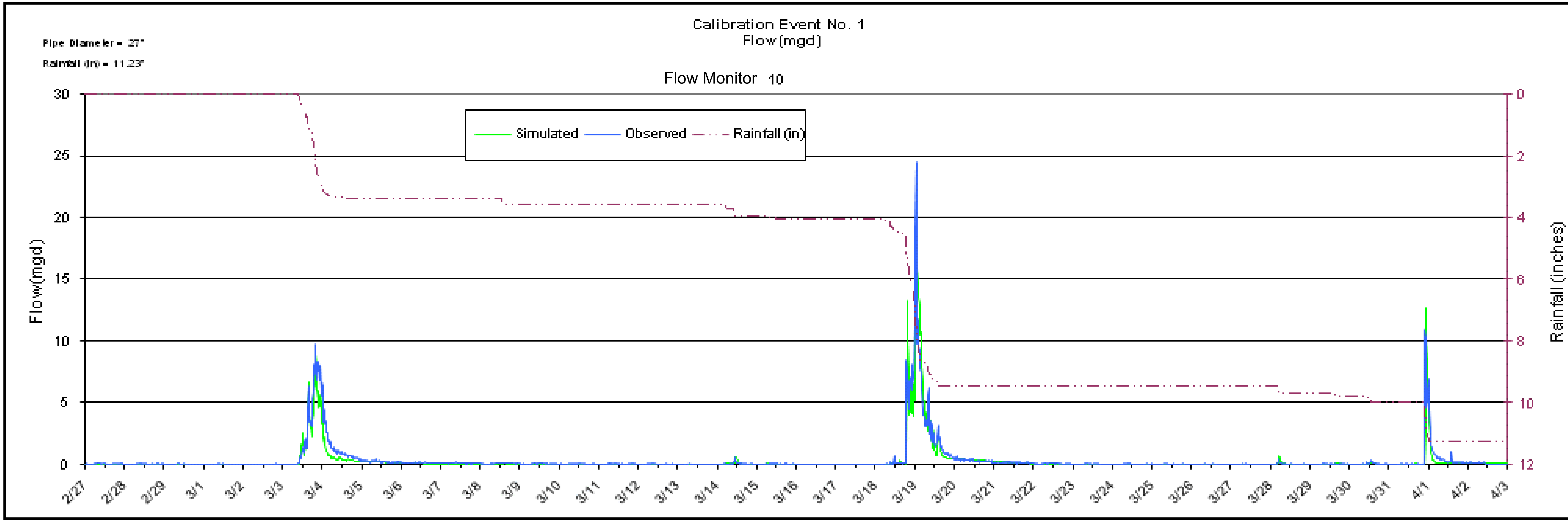

Calibration Event No. 1
Level (ft)
Pipe Diameter = 24"
Rainfall (in) = 11.23"
Flow Monitor 8
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
0
0.5
1
1.5
2
2.5
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

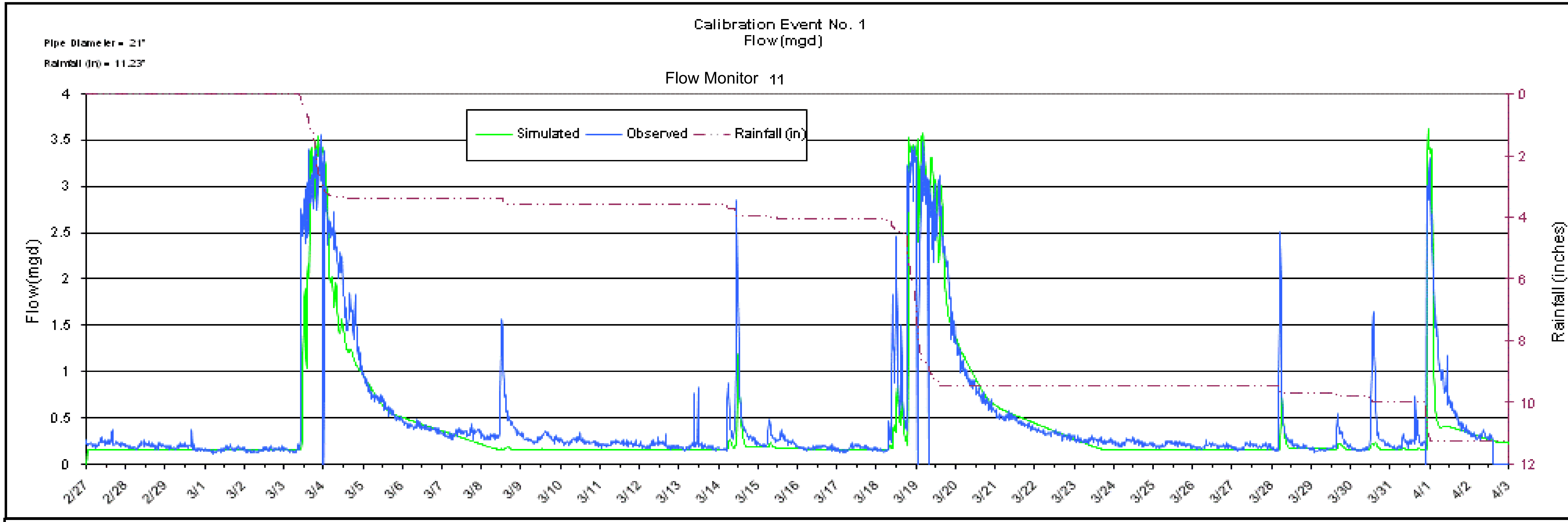


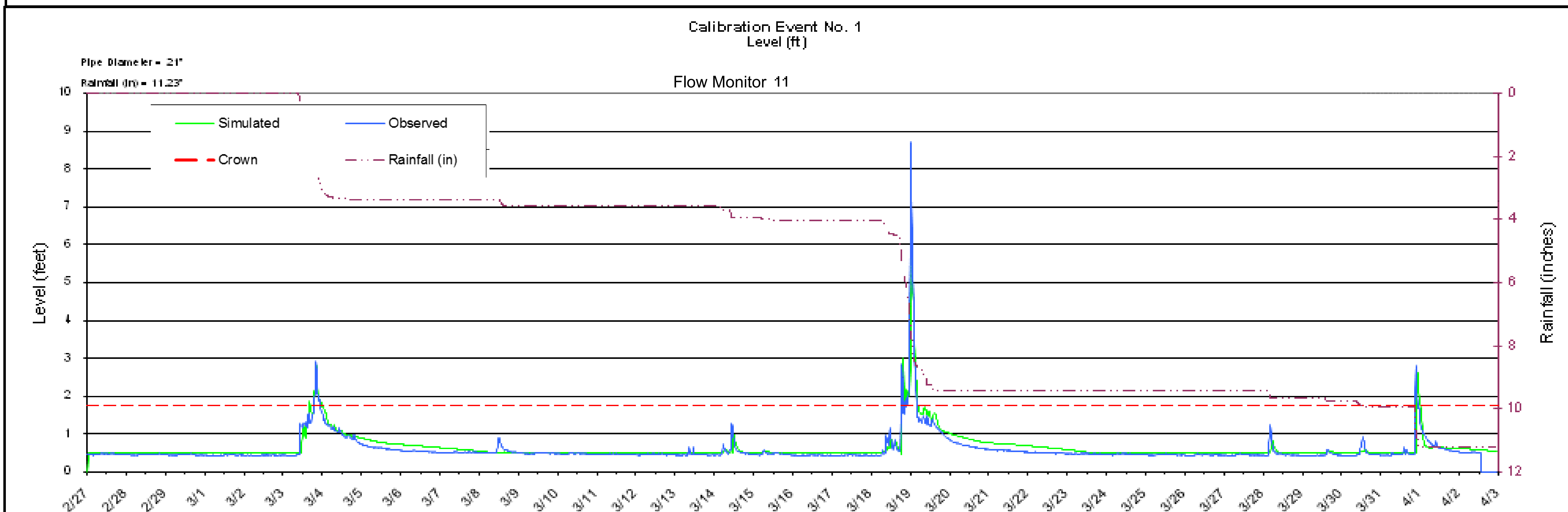
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 24"
Rainfall (in) = 11.23"
Flow Monitor 9
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)

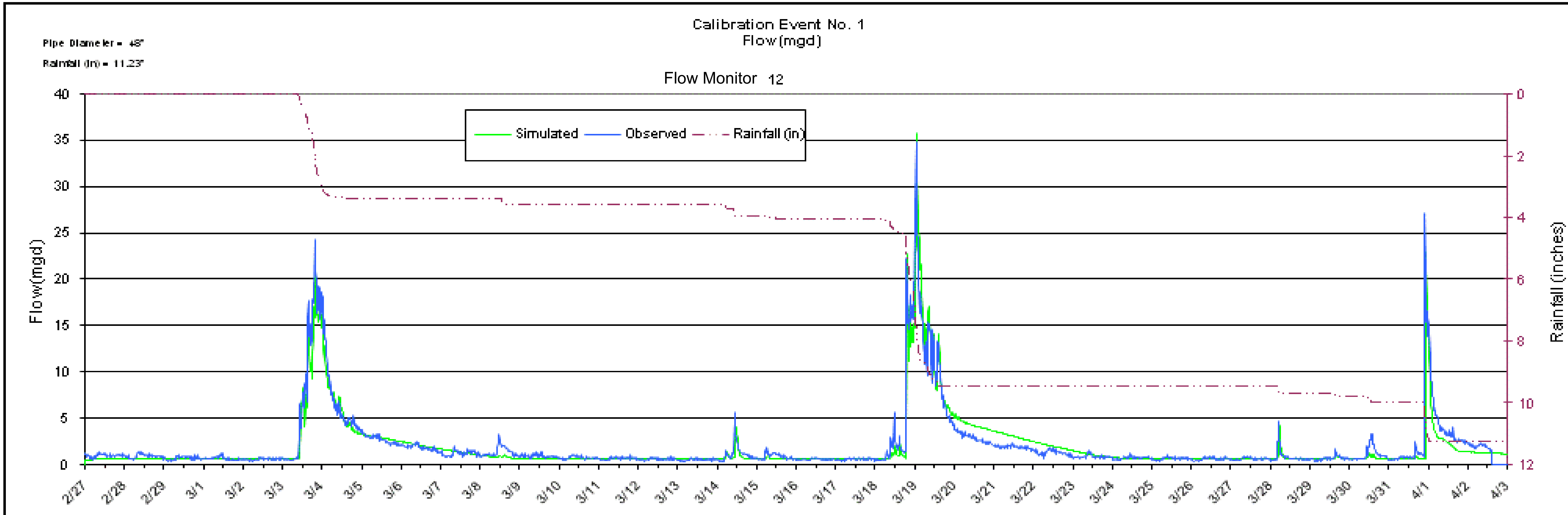


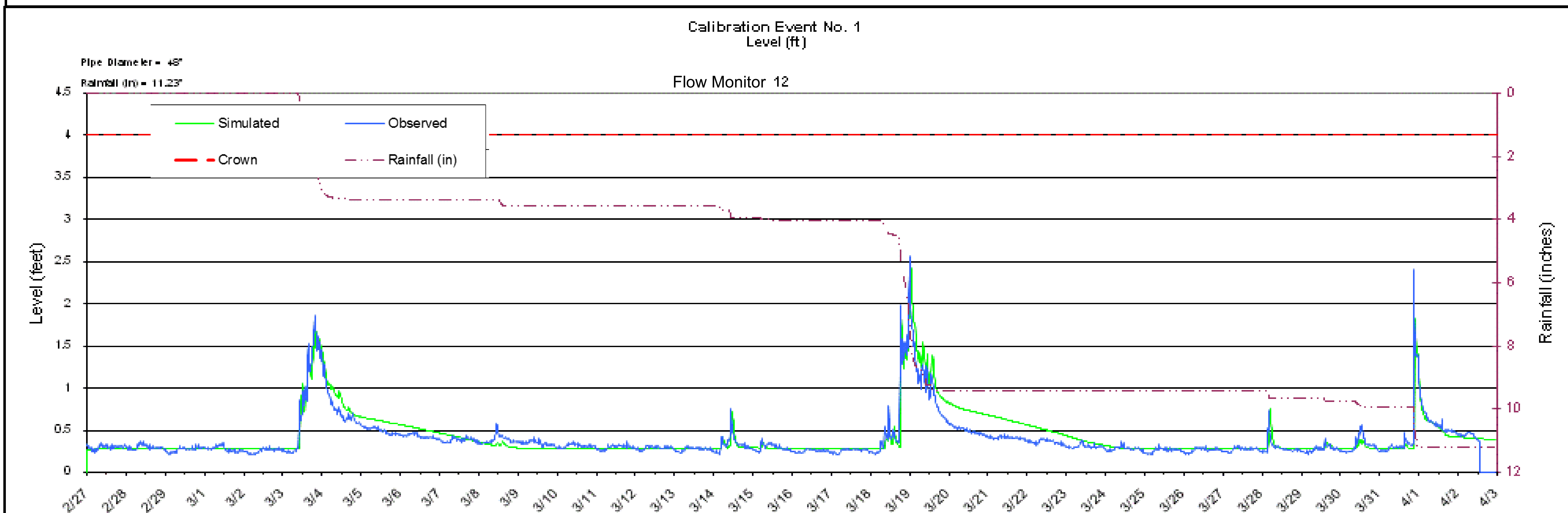
Calibration Event No. 1
Level (ft)
Pipe Diameter = 24"
Rainfall (in) = 11.23"
Flow Monitor 9
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)

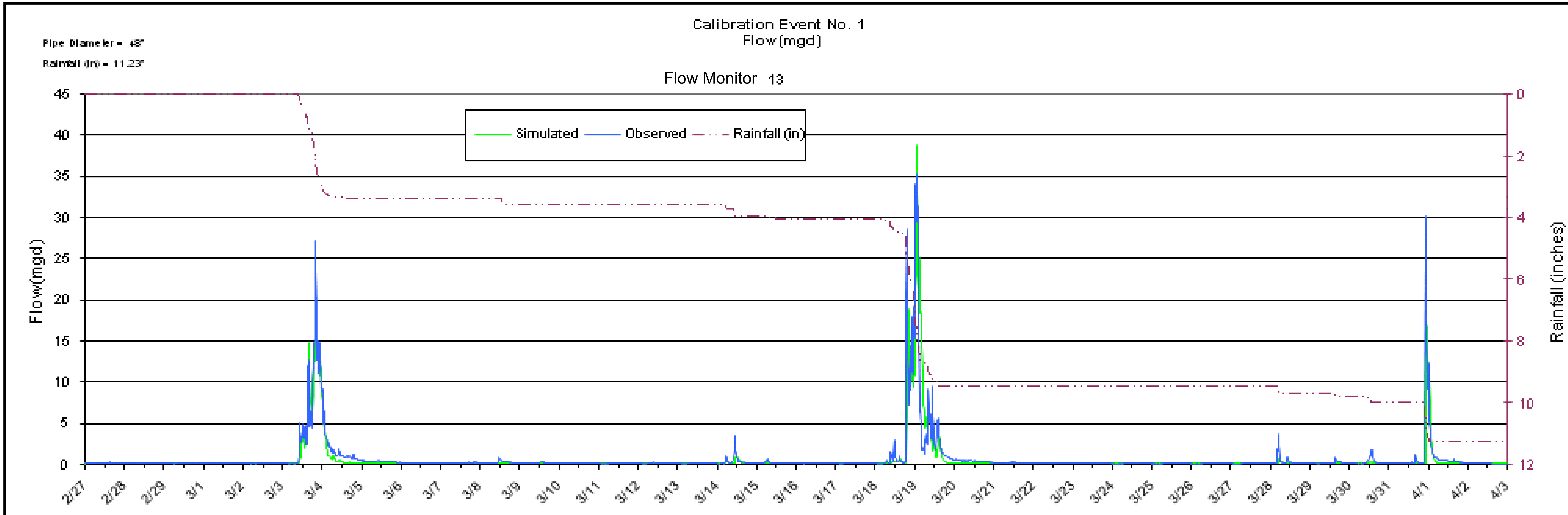

Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 27"
Rainfall (in) = 11.23"
Flow Monitor 10
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
30
25
20
15
10
5
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 21"
Rainfall (in) = 11.23"
Flow Monitor 11
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

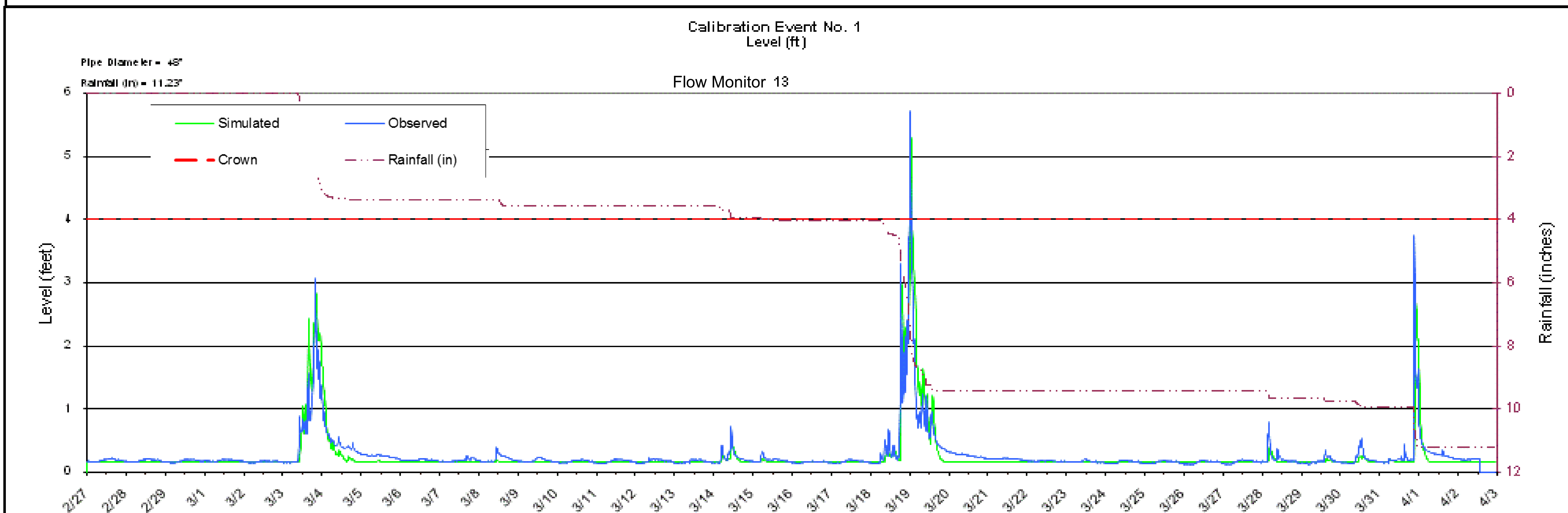

Calibration Event No. 1
Level (ft)
Pipe Diameter = 21"
Rainfall (in) = 11.23"
Flow Monitor 11
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 48"
Rainfall (in) = 11.23"
Flow Monitor 12
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

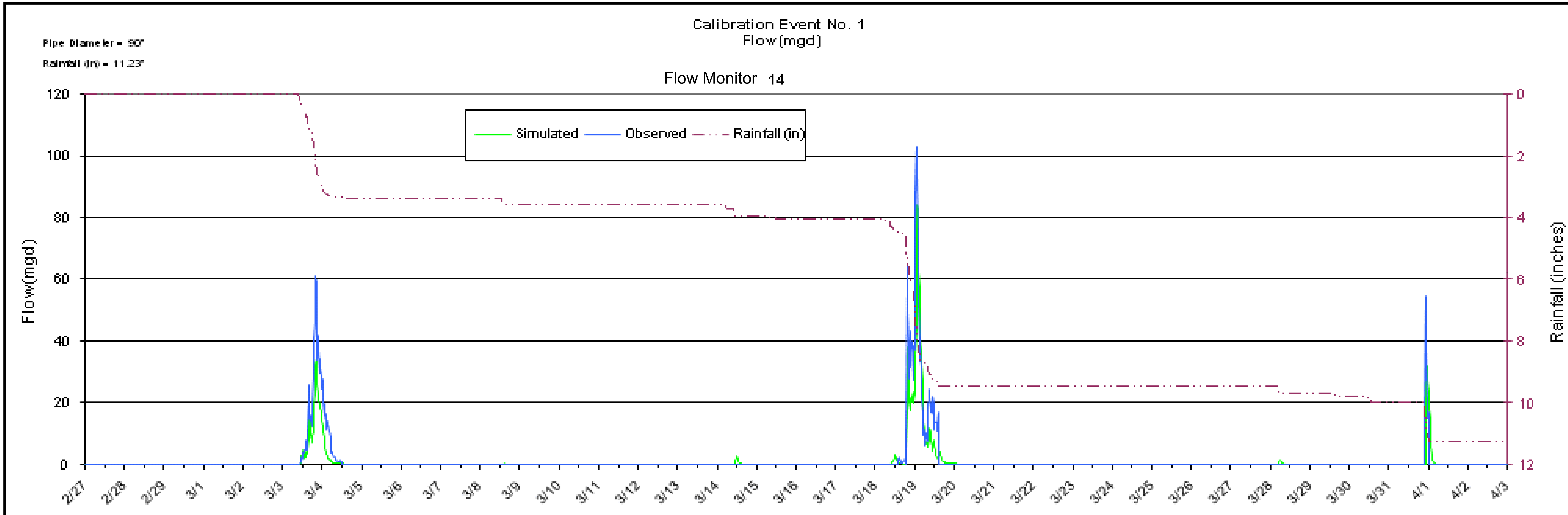

Calibration Event No. 1
Level (ft)
Pipe Diameter = 48"
Rainfall (in) = 11.23"
Flow Monitor 12
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

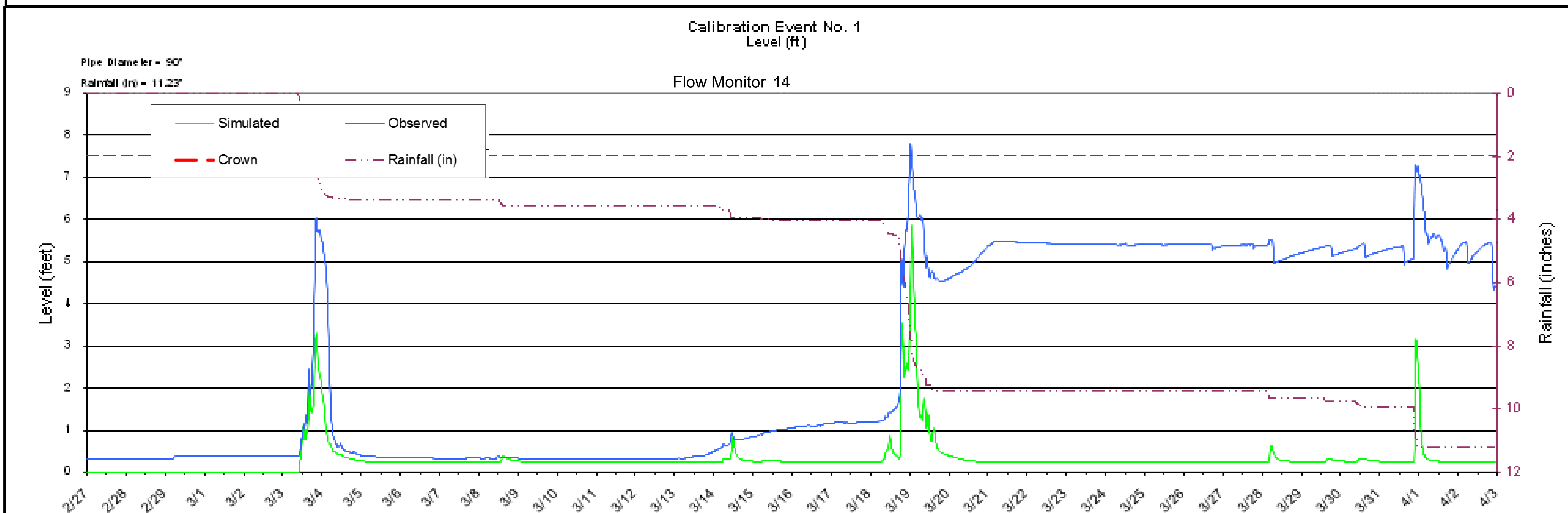


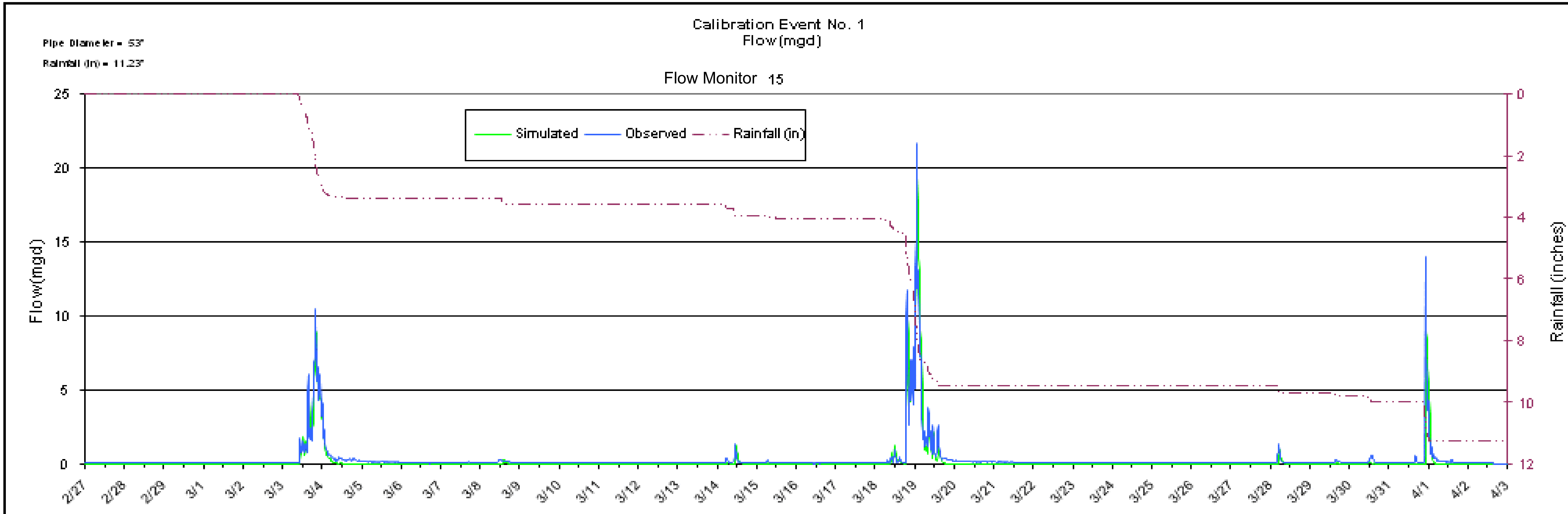
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 48"
Rainfall (in) = 11.23"
Flow Monitor 13
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)

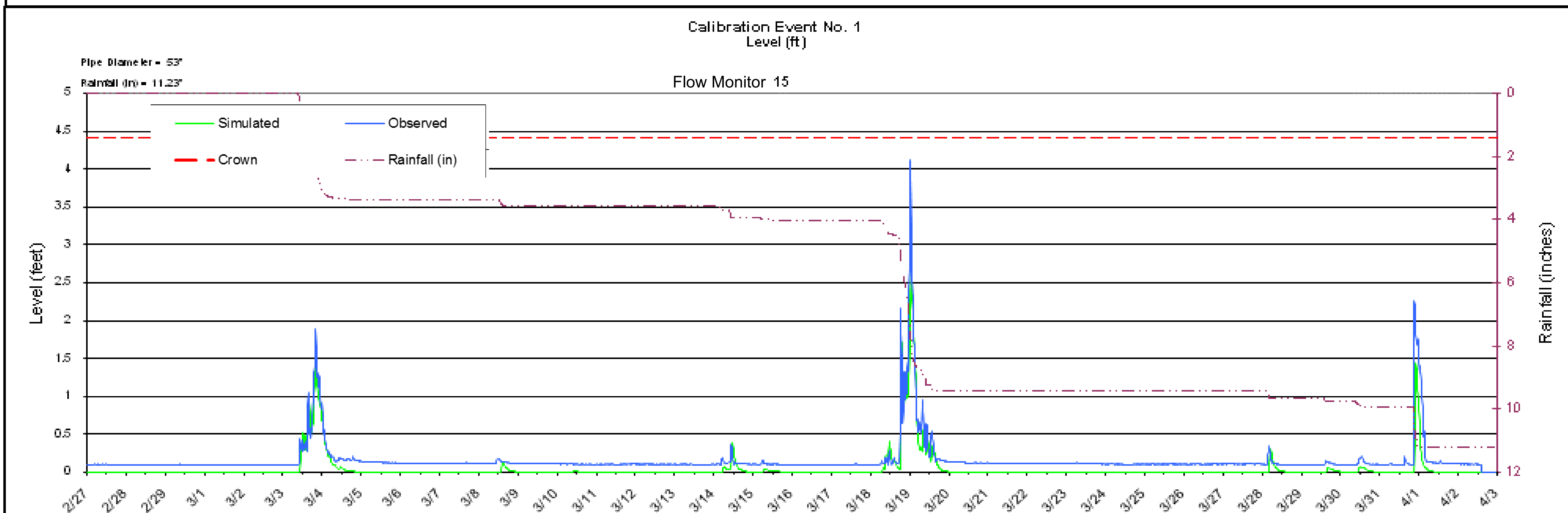


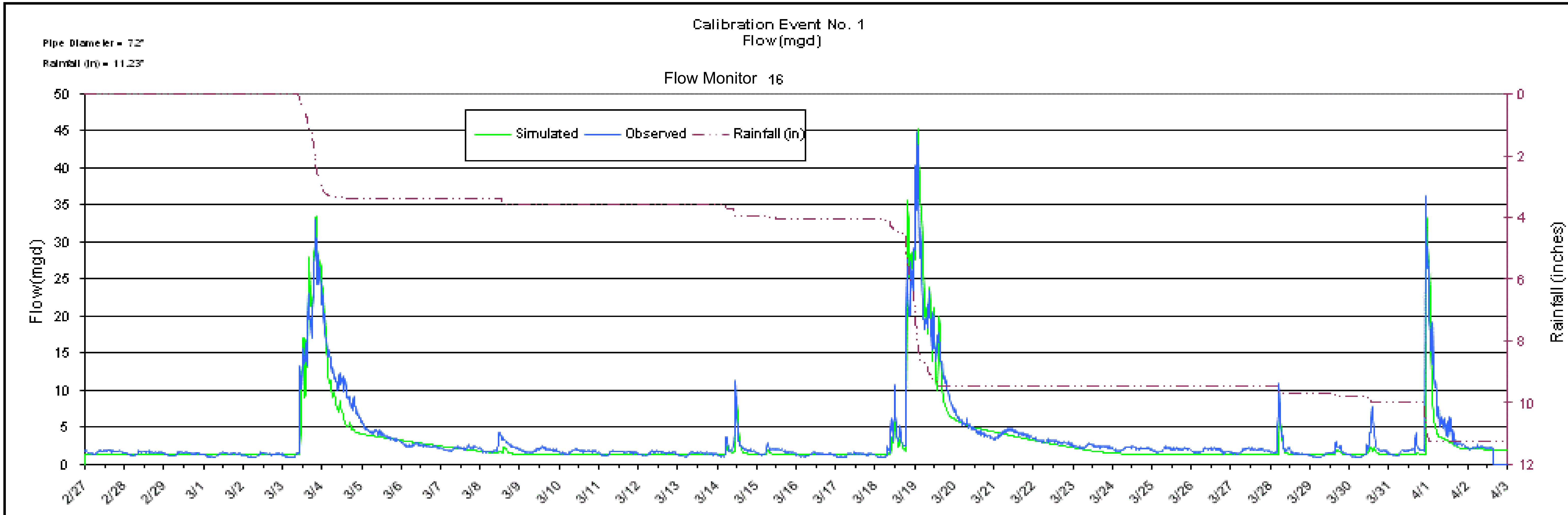
Calibration Event No. 1
Level (ft)
Pipe Diameter = 48"
Rainfall (in) = 11.23"
Flow Monitor 13
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 90"
Rainfall (in) = 11.23"
Flow Monitor 14
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
120
100
80
60
40
20
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3

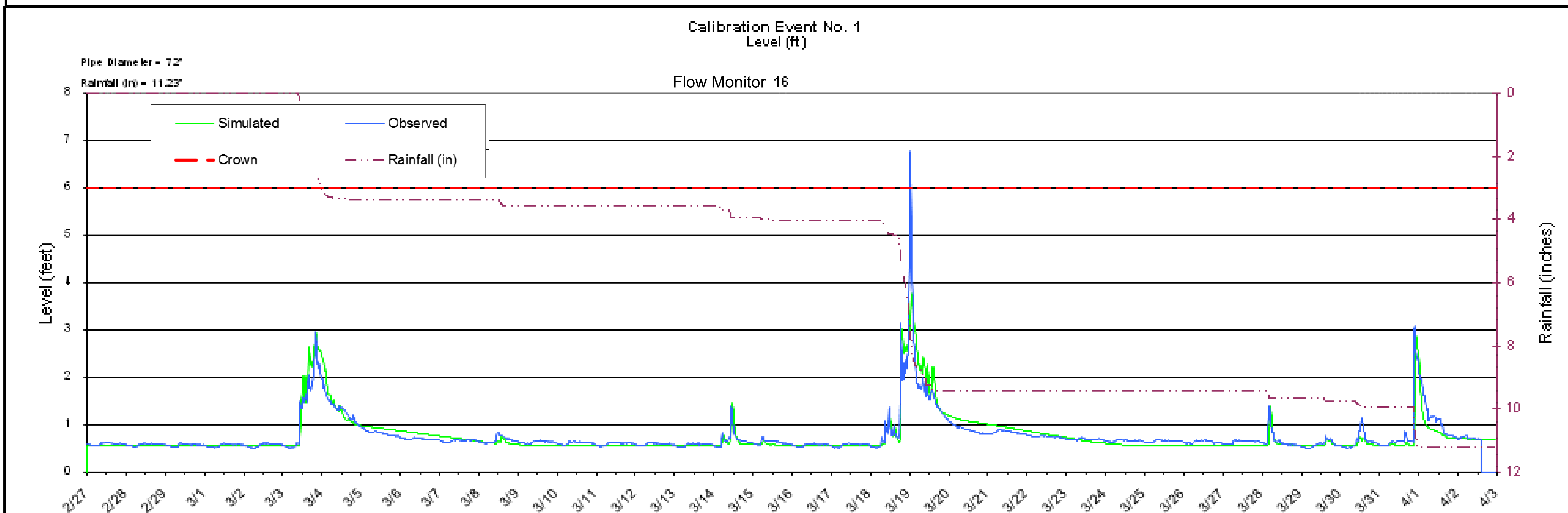

Calibration Event No. 1
Level (ft)
Pipe Diameter = 90"
Rainfall (in) = 11.23"
Flow Monitor 14
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 53"
Rainfall (in) = 11.23"
Flow Monitor 15
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
25
20
15
10
5
0
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3

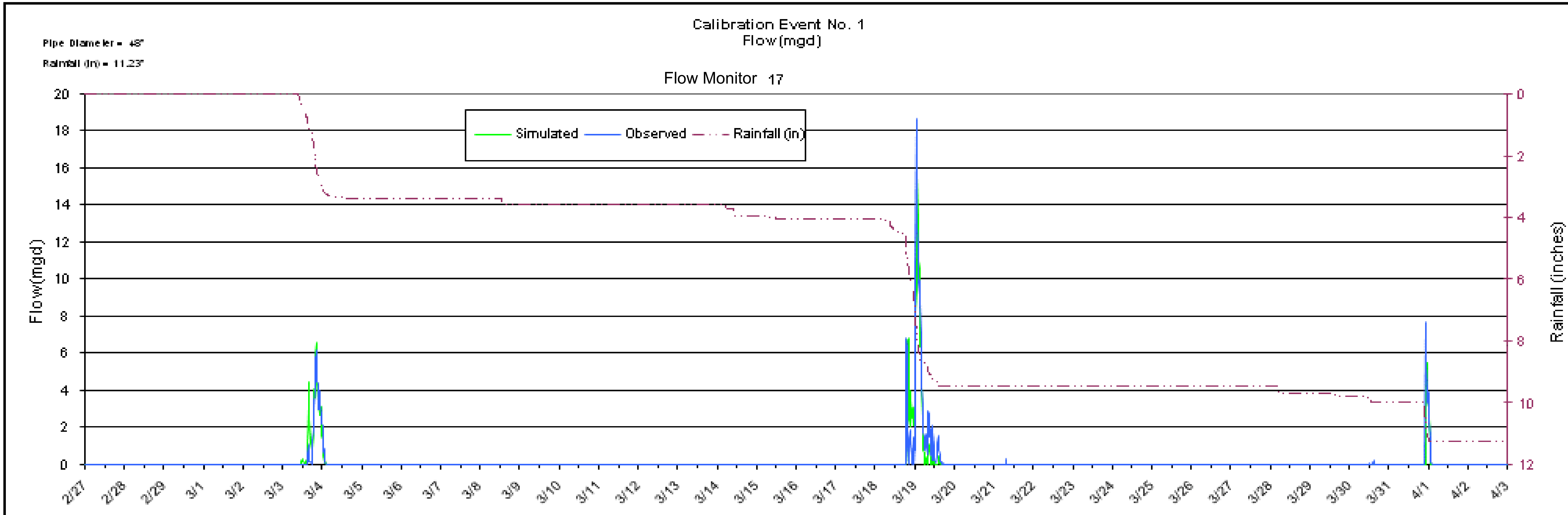

Calibration Event No. 1
Level (ft)
Pipe Diameter = 53"
Rainfall (in) = 11.23"
Flow Monitor 15
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3



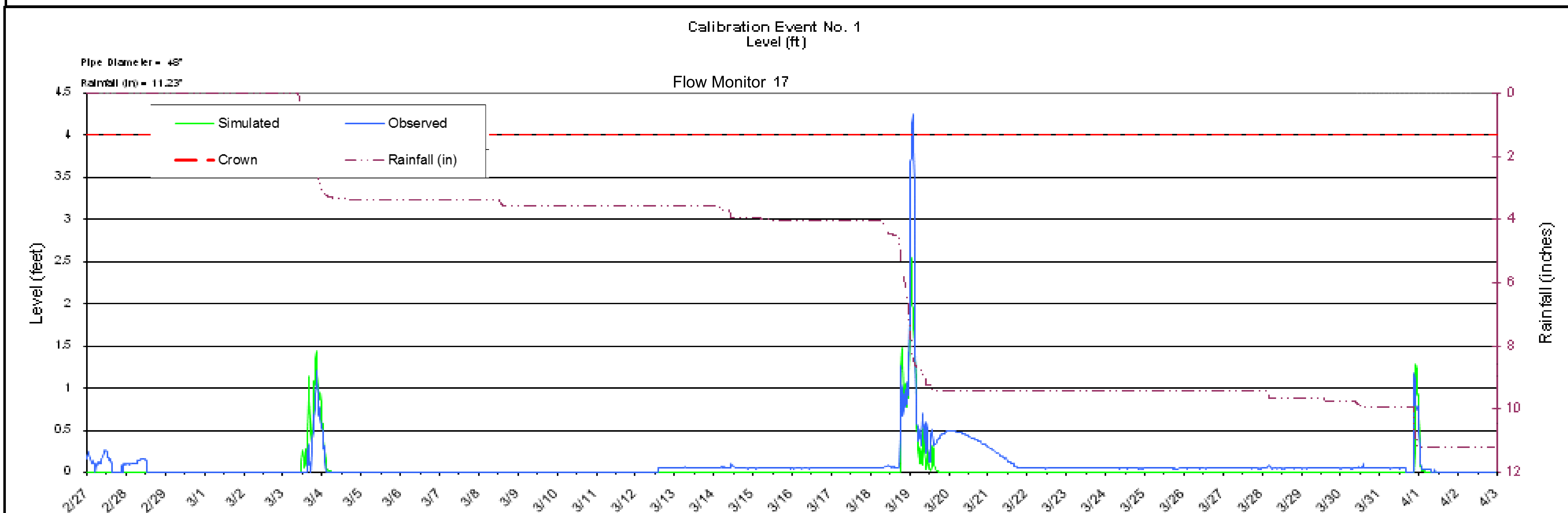
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 72"
Rainfall (in) = 11.23"
Flow Monitor 16
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3



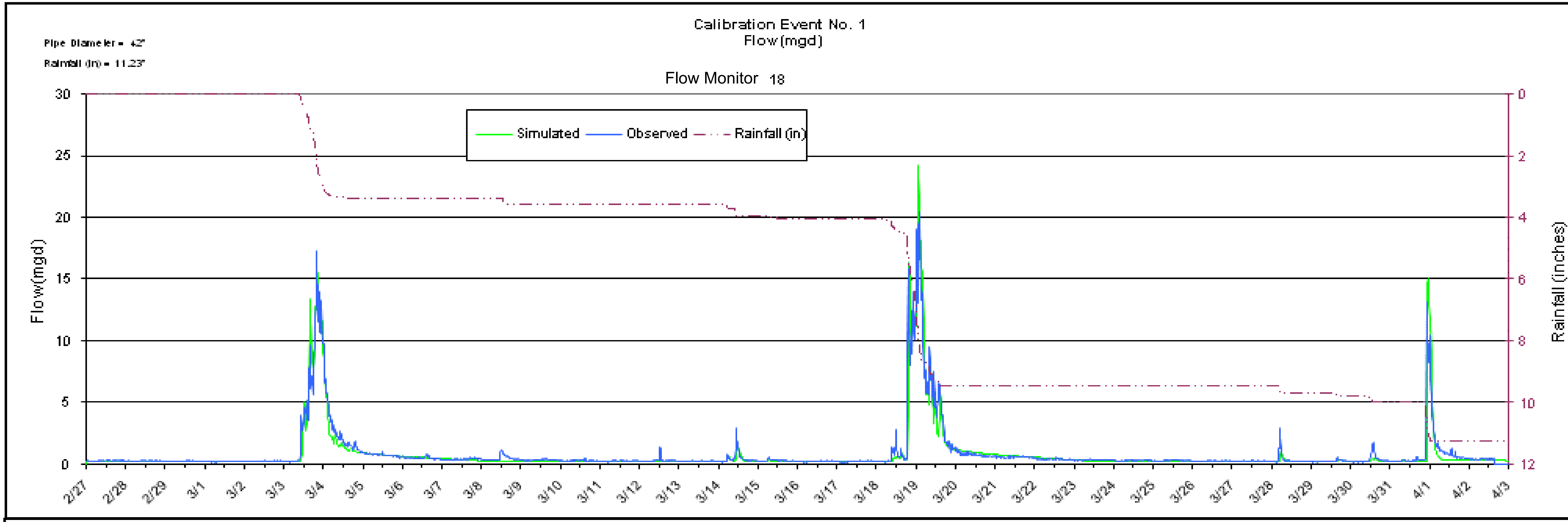
Calibration Event No. 1
Level (ft)
Pipe Diameter = 72"
Rainfall (in) = 11.23"
Flow Monitor 16
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
8
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3

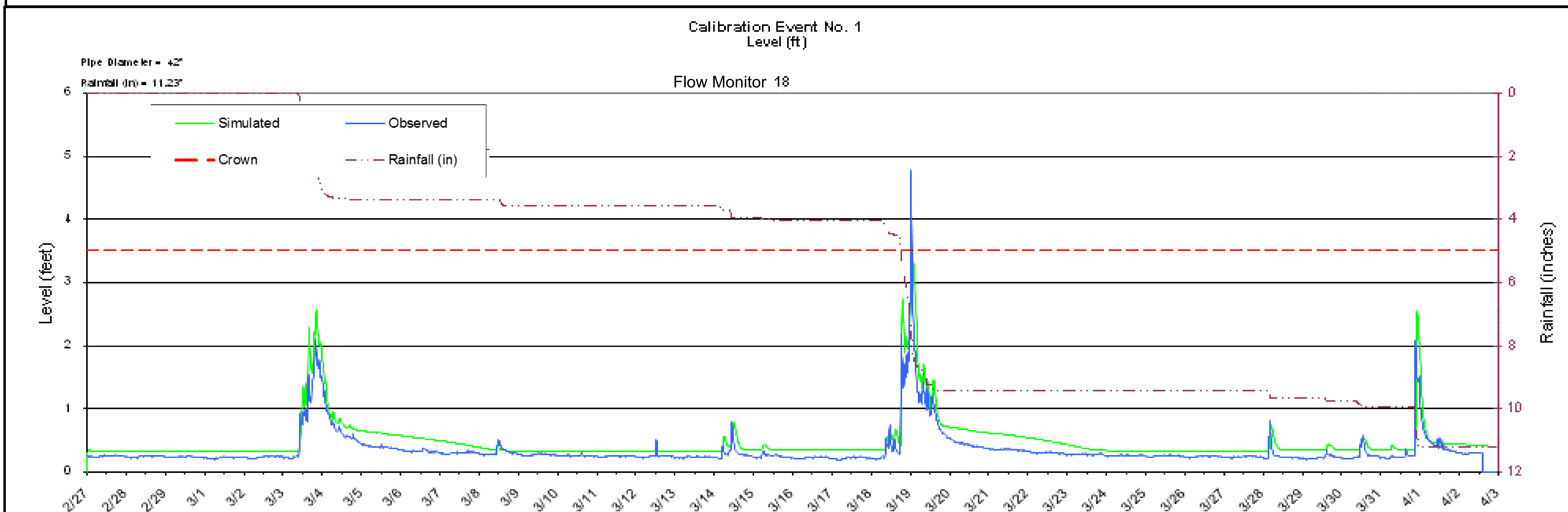


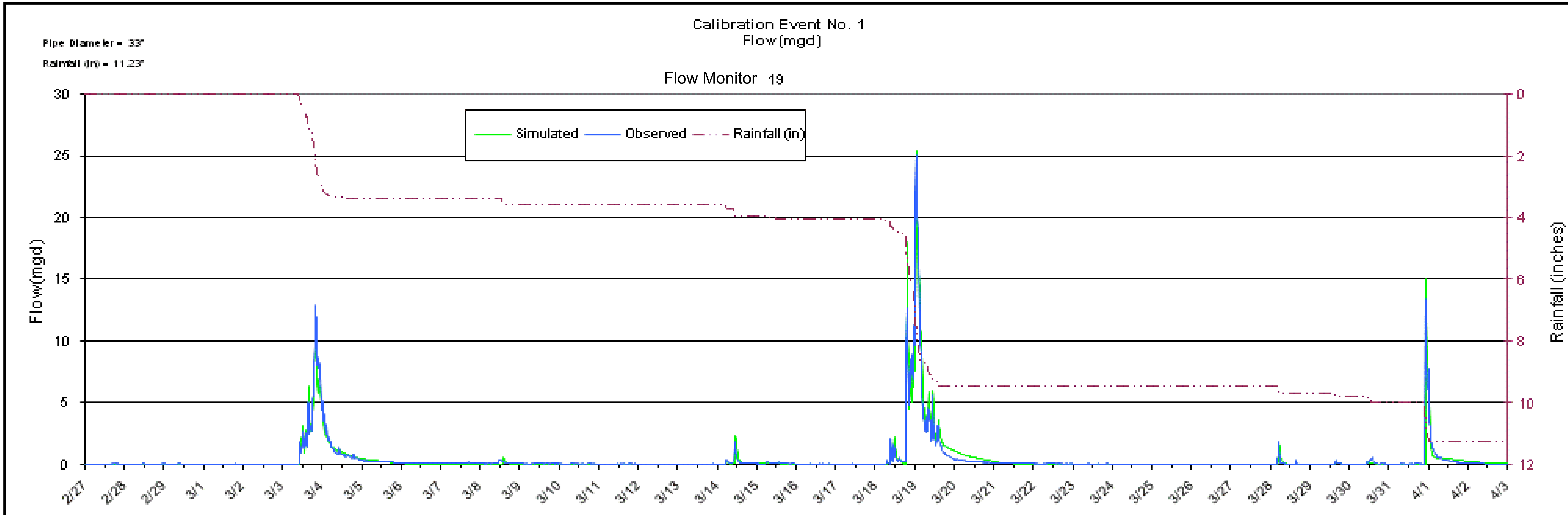
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 48"
Rainfall (in) = 11.23"
Flow Monitor 17
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)



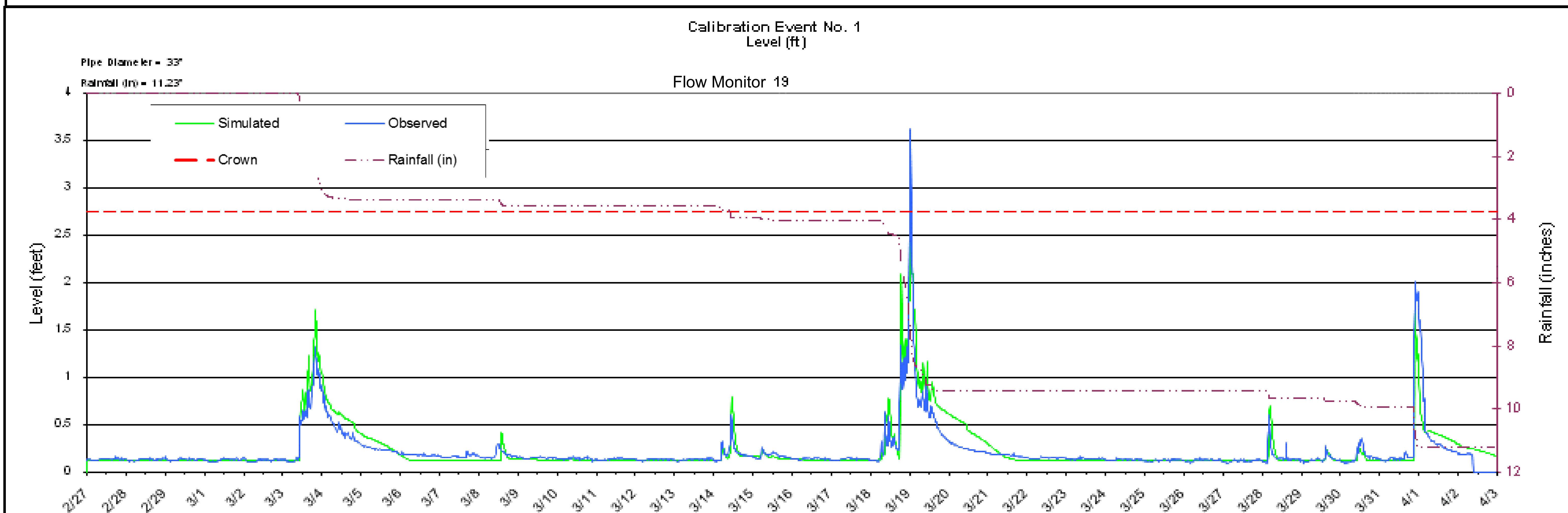
Calibration Event No. 1
Level (ft)
Pipe Diameter = 48"
Rainfall (in) = 11.23"
Flow Monitor 17
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 42"
Rainfall (in) = 11.23"
Flow Monitor 18
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)
30
25
20
15
10
5
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

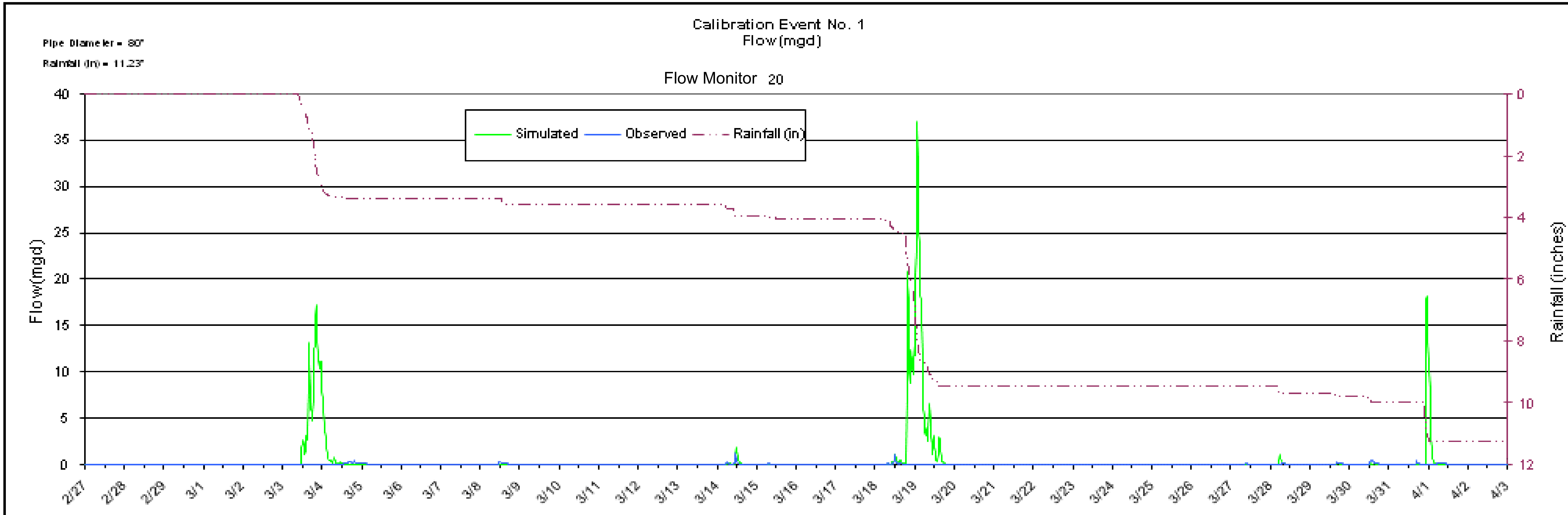

Calibration Event No. 1
Level (ft)
Pipe Diameter = 42"
Rainfall (in) = 11.23"
Flow Monitor 18
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
6
5
4
3
2
1
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

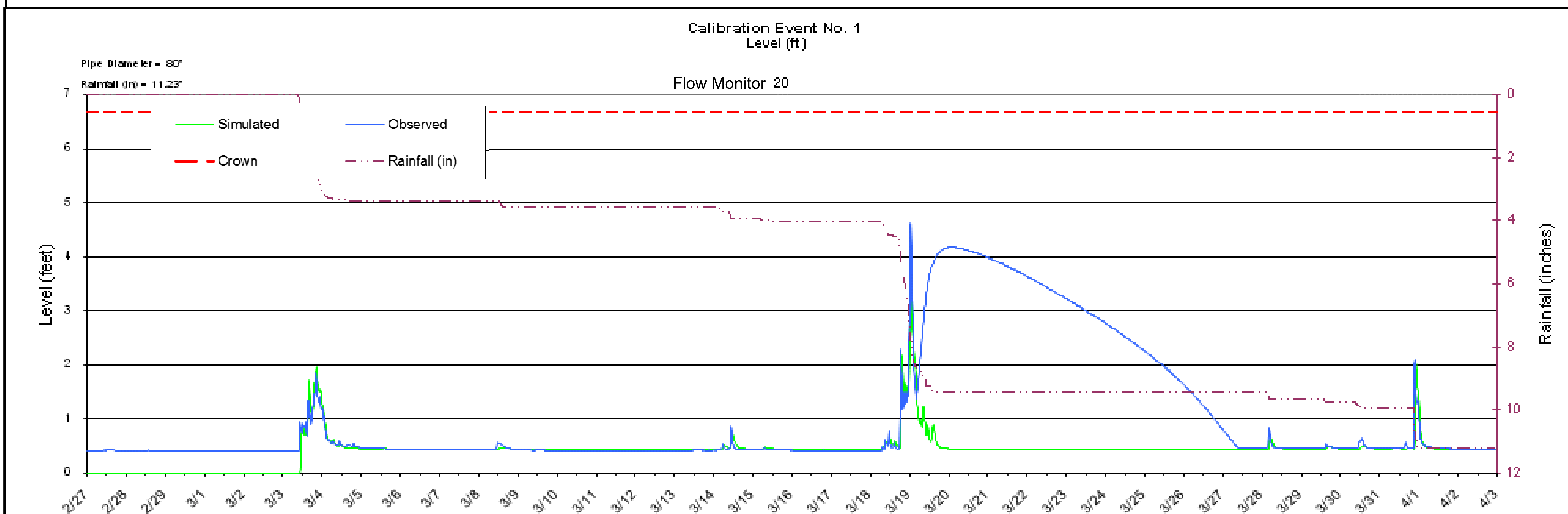


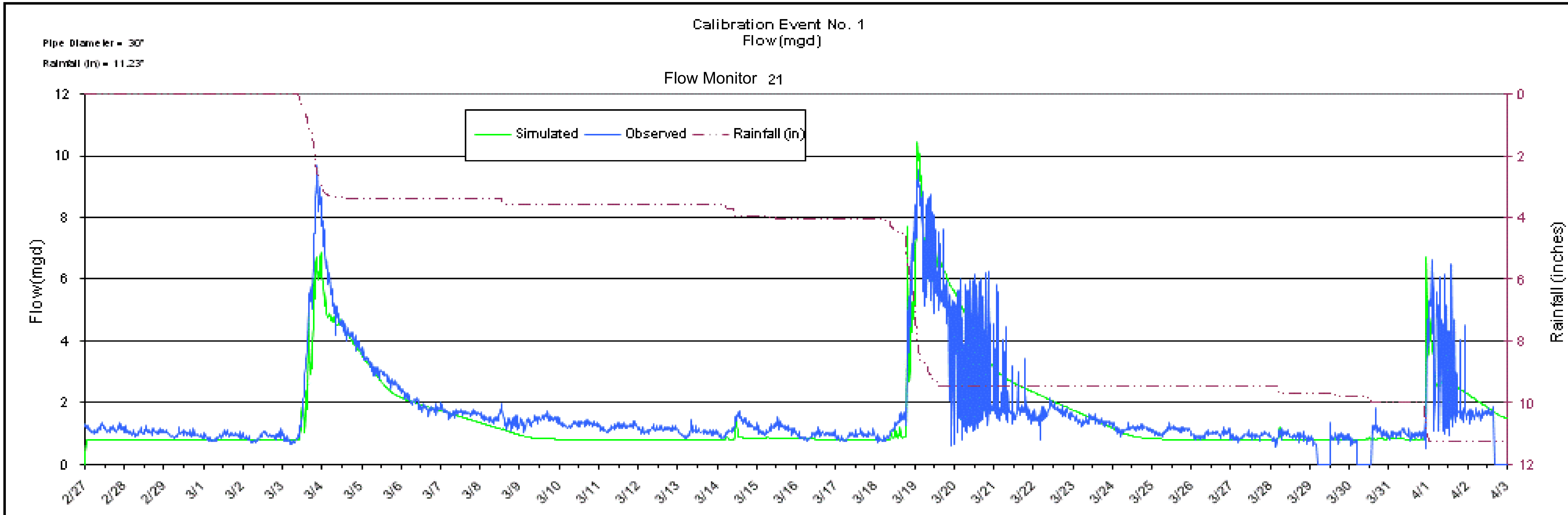
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 33"
Rainfall (in) = 11.23"
Flow Monitor 19
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)
30
25
20
15
10
5
0
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3

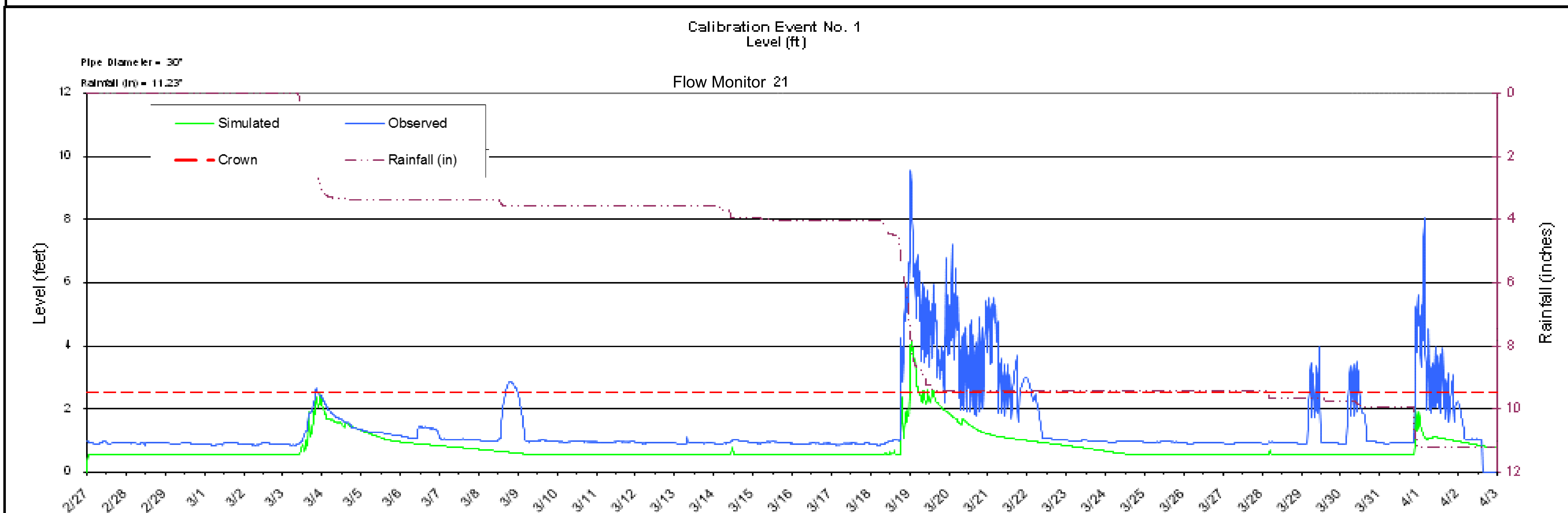


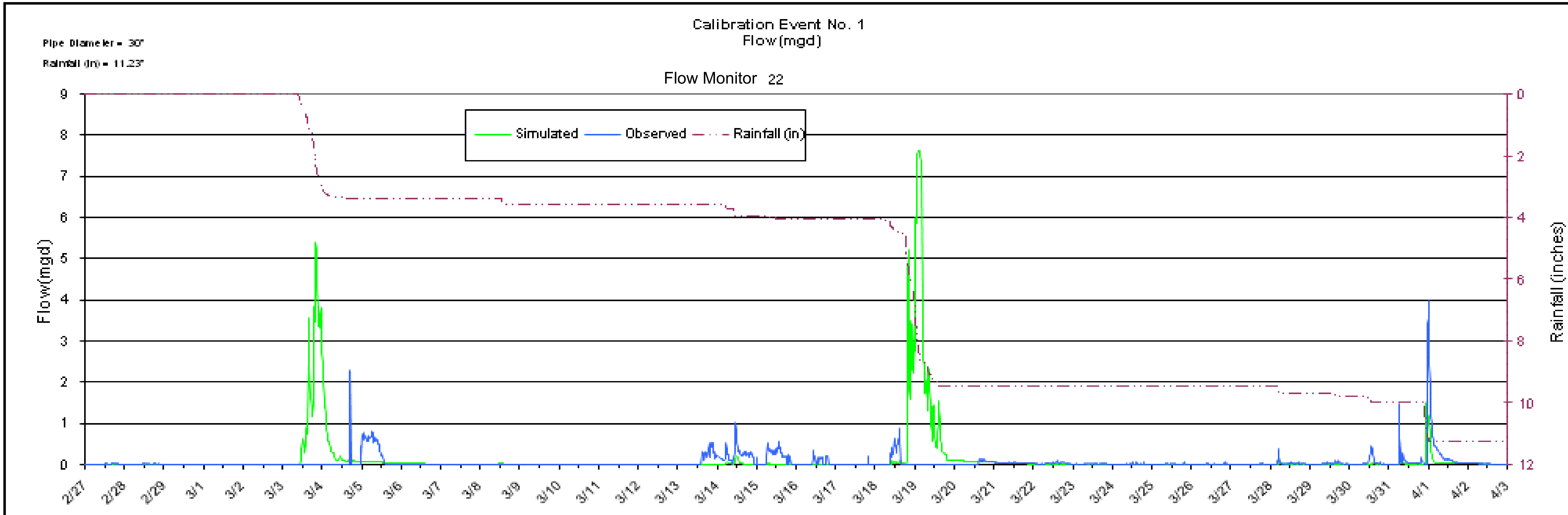
Calibration Event No. 1
Level (ft)
Pipe Diameter = 33"
Rainfall (in) = 11.23"
Flow Monitor 19
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3

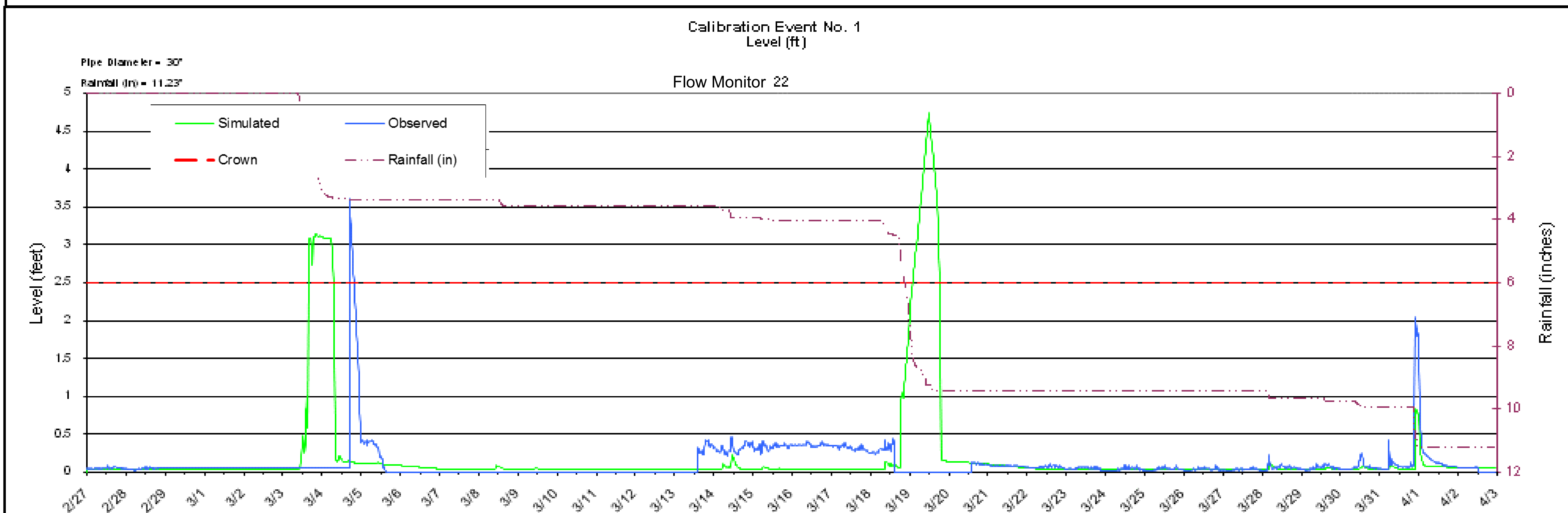

Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 80"
Rainfall (in) = 11.23"
Flow Monitor 20
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
40
35
30
25
20
15
10
5
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

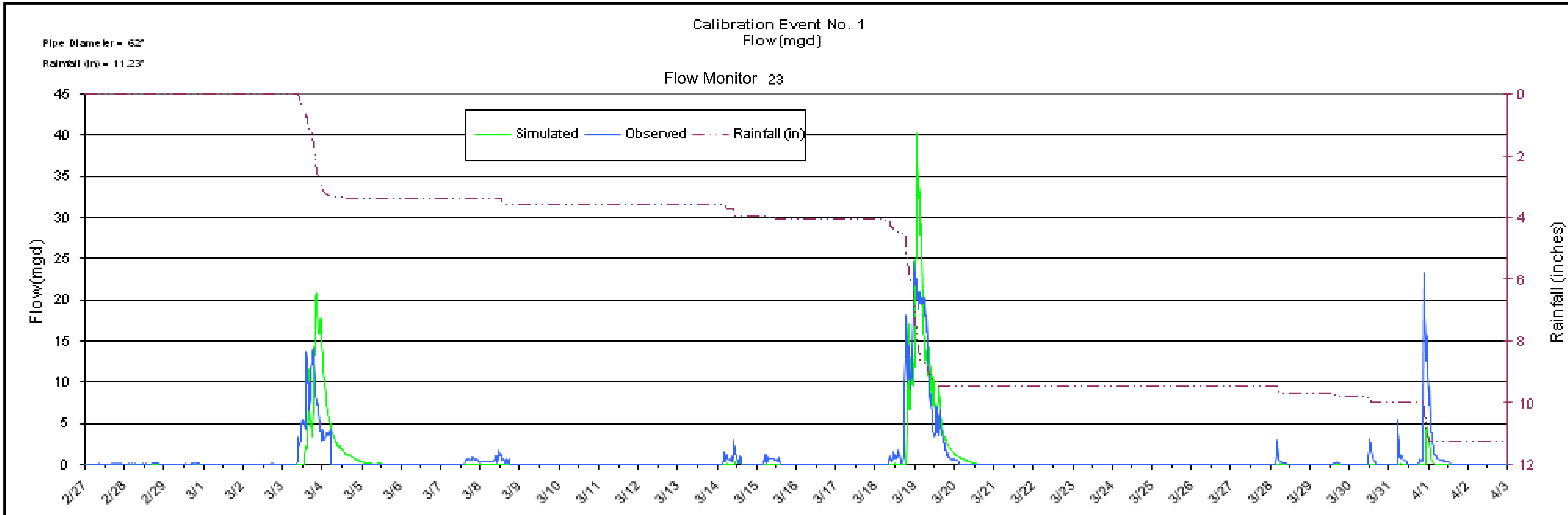

Calibration Event No. 1
Level (ft)
Pipe Diameter = 80"
Rainfall (in) = 11.23"
Flow Monitor 20
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
7
6
5
4
3
2
1
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

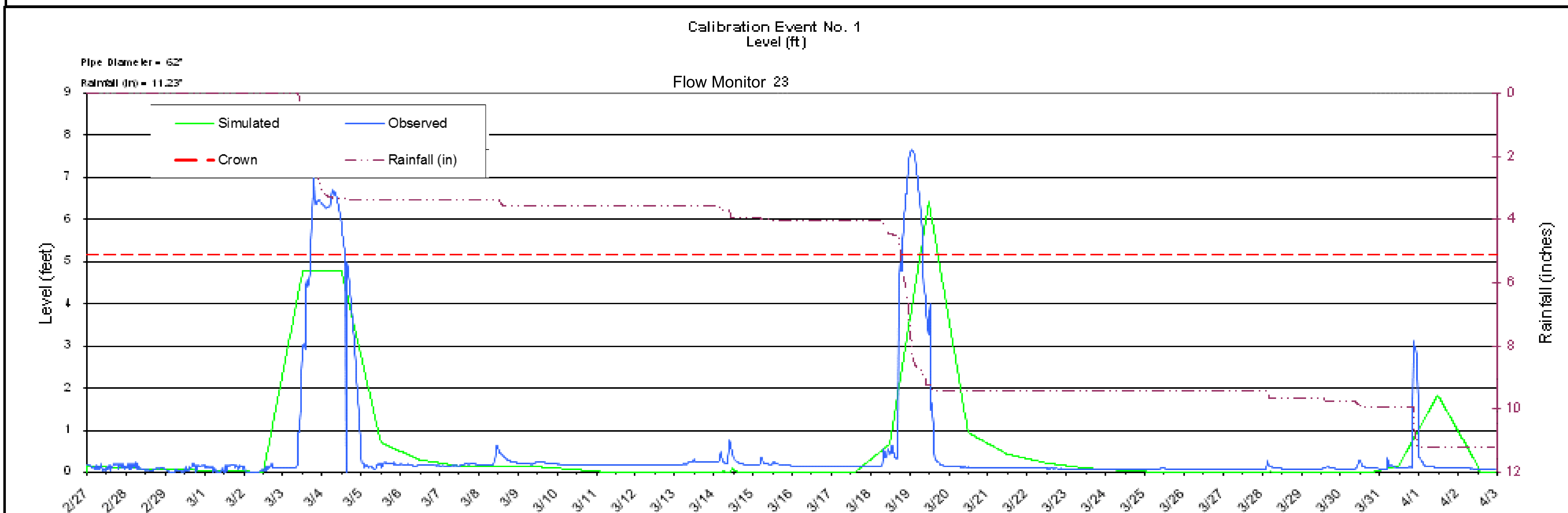

Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 30"
Rainfall (in) = 11.23"
Flow Monitor 21
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3

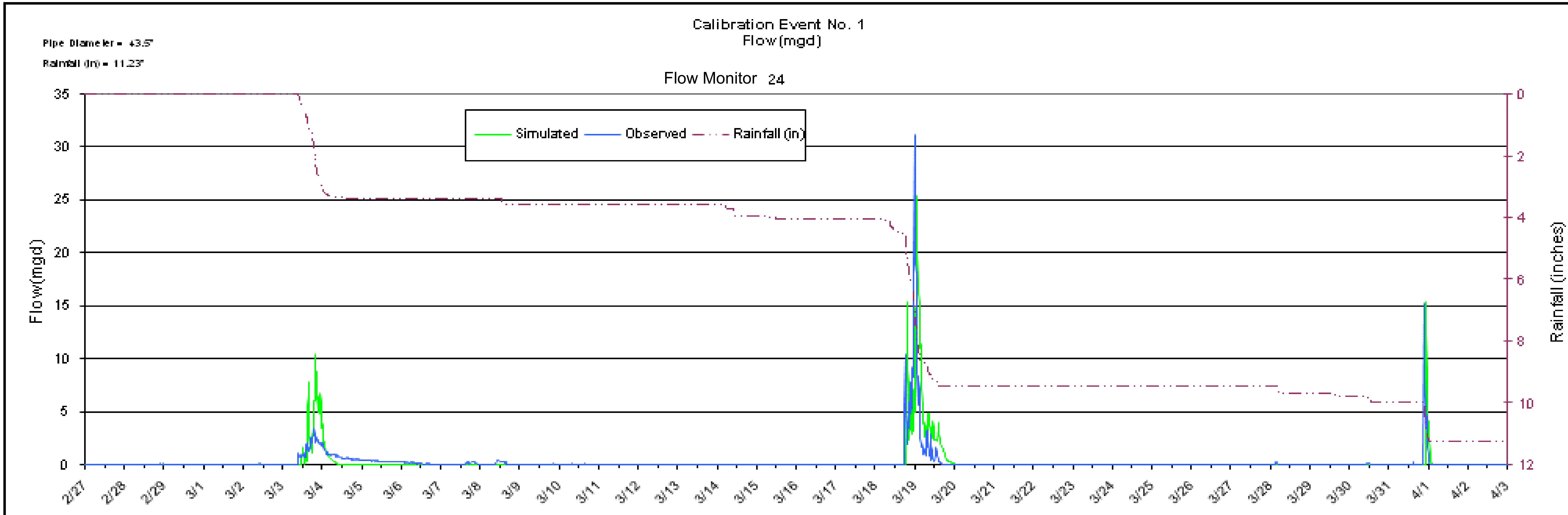

Calibration Event No. 1
Level (ft)
Pipe Diameter = 30"
Rainfall (in) = 11.23"
Flow Monitor 21
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3

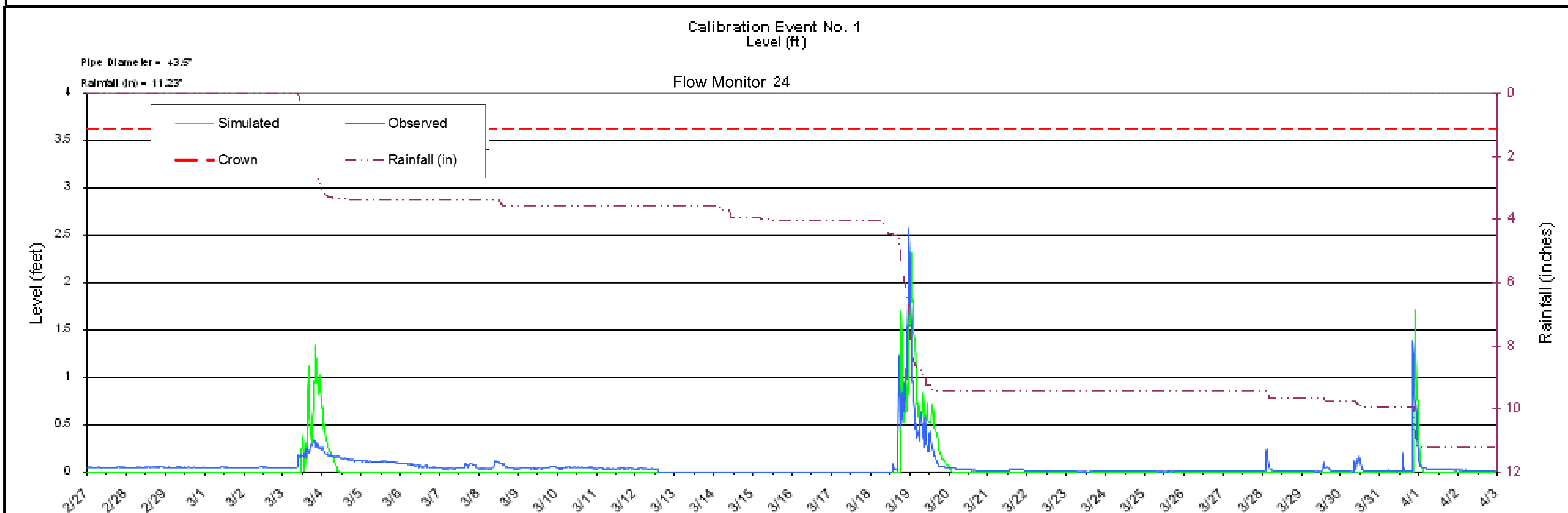

Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 30"
Rainfall (in) = 11.23"
Flow Monitor 22
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)

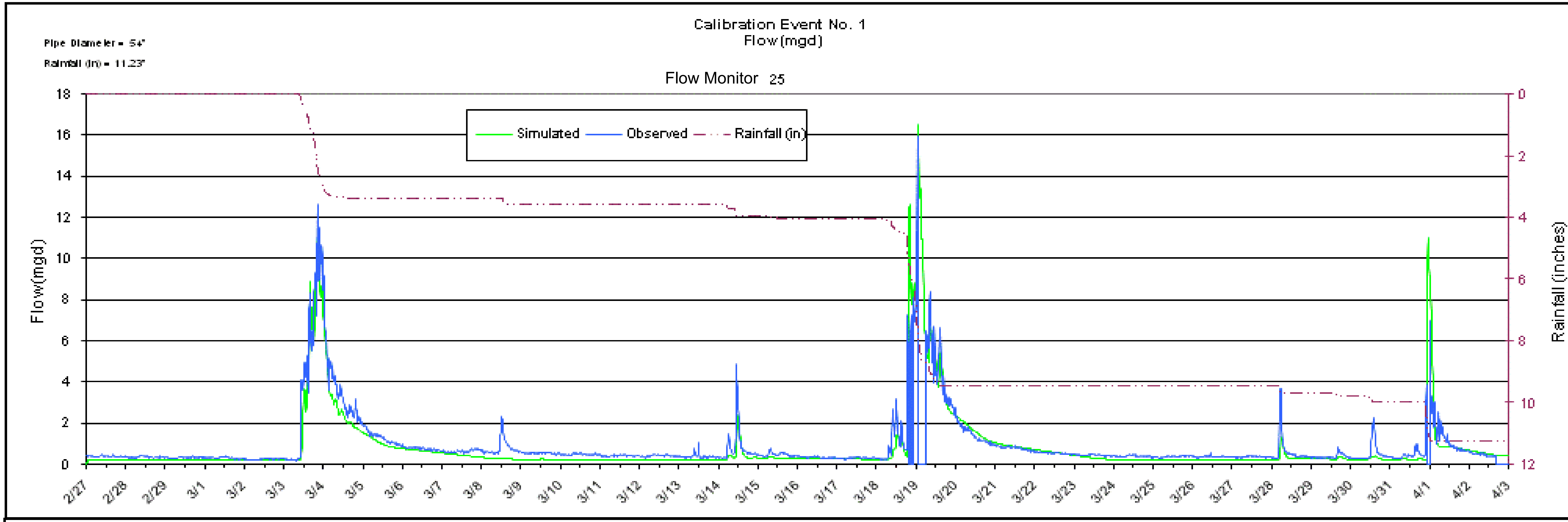

Calibration Event No. 1
Level (ft)
Pipe Diameter = 30"
Rainfall (in) = 11.23"
Flow Monitor 22
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 62"
Rainfall (in) = 11.23"
Flow Monitor 23
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)

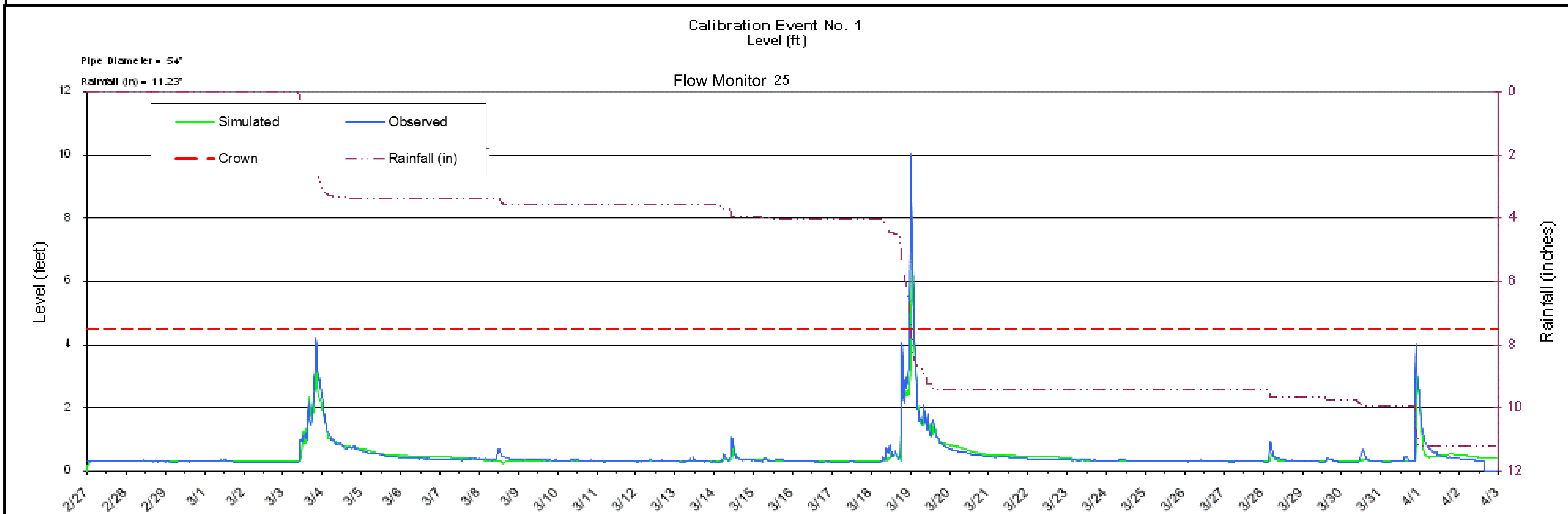

Calibration Event No. 1
Level (ft)
Pipe Diameter = 62"
Rainfall (in) = 11.23"
Flow Monitor 23
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 43.5"
Rainfall (in) = 11.23"
Flow Monitor 24
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3

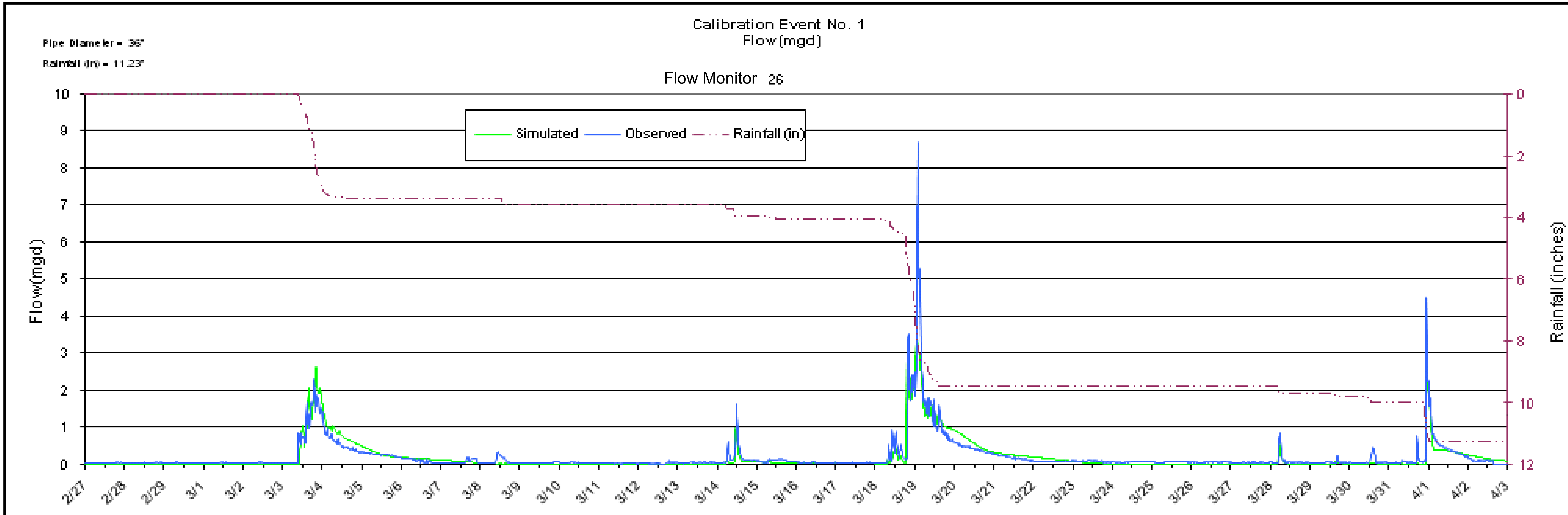

Calibration Event No. 1
Level (ft)
Pipe Diameter = 43.5"
Rainfall (in) = 11.23"
Flow Monitor 24
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3



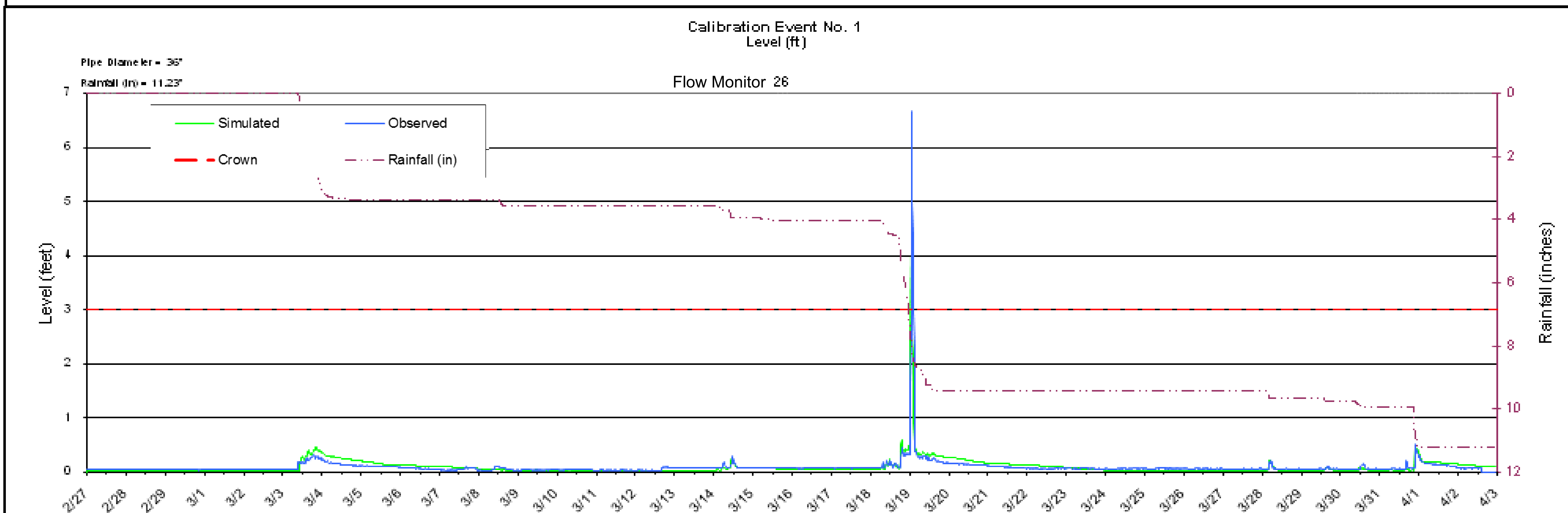
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 54"
Rainfall (in) = 11.23"
Flow Monitor 25
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)
0
2
4
6
8
10
12
14
16
18
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3



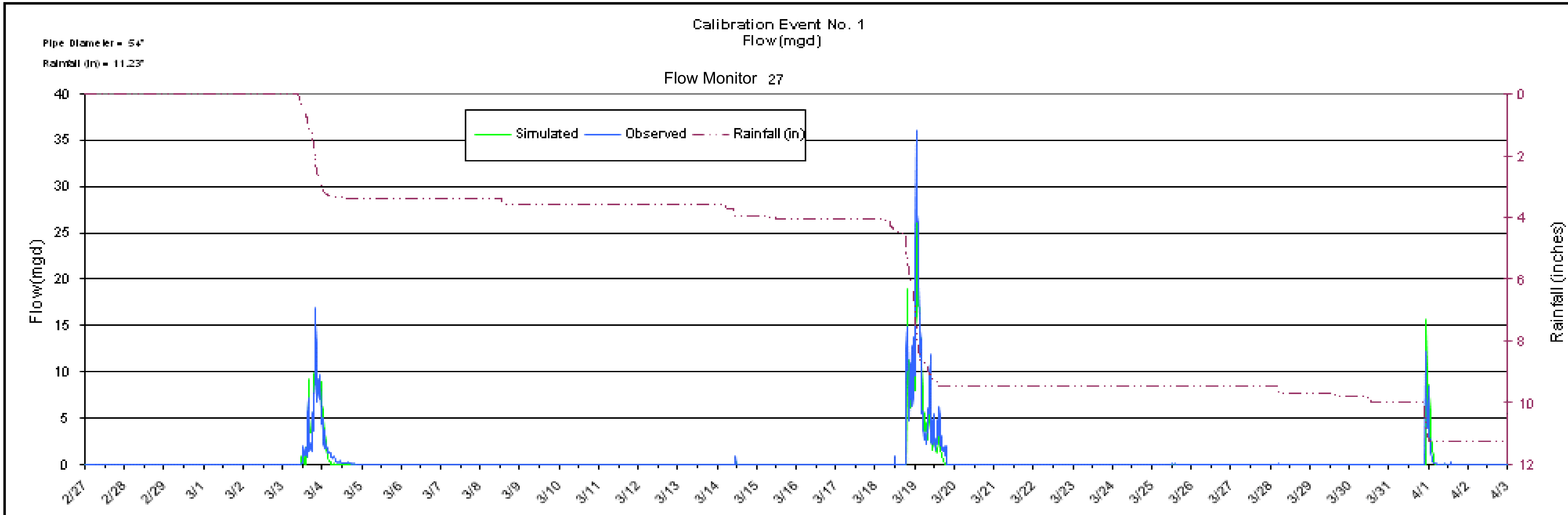
Calibration Event No. 1
Level (ft)
Pipe Diameter = 54"
Rainfall (in) = 11.23"
Flow Monitor 25
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
0
2
4
6
8
10
12
0
2
4
6
8
10
12
2/27
2/28
2/29
3/1
3/2
3/3
3/4
3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12
3/13
3/14
3/15
3/16
3/17
3/18
3/19
3/20
3/21
3/22
3/23
3/24
3/25
3/26
3/27
3/28
3/29
3/30
3/31
4/1
4/2
4/3

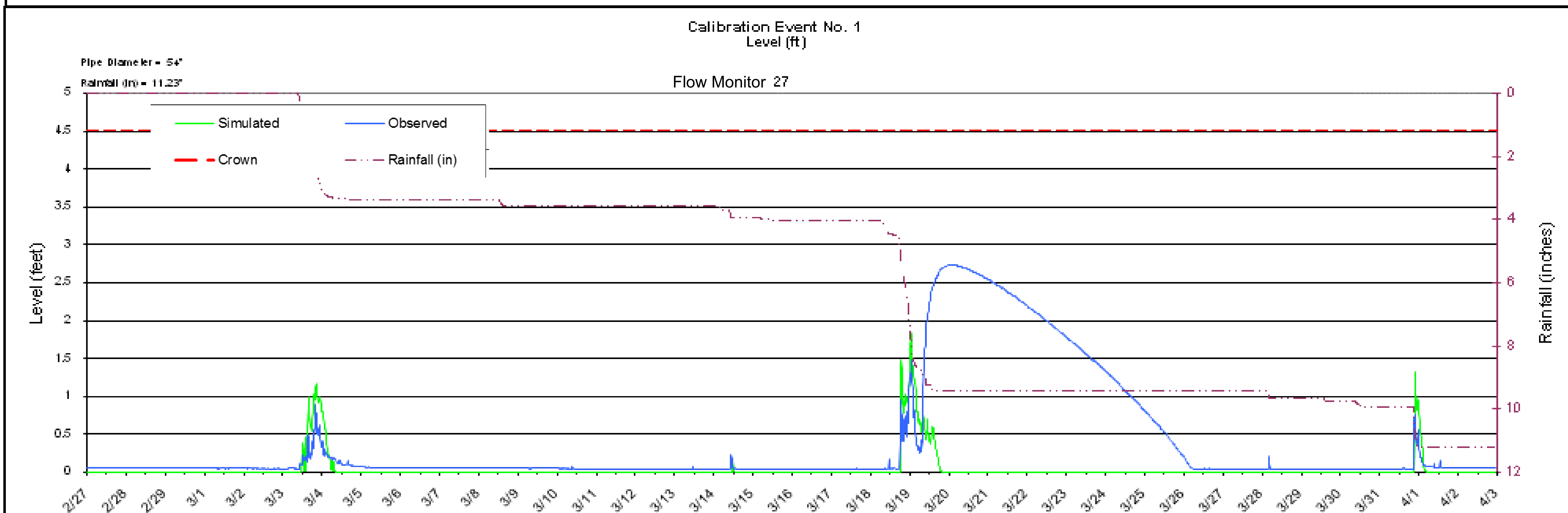


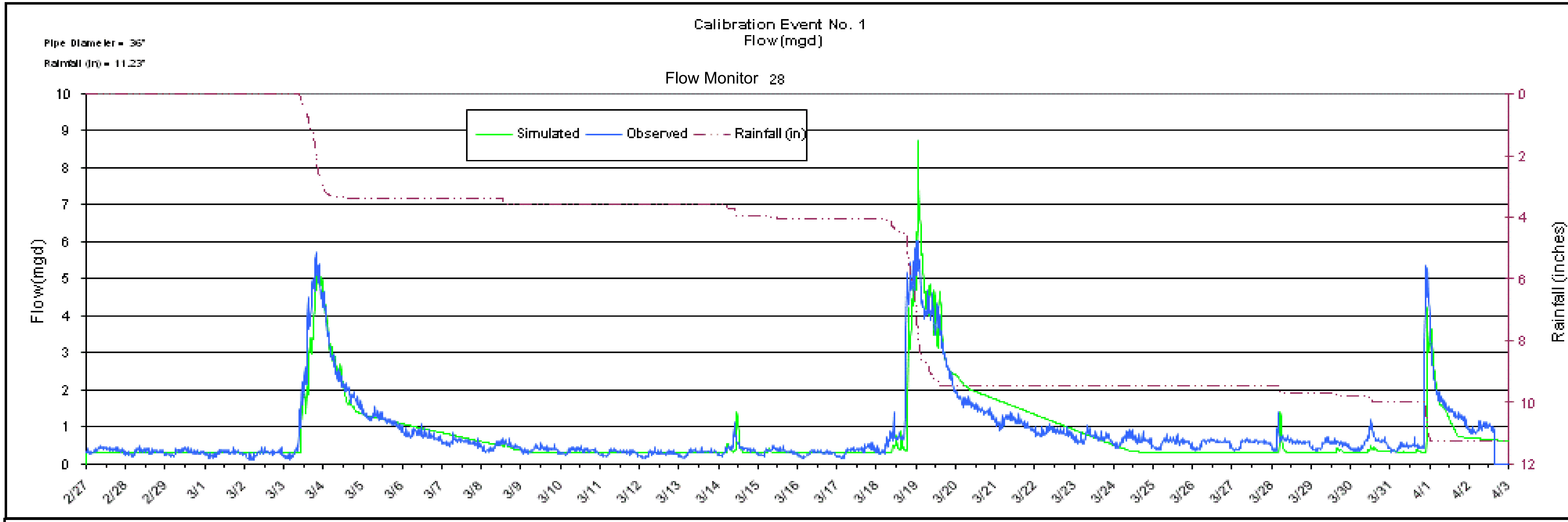
Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 36"
Rainfall (in) = 11.23"
Flow Monitor 26
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)



Calibration Event No. 1
Level (ft)
Pipe Diameter = 36"
Rainfall (in) = 11.23"
Flow Monitor 26
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 54"
Rainfall (in) = 11.23"
Flow Monitor 27
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)
0
5
10
15
20
25
30
35
40
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3


Calibration Event No. 1
Level (ft)
Pipe Diameter = 54"
Rainfall (in) = 11.23"
Flow Monitor 27
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
2
4
6
8
10
12
2/27 2/28 2/29 3/1 3/2 3/3 3/4 3/5 3/6 3/7 3/8 3/9 3/10 3/11 3/12 3/13 3/14 3/15 3/16 3/17 3/18 3/19 3/20 3/21 3/22 3/23 3/24 3/25 3/26 3/27 3/28 3/29 3/30 3/31 4/1 4/2 4/3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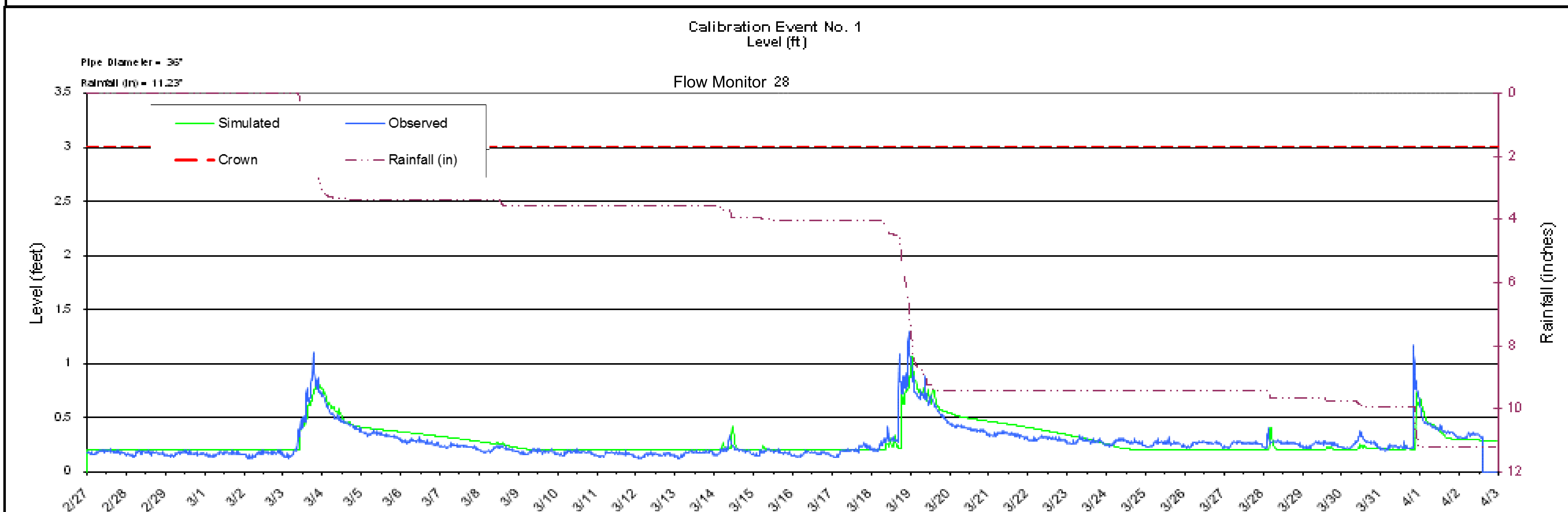
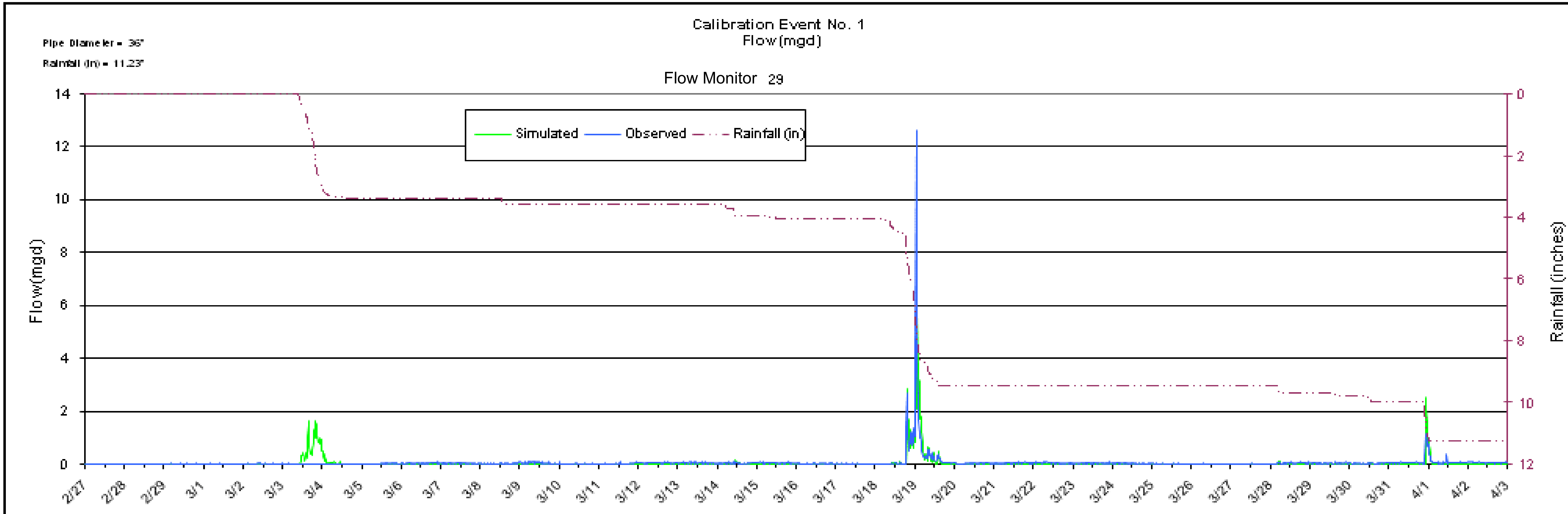
Pipe Diameter = 36"
Rainfall (in) = 11.23"
Flow Monitor 28
Simulated
Observed
Rainfall (in)
Flow(mgd)
Rainfall (inches)


Calibration Event No. 1
Level (ft)
Pipe Diameter = 36"
Rainfall (in) = 11.23"
Flow Monitor 28
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)


Calibration Event No. 1
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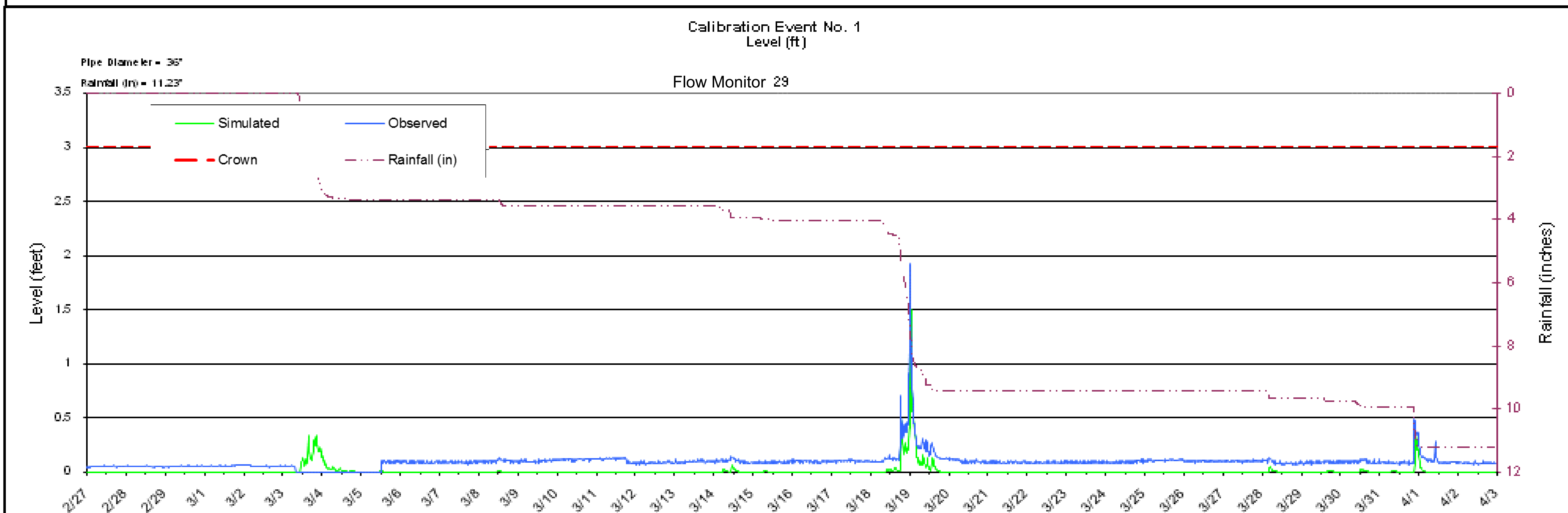
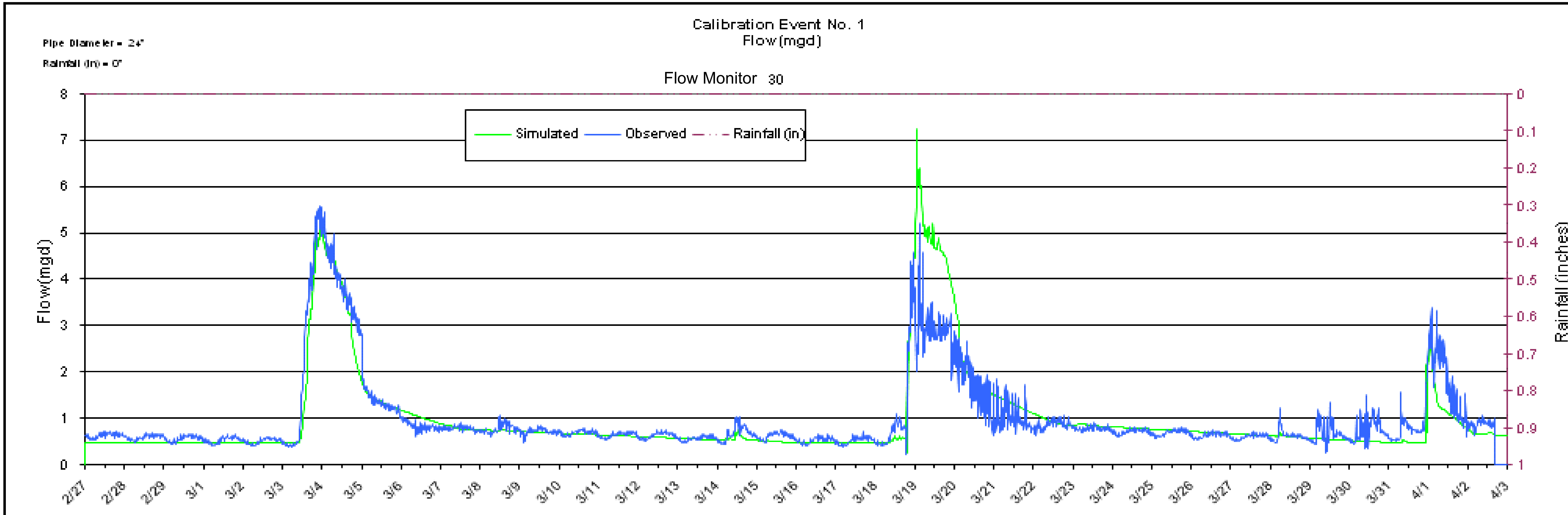
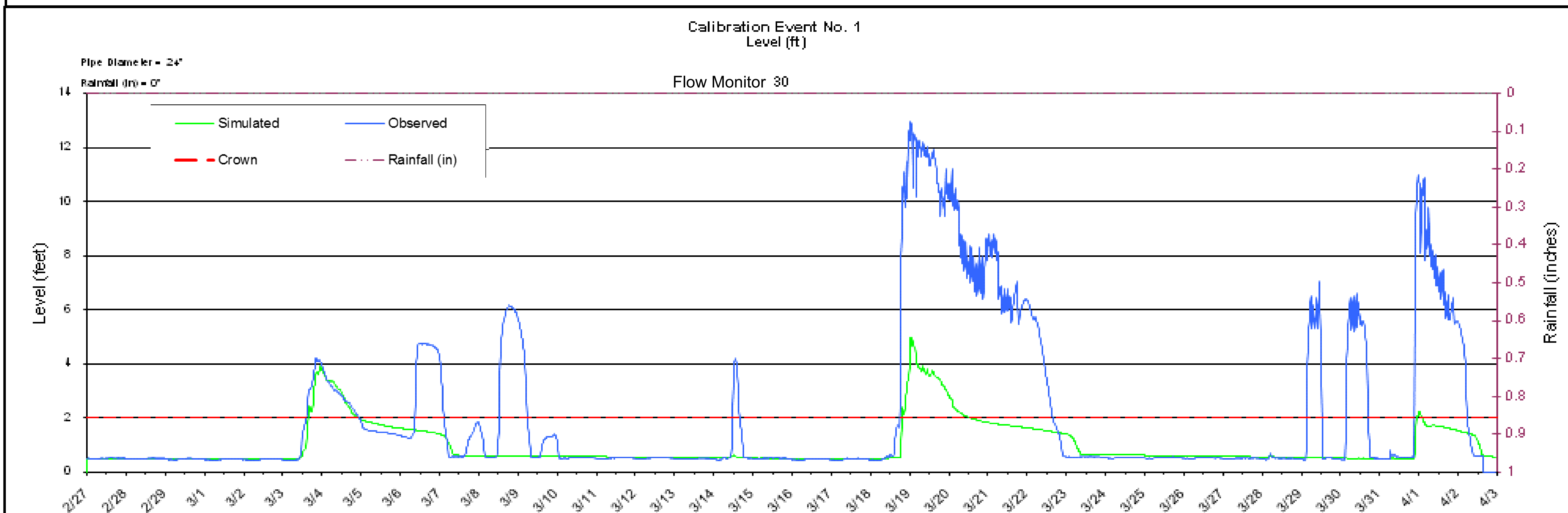
Pipe Diameter = 36"
Rainfall (in) = 11.23"
Flow Monitor 29
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)


Calibration Event No. 1
Level (ft)
Pipe Diameter = 36"
Rainfall (in) = 11.23"
Flow Monitor 29
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)


Calibration Event No. 1
Flow (mgd)
Pipe Diameter = 24"
Rainfall (in) = 0"
Flow Monitor 30
Simulated
Observed
Rainfall (in)
Flow (mgd)
Rainfall (inches)


Calibration Event No. 1
Level (ft)
Pipe Diameter = 24"
Rainfall (in) = 0"
Flow Monitor 30
Simulated
Observed
Crown
Rainfall (in)
Level (feet)
Rainfall (inches)

Appendix E

Design Period Selection Memorandum

Memorandum

To: *Project File*

From: *Kimberly Martin*

Date: *July 13, 2009, Revised July 16, 2010*

Subject: *Development of the Wet Weather Design Period for the Long-Term Control Plan (LTCP)*

The purpose of this technical memorandum is to describe the approach used to define the wet weather design period that will be used as the basis for the development of a Long-Term Control Plan (LTCP) for the Paducah-McCracken Joint Sewer Agency's combined sewer system. In order to assess the average annual volume, duration, and frequency of combined sewer overflows (CSOs) for the LTCP, a long-term or continuous simulation period was selected. Since a continuous simulation period, as opposed to a single design storm, includes periods of both dry weather and wet weather flows, it better accounts for the sequencing of storm events over time and, as such, allows a better evaluation of the effects of dry periods on parameters such as infiltration. In contrast, single event design storms focus only on wet weather processes and may be appropriate to preliminary assessments of proposed solutions, such as pipe sizing.

For this analysis, a five-year period was selected for the continuous simulation duration. This memorandum discusses the process for selecting this design period.

Historical Data

For this analysis, hourly rainfall records were obtained from the National Climatic Data Center for two sources in the Paducah area. Datasets are available at the Paducah Barkley Airport (15-6110) from August 1949 to September 1951 and from October 1984 to December 2006. A second data set is also available from the Paducah Walker Boat Yard (15-6117) for the period August 1948 through July 1995. **Table 1** provides the annual rainfall totals for both sites for years when complete datasets were available.

The two datasets, particularly the period of overlap, were analyzed as presented in a separate memorandum, *Development of the Wet Weather Design Storm for the Sanitary Sewer Overflow Plan (SSOP)*, dated October 17, 2008. Through this, it was established that the similarities between the two datasets suggest that the differences in storm volumes are more likely temporal than a bias at one of the locations, and thus use of a combined dataset would be appropriate. The two datasets were merged to create a representative rainfall record that covers a greater period. From August 1948 through September 1984, the Walker data was used; from October 1984 through December 2006, the Barkley data was used.

Table 1
Annual Rainfall Volumes

	Annual Rainfall Volumes (inches)			Annual Rainfall Volumes (inches)	
Year	Walker (15-6117)	Barkley (15-6110)	Year	Walker (15-6117)	Barkley (15-6110)
1949	52.4	27.2	1978	35.6	--
1950	63.9	70.6	1979	50.9	--
1951	58.2	40.2	1980	33.5	--
1952	39.2	--	1981	42.9	--
1953	37.0	--	1982	48.5	--
1954	35.6	--	1983	52.5	--
1955	36.7	--	1984	54.6	--
1956	34.3	--	1985	52.7	53.9
1957	61.8	--	1986	44.7	46.1
1958	41.1	--	1987	34.2	36.4
1959	45.2	--	1988	44.0	43.0
1960	38.4	--	1989	53.4	57.4
1961	55.5	--	1990	54.0	56.6
1962	51.2	--	1991	--	39.5
1963	26.3	--	1992	--	40.8
1964	49.3	--	1993	--	47.3
1965	45.8	--	1994	--	38.5
1966	47.9	--	1995	--	38.5
1967	47.5	--	1996	--	45.7
1968	47.4	--	1997	--	31.9
1969	43.3	--	1998	--	41.9
1970	44.7	--	1999	--	30.5
1971	42.8	--	2000	--	46.2
1972	53.0	--	2001	--	50.0
1973	49.3	--	2002	--	37.0
1974	41.6	--	2003	--	46.8
1975	53.2	--	2004	--	38.1
1976	33.7	--	2005	--	37.3
1977	40.4	--	2006	--	66.9

Using this combined dataset of hourly rainfall data, CDM's NetSTORM software (Sehlke et al., 2004)[1] was used to analyze precipitation intensity, duration, and frequency (IDF). The tool was used to statistically analyze and summarize event fixed-interval durations for various return periods. Results of the intensity-duration-frequency analysis are presented in **Table 2**.

Table 2
Paducah Combined Dataset
Intensity, Duration, Frequency Analysis

	Storm Depth (inches) at Recurrence Interval (years)							
Duration (hours)	**0.5**	**1**	**2**	**5**	**10**	**25**	**50**	**100**
1	0.9	1.17	1.41	1.68	1.90	2.23	2.53	2.87
2	1.22	1.52	1.84	2.17	2.43	2.81	3.14	3.52
3	1.38	1.69	2.05	2.46	2.82	3.41	3.96	4.64
4	1.50	1.86	2.20	2.64	3.05	3.78	4.52	5.50
6	1.68	2.06	2.45	2.93	3.40	4.22	5.07	6.19
12	1.92	2.50	3.01	3.64	4.21	5.15	6.07	7.23
24	2.40	3.06	3.60	4.31	4.95	6.04	7.11	8.46

Determination of Continuous Simulation Period

The long-term combined dataset was analyzed to establish a five-year continuous simulation period that appears representative of the long-term record, using a series of screening criteria.

Large Storm Events

In order to ensure that statistics developed through the continuous simulation are not biased towards large storm events, the long-term dataset was evaluated to exclude storm events with return periods greater than ten years for durations of 1, 2, 3, 4, 6, 12, and 24 hours. Storm events with return periods greater than five years are shown in **Table 3**. Based on results of the table below, the following years were excluded: 1949, 1958, 1959, 1962, 1964, 1967, 1969, 1983, 1985, 1989, 1992, 1996, 1998, 1999, and 2000.

[1] *World Water Congress 2004: Critical Transitions in Water and Environmental Resources Management*, Gerald Sehlke, Donald F. Hayes, David K. Stevens - Editors, June 27 – July 1, 2004, Salt Lake City, Utah, USA; "NetSTORM — A Computer Program for Rainfall-Runoff Simulation and Precipitation Analysis", Mitch Heineman, CDM

Table 3
Paducah Combined Dataset
Large Storm Events

	Recurrence Interval (years) at Duration (hour)							
Date	**1**	**2**	**3**	**4**	**6**	**8**	**12**	**24**
9/5/1949	2	3	2	4	10	10	4	2
2/12/1950	<1	<1	<1	<1	1	1	1	1
6/28/1951	7	4	5	6	3	2	1	1
7/15/1958	1	<1	16	8	8	5	2	1
7/16/1958	5	2	<1	<1	<1	<1	<1	<1
5/27/1959	8	13	7	6	2	1	1	<1
9/9/1959	9	6	6	5	2	1	1	1
6/14/1961	2	4	4	3	2	2	13	5
9/13/1962	37	23	13	10	7	4	2	7
3/4/1964	2	3	9	37	37	37	37	37
3/8/1964	<1	<1	<1	<1	1	1	7	16
9/11/1965	<1	<1	<1	1	3	6	6	3
12/31/1965	<1	<1	<1	<1	<1	<1	<1	1
5/14/1967	<1	1	2	3	5	4	3	<1
7/10/1967	13	5	4	4	2	1	1	<1
9/9/1967	2	6	4	3	2	1	1	<1
6/13/1969	5	16	23	13	9	6	2	2
4/19/1973	4	3	3	4	6	7	3	2
5/27/1973	6	5	5	4	2	1	1	<1
4/23/1977	6	4	2	2	1	1	1	<1
4/29/1983	<1	1	2	2	4	9	5	10
10/1/1984	<1	<1	<1	<1	1	2	8	6
9/5/1985	23	98	98	98	98	98	98	98
2/13/1989	<1	1	1	1	3	8	23	23
6/28/1989	1	10	37	23	13	13	9	4
10/16/1989	4	2	3	5	4	4	2	1
2/15/1990	<1	1	1	1	1	1	5	<1
8/23/1992	1	7	10	7	5	3	2	1
11/7/1996	1	2	3	9	23	23	16	8
6/9/1998	1	1	1	2	6	3	<1	<1
7/30/1998	98	9	6	3	2	2	2	1
10/6/1998	<1	1	1	1	3	4	3	6
4/3/1999	16	8	4	3	2	1	1	1
1/2/2000	<1	<1	<1	<1	3	3	6	13
7/29/2000	1	2	8	16	16	16	10	4
12/16/2001	<1	<1	<1	<1	<1	<1	1	3
8/30/2005	<1	1	2	2	4	5	2	<1
9/22/2006	1	4	2	2	1	1	4	9

Average Annual Precipitation

The long-term dataset was further evaluated relative to the average annual precipitation to prevent the selection of extremely wet or dry years and to ensure that the continuous simulation period reflects the average annual precipitation.

Figure 1 shows annual precipitation from the combined dataset from 1949 through 2006 and the average annual precipitation of 42.8 inches. As shown, there are several years, such as 1949, 1957, and 2006 which are extremely wet years, while others, such as 1963, are examples of drought years. Years containing extreme averages were excluded from further evaluation.

Additionally, examination of the five-year rolling average precipitation indicates that several five-year periods would not represent the average annual precipitation. These were also excluded from potential continuous simulation periods.

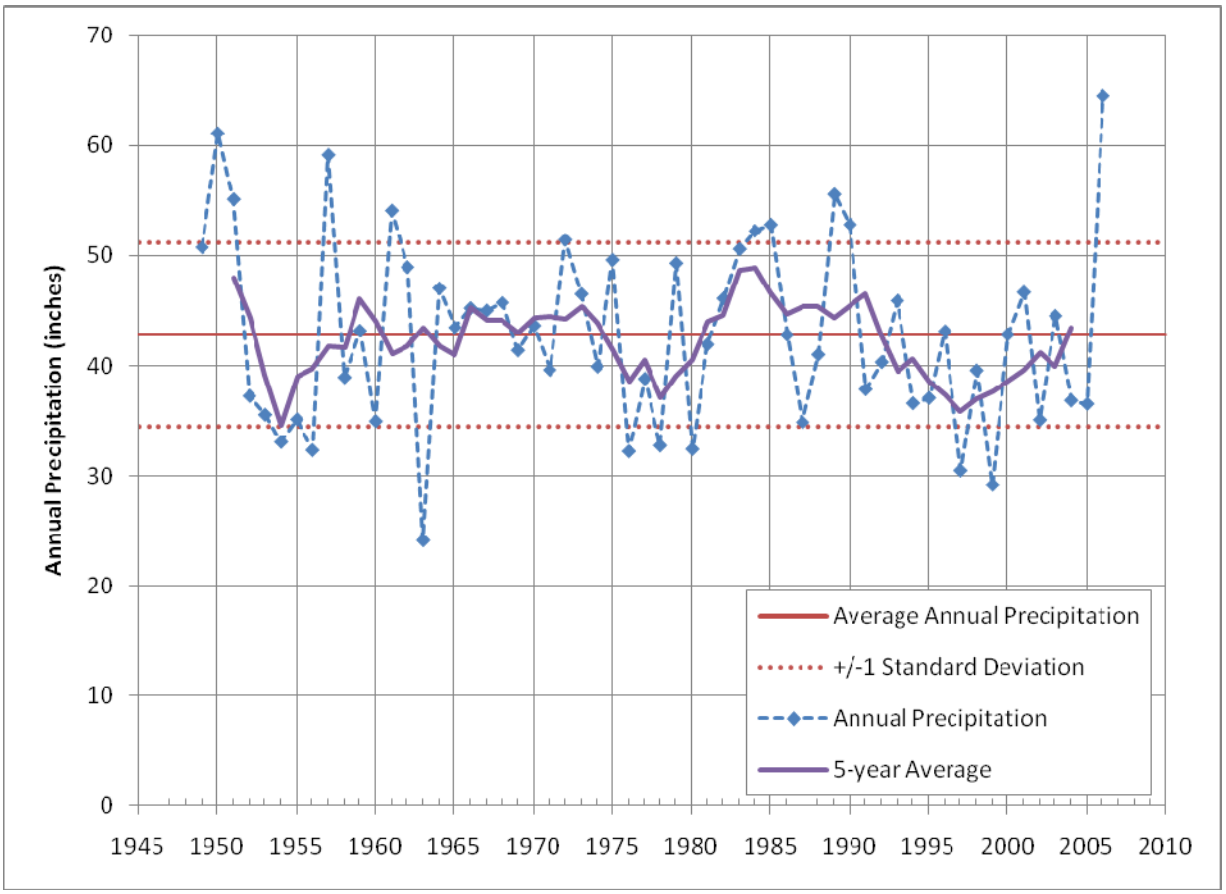


Figure 1
Annual Precipitation for Paducah

Distribution of Storm Events

In addition to the above criteria, the long-term dataset was further evaluated to select a continuous simulation period that contained an appropriate distribution of significant storm events. Ideally, the five-year continuous simulation period would include five 1-year storms, two to three 2-year storms, and one 5-year storm at durations from 1 to 24 hours.

Upon review, the following years were selected for the continuous simulation period: 1965, 1973-1975, and 1977. For this five-year period, the number of storm events for a given recurrence interval and duration are shown in **Table 4**. Although these do not match the ideal storm distribution, they are reasonably close.

Table 4
Count of Storms by Recurrence Intervals

Minimum Recurrence Interval	Number of Storm Events at Duration							
	1 hour	2 hour	3 hour	4 hour	6 hour	8 hour	12 hour	24 hour
1 year	5	6	5	6	5	4	4	4
2 year	4	4	3	2	2	3	2	2
5 year	2	1	0	0	1	2	1	0

A comparison of the storm depths at 3-month, 6-month, 1-year, 2-year, and 5-year recurrence intervals determined for the long-term dataset and the continuous simulation period is shown in **Table 5**.

Additionally, because the frequency of CSO events can be sensitive to events smaller than a storm with a 3-month recurrence interval, the average annual number of small events for the selected continuous simulation period was compared to the full dataset. This comparison is shown in **Table 6**.

Table 5
Comparison of Storm Depths

Recurrence Interval	Duration	Storm Depth (inches)	
		Long-Term Dataset	1965, 1973-1975, 1977
3-month	1-hour	0.71	0.70
	6-hour	1.35	1.40
	12-hour	1.60	1.70
	24-hour	1.85	1.90
6-month	1-hour	0.90	0.90
	6-hour	1.68	1.70
	12-hour	1.92	2.00
	24-hour	2.40	2.28
1-year	1-hour	1.17	1.10
	6-hour	2.06	2.00
	12-hour	2.50	2.13
	24-hour	3.06	2.60
2-year	1-hour	1.41	1.70
	6-hour	2.45	2.56
	12-hour	3.01	2.88
	24-hour	3.60	3.40
5-year	1-hour	1.68	2.00
	6-hour	2.93	2.97
	12-hour	3.64	3.62
	24-hour	4.31	4.13

Table 6
Comparison of Small Storm Events

Event Size (inches)	Average Number of Events per Year	
	Long-Term Dataset	1965,1973-1975,1977
<0.1	42.5	42.6
0.1 to 0.25	17.1	16.4
0.25 to 0.5	17.6	18.4
0.5 to 1.0	15.4	16.6
1.0 to 2.0	8.7	8.2
>2	2.5	2

Screening for Major Snow Events

According to National Weather Service records, the average seasonal snowfall in the Paducah area is 10.2 inches. Because snow and snowmelt are not significant drivers of CSOs in the area, snowmelt was not included in the hydraulic model developed to support the LTCP. However, the selected continuous simulation period (1965, 1973-1975, 1977) was reviewed relative to seasonal snowfalls. The winters including years 1973 to 1975 received lower than average snowfall, while the 1964-1965 season and the 1977-1978 season received 19.0 inches and 35.9 inches, respectively. For the 1977-1978 season, the majority of the snow recorded fell in January 1978, which is not included in the selected continuous simulation period. For the 1964-1965 season, hourly precipitation records were reviewed, and it did not appear that any individual storm event would skew the results.

Summary

Based on this analysis, the five year period including the years 1965, 1973-1975, and 1977 have been determined to reasonably represent the full historical precipitation record for the Paducah combined sewer system. This dataset will be utilized in conjunction with the hydraulic model to predict annual CSO volume, duration, and frequency and to evaluate the effectiveness of potential improvements for inclusion in the LTCP.

Appendix F

Discussion on Floodwall Impacts

Introduction

In response to the Paducah-McCracken Joint Sewer Agency (JSA) Long Term Control Plan and proposed combined sewer overflow (CSO) control projects, the Kentucky Department for Environmental Protection (KDEP) and the U.S. Environmental Protection Agency (EPA) requested additional descriptions of the potential impacts of the floodwall pump stations on JSA's combined sewer system and on the feasibility of certain alternatives for control of the CSO outfalls impacted by the floodwall pump stations (letter from EPA and KDEP dated January 30, 2015). This technical report serves as a response to those comments.

Floodwall Operation

Like many river cities, Paducah is protected from flooding during high river stages through a system of concrete floodwalls, earthen levees, gates, and flood pump stations. Since 1950, this system has been operated and maintained by the City of Paducah, and although design of improvements to the floodwall system are currently underway, no significant changes to the operation of the flood protection system is expected.

During elevated levels in the Ohio River (and its tributaries in the area), the City of Paducah closes gates to isolate portions of Paducah from river flooding. This includes closing gates associated with the following CSO outfall pipes, as shown in Table 1. Note that the outfall pipe associated with EPA 003 at Terrell also serves as the effluent discharge for the WWTP. In addition to the pump stations noted in Table 1, Floodwall Pump Station 11 is located on Island Creek, within the backwater zone of the Tennessee River. Floodwall pump stations locations are shown on Figure F-1 (located at the end of this appendix).

Table 1 CSOs and Associated Floodwall Pump Stations

CSO Location	CSO Description	Floodwall Pump Station ID Number	River Stage for Gate Closing	Average Annual Number of Days Closed (2007-2014)
EPA 002	Noble Park	1	42	5
EPA 003	Terrell	2	27.5	35
EPA 004	Harrison	4	35.5	14
EPA 006	Husbands	9	30	30
EPA 007	Husbands	10	30	30

When the floodwall gates are closed, the City of Paducah begins manual operation of the floodwall pump stations. Excluding Floodwall Pump Station 2, which is associated with Terrell and the WWTP, these stations are operated during local rainfall events to pump local runoff (including CSO discharges) to the river system when closed gates prevent free flow to the river. Floodwall Pump Station 2, however, must be continuously operated during high river stages (above 27.5 feet) in order to discharge the WWTP's effluent to the Ohio River.

The floodwall pump stations are shallow stations, which were designed to operate only when depths at the pump station are fairly high. Figure F-2 shows a portion of the construction drawings for Floodwall Pump Station 1, located in Noble Park. As shown, the minimum pumping stage (when the pumps are turned off) is 330 feet which corresponds to a depth in the channel leading to the station of 4 feet. The maximum pumping stage (highest depth before the pumps are turned on) is shown on a different sheet as 336 feet, or a channel depth of 10 feet. While this pump operating protocol is sufficient to prevent local flooding, these depths could potentially present problems for CSO control facilities located near these floodwall pump stations. These problems could include both hydraulic gradient issues for facility hydraulic design, as well as flood protection issues for facility site design.

Floodwall Pump Station 1 is the only one associated with JSA's CSOs that has an open channel leading into the floodwall pump station. The remaining stations have closed pipe systems, although their design and operation is similar to Floodwall Pump Station 1. As a result, there is a significant likelihood that the outfall pipes store flow and become surcharged when the floodwall gates are closed.

Significant surcharging has been observed in proximity to EPA 007 when the floodwall gates are closed. Although Floodwall Pump Station 10 can be used to discharge flows from EPA 007 to the river, that station is small and rarely utilized. Instead, the combined sewer system stores flows until EPA 006 and its associated floodwall pump station (9) are activated. The outfall pipe for EPA 006 is located between 2 and 3 feet higher than the outfall pipe for EPA 007. This configuration results in surcharging and temporary in-system storage at this location. These flows are routed through the Husbands Pump Station for treatment at the WWTP.

In general, the complexity of the floodwall pump stations may affect the feasibility of some CSO control alternatives, or at a minimum, require additional components and design features to allow the CSO control facilities to be isolated and protected from these impacts. Additional information is provided as part of the alternatives evaluation for the individual CSOs impacted by the floodwall.

Paducah LTCP

Figure F-1 - Floodwall Pump Stations

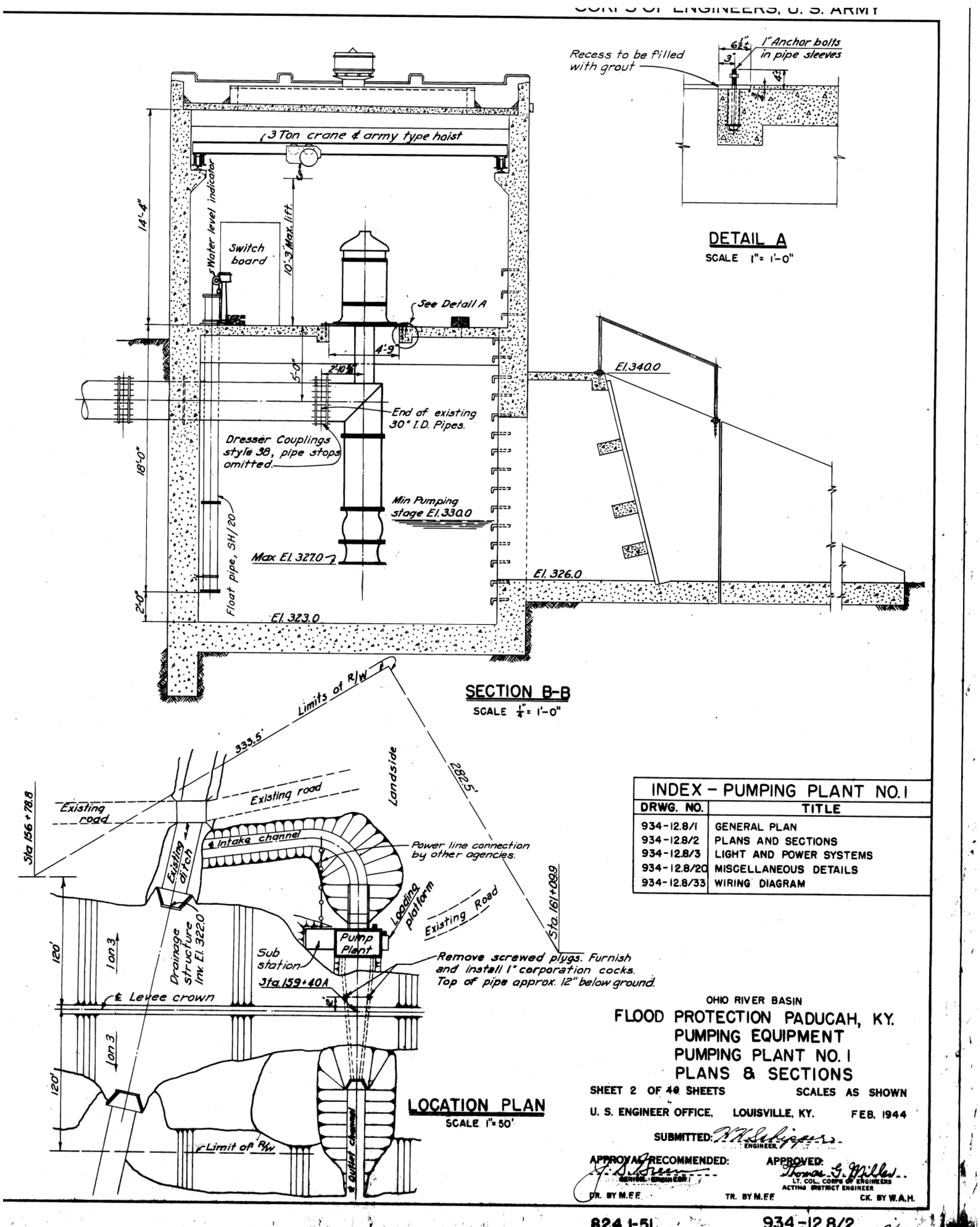


Figure F-2. Example Floodwall Pump Station Drawing

Appendix G
Discussion on Anticipated Treatment Levels

Introduction

In response to the Paducah-McCracken Joint Sewer Agency (JSA) Long Term Control Plan and proposed combined sewer overflow (CSO) control projects, the Kentucky Department for Environmental Protection (KDEP) and the U.S. Environmental Protection Agency (EPA) requested an engineering discussion on how fine screens, high rate treatment, and other technologies meet the requirement for treatment levels equivalent to primary clarification (letter dated January 30, 2015). This technical report serves as a response to those comments.

Primary Clarification

Primary clarification, or primary treatment, typically follows preliminary treatment in the wastewater treatment plant process. While preliminary treatment is intended to remove gross solids, such as rags or grit, which may damage downstream equipment, primary clarification utilizes a physical process, usually sedimentation, to remove floating and settleable materials (Metcalf & Eddy 2003). Primary treatment typically removes 35 to 65 percent of total suspended solids (TSS), and results in a 20 to 40 percent reduction of biochemical oxygen demand (BOD), although BOD reduction is not the goal of primary clarification (Lindeburg 2003). However, removal rates are dependent not only on the design and operation of the primary clarification processes but also on the characteristics of the wastewater (removal rates decrease as influent concentrations decrease).

The above removal efficiencies are based on typical municipal wastewater, not the highly variable and often dilute flows associated with combined sewer overflow discharges. Figure G-1 (Metcalf & Eddy 2003) shows an example of the variations in BOD, TSS, and fecal coliform measured in a combined sewer system during and following a rainfall event. As shown in the figure, BOD and fecal coliform decrease during the rainfall event when runoff flows are high and return to concentrations typically found in municipal wastewater as the flow returns to normal (dry weather) levels. However, TSS concentrations are slightly increased during the initial portion of the runoff response to a rainfall event, representing the "first flush" effect, and then may decrease due to dilution as the event continues, eventually returning to levels typically found in municipal wastewater. The characteristics of combined sewer overflows, therefore, may vary considerably from outfall to outfall, and from event to event, depending on numerous factors, including the rainfall intensity and duration, the characteristics of the drainage basin, and the system hydraulics that dictate when the overflow occurs.

While traditional primary clarification units (e.g. sedimentation tanks) have been used for CSO control, these installations are relatively rare and this approach to CSO treatment has more recently been replaced by other technologies (including those discussed below). This is due to the high costs for both construction and operations and maintenance (O&M) of these units, as well as the limited removal efficiencies of traditional sedimentation with the relatively dilute solids concentrations (and specific gravity characteristics) typical of CSO discharges. The use of traditional primary clarification units will not be considered further for the JSA system.

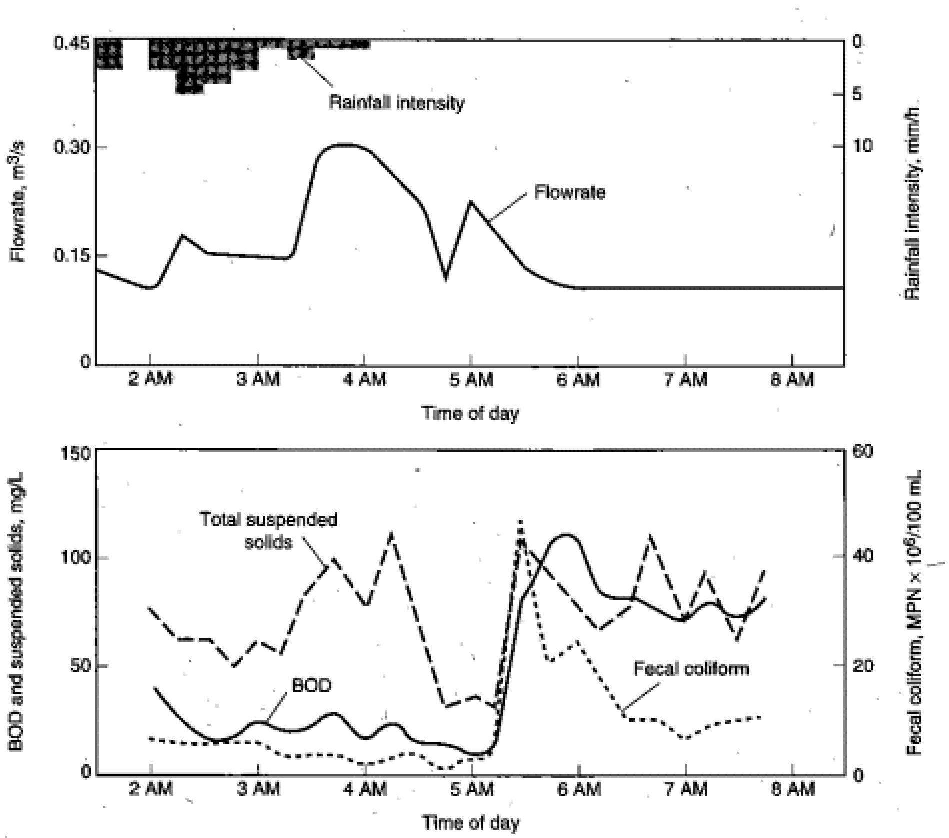


Figure G-1. Example variations in combined sewer flow (Metcalf & Eddy 2003)

Vortex Separators

Because traditional sedimentation processes are often costly and inefficient for CSO treatment, alternative solids removal technologies were developed for application to dilute urban runoff and CSO flows. Among these alternative approaches, vortex separators emerged in the 1980s as the most popular. Since then a few full-scale installations have been put into service, although most installations were constructed as test or demonstration facilities.

In recent years, vortex separators have fallen out of favor, as actual operating data has shown disappointing results. No vortex units have been installed in the U.S. in recent years, and this technology will not be considered further for the JSA system.

Fine Screens

Fine screens can be used as a preliminary treatment process, applied for solids removal in lieu of primary clarifiers (typically at small treatment plants), or used to treat combined sewer overflows. There are numerous types of screens that may fall into the “fine screen” category, but fine screens are generally defined as screens with openings ranging from 0.2 mm to 6 mm (Metcalf & Eddy 2003). Smaller opening sizes typically result in better solids capture, but that additional capture comes with greater headloss associated with the screen, higher operation and maintenance costs, and a greater chance of screen clogging, binding, or other malfunction.

When fine screens are utilized in place of sedimentation, removal efficiencies are usually lower than that of traditional sedimentation. In those cases, fine screens with openings from 1 mm to 6 mm typically achieve removal efficiencies of 15 to 30 percent for suspended solids, 15 to 25 percent for BOD, and 10 to 20 percent for bacteria loadings (Water Environment Federation 1998).

The fine screens currently considered for use in the JSA system are those with 4 to 6 mm openings (approximately 0.157 to 0.236 inches), which have been used in other CSO locations and have been found to be highly effective at the removal of solids and floatables, while keeping headloss reasonable for the system. If fine screens are selected, additional evaluation of the screen opening size can be conducted during preliminary design with a preference given to smaller screen openings.

Fine screens alone are not anticipated to achieve the TSS and BOD removal rates typically associated with primary clarification. However, fine screens are commonly used for enhanced solids and floatables control and as a preliminary process to support disinfection of CSO discharges. EPA published additional information on the use of screens for CSOs (EPA 1999), including the following information on typical fine screening capabilities and limitations:

- The primary function of CSO screening technology is to remove large solids, rags, and floatables from the overflow. One example of successful CSO fine screen installations is at the Detroit Water & Sewer CSO screening and disinfection facilities; during a testing period that included 13 overflow events at 2 different facilities, only two pieces of identifiable sanitary waste were observed. The solids removal rate was estimated at over 99%.
- Filtering of smaller particles increases as the mat of solids on the screen increases; the mat can catch smaller particles that would otherwise pass through the screen opening. This reinforces the coincidental capture of BOD and TSS that are attached to large particles that are captured.
- As part of the document's applicability section, it is noted that screens are frequently used at remote CSO sites for removal of large solids and perform well.
- The EPA document notes that there has been less success with removal of fine solids from stormwater and CSO discharges, however some proprietary methods developed more recently, such as Romag screens, have addressed this issue. Romag screens are one of the fine screen technologies reviewed for the JSA system.

Micro Screens

Micro screens have smaller opening sizes than fine screen, typically from 10 microns to 0.5 mm, and may also take the form of filter fabrics. As a result, these are typically preceded by screens with larger openings in order to reduce the likelihood of clogging. As with fine screens, the anticipated BOD and TSS removal efficiencies are dependent on the characteristics of the wastewater (overflow) stream as well as the type / configuration of screen utilized. Typical suspended solids removal achieved with microscreens ranges from 10 to 80 percent, with an average of 55 percent (Metcalf & Eddy 2003). A rotary drum type screen with 0.25 mm openings was observed to remove 25 to 50 percent of BOD and 25 to 45 percent of TSS (Metcalf & Eddy 2003) when used to replace primary sedimentation.

Micro screens are not in common use for CSO applications due to the high potential for clogging with typical overflow characteristics (high flow rates and high solids loads). This technology is not considered appropriate for JSA's system and will not be considered further.

High Rate Treatment – Ballasted Flocculation

The high rate treatment systems considered by JSA as part of the CSO control alternatives consist of ballasted flocculation units. Two commonly used commercial processes are Actiflo by Kruger and DensaDeg by Infilco. These proprietary processes use a flocculation aid and a ballasting agent to form dense microfloc particles which rapidly settle. Generally, the following removal rates can be anticipated when ballasted flocculation is utilized to treat wet weather flows:

	BOD Removal (%)	TSS Removal (%)
At low overflow rates	35-50	70-90
At medium overflow rates	40-60	40-80
At high overflow rates	30-60	30-80

(Metcalf & Eddy 2003)

The Actiflo process was also tested in Galveston, Texas, under simulated CSO conditions. TSS removal was observed to range from 80 to 94 percent, and BOD removal ranged from 48 to 75 percent (EPA 2003). Additionally, results of pilot testing of both Actiflo and DensaDeg conducted by Fort Worth indicate that BOD and TSS removals of 36 to 63 percent and 74 to 92 percent, respectively, was observed (EPA 2003).

These results confirm that not only does the ballasted flocculation high rate treatment process meet the removal rates typical of tradition primary clarification, they potentially can exceed those rates. Ballasted flocculation units are more costly to construct and operate/maintain than fine screens, but provide higher levels of treatment for CSO discharges. This technology will be carried forward as a feasible option for consideration in selecting the recommended facilities for the JSA LTCP.

High Rate Treatment – Lamella Plate Clarification

Another type of high rate clarification is Lamella plate clarification, which is typically utilized in conjunction with coagulation and flocculation units. This system utilizes a series of inclined plates to reduce the settling time and increase the surface area over which particles can settle out. Generally, the following removal rates can be anticipated when Lamella plate clarification is utilized to treat wet weather flows:

	BOD Removal (%)	TSS Removal (%)
At low overflow rates	45-55	60-70
At medium overflow rates	35-40	65-75
At high overflow rates	35-40	40-50

(Metcalf & Eddy 2003)

Additionally, results of pilot testing conducted by Fort Worth indicate that BOD and TSS removals of 41 to 57 percent and 53 to 73 percent, respectively, were observed (EPA 2003).

These results suggest that Lamella plate clarification would meet or exceed the removal rates typical of traditional primary clarification. This technology is a variation of the ballasted flocculation approach discussed above, and may be considered later in selecting the specific technology approach for the recommended facilities in the JSA LTCP. For purposes of initial screening, High Rate Treatment will assume a ballasted flocculation process.

References

Environmental Protection Agency. 1999. Combined Sewer Overflow Technology Fact Sheet: Screens.

Environmental Protection Agency. 2003. Wastewater Technology Fact Sheet: Ballasted Flocculation.

Metcalf & Eddy. 2003. Wastewater Engineering: Treatment and Reuse, Fourth Edition.

Lindeburg, Michael. 2003. Civil Engineering Reference Manual for the PE Exam, Ninth Edition.

Water Environment Federation and American Society of Civil Engineers. 1998. Design of Municipal Wastewater Treatment Plants, WEF Manual of Practice No. 8, Fourth Edition.

Appendix H

EPA 002 Alternative Analysis

Note 1: Costs presented are screening-level estimates for comparison of the alternatives. Costs of selected alternatives will be reviewed in further detail for the financial analysis.

Note 2: When additional land is required to site the facilities, the placement of the facilities and the selected parcels are shown for illustrative purposes only. Alternative nearby sites would also be evaluated during design.

EPA 002, shown in **Figure H-1**, is located adjacent to Noble Park and discharges to an unnamed tributary of Perkins Creek. Pedestrian and automobile access is currently discouraged by the presence of a locked gate off Noble Park Trace. Sampling at Perkins Creek was included in the water quality monitoring program, although the creek is not included on either the 303(d) or 305(b) lists. For more details concerning the water quality monitoring program, see Section 2 of the LTCP.

EPA 002 consists of three separate outfall pipes that collect and transport combined sewer from the approximately 1130-acre combined sewer system tributary area to the outfall. This outfall contributes the second greatest annual average CSO overflow volume in the system. Approximately one third of the drainage area for this outfall is served by direct separate stormwater systems that discharge directly to the outfall pipes, which also serve as stormwater conveyance. As a result, only approximately 40 percent of average annual CSO volume discharged at EPA 002 originates in the combined system. The remaining 60 percent of the flows originate from separate storm sewers that directly enter the outfall pipes. In other words, the majority of flow from this outfall is not combined sewage but separate stormwater, and the direct stormwater contributions result in discharges at EPA 002 with each runoff-producing rain event. The tributary area for EPA 002 is shown in **Figure H-2**.

The discharge point for EPA 002 is located less than 400 feet from the flood control levee. During normal conditions, flows from the CSO outfall pass through the open flood control gates at the base of the levee. When the Ohio River level reaches 42 feet, the levee gates are closed, and the floodwall pump station is operated by the City of Paducah to transfer flows across the levee. Because of the original design of the floodwall pump station, when the gates are closed, the operation of the pump station results in a depth of water in the discharge channel for EPA 002 between four and ten feet, which affects the possible CSO control alternatives for EPA 002. Based on a review of available data for 2007 through 2014, the flood gates are typically closed approximately once per year for an average of duration of 17 days per occurrence with 8 of those days receiving rainfall. Alternatives evaluated below include slide gates or other devices that can be used to protect and isolate the new facilities if backwater effects are experienced from the flood pump station's operation.

Evaluation of CSO control alternatives for this outfall assume a target percent capture of 93.4 percent, which is consistent with the knee of the curve sizing for screening as presented in the LTCP. This results in a required sizing of 40 million gallon per day (mgd) for alternatives based on overflow treatment at this site. The target percent capture will be utilized to compare alternatives; however, JSA recognizes that the need to achieve a minimum system-wide capture of 85 percent and may adjust the sizing of the selected alternative at EPA 002 to achieve this goal. The 93.4 percent capture results in 19 CSO events per year relative to 68 events per year under the current system.

It is noted that every alternative discussed herein will be evaluated based on a configuration that keeps treatment units out of the flood zone created by closure of the flood control gates and that any outfall collection structure will be designed to minimize the possibility of water in the impoundment backflowing into the collection structure.

The following alternatives were evaluated for EPA 002:

A. Separation of the tributary area to this outfall
B. Storage
C. Pumping to a new wet weather treatment facility to be constructed near the WWTP (no on-site storage)
D. Fine screening
E. Fine screening with disinfection
F. High rate treatment
G. High rate treatment with disinfection

A. Separation

System separation was considered for this large tributary area, but total project costs are expected to exceed $110 million. The unit construction cost for separation presented in the LTCP ($100,000 per acre) was revised to $80,000 per acre based upon the costs associated with the separation project for EPA 012. With anticipated engineering, legal, and other administrative costs, the assumed total project unit cost is $100,000 per acre. Costs associated with the separation of EPA 014 were lower than this value but are not believed to be appropriate for planning purposes since that project was completed in conjunction with Department of Transportation work. However, since the tributary area for EPA 002 also includes larger, conveyance sewers the above estimate may be somewhat understated.

Sewer separation for a portion of the tributary may be feasible; however, separating a portion of the area would not eliminate the need for CSO controls for the remaining CSO discharge.

B. Storage

In order to achieve the target percent capture, the storage alternative must consider three components: the rate at which flow must be captured and stored, the volume of storage required, and how quickly the stored flows can be drained back to the system for treatment. Because of the location of EPA 002, stored flows were assumed to be pumped to the WWTP as treatment capacity becomes available. Utilizing the results of the hydraulic model, several combinations of those three factors were analyzed in order to assess the feasibility of this alternative and to attempt to determine appropriate sizes for those three components while achieving the target percent capture. The following sizes were estimated, and the resulting facility is shown as **Figure H-3**:

- Pumping rate into storage: 40 mgd
- Required storage: 85 million gallons
- Dewatering rate to WWTP: 8 mgd (the limit of available post-event plant capacity)

Elements of this system include the following:

1. A diversion structure that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 40 mgd to a new coarse screening facility; (2) flow over 40 mgd on any given event goes over a weir directly to the outfall.
2. A coarse screening facility upstream of the storage tank pump station. The screening capacity would be 40 mgd, with two 20 mgd screen channels and a 40 mgd bypass channel. Screen openings are assumed to be 1.5-inch size, which is meant to protect the pumps.
3. A low head, 40 mgd storage tank pump station. As many overflow events are low volume, the station would consist of a constant speed, base flow pump (2,000 gpm) to handle the low flow events and four 13.4 mgd (7,650 gpm) pumps, all variable frequency drive (VFD) operated, operating on a lead-lag1-lag2-standby scheme. The base flow pump would turn off at a preset wetwell level and would not turn on again until the next storm cycle; the VFD-driven pumps would operate for the rest of the cycle. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 40 mgd flow (140,000 gallons).
4. 85 million gallons of storage, which is the storage required to achieve the target percent capture given dewatering limitations of the WWTP. The storage is assumed to be above ground tanks, four 21.25 million gallon tanks, as shown in **Figure H-3.** Prestressed concrete tanks are assumed at this stage, but steel would also be considered at the time of construction if there is an indication that they can be cost-competitive. Buried storage would be more expensive. Tank dimensions would be approximately 275 feet in diameter and 50 feet tall. Overflow standpipes would be constructed in each tank, with overflow elevation set to provide 2 feet of freeboard. Tank washdown systems are assumed to be provided.
5. An 8 mgd pump station to pump flow to the WWTP, which is sized based on the typical maximum capacity available following storm events. Two 8 mgd (5,000 gpm) submersible pumps, VFD operated, are included. As with the tank inflow pump station, Flygt N type submersible pumps (or equivalent) would be provided. The pump station would be underground (but not as deep as the tank inflow pump station), with a wetwell sized to provide 5 minutes of detention time at the 8 mgd flow (28,000 gallons).
6. A force main routed from the pump station to the WWTP. Existing gravity sewers can be reviewed to assess available capacity, which may allow a reduction in the length of the force main. The connection point to the gravity system or the WWTP's influent pipe/channel would be determined during detailed design, in coordination with the project's hydraulic analysis.
7. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 40 feet by 25 feet, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.

The screening-level cost estimate for this project is $171 million.

The above option is not practical for three primary reasons: (1) cost; (2) the low dewatering rate drives the storage volume requirement to 85 MG; and (3) dewatering full tanks would require over 10 days (and this assumes that there are no other rain events within the period), which is too long to retain stored flow.

It is noted that it may be possible to define a hybrid storage-treatment option for which the combination of storage and treatment would be more reasonable. This would entail the use of some form of high-rate treatment (for solids removal and disinfection of the dewatered flow from storage) at the existing WWTP. It has been determined through model simulations of the system that multiple combinations of storage and dewatering could achieve the defined target capture if that volume could be dewatered at through a treatment facility. Those options can be explored further as the system-wide alternative evaluations continue.

C. Pumping to a new wet weather treatment facility to be constructed near the WWTP (no on-site storage)

This alternative consists of diverting a maximum of 40 mgd through a coarse screening facility and pump station for transport to a new wet weather treatment facility located near the WWTP that would receive wet weather flows from other CSO outfalls. The flow being pumped to this facility would be pumped to the WWTP, where the flow can be routed to the WWTP if there is available capacity or to the dedicated wet weather treatment facility if WWTP capacity is not available.

Elements of this system include the following (See **Figure H-4**):

1. A diversion structure that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 40 mgd to a new coarse screening facility; (2) flow over 40 mgd on any given event goes over a weir directly to the outfall.
2. A screening facility upstream of the pump station. The screening capacity would be 40 mgd, with two 20 mgd screen channels and a 40 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to protect the pumps.
3. A 40 mgd pump station. As many overflow events are low volume, the station would consist of a constant speed, base flow pump (2,000 gpm) to handle the low flow events and four 13.4 mgd (7,650 gpm) pumps, all VFD operated, operating on a lead-lag1-lag2-standby scheme. The base flow pump would turn off at a preset wetwell level and would not turn on again until the next storm cycle; the VFD-driven pumps would operate for the rest of the cycle. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 20 minutes of detention time at the 40 mgd flow (560,000 gallons).
4. A force main routed from the pump station to the new wet weather treatment facility. The connection point to the influent pipe/channel would be determined during detailed design, in coordination with the project hydraulic analysis.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30 feet by 20 feet, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. A new wet weather treatment facility located near the WWTP. For purposes of this analysis, it is assumed that this facility would consist of a high rate treatment (HRT) and disinfection facility that would provide the equivalent of primary treatment and disinfection for flows from outfall EPA 003 as well as potentially other remote outfalls. Costing assumes that an HRT and disinfection facility is the recommended CSO control project to address EPA 003. Costs to send additional flow are allocated on a per-mgd basis for flows over 70 mgd (the assumed capacity of the facility to treat only EPA 003) at a rate of $300,000 per mgd. For EPA 002, this amounts to an additional $12 million. At this time, the HRT system is being evaluated using two vendors – Actiflo and DensaDeg. A detailed analysis of these systems should be performed during the design of the project, if this is the preferred alternative. For now, though, preliminary cost and system “footprint” data have been collected for the two treatment trains and the costs among the two systems have been averaged to determine a cost opinion for the work of this alternative.

7. As the captured flow is being pumped to treatment, there would be no additional treatment or disinfection facilities provided at this location for flows that go directly to the outfall.

The screening-level cost estimate for this project is $31.3 million.

This alternative provides a sound technical solution to treating flows that currently discharge at EPA 002 without placing a significant amount of maintenance-heavy or surface-disruptive structures in the park. However, the option may not be feasible due to the limited capacity of the discharge sewer and/or the floodwall pump station that serves as the outfall pipe for EPA 003 as well as the effluent discharge pipe for the WWTP. Further evaluation is needed to assess of the available capacity of the existing system. No improvements to the discharge sewer or floodwall pump station are included in this screening-level cost estimate.

This alternative does not include on-site storage, but it is possible that a hybrid alternative could be considered as the system-wide solutions are evaluated that balances the need for storage and wet weather treatment. Adding storage could allow for pumping more flow directly to the WWTP one or two days after the storm event; this could reduce the amount of HRT treatment that would be required. On-site storage would also reduce the peak flow rates that drive the pump station and force main sizing requirements.

D. Fine Screening

This alternative consists of diverting the flow from the outfalls through a fine screening system prior to discharge. This alternative was presented as the recommended alternative for treatment at this location in the initial LTCP submission. JSA recognizes the concerns raised by KDEP and EPA in their January 30, 2015 letter and has provided more detailed review of multiple alternatives within this document.

The system consists of the following items (See **Figure H-5**):

1. An influent diversion structure that channels the flow from the outfall into the screening channels. The overflow weir that sends flows over 40 mgd directly to the outfall channel would be built into the forebay. The weir would be adjustable to allow for minor adjustments to insure that 40 mgd is captured in the screens. The structure would be enclosed to prevent backflow created when the floodwall gates are closed and the water level in the existing channel rises.
2. A screening facility consisting of two 20 mgd screening channels and a 40-mgd screen bypass channel. Each screen channel would have a dual screen system installed; a 1.5 inch coarse screen to screen large debris in the flow stream, followed by a fine screen (4-6 mm clear spacing) to screen smaller debris, leaves, etc. The screens are assumed to be mechanically cleaned, with screenings delivered to trash dumpsters for easy maneuvering and hauling offsite. The screens and channels would be underground structures, extending the enclosed concept of the diversion structure so as not to flood when the floodwall gates are closed, but the screenings would be delivered to the dumpsters in an “at-grade” facility to make the removal of the screenings convenient for operations staff.
3. A low head, 40 mgd pump station would be required to move the screened water back into the outfall channel. As many overflow events are low volume, the station would consist of a constant speed, base flow pump (2,000 gpm) to handle the low flow events and four 13.4 mgd (7,650 gpm) pumps, all VFD operated, operating on a lead-lag1-lag2-standby scheme. The base flow pump would turn off at a preset wetwell level and would not turn on again until the next storm cycle; the VFD-driven pumps would operate for the rest of the cycle. Flygt

submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage and are expected to continue operation in the event that the screens fail. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 40 mgd flow (140,000 gallons).

The screening-level cost estimate for this project is $12.5 million.

E. Fine Screening with Disinfection

This alternative includes the full screening facility described in Alternative D, followed by disinfection. (See **Figure H-6**). The low head pump station would pump the flow into the disinfection basin instead of the outfall but would have bypass capability to pump into the outfall channel in the event that the disinfection system is offline. Disinfection alternatives that were reviewed include ultraviolet (UV) radiation, chlorination / dechlorination, and peracetic Acid (PAA). Advantages and disadvantages of these alternatives are summarized briefly below.

1. UV
   a. Advantages
      i. Instantaneous inactivation of organisms
      ii. Takes the least amount of space; no contact tank required
      iii. No chemicals on the site
      iv. Least capital cost alternative
   b. Disadvantages
      i. Intermittent use of facility can be an issue; UV works best with a continuous flow stream.
      ii. Particle size in the flow stream may limit UV effectiveness
2. Chlorination/Dechlorination
   a. Advantages
      i. Proven disinfecting capability for a wide variety of organics
      ii. Can be used in intermittent flow situation
      iii. Operator familiarity; already used in the system
   b. Disadvantages
      i. Two chemical systems in separate buildings are required at a remote location
      ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 420,000 gallons) is required
      iii. Liquid Sodium Hypochlorite has a limited shelf life. As design volumes must be for peak storm events, during long periods of low rainfall the chemical may have to be withdrawn from the tank and replaced
      iv. Most expensive capital cost alternative
3. PAA
   a. Advantages
      i. Does not need a secondary chemical for dechlorination
      ii. Can be used in intermittent flow situation
      iii. Equipment is typically leased; may be able to subcontract operation
      iv. Capital cost is lower than chlorination/dechlorination alternative
      v. PAA has longer shelf-life than other alternatives
   b. Disadvantages
      i. Typically, higher doses of chemical are required for disinfection than sodium hypochlorite.

ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 420,000 gallons) is required. Volume may be higher, depending on results of pilot testing of effectiveness.
iii. A chemical system is required at a remote location.

Figure H-6 shows the worst case scenario for land use if chemical disinfection and low head pumping is required.

The screening-level cost estimate for this project is $17.3 million, which assumes chlorination / dechlorination is the selected type of disinfection. Bench and pilot scale testing of the disinfectants at this site would be conducted during preliminary design if this alternative is selected.

F. High Rate Treatment

This alternative consists of installing a high rate clarification (ballasted flocculation) system that is designed to remove settleable solids and the insoluble BOD fraction with a construction footprint that is much smaller than conventional primary treatment processes and provides a higher level of treatment than conventional primary treatment processes. The units typically are provided as equipment packages by the vendors that supply them, oftentimes complete with basins, the mixing, flocculation, and sedimentation equipment internal to the basins, and chemical feed system components, although what is provided can vary from manufacturer to manufacturer. The composition of the system goes beyond just the equipment package, though, especially at this site, which is flat and would require pumping to meet the hydraulic needs of the system. The system would contain the following elements (See **Figure H-7**, which includes the footprint of the larger HRT system):

1. A screening facility, as described in Parts 1, 2 and 3 of Alternative D. The only difference is that the screen bypass channel would bypass the HRT. Unscreened CSO flow can damage the HRT equipment.
2. A low head pump station, as described in Part 3 of Alternative D. For the HRT alternative, the alternatives are to either build the treatment system in-ground and pump after treatment, or pump prior to treatment and build the treatment system above ground. While building above-ground has a negative impact on the aesthetics of the park, the above-ground system is more cost effective and less prone to flooding. The above ground option is considered in this analysis.
3. The HRT unit. The units are physical / chemical treatment processes that use a combination of rapid mixing of chemicals, flocculation chambers, and settling basins to obtain settling of total suspended solids (TSS) and biochemical oxygen demand (BOD). For purposes of this evaluation, two systems were reviewed for general compatibility:
    a. Kruger's Actiflo system
    b. Infilco Degremont's DensaDeg system
4. Sludge withdrawal and disposal is required. For purposes of this evaluation, it is assumed that there is a connection off the bottom of the sedimentation basin for a sludge truck (with pump) to dock, offload the sludge from the basin, and transport the sludge to the WWTP. However, a separate storage tank may be required for temporarily holding sludge which is not included in this estimate. It is also noted that the cost for sludge handling is not included as a capital expense at this time; it is assumed that JSA would enter into a contract with a waste hauler instead of buying their own truck. Pumping the sludge into the local sewer may also be possible, but an evaluation of the sewer system would be required between the entry point and the WWTP to insure that there would be no potential overflows to other outfalls.

5. Gravity discharge channel from the HRT to the outfall channel. A channel would be provided, with energy dissipation structure (river rock cemented together or spread concrete pad at the bottom of the channel) to minimize potential erosion in the existing channel. The discharge at the treatment unit would be above the water level that is generated when the floodwall gates are closed.

The screening-level cost estimate for this project is $26.3 million. Budgetary estimates have been provided by the two vendors listed above. These costs were reviewed and the costs were averaged for use in this evaluation.

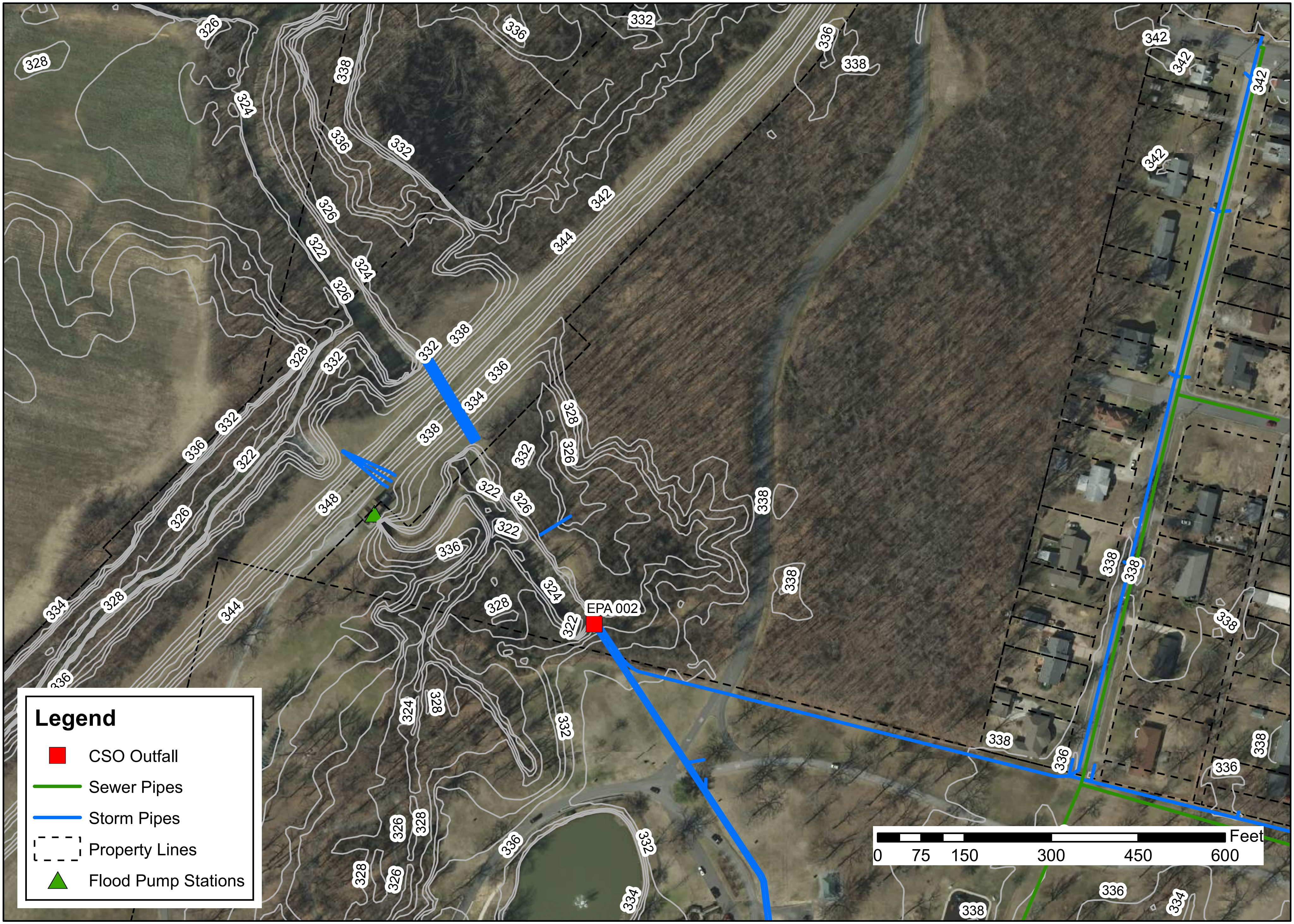
When considering this alternative, the following disadvantages are noted:

1. Capital and operating costs would be very high.
2. The system is relatively complex to operate remotely. It is likely that JSA would send staff to monitor operation during rain events.
3. Multiple chemical systems would be at a remote site.
4. There would be significant impact to the park aesthetic.
5. If HRT technology is used for JSA, it makes more sense to combine all outfalls that would be treated at the WWTP. An HRT unit can be constructed there that would be more cost effective for the entire system and would have reduced impact to public park facilities.

G. High Rate Treatment with Disinfection

This alternative consists of using the HRT system described in Alternative F and adding a disinfection facility (See **Figure H-8**). The HRT discharge pipe would route treated flow to either the UV channel or the contact chamber, depending on which disinfection alternative would be selected through bench and pilot testing of disinfection alternatives. It is noted that **Figure H-8** shows the largest configuration of HRT treatment on the site and the chlorination / dechlorination disinfection system.

While adding disinfection would improve the level of treatment provided at EPA 002, it would increase the cost (by approximately $4.3 million) and operational complexity of this remote facility. For this reason and the reasons stated above in Alternative F, CDM Smith has determined that this is not a feasible alternative for outfall EPA 002.



Paducah LTCP - Outfall EPA 002

Figure H-1 - Site Overview

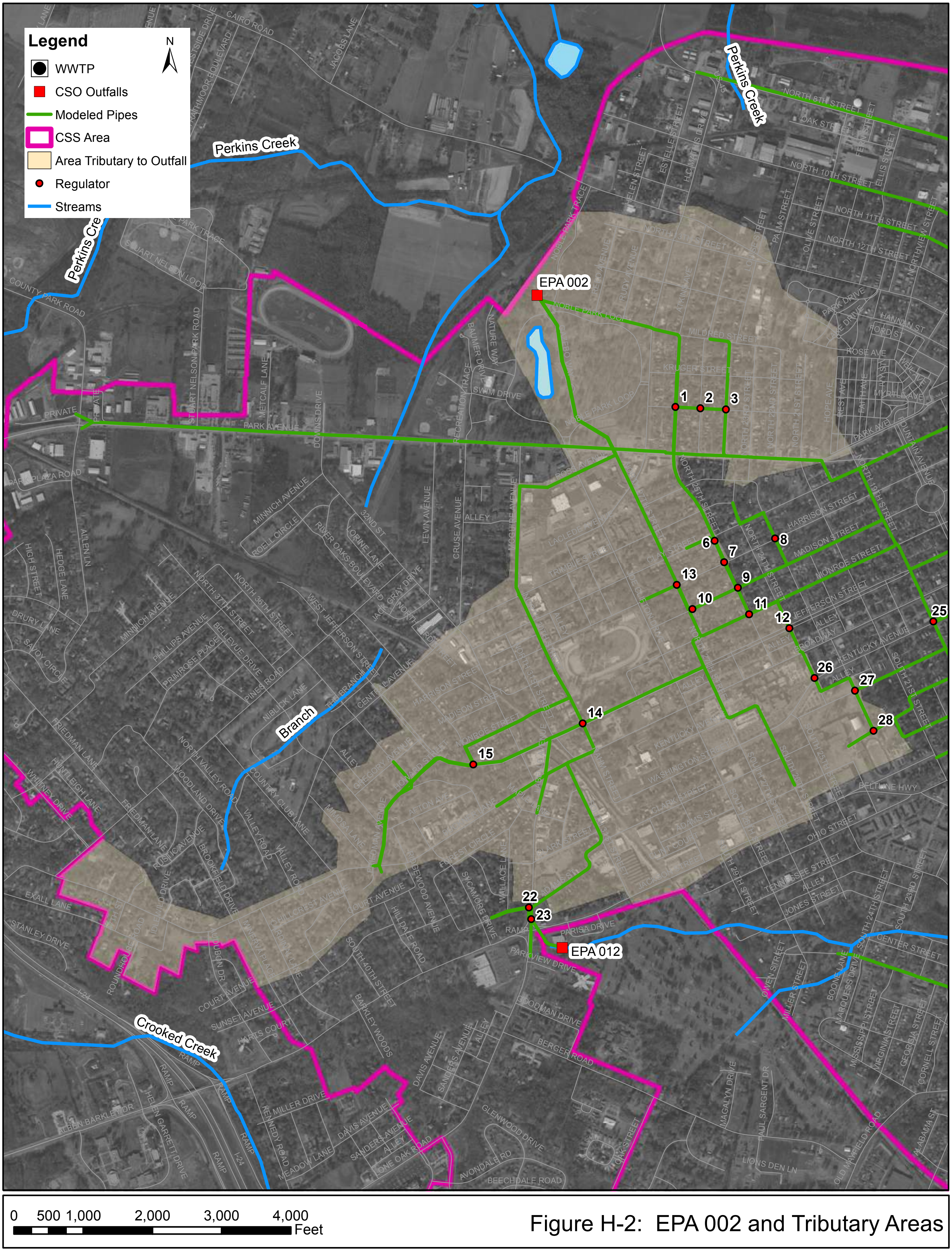
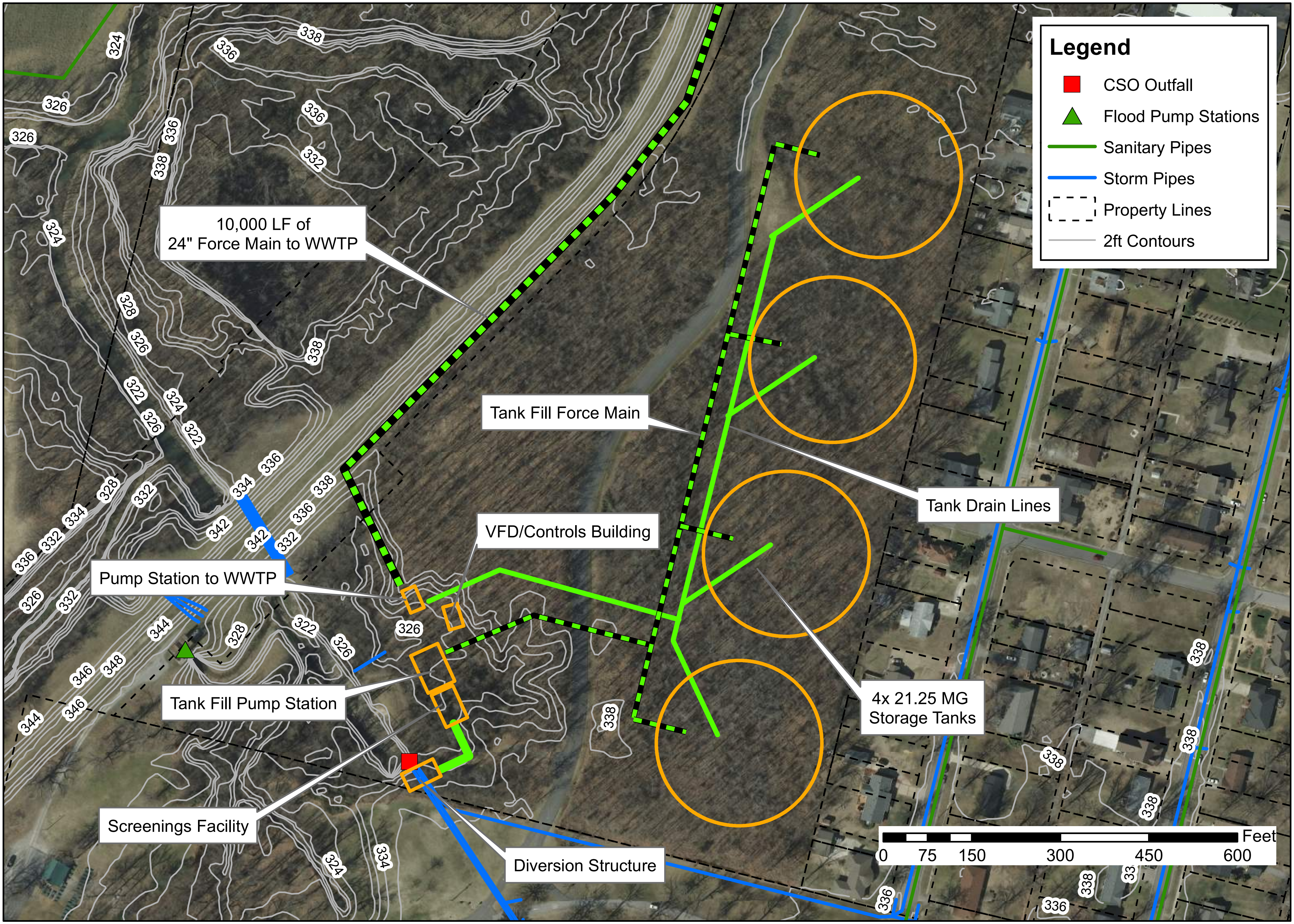
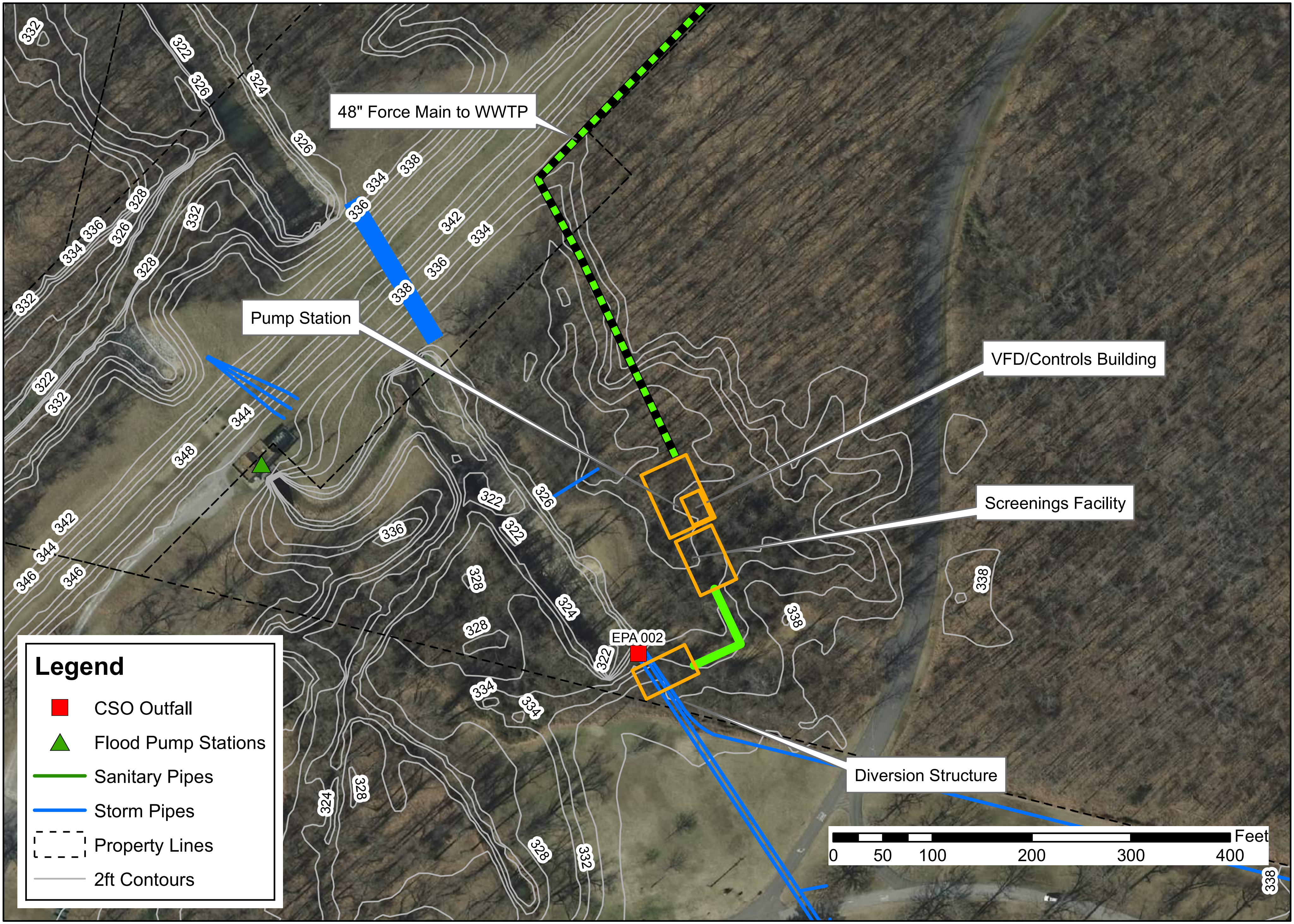


Figure H-2: EPA 002 and Tributary Areas



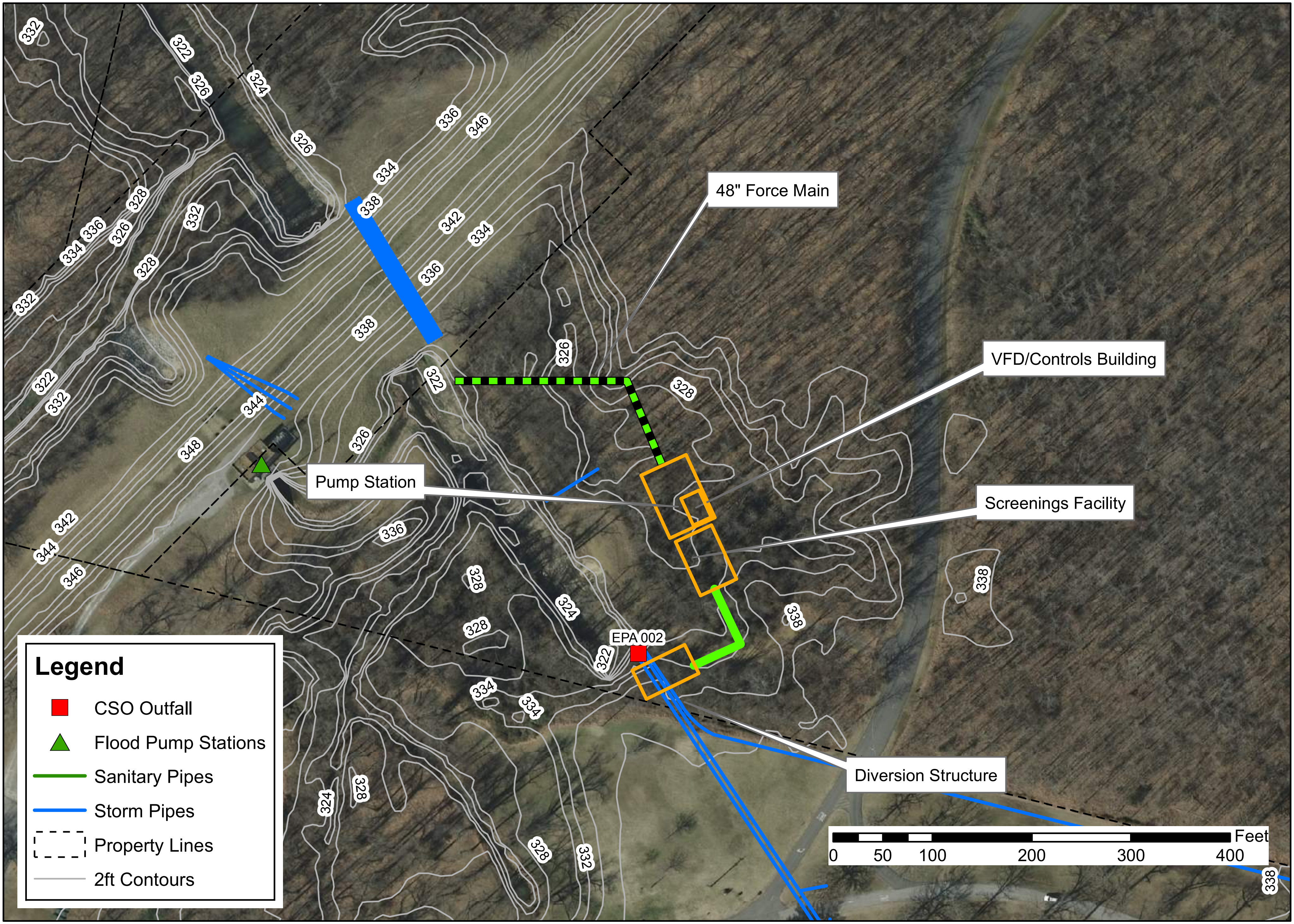
Paducah LTCP - Outfall EPA 002

Figure H-3 - Storage



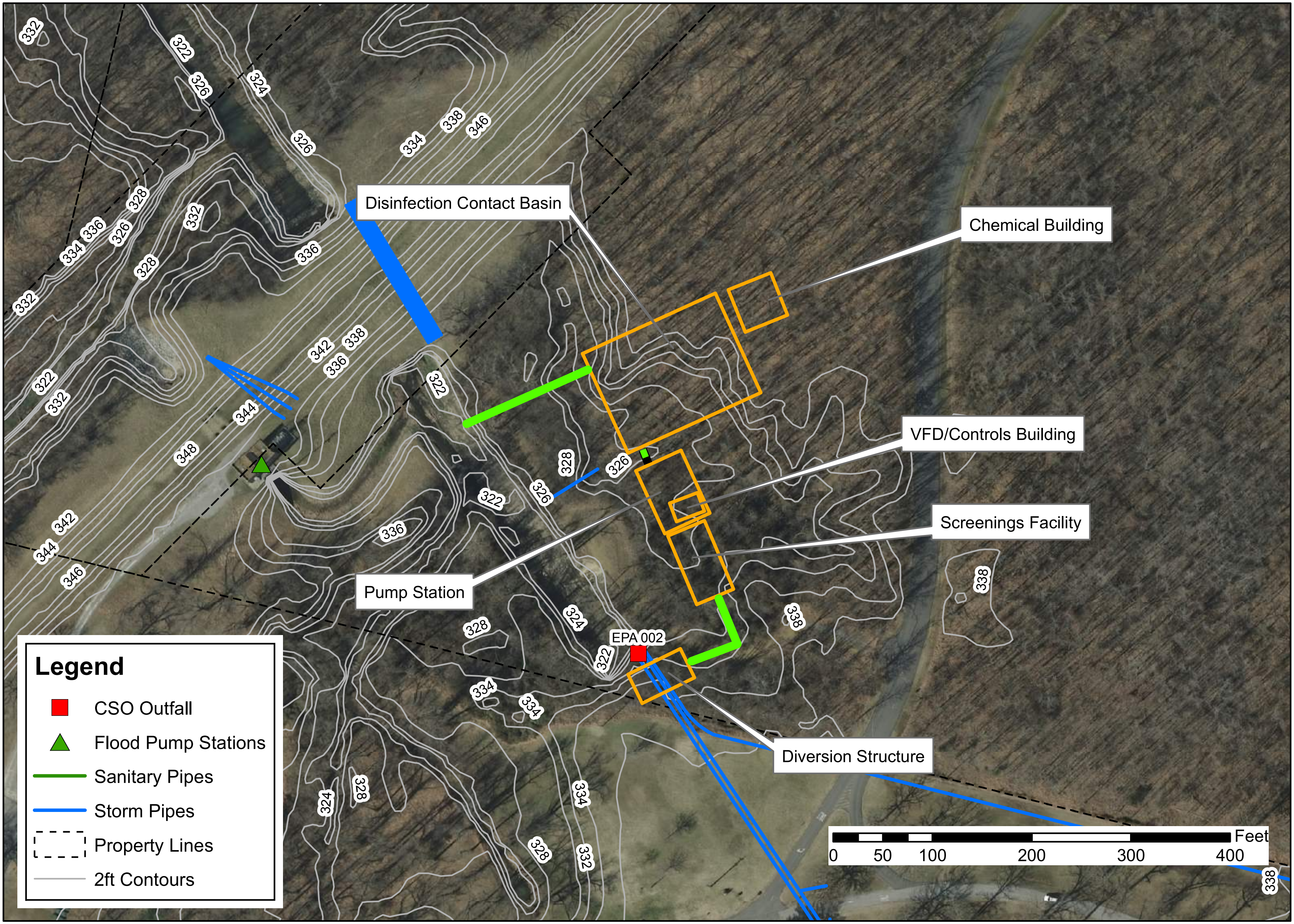
Paducah LTCP - Outfall EPA 002

Figure H-4 - Pumping to Treatment



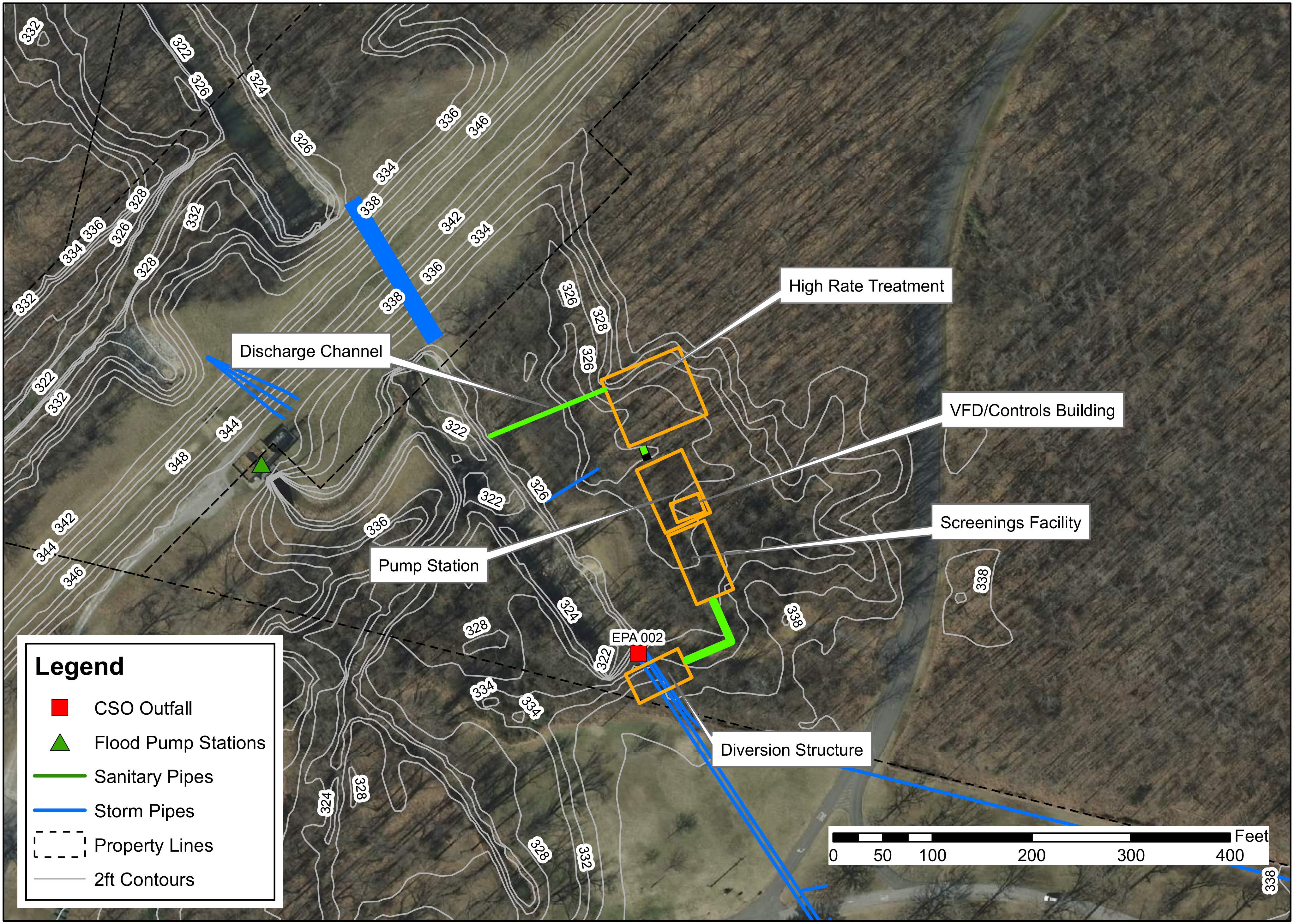
Paducah LTCP - Outfall EPA 002

Figure H-5 - Fine Screening



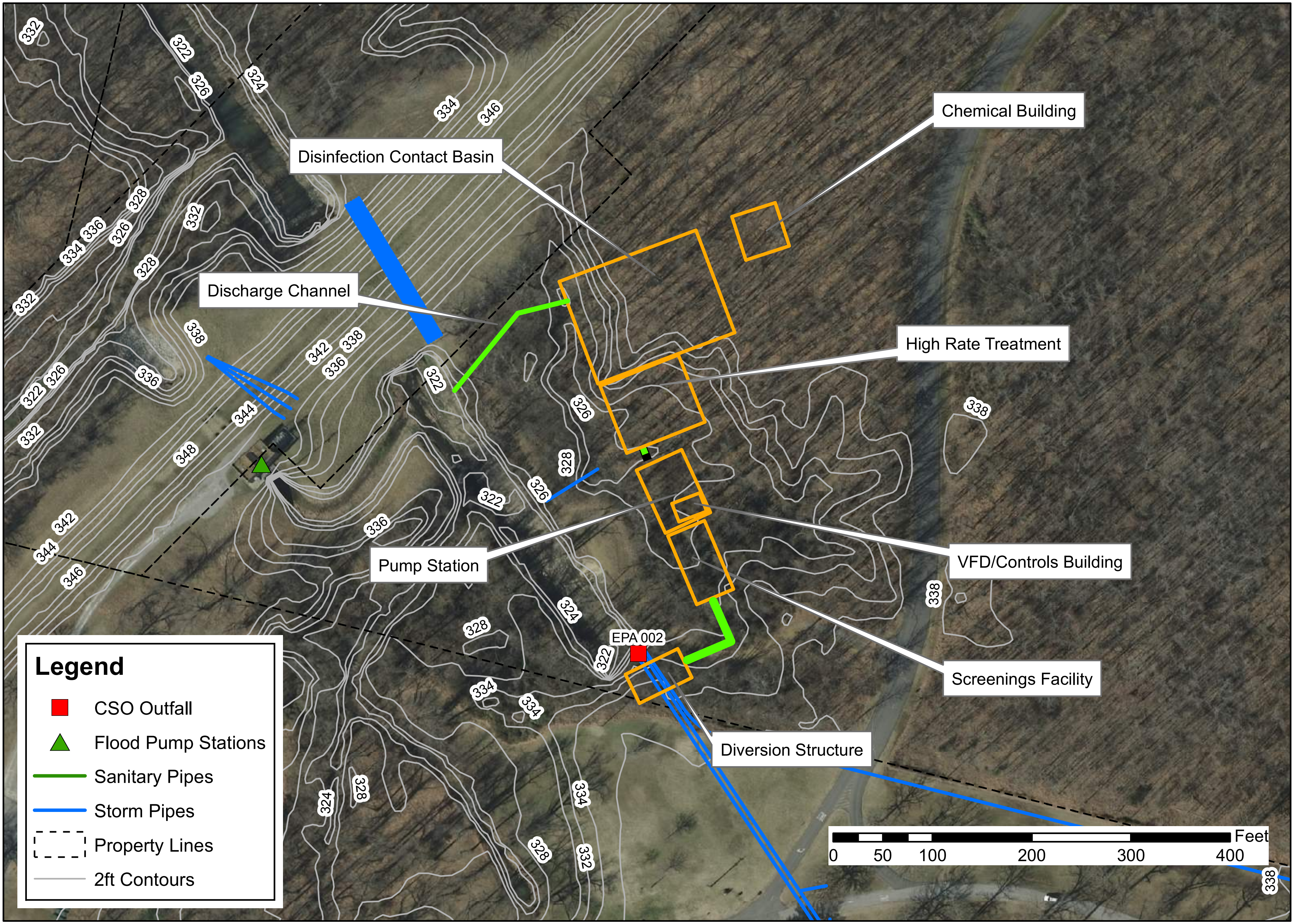
Paducah LTCP - Outfall EPA 002

Figure H-6 - Fine Screening and Disinfection



Paducah LTCP - Outfall EPA 002

Figure H-7 - HRT



Paducah LTCP - Outfall EPA 002

Figure H-8 - HRT and Disinfection

Appendix I

EPA 003 Alternative Analysis

Note 1: Costs presented are screening-level estimates for comparison of the alternatives. Costs of selected alternatives will be reviewed in further detail for the financial analysis.

Note 2: When additional land is required to site the facilities, the placement of the facilities and the selected parcels are shown for illustrative purposes only. Alternative nearby sites would also be evaluated during design.

EPA 003, shown in **Figure I-1,** is a CSO outfall located along the Ohio River, immediately upstream of the WWTP. During normal, dry weather flow conditions, the Terrell Pump Station conveys flow to the WWTP; however during periods of high flows, regulator 42 allows the discharge of combined sewer flows to the outfall. This outfall discharges the largest annual volume. The tributary area for EPA 003 is shown in **Figure I-2**.

During normal conditions, flow from the CSO outfall passes through the open flood control gates. When the Ohio River level reaches 27.5 feet, the gates are closed, and the floodwall pump station is operated by the City of Paducah to transfer flows across the floodwall to the Ohio River. This includes both CSO discharges as well as the WWTP's effluent. Because of the original design of the floodwall pump station, when the gates are closed, the operation of the pump station results in an approximate depth of water in the pump station between ten and fifteen feet. Based on a review of available data for 2007 through 2014, the flood gates are typically closed approximately five times per year for an average of duration of 18 days per occurrence with six of those days receiving rainfall. Alternatives evaluated below include slide gates or other devices that can be used to protect and isolate the new facilities if backwater effects are experienced from the floodwall pump station's operation.

Evaluation of CSO control alternatives for this outfall assume a target percent capture of 96 percent of total annual CSO volume, which is consistent with the knee of the curve sizing for screening as presented in the LTCP. This results in a required sizing of 70 million gallons per day (mgd) for alternatives based on overflow treatment at this site, which assumes that the maximum capacity of the Terrell Pump Station (approximately 12 mgd) is sent to the WWTP for treatment. The target percent capture will be utilized to compare alternatives; however, JSA recognizes that the need to achieve a minimum system-wide capture of 85 percent and may adjust the sizing of the selected alternative at EPA 003, which is also dependent upon the selected alternatives at other outfalls.

The following alternatives were evaluated for EPA 003:

A. System separation of the tributary area to this outfall
B. Storage
C. Fine Screening
D. Fine screening with disinfection
E. High rate treatment

F. High rate treatment with disinfection

G. Expansion of conventional treatment

For each alternative, it is assumed that properties are acquired, and that a portion of these properties can be utilized to construct the elements in each alternative.

A. System Separation

System separation was considered for the combined sewer system portion of this tributary area. Excluding areas that are also tributary to other outfalls and/or are believed to be separate sanitary sewer areas upstream of this location, the area assumed for separation includes approximately 750 acres. Construction costs are expected to exceed $60 million and total project costs would be approximately $75 million. The unit cost for separation presented in the LTCP ($100,000 per acre) was revised to $80,000 per acre based upon the costs associated with the separation project for EPA 012. With anticipated engineering, legal, and other administrative costs, the assumed total project unit cost is $100,000 per acre. Costs associated with the separation of EPA 014 were lower than this value but are not believed to be appropriate for planning purposes since that project was completed in conjunction with Department of Transportation work. Additionally, since the tributary area for EPA 003 also includes very large conveyance sewers the above $75 million estimate may be understated.

Sewer separation for a portion of the tributary may be feasible; however, separating a portion of the area would not eliminate the need for CSO controls for the remaining CSO discharge.

B. Storage

In order to achieve the target percent capture, the storage alternative must consider three components: the rate at which flow must be captured and stored, the volume of storage required, and how quickly the stored flows can be drained back to the system for treatment. Stored flows were assumed to be drained through the Terrell Pump Station, although if above-ground storage is utilized it may be possible to dewater the tanks to the WWTP directly by gravity.

Utilizing the results of the hydraulic model, several combinations of those three factors were analyzed in order to assess the feasibility of this alternative and to attempt to determine appropriate sizes for those three components while achieving the target percent capture.

To achieve the target 96 percent capture at this location, the following sizes were estimated:

- Pumping rate into storage: 70 mgd
- Required storage: 250 million gallons
- Dewatering rate: based on the available capacity of the Terrell Pump Station (max of less than 9 mgd)

Due to the low dewatering rate requiring several weeks to dewater when the storage is full (assuming no other rain events occur during that time) and the high capital cost of constructing the storage, this alternative is infeasible and will not be considered further.

Storage, however, may be considered in conjunction with other alternatives, as the system-wide alternatives are evaluated, in order to better manage peak flows arriving at the WWTP, especially if additional flows are being conveyed to this location from remote CSOs.

C. Fine Screening

This alternative consists of diverting the flow from the outfalls through a fine screening system prior to discharge. This alternative was presented as the recommended alternative for treatment at this location in the initial LTCP submission. JSA recognizes the concerns raised by KDEP and EPA in their January 30, 2015 letter and has provided more detailed review of multiple alternatives within this document.

The system consists of the following items (See **Figure I-3**):

1. An influent diversion structure that channels the flow from the outfall into the screening channels. The overflow weir that sends flows over 70 mgd directly to the outfall channel would be built into the forebay. The weir would be adjustable to allow for minor adjustments to insure that 70 mgd is captured in the screens. The depth of the current overflow pipe invert in this area is approximately 26' deep, which will increase construction costs over an at-grade or shallow bury facility.
2. A screening facility consisting of three 23.33 mgd screening channels and a 70-mgd screen bypass channel. Each screen channel would have a dual screen system installed; a 1.5 inch coarse screen to screen large debris in the flow stream, followed by a fine screen (4-6 mm clear spacing) to screen smaller debris, leaves, etc. The screens are assumed to be mechanically cleaned, with screenings delivered to trash dumpsters for easy maneuvering and hauling offsite. The screens and channels would be underground structures designed to fit into the existing hydraulic grade line and will be custom-built to have sufficient height to not be fully submerged when the floodwall gates are closed. The screenings would be conveyed to the dumpsters in an "at-grade" facility to make the removal of the screenings convenient for operations staff. If screening is selected for implementation, analysis of the WWTP's screening processes will be conducted to assess whether capacity exists to handle the additional screened materials. If so, diversion-type, in-system screens may be utilized.
3. As the head loss through the diversion structure and the screening facility will impact the ability of all influent flow to travel by gravity back into the outfall, two sump pumps will be placed in the downstream well of the screen facility to drain the screen facility of any water that collects in the bottom of the channels.

For this option, construction of the new screening facility will require the purchase and clearing of the property adjacent to the Terrell Pump Station on North 6th Street.

The screening-level cost estimate for this project is $13.8 million.

D. Fine Screening with Disinfection

This alternative includes the full screening facility described in Alternative C, followed by disinfection. The system consists of the following items (See **Figure I-4**):

1. A new screening facility as described in Alternative C.
2. A low head, 70 mgd pump station would be required to move the screened water into the disinfection process channel. The station would consist of five 17.6 mgd (12,230 gpm) pumps, all variable frequency drive (VFD) operated, operating on a lead-lag1-lag2-lag3-standby scheme. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage and are expected to continue operation in the event that the screens fail. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 70 mgd flow (244,000 gallons).
3. A disinfection alternative, as described below.

Disinfection alternatives that were reviewed include ultraviolet (UV) radiation, chlorination / dechlorination, and peracetic Acid (PAA). Advantages and disadvantages of these alternatives are summarized briefly below.

1. UV
    a. Advantages
        i. Instantaneous inactivation of organisms
        ii. Takes the least amount of space; no contact tank required
        iii. No chemicals on the site
        iv. Least capital cost alternative
    b. Disadvantages
        i. Intermittent use of facility can be an issue; UV works best with a continuous flow stream.
        ii. Particle size in the flow stream may limit UV effectiveness
2. Chlorination/Dechlorination
    a. Advantages
        i. Proven disinfecting capability for a wide variety of organics
        ii. Can be used in intermittent flow situation
        iii. Operator familiarity; already used in the system
    b. Disadvantages
        i. Two chemical systems in separate buildings are required
        ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 730,000 gallons) is required
        iii. Liquid Sodium Hypochlorite has a limited shelf life. As design volumes must be for peak storm events, during long periods of low rainfall the chemical may have to be withdrawn from the tank and replaced
        iv. Most expensive capital cost alternative
3. PAA
    a. Advantages
        i. Does not need a secondary chemical for dechlorination
        ii. Can be used in intermittent flow situation
        iii. Equipment is typically leased; may be able to subcontract operation
        iv. Capital cost is lower than chlorination/dechlorination alternative
        v. PAA has longer shelf-life than other alternatives
    b. Disadvantages
        i. Typically, higher doses of chemical are required for disinfection than sodium hypochlorite.
        ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 730,000 gallons) is required. Volume may be higher, depending on results of pilot testing of effectiveness.

Figure I-4 shows the worst case scenario for land use if chemical disinfection and low head pumping is required. As with Alternative C, property purchases would be required to construct the screening and disinfection system. For illustrative purposes, the property adjacent to the Terrell Pump Station has been selected to show the facility's size.

The screening-level cost estimate for this project is $33.2 million, which assumes chlorination / dechlorination is the selected type of disinfection. Bench and pilot scale testing of the disinfectants at this site would be conducted during preliminary design if this alternative is selected.

E. High Rate Treatment

This alternative consists of installing a high rate clarification (ballasted flocculation) system that is designed to remove settleable solids and the insoluble BOD fraction with a construction footprint that is much smaller than conventional primary treatment processes and provides a higher level of treatment than conventional primary treatment processes. The units typically are provided as equipment packages by the vendors that supply them, oftentimes complete with basins, the mixing, flocculation, and sedimentation equipment internal to the basins, and chemical feed system components, although what is provided can vary from manufacturer to manufacturer. The composition of the system goes beyond just the equipment package, though, especially at this site, which is flat and would require pumping to meet the hydraulic needs of the system. The system would contain the following elements (See **Figure I-5,** which includes the footprint of the larger HRT system):

1. A screening facility, as described in Alternative C. The only difference is that the screen bypass channel would bypass the HRT. Unscreened CSO flow can damage the HRT equipment.
2. A low head pump station, as described in Part 2 of Alternative D. For the HRT alternative, the options are to either build the treatment system in-ground and pump after treatment, or pump prior to treatment and build the treatment system above ground. As the above-ground system is more cost effective and less prone to flooding, it is the option considered in this analysis.
3. The HRT unit. The units are physical / chemical treatment processes that use a combination of rapid mixing of chemicals, flocculation chambers, and settling basins to obtain settling of total suspended solids (TSS) and Biochemical Oxygen demand (BOD). For purposes of this evaluation, two systems were reviewed for general compatibility:
    a. Kruger's Actiflo system
    b. Infilco Degremont's DensaDeg system
4. Sludge withdrawal and disposal is required. For purposes of this evaluation, it is assumed that sludge is pumped from the bottom of the sedimentation tanks to the existing sludge treatment process at the WWTP site. A more detailed analysis of sludge processing will be performed if a process involving an HRT system is considered further for CSO treatment.
5. Gravity discharge channel from the HRT to the outfall pipe. The discharge at the treatment unit would be above the water level that is generated when the floodwall gates are closed.

The screening-level cost estimate for this project is $44.3 million. Budgetary estimates have been provided by the two vendors listed above. These costs were reviewed and the costs were averaged for use in this evaluation.

Given the large flows at this outfall compared to other outfalls in the JSA system and the fact that this location is adjacent to the existing WWTP, the selection of HRT could be feasible. The proximity of EPA 003 adjacent to the WWTP is an advantage in the sense that plant staff are immediately available to the site in the event they are needed for monitoring and control, and construction would likely not meet public opposition because it is an expansion of an existing facility. There is sufficient space available at the selected site to host HRT technologies, assuming the property adjacent to the Terrell Pump Station is purchased. Additionally, if flows from other outfalls are combined and pumped to the WWTP, a combined HRT facility at outfall 003 would be used. An HRT unit can be constructed here that would be more cost effective for the entire system.

F. High Rate Treatment with Disinfection

This alternative consists of using the HRT system described in Alternative E and adding a disinfection facility (See **Figure I-6**). The HRT discharge pipe would route treated flow to either the UV channel or the contact chamber, depending on which disinfection alternative would be selected through bench and pilot testing of disinfection alternatives. It is noted that **Figure I-6** shows the larger configuration of HRT treatment on the site and the chlorination / dechlorination disinfection system.

Adding disinfection would improve the level of treatment provided at EPA 003 and would increase the cost (by approximately $5 million) and operational complexity of this facility. However, as with the HRT system described in Alternative E, using disinfection at a single facility becomes more cost effective and more operator friendly than at remote facilities through the system. Having the HRT and disinfection facility adjacent to the WWTP would allow for effective operation in wet weather events. Due to the desire to have CSO flow disinfected prior to discharge into the river, this alternative will be considered further.

G. Expansion of Conventional Treatment

JSA completed construction of a $4.5 million improvement project at the WWTP in 2009. That project increased the WWTP's peak hydraulic capacity from 9 mgd to 18 mgd. An additional study has indicated that it may be possible to further increase the WWTP's capacity to 22 to 24 mgd; however, those improvements are anticipated to cost $9 million.

Although the additional 4 to 6 mgd treatment capacity would have a positive impact on reducing CSO discharges from EPA 003, the overall impact would be small and would not allow JSA to meet the minimum system-wide capture of 85 percent without additional CSO controls at EPA 003. Because of this, further expansion of the WWTP is not considered cost effective at this time.

Paducah LTCP - Outfall EPA 003

Figure I-1 - Site Overview

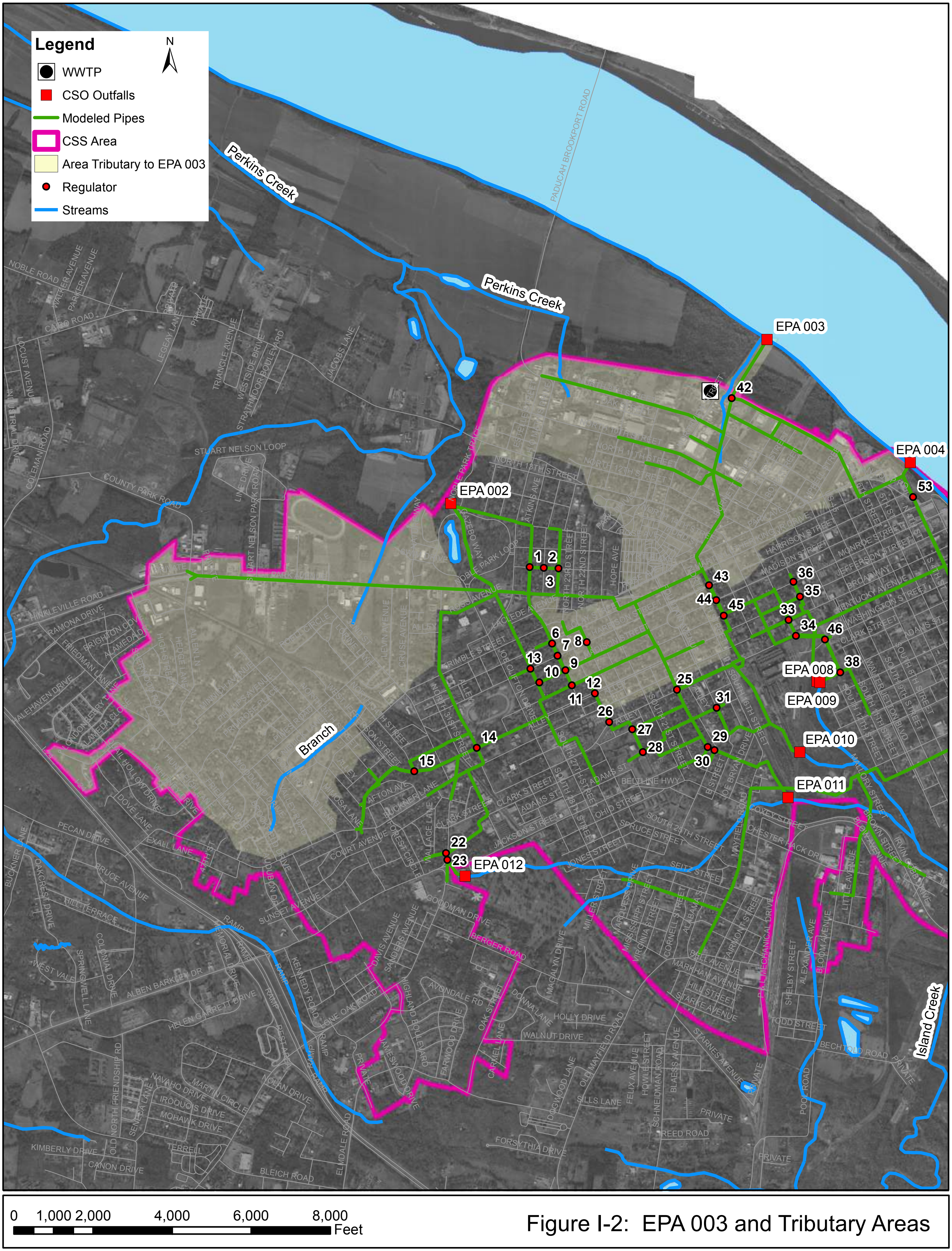
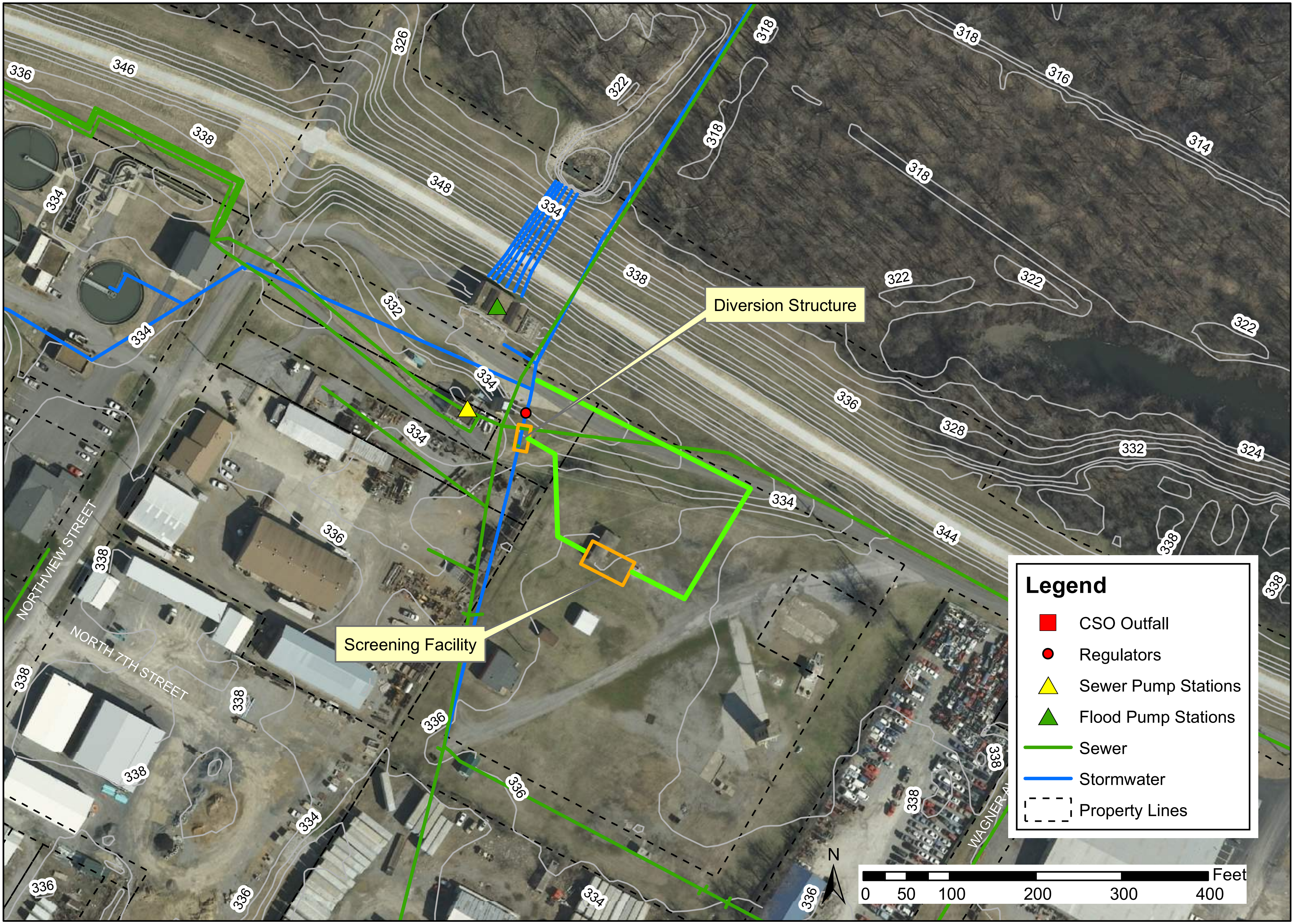
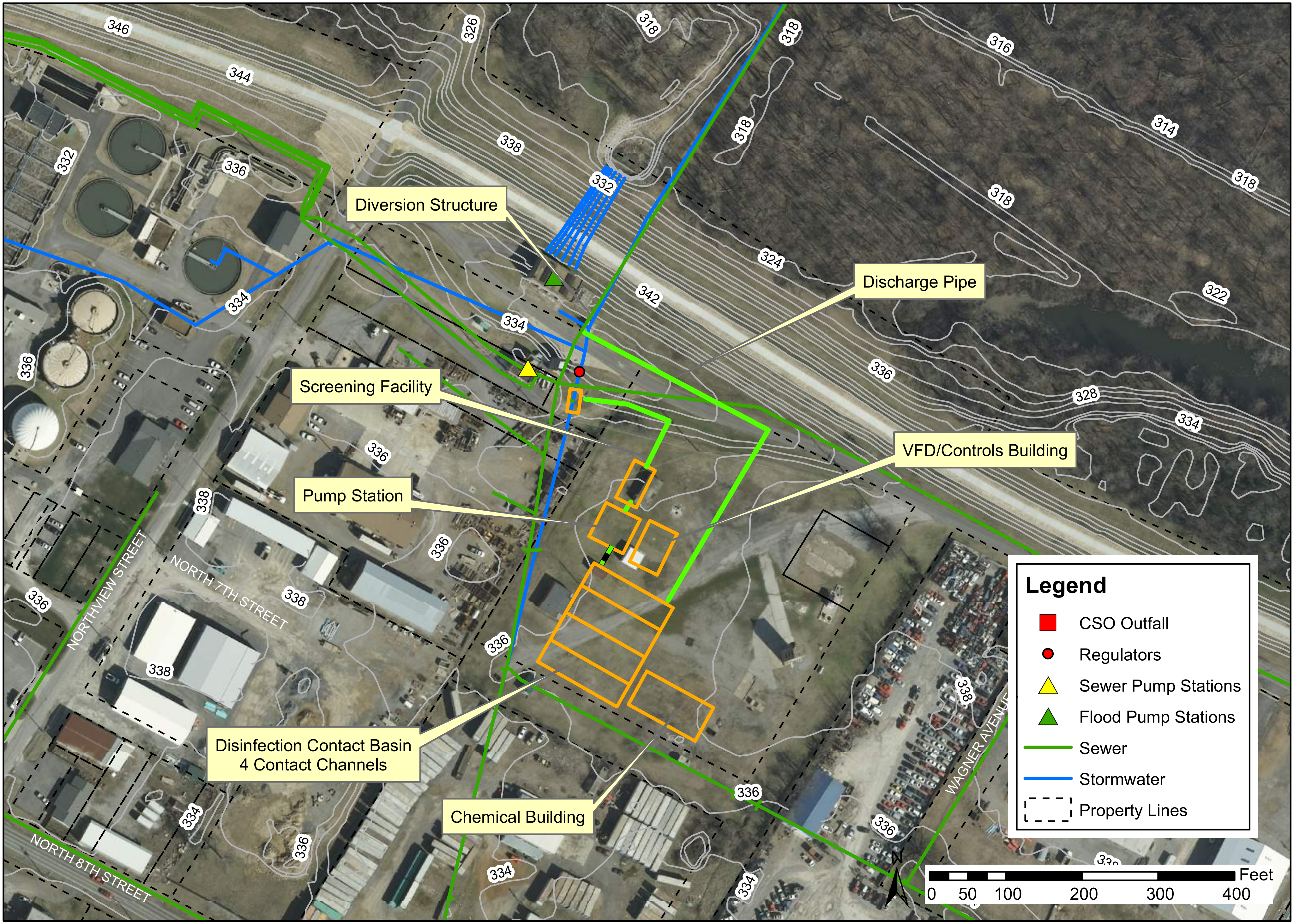


Figure I-2: EPA 003 and Tributary Areas



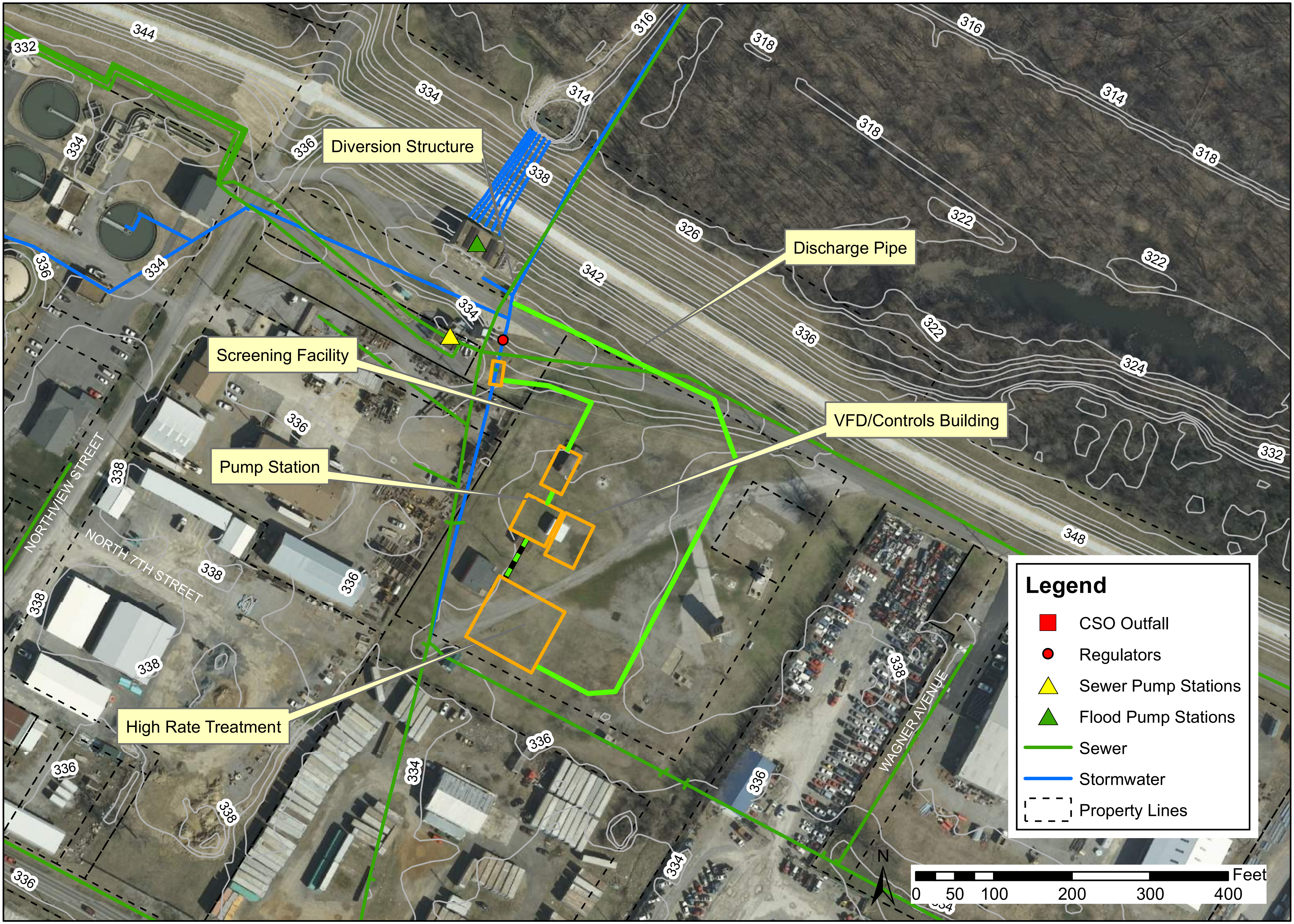
Paducah LTCP - Outfall EPA 003

Figure I-3 - Fine Screening



Paducah LTCP - Outfall EPA 003

Figure I-4 - Screening and Disinfection



Paducah LTCP - Outfall EPA 003

Figure I-5 - HRT

Paducah LTCP - Outfall EPA 003

Figure I-6 - HRT and Disinfection

Appendix J

EPA 004 Alternative Analysis

Note 1: Costs presented are screening-level estimates for comparison of the alternatives. Costs of selected alternatives will be reviewed in further detail for the financial analysis.

Note 2: When additional land is required to site the facilities, the placement of the facilities and the selected parcels are shown for illustrative purposes only. Alternative nearby sites would also be evaluated during design.

EPA 004, shown in **Figure J-1,** is a CSO outfall located along the Ohio River. During normal, dry weather flow conditions, the Harrison Pump Station conveys flow to the downstream gravity system; however during periods of high flows, regulator 53 allows the discharge of combined sewer flows to the outfall. The tributary area for EPA 004 is shown in **Figure J-2**.

Much of the area tributary to the Harrison Pump Station (excluding areas that are also tributary to other outfalls) is also served by a separate stormwater system. However, due to the age of the sewers in this area (which includes the downtown area) it is expected that there is a high likelihood that stormwater is also conveyed by the sewers in this area. Flows from the Husbands Pump Station, as well as the portions of tributary areas associated with EPA 008 and EPA 009, are routed through the Harrison Pump Station.

During normal conditions, flow from the CSO outfall passes through the open flood control gates. When the Ohio River level reaches 35.5 feet, the gates are closed, and the floodwall pump station is operated by the City of Paducah to transfer flows across the floodwall. Because of the original design of the floodwall pump station, when the gates are closed, the operation of the pump station results in an approximate depth of water in the in the floodwall pump station between two and six feet. Based on a review of available data for 2007 through 2014, the flood gates are closed approximately two times per year, with an average closure duration of 18 days per occurrence with seven of those days receiving rainfall. The alternatives evaluated below include slide gates or other devices that can be used to protect and isolate the new facilities if backwater effects are experienced from the floodwall pump station's operation.

Because this CSO is the closest to the drinking water intake, evaluation of CSO control alternatives for this outfall assume a target of four overflow events per year, which results in a percent capture of greater than 99 percent of total annual CSO volume. This results in a required sizing of 7.1 million gallons per day (mgd) for alternatives based on overflow treatment at this site. This target percent capture will be utilized to compare alternatives; however, JSA recognizes that the need to achieve a minimum system-wide capture of 85 percent and may adjust the sizing of the selected alternative at EPA 004, which is also dependent upon the selected alternative for EPA 006 and EPA 007.

The following alternatives were evaluated for EPA 004:

A. System separation of the tributary area to this outfall
B. Storage

C. Pump station improvements with additional wet weather treatment facility to be constructed near the WWTP (no on-site storage)

D. Fine screening

E. Fine screening with disinfection

F. High rate treatment

G. High rate treatment with disinfection

For each alternative, it is assumed that properties adjacent to the outfall are acquired, and that a portion of these properties can be utilized to construct the elements in each alternative.

A. System Separation

System separation was considered for the combined sewer system portion of this tributary area. The tributary area (excluding areas that are also tributary to other outfalls) is approximately 500 acres. A portion of this area also has a separate stormwater system, but the entire area would need to be investigated and would possibly require separation or other modifications to ensure that stormwater is directed to the stormwater system and not the combined system. Because of this only 75 percent of the area is assumed to require separation, and results in estimated construction cost of $30 million with a total project cost of $37.5 million. This may be an overestimate of the area, but it is also expected that the congestion associated with this area would increase the per acre cost.

The unit cost for separation presented in the LTCP ($100,000 per acre) was revised to $80,000 per acre based upon the costs associated with the separation project for EPA 012. With anticipated engineering, legal, and other administrative costs, the assumed total project unit cost is $100,000 per acre. Costs associated with the separation of EPA 014 were lower than this value but are not believed to be appropriate for planning purposes since that project was completed in conjunction with Department of Transportation work.

B. Storage

In order to achieve target percent capture, the storage alternative must consider three components: the rate at which flow must be captured and stored, the volume of storage required, and how quickly the stored flows can be drained back to the system for treatment. Stored flows were assumed to be drained through the Harrison Pump Station, although if above-ground storage is utilized it may be possible to dewater the tank to the gravity sewer system where the station's force main currently discharges (manhole Z05__0019009).

Utilizing the results of the hydraulic model, several combinations of those three factors were analyzed in order to assess the feasibility of this alternative and to attempt to determine appropriate sizes for those three components while achieving the target percent capture.

To achieve a 99 percent capture at this location, the following sizes were estimated:

- Pumping rate into storage: 7.1 mgd
- Required storage: 20 million gallons
- Dewatering rate: based on the available capacity of the Harrison Pump Station (max of less than 3 mgd)

In this case, the low dewatering rate drives the storage volume, requiring a week to dewater when the storage is full (assuming no other rain events occur during that time).

Due to the size of the 99 percent capture facility, a lower percent capture of 95 percent capture was also evaluated at this location. The following sizes were estimated, and the resulting facility is shown as **Figure J-3**:

- Pumping rate into storage: 2 mgd
- Required storage: 3 million gallons
- Dewatering rate: based on the available capacity of the Harrison Pump Station (max of less than 3 mgd)

Although it achieves a lower capture, this alternative was further evaluated, and the elements of this system include the following:

1. A diversion structure at regulator 53 that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 2 mgd to a new coarse screening facility; (2) flow over 2 mgd on any given event goes over a weir directly to the outfall.
2. A coarse screening facility upstream of the storage tank pump station. The screening capacity would be 2 mgd, with two 1 mgd screen channels and a 2 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to protect the pumps.
3. A low head, 2 mgd storage tank pump station. Two 2 mgd pumps with variable frequency drives (VFDs) would be installed, operating on a lead-standby scheme. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 2 mgd flow (7,000 gallons).
4. Three million gallons of storage, which is the storage required to achieve a 95 percent capture given dewatering limitations of the Harrison Pump Station. The storage is assumed to be an above ground three million gallon tank, as shown in **Figure J-3.** A prestressed concrete tank is assumed at this stage, but steel would also be considered at the time of construction if there is an indication that they can be cost-competitive. Buried storage would be more expensive. Tank dimensions would be approximately 120 feet in diameter and 35.5 feet tall. Overflow standpipes would be constructed in each tank, with overflow elevation set to provide 2 feet of freeboard. Tank washdown systems are assumed to be provided.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30 feet by 25 feet, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. A gravity discharge pipe will be installed to Harrison Street Pump Station's wetwell to dewater the tank contents.

The screening-level cost estimate for this project is $11.6 million.

The above option is not practical for two primary reasons: (1) cost and (2) the site constraints would require purchases of properties and demolition of existing structures along North 3rd Street to construct the tank. Nearby sites that are large enough to construct the tank are occupied by an events center and a retirement home. The location shown in **Figure J-3** assumes the new facility is located on the existing events center property, but this is adjacent to the floodwall, which could also pose construction issues. Overall, the impact to the local community makes this alternative impractical.

C. Pump station improvements with additional wet weather treatment facility to be constructed (no on-site storage)

Increasing the pumping capacity at Harrison Pump Station, either through construction of a new, larger facility or through the construction of a wet weather pump station, would achieve the target percent capture at EPA 004. However, these additional flows would need to be transported and treated at another location within the system. This solution is also dependent on the selected improvements at other outfalls, particularly EPA 006 and EPA 007. For the purposes of this evaluation, though, no additional flows from other areas are assumed.

Several options exist for the routing of the additional flows at Harrison Pump Station:

- Construct a new pump station to route all flows (dry and wet weather) directly to the WWTP where the flow can be routed to the WWTP if there is available capacity or to a new, dedicated wet weather treatment facility if WWTP capacity is not available. The required size for this new pump station would be approximately 11.3 mgd.
- Continue to utilize the existing pump station for normal, dry weather flows but construct a new wet weather pump station to route flows to the WWTP as described above. The required size for the wet weather pump station would be approximately 7.1 mgd.

For the purposes of this evaluation, a new pump station designed to convey both dry weather and wet weather flows that is routed to the WWTP is assumed. The other option can be explored further as the system-wide alternative evaluations continue.

This pumping alternative consists of diverting a maximum of 11.3 mgd through a coarse screening facility and pump station for transport of normal, dry weather flows to the WWTP and wet weather flows to a new wet weather treatment facility located near the WWTP that would receive wet weather flows from other CSO outfalls. Elements of this system include the following (See **Figure J-4**):

1. A diversion structure at regulator 53 that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 11.3 mgd to a new screening facility and pump station; (2) flow over 11.3 mgd on any given event goes over a weir directly to the outfall.
2. A coarse screening facility upstream of the pump station. The screening capacity would be 11.3 mgd, with two 5.65 mgd screen channels and an 11.3 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to protect the pumps.
3. An 11.3 mgd pump station. Three 5.65 mgd (3,900 gpm) pumps would be installed, all VFD operated, operating on a lead-lag-standby scheme. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 20 minutes of detention time at the 11.3 mgd flow (157,000 gallons).
4. A force main routed from the pump station to the WWTP / new wet weather treatment facility. The connection point to the influent pipe/channel would be determined during detailed design, in coordination with the project hydraulic analysis.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30 feet by 20 feet, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. A new wet weather treatment facility located near the WWTP. For purposes of this analysis, it is assumed that this facility would consist of a high rate treatment (HRT) and disinfection facility that would provide the equivalent of primary treatment and disinfection for flows from outfall EPA 003 as well as potentially other remote outfalls. Costing assumes that an HRT

facility is the recommended CSO control project to address EPA 003. Costs to send additional flow are allocated on a per-mgd basis for flows over 70 mgd (the assumed capacity of the facility to treat only EPA 003) at a rate of $300,000 per mgd. For EPA 004, this amounts to an additional $2.1 million. At this time, the HRT system is being evaluated using two vendors – Actiflo and DensaDeg. A detailed analysis of these systems should be performed during the design of the project, if this is the preferred alternative. For now, though, preliminary cost and system "footprint" data have been collected for the two treatment trains and the costs among the two systems have been averaged to determine a cost opinion for the work of this alternative.

7. As the captured flow is being pumped to treatment, there would be no additional treatment or disinfection facilities provided at this location for flows that go directly to the outfall.

The screening-level cost estimate for this project is $12.7 million.

This alternative provides a sound technical solution to treating flows that currently discharge at EPA 004 without the requirement for purchasing and clearing nearby occupied properties to construct other treatment structures. While the initial capital cost is high, actually removing flow from the site is a distinct advantage for meeting the treatment goal of JSA and this alternative would be considered further. However, the option may not be feasible due to the limited capacity of the discharge sewer and/or the floodwall pump station that serves as the outfall pipe for EPA 003 as well as the effluent discharge pipe for the WWTP. Further evaluation is needed to assess of the available capacity of the existing system. No improvements to the discharge sewer or floodwall pump station are included in this screening-level cost estimate.

D. Fine Screening

This alternative consists of diverting the flow from the outfalls, through a fine screening system, and back into the outfall channel. This alternative was presented as the recommended alternative for treatment at this location in the initial LTCP submission and CDM Smith maintains that the recommendations in the initial LTCP conform to the 85% capture provision of the CSO Policy Presumptive Approach. CDM Smith recognizes the concerns raised by KDEP and EPA in their January 30, 2015 letter to the JSA and has provided more detailed review of multiple alternatives within this document. In the meantime, this alternative is the least cost alternative available to JSA, so it would be included in this analysis.

The system would consist of a fine screening facility consisting of a 7.1 mgd CSO deflection screen installed at the regulator (See **Figure J-5**). The CSO deflection screen is assumed to feature a 4-6 mm clear spacing to screen small solids, debris, etc. The screen is assumed to be mechanically cleaned by automated combs, with screened material falling away from the screen and back into the wastewater channel to be pumped to the WWTP by the Harrison Pump Station. Due to the unknown condition of the regulator in regards to retrofitting it, it is assumed that a new regulator will be constructed with the CSO deflection screen integrated into the new design. The new regulator would be sized to appropriately house the CSO deflection screen and provide adequate room to maintain the screens.

The existing regulator is located in the middle of an extension of North 3rd Street. The construction of a new, larger regulator that contains the screens would possibly require this street extension directly in front of the Harrison Pump Station to be closed temporarily during construction and periodically for system maintenance. As North 3rd Street in this location is not a main traffic route, traffic should not be altered significantly by this, but the cost for detours and maintaining local traffic is a real cost that must be factored into the overall project cost.

The screening-level cost estimate for this project is $3.5 million.

E. Fine Screening with Disinfection

This alternative includes the full screening facility described in Alternative D, followed by disinfection. The system consists of the following items (See **Figure J-6**):

1. A new screening facility as described in Alternative D.
2. Connecting piping that routes the screened flow from the screening facility into a low head pump station. Additional piping would route flows over 7.1 mgd directly to the outfall/floodwall pump station. The weir would be adjustable to allow for minor adjustments to ensure that 7.1 mgd is sent to the disinfection channel. The structure would be enclosed to prevent backflow created when the floodwall gates are closed and the water level in the existing channel rises.
3. A low head, 7.1 mgd pump station would be required to move the screened flow into the disinfection basin. The station would consist of three 3.55 mgd (2,500 gpm) pumps, all VFD operated, operating on a lead-lag-standby scheme. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage and are expected to continue operation in the event that the screens fail. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 7.1 mgd flow (25,000 gallons).
4. A disinfection alternative, as described below.

Disinfection alternatives that were reviewed include ultraviolet (UV) radiation, chlorination / dechlorination, and peracetic Acid (PAA). Advantages and disadvantages of these alternatives are summarized briefly below.

1. UV
    a. Advantages
        i. Instantaneous inactivation of organisms
        ii. Takes the least amount of space; no contact tank required
        iii. No chemicals on the site
        iv. Least capital cost alternative
    b. Disadvantages
        i. Intermittent use of facility can be an issue; UV works best with a continuous flow stream.
        ii. Particle size in the flow stream may limit UV effectiveness
2. Chlorination/Dechlorination
    a. Advantages
        i. Proven disinfecting capability for a wide variety of organics
        ii. Can be used in intermittent flow situation
        iii. Operator familiarity; already used in the system
    b. Disadvantages
        i. Two chemical systems in separate buildings are required at a remote location
        ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 75,000 gallons) is required
        iii. Liquid Sodium Hypochlorite has a limited shelf life. As design volumes must be for peak storm events, during long periods of low rainfall the chemical may have to be withdrawn from the tank and replaced
        iv. Most expensive capital cost alternative

3. PAA
    a. Advantages
        i. Does not need a secondary chemical for dechlorination
        ii. Can be used in intermittent flow situation
        iii. Equipment is typically leased; may be able to subcontract operation
        iv. Capital cost is lower than chlorination/dechlorination alternative
        v. PAA has longer shelf-life than other alternatives
    b. Disadvantages
        i. Typically, higher doses of chemical are required for disinfection than sodium hypochlorite.
        ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 75,000 gallons) is required. Volume may be higher, depending on results of pilot testing of effectiveness.
        iii. A chemical system is required at a remote location.

The screening-level cost estimate for this project is $7.6 million, which assumes chlorination / dechlorination is the selected type of disinfection. Bench and pilot scale testing of the disinfectants at this site would be conducted during preliminary design if this alternative is selected.

Figure J-6 shows the worst case scenario for land use if chemical disinfection and low head pumping is required. As with Alternative B, purchases of property that are currently occupied would be required to construct the disinfection system.

While the facilities described above can be constructed, there are several potential disadvantages to the work:

1. Third Street, Park Avenue and Harrison Street would likely be impacted during construction. Third Street would likely be closed between Madison and Harrison to allow for construction staging, and Park and Harrison Streets would likely have traffic lanes restricted.
2. If chemical disinfection is proven to be the cost-effective alternative at this location, chemical feed systems will be installed adjacent to the events center, as well as adjacent to a retirement/nursing home. It is expected that there will be significant public concern with the location of the facility.
3. Zoning may have to be modified to allow for chemical systems and the contact basin to be constructed.
4. Construction close to the floodwall may require special construction methods to ensure floodwall foundation stability through and after construction.

F. High Rate Treatment

This alternative consists of installing a high rate clarification (ballasted flocculation) system that is designed to remove settleable solids and the insoluble BOD fraction with a construction footprint that is much smaller than conventional primary treatment processes and provides a higher level of treatment than conventional primary treatment processes. The units typically are provided as equipment packages by the vendors that supply them, oftentimes complete with basins, the mixing, flocculation, and sedimentation equipment internal to the basins, and chemical feed system components, although what is provided can vary from manufacturer to manufacturer. The composition of the system goes beyond just the equipment package and would require pumping to meet the hydraulic needs of the system. The system would contain the following elements (See **Figure J-7**, which includes the footprint of the larger HRT system):

1. Reconstruction of the existing regulator to allow for the following scenarios:
    a. Dry weather flow to continue flowing to the Harrison Pump Station.
    b. Wet weather flows up to 7.1 mgd to be sent to a fine screening facility and high rate treatment outlined below.
    c. Flow over 7.1 mgd to be sent directly to the outfall/floodwall pump station.
2. A screening facility, similar to Alternative D. The system consists of a screening facility with a 7.1 mgd CSO deflection screen installed at the reconstructed regulator. The CSO deflection screens would feature a 4 mm clear spacing to screen small solids, debris, etc. The screens would be mechanically cleaned by automated combs, with screened material falling away from the screens and back into the wastewater channel to be pumped to the WWTP by the Harrison Pump Station. A screen bypass channel would be included that would bypass the HRT. Unscreened CSO flow can damage the HRT equipment.
3. A low head pump station, as described in Part 3 of Alternative E. For the HRT alternative, the alternatives are to either build the treatment system in-ground and pump after treatment, or pump prior to treatment and build the treatment system above ground. While building above-ground has a negative impact on the aesthetics of the surrounding area, the above-ground system is more cost effective and less prone to flooding. The above ground option is considered in this analysis.
4. The HRT unit. The units are physical / chemical treatment processes that use a combination of rapid mixing of chemicals, flocculation chambers, and settling basins to obtain settling of total suspended solids (TSS) and biochemical oxygen demand (BOD). For purposes of this evaluation, two systems were reviewed for general compatibility:
    a. Kruger's Actiflo system
    b. Infilco Degremont's DensaDeg system
5. Sludge withdrawal and disposal is required. For purposes of this evaluation, it is assumed that there is a connection off the bottom of the sedimentation basin for a sludge truck (with pump) to dock, offload the sludge from the basin, and transport the sludge to the WWTP. However, a separate storage tank may be required for temporarily holding sludge which is not included in this estimate. It is also noted that the cost for sludge handling is not included as a capital expense at this time; it is assumed that JSA would enter into a contract with a waste hauler instead of buying their own truck. Pumping the sludge into the local sewer may also be possible, but an evaluation of the sewer system would be required between the entry point and the WWTP to insure that there would be no potential overflows to other outfalls.
6. Gravity discharge channel from the HRT to the outfall pipe.

The screening-level cost estimate for this project is $12.9 million. Budgetary estimates have been provided by each of the vendors listed above. These costs were reviewed and the costs were averaged for use in this evaluation.

When considering this alternative, the following disadvantages are noted:

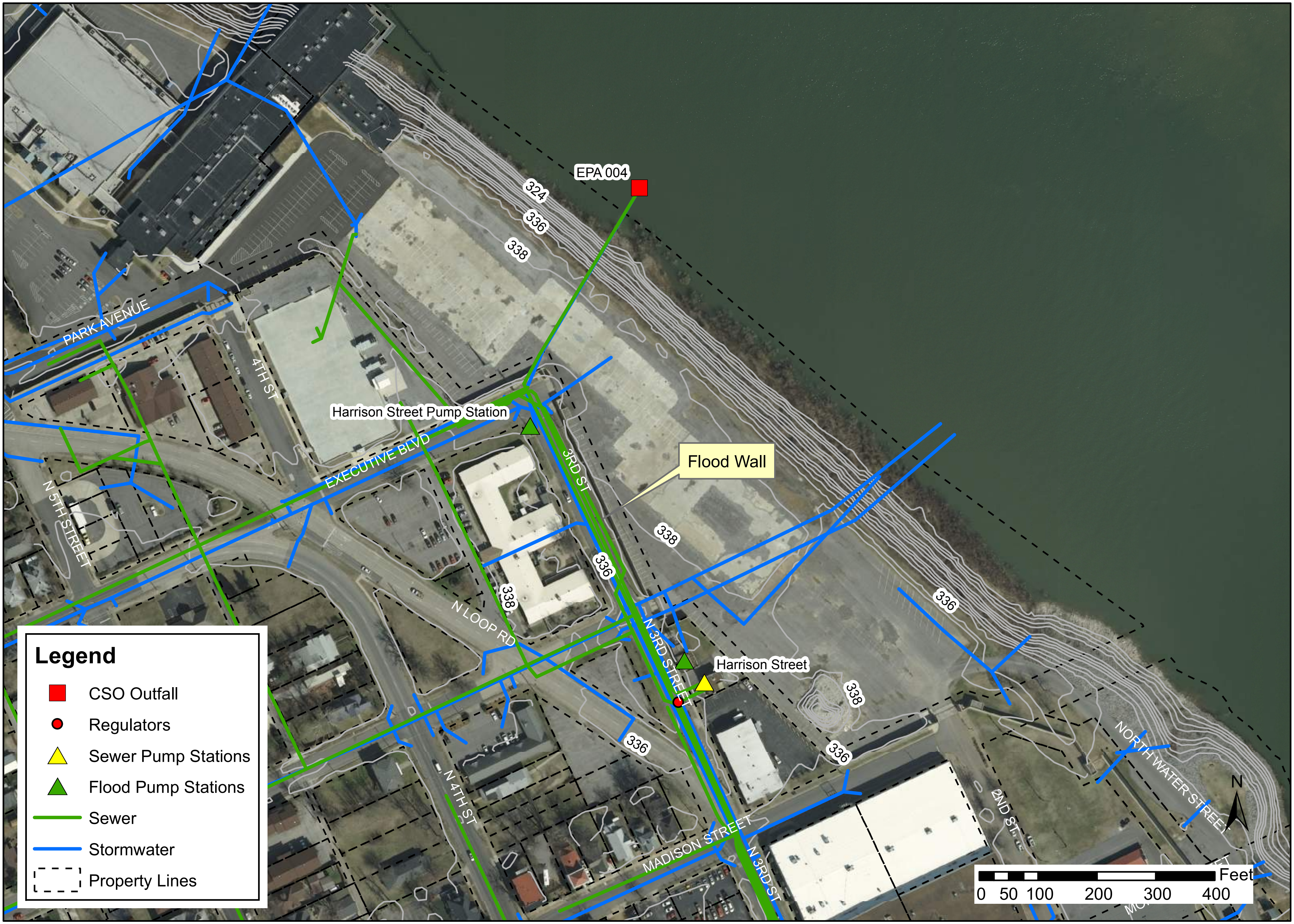
1. Capital and operating costs would be very high.
2. Site constraints prohibit the construction of the large HRT units and would require nearby occupied properties to be purchased and cleared.
3. The system is relatively complex to operate remotely. It is likely that JSA would need to send staff to monitor operation during rain events.
4. Multiple chemical systems would be at a remote site.
5. There would be significant impact to the aesthetic of the surrounding downtown area, as well as potential concerns with odors.

6. If HRT technology is used for JSA, it may be preferred to combine all outfalls that would be treated at the WWTP. An HRT unit can be constructed there that would be more cost effective for the entire system.

G. High Rate Treatment with Disinfection

This alternative consists of using the HRT system described in Alternative F and adding a disinfection facility (See **Figure J-8**). The HRT discharge pipe would route treated flow to either the UV channel or the contact chamber, depending on which disinfection alternative would be selected through bench and pilot testing of disinfection alternatives. It is noted that **Figure J-8** shows the largest configuration of HRT treatment on the site and the chlorination / dechlorination disinfection system.

While adding disinfection would improve the level of treatment provided at EPA 004, it would increase the cost (over $900,000) and operational complexity of this remote facility. For this reason and the reasons stated above in Alternative F, CDM Smith has determined that this is not a feasible alternative for outfall EPA 004.



Paducah LTCP - Outfall EPA 004 Figure J-1 - Site Overview

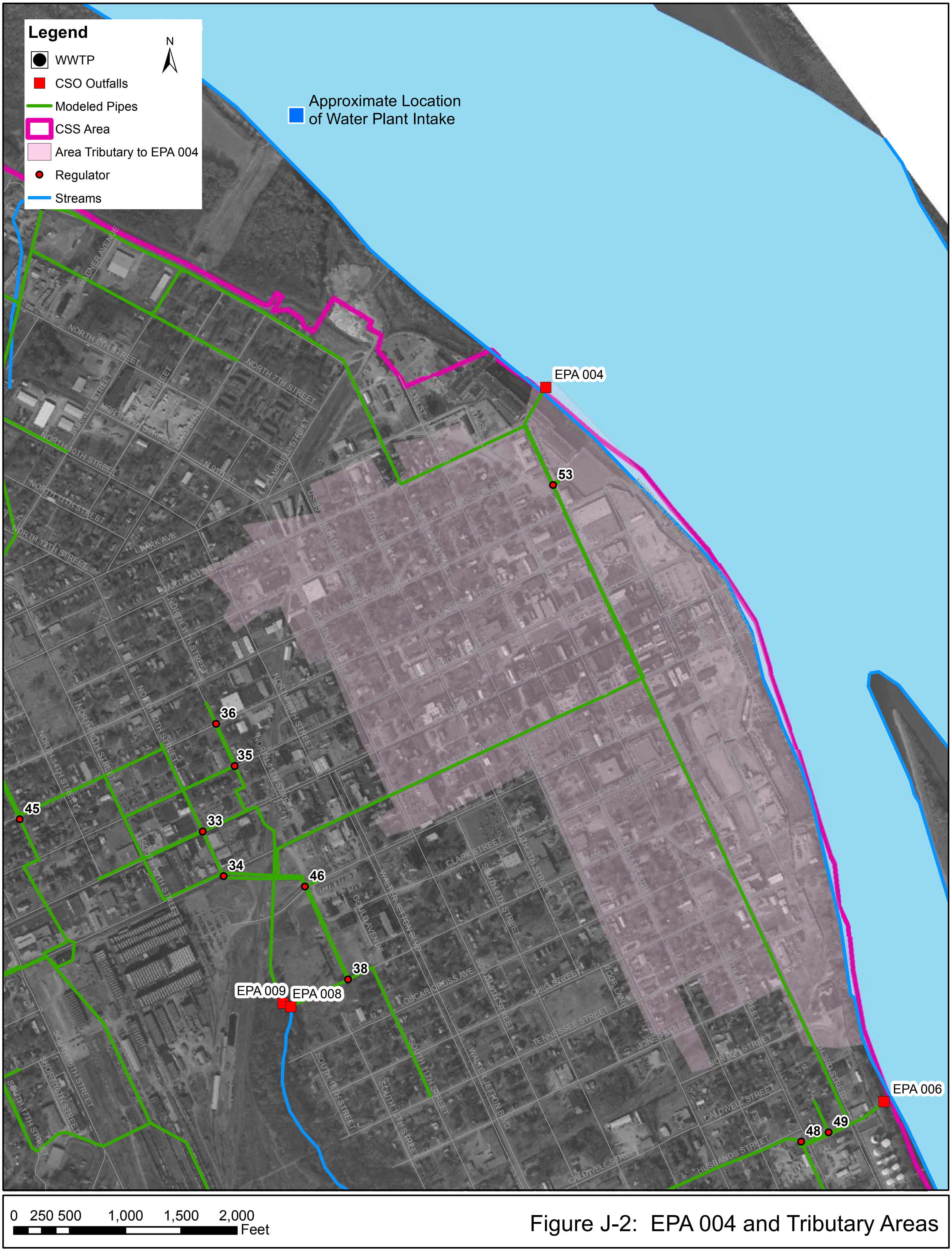
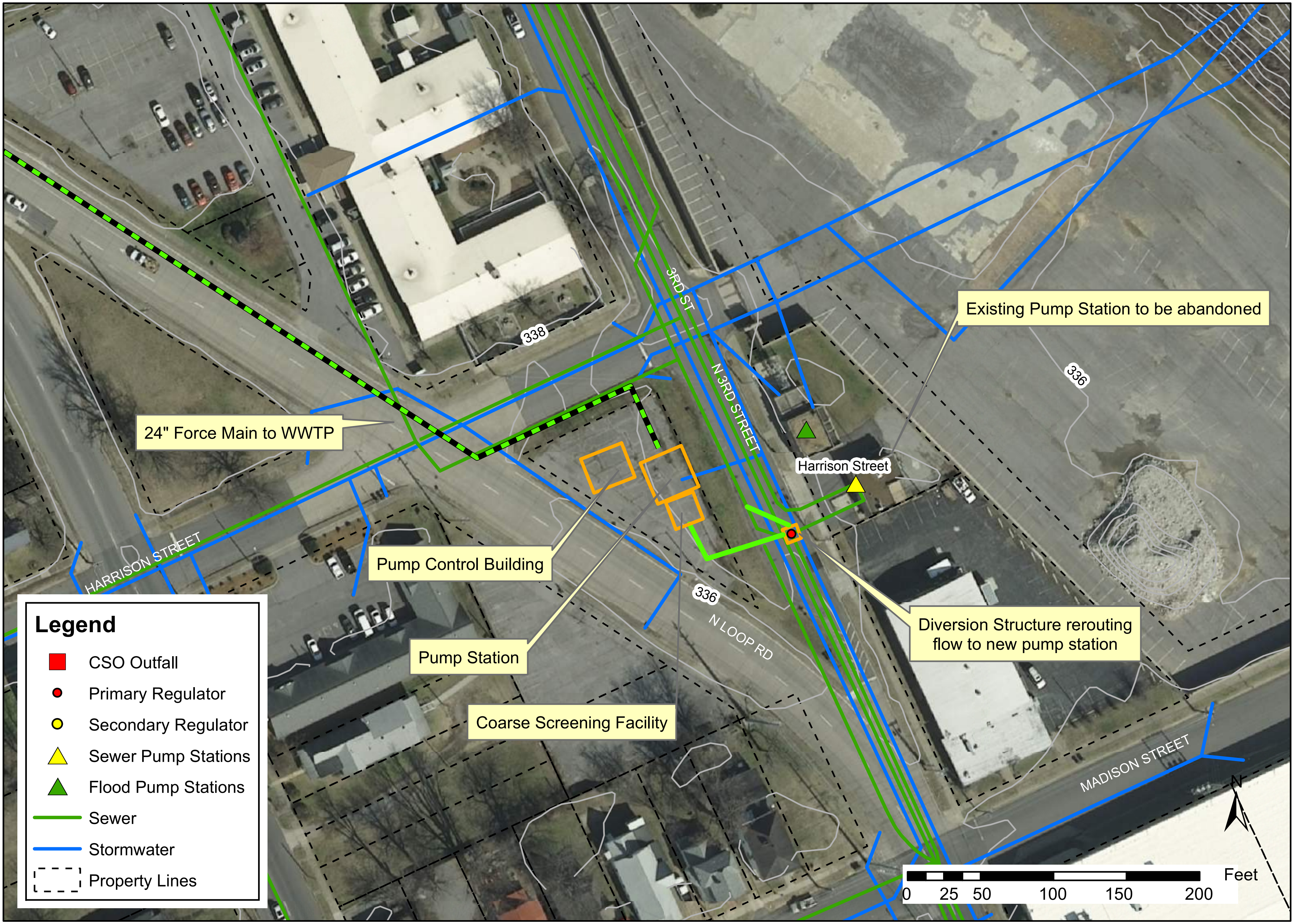


Figure J-2: EPA 004 and Tributary Areas

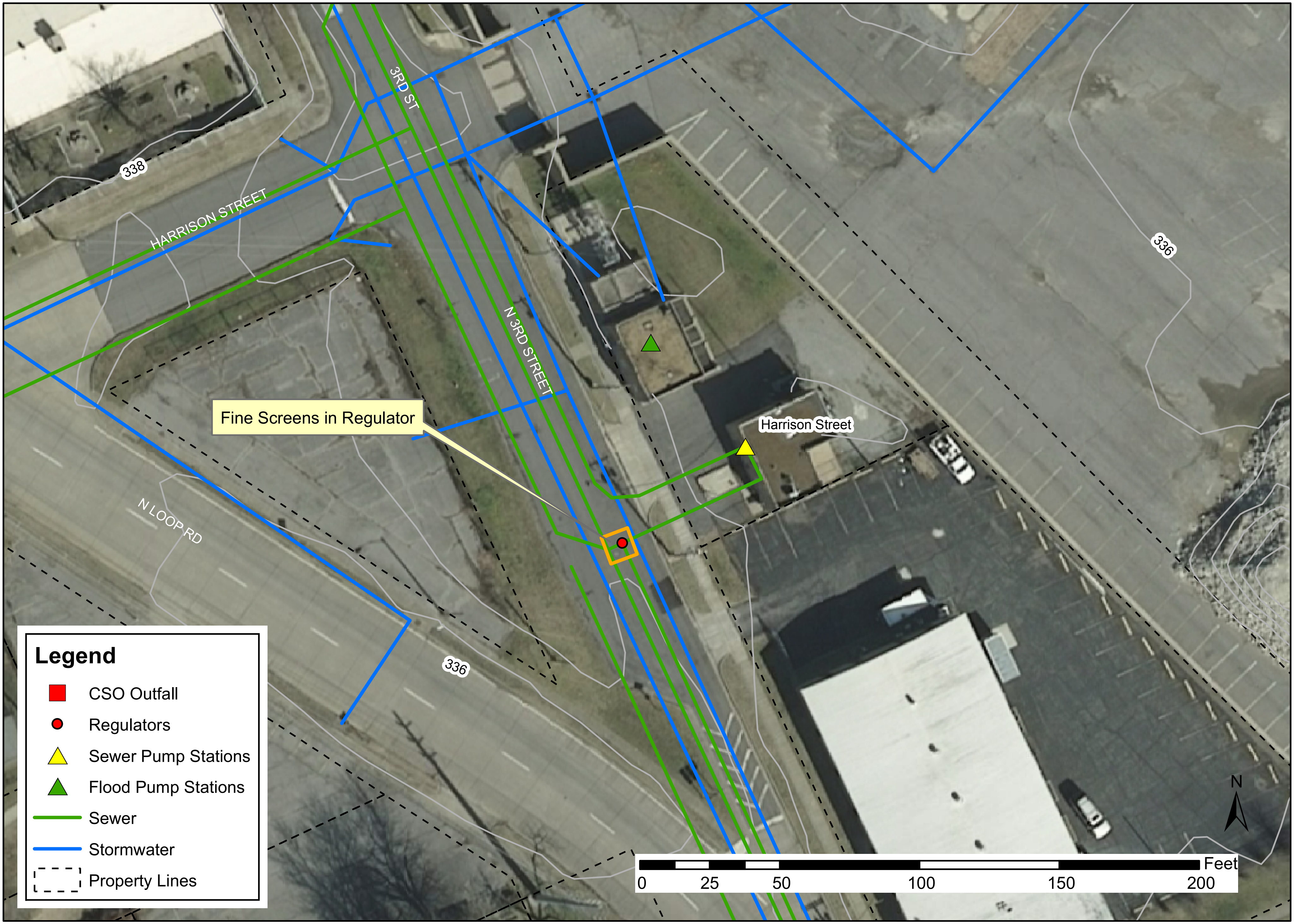
Paducah LTCP - Outfall EPA 004

Figure J-3 - Storage



Paducah LTCP - Outfall EPA 004

Figure J-4 - Pumping to Treatment

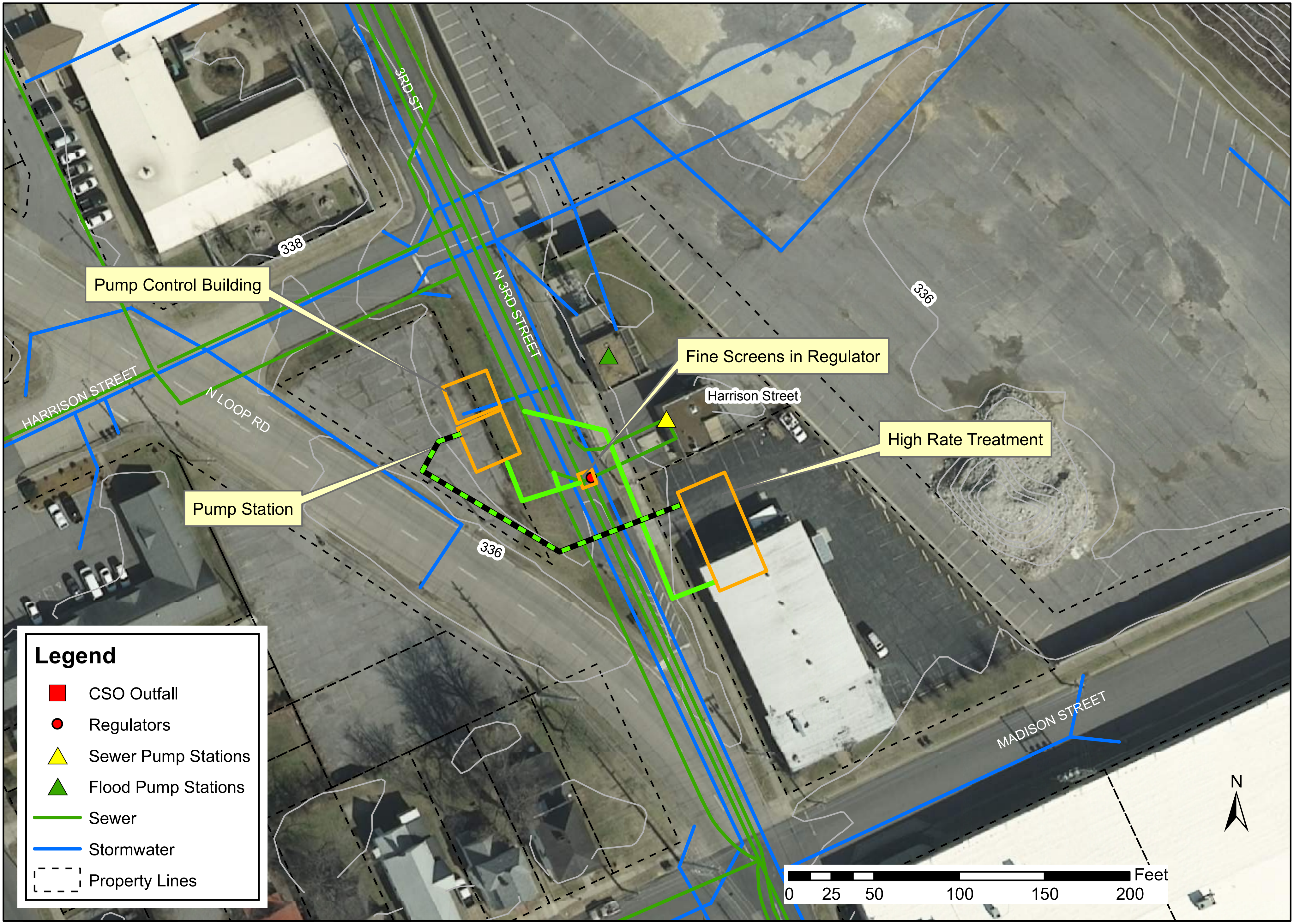


Paducah LTCP - Outfall EPA 004

Figure J-5 - Fine Screening

Paducah LTCP - Outfall EPA 004

Figure J-6 - Screening and Disinfection



Paducah LTCP - Outfall EPA 004

Figure J-7 - HRT

Paducah LTCP - Outfall EPA 004

Figure J-8 - HRT and Disinfection

Appendix K

EPA 006/007 Alternative Analysis

Note 1: Costs presented are screening-level estimates for comparison of the alternatives. Costs of selected alternatives will be reviewed in further detail for the financial analysis.

Note 2: When additional land is required to site the facilities, the placement of the facilities and the selected parcels are shown for illustrative purposes only. Alternative nearby sites would also be evaluated during design.

EPA 006 and EPA 007, shown in **Figure K-1,** are CSO outfalls located along the Tennessee River, just upstream of its confluence with the Ohio River. Due to their proximity and the influence of the Husbands Pump Station, these locations are evaluated collectively for CSO control alternatives.

During normal, dry-weather flow conditions, the Husbands Pump Station conveys flow to the downstream gravity system. However during periods of high flows, the regulator structures allow the discharge of combined sewer flows to the outfalls. The majority of the flows that are discharged are through regulators 39 and 48 which are located along South 4th Street. The remaining regulators, 49 and 50/51, serve smaller areas. The tributary areas for EPA 006 and EPA 007 are shown in **Figure K-2**.

The sewer system immediately upstream of these outfalls are combined sewers, but the sewer system further upstream is believed to be separate sanitary sewer systems, including the EPA 014 area was recently separated.

During normal conditions, flows from the CSO outfalls pass through the open flood control gates. When the Ohio River level reaches 30 feet, the gates are closed, and the two floodwall pump stations are operated by the City of Paducah to transfer flows across the floodwall. In general, the floodwall pump station associated with EPA 006 is the primary station, which the floodwall pump station associated with EPA 007 used as a backup when needed. Because of the original design of the floodwall pump stations, when the gates are closed, the operation of the pump stations result in an approximate depth of water in the floodwall pump stations between two and six feet for EPA 006 and between eight and thirteen feet for EPA 007. Anecdotally, when the gates are closed the existing sewer system stores a portion of the flow until the Husbands Pump Station has available capacity. Based on a review of available data for 2007 through 2014, the flood gates are typically closed approximately four times per year for an average of duration of 16 days per occurrence, with six of those days receiving rainfall.

Evaluation of CSO control alternatives for this outfall assume a target percent capture of 95 percent of total annual CSO volume, which is consistent with the knee of the curve sizing for screening as presented in the LTCP. This results in a combined required sizing of 7 million gallons per day (mgd) for alternatives based on overflow treatment at this site. This target percent capture will be utilized to compare alternatives; however, JSA recognizes that the need to achieve a minimum system-wide capture of 85 percent and may adjust the sizing of the selected alternative at EPA 006 and EPA 007 to achieve this goal. The 95 percent capture results in 10 CSO events per year relative to 36 events per year under the current system.

In order to simplify the design, construction, and operation of the CSO control facility, each of the alternatives evaluated (excluding separation and fine screenings only) assume that flows can be routed to a single facility. In order to accommodate this, the area east of South 4th Street, which represents approximately 28 acres, is assumed to require rerouting and/or separation. Additionally, the existing 18-inch diameter sewer between regulator 39 and the Husbands Pump Station is assumed to be replaced with 1,150 feet of 24- inch diameter pipe. Together these costs add approximately $3.5 million to each alternative described below excluding separation.

The following alternatives were evaluated for EPA 006 and EPA 007:

A. System separation of the tributary area to these outfalls
B. Storage
C. Pump station improvements with additional wet weather treatment facility to be constructed near the WWTP (no on-site storage)
D. Fine Screening
E. Fine Screening with Disinfection
F. High Rate Treatment
G. High Rate Treatment with Disinfection

For each alternative, it is assumed that properties are acquired, and that a portion of these properties can be utilized to construct the elements in each alternative.

A. System Separation

System separation was considered for the combined sewer system portion of this tributary area. That area is assumed to include approximately 300 acres. Construction costs are expected to exceed $24 million and total project costs would be approximately $30 million. The unit cost for separation presented in the LTCP ($100,000 per acre) was revised to $80,000 per acre based upon the costs associated with the separation project for EPA 012. With anticipated engineering, legal, and other administrative costs, the assumed total project unit cost is $100,000 per acre. Costs associated with the separation of EPA 014 were lower than this value but are not believed to be appropriate for planning purposes since that project was completed in conjunction with Department of Transportation work.

Sewer separation for a portion of the tributary may be feasible; however, separating a portion of the area would not eliminate the need for CSO controls for the remaining CSO discharge.

B. Storage

In order to achieve the target percent capture, the storage alternative must consider three components: the rate at which flow must be captured and stored, the volume of storage required, and how quickly the stored flows can be drained back to the system for treatment. Because of the limitations of the Husbands Pump Station, stored flows were assumed to be drained by gravity to the current discharge location of the Husbands Pump Station (manhole Z02_0040001). This sewer has a total peak capacity of approximately 6 million gallons per day. Utilizing the results of the hydraulic model, several combinations of those three factors were analyzed in order to assess the feasibility of this alternative and to attempt to determine appropriate sizes for those three components while achieving the target percent capture. The following sizes were estimated, and the resulting facility is shown as **Figure K-3**:

- Pumping rate into storage: 7 mgd
- Required storage: 50 million gallons
- Dewatering rate: 6 mgd (the limit of available sewer capacity)

Elements of this system include the following:

1. A diversion structure near the Husbands Pump Station that diverts up to 7 mgd to a new coarse screening facility. Flow over 7 mgd on any given event goes continues to the outfalls.
2. A coarse screening facility upstream of the storage tank pump station. The screening capacity would be 7 mgd, with two 3.5 mgd screen channels and a 7 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to protect the pumps. Screenings would be collected and disposed of in a new screenings building, with dumpsters provided to collect screenings and for ease of transport out of the facility.
3. A low head, 7 mgd storage tank pump station. Three 3.5 mgd (2,437 gallons per minute) pumps will be installed, all variable frequency drive (VFD) operated and operating on a lead-lag-standby scheme. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 7 mgd flow (25,000 gallons).
4. 50 million gallons of storage, which is the storage required to achieve the target percent capture given dewatering limitations of the WWTP. The storage is assumed to be four, 12.5 million gallon above ground tanks, as shown in **Figure K-3.** Prestressed concrete tanks are assumed at this stage, but steel would also be considered at the time of construction if there is an indication that they can be cost-competitive. Tank dimensions would be approximately 218 feet in diameter and 45 feet tall. Overflow standpipes would be constructed in each tank, with the overflow elevation set to provide 2 feet of freeboard. Tank washdown systems are assumed to be provided.
5. A 24-inch gravity pipe from the storage tanks to the current discharge location of the Husbands Pump Station's force main at manhole Z02_0040001.
6. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 40 feet by 25 feet, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.

The screening-level cost estimate for this project is $102 million.

The above option is not practical for four primary reasons: (1) cost; (2) the low dewatering rate drives the storage volume requirement to 50 MG; (3) dewatering full tanks would require over a week (and this assumes that there are no other rain events within the period), which is too long to retain stored flow; and (4) a significant amount of property would be required for the storage tanks. For this option, constructing the four storage tanks would require the purchase and clearing of multiple properties. For illustrative purposes, 14 properties along South 4th Street were assumed to be acquired, five of those are occupied by residences and one by a commercial facility. The site also features topographic elevation changes up to 20 feet, which would require significant earthwork.

It is noted that it may be possible to define a hybrid storage-treatment option for which the combination of storage and treatment would be more reasonable. This would entail the use of some form of high-rate treatment (for solids removal and disinfection of the dewatered flow from storage) at the site. It has been determined through model simulations of the system that multiple combinations of storage and dewatering could achieve the defined target capture if that volume could be dewatered at through a treatment facility. Those options can be explored further as the system-wide alternative evaluations continue.

C. Pump station improvements with additional wet weather treatment facility to be constructed (no on-site storage)

Increasing the pumping capacity at Husbands Pump Station, either through construction of a new, larger facility or through the construction of a wet weather pump station, would achieve the target percent capture at EPA 006 and EPA 007. However, these additional flows would need to be transported and treated at another location within the system. Several options exist for the routing of these additional flows:

- Construct a new pump station to route all flows directly to the WWTP where the flow can be routed to the WWTP if there is available capacity or to a new, dedicated wet weather treatment facility if WWTP capacity is not available. The required size for this new pump station would be approximately 10 mgd. This alternative would reduce the existing peak flow to the Harrison Pump Station by approximately 2.6 mgd, allowing greater capture of CSO discharge at EPA 004.
- Continue to utilize the existing pump station for normal, dry weather flows but construct a new wet weather pump station to route flows to the WWTP as described above. The required size for the wet weather pump station would be approximately 7 mgd.
- Construct a new pump station but continue to route flows through the Harrison Pump Station. The required size for this new pump station would be approximately 10 mgd. This solution would require additional gravity and/or force main conveyance capacity from the new pump station to the Harrison Pump Station, as well as improvements at the Harrison Pump Station to convey and/or treat these additional flows.

For the purposes of this evaluation, a new pump station designed to convey both dry weather and wet weather flows that is routed to the WWTP is assumed. The other options can be explored further as the system-wide alternative evaluations continue.

This pumping alternative consists of diverting a maximum of 10 mgd through a coarse screening facility and pump station for transport of normal, dry weather flows to the WWTP and wet weather flows to a new wet weather treatment facility located near the WWTP that would receive wet weather flows from other CSO outfalls. Elements of this system include the following (See **Figure K-4**):

1. A diversion structure at regulator 48 that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 10 mgd to a new coarse screening facility; (2) flow over 10 mgd on any given event goes over a weir directly to the outfall.
2. A coarse screening facility upstream of the pump station. The screening capacity would be 10 mgd, with two 5 mgd screen channels and a 10 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to protect the pumps. Screenings would be collected and disposed of in a new screenings building, with dumpsters provided to collect screenings and for ease of transport out of the facility.
3. A 10 mgd pump station. Three 5.0 mgd (3,500 gpm) pumps, all VFD operated, operating on a lead-lag-standby scheme, are assumed to be included. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage.

The pump station would be underground, with a wetwell sized to provide 20 minutes of detention time at the 10 mgd flow (140,000 gallons).

4. A force main routed from the pump station to the WWTP / new wet weather treatment facility. The connection point to the influent pipe/channel would be determined during detailed design, in coordination with the project's hydraulic analysis. Although the routing of the force main to the WWTP has not been determined, it was assumed to be approximately 15,000 feet in length.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30 feet by 20 feet, climate controlled for the VFDs would be provided. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. A new wet weather treatment facility located near the WWTP. For purposes of this analysis, it is assumed that this facility would consist of a high rate treatment (HRT) and disinfection facility that would provide the equivalent of primary treatment and disinfection for flows from outfall EPA 003 as well as potentially other remote outfalls. Costing assumes that an HRT and disinfection facility is the recommended CSO control project to address EPA 003. Costs to send additional flow are allocated on a per-mgd basis for flows over 70 mgd (the assumed capacity of the facility to treat only EPA 003) at a rate of $300,000 per mgd. For EPA 006 and 007, this amounts to an additional $1.3 million. At this time, the HRT system is being evaluated using two vendors – Actiflo and DensaDeg. A detailed analysis of these systems should be performed during the design of the project, if this is the preferred alternative. For now, though, preliminary cost and system "footprint" data have been collected for the two treatment trains and the costs among the two systems have been averaged to determine a cost opinion for the work of this alternative
7. As the captured flow is being pumped to treatment, there would be no additional treatment or disinfection facilities provided at this location for flows that go directly to the outfall.

The screening-level cost estimate for this project is $21.0 million.

This alternative provides a sound technical solution to treating flows that currently discharge at EPA 006 and 007 without placing a significant amount of maintenance-heavy or surface-disruptive structures in the area. While the initial capital cost is high, actually removing flow from the site is a distinct advantage for meeting the treatment goal of JSA and this alternative would be considered further. However, the option may not be feasible due to the limited capacity of the discharge sewer and/or the floodwall pump station that serves as the outfall pipe for EPA 003 as well as the effluent discharge pipe for the WWTP. Further evaluation is needed to assess of the available capacity of the existing system. No improvements to the discharge sewer or floodwall pump station are included in this screening-level cost estimate.

This alternative does not include on-site storage, but it is possible that a hybrid alternative could be considered as the system-wide solutions are evaluated that balances the need for storage and wet weather treatment. Adding storage could allow for pumping more flow directly to the WWTP one or two days after the storm event; this could reduce the amount of HRT treatment that would be required. On-site storage would also reduce the peak flow rates that drive the pump station and force main sizing requirements. It is noted, though, that construction of any storage would require property acquisition.

D. Fine Screening

This alternative consists of diverting the flow from the outfalls, through a fine screening system, and back into the outfall channel. This alternative was presented as the recommended alternative for treatment at this location in the initial LTCP submission and CDM Smith maintains that the recommendations in the initial LTCP conform to the 85% capture provision of the CSO Policy Presumptive Approach. CDM Smith recognizes the concerns raised by KDEP and EPA in their January 30, 2015 letter to the JSA and has provided more detailed review of multiple alternatives within this document. In the meantime, this alternative is the least cost alternative available to JSA, so it would be included in this analysis.

The system would consist of a fine screening facility consisting of a CSO deflection screen installed at each of the two regulators leading to EPA 006 and EPA 007 (See **Figure K-5**). For cost estimating purposes, both screens were assumed to have a 5 mgd capacity. The CSO deflection screens are assumed to feature a 4 mm clear spacing to screen smaller solids, debris, etc. The screens are assumed to be mechanically cleaned by automated combs, with screened material falling away from the screen and back into the wastewater channel to be pumped to the WWTP by the Husbands Pump Station. Due to the unknown condition of the regulators in regards to retrofitting it, it is assumed that new regulators will be constructed with the CSO deflection screens integrated into the new design. The new regulators would be sized to appropriately house the CSO deflection screen and provide adequate room to maintain the screens.

In addition, it is assumed that a new 1.5-inch coarse screening facility is installed at Husbands Pump Station to protect the pumps, with screenings collected and disposed of in a new screenings building. Facility will be sized to match the Husbands Pump Station capacity, built similar to item 2 of Alternative C.

The CSO deflection screens would feature a 4 mm clear spacing between the bars to screen smaller debris, leaves, etc. The screens would be mechanically cleaned by automated combs, with screened material falling away from the screens and back into the "dry flow" wastewater channel to the Husbands Street Pump Station.

The screening-level cost estimate for this project is $8.7 million.

E. Fine Screening with Disinfection

This alternative consists of diverting the flow from the outfalls, through a fine screening system and a disinfection system as described below, and back into the outfall channel. The system consists of the following items (See **Figure K-6**):

1. Modifications to regulator structures at 39 and 48 and diversion piping to route flows up to 7 mgd (excluding the existing capacity of the Husbands Pump Station) to the on-site screening facility
2. A screening facility consisting of two 3.5 mgd screening channels and a 7-mgd screen bypass channel. Each screen channel would have a dual screen system installed; a 1.5 inch coarse screen to screen large debris in the flow stream, followed by a fine screen (4-6 mm clear spacing) to screen small solids, debris, etc. The screens would be mechanically cleaned, with screenings delivered to trash dumpsters for easy maneuvering and hauling offsite. The screens and channels would be underground structures designed to fit into the existing hydraulic grade line. The screenings would be conveyed to the dumpsters in an "at-grade" facility to make the removal of the screenings convenient for operations staff.
3. A low head, 7 mgd pump station would be required to move the screened water into the disinfection basin. Three 3.5 mgd (2,437 gpm) pumps, all VFD operated, operating on a lead-lag1-standby scheme, are included. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage and are

expected to continue operation in the event that the screens fail. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 7 mgd flow (25,000 gallons).

4. A disinfection alternative, as described below.

Disinfection alternatives that were reviewed include ultraviolet (UV) radiation, chlorination / dechlorination, and peracetic Acid (PAA). Advantages and disadvantages of these alternatives are summarized briefly below.

1. UV
    a. Advantages
        i. Instantaneous inactivation of organisms
        ii. Takes the least amount of space; no contact tank required
        iii. No chemicals on the site
        iv. Least capital cost alternative
    b. Disadvantages
        i. Intermittent use of facility can be an issue; UV works best with a continuous flow stream.
        ii. Particle size in the flow stream may limit UV effectiveness
2. Chlorination/Dechlorination
    a. Advantages
        i. Proven disinfecting capability for a wide variety of organics
        ii. Can be used in intermittent flow situation
        iii. Operator familiarity; already used in the system
    b. Disadvantages
        i. Two chemical systems in separate buildings are required at a remote location
        ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 75,000 gallons) is required
        iii. Liquid Sodium Hypochlorite has a limited shelf life. As design volumes must be for peak storm events, during long periods of low rainfall the chemical may have to be withdrawn from the tank and replaced
        iv. Most expensive capital cost alternative
3. PAA
    a. Advantages
        i. Does not need a secondary chemical for dechlorination
        ii. Can be used in intermittent flow situation
        iii. Equipment is typically leased; may be able to subcontract operation
        iv. Capital cost is lower than chlorination/dechlorination alternative
        v. PAA has longer shelf-life than other alternatives
    b. Disadvantages
        i. Typically, higher doses of chemical are required for disinfection than sodium hypochlorite.
        ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 75,000 gallons) is required. Volume may be higher, depending on results of pilot testing of effectiveness.
        iii. A chemical system is required at a remote location.

Figure K-6 shows the worst case scenario for land use if chemical disinfection and low head pumping is required. As with Alternative B, property purchases would be required to construct the disinfection system. For this option, constructing the disinfection contact basin and associated chemical buildings and pump station would require the purchase and clearing of one or more properties adjacent to the Husbands Pump Station. For illustrative purposes, the facility was shown on the single, adjacent large property.

The screening-level cost estimate for this project is $13.0 million, which assumes chlorination / dechlorination is the selected type of disinfection. Bench and pilot scale testing of the disinfectants at this site would be conducted during preliminary design if this alternative is selected.

F. High Rate Treatment

This alternative consists of installing a high rate clarification (ballasted flocculation) system that is designed to remove settlable solids and the insoluble BOD fraction with a construction footprint that is much smaller than conventional primary treatment processes and provides a higher level of treatment than conventional primary treatment processes. The units typically are provided as equipment packages by the vendors that supply them, oftentimes complete with basins, the mixing, flocculation, and sedimentation equipment internal to the basins, and chemical feed system components, although what is provided can vary from manufacturer to manufacturer. The composition of the system goes beyond just the equipment package and would require pumping to meet the hydraulic needs of the system. The system would contain the following elements (See **Figure K-7,** which includes the footprint of the larger HRT system):

1. Modifications to regulator structures at 39 and 48 and diversion piping to route flows up to 7 mgd (excluding the existing capacity of the Husbands Pump Station) to the on-site screening facility
2. A screening facility consisting of two 3.5 mgd screening channels and a 7-mgd screen bypass channel. Each screen channel would have a dual screen system installed; a 1.5 inch coarse screen to screen large debris in the flow stream, followed by a fine screen (4-6 mm clear spacing) to screen small solids, debris, etc. The screens would be mechanically cleaned, with screenings delivered to trash dumpsters for easy maneuvering and hauling offsite. The screens and channels would be underground structures designed to fit into the existing hydraulic grade line. The screenings would be conveyed to the dumpsters in an "at-grade" facility to make the removal of the screenings convenient for operations staff.
3. A low head pump station, as described in Part 3 of Alternative E. For the HRT alternative, the alternatives are to either build the treatment system in-ground and pump after treatment, or pump prior to treatment and build the treatment system above ground. While building above-ground has a negative impact on the aesthetics of the surrounding area, the above-ground system is more cost effective and less prone to flooding. The above ground option is considered in this analysis.
4. The HRT unit. The units are physical / chemical treatment processes that use a combination of rapid mixing of chemicals, flocculation chambers, and settling basins to obtain settling of total suspended solids (TSS) and biochemical oxygen demand (BOD). For purposes of this evaluation, two systems were reviewed for general compatibility:
   a. Kruger's Actiflo system
   b. Infilco Degremont's DensaDeg system
2. Sludge withdrawal and disposal is required. For purposes of this evaluation, it is assumed that there is a connection off the bottom of the sedimentation basin for a sludge truck (with pump) to dock, offload the sludge from the basin, and transport the sludge to the WWTP. However, a separate storage tank may be required for temporarily holding sludge which is not included in this estimate. It is also noted that the cost for sludge handling is not included as a capital expense at this time; it is assumed that JSA would enter into a contract with a waste hauler

instead of buying their own truck. Pumping the sludge into the local sewer may also be possible, but an evaluation of the sewer system would be required between the entry point and the WWTP to insure that there would be no potential overflows to other outfalls.

5. Gravity discharge pipe from the HRT to the outfall pipes.

The screening-level cost estimate for this project is $19.5 million. Price proposals have been provided by each of the vendors listed above. These costs were reviewed and the costs were averaged for use in this evaluation.

When considering this alternative, the following disadvantages are noted:

1. Capital and operating costs would be very high.
2. The system is relatively complex to operate remotely. It is likely that JSA would need to send staff to monitor operation during rain events.
3. Multiple chemical systems would be at a remote site.
4. Purchase of a significant land area for construction of this alternative would drive up costs, may delay implementation of the work due to landowner protest, and may lower surrounding property values due to having a form of wastewater treatment installed in the immediate area.
5. If HRT technology is used for JSA, it may be preferred to combine all outfalls that would be treated at the WWTP. An HRT unit can be constructed there that would be more cost effective for the entire system.

G. High Rate Treatment, with Disinfection

This alternative consists of using the HRT system described in Alternative F and adding a disinfection facility (See **Figure K-8**). The HRT discharge pipe would route treated flow to either the UV channel or the contact chamber, depending on which disinfection alternative would be selected through bench and pilot testing of disinfection alternatives. It is noted that **Figure K-8** shows the largest configuration of HRT treatment on the site and the chlorination / dechlorination disinfection system.

While adding disinfection would improve the level of treatment provided at EPA 006/007, it would increase the cost (over $1.7 million) and operational complexity of this remote facility. For this reason and the reasons stated above in Alternative F, CDM Smith has determined that this is not a feasible alternative for outfall EPA 006/007.

Paducah LTCP - Outfall EPA 006/007

Figure K-1 - Site Overview

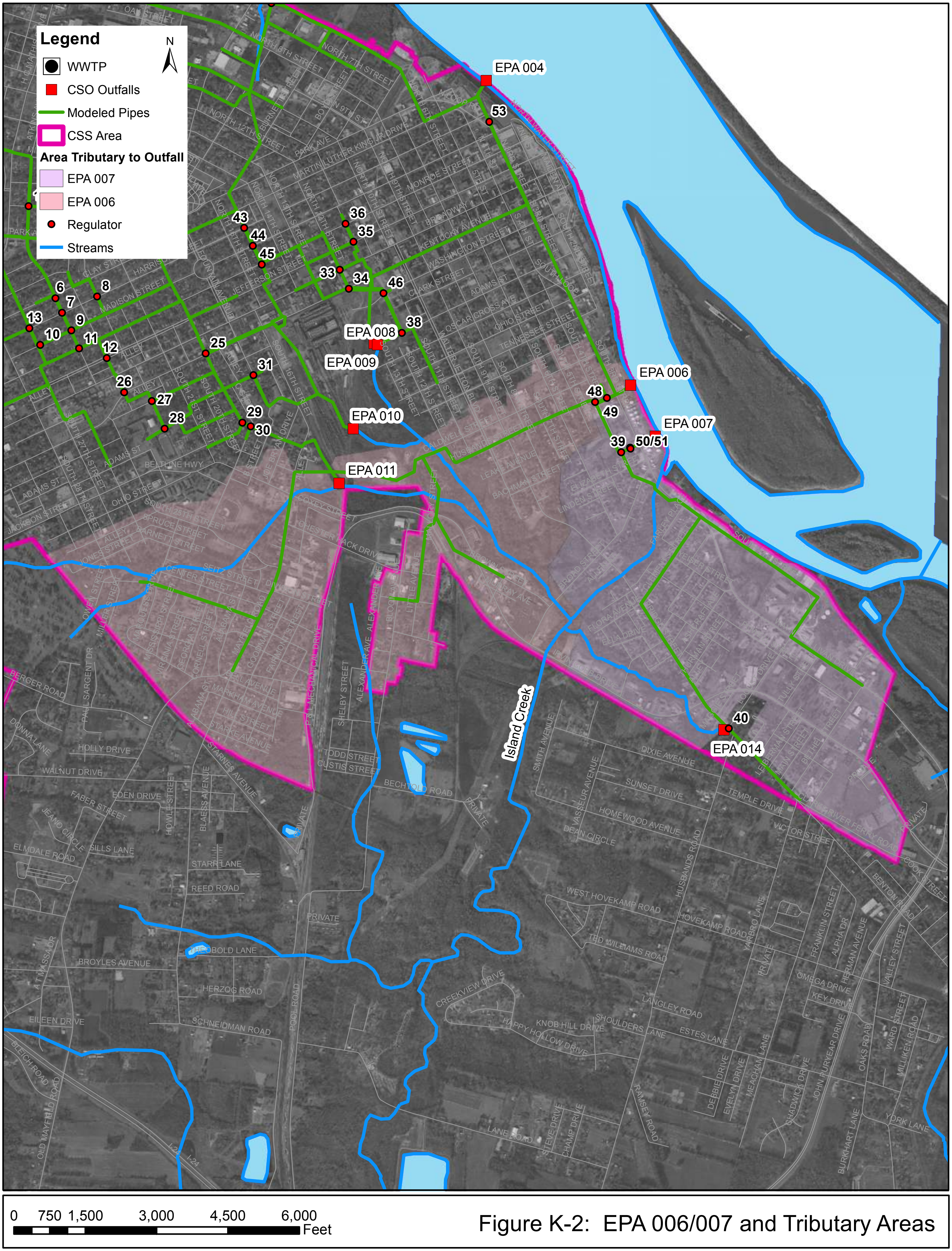
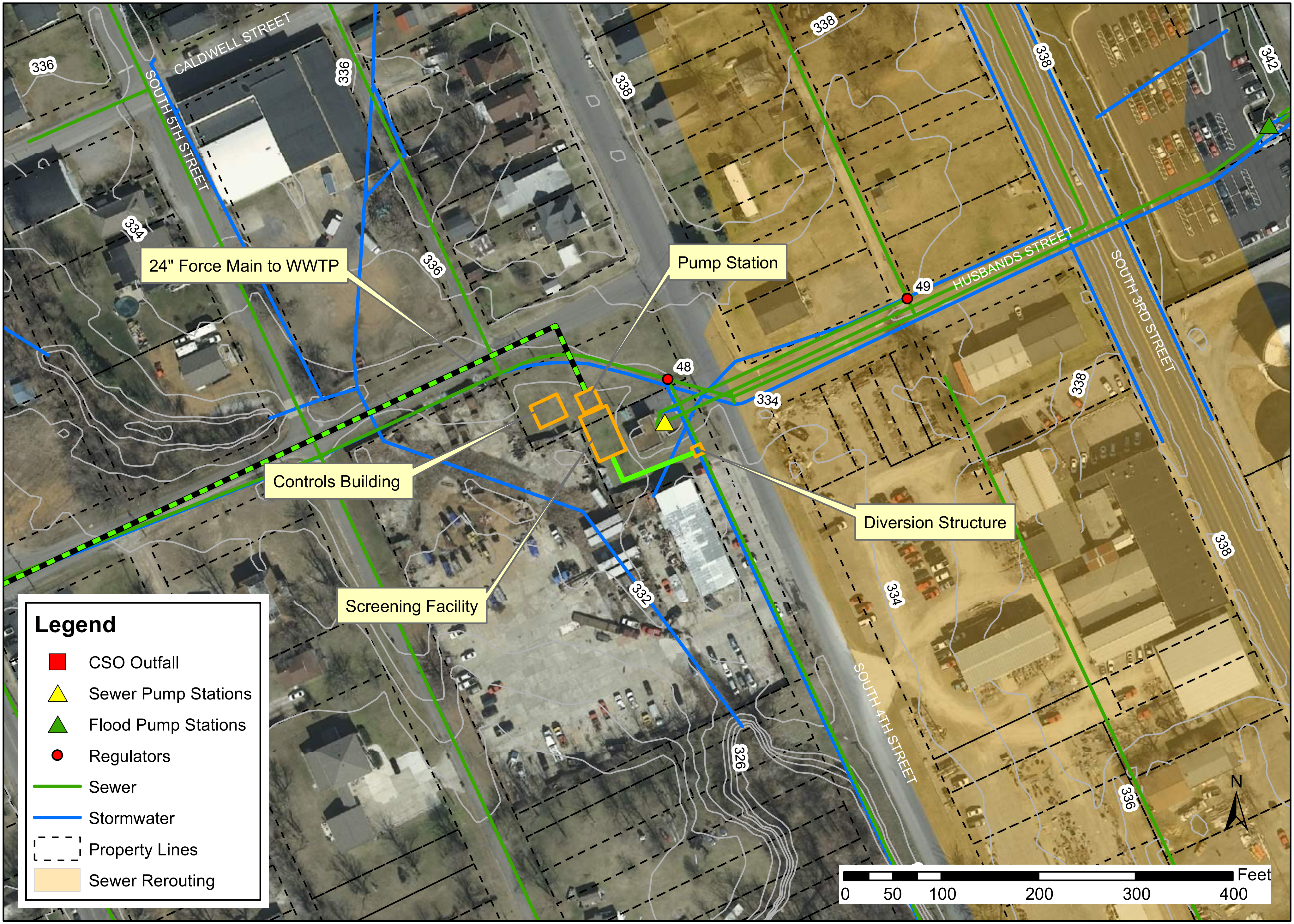


Figure K-2: EPA 006/007 and Tributary Areas

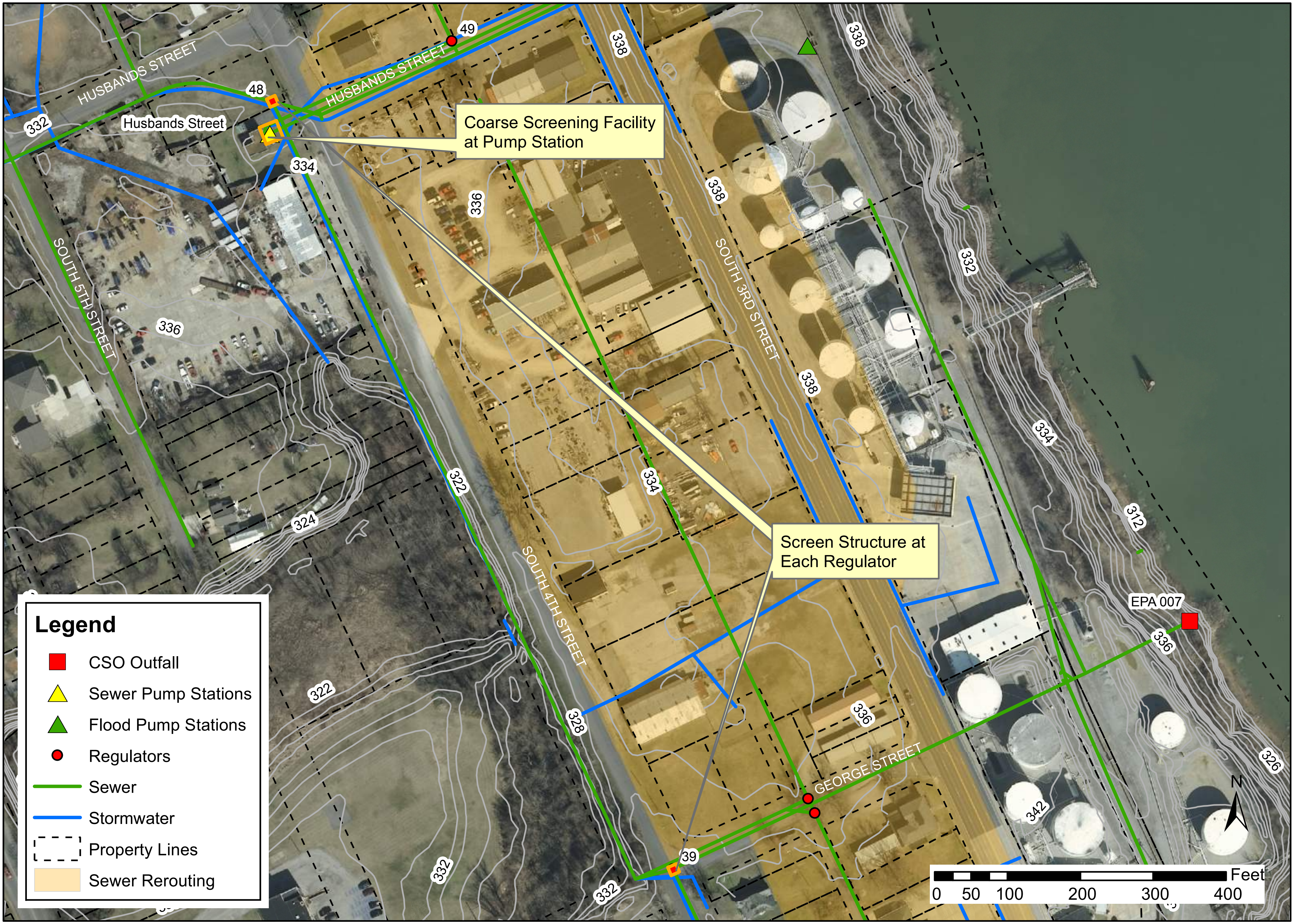
Paducah LTCP - Outfall EPA 006/007

Figure K-3 - Storage

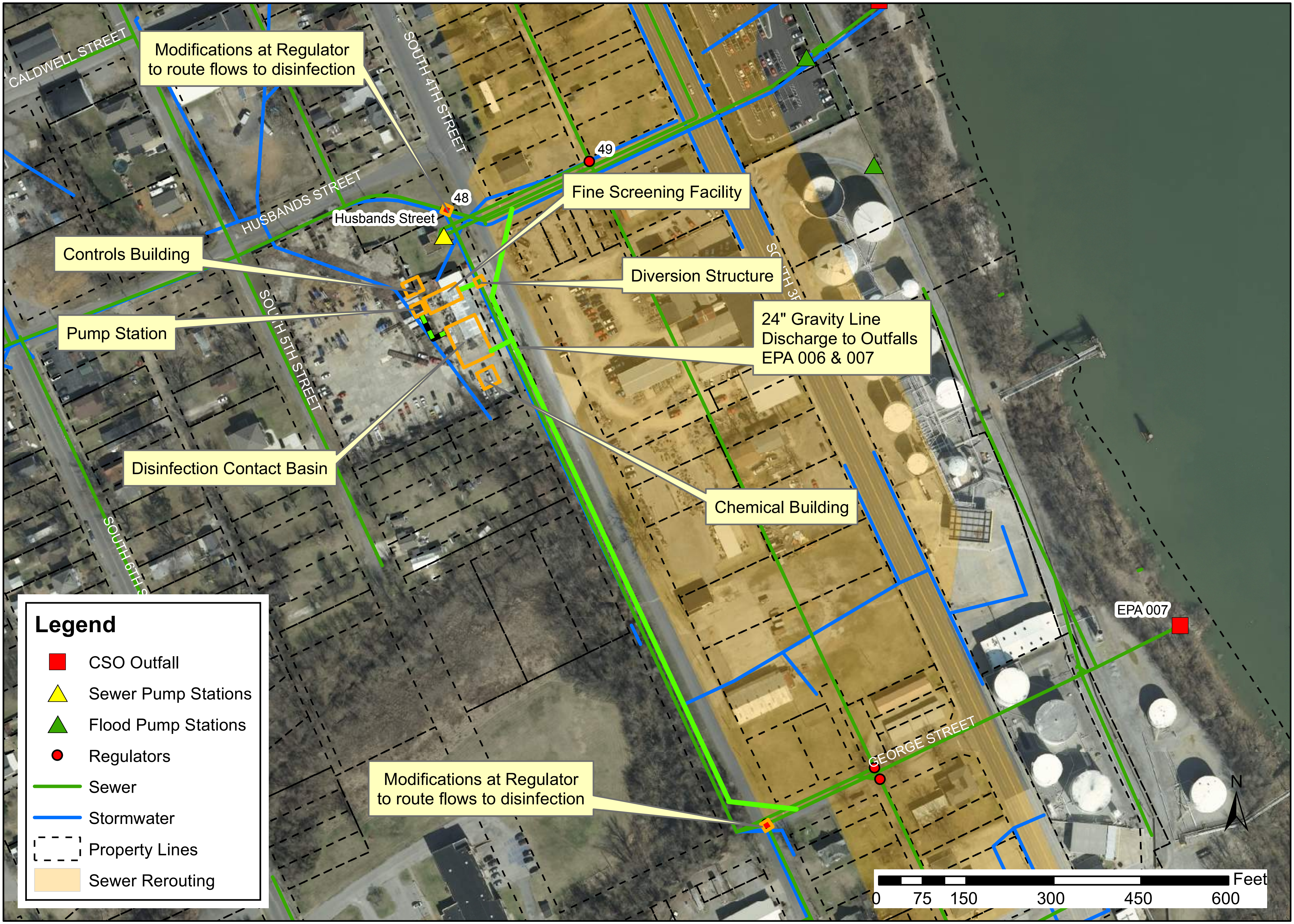


Paducah LTCP - Outfall EPA 006/007

Figure K-4 - Pumping to Treatment

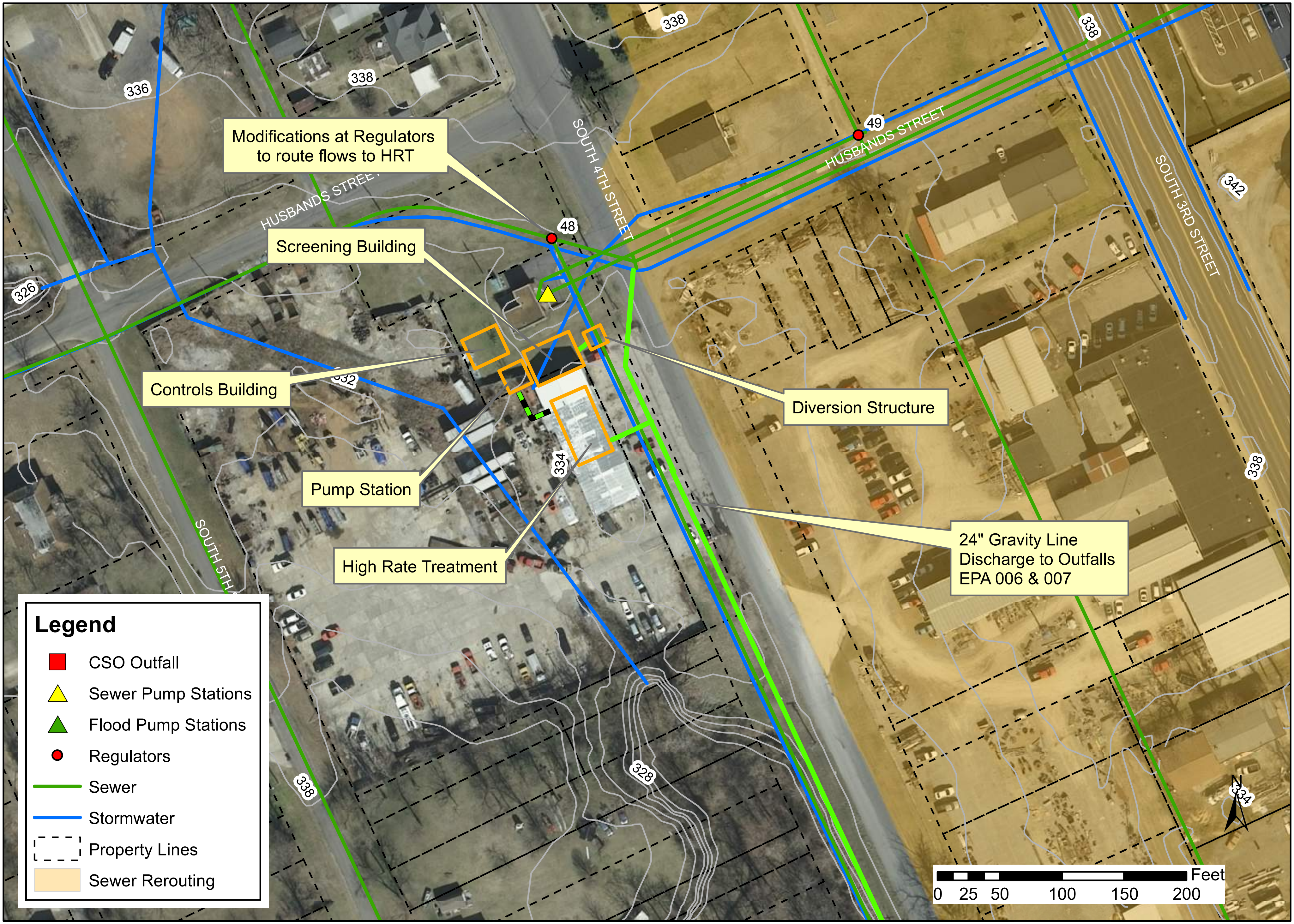


Paducah LTCP - Outfall EPA 006/007 Figure K-5 - Fine Screening



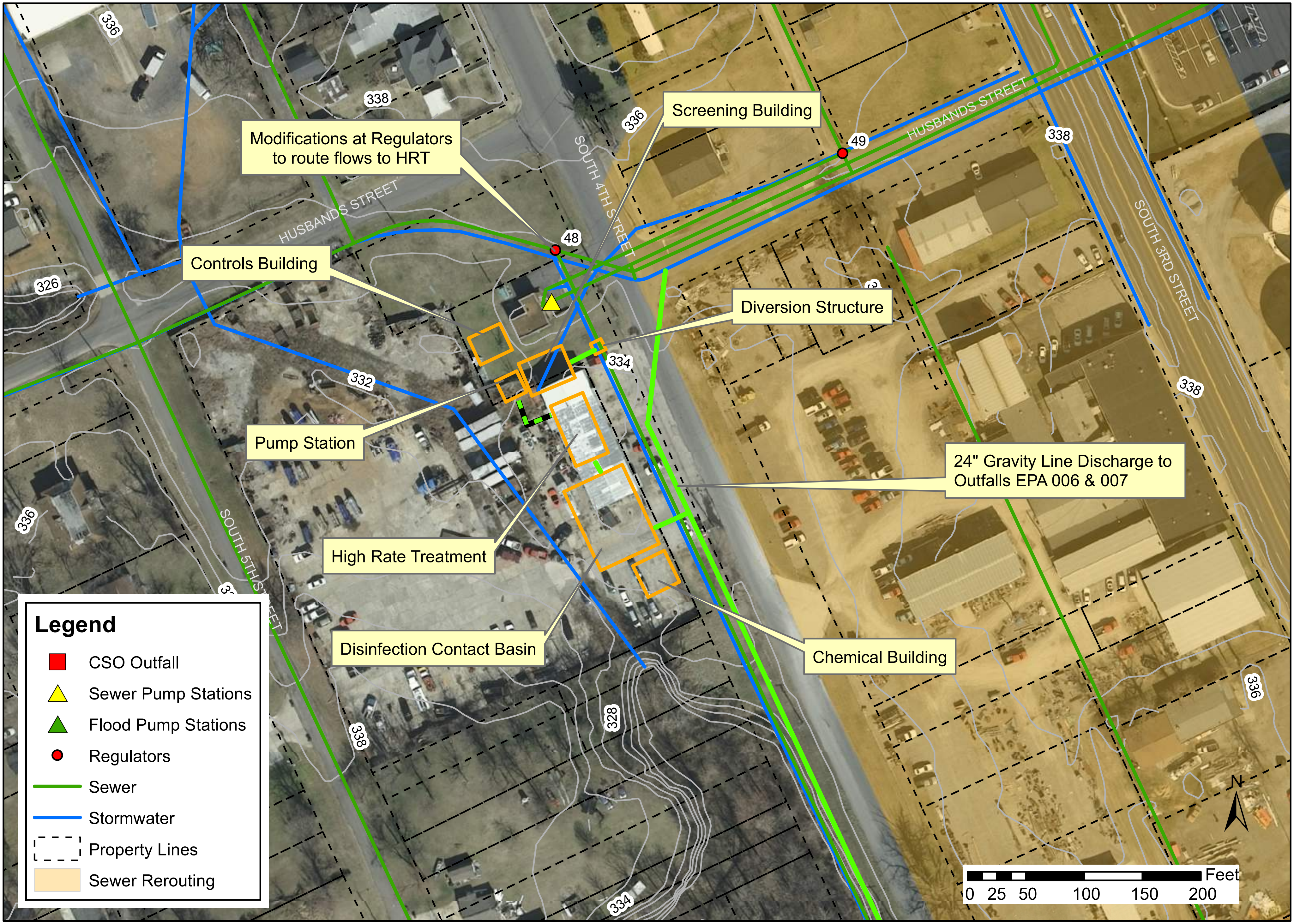
Paducah LTCP - Outfall EPA 006/007

Figure K-6 - Fine Screening and Disinfection



Paducah LTCP - Outfall EPA 006/007

Figure K-7 - HRT



Paducah LTCP - Outfall EPA 006/007

Figure K-8 - HRT and Disinfection

Appendix L

EPA 008/009 Alternative Analysis

Note 1: Costs presented are screening-level estimates for comparison of the alternatives. Costs of selected alternatives will be reviewed in further detail for the financial analysis.

Note 2: When additional land is required to site the facilities, the placement of the facilities and the selected parcels are shown for illustrative purposes only. Alternative nearby sites would also be evaluated during design.

EPA 008 and EPA 009, shown in **Figure L-1,** are CSO outfalls located along an unnamed tributary to Island Creek. Since they are located less than 100 feet from each other and are interconnected within the combined sewer system, these locations are evaluated collectively for CSO control alternatives.

Collectively, there are six regulators associated with these two outfalls. Regulators 38 and 46 are associated with EPA 008, and the remaining regulators (33, 34, 35, 36) are primarily associated with EPA 009. The tributary area includes residential, commercial, and industrial land use. A portion of the overflow volume is believed to be separate stormwater that is discharged directly into the outfall pipes downstream of regulators. The tributary areas for EPA 008 and EPA 009 are shown in **Figure L-2**.

When the Ohio River stage is high and the floodwall gates on Island Creek are closed, Island Creek has the potential to hold water, which under some conditions can result in high depths at the CSO outfalls. JSA does not believe that Island Creek would back up into the combined sewer system excluding extreme flooding conditions or failure of the floodwall pump stations. However, the alternatives evaluated below include slide gates or other devices that can be used to protect and isolate the new facilities if backwater effects are experienced from the floodwall pump station's operation.

Evaluation of CSO control alternatives for this outfall assumes a target percent capture of 94 percent of total annual CSO volume, which is consistent with the knee of the curve sizing for screening as presented in the LTCP. This results in a combined required sizing of 22 million gallons per day (mgd) for alternatives based on overflow treatment at this site. This target percent capture will be utilized to compare alternatives; however, JSA recognizes that the need to achieve a minimum system-wide capture of 85 percent and may adjust the sizing of the selected alternative at EPA 008 and EPA 009 to achieve this goal. The 94 percent capture results in 15 CSO events per year relative to 67 events per year under the current system.

In order to simplify the design, construction, and operation of the CSO control facility, each of the alternatives evaluated (excluding separation) assume that flows can be routed through single facility.

The following alternatives were evaluated for EPA 008 and EPA 009:

A. System separation of the tributary area to these outfalls

B. Storage

C. Pumping to a new wet weather treatment facility to be constructed near the WWTP (no on-site storage)

D. Fine Screening

E. Fine Screening with Disinfection

F. High Rate Treatment

G. High Rate Treatment with Disinfection

For each alternative, it is assumed that the large open property adjacent to the two outfalls is acquired, and that the entirety or a portion of this property can be utilized to construct the elements in each alternative. The property's location allows for each alternative to be constructed, but it is in close proximity to residential houses. In addition, it appears that the property is used as a park/greenspace. Utilization of this property for improvements at these outfalls could meet with significant public resistance.

A. System Separation

System separation was considered for this tributary area, but total project costs are expected to be approximately$30 million. The unit construction cost for separation presented in the LTCP ($100,000 per acre) was revised to $80,000 per acre based upon the costs associated with the separation project associated with EPA 012. With anticipated engineering, legal, and other administrative costs, the assumed total project unit cost is $100,000 per acre. Costs associated with the separation of EPA 014 were lower than this value but are not believed to be appropriate for planning purposes since that project was completed in conjunction with Department of Transportation work.

Sewer separation for a portion of the tributary may be feasible; however, separating a portion of the area would not eliminate the need for CSO controls for the remaining CSO discharge.

B. Storage

In order to achieve the target percent capture, the storage alternative must consider three components: the rate at which flow must be captured and stored, the volume of storage required, and how quickly the stored flows can be drained back to the system for treatment. Because of the location of EPA 008-009, stored flows were assumed to be pumped to the 96-inch sewer along Burnett Street which leads to the WWTP as treatment capacity becomes available. Utilizing the results of the hydraulic model, several combinations of those three factors were analyzed in order to assess the feasibility of this alternative and to attempt to determine appropriate sizes for those three components while achieving the target percent capture. The following sizes were estimated, and the resulting facility is shown as **Figure L-3:**

- Pumping rate into storage: 22 mgd
- Required storage: 30 million gallons
- Dewatering rate: 8 mgd (the limit of available post-event plant capacity)

Elements of this system include the following:

1. Rerouting of the outfall pipes to combine them in a single diversion structure. The diversion structure would collect all flow from the current outfalls and divert it to one of two locations: (1) up to 22 mgd to a new coarse screening facility; (2) flow over 22 mgd on any given event goes over a weir directly to the outfall.

2. A coarse screening facility upstream of the storage tank pump station. The screening capacity would be 22 mgd, with two 11 mgd screen channels and a 22 mgd bypass channel. Screen openings are assumed to be 1.5-inch size, which is meant to protect the pumps.
3. A low head, 22 mgd storage tank pump station. Three 11 mgd (7600 gpm) pumps with variable frequency drive (VFDs) would be installed, operating on a lead-lag-standby scheme. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 22 mgd flow (77,000 gallons).
4. Thirty million gallons of storage, which is the storage required to achieve the target percent capture given dewatering limitations of the WWTP. The storage is assumed to be three above ground ten million gallon tanks, as shown in **Figure L-3.** A prestressed concrete tank is assumed at this stage, but steel would also be considered at the time of construction if there is an indication that they can be cost-competitive. Buried storage would be more expensive. Tank dimensions would be approximately 185' in diameter and 50' tall. Overflow standpipes would be constructed in each tank, with overflow elevation set to provide 2 feet of freeboard. Tank washdown systems are assumed to be provided.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30 feet by 25 feet, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. An 8 mgd pump station to pump flow to the 96-inch diameter sewer near Burnett Street which leads to the WWTP. This pump station is sized based on the typical maximum WWTP capacity available following storm events. Two 8 mgd (5,500 gpm) submersible pumps, VFD operated, are included. As with the tank inflow pump station, Flygt N type submersible pumps (or equivalent) would be provided. The pump station would be underground (but not as deep as the tank inflow pump station), with a wetwell sized to provide 5 minutes of detention time at the 8 mgd flow (28,000 gallons). If this alternative is selected, additional evaluation on the feasibility of dewatering the tank by gravity to the 96-inch sewer will be conducted.
7. An 18-inch force main approximately 6,500 feet long routed from the pump station to the 96-inch diameter sewer near Burnett Street which leads to the WWTP. Additional existing gravity sewers can be reviewed to assess available capacity, which may allow a reduction in the length of the force main. The connection point to the gravity system or the WWTP's influent pipe/channel would be determined during detailed design, in coordination with the project hydraulic analysis.

The screening-level cost estimate for this project is $72.5million.

The above option is not practical for several reasons: (1) cost; (2) the low dewatering rate requires over 3 days to empty the tanks based on limitations at the wastewater plant, assuming there are no other events within this period; (3) the facility would significantly impact the aesthetics of the surrounding area as well as the community usage, as the location appears to be inside a park/greenspace.

It is noted that it may be possible to define a hybrid storage-treatment option for which the combination of storage and treatment would be more reasonable. This would entail the use of some form of high-rate treatment (for solids removal and disinfection of the dewatered flow from storage) at the site. It has been determined through model simulations of the system that multiple combinations of storage and dewatering could achieve the defined target capture if that volume could be dewatered at through a treatment facility. Those options can be explored further as the system-wide alternative evaluations continue.

C. Pumping to a new wet weather treatment facility to be constructed (no on-site storage)

This alternative consists of diverting a maximum of 22 mgd through a coarse screening facility and pump station for transport to a new wet weather treatment facility located near the WWTP that would receive wet weather flows from other CSO outfalls. The flow being pumped to this facility would be pumped to the WWTP, where the flow can be routed to the WWTP if there is available capacity or to the dedicated wet weather treatment facility if WWTP capacity is not available.

Elements of this system include the following (See **Figure L-4**):

1. Rerouting of the outfall pipes to combine them in a single diversion structure. The diversion structure would collect all flow from the current outfalls and divert it to one of two locations: (1) up to 22 mgd to a new coarse screening facility; (2) flow over 22 mgd on any given event goes over a weir directly to the outfall.
2. A coarse screening facility upstream of the pump station. The screening capacity would be 22 mgd, with two 11 mgd screen channels and a 22 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to protect the pumps.
3. A 22 mgd pump station. As many overflow events are low volume, the station would consist of a constant speed, base flow pump (2,000 gpm) to handle the low flow events and three 11 mgd (7600 gpm) pumps with VFDs would be installed, operating on a lead-lag-standby scheme. The base flow pump would turn off at a preset wetwell level and would not turn on again until the next storm cycle; the VFD-driven pumps would operate for the rest of the cycle. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 20 minutes of detention time at the 22 mgd flow (306,000 gallons).
4. A force main routed from the pump station to the new wet weather treatment facility located near the existing WWTP. The connection point to the influent pipe/channel would be determined during detailed design, in coordination with the project hydraulic analysis.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30’ x 20’, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. A new wet weather treatment facility located near the WWTP. For purposes of this analysis, it is assumed that this facility would consist of a high rate treatment (HRT) and disinfection facility that would provide treatment for flows from outfall EPA 003 as well as potentially other remote outfalls. Costing assumes that an HRT facility is the recommended CSO control project to address EPA 003. Costs to send additional flow are allocated on a per-mgd basis for over 70 mgd (the assumed capacity of the facility to treat only EPA 003) at a rate of $300,000 per mgd. For 008/009, this amounts to an additional $6.6 million. At this time, the HRT system is being evaluated using two vendors – Actiflo and DensaDeg. A detailed analysis of these systems should be performed during the design of the project, if this is the preferred alternative. For now, preliminary cost and system “footprint” data have been collected for the three treatment trains and the costs among the three systems have been averaged to determine a cost opinion for the work of this alternative.
7. As the captured flow is being pumped to treatment, there would be no additional treatment or disinfection facilities provided at this location for flows that go directly to the outfall.

The screening-level cost estimate for this project is $22.9 million.

This alternative provides a sound technical solution to collecting and treating flows that currently discharge at these two outfalls. However, the option may not be feasible due to the limited capacity of the discharge sewer and/or the floodwall pump station that serves as the outfall pipe for EPA 003 as well as the effluent discharge pipe for the WWTP. Further evaluation is needed to assess of the available capacity of the existing system. No improvements to the discharge sewer or floodwall pump station are included in this screening-level cost estimate.

This alternative does not include on-site storage, but it is possible that a hybrid alternative could be considered as the system-wide solutions are evaluated that balances the need for storage and wet weather treatment. Adding storage could allow for pumping more flow directly to the WWTP one or two days after the storm event; this could reduce the amount of HRT treatment that would be required. On-site storage would also reduce the peak flow rates that drive the pump station and force main sizing requirements.

D. Fine Screening

This alternative consists of diverting the flow from the outfalls through a fine screening system prior to discharge. This alternative was presented as the recommended alternative for treatment at this location in the initial LTCP submission. JSA recognizes the concerns raised by KDEP and EPA in their January 30, 2015 letter and has provided more detailed review of multiple alternatives within this document.

The system consists of the following items (See **Figure L-5**):

1. Rerouting of the outfall pipes to combine them in a single diversion structure. The diversion structure would collect all flow from the current outfalls and divert it to one of two locations: (1) up to 22 mgd to a new fine screening facility; (2) flow over 22 mgd on any given event goes over a weir directly to the outfall. The structure would be enclosed to prevent backflow created when the floodwall gates on Island Creek are closed.
2. The screening facility's capacity would be 22 mgd, with two 11 mgd screen channels and a 22 mgd bypass channel. Each screen channel would have a dual screen system installed; a 1.5 inch coarse screen to screen large debris in the flow stream, followed by a fine screen (4-6 mm clear spacing) to screen smaller debris. The screens are assumed to be mechanically cleaned, with screenings delivered to trash dumpsters for easy maneuvering and hauling offsite. The screens and channels would be underground structures, extending the enclosed concept of the diversion structure, but the screenings would be delivered to the dumpsters in an "at-grade" facility to make the removal of the screenings convenient for operations staff.
3. A low head, 22 mgd pump station would be required to move the screened water back into the outfall channel. As many overflow events are low volume, the station would consist of a constant speed, base flow pump (2,000 gpm) to handle the low flow events and three 11 mgd (7600 gpm) pumps with VFDs would be installed, operating on a lead-lag-standby scheme. The base flow pump would turn off at a preset wetwell level and would not turn on again until the next storm cycle; the VFD-driven pumps would operate for the rest of the cycle. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage and are expected to continue operation in the event that the screens fail. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 22 mgd flow (77,000 gallons).

The outfall pipes are not constructed in such a way that deflection screens are able to be used to keep screening material in the CSO flow and send the screenings to the plant. Vertical screens that remove screenings from the CSO flow are therefore required. As with Alternative C, screening material generated by the screening facility would need to be removed disposed of periodically.

The screening-level cost estimate for this project is $11.9 million.

E. Fine Screening with Disinfection

This alternative includes the full screening facility described in Alternative D, followed by disinfection. (See **Figure L-6**). The low head pump station would pump the flow into the disinfection basin instead of the outfall, but would have bypass capability to pump into the outfall channel in the event that the disinfection system is offline. Disinfection alternatives that were reviewed include ultraviolet (UV) radiation, chlorination / dechlorination, and peracetic Acid (PAA). Advantages and disadvantages of these alternatives are summarized briefly below.

1. UV
    a. Advantages
        i. Instantaneous inactivation of organisms
        ii. Takes the least amount of space; no contact tank required
        iii. No chemicals on the site
        iv. Least capital cost alternative
    b. Disadvantages
        i. Intermittent use of facility can be an issue; UV works best with a continuous flow stream.
        ii. Particle size in the flow stream may limit UV effectiveness
2. Chlorination/Dechlorination
    a. Advantages
        i. Proven disinfecting capability for a wide variety of organics
        ii. Can be used in intermittent flow situation
        iii. Operator familiarity; already used in the system
    b. Disadvantages
        i. Two chemical systems in separate buildings are required at a remote location
        ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 273,000 gallons) is required
        iii. Liquid Sodium Hypochlorite has a limited shelf life. As design volumes must be for peak storm events, during long periods of low rainfall the chemical may have to be withdrawn from the tank and replaced
        iv. Most expensive capital cost alternative
3. PAA
    a. Advantages
        i. Does not need a secondary chemical for dechlorination
        ii. Can be used in intermittent flow situation
        iii. Equipment is typically leased; may be able to subcontract operation
        iv. Capital cost is lower than chlorination/dechlorination alternative
        v. PAA has longer shelf-life than other alternatives
    b. Disadvantages
        i. Typically, higher doses of chemical are required for disinfection than sodium hypochlorite.
        ii. Contact basin, sized for a minimum of 15 minutes at peak flow (approximately 273,000 gallons) is required. Volume may be higher, depending on results of pilot testing of effectiveness.
        iii. A chemical system is required at a remote location.

The screening-level cost estimate for this project is $14.8 million, which assumes chlorination / dechlorination is the selected type of disinfection. Bench and pilot scale testing of the disinfectants at this site would be conducted during preliminary design if this alternative is selected.

As with Alternative D, screened material generated by screening facility would need to be removed from the site and disposed of periodically in addition to the other maintenance of the chemical disinfection systems. **Figure L-6** shows the worst case scenario for land use if chemical disinfection and low head pumping is required. This alternative becomes more infeasible due to the increased complexity and presence of chemical systems located at this remote site.

F. High Rate Treatment

This alternative consists of installing a high rate clarification (ballasted flocculation) system that is designed to remove settleable solids and the insoluble BOD fraction with a construction footprint that is much smaller than conventional primary treatment processes and provides a higher level of treatment than conventional primary treatment processes. The units typically are provided as equipment packages by the vendors that supply them, oftentimes complete with basins, the mixing, flocculation, and sedimentation equipment internal to the basins, and chemical feed system components, although what is provided can vary from manufacturer to manufacturer. The composition of the system goes beyond just the equipment package and would require pumping to meet the hydraulic needs of the system. The system would contain the following elements (See **Figure L-7,** which includes the footprint of the larger HRT system):

1. A screening facility, as described in Parts 1, 2 and 3 of Alternative D. The only difference is that the screen bypass channel would bypass the HRT. Unscreened CSO flow can damage the HRT equipment.
2. A low head pump station, as described in Part 3 of Alternative D. For the HRT alternative, the alternatives are to either build the treatment system in-ground and pump after treatment, or pump prior to treatment and build the treatment system above ground. While building above-ground has a negative impact on the aesthetics of the park, the above-ground system is more cost effective and less prone to flooding. The above ground option is considered in this analysis.
3. The HRT unit. The units are physical / chemical treatment processes that use a combination of rapid mixing of chemicals, flocculation chambers, and settling basins to obtain settling of total suspended solids (TSS) and biochemical oxygen demand (BOD). For purposes of this evaluation, two systems were reviewed for general compatibility:
    a. Kruger's Actiflo system
    b. Infilco Degremont's DensaDeg system
4. Sludge withdrawal and disposal is required. For purposes of this evaluation, it is assumed that there is a connection off the bottom of the sedimentation basin for a sludge truck (with pump) to dock, offload the sludge from the basin, and transport the sludge to the WWTP. However, a separate storage tank may be required for temporarily holding sludge which is not included in this estimate. It is also noted that the cost for sludge handling is not included as a capital expense at this time; it is assumed that JSA would enter into a contract with a waste hauler instead of buying their own truck. Pumping the sludge into the local sewer may also be possible, but an evaluation of the sewer system would be required between the entry point and the WWTP to insure that there would be no potential overflows to other outfalls.
5. Gravity discharge channel from the HRT to the outfall channel. A channel would be provided, with energy dissipation structure (river rock cemented together or spread concrete pad at the bottom of the channel) to minimize potential erosion in the existing channel. The discharge at

the treatment unit would be above the water level that is generated when the floodwall gates are closed.

The screening-level cost estimate for this project is $22.5 million. Budgetary estimates have been provided by the two vendors listed above. These costs were reviewed and the costs were averaged for use in this evaluation.

When considering this alternative, the following disadvantages are noted:

1. Capital and operating costs would be very high.
2. The system is relatively complex to operate remotely. It is likely that JSA would send staff to prepare chemicals and monitor operation during rain events.
3. Multiple chemical systems would be at a remote site.
4. If HRT technology is used for JSA, it may be preferred to combine all outfalls that would be treated at the WWTP. An HRT unit can be constructed there that would be more cost effective for the entire system and would have reduced impact to the public.

G. High Rate Treatment with Disinfection

This alternative consists of using the HRT system described in Alternative F and adding a disinfection facility (See **Figure L-8**). The HRT discharge pipe would route treated flow to either the UV channel or the contact chamber, depending on which disinfection alternative would be selected through bench and pilot testing of disinfection alternatives. It is noted that **Figure L-8** shows the largest configuration of HRT treatment on the site and the chlorination / dechlorination disinfection system.

While adding disinfection would improve the level of treatment provided at EPA 008/009, it would increase the cost (by approximately $2.6 million) and operational complexity of this remote facility. For this reason and the reasons stated above in Alternative F, CDM Smith has determined that this is not a feasible alternative for outfall EPA 008/009.

Paducah LTCP - Outfall EPA 008/009

Figure L-1 - Overview

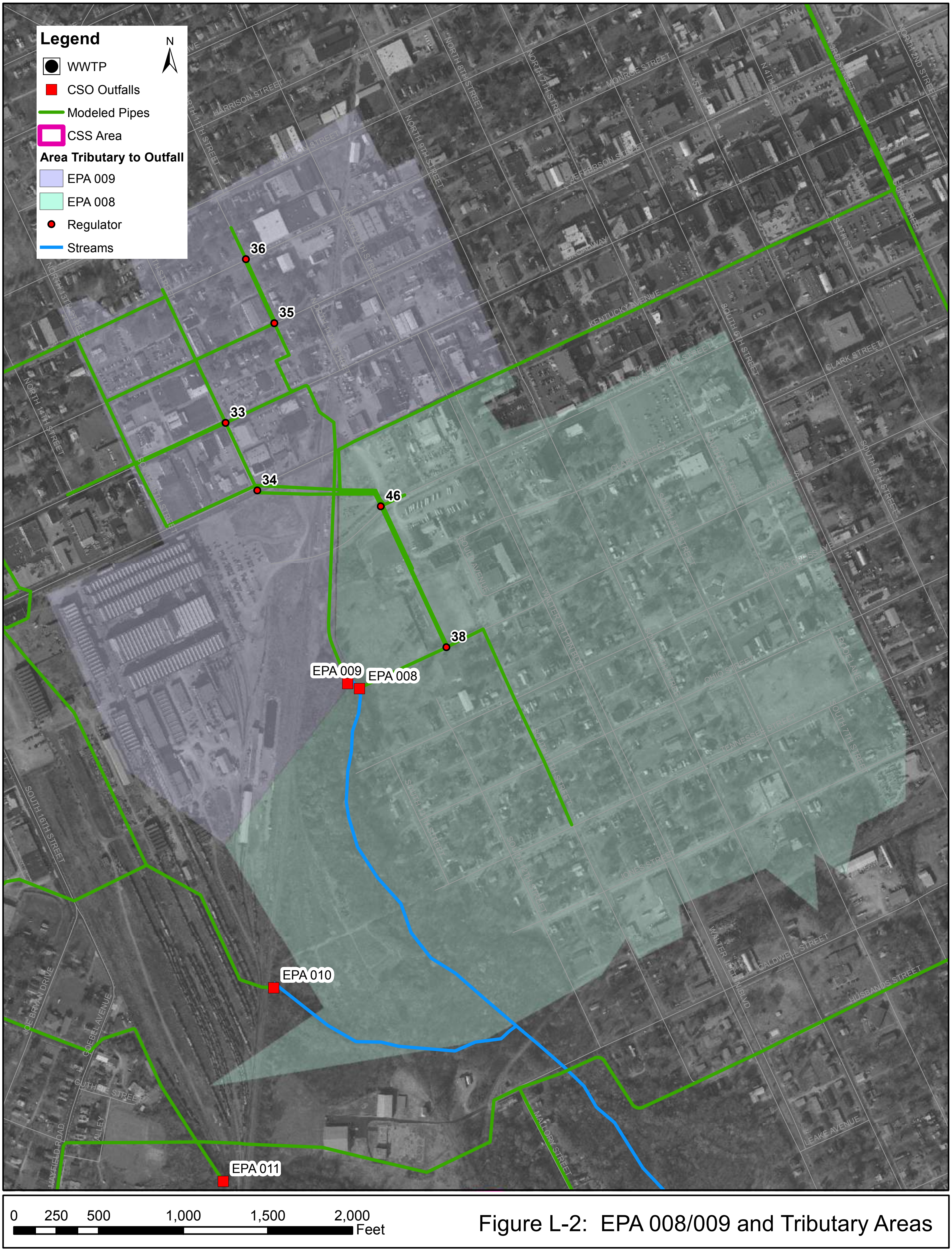
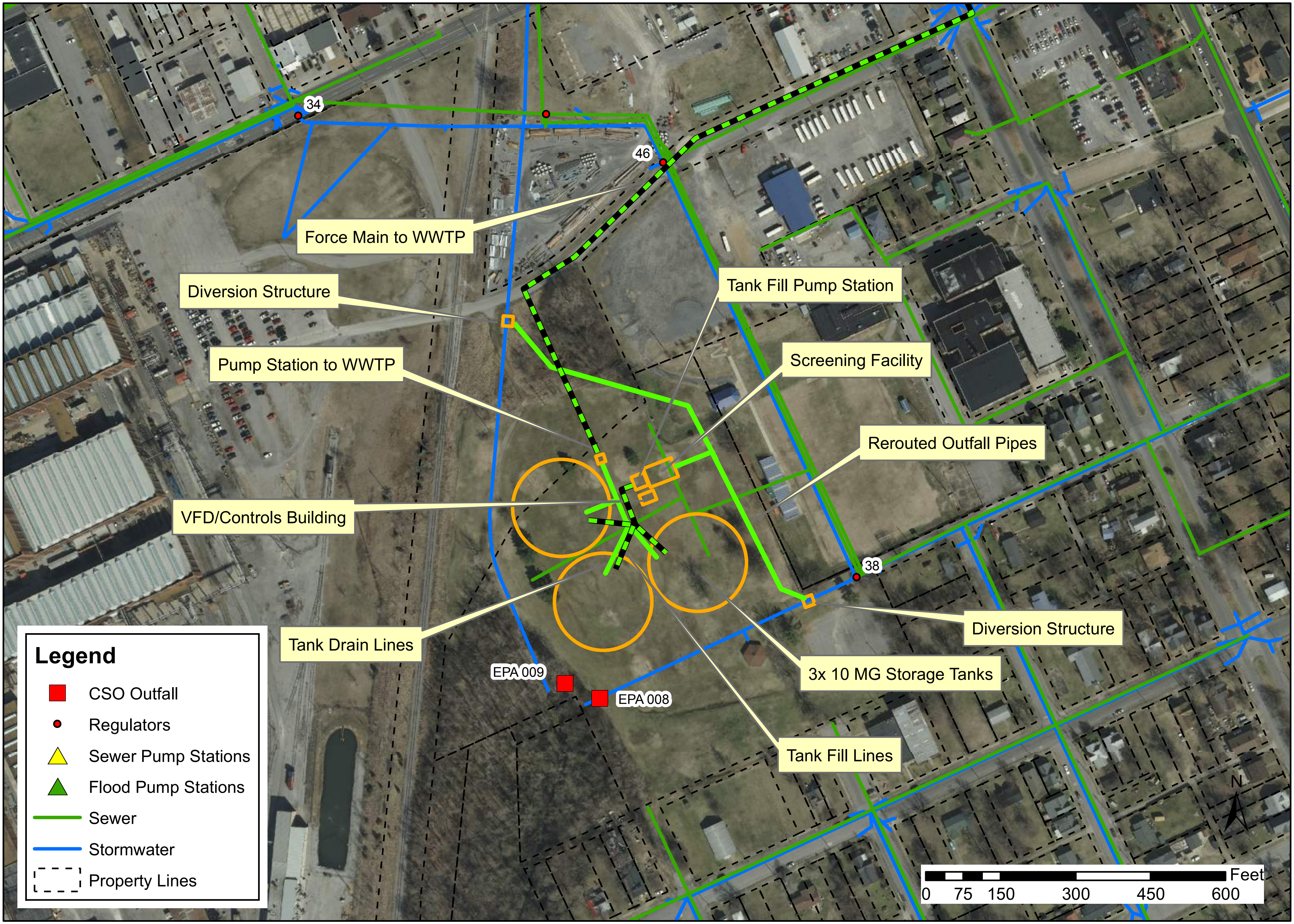


Figure L-2: EPA 008/009 and Tributary Areas



Paducah LTCP - Outfall EPA 008/009

Figure L-3 - Storage

Paducah LTCP - Outfall EPA 008/009

Figure L-4 - Pumping to Treatment

Paducah LTCP - Outfall EPA 008/009

Figure L-5 - Fine Screening

Paducah LTCP - Outfall EPA 008/009

Figure L-6 - Fine Screening and Disinfection

Paducah LTCP - Outfall EPA 008/009

Figure L-7 - HRT

Paducah LTCP - Outfall EPA 008/009

Figure L-8 - HRT and Disinfection

Appendix M

EPA 010 Alternative Analysis

Note 1: Costs presented are screening-level estimates for comparison of the alternatives. Costs of selected alternatives will be reviewed in further detail for the financial analysis.

Note 2: When additional land is required to site the facilities, the placement of the facilities and the selected parcels are shown for illustrative purposes only. Alternative nearby sites would also be evaluated during design.

EPA 010, shown in **Figure M-1,** is one of the CSO outfalls located along an unnamed tributary to Island Creek. The tributary area includes residential, commercial, and industrial land use, with the outfall pipe passing through the rail yard. There are two main regulators associated with this outfall, regulators 25 and 31. Regulators 43, 44, and 45 along Harahan Boulevard are also associated with this outfall, although it is important to note that these structures are debris traps for the stormwater system that under most flows prevent debris from entering the adjacent combined sewer system. Under periods of high flow in the combined system, however, there is the possibility that flow from the combined system is released into the stormwater outfall pipe from these structures and discharged at EPA 010. The tributary area for EPA 011 is shown in **Figure M-2.**

A portion of the overflow volume is believed to be separate stormwater that is discharged directly into the outfall pipes downstream of regulators.

When the Ohio River stage is high and the floodwall gates on Island Creek are closed, Island Creek has the potential to hold water, which under some conditions can result in high depths at the CSO outfalls. JSA does not believe that Island Creek would back up into the combined sewer system excluding extreme flooding conditions or failure of the floodwall pump stations. However, the alternatives evaluated below include slide gates or other devices that can be used to protect and isolate the new facilities if backwater effects are experienced from the floodwall pump station's operation.

Evaluation of CSO control alternatives for this outfall assumes a target percent capture of 93.6 percent of total annual CSO volume, which is consistent with the knee of the curve sizing for screening as presented in the LTCP. This results in a combined required sizing of 14.5 million gallons per day (mgd) for alternatives based on overflow treatment at this site. This target percent capture will be utilized to compare alternatives; however, JSA recognizes that the need to achieve a minimum system-wide capture of 85 percent and may adjust the sizing of the selected alternative at EPA 010 to achieve this goal. The 93.6 percent capture results in 14 CSO events per year relative to 64 events per year under the current system.

The following alternatives were evaluated for EPA 010:

A. System separation of the tributary area to this outfall

B. Storage

C. Pumping to a new wet weather treatment facility to be constructed near the WWTP (no on-site storage)

D. Fine Screening

E. Fine Screening with Disinfection

F. High Rate Treatment

G. High Rate Treatment with Disinfection

For each alternative, it is assumed that properties adjacent to the outfall are acquired, and that a portion of these properties can be utilized to construct the elements in each alternative.

Additionally, the close proximity of the outfall to a nearby railroad could pose construction challenges. As shown on the figures, the outfall appears to be located within the railroad's right of way and therefore obtaining permits to perform work in this area could be time consuming and costly. A diversion structure would need to be constructed at the outfall for every alternative and could pose a large challenge due to the location of the railroad tracks. The outfall pipe could be extended to avoid some of the construction challenges, but for the purposes of this analysis, it is assumed that the diversion structure is constructed at the face of the outfall.

A. System Separation

System separation was considered for the combined sewer system portion of this tributary area, which consists of approximately 135 acres. The estimated total project cost are expected to be approximately $14 million. The unit construction cost for separation presented in the LTCP ($100,000 per acre) was revised to $80,000 per acre based upon the costs associated with the separation project associated with EPA 012. With anticipated engineering, legal, and other administrative costs, the assumed total project unit cost is $100,000 per acre. Costs associated with the separation of EPA 014 were lower than this value but are not believed to be appropriate for planning purposes since that project was completed in conjunction with Department of Transportation work.

Sewer separation for a portion of the tributary may be feasible; however, separating a portion of the area would not eliminate the need for CSO controls for the remaining CSO discharge.

B. Storage

In order to achieve target percent capture, the storage alternative must consider three components: the rate at which flow must be captured and stored, the volume of storage required, and how quickly the stored flows can be drained back to the system for treatment. Because of the location of EPA 010, stored flows were assumed to be pumped to the 96-inch sewer along Clay Street which leads to the WWTP as treatment capacity becomes available. Utilizing the results of the hydraulic model, several combinations of those three factors were analyzed in order to assess the feasibility of this alternative and to attempt to determine appropriate sizes for those three components while achieving the target percent capture. The following sizes were estimated, and the resulting facility is shown as **Figure M-3**:

- Pumping rate into storage: 14.5 mgd
- Required storage: 18 million gallons
- Dewatering rate to WWTP: 8 mgd (the limit of available post-event plant capacity)

Elements of this system include the following:

1. A diversion structure at the outfall that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 14.5 mgd to a new coarse screening facility; (2) flow over 14.5 mgd on any given event goes over a weir directly to the outfall.

2. A coarse screening facility upstream of the storage tank pump station. The screening capacity would be 14.5 mgd, with two 7.5 mgd screen channels and a 7.5 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to only protect the pumps, not to serve as primary treatment.
3. A low head, 14.5 mgd storage tank pump station. Three 7.25 mgd (5100 gpm) pumps with variable frequency drives (VFDs) would be installed, operating on a lead-lag-standby scheme. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 14.5 mgd flow (51,000 gallons).
4. Eighteen million gallons of storage, which is the storage required to achieve the target percent capture given dewatering limitations of the WWTP. The storage is assumed to be two above ground nine million gallon tanks, as shown in **Figure M-3.** A prestressed concrete tank is assumed at this stage, but steel would also be considered at the time of construction if there is an indication that they can be cost-competitive. Buried storage would be more expensive. Tank dimensions would be approximately 185' in diameter and 50' tall. Overflow standpipes would be constructed in each tank, with overflow elevation set to provide 2 feet of freeboard. Tank washdown systems are assumed to be provided.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30' x 25', climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. An 8 mgd pump station to pump flow to the 96-inch diameter sewer near Burnette Street which leads to the WWTP. This pump station is sized based on the typical maximum WWTP capacity available following storm events. Two 8 mgd (5,500 gpm) submersible pumps, VFD operated, are included. As with the tank inflow pump station, Flygt N type submersible pumps (or equivalent) would be provided. The pump station would be underground (but not as deep as the tank inflow pump station), with a wetwell sized to provide 5 minutes of detention time at the 8 mgd flow (28,000 gallons). If this alternative is selected, additional evaluation on the feasibility of dewatering the tank by gravity to the 96-inch sewer will be conducted.
7. An 18-inch force main approximately 9,500 feet long routed from the pump station to the 96-inch diameter sewer near Burnette Street which leads to the WWTP. Additionall existing gravity sewers can be reviewed to assess available capacity, which may allow a reduction in the length of the force main. The connection point to the gravity system or the WWTP's influent pipe/channel would be determined during detailed design, in coordination with the project hydraulic analysis.

The screening-level cost estimate for this project is $49.1 million.

The above option is not practical mainly due to cost and the low dewatering rate. Based on limitations at the wastewater plant, it would take over 2 days to empty the tanks, assuming there are no other events within this period.

It is noted that it may be possible to define a hybrid storage-treatment option for which the combination of storage and treatment would be more reasonable. This would entail the use of some form of high-rate treatment (for solids removal and disinfection of the dewatered flow from storage) at the site. It has been determined through model simulations of the system that multiple combinations of storage and dewatering could achieve the defined target capture if that volume could be dewatered at through a treatment facility. Those options can be explored further as the system-wide alternative evaluations continue.

C. Pumping to a new wet weather treatment facility to be constructed (no on-site storage)

This alternative consists of diverting a maximum of 14.5 mgd through a coarse screening facility and pump station for transport to a new wet weather treatment facility located near the WWTP that would receive wet weather flows from other CSO outfalls. The flow being pumped to this facility would be pumped to the WWTP, where the flow can be routed to the WWTP if there is available capacity or to the dedicated wet weather treatment facility if WWTP capacity is not available.

Elements of this system include the following (See **Figure M-4**):

1. A diversion structure at the outfall that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 14.5 mgd to a new coarse screening facility; (2) flow over 14.5 mgd on any given event goes over a weir directly to the outfall.
2. A coarse screening facility upstream of the pump station. The screening capacity would be 14.5 mgd, with two 7.25 mgd screen channels and a 14.5 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to protect the pumps.
3. A 14.5 mgd pump station. As many overflow events are low volume, the station would consist of a three 7.25 mgd (5100 gpm) pumps with VFDs would be installed, operating on a lead-lag-standby scheme. The base flow pump would turn off at a preset wetwell level and would not turn on again until the next storm cycle; the VFD-driven pumps would operate for the rest of the cycle. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 20 minutes of detention time at the 14.5 mgd flow (202,000 gallons).
4. A force main routed from the pump station to the new wet weather treatment facility located near the existing WWTP. The connection point to the influent pipe/channel would be determined during detailed design, in coordination with the project's hydraulic analysis.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30 feet by 20 feet, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. A new wet weather treatment facility located near the WWTP. For purposes of this analysis, it is assumed that this facility would consist of a high rate treatment (HRT) and disinfection facility that would provide the equivalent of primary treatment and disinfection for flows from outfall EPA 003 as well as potentially other remote outfalls. Costing assumes that an HRT facility is the recommended CSO control project to address EPA 003. Costs to send additional flow are allocated on a per-MGD basis for flows over 70 MGD (the assumed capacity of the facility to treat only EPA 003) at a rate of $300,000 per MGD. For 010, this amounts to an additional $4.35 million. At this time, the HRT system is being evaluated using two vendors – Actiflo and DensaDeg. A detailed analysis of these systems should be performed during the design of the project, if this is the preferred alternative. For now preliminary cost and system "footprint" data have been collected for the three treatment trains and the costs among the three systems have been averaged to determine a cost opinion for the work of this alternative.
7. As the captured flow is being pumped to treatment, there would be no additional treatment or disinfection facilities provided at this location for flows that go directly to the outfall.

The screening-level cost estimate for this project is $19.9 million.

This alternative provides a sound technical solution to collecting and treating flows that currently discharge at this outfall. However, the option may not be feasible due to the limited capacity of the discharge sewer and/or the floodwall pump station that serves as the outfall pipe for EPA 003 as well as the effluent discharge pipe for the WWTP. Further evaluation is needed to assess of the available capacity of the existing system. No improvements to the discharge sewer or floodwall pump station are included in this screening-level cost estimate.

This alternative does not include on-site storage, but it is possible that a hybrid alternative could be considered as the system-wide solutions are evaluated that balances the need for storage and wet weather treatment. Adding storage could allow for pumping more flow directly to the WWTP one or two days after the storm event; this could reduce the amount of HRT treatment that would be required. On-site storage would also reduce the peak flow rates that drive the pump station and force main sizing requirements.

D. Fine Screening

This alternative consists of diverting the flow from the outfalls, through a fine screening system, and back into the outfall channel. This alternative was presented as the recommended alternative for treatment at this location in the initial LTCP submission and CDM Smith maintains that the recommendations in the initial LTCP conform to the 85% capture provision of the CSO Policy Presumptive Approach. CDM Smith recognizes the concerns raised by KDEP and EPA in their January 30, 2015 letter to the JSA and has provided more detailed review of multiple alternatives within this document. In the meantime, this alternative is the least cost alternative available to JSA, so it would be included in this analysis.

The system consists of the following items (See **Figure M-5**):

1. A diversion structure at the outfall that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 14.5 mgd to a new coarse screening facility; (2) flow over 14.5 mgd on any given event goes over a weir directly to the outfall. The structure would be enclosed to prevent backflow created when the floodwall gates on Island Creek are closed.
2. The screening facility's capacity would be 14.5 mgd, with two 7.25 mgd screen channels and a 14.5 mgd bypass channel. Each screen channel would have a dual screen system installed; a 1.5-inch coarse screen to screen large debris in the flow stream, followed by a fine screen (4-6 mm clear spacing) to screen smaller debris. The screens are assumed to be mechanically cleaned, with screenings delivered to trash dumpsters for easy maneuvering and hauling offsite. The screens and channels would be underground structures, extending the enclosed concept of the diversion structure, but the screenings would be delivered to the dumpsters in an "at-grade" facility to make the removal of the screenings convenient for operations staff
3. A low head, 14.5 mgd pump station would be required to move the screened water back into the outfall channel. Three 7.25 mgd (5100 gpm) pumps with VFDs would be installed, operating on a lead-lag-standby scheme. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage and are expected to continue operation in the event that the screens fail. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 14.5 mgd flow (51,000 gallons).

Because of the number of regulators, deflection screens are not able to be used to keep screening material in the CSO flow and send the screenings to the plant. Vertical screens that remove screenings from the CSO flow are required. As with Alternative C, screening material generated by the screening facility would need to be removed disposed of periodically.

The screening-level cost estimate for this project is $9.6 million.

E. Fine Screening with Disinfection

This alternative includes the full screening facility described in Alternative D, followed by disinfection. (See **Figure M-6**). The low head pump station would pump the flow into the disinfection basin instead of the outfall, but would have bypass capability to pump into the outfall channel in the event that the disinfection system is offline. Disinfection alternatives that were reviewed include ultraviolet (UV) radiation, chlorination / dechlorination, and peracetic Acid (PAA). Advantages and disadvantages of these alternatives are summarized briefly below.

1. UV
   a. Advantages
      i. Instantaneous inactivation of organisms
      ii. Takes the least amount of space; no contact tank required
      iii. No chemicals on the site
      iv. Least capital cost alternative
   b. Disadvantages
      i. Intermittent use of facility can be an issue; UV works best with a continuous flow stream.
      ii. Particle size in the flow stream may limit UV effectiveness
2. Chlorination/Dechlorination
   a. Advantages
      i. Proven disinfecting capability for a wide variety of organics
      ii. Can be used in intermittent flow situation
      iii. Operator familiarity; already used in the system
   b. Disadvantages
      i. Two chemical systems in separate buildings are required at a remote location
      ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 152,000 gallons) is required
      iii. Liquid Sodium Hypochlorite has a limited shelf life. As design volumes must be for peak storm events, during long periods of low rainfall the chemical may have to be withdrawn from the tank and replaced
      iv. Most expensive capital cost alternative
3. PAA
   a. Advantages
      i. Does not need a secondary chemical for dechlorination
      ii. Can be used in intermittent flow situation
      iii. Equipment is typically leased; may be able to subcontract operation
      iv. Capital cost is lower than chlorination/dechlorination alternative
      v. PAA has a longer shelf-life than other alternatives
   b. Disadvantages
      i. Typically, higher doses of chemical are required for disinfection than sodium hypochlorite.
      ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 152,000 gallons) is required. Volume may be higher, depending on results of pilot testing of effectiveness.
      iii. A chemical system is required at a remote location.

The screening-level cost estimate for this project is $12.4 million, which assumes chlorination / dechlorination is the selected type of disinfection. Bench and pilot scale testing of the disinfectants at this site would be conducted during preliminary design if this alternative is selected.

Figure M-6 shows the worst case scenario for land use if chemical disinfection and low head pumping is required. This alternative becomes more infeasible due to the increased complexity and presence of chemical systems located at this remote site.

F. High Rate Treatment

This alternative consists of installing a high rate clarification (ballasted flocculation) system that is designed to remove settlable solids and the insoluble BOD fraction with a construction footprint that is much smaller than conventional primary treatment processes and provides a higher level of treatment than conventional primary treatment processes. The units typically are provided as equipment packages by the vendors that supply them, oftentimes complete with basins, the mixing, flocculation, and sedimentation equipment internal to the basins, and chemical feed system components, although what is provided can vary from manufacturer to manufacturer. The composition of the system goes beyond just the equipment package and would require pumping to meet the hydraulic needs of the system. The system would contain the following elements (See **Figure M-7,** which includes the footprint of the larger HRT system):

1. A screening facility, as described in Parts 1, 2 and 3 of Alternative D. The only difference is that the screen bypass channel would bypass the HRT. Unscreened CSO flow can damage the HRT equipment.
2. A low head pump station, as described in Part 3 of Alternative D. For the HRT alternative, the alternatives are to either build the treatment system in-ground and pump after treatment, or pump prior to treatment and build the treatment system above ground. While building above-ground has a negative impact on the aesthetics of the park, the above-ground system is more cost effective and less prone to flooding. The above ground option is considered in this analysis.
3. The HRT unit. The units are physical / chemical treatment processes that use a combination of rapid mixing of chemicals, flocculation chambers, and settling basins to obtain settling of total suspended solids (TSS) and Biochemical Oxygen demand (BOD). For purposes of this evaluation, two systems were reviewed for general compatibility:
    a. Kruger's Actiflo system
    b. Infilco Degremont's DensaDeg system
4. Sludge withdrawal and disposal is required. For purposes of this evaluation, it is assumed that there is a connection off the bottom of the sedimentation basin for a sludge truck (with pump) to dock, offload the sludge from the basin, and transport the sludge to the WWTP. However, a separate storage tank may be required for temporarily holding sludge which is not included in this estimate. It is also noted that the cost for sludge handling is not included as a capital expense at this time; it is assumed that JSA would enter into a contract with a waste hauler instead of buying their own truck. Pumping the sludge into the local sewer is also something that could be done, but an evaluation of the sewer system would be required between the entry point and the WWTP to insure that there would be no potential overflows to other outfalls.
5. Gravity discharge channel from the HRT to the outfall channel. A channel would be provided, with energy dissipation structure (river rock cemented together or spread concrete pad at the bottom of the channel) to minimize potential erosion in the existing channel. The discharge at the treatment unit would be above the water level that is generated when the floodwall gates are closed.

The screening-level cost estimate for this project is $19.1 million. Budgetary estimates have been provided by the two vendors listed above. These costs were reviewed and the costs were averaged for use in this evaluation.

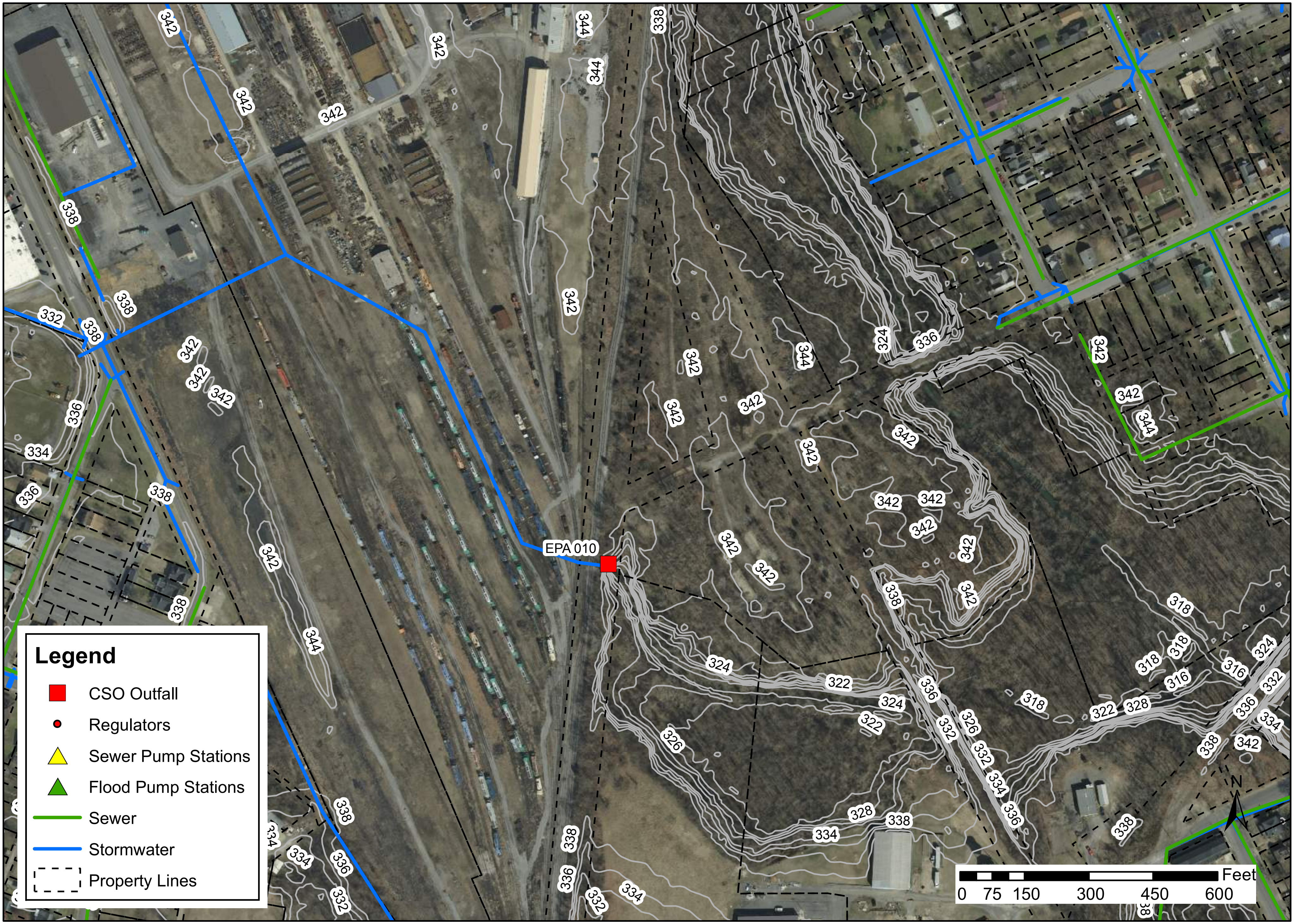
When considering this alternative, the following disadvantages are noted:

1. Capital and operating costs would be very high.
2. The system is relatively complex to operate remotely. It is likely that JSA would send staff to prepare chemicals and monitor operation during rain events.
3. Multiple chemical systems would be at a remote site.
4. If HRT technology is used for JSA, it may be preferred to combine all outfalls that would be treated at the WWTP. An HRT unit can be constructed there that would be more cost effective for the entire system.

G. High Rate Treatment, with Disinfection

This alternative consists of using the HRT system described in Alternative F and adding a disinfection facility (See **Figure M-8**). The HRT discharge pipe would route treated flow to either the UV channel or the contact chamber, depending on which disinfection alternative would be selected through bench and pilot testing of disinfection alternatives. It is noted that **Figure M-8** shows the largest configuration of HRT treatment on the site and chlorination / dechlorination disinfection system.

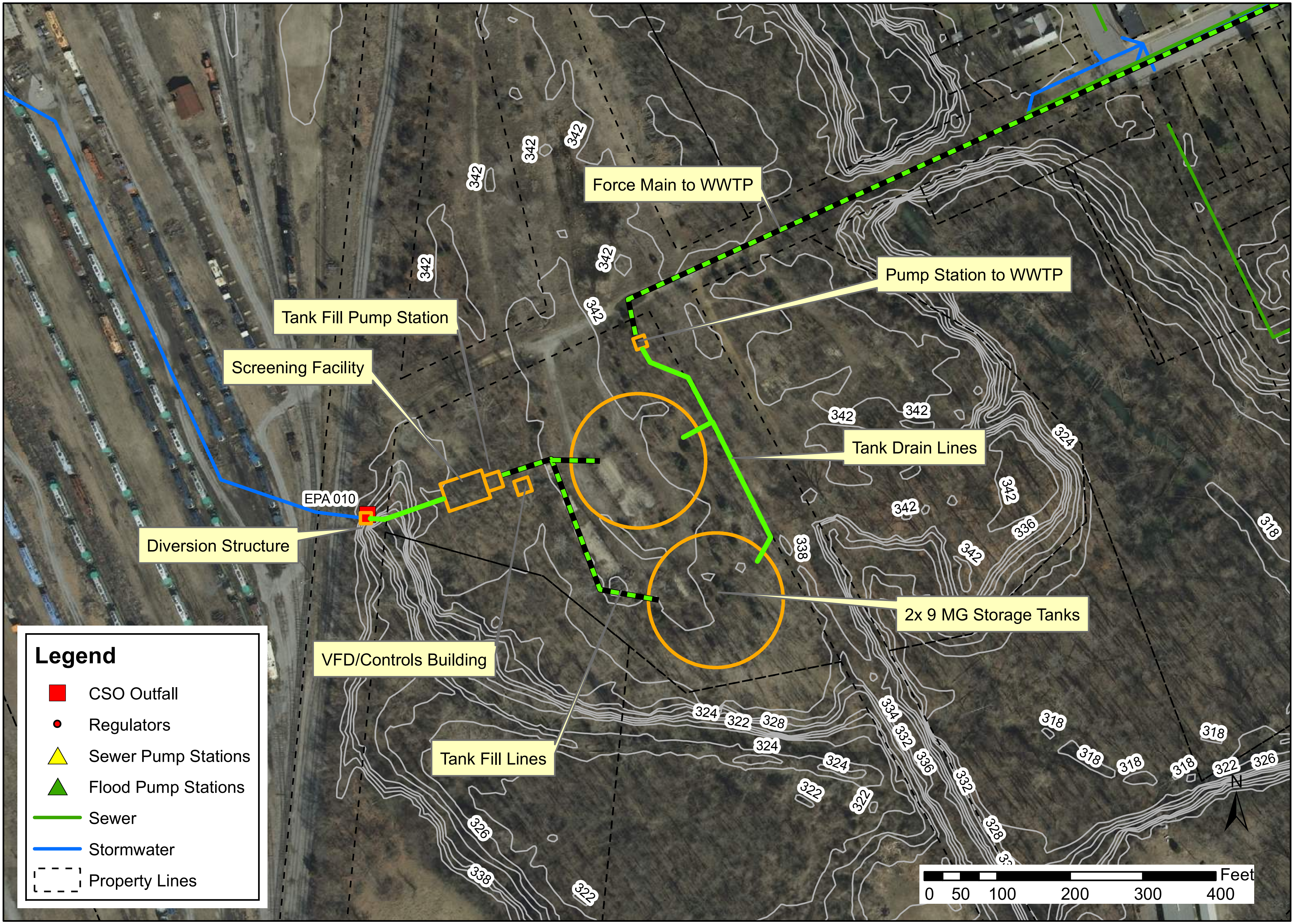
While adding disinfection would improve the level of treatment provided at EPA 010, it would increase the cost (by approximately $2.5 million) and operational complexity of this remote facility. For this reason and the reasons stated above in Alternative F, CDM Smith has determined that this is not a feasible alternative for outfall EPA 010.



Paducah LTCP - Outfall EPA 010

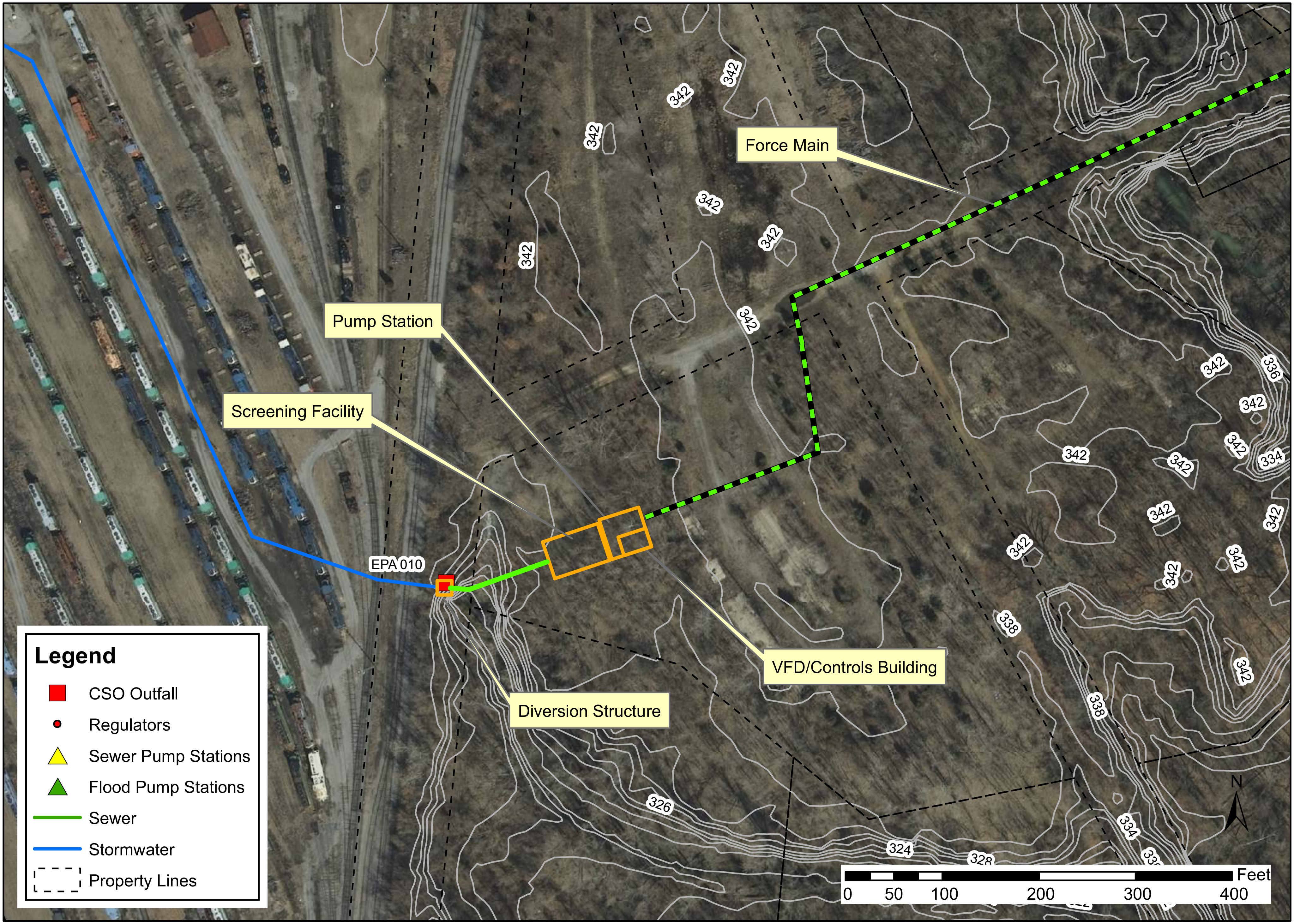
Figure M-1 - Overview

Figure M-2: EPA 010 and Tributary Areas



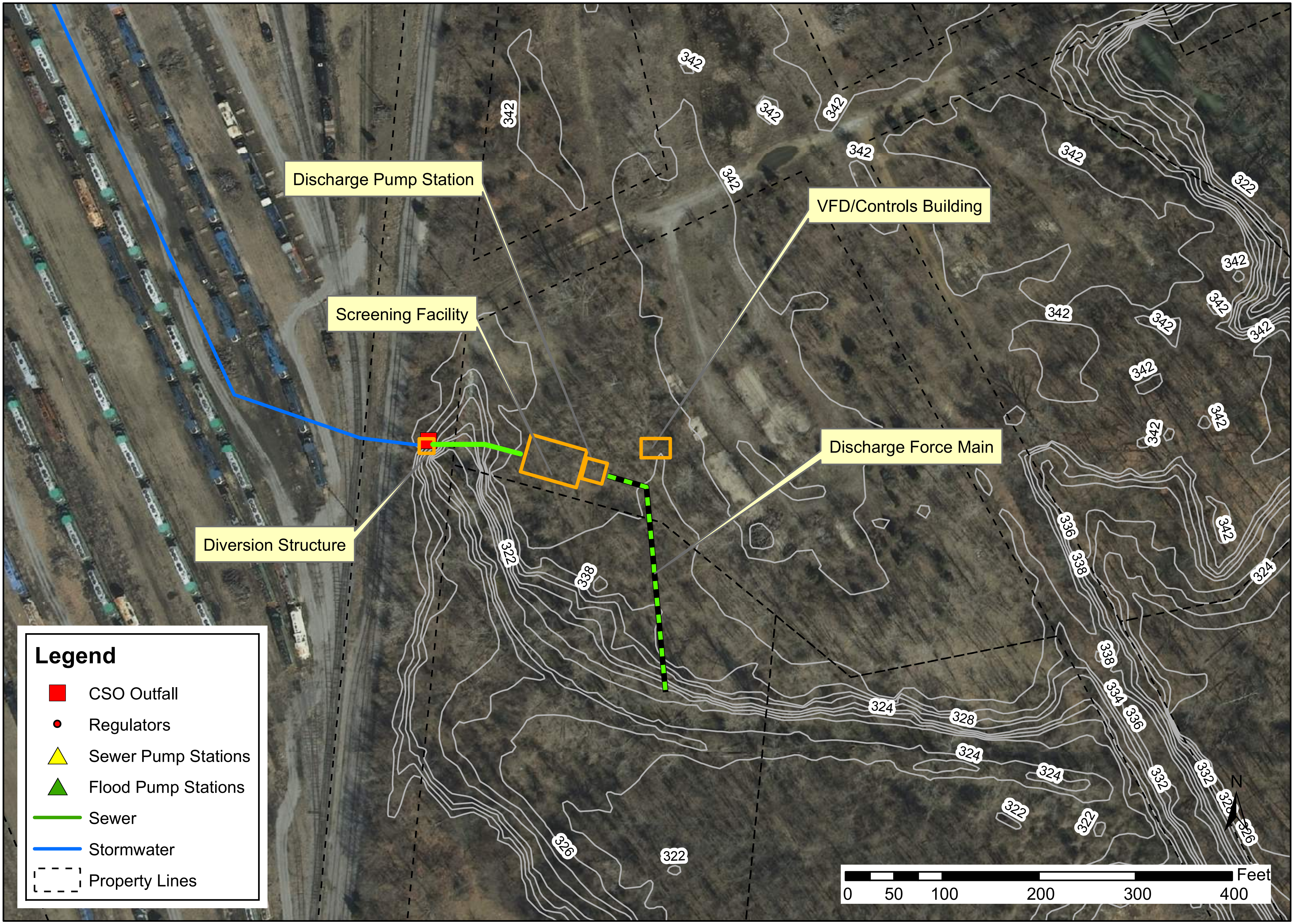
Paducah LTCP - Outfall EPA 010

Figure M-3 - Storage



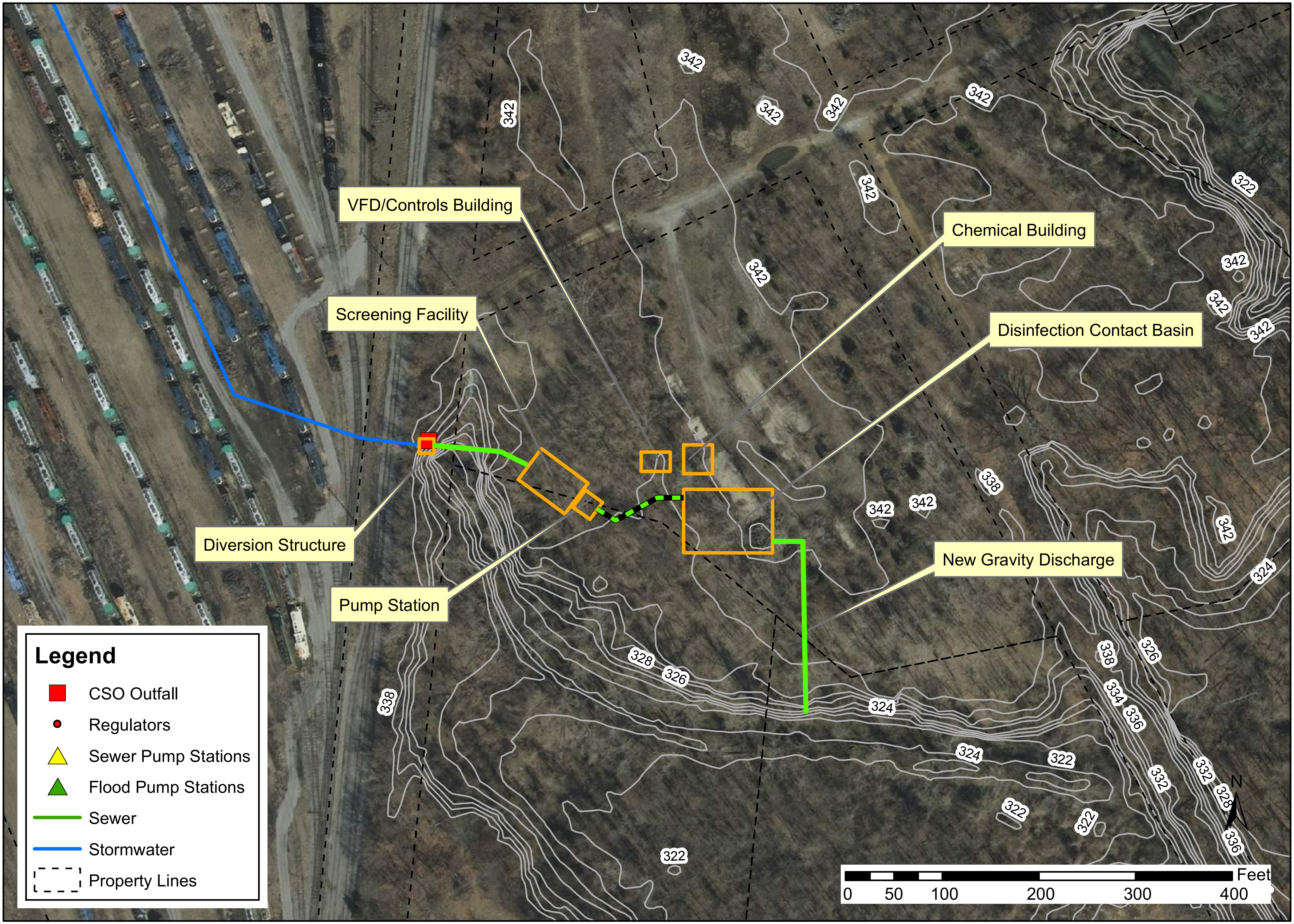
Paducah LTCP - Outfall EPA 010

Figure M-4 - Pumping to Treatment



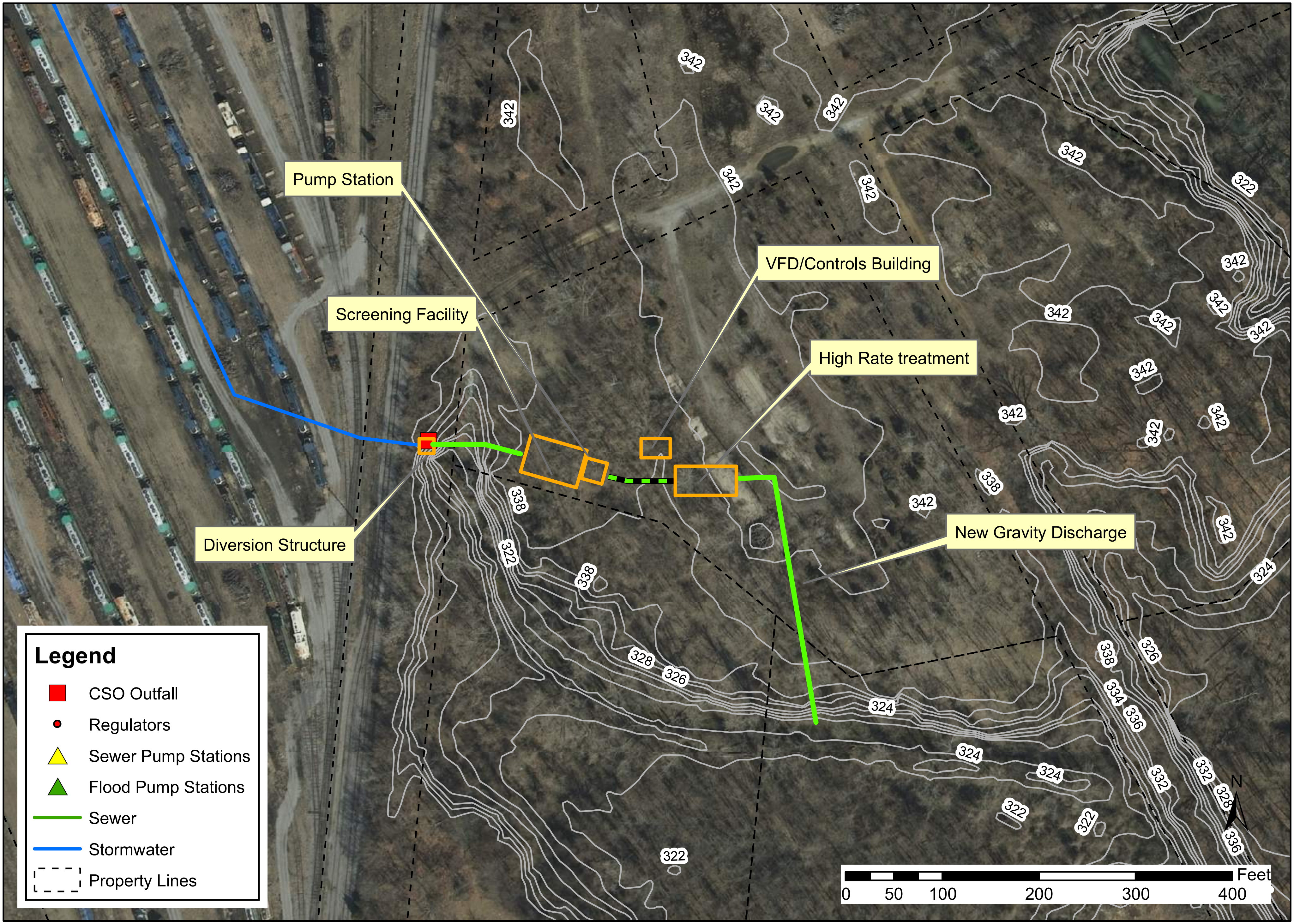
Paducah LTCP - Outfall EPA 010

Figure M-5 - Fine Screening



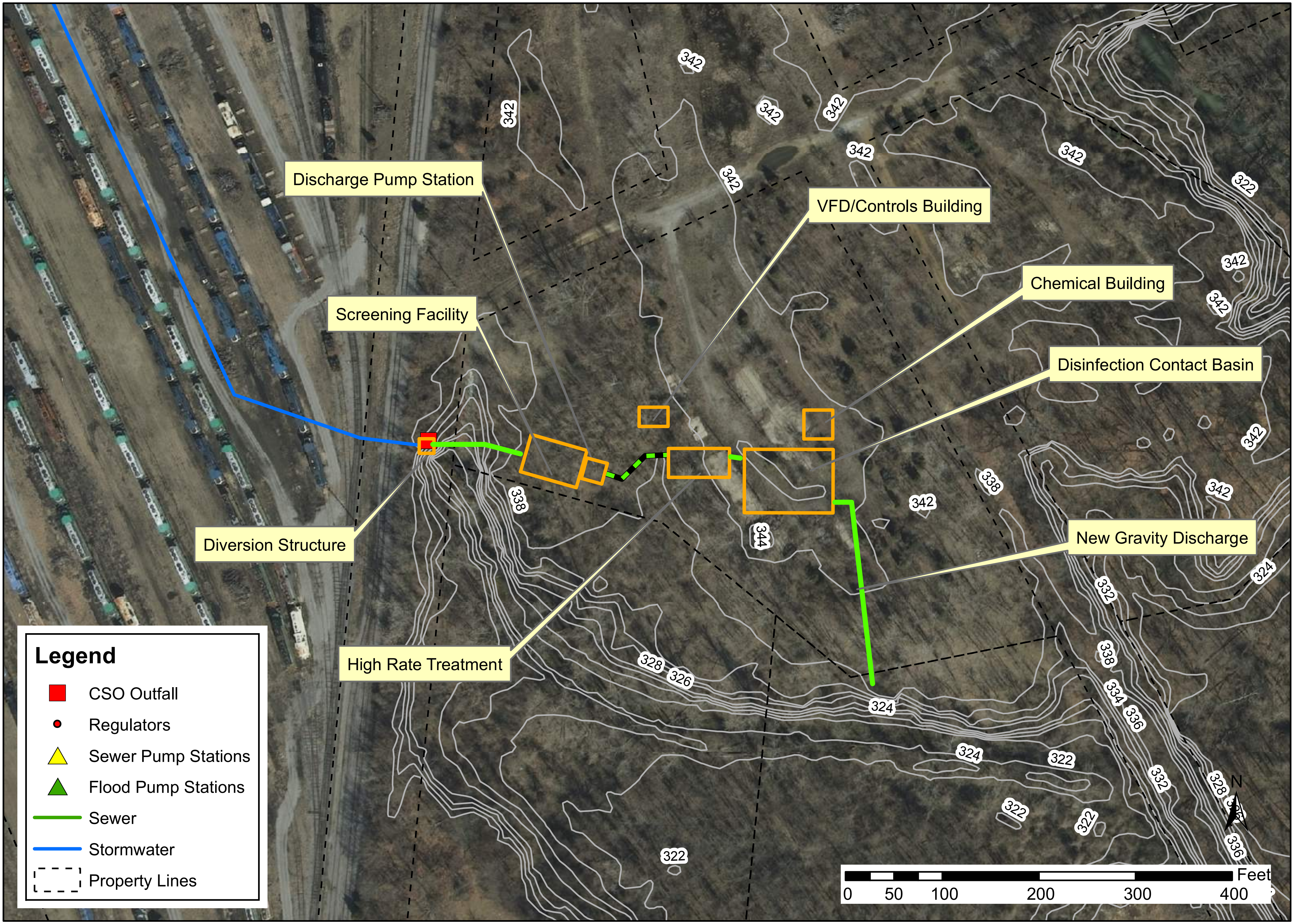
Paducah LTCP - Outfall EPA 010

Figure M-6 - Fine Screening and Disinfection



Paducah LTCP - Outfall EPA 010

Figure M-7 - HRT



Paducah LTCP - Outfall EPA 010

Figure M-8 - HRT and Disinfection

Appendix N

EPA 011 CSO Control Alternatives

Note 1: Costs presented are screening-level estimates for comparison of the alternatives. Costs of selected alternatives will be reviewed in further detail for the financial analysis.

Note 2: When additional land is required to site the facilities, the placement of the facilities and the selected parcels are shown for illustrative purposes only. Alternative nearby sites would also be evaluated during design.

EPA 011, shown in Figure N-1, is one of the CSO outfalls located along an unnamed tributary to Island Creek. The tributary area primarily includes residential and commercial land use. There are two regulators associated with this outfall, regulators 29 and 30. The tributary area for EPA 011 is shown in Figure N-2.

A portion of the overflow volume is believed to be separate stormwater that is discharged directly into the outfall pipes downstream of regulators.

When the Ohio River stage is high and the floodwall gates on Island Creek are closed, Island Creek has the potential to hold water, which under some conditions can result in high depths at the CSO outfalls. JSA does not believe that Island Creek would back up into the combined sewer system excluding extreme flooding conditions or failure of the floodwall pump stations. However, alternatives evaluated below include slide gates or other devices that can be used to protect and isolate the new facilities if backwater effects are experienced from the floodwall pump station's operation.

Evaluation of CSO control alternatives for this outfall assumes a target percent capture of 96.4 percent of total annual CSO volume, which is consistent with the knee of the curve sizing for screening as presented in the LTCP. This results in a combined required sizing of 5 million gallons per day (mgd) for alternatives based on overflow treatment at this site. The target percent capture will be utilized to compare alternatives; however, JSA recognizes that the need to achieve a minimum system-wide capture of 85 percent and may adjust the sizing of the selected alternative at EPA 011 to achieve this goal. The 96.4 percent capture results in 13 CSO events per year relative to 85 events per year under the current system.

The following alternatives were evaluated for EPA 011:

A. System separation of the tributary area to this outfall
B. Storage
C. Pumping to a new wet weather treatment facility to be constructed near the WWTP (no on-site storage)
D. Fine Screening
E. Fine Screening with Disinfection

F. High Rate Treatment

G. High Rate Treatment with Disinfection

For each alternative, it is assumed that properties near to the outfall are acquired and that the entirety or a portion of this property can be utilized to construct the elements in each alternative. Outfall EPA 011 is in an existing floodway to the unnamed tributary to Island Creek and the flood zone extends into one of the properties adjacent to the outfall. This is shown on **Figure N-1** Since structures cannot be built in the flood zone, the alternatives listed below will not be located directly at the outfall. Due to the flood zone, properties that are occupied will need to be purchased and cleared for some of the alternatives.

A. System Separation

System separation was considered for the combined sewer system portion of this tributary area, which consists of approximately 110 acres. The estimated total project cost is approximately $11 million. The unit construction cost for separation presented in the LTCP ($100,000 per acre) was revised to $80,000 per acre based upon the costs associated with the separation project associated with EPA 012. With anticipated engineering, legal, and other administrative costs, the assumed total project unit cost is $100,000 per acre. Costs associated with the separation of EPA 014 were lower than this value but are not believed to be appropriate for planning purposes since that project was completed in conjunction with Department of Transportation work.

Sewer separation for a portion of the tributary may be feasible; however, separating a portion of the area would not eliminate the need for CSO controls for the remaining CSO discharge.

B. Storage

In order to achieve target percent capture, the storage alternative must consider three components: the rate at which flow must be captured and stored, the volume of storage required, and how quickly the stored flows can be drained back to the system for treatment. Because of the location of EPA 010, stored flows were assumed to be pumped to the 96-inch sewer along Clay Street which leads to the WWTP as treatment capacity becomes available. Utilizing the results of the hydraulic model, several combinations of those three factors were analyzed in order to assess the feasibility of this alternative and to attempt to determine appropriate sizes for those three components while achieving the target percent capture. The following sizes were estimated, and the resulting facility is shown as **Figure N-3**:

- Pumping rate into storage: 5 mgd
- Required storage: 5 million gallons
- Dewatering rate to WWTP: 8 mgd (the limit of available post-event plant capacity)

Elements of this system include the following:

1. A diversion structure on the outfall pipe that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 5 mgd to a new coarse screening facility; (2) flow over 5 mgd on any given event goes over a weir directly to the outfall.
2. A coarse screening facility upstream of the storage tank pump station. The screening capacity would be 5 mgd, with two 2.5 mgd screen channels and a 5 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to protect the pumps.
3. A low head, 5 mgd storage tank pump station. Three 2.5 mgd (1800 gallons per minute) pumps with variable frequency drives (VFDs) would be installed, operating on a lead-lag-standby scheme. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be

underground, with a wetwell sized to provide 5 minutes of detention time at the 5 mgd flow (18,000 gallons).

4. Five million gallons of storage, which is the storage required to achieve the target percent capture given dewatering limitations of the WWTP. The storage is assumed to be as shown in **Figure N-3.** A prestressed concrete tank is assumed at this stage, but steel would also be considered at the time of construction if there is an indication that they can be cost-competitive. Buried storage would be more expensive. Tank dimensions would be approximately 150 feet in diameter and 35 feet tall. Overflow standpipes would be constructed in each tank, with overflow elevation set to provide 2 feet of freeboard. Tank washdown systems are assumed to be provided.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30 feet by 25 feet, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. An 8 mgd pump station to pump flow to the 96-inch diameter sewer near Clay Street which leads to the WWTP. This pump station is sized based on the typical maximum WWTP capacity available following storm events. Two 8 mgd (5,500 gpm) submersible pumps, VFD operated, are included. As with the tank inflow pump station, Flygt N type submersible pumps (or equivalent) are assumed to be provided. The pump station would be underground (but not as deep as the tank inflow pump station), with a wetwell sized to provide 5 minutes of detention time at the 8 mgd flow (28,000 gallons). If this alternative is selected, additional evaluation on the feasibility of dewatering the tank by gravity to the 96-inch sewer will be conducted.
7. A 16-inch force main approximately 6,500 feet long routed from the pump station to the 96-inch diameter sewer near Clay Street which leads to the WWTP. Additional existing gravity sewers can be reviewed to assess available capacity, which may allow a reduction in the length of the force main. The connection point to the gravity system or the WWTP's influent pipe/channel would be determined during detailed design, in coordination with the project hydraulic analysis.

The screening-level cost estimate for this project is $21.8 million.

It is noted that it may be possible to define a hybrid storage-treatment option for which the combination of storage and treatment would be more reasonable. This would entail the use of some form of high-rate treatment (for solids removal and disinfection of the dewatered flow from storage) at the site. It has been determined through model simulations of the system that multiple combinations of storage and dewatering could achieve the defined target capture if that volume could be dewatered at through a treatment facility. Those options can be explored further as the system-wide alternative evaluations continue.

C. Pumping to a new wet weather treatment facility to be constructed (no on-site storage)

This alternative consists of diverting a maximum of 5 mgd through a coarse screening facility and pump station for transport to a new wet weather treatment facility located near the WWTP that would receive wet weather flows from other CSO outfalls. The flow being pumped to this facility would be pumped to the WWTP, where the flow can be routed to the WWTP if there is available capacity or to the dedicated wet weather treatment facility if WWTP capacity is not available.

Elements of this system include the following (See Figure N-4):

1. A diversion structure on the outfall pipe that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 5 mgd to a new coarse screening facility; (2) flow over 5 mgd on any given event goes over a weir directly to the outfall.
2. A coarse screening facility upstream of the pump station. The screening capacity would be 5 mgd, with two 2.5 mgd screen channels and a 5 mgd bypass channel. Screen openings would be 1.5-inch size, which is meant to protect the pumps.
3. A 5 mgd pump station which would consist of three 2.5 mgd (1800 gpm) pumps with VFDs would be installed, operating on a lead-lag-standby scheme. The base flow pump would turn off at a preset wetwell level and would not turn on again until the next storm cycle; the VFD-driven pumps would operate for the rest of the cycle. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage. The pump station would be underground, with a wetwell sized to provide 20 minutes of detention time at the 5 mgd flow (70,000 gallons).
4. A force main routed from the pump station to the new wet weather treatment facility located near the existing WWTP. The connection point to the influent pipe/channel would be determined during detailed design, in coordination with the project's hydraulic analysis.
5. A control building, block, with sloped roof, would house electrical and controls equipment. One room, 30 feet by 20 feet, climate controlled for the VFDs. A generator would be provided in an exterior location inside a weatherproof enclosure, sized to provide firm capacity of both pump stations.
6. A new wet weather treatment facility located near the WWTP. For purposes of this analysis, it is assumed that this facility would consist of a high rate treatment (HRT) and disinfection facility that would provide the equivalent of primary treatment and disinfection for flows from outfall EPA 003 as well as potentially other remote outfalls. Costing assumes that an HRT and disinfection facility is the recommended CSO control project to address EPA 003. Costs to send additional flow are allocated on a per-mgd basis for flows over 70 mgd (the assumed capacity of the facility to treat only EPA 003) at a rate of $300,000 per mgd. For 011, this amounts to an additional $1.5 million. At this time, the HRT system is being evaluated using two vendors – Actiflo and DensaDeg. A detailed analysis of these systems should be performed during the design of the project, if this is the preferred alternative. For now, preliminary cost and system "footprint" data have been collected for the three treatment trains and the costs among the three systems have been averaged to determine a cost opinion for the work of this alternative.
7. As the captured flow is being pumped to treatment, there would be no additional treatment or disinfection facilities provided at this location for flows that go directly to the outfall.

The screening-level cost estimate for this project is $14.6 million.

This alternative provides a sound technical solution to collecting and treating flows that currently discharge at this outfall. However, the option may not be feasible due to the limited capacity of the discharge sewer and/or the floodwall pump station that serves as the outfall pipe for EPA 003 as well as the effluent discharge pipe for the WWTP. Further evaluation is needed to assess of the available capacity of the existing system. No improvements to the discharge sewer or floodwall pump station are included in this screening-level cost estimate.

This alternative does not include on-site storage, but it is possible that a hybrid alternative could be considered as the system-wide solutions are evaluated that balances the need for storage and wet weather treatment. Adding storage could allow for pumping more flow directly to the WWTP one or two days after the storm event; this could reduce the amount of HRT treatment that would be required. On-site storage would also reduce the peak flow rates that drive the pump station and force main sizing requirements.

D. Fine Screening

This alternative consists of diverting the flow from the outfalls, through a fine screening system, and back into the outfall channel. This alternative was presented as the recommended alternative for treatment at this location in the initial LTCP submission and CDM Smith maintains that the recommendations in the initial LTCP conform to the 85% capture provision of the CSO Policy Presumptive Approach. CDM Smith recognizes the concerns raised by KDEP and EPA in their January 30, 2015 letter to the JSA and has provided more detailed review of multiple alternatives within this document. In the meantime, this alternative is the least cost alternative available to JSA, so it would be included in this analysis.

The system consists of the following items (See **Figure N-5**):

1. A diversion structure at the outfall that collects all flow from the current outfall and diverts it to one of two locations: (1) up to 5 mgd to a new coarse screening facility; (2) flow over 5 mgd on any given event goes over a weir directly to the outfall. The structure would be enclosed to prevent backflow created when the floodwall gates on Island Creek are closed.
2. The screening facility's capacity would be 5 mgd, with two 2.5 mgd screen channels and a 5 mgd bypass channel. Each screen channel would have a dual screen system installed; a 1.5-inch coarse screen to screen large debris in the flow stream, followed by a fine screen (4-6 mm clear spacing) to screen smaller debris. The screens are assumed to be mechanically cleaned, with screenings delivered to trash dumpsters for easy maneuvering and hauling offsite. The screens and channels would be underground structures, extending the enclosed concept of the diversion structure, but the screenings would be delivered to the dumpsters in an "at-grade" facility to make the removal of the screenings convenient for operations staff.
3. A low head, 5 mgd pump station would be required to move the screened water back into the outfall channel. This would consist of three 2.5 mgd (1800 gpm) pumps with VFDs would be installed, operating on a lead-lag-standby scheme. The base flow pump would turn off at a preset wetwell level and would not turn on again until the next storm cycle; the VFD-driven pumps would operate for the rest of the cycle. Flygt submersible pumps with N-type impellers (or equivalent) would be provided; the N type impellers are durable for raw sewage and are expected to continue operation in the event that the screens fail. The pump station would be underground, with a wetwell sized to provide 5 minutes of detention time at the 5 mgd flow (18,000 gallons).

The outfall pipe is not constructed in such a way that deflection screens are able to be used to keep screening material in the CSO flow and send the screenings to the plant. Vertical screens that remove screenings from the CSO flow are therefore required. As with Alternative C, screening material generated by the screening facility would need to be removed disposed of periodically.

The screening-level cost estimate for this project is $7 million.

E. Fine Screening with Disinfection

This alternative includes the full screening facility described in Alternative D, followed by disinfection. (See **Figure N-6**). The low head pump station would pump the flow into the disinfection basin instead of the outfall, but would have bypass capability to pump into the outfall channel in the event that the disinfection system is offline. Disinfection alternatives that were reviewed include ultraviolet (UV) radiation, chlorination / dechlorination, and peracetic Acid (PAA). Advantages and disadvantages of these alternatives are summarized briefly below.

1. UV
    a. Advantages
        i. Instantaneous inactivation of organisms
        ii. Takes the least amount of space; no contact tank required
        iii. No chemicals on the site
        iv. Least capital cost alternative
    b. Disadvantages
        i. Intermittent use of facility can be an issue; UV works best with a continuous flow stream.
        ii. Particle size in the flow stream may limit UV effectiveness
2. Chlorination/Dechlorination
    a. Advantages
        i. Proven disinfecting capability for a wide variety of organics
        ii. Can be used in intermittent flow situation
        iii. Operator familiarity; already used in the system
    b. Disadvantages
        i. Two chemical systems in separate buildings are required at a remote location
        ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 53,000 gallons) is required
        iii. Liquid Sodium Hypochlorite has a limited shelf life. As design volumes must be for peak storm events, during long periods of low rainfall the chemical may have to be withdrawn from the tank and replaced
        iv. Most expensive capital cost alternative
3. PAA
    a. Advantages
        i. Does not need a secondary chemical for dechlorination
        ii. Can be used in intermittent flow situation
        iii. Equipment is typically leased; may be able to subcontract operation
        iv. Capital cost is lower than chlorination/dechlorination alternative
        v. PAA has a longer shelf-life than other alternatives
    b. Disadvantages
        i. Typically, higher doses of chemical are required for disinfection than sodium hypochlorite.
        ii. Contact basin, sized for a minimum of 15 minutes of peak flow (approximately 53,000 gallons) is required. Volume may be higher, depending on results of pilot testing of effectiveness.
        iii. A chemical system is required at a remote location.

The screening-level cost estimate for this project is $8.6 million, which assumes chlorination / dechlorination is the selected type of disinfection. Bench and pilot scale testing of the disinfectants at this site would be conducted during preliminary design if this alternative is selected.

As with Alternative D, screened material generated by screening facility would need to be removed from the site and disposed of periodically in addition to the other maintenance of the chemical disinfection systems. **Figure N-6** shows the worst case scenario for land use if chemical disinfection and low head pumping is required. This alternative becomes more infeasible due to the increased complexity and presence of chemical systems located at this remote site.

F. High Rate Treatment

This alternative consists of installing a high rate clarification (ballasted flocculation) system that is designed to remove settlable solids and the insoluble BOD fraction with a construction footprint that is much smaller than conventional primary treatment processes and provides a higher level of treatment than conventional primary treatment processes. The units typically are provided as equipment packages by the vendors that supply them, oftentimes complete with basins, the mixing, flocculation, and sedimentation equipment internal to the basins, and chemical feed system components, although what is provided can vary from manufacturer to manufacturer. The composition of the system goes beyond just the equipment package, though and would require pumping to meet the hydraulic needs of the system. The system would contain the following elements (See **Figure N-7,** which includes the footprint of the larger HRT system):

1. A screening facility, as described in Parts 1, 2 and 3 of Alternative D. The only difference is that the screen bypass channel would bypass the HRT. Unscreened CSO flow can damage the HRT equipment.
2. A low head pump station, as described in Part 3 of Alternative D. For the HRT alternative, the alternatives are to either build the treatment system in-ground and pump after treatment, or pump prior to treatment and build the treatment system above ground. While building above-ground has a negative impact on the aesthetics of the park, the above-ground system is more cost effective and less prone to flooding. The above ground option is considered in this analysis.
3. The HRT unit. The units are physical / chemical treatment processes that use a combination of rapid mixing of chemicals, flocculation chambers, and settling basins to obtain settling of total suspended solids (TSS) and biochemical oxygen demand (BOD). For purposes of this evaluation, two systems were reviewed for general compatibility:
    a. Kruger's Actiflo system
    b. Infilco Degremont's DensaDeg system
4. Sludge withdrawal and disposal is required. For purposes of this evaluation, it is assumed that there is a connection off the bottom of the sedimentation basin for a sludge truck (with pump) to dock, offload the sludge from the basin, and transport the sludge to the WWTP. However, a separate storage tank may be required for temporarily holding sludge which is not included in this estimate. It is also noted that the cost for sludge handling is not included as a capital expense at this time; it is assumed that JSA would enter into a contract with a waste hauler instead of buying their own truck. Pumping the sludge into the local sewer may also be possible, but an evaluation of the sewer system would be required between the entry point and the WWTP to insure that there would be no potential overflows to other outfalls.
5. Gravity discharge channel from the HRT to the outfall channel. A channel would be provided, with energy dissipation structure (river rock cemented together or spread concrete pad at the bottom of the channel) to minimize potential erosion in the existing channel. The discharge at the treatment unit would be above the water level that is generated when the floodwall gates are closed.

The screening-level cost estimate for this project is $13.8 million. Price proposals have been provided by the two vendors listed above. These costs were reviewed and the costs were averaged for use in this evaluation.

When considering this alternative, the following disadvantages are noted:

1. Capital and operating costs would be very high.
2. The system is relatively complex to operate remotely. It is likely that JSA would send staff to prepare chemicals and monitor operation during rain events.
3. Multiple chemical systems would be at a remote site.
4. If HRT technology is used for JSA, it may be preferred to combine all outfalls that would be treated at the WWTP. An HRT unit can be constructed there that would be more cost effective for the entire system and would have reduced impact to public park facilities.

G. High Rate Treatment, with Disinfection

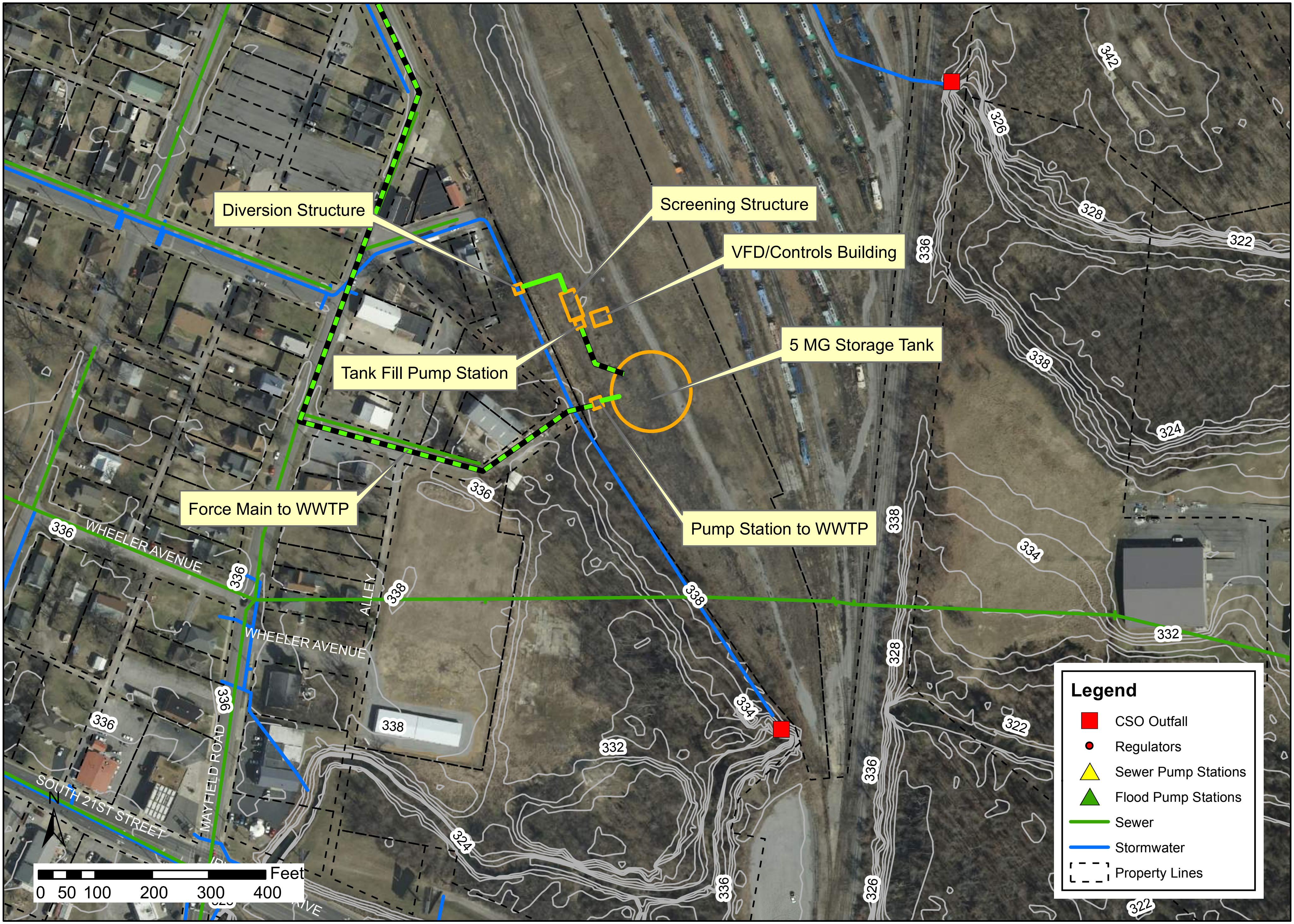
This alternative consists of using the HRT system described in Alternative F and adding a disinfection facility (See **Figure N-8**). The HRT discharge pipe would route treated flow to either the UV channel or the contact chamber, depending on which disinfection alternative would be selected through bench and pilot testing of disinfection alternatives. It is noted that **Figure N-8** shows the largest configuration of HRT treatment on the site and chlorination / dechlorination disinfection system.

While adding disinfection would improve the level of treatment provided at EPA 011, it would increase the cost (by approximately $1.5 million) and operational complexity of this remote facility. For this reason and the reasons stated above in Alternative F, CDM Smith has determined that this is not a feasible alternative for outfall EPA 011.

Paducah LTCP - Outfall EPA 011

Figure N-1 - Overview

Figure N-2: EPA 011 and Tributary Areas

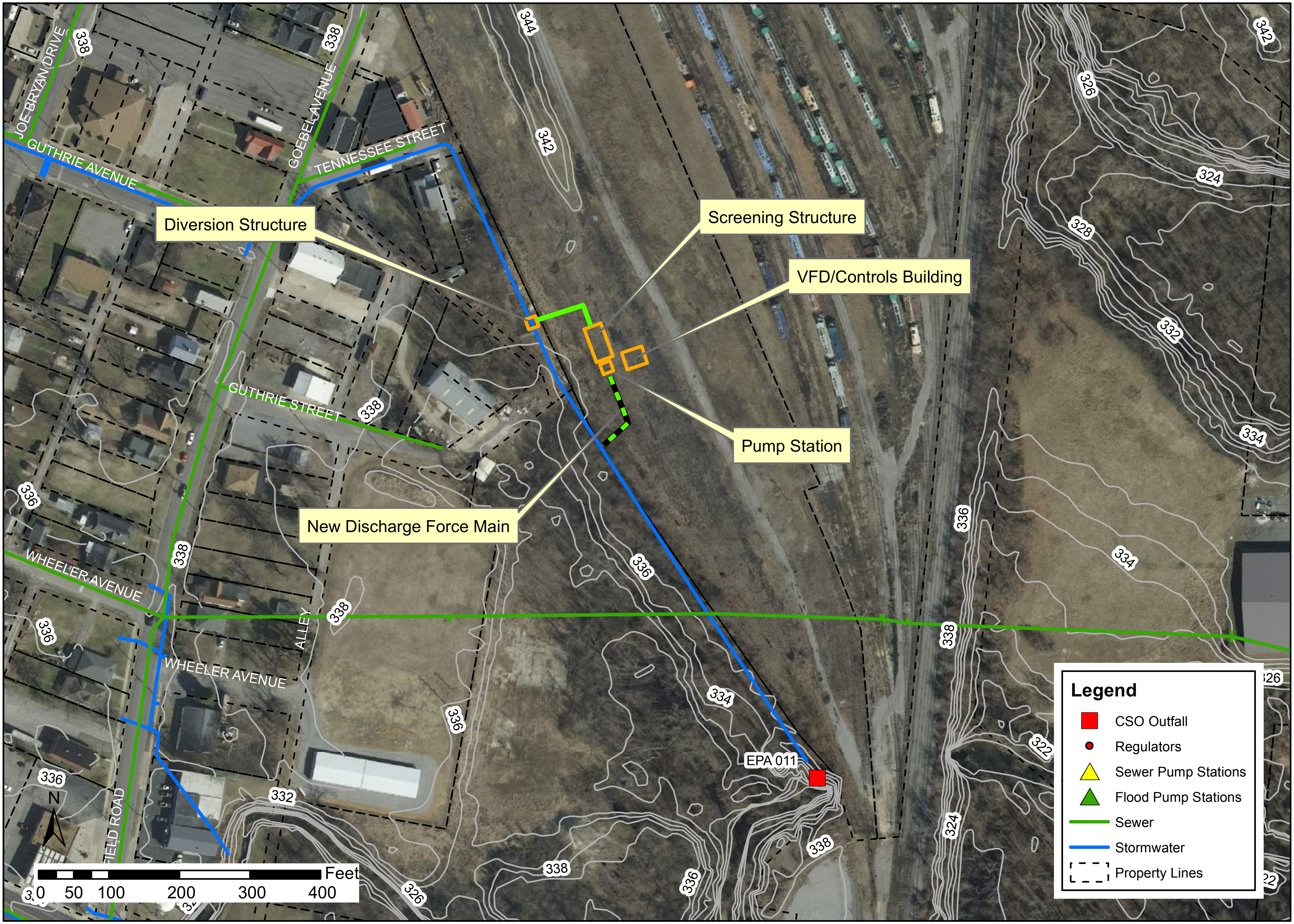


Paducah LTCP - Outfall EPA 011

Figure N-3 - Storage

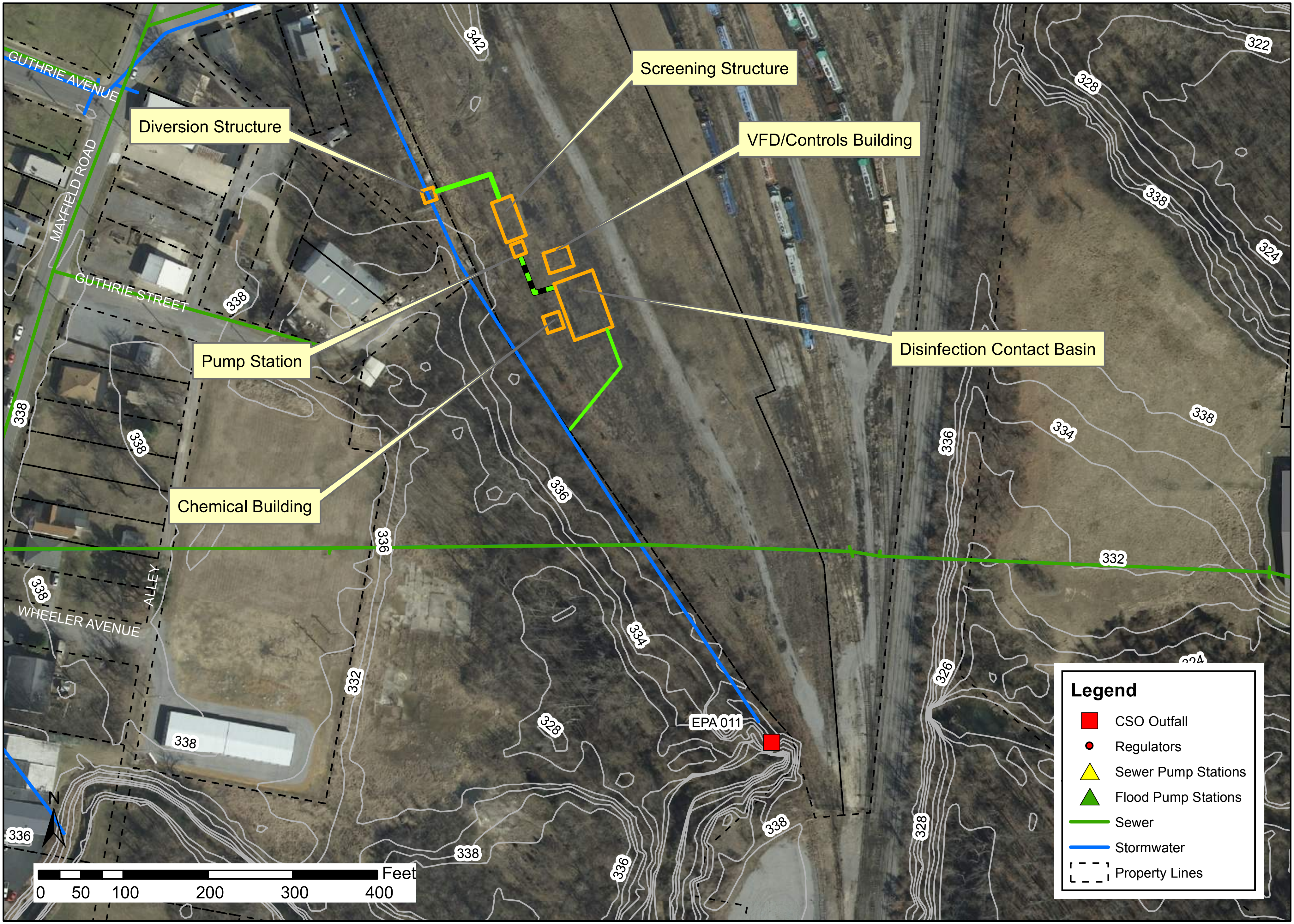
Paducah LTCP - Outfall EPA 011

Figure N-4 - Pumping to Treatment



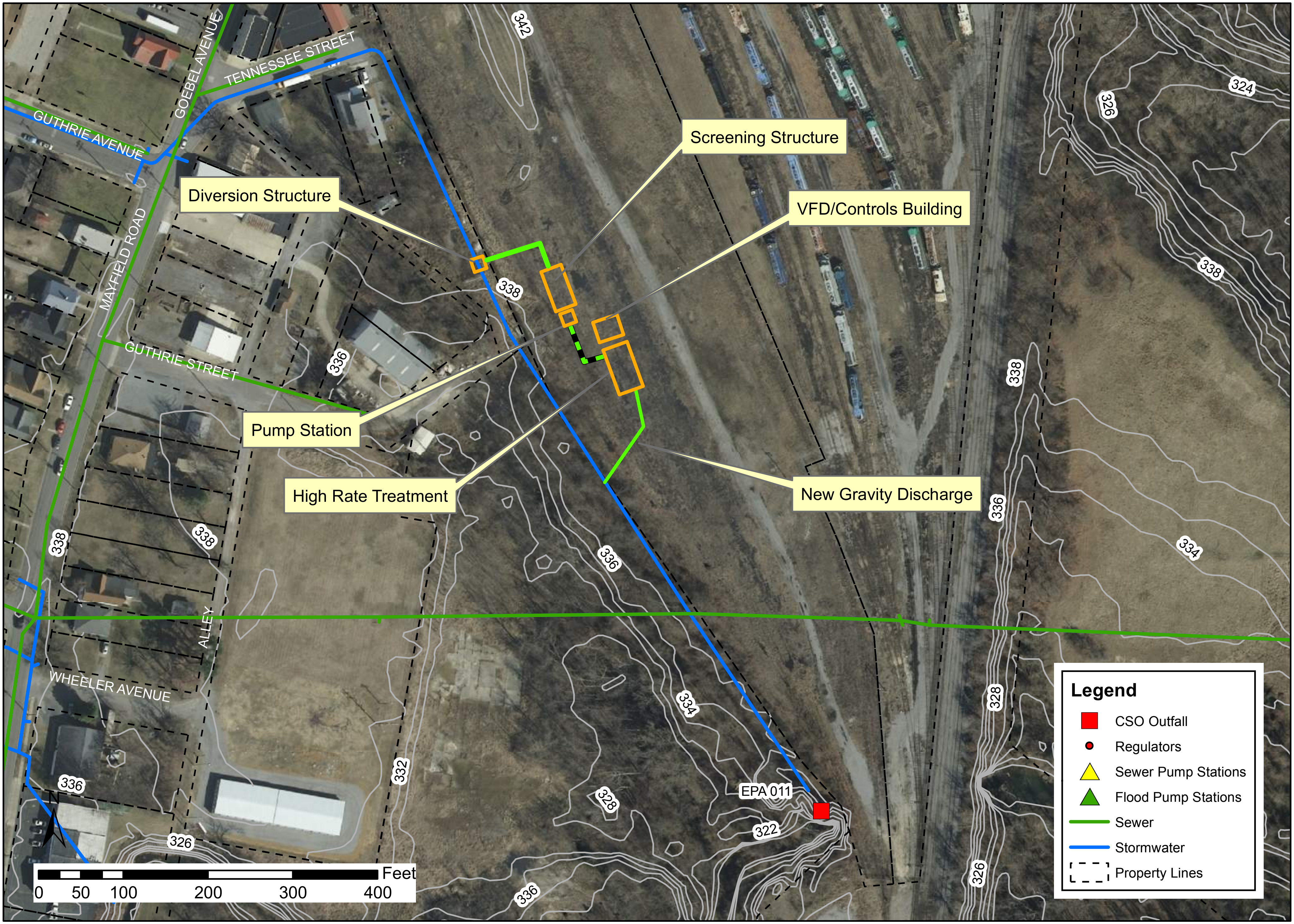
Paducah LTCP - Outfall EPA 011

Figure N-5 - Fine Screening



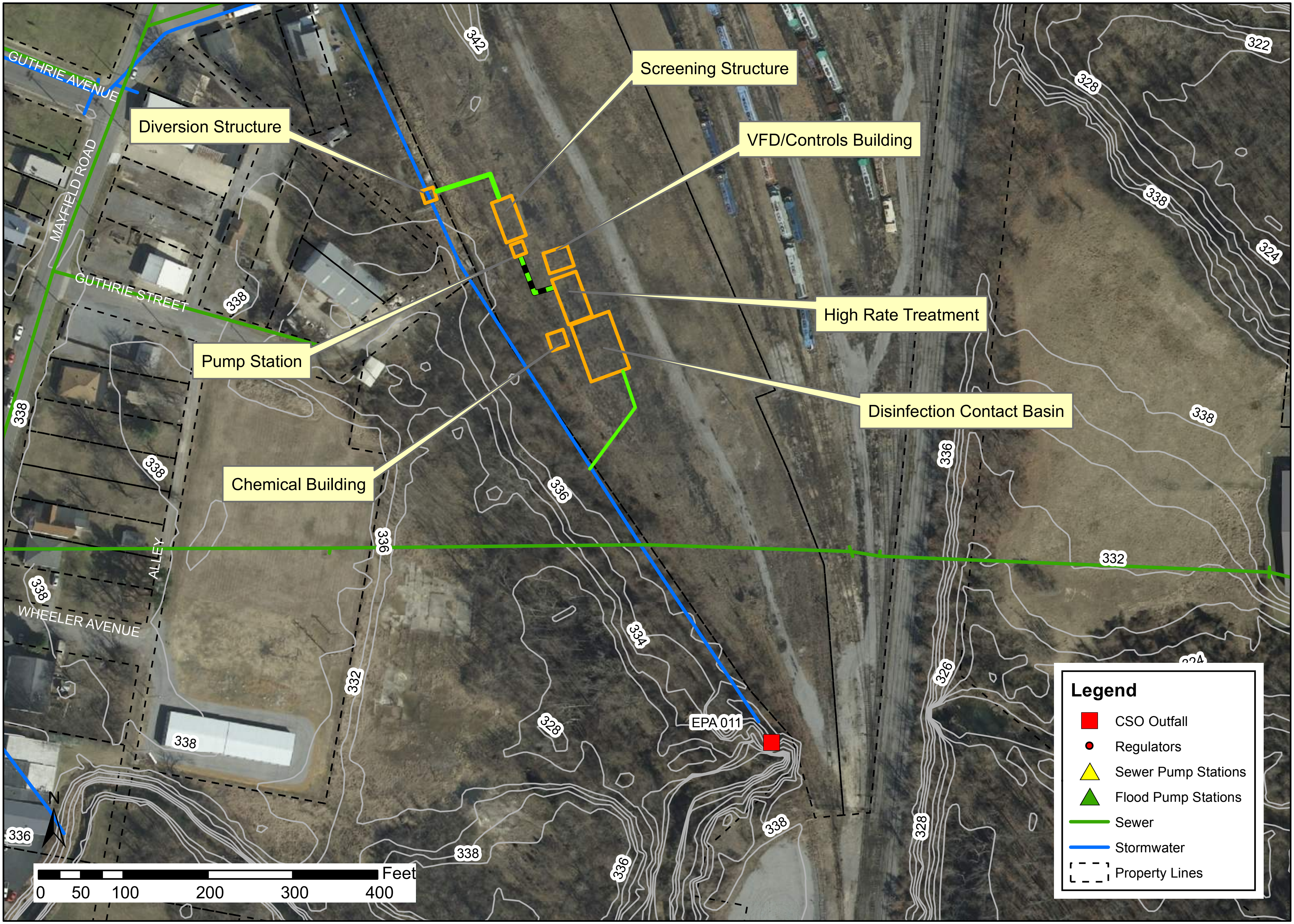
Paducah LTCP - Outfall EPA 011

Figure N-6 - Fine Screening and Disinfection



Paducah LTCP - Outfall EPA 011

Figure N-7 - HRT



Paducah LTCP - Outfall EPA 011

Figure N-8 - HRT and Disinfection

Appendix O

System-wide Percent Capture Calculation

JSA's LTCP utilizes the presumptive approach to meet the water quality goals of the CSO Control Policy. More specifically, the analyses that JSA has conducted to select the CSO control projects included in the LTCP are based on the following target:

The elimination or the capture for treatment of no less than 85 percent by volume of the combined sewage collected in the combined sewer system during precipitation events on a system-wide average annual basis. (U.S. Environmental Protection Agency; Combined Sewer Overflow (CSO) Control Policy; Federal Register Vol. 59, No. 75; FR18692; April 19, 1994).

JSA utilized a hydraulic model to assess the percent capture of the baseline system and the system with various possible CSO control projects. This was achieved by identifying a representative five-year precipitation record that could be simulated with the hydraulic model to establish the average annual statistics. Additional information regarding the hydraulic model development and the five-year representative precipitation period is included in the *Revised LTCP.*

For the purposes of the calculation of percent capture, the start (and end) of each precipitation event is defined as the point in time where the simulated flow in the system rises above (or falls below) the value that is 5 percent higher than the expected dry-weather flow. Dry-weather flows included in the hydraulic model were developed from the observed data obtained during the temporary monitoring period in 2008. Because the JSA system also experiences seasonal variations in groundwater infiltration throughout the year, adjustment factors were established following a review of historical records at the WWTP, and these factors applied for each month in the hydraulic model. The expected dry-weather flow utilized to define the start and end of the precipitation event is the typical daily average dry-weather flow value for the month. Dry-weather flow patterns are highly consistent over time, and detailed review of the hydraulic model results has shown that flow in the system only rises 5 percent or more above the expected dry weather flow value as a result of precipitation runoff.

Unlike the combined sewer systems in many other similar-sized communities, JSA has a very complex system, including the following elements:

- In many cases, there are multiple regulators that may allow the discharge of combined sewage to the same CSO outfall. For instance, there are two regulators associated with EPA 011. Regulator 29 is a weir-type regulator where high flows overtop the weir and travel through approximately 0.5 miles of sewer prior to being discharged at EPA 011. The second regulator associated with EPA 011 is trough-style regulator where flows that exceed the pipe capacity drop from the combined sewer into the lower pipe that routes flow to EPA 011.

- In most cases, combined sewage has the possibility of being discharged through numerous regulator structures to different CSOs. For instance, combined sewage entering upstream of Husbands Street Pump Station may be diverted to EPA 006 via regulator 48 or it may continue downstream towards the Harrison Street Pump Station. At that location, it may either continue downstream towards the Terrell Pump Station or it may be diverted to EPA 004 via regulator

53. As the combined sewage approaches Terrell Pump Station, it may be pumped by Terrell to the WWTP or it may be diverted to EPA 003 via regulator 42.

- Excluding the CSOs located on the Ohio and Tennessee Rivers, direct stormwater runoff is also discharged to the CSO outfall pipe downstream of regulators. In other words, the pipe that is used to convey combined sewer overflows from the regulator to the permitted CSO location is also utilized for separate stormwater conveyance. These stormwater flows were estimated and included in the hydraulic model to determine the total discharge at the CSO locations. For CSO control projects that were located at or near the discharge point of the CSO, the facilities will capture and/or treat the flow arriving at the location, which will be a mixture of both the direct stormwater runoff and the overflow of combined sewage from the upstream CSO regulator structure(s).

Because of these complexities and the inter-dependencies, the impact of any one solution on specific downstream CSOs is extremely difficult to quantify. Therefore, the analysis of percent capture was conducted by considering the entire combined sewer system, as opposed to estimating the percent capture on an individual basis by CSO. This is consistent with the CSO Control Policy, which established the 85 percent capture goal on a system-wide basis.

Baseline Percent Capture

The baseline conditions represent the existing system during the 2008 temporary monitoring period. Excluding the separation projects associated with EPA 012 and EPA 014, few significant changes have occurred within the system. The baseline statistics reflect EPA 012 and EPA 014 as active CSOs during the baseline (2008) period. The basis of the percent capture calculation, which was developed utilizing the hydraulic model under the five-year representative rainfall period, is summarized below:

- Average annual base flow (sanitary and groundwater infiltration) during precipitation events: 1.0 billion gallons
- Average annual combined sewage volume (including base flow) during precipitation events: 3.3 billion gallons
- Average annual combined sewerage volume captured and treated at the WWTP during precipitation events: 1.8 billion gallons
- Percent capture: 55 percent

Long Term Control Plan Percent Capture

Following the implementation of the selected CSO control projects presented in this LTCP, JSA anticipates achieving the elimination or the capture for treatment of more than 85 percent (approximately 87 percent) by volume of the combined sewage collected in the combined sewer system during precipitation events on a system-wide average annual basis. The basis of that calculation is described as follows:

- Average annual base flow (sanitary and groundwater infiltration) during precipitation events: 1.0 billion
- Average annual combined sewage volume (including base flow) during precipitation events: 3.3 billion gallons

- Average annual untreated volume discharged at CSO outfalls:
  - EPA 002: 74 million gallons
  - EPA 003: 111 million gallons
  - EPA 004: <1 million gallons
  - EPA 006-007: 26 million gallons
  - EPA 008: 75 million gallons
  - EPA 009: 47 million gallons
  - EPA 010: 82 million gallons
  - EPA 011: 17 million gallons
  - EPA 012: 0 gallons
  - EPA 014: 0 gallons
  - Total untreated CSO volume: 0.43 billion gallons
- Percent capture: 87 percent

Appendix P

Post Construction Compliance Monitoring Plan

This Post Construction Compliance Monitoring Plan (PCCMP) will be implemented by JSA to assess the effectiveness of the facilities constructed under the *Revised LTCP*. The specific types of equipment and locations of monitoring and sampling, however, are presented for illustrative purposes. These aspects will be further assessed as the designs of the facilities are completed, although the concepts presented herein will be applied. Additionally, for the purposes of this PCCMP, it is assumed that disinfection is accomplished via chlorination/dechlorination facilities. If alternate (non-chlorination) disinfection technologies are selected during design, sampling of total residual chlorine will be removed.

1. Monitoring Objectives

The LTCP applies the Presumptive Approach defined in EPA's CSO Control Policy to establish the target level of CSO control to be provided. Specifically, the facilities have been sized to provide for the capture for treatment of 85 percent by volume of the combined sewage collected during precipitation events on a system-wide average annual basis. It is therefore important that the PCCMP provide a methodology to determine the actual capture of wet-weather flow by volume and a methodology for evaluating the actual level of capture against the 85 percent target. These facilities also provide treatment of captured flows, primarily for reduction in bacteria, therefore monitoring of effluent bacteria concentrations is also provided.

The facilities proposed in this LTCP include sewer separation at EPA 012 and EPA 014, increased pumping capacity at EPA 004, and fine screening and disinfection facilities at EPA 002, EPA 003, EPA 006, and EPA 007. The use of the Presumptive Approach to set the performance objectives for these facilities requires that the PCCMP focuses on the ability of the proposed facilities, post-construction, to capture and treat 85 percent of the combined sewage collected during precipitation events on a system-wide average annual basis. This is in contrast with the Demonstration Approach in which the performance objectives of the LTCP are defined by water quality conditions in the receiving waters. Because the LTCP objectives are defined by facility performance, not in-stream water quality, this PCCMP does not include instream monitoring. It should also be noted that the Consent Judgment excludes characterization, monitoring, and modeling activities of the Ohio River and the Tennessee River at the confluence of the Ohio River, and that work has not been undertaken by JSA.

The specific plan for post-construction compliance monitoring, which includes both monitoring and modeling of the CSO control facilities, is described below.

2. Previous and Current Monitoring

As part of developing the LTCP, in particular to support model calibration, 30 temporary flow monitors were installed in the combined sewer system area from late January 2008 through early April 2008. These monitors recorded depth and velocity of flow in 5-minute intervals and included monitors located on each CSO outfall, excluding those that discharge directly to the Tennessee or Ohio Rivers. Monitors were also located on combined trunk sewers to collect data that could be used to calibrate model runoff parameters from different land use types, on key interceptors within the CSS to calibrate hydraulic parameters for those sewers, and on separate sanitary sewers that drain a significant area before connecting to the CSS to define dry- and wet-weather flows into the combined sewer system from those areas.

Eight rain gauges were installed during the above-referenced monitoring period throughout the combined sewer system to provide precipitation data. These rain gauges recorded rainfall data in 0.01 inch increments at 5-minute intervals. Rainfall data from temporary rain gauges installed as part of the sanitary sewer overflow plan was also available for use. Additionally, historical precipitation data, obtained from the National Climatic Data Center, was used to develop a representative five year precipitation record in order to assess the average annual volume, duration, and frequency of CSOs.

Currently, JSA continues to monitor flow at major pump stations, and these datasets are captured on SCADA.

3. Compliance Monitoring Approach

The *Revised LTCP* applies the Presumptive Approach defined in the CSO Control Policy, specifically the capture target of 85 percent by volume of the combined sewage collected during precipitation events on average annual basis, to define the system-wide objectives for CSO control.

Because the CSO control objectives for the proposed facilities are defined in terms of average annual volume statistics, a model-based approach must be used. Monitoring of the facilities is useful to understand the facility's operation under a specific, observed storm event, but it cannot define volume captured on an average annual basis since it is not possible to monitor average annual conditions. The industry-accepted approach to post-construction compliance evaluations is to model the performance of the constructed facilities with average annual precipitation conditions (such as the representative five year period used by JSA) to evaluate performance. Simulating a precipitation record selected to represent average annual conditions avoids uncertainties that arise when attempting to compare precipitation associated with specific, observed precipitation events to the average annual precipitation conditions.

As facilities are constructed and put into service, the model must be updated to include the constructed CSO facilities and re-calibrated with data collected during the post-construction period to ensure that the model accurately simulates the performance of the facilities. Once that has been accomplished, the model can be used to evaluate CSO capture, both at the individual facility level and system-wide, and determine compliance with the established CSO capture target.

Re-calibration of the model to ensure proper simulation of the constructed CSO facilities will require flow monitoring of both the influent flows (prior to diversion of flow into each proposed facility) and the flows passing through each facility. In the latter case, metering of the discharge line will generally provide the needed information. In the former case, monitoring equipment capable of accurately measuring flow depth/area and velocity is expected to generally be required.

The above approach will enable JSA to determine that the constructed facilities are meeting CSO volume capture objectives.

The other important CSO control facility performance metrics relate to treatment of the captured flow. Although facility-specific limits on effluent discharge (e.g. bacteria concentration, residual chlorine concentration, etc.) have not been established, and may or may not be included in any permits that may be issued to operate the facilities, it will be important to monitor these parameters to ensure that the facilities are operating properly.

The following is a summary of the overall compliance monitoring approach to satisfy the above requirements, and Section 4 provides the specific plan for each facility.

- Flow capture: Permanent flow monitoring equipment will be installed to provide the necessary data as described. In general, influent flows to each facility will be monitored using depth/area/velocity monitoring equipment, and flows captured by each facility will be monitored using a magnetic flow meter on the pump discharge line or other equipment as appropriate. The specific types of equipment and locations of monitoring and sampling, however, are presented for illustrative purposes. These aspects will be further assessed as the designs of the facilities are completed. The model will be updated to include the facilities, re-calibrated (especially the facility parameters added to the model), and used to simulate average annual facility performance (combined sewer flow capture) using the same five year representative period used for system characterization in the LTCP.

- Effluent discharge (bacteria concentration and total residual chlorine): Automatic sampling equipment will be installed to measure effluent bacteria (*E. coli*) concentrations at selected monitoring periods when the proposed fine screening and disinfection facilities are in service and discharging disinfected effluent. De-chlorination performance will be evaluated using a chlorine analyzer to measure total residual chlorine (TRC) concentrations. Because the screening and disinfection facilities are expected to operate 3 to 6 times per month (on average), the relatively difficult and costly bacteria sampling will be performed once per month. TRC concentrations will be measured continuously.

- Precipitation: A network of 5 to 9 rain gauges will be installed across the service area. These gauges will be permanent installations capable of capturing the rainfall time series. The location and type of these rain gauges will be determined in conjunction with the associated permanent flow monitoring equipment.

A Quality Assurance Project Plan will be submitted to the Kentucky Division of Water for review and comment at least 90 days in advance of the scheduled start of post-construction compliance monitoring activities at each CSO control facility.

4. Monitoring Plan for CSO Control Facilities

This section describes the site-specific approach to monitoring each of the proposed CSO control facilities. The specific types of equipment and locations of monitoring and sampling are presented for illustrative purposes. These aspects will be further assessed as the designs of the facilities are completed.

EPA 002

As shown in Figure P-1, the CSO control facility for EPA 002 includes fine screening and disinfection. Three existing CSO outfall conduits converge at the site (existing point of discharge), and the proposed facility includes a diversion structure just upstream of the outfall site which will divert flow through a new conduit to the proposed fine screens. After passing through the fine screens, flow will be pumped into the disinfection contact basin.

Flow monitors will be installed in each of the three CSO outfall conduits above the proposed diversion structure. These flow monitors will provide the data needed to estimate total CSO flow at this site. Depth/area/velocity flow monitoring equipment is currently anticipated, although the location and type of monitor will be assessed during design of the facility.

Flow passing through the facility will be measured using a fourth flow monitor, which is assumed to be installed in the discharge line from the proposed pump station (suitable for full pipe flow, such as a magnetic type meter); this monitor will provide the data needed to estimate flow captured and treated at this site for the monitored events.

An automatic sampler unit will be installed at the point of discharge from the proposed disinfection contact basin. It is expected that precipitation events of sufficient magnitude to activate the facility will occur five or more times per month on average, and samples will be collected and analyzed for *E. coli* concentrations for at least one event per month. A chlorine analyzer will provide continuous measurement of TRC concentrations.

EPA 003

As shown in Figure P-2, the CSO control facility for EPA 003 includes facilities for fine screening and disinfection, which will be located adjacent to the existing Paducah WWTP, near the Terrell Pump Station. Existing 27-inch and 102-inch sewers converge at the pump station, and the proposed facility includes a diversion structure in the existing CSO outfall, which will divert flow through a new conduit to the proposed fine screening facility. After passing through the fine screens, flow will be pumped into the disinfection contact basin.

Flow monitors will be installed to adequately measure the flow from both the 27-inch and 102-inch sewers prior to the existing regulator structure near the Terrell Pump Station. Depth/area/velocity flow monitoring equipment is currently anticipated, although the location and type of monitor will be assessed during design of the facility. Additional flow monitors will be installed to record flow to/ through the Terrell Pump Station. These flow monitors will provide the data needed to estimate total CSO flow at this site.

Flow passing through the facility will be measured using a third flow monitor, which is assumed to be installed in the discharge line from the proposed pump station (suitable for full pipe flow, such as a magnetic type meter); this monitor will provide the data needed to estimate flow captured and treated at this site for the monitored events.

An automatic sampler unit will be installed at the point of discharge from the proposed disinfection contact basin. It is expected that precipitation events of sufficient magnitude to activate the facility will occur four or more times per month on average, and samples will be collected and analyzed for *E. coli* concentrations for at least one event per month. A chlorine analyzer will provide continuous measurement of TRC concentrations.

EPA 004

As shown in Figure P-3, the CSO control project at EPA 004 consists of replacing the existing Harrison Pump Station with a new pump station providing a greater pumping capacity and thus capturing additional combined sewer flow for treatment. The data needed to support CSO capture estimates for this facility will be collected using two flow meters installed on the two existing conduit lines coming into the new pump station, above the diversion structure that will divert flow to the new facility.

Depth/area/velocity flow monitoring equipment is currently anticipated, although the location and type of monitor will be assessed during design of the facility.

Flow passing through the new pump station will be measured using a third flow monitor, which is assumed to be installed in the discharge line from the pump station (suitable for full pipe flow, such as a magnetic type meter); this monitor will provide the data needed to estimate flow captured and delivered for treatment at the Paducah WWTP.

Because no treatment is taking place at this site, there is no need for sampling equipment or a chlorine analyzer.

EPA 006 / EPA 007

As shown in Figure P-4, the CSO control facility for EPA 006 and EPA 007 includes facilities for fine screening and disinfection and will be located near the existing Husbands Pump Station. The proposed facility includes a diversion structure which will divert flow to the proposed fine screening facility. After passing through the fine screens, flow will be pumped into the disinfection contact basin.

The monitoring strategy at this site is slightly different than for the other fine screening and disinfection facilities. Because of the complexity of the pipe network at this site, flow monitors will be installed in both the CSO outfall conduit discharging to the Ohio River, rather than measuring flow above the proposed diversion structure. These flow monitors will provide the data needed to estimate total untreated CSO flow at this site. Depth/area/velocity flow monitoring equipment is currently anticipated, although the location and type of monitor will be assessed during design of the facility.

Flow passing through the proposed CSO control facility will be measured using a third flow monitor, which is assumed to be installed in the discharge line from the proposed pump station (suitable for full pipe flow, such as a magnetic type meter); this monitor will provide the data needed to estimate flow captured and treated at this site for the monitored events.

An automatic sampler unit will be installed at the point of discharge from the proposed disinfection contact basin. It is expected that precipitation events of sufficient magnitude to activate the facility will occur roughly three times per month on average, and samples will be collected and analyzed for *E. coli* concentrations for at least one event per month. A chlorine analyzer will provide continuous measurement of TRC concentrations.

EPA 012 / EPA 014

The outfall at EPA 014 has been completely eliminated, and no further monitoring/evaluation is required. At EPA 012, upstream sewer separation work has been completed, and the status of the outfall is being evaluated under large storm and high river conditions. If the evaluation concludes adequate storm flows have not been removed that the regulator should not be removed, this PCCM plan will be updated to include monitoring of the outfall.

5. Precipitation Monitoring Plan

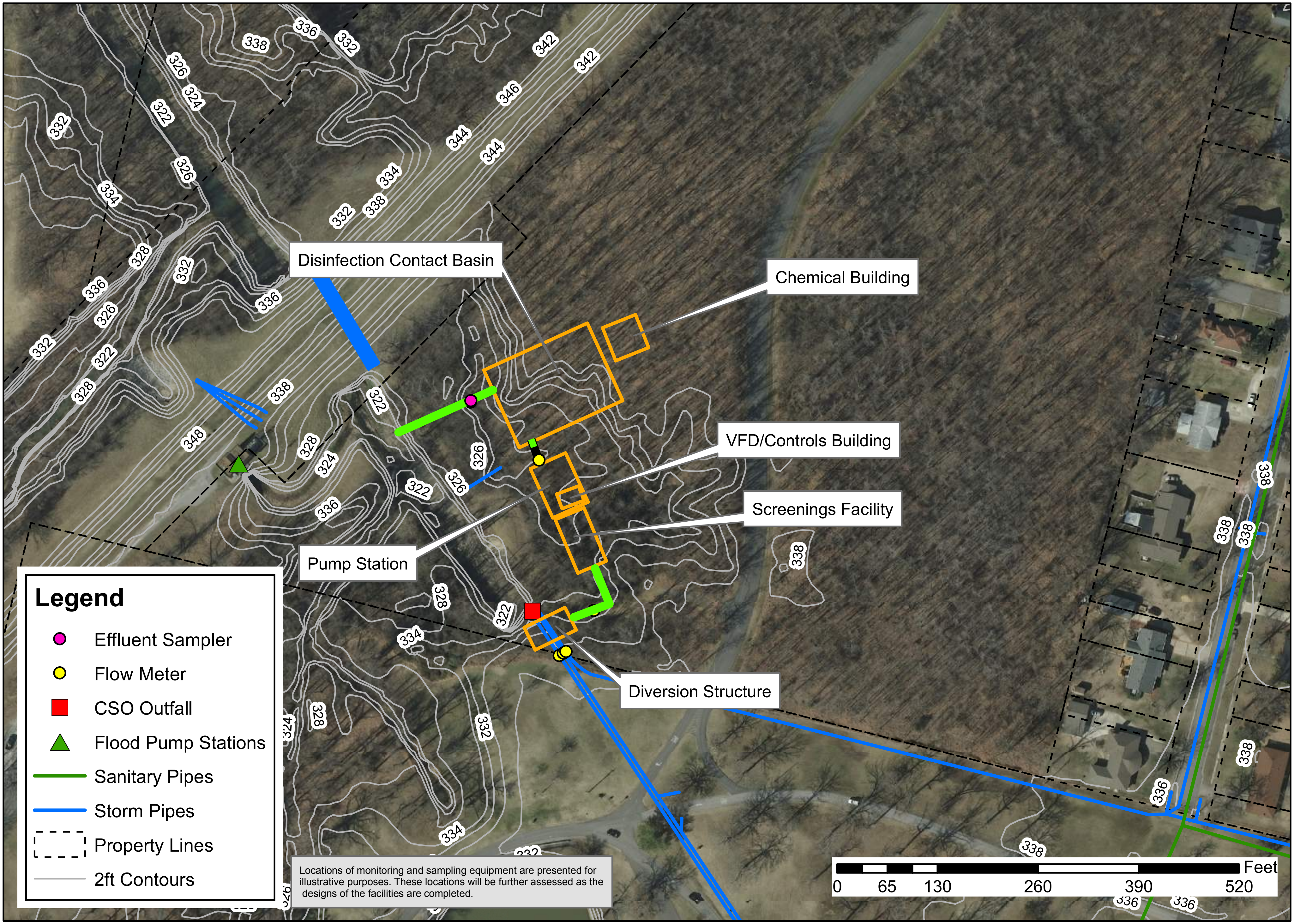
Sufficient rain gauges will be installed to properly characterize precipitation across the service area tributary to the proposed CSO control facilities for the purpose of model re-calibration and data analysis. One or more rain gauges will be located in the drainage area tributary to each of the proposed CSO control facilities, for a total of between 5 and 9 rain gauges installed across the service area. These gauges will be permanent installations capable of recording the rainfall time series. Field investigations will be performed together with the rain gauge supplier/installer to identify the specific sites for the equipment.

6. Model Updating, Re-Calibration and Application Plan

The most up-to-date version of the collection system model used in characterizing system performance for this *Revised LTCP* will be used for evaluating facility performance and determining compliance with the LTCP objectives. As each new CSO facility is completed and put into service, the model will be updated to include the constructed facilities represented using new links, nodes, pumps, weir/orifice structures, and storage elements as appropriate to each facility.

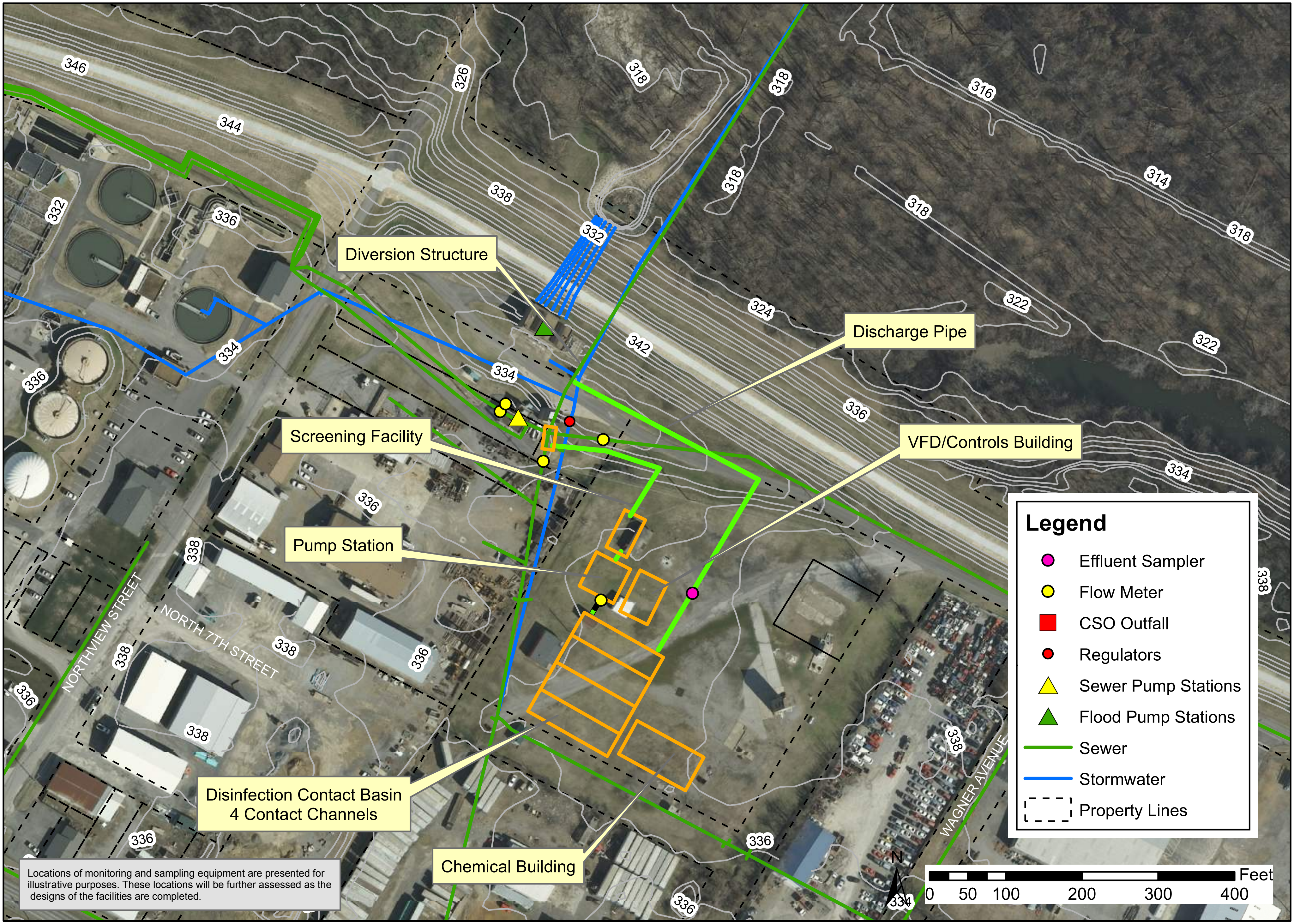
The flow data collected for each facility as described in Section 4 will be used, together with the precipitation data collected as described in Section 5, to re-calibrate the model. For each facility, at least three calibration events will be selected, along with at least one independent validation event, as part of this effort. The schedule for model updates and re-calibration will be integrated with the final schedule for construction and start-up of the proposed facilities. It is expected that model updating and re-calibration will be completed no later than 18 months following completion of construction for each individual facility. Additionally, model updating and re-calibration will every three years following completion of the projects identified in the *Revised LTCP* to track ongoing system performance against the established CSO capture objectives.

Following model update and re-calibration, it will be used to simulate the performance of the system, in particular the flow volume captured for treatment versus flow lost through the CSO outfalls, for the representative five year precipitation record used to characterize average annual CSO statistics for the existing system. These simulations will enable calculation of system-wide and facility-specific CSO capture rates being achieved by the facilities for average annual conditions.



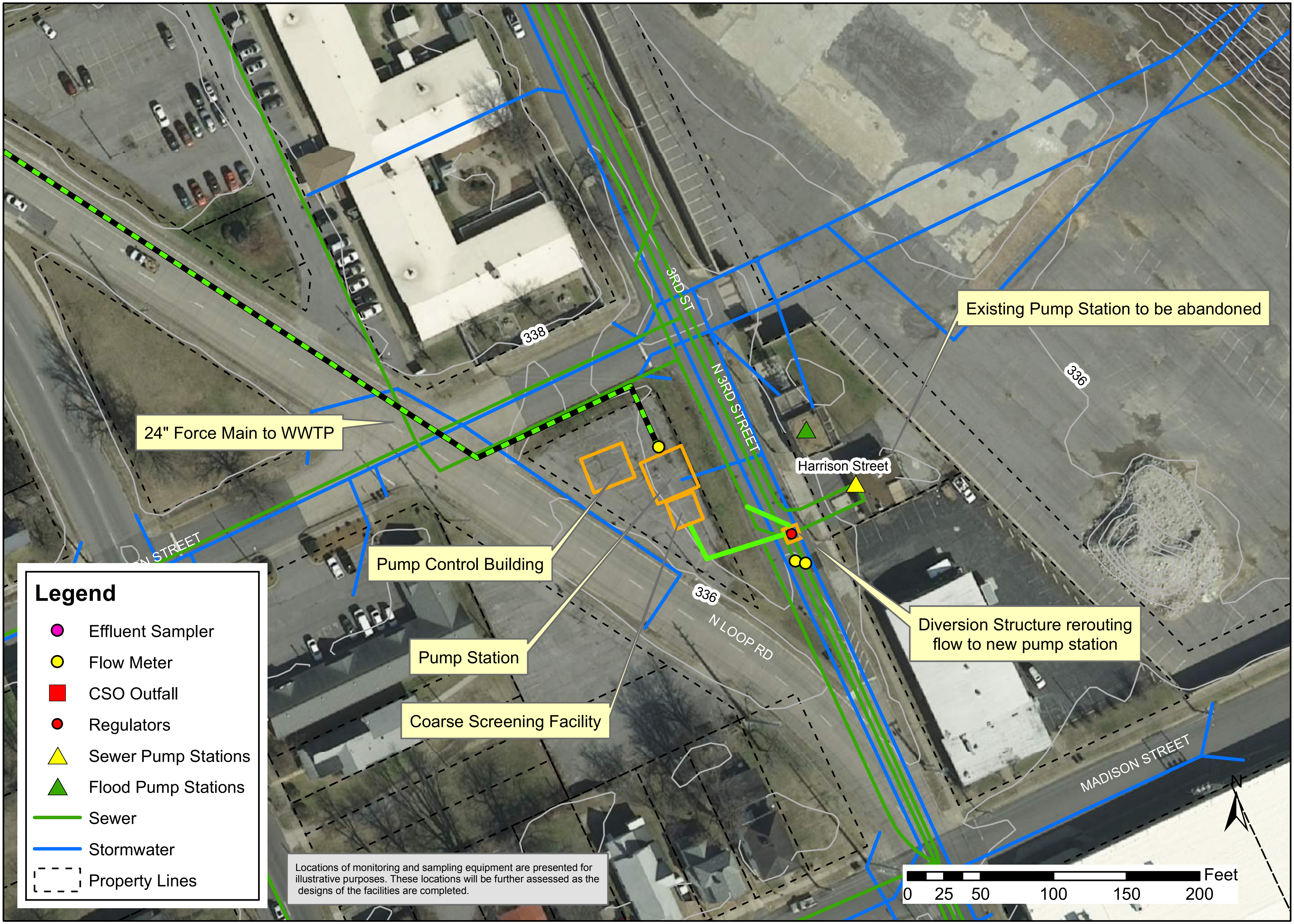
Paducah LTCP - Outfall EPA 002

Figure P-1 - Flow Meter and Sampler Locations



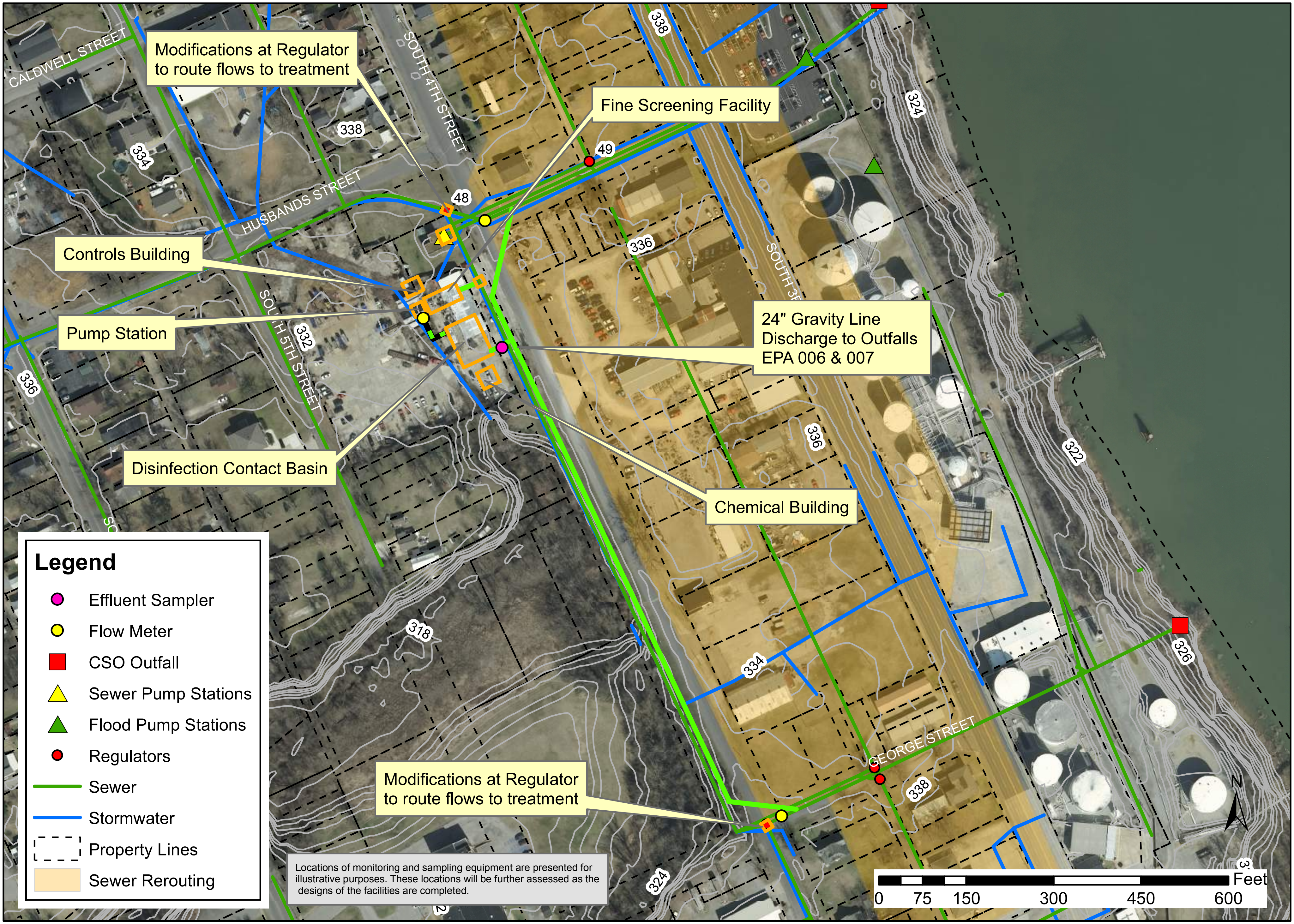
Paducah LTCP - Outfall EPA 003

Figure P-2 - Flow Meter and Sampler Locations



Paducah LTCP - Outfall EPA 004

Figure P-3 - Flow Meter Locations



Paducah LTCP - Outfall EPA 006/007

Figure P-4 - Flow Meter and Sampler Locations